Opportunities for increasing livestock water productivity in the Nile River Basin

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Abstract

Livestock keeping in the Nile Basin contributes greatly to human security, income, culture and agricultural gross domestic product (GDP). Inappropriate livestock management uses excessive water and causes water and land degradation. Livestock-water interactions are complex, not well understood, and often ignored in agricultural water development. This results in lost opportunities to achieve sustainable and higher investment returns. Typically, livestock management also ignores important livestock-water issues. This lack of integration creates knowledge gaps resulting in inefficient and inequitable use of water resources. This paper summarizes selected research findings on livestock-water productivity (LWP) in the Ethiopian Blue Nile Highlands, Uganda's Cattle Corridor, and the Central Belt of Sudan. It suggests selected intervention options to increase LWP, improve livelihoods and reduce land and water degradation. Overall, LWP compares favorably with crop-water productivity. Yet, huge opportunities remain to further increase LWP potentially enabling more agricultural production and support for ecosystem services without depleting additional water.

Four strategies to increase LWP are selection of animal feeds derived from plant materials with high crop water productivity, improved water conservation through better management of watering sites, vegetation and soil on grazing, crop and riparian lands, adoption of technologies to improve animal health, genetics, nutrition and husbandry, and strategic allocation of watering sites to adjust grazing pressure to sustainably match the spatial distributions of pasture and drinking water availability. Implications and opportunities for benefit sharing, IWRM, and poverty reduction in the Nile Basin are discussed in the context of the Ethiopian, Sudanese and Ugandan case studies.

Introduction

More livestock than people live in the Nile basin, and animal demand for feed exceeds the amount of food required to maintain human nutrition. Investing in agricultural water for food security is a high priority in the Basin. It follows that water required by livestock must be comparatively large and may compete with other uses for water including crop production. There has been little systematic consideration of livestock use of and impact on water resources and of options to make more effective and sustainable use of water for livestock production. This paper synthesizes results arising from research on *livestock water productivity* that is part of the CGIAR Challenge Program on Water and Food (CPWF). The aims of the project are to understand the nature of livestock-water interactions at basin, watershed and community levels and to develop technical, policy and management options to enable livestock keeping that uses agricultural water more effectively and sustainably.

The paper first introduces the concept of livestock water productivity (LWP) that underpins this research and identifies strategies for more effective use of water by the livestock sector. Second, spatial analyses of agricultural production systems provide an overview of livestock distributions and water use in the basin. Third, cases studies from Ethiopia, Sudan and Uganda are presented that highlight selected intervention options for improving LWP. The paper closes with some initial guidelines for better integration of livestock and water development in the Nile Basin. In this paper we focus mostly on cattle, sheep and goats but recognize that poultry, fish, pigs and camels and equines are also important. Future work needs to address these in more detail.

Livestock water productivity

The project developed a framework (Peden et al., 2007) for understanding livestock-water interactions from the perspective of assessing *livestock water productivity* (LWP). This framework (Figure 1) became the organizing principle for subsequent research on livestock and water at the scales of river basins and watersheds and communities within basins. LWP is a *systems concept* derived from water accounting principles (Figure 1). In brief, LWP is defined as the ratio of the sum of the net benefits derived from animal products and services to the amount of water that is depleted in the process of producing these goods and services. Livestock provide multiple benefits such as meat, milk, hides, manure, traction power, insurance against drought, a preferred means of storing wealth, and cultural values. In most cases, summing the benefits was accomplished by converting the produced physical units such oxen-days of work, milk volumes and meat weights to monetary value (USA dollars). Depleted water includes evaporation, transpiration, run-off or downstream discharge and contamination. The framework was used in two ways in this research as 1) a communication tool to help focus partners' research on important water-livestock processes, strategies and intervention options that can sustainably increase short term and long term benefits to people and ecosystems and 2) a means to quantify livestock and crop production in terms of monetary benefits received from investing in agricultural water development. LWP concepts were used to formulate research data collection and analyses at the different scales within the Nile Basin.

In essence, any agricultural system regardless of scale receives water from rainfall and from surface or sometimes subsurface in-flows. This water may remain within the system in surface water bodies, soil water, groundwater and, to a very small degree, water contained within living plants and animals. Water that does not remain in the system is depleted through transpiration, evaporation, run-off (discharge), and contamination that refers to water that has become degraded in quality and is essentially lost because it has little further value even though it may remain within the production system. Transpiration constitutes an essential loss of water as the primary driver of plant production including crops, pasture and trees. Apart from cooling effects, evaporation has relatively little value within the system. Downstream discharge is a major depletion pathway especially on degraded sloping lands such as found in the Ethiopian highlands. Some discharge may be desirable or obligatory such as sustaining livelihoods of downstream users and as determined by agreements that entitle Egypt to receive specified volumes of water annually. However, excessive discharge in the form of flooding benefits neither upstream nor downstream stakeholders.

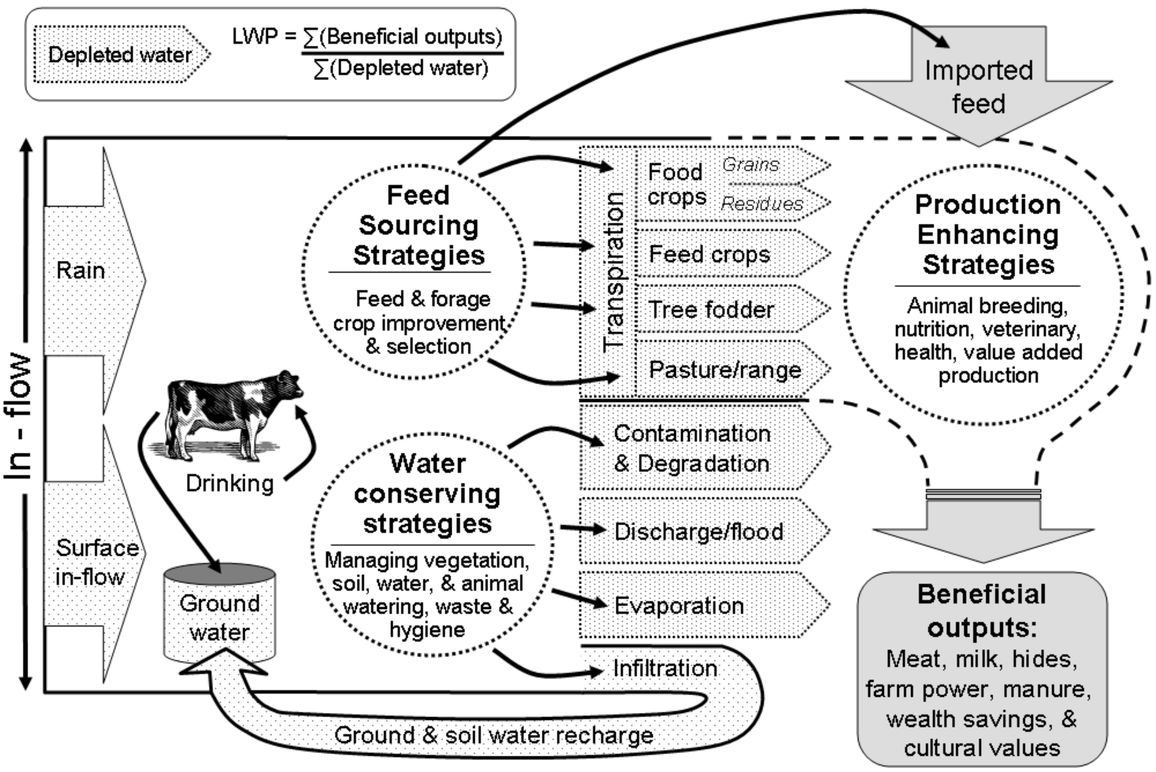

Figure 1: Livestock water productivity (LWP) assessment framework based on water accounting principals helps show relationships between water depletion and benefits derived from livestock and suggests four LWP increasing strategies (Peden et al., 2007).

Transpiration is water depletion through vegetation and associated with photosynthesis that drives plant growth. An overarching concept for increasing agricultural water productivity is to encourage transpiration while discouraging evaporation, discharge and contamination. Transpired water passes through various types of vegetation that have differing uses and benefits for people and ecosystems. To increase LWP, water must pass through plants that are palatable, nutritious and available to animals, but this may entail trade-offs with other legitimate demands for water for plant production including forestry, crops and ecosystem services.

Four basic strategies can be integrated to increase LWP. They are: 1) strategic sourcing of feeds based on plant materials having low water requirements and that are nutritionally suitable for animal intake, 2) enhancing animal production through better nutrition, genetics, veterinary health care and animal husbandry, 3) conserving water resources through better management of grazing lands, crop lands from which crop residues and part of the grain contribute to animal diets, and watering sites where uncontrolled access of animals to water leads to contamination and sedimentation, and 4) strategic provisioning of drinking water allocated spatially to optimize the balance between animal and pasture distributions thereby avoiding overgrazing in some places and undergrazing in others.

Strategic sourcing of feed

To a large extent, LWP depends on the water productivity of the plants that make up animal feeds. Higher crop and pasture water productivity will result in higher LWP if the feeds derived from the crops and pasture plants are palatable, have high nutrient value and metabolizable energy and are available to animals. In particular, one of the best ways to increase LWP is through use of crop residues and by-products. Because human food crops will be grown and use water with or without animals being present, animal production based on use of crop residues and by-products requires little or no additional use of water beyond what the crop itself needs. In contrast, irrigated forage production uses much water and will result in lower LWP. In principle, livestock can consume human foods, trees, pasture and crop residues. The key is to select appropriate mixes of productive feed options that have minimal crop water requirements for feed production.

Enhancing animal production

Provision of water productive feeds may contribute little to increasing LWP if animals have high morbidity and mortality and sub-optimal growth rates and farmers receive low market prices for animals and animal products. Thus, measures taken to improve animal health, nutrition, selection of appropriate animals species and breeds, and husbandry including management of grazing, watering, shelter to reduce stress, and access to markets will increase animal production per unit of water utilized in animal production. Limiting animal numbers may be necessary to ensure that each animal has access to adequate feed to meet maintenance, growth, lactation, reproductive, thermoregulation and activity requirements. In many places, livestock keepers allow herd sizes to increase to unsustainable levels resulting in overall decreases in production. Increasing access to markets can help increase benefits derived by farmers and herders from the sale of animals and animal products.

Conserving water resources

Water conservation through better vegetation management can help increase LWP by maximizing vegetative ground cover that reduces evaporation and discharge and promotes infiltration and transpiration. The key here is to restrict grazing pressure to levels that ensure maintenance of vegetative cover to at least 70% and above ground plant biomass to 50% of net primary production. Grazing management also requires appropriate mixes of animal species and grazing patterns that minimize trails and protect riparian buffer zones around watering resources. Intervention options such as limiting herd sizes to sustainable levels may help by not only enhancing animal production as noted above but also by enabling better water conservation through maintenance of higher levels of vegetative cover.

Provisioning of drinking water

Large areas within the Nile Basin are overgrazed and yet much of the pasture resources remains underutilized due to lack of access to nearby drinking water. This is particularly important in pastoral and agro-pastoral systems. Opportunities exist to increase LWP by more optimally distributing grazing pressure so that there is a better balance between feed supply and animal demand for this feed. One effective strategy to achieve this is through development of strategically allocated watering sites especially for cattle. To be effective, stocking rates near any given watering site must be limited to levels that allow maintenance of adequate vegetative ground cover and prevents excessive run-off, siltation and contamination of the water resources. Although drinking water requirements are less than 2% of water needed to produce feed, investments in drinking water can greatly increase animal production by making underutilized and inaccessible feed resources more available for consumption by animals.

Nile basin-wide distribution of livestock[1]

Spatial data including available livestock and human demographics, vegetation types, distributions of agricultural productions systems, topography, national boundaries and climatic patters were used to delineate major livestock production systems of terrestrial areas of the Nile basin (van Breugel *et al*. 2008). They are livestock dominated grazing and pastoral systems, mixed crop-livestock systems, and irrigated systems (Table 1). These systems were further divided according to climate (hyper arid, arid, temperate and humid). Urban production is not considered in this paper. “Other” areas refer to rural lands where livestock are relatively unimportant. Overlays of these production systems on water availability, market opportunities and length of growing season were used to identify hotspots where animal water requirements for feed production and drinking make up a high percentage of total evapotranspiration.

Table 1: Livestock production systems and their codes used in the basin-wide analyses of livestock-water interactions

Production systems	Codes	Production systems	Codes
Grazing & pastoral: Hyper arid	LGHYP	Rainfed mixed crop-livestock: Hyper arid	MRHYP
Grazing & pastoral: Arid	LGA	Rainfed mixed crop-livestock: Arid	MRA
Grazing & pastoral: Humid	LGH	Rainfed mixed crop-livestock: Humid	MRH
Grazing & pastoral: Temperate	LGT	Rainfed mixed crop-livestock: Temperate	MRT
Irrigated crop-livestock: Hyper arid	MIHYP	Urban livestock production	URBAN
Irrigated crop-livestock: Arid	MIA	Other land-uses	OTHER

Livestock keeping and production takes place in more than 90% of the land area of the Nile Basin, all-be-it with varying productivity and intensity (Table 2). More than 60% of the basin is predominantly grazing land (LGHYP, LGA, LGH and LGT). Mixed crop-livestock systems (MRHYP, MRA, MRT and MRH) occupy about one third of the land area with other land uses and irrigation being negligible in land area occupied. The three most important livestock production systems in the basin in terms of land area are LGHYP (940,838 km^2), LGA (759,685 km^2) and MRA (606,935 km^2). Approximately two-thirds of the area of the Nile’s livestock systems lies within Sudan, but Ethiopia, Egypt and Uganda each has more than 200,000 km^2 of land where livestock are kept. The diversity and spatially great extent of livestock production systems in Sudan, Ethiopia and Uganda are part of the justification for establishing our national case studies within them.

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[1] Being a synthesis paper derived from several other studies, the methods are only briefly described here, but the methods are more fully described by the authors cited who are collaborators in this CPWF project.

Table 2: Distribution of livestock production systems as a percent of the riparian country land areas lying within the Nile Basin area. Countries are ranked, top-left to bottom-right, according to their total area of livestock systems (km^2) located within the basin

Production system	**Percent of Nile part of riparian country territory with designated production system**					**Basin total (%)**
	Sudan	**Ethiopia**	**Egypt**	**Uganda**	**Tanzania**	
LGHYP	35.8	-	87.0	<0.1	-	31.4
LGA	33.6	22.0	<0.1	9.3	5.6	25.4
MRA	22.1	24.7	-	16.7	31.7	20.3
MRT	<0.1	43.4	-	7.6	5.9	7.7
MRH	<0.0	2.4	-	47.7	38.4	5.2
LGH	5.3	0.5	-	9.0	0.6	4.1
MIHYP	0.3	-	10.6	-	-	1.2
LGT	<0.1	0.7	-	0.6	4.9	0.5
MRHYP	0.3	-	0.8	<0.1	-	0.3
MIA	0.1	-	<0.1	-	-	0.1
OTHER	2.3	6.4	1.2	9.1	12.9	3.7
Land area (1000s km^2)	**1,932.9**	**361.5**	**285.6**	**204.2**	**85.6**	**2,992.9**
	Kenya	**Eritrea**	**Rwanda**	**DR Congo**	**Burundi**	
LGHYP	-	0.5	-	-	-	31.4
LGA	1.2	26.3	-	<0.1	-	25.4
MRA	10.2	64.8	25.2	14.2	1.1	20.3
MRT	49.9	8.0	57.8	22.6	86.1	7.7
MRH	17.5	-	10.7	25.0	10.5	5.2
LGH	<0.1	-	-	4.9	-	4.1
MIHYP	-	-	-	-	-	1.2
LGT	11.6	0.3	0.1	0.1	-	0.5
MRHYP	-	-	-	-	-	0.3
MIA	-	0.2	-	-	-	0.1
OTHER	9.5	<0.1	6.2	33.2	2.3	3.7
Land area (1000s km^2)	**47.2**	**25.0**	**20.7**	**17.4**	**12.7**	**2,992.9**

Production systems not found within the countries are designated by “-“.

Tables 3 and 4 show the estimated populations and densities of sheep, goats, cattle and people residing within the livestock production systems in the Nile Basin portion of the ten Nile riparian countries. Sudan and Ethiopia dominate the livestock sector with respect to these three animal species. However, the smaller countries (e.g. Kenya, Tanzania, Rwanda, Eritrea and Burundi) have higher densities for at least some types of animals. The estimated total numbers of sheep, goats and cattle within the Nile Basin sum to about 153 million. With camels, swine, equines, and poultry, the total will greatly exceed the 169 million people in the Basin. In general, livestock densities, especially cattle, tend to correlate positively with human densities because many people keep animals as a preferred means for securing wealth, use them as insurance in drought periods, and sell meat and milk wherever they have market access. As will be shown later, animal populations are also limited by access to feed and water resources.

Table 3: Estimated populations and densities of sheep, goats, cattle and people within Nile Basin livestock production systems (van Breugel et al., 2008).

LPS	**Land area** (km^2)	**Sheep total** (1000s)	**Sheep density** (no/km^2)	**Goats total** (1000s)	**Goats density** (no/km^2)	**Cattle total** (1000s)	**Cattle density** (no/km^2)	**Human Pop. (1000s)**	**Human Density** (no/km^2)
LGHYP	940,838	3,000	3	2,383	3	2,403	3	11,061	12
LGA	759,685	15,213	20	12,626	17	17,058	22	10,738	14
MRA	606,935	15,973	26	14,119	23	22,297	37	19,464	32
MRT	230,513	5,027	22	4,264	18	13,164	57	36,896	160
MRH	155,864	1,193	8	3,298	21	6,029	39	22,591	145
LGH	123,692	1,680	14	1,692	14	1,195	10	835	7
MIHYP	36,689	1,746	48	1,179	32	2,225	61	45,850	1,250
LGT	13,733	207	15	282	21	314	23	251	18
MRHYP	8,237	252	31	245	30	193	23	676	82
MIA	3,066	90	29	89	29	164	53	750	244
OTHER	111,580	793	7	1,070	10	1,857	17	7,055	63
URBAN	2,089	42	20	80	39	27	13	13,617	6,520
TOTAL	**2,992,921**	**45,216**	**15**	**41,327**	**14**	**66,926**	**22**	**169,784**	**57**

Table 4**:** Estimated populations and densities of sheep, goats, cattle and people within only the Basin parts of Nile riparian countries (van Breugel et al., 2008).

Country	**Land area** (km^2)	**Sheep total** (1000s)	**Sheep density** (no/km^2)	**Goats total** (1000s)	**Goats density** (no/km^2)	**Cattle total** (1000s)	**Cattle density** (no/km^2)	**Human Total** (1000s)	**Human Density** (no/km^2)
Sudan	1,932,939	32,305	17	25,978	13	33,687	17	27,125	14
Ethiopia	361,541	5,318	15	3,722	10	13,961	39	25,303	70
Egypt	285,606	3,055	11	1,973	7	2,779	10	61,963	217
Uganda	204,231	1,253	6	2,967	15	4,968	24	23,164	113
Tanzania	85,575	759	9	2,886	34	5,506	64	7,250	85
Kenya	47,216	1,409	30	1,583	34	4,188	89	12,087	256
Eritrea	25,032	732	29	830	33	846	34	1,123	45
Rwanda	20,681	241	12	825	40	743	36	6,245	302
DR Congo	17,384	32	2	103	6	59	3	1,932	111
Burundi	12,716	112	9	459	36	188	15	3,592	282
TOTAL	**2,992,921**	**45,216**	**15**	**41,326**	**14**	**66,925**	**22**	**169,784**	**57**

Van Breugel et al. (2008) use their foregoing results on animal distributions, production systems and climatic data to assess the balance between actual annual evapotranspiration (ET) during the historic lowest rainfall year and the water required to produce feed to satisfy energy requirements for livestock (Figure 1). Sudan’s Central Belt appears to experience the greatest pressure on available water for feed production and this is confirmed by Faki et al. (2008) as noted later in this paper suggesting that investments in provision of drinking water for livestock could be a useful strategy to increase LWP. However, there are anomalies that require further analyses. For example, in temperate mixed crop-livestock systems of Ethiopia, food security depends on cereal-based crop production. Because livestock are also dependent on cereal crop residues, drought induced declines in crop production impose famine on people and animals alike, but overall, livestock may use a lesser proportion of actual ET than has been observed in grazing lands. Excessive run-off also takes place on steep degraded croplands resulting in physical water scarcity that limits food and feed production. In irrigated areas, animals often migrate to distant pastoral areas for part of the year to offset feed shortages caused by physical water scarcity. Although the researchers have yet to quantify LWP across the Nile Basin, providing drinking water may be a promising strategy for increasing LWP (Figure 1), an option that Peden et al. (2007) suggest could also increase sustainability and profitability of agricultural water investments.

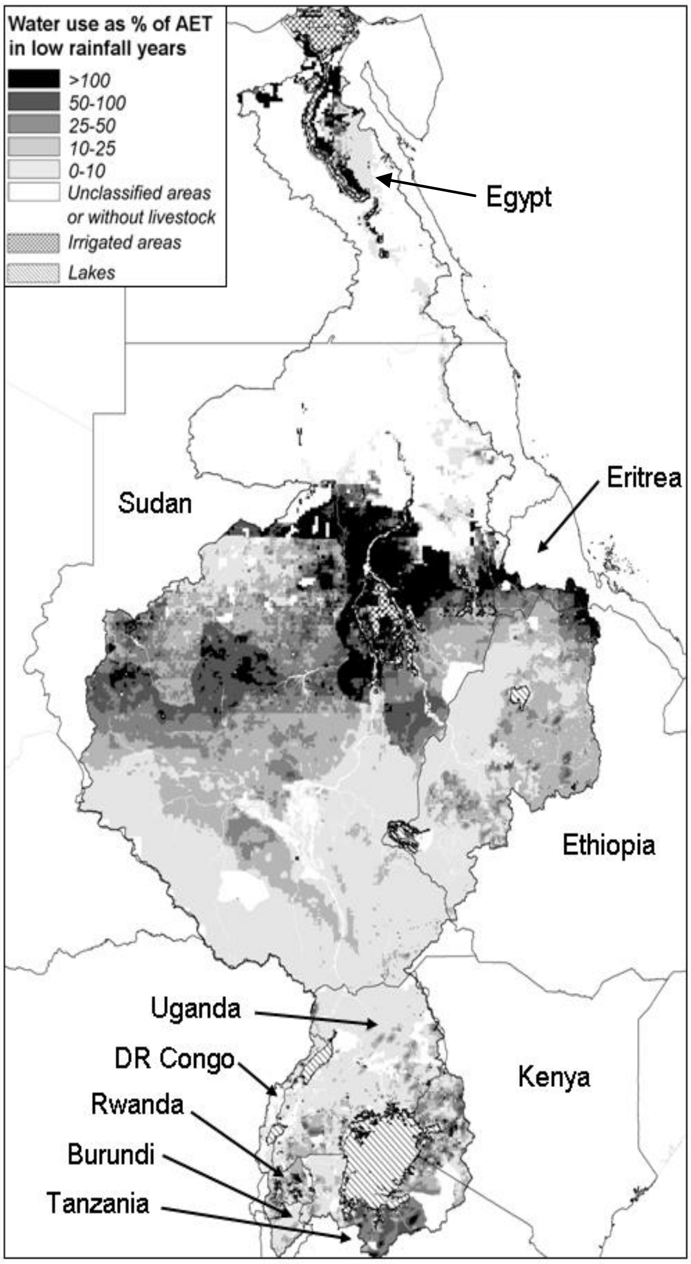

Figure 2: Total annual livestock water use for feed and drinking as percent of actual total annual evaporation in low rainfall years in the Nile River Basin parts of the ten riparian countries

Ethiopian case study

The Ethiopian Institute for Agricultural Research (EIAR), ILRI and IWMI focused research on the Blue Nile with much of the field work undertaken in the Gumera Watershed lying east of Lake Tana (Alemayehu et al., 2008; Haileslassie et al., 2008; Gebreselassie et al., 2008). The research team developed field based approaches to quantitatively assess LWP and identify biophysical and socio economic factors that affect LWP and options to increase LWP. The Ethiopian studies capture key aspects of feed sourcing and water conservation strategies highlighted in the LWP framework (Figure 1) and found to be important in the temperate rainfed mixed crop-livestock systems where domestic animals depend on both grazing and crop residues and by-products. These systems comprise various sub-systems defined by their suitability for crops. They vary in levels productivity, sustainability, climate, topography, human demographics and socio-economics. They include banana-coffee mid highlands to barley-fallow-barley systems in the Simien Mountains. Wheat, maize and teff are commonly grown. Low input farming heavily relying on recycling of internal resources dominates and is sustained by relatively high annual rainfall and generally productive soils compared to adjacent marginal lowlands. Livestock are important throughout the region contributing greatly to food production, income and social security. Animal power plays a critical role by allowing cultivation of more land, maintaining labour productivity. Manure is used for fuel and soil fertility replenishment. Livestock and crops are produced within the same farm unit that utilizes both privately and community managed land resources. Mixed crop-livestock systems host 70% of Ethiopia's people, and 80% of the cattle, sheep and goats (Thornton et al., 2002). Animal densities are among the highest in the Nile Basin (Table 3).

Steep slopes, high population density, land shortage, soil nutrient depletion, overgrazing and water degradation, and periodic physical water scarcity (Haileslassie et al., 2005; Amede et al., 2006) contribute to low LWP and severe poverty and malnutrition. Fifteen percent of these mixed crop-livestock systems are so seriously affected that it will be difficult to restore to economic productivity (Amede, 2003). A major challenge in the temperate mixed crop-livestock systems of the Blue Nile and adjacent highlands in Ethiopia is to increase water productivity and LWP in particular. Project results suggest LWP increases will require better feed sourcing, water conservation, and improved animal production and provision of animal drinking water. In contrast to developed country animal production, LWP compares favorably with crop water productivity (Peden et al., 2007). Effective use of crop residues and by products can further increase LWP (Gebreselassie et al., 2008). Haileslassie et al. (2008) suggests that LWP is inversely correlated with poverty because adoption of LWP enhancing interventions requires investments to improve crop production, soil and water conservation and animal health – all of which are needed to increase LWP. Alemayehu et al., (2008) further suggest that communal pastures within these mixed crop-livestock systems are critical areas where LWP improving interventions are needed (Table 5). He notes that privately tenured pastures experience 90% less run-off and soil erosion than collectively managed community tenured grazing areas and that water and soil losses are greater on steeper slopes where many pastures are located. These results also indicate that community bylaws to control grazing can help reduce degradation caused by livestock.

Although over-grazing causes low LWP, annual cropping also leads to substantial water depletion and soil loss in Ethiopia especially where virtually all crop residues are removed from the fields after harvest. Hurni (1990) demonstrated that about half of Ethiopia's soil erosion occurs on annual croplands that cover about 15% of the country, but grazing lands covering 50% of the country account for only about 15% of the erosion. Crop residues sustain some of the highest livestock densities in the Nile (Table 3) but little manure is returned to replenish soil fertility. Increasing LWP requires improved management of both pastures and annual croplands within the mixed crop-livestock systems implying need for enabling policy, investments, and support for collective action. Technologies that maintain vegetative cover and soil organic matter are essential. Together these strategies can help increase LWP through better water conservation as indicated in the LWP framework (Figure 1).

Table 5: Runoff volume and sediment load of the main rainy season from pastures having different ownership pattern and slope (Alemayehu et al., 2008)

Pastureland ownership pattern	**Slope of the pastureland (%)**	**Runoff (m^3/ha)**	**Sediment load (ton/ha)**
Communally owned and open unrestricted grazing	<10	10,125	26.3
	15 - 25	12,825	45.3
Community owned pasture supported with local by-laws	<10	3,308	7.8
	15 - 25	4,928	14.2
Privately owned enclosed pasture	<10	1,148	1.7
	15 - 25	1,688	3.4
SE +/-		608	1.5

Sudan case study

In Sudan, the Agricultural Economics and Policy Research Center of the Agricultural Research Corporation and the Animal Resources Research Corporation selected the Central Belt of Sudan as their study area (Faki et al., 2008). This region provides examples of arid and hyper arid grazing areas, arid and semi-arid mixed crop-livestock systems and also irrigation schemes where livestock are often unrecognized but important. In this paper, emphasis is given to the balance between the distribution and availability drinking water and drinking water requirements of livestock in the Central Belt. Although LWP remains to be quantitatively assessed, key informants' perceptions analyzed in the context of the LWP assessment framework (Figure 1) suggest that strategic provision of drinking water may be a key entry point for improving LWP in the region.

Sudan's livestock numbered about 138 million animals[2] in 2006 (MoARF, 2006), play pivotal roles in the economy, contribute 22% to total GDP, and provide livelihoods for many people. Within the country, most of Sudan's crop and livestock production (Figure 1) takes place within the Central Belt of Sudan that extends from its western to eastern borders (roughly between latitudes 10^{o} and 20^{o} N). The Belt covers 75% of Sudan, accommodates 80% of its people, and hosts 73% of Sudan's total livestock. Rainfall is the major water source, ranging from less than 100 mm/year in the far north to about 800 mm/year in the south. The western region depends primarily on rainfall, ground water, and some seasonal streams. Large numbers of domestic animals depend partly on the water from the Nile system for feed production and for drinking especially during the dry season. Without access to feed produced in the Nile's irrigation systems and riparian areas, many livestock could not survive dry periods and benefit from vast grazing lands accessible during more favorable times. Yet, the livestock sector faces tremendous challenges including suboptimal use of land and water resources, especially in rain-fed areas, leading to resource degradation and variable and low livestock productivity, but large grazing areas with surplus feed are too far from water to enable their use by livestock.

Water supply for livestock is critical, especially in the dry season in pastoral areas when use is made of human-made watering points. For many years, the government established water

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[2] This estimate is substantially higher than the 92 million reported in Table 4 based on ILRI's and FAO's data. This discrepancy highlights the need for a standardized Nile-wide livestock census.

sources in the form of wells, dams, small pumps and 'hafirs'[3]. Between 1989 and 2007 the annual total rural water supply from these sources increased from about 100 million to 349 million m^3. However, water supplied for household and animal consumption must be weighed against requirements. In most states in the belt, a drinking water deficit (Table 6) still exists. Most of the pressures and water imbalances are found in the states of West and South Darfur, West Kordofan, Blue Nile, Gezira and White Nile. Within states, many areas still lack drinking water infrastructure. But the latter three states are endowed with rich and fairly permanent surface water sources, leaving most of the pressures in the former three states. Positive balances exist in Khartoum and Red Sea states because of proximity to the Nile River and high priority for water development respectively.

Table 6: Average daily rural drinking water availability from available human-made infrastructures, demand and balance (thousand m^3/day) in different states within Sudan's Central Belt, 2007

State/Region	Available Water	Average drinking demand	Peak drinking demand	Balance at average demand	Balance at peak demand
Red Sea	126	20	32	106	95
Kassala	44	61	87	-17	-43
Gedarif	55	66	86	-11	-31
Blue Nile	19	152	203	-133	-184
Sennar	33	72	92	-39	-59
Gezira	62	141	170	-79	-109
White Nile	48	119	157	-71	-109
Greater Kordofan	244	335	464	-91	-220
North Darfur	52	87	116	-35	-63
South Darfur	51	187	236	-136	-185
West Darfur	29	172	229	-143	-200
Khartoum	83	25	28	58	55

Access to water for feed production and drinking is a critical constraint. On one hand, LWP is low near the watering points because overgrazing causes soil and vegetation loss. Available rainfall produces little feed if vegetation is absent. On the other hand, LWP is also low far from watering points because animals cannot get access to surplus and otherwise available feed. Without utilizing this feed, the transpired water that enabled its production results in no agricultural benefits although it may contribute to environmental services. There is need to limit grazing near watering points and to expand watering sites into areas where there is surplus/unused pasture. Improvement in legislative structure and institutional arrangements, promotion of community-based natural resources management and marketing opportunities and provision of better veterinary services can help increase LWP in this important part of the Nile Basin. Providing drinking water in relatively small amount in areas of surplus pasture can be an effective means to increase LWP if grazing pressure is limited to levels that allow increased animal and herd productivity and enable maintenance of ecosystem services. Aggravating the challenge of supplying livestock drinking water are high rates of prevalence of snail-borne diseases and coliform bacteria that threaten both human and animal health (Goreish and Musa, 2008; Fathelbari and Musa, 2008). To increase LWP, livestock need to be physically separated from the watering site through measures such as use of watering troughs in addition to increasing veterinary services. In these extensive grazing areas of the Nile, the strategies of water conservation, enhancing animal production and provisioning of water (Figure 1) are needed to increase LWP.

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[3] A water harvesting system in which earth embankments catch and store rain water according to topographic contours.

Uganda case study

In Uganda, the Makerere University team selected the Cattle Corridor because of past neglect in terms of national development, the region's severe degree of desertification and expert opinion that the underlying challenge was the need for better agricultural water management. The Corridor covers about one third of the country extending from Mbarara in the southwest, northeasterly beyond Lake Kyoga to the northern part of the country. Within the Corridor, Nakasongola was selected as the primary research site where livestock keeping has been the traditional livelihood strategy and where much land and water degradation had greatly reduced agricultural production and threatened the well-being of the people through poverty and hunger. In Nakasongola, community based systems research was undertaken to understand: a) the socio-economic factors affecting livestock-water productivity, b) how to rehabilitate degraded rangelands through reseeding, fencing and use of manure to restore pasture productivity while controlling soil erosion, and c) the effect of upper catchment management and water cover plants on the quality and quantity of water in reservoirs for improved LWP (Mpairwe et al., 2008). The Ugandan research provides a case study of pastoral and agro-pastoral production systems in relatively warm and semi-arid to humid environments of the Nile. It addresses the water conservation, feed sourcing and watering strategies identified in the LWP assessment framework (Figure 1).

Much of the production capacity of Uganda's Cattle Corridor has been lost due to overgrazing and charcoal production (Figure 3). The results indicate that fencing, reseeding and application of manure can increase dry matter pasture production from nil to 3000 kg/ha or more within one year and eliminate the devastating impacts of termites (Figure 3; Table 7). These interventions also greatly increased ground cover, a key requirement to reduce run-off and increase infiltration. In addition to increasing pasture production, reseeding with manure reduced upslope erosion leading in turn to reduced sedimentation of valley tanks from about 501 m^3 to 23 m^3 of sediments during the study period (Table 8). The interventions suggest that restoration of pasture production increases water productivity by shifting water depletion from excessive run-off and probably evaporation to greater transpiration that drives plant growth while at the same time making the water harvesting valley tanks more sustainable.

Figure 3: Degraded rangelands at Nakasongola in Uganda's Cattle Corridor (left) and the affect of reseeding with manure one year later (right)

Table 7: Effect of manure application on vegetative cover and pasture dry matter production

Season	Treatment	% ground cover		Dry matter (kg/ha)
		Bare	Vegetation	
Wet	Control	100.0	0.0	0.0
	Fencing + Reseeding only	60.6	39.1	1778
	Fencing + Reseeding + Manure	12.2	89.5	3641
Dry	Control	100.0	0.0	0.0
	Fencing + Reseeding only	79.1	21.2	1426
	Fencing + Reseeding + Manure	35.6	65.2	2964
	SE	5.3	3.0	396.4

Table 8: Effect of upper catchment management on the quantity of water and siltation in valley tanks

	Period	Max. vol. of water (m^3)	Volume of silt deposited (m^3)	% age reduction pond capacity
Un-protected (degraded) catchment	Nov. 06 –Apr. 07	1260	233	16.9
	Apr. 07 – Oct. 07	1135	15	1.3
	Oct. 07 – Apr. 08	1001	253	22.4
	Total		**501**	
Protected (vegetated) catchment	Nov. 06 –Apr. 07	1861	-	-
	Apr. 07 – Oct. 07	1857	9	0.5
	Oct. 07 – Apr. 08	1846	14	0.8
	Total		**23**	

In response to the development of technology that restores pasture productivity and increases the sustainability of investments in water harvesting, the local communities have passed by-laws to protect the riparian vegetation and water quality. Local livestock keepers are now investing their own resources in the development and maintenance of common property pasture and water resources. The result of this Ugandan experience is that LWP, animal production and environmental quality can be increased through integration of livestock, pasture and water management that involves better sourcing of more water productive feed, water conservation and strategic provision of drinking water. Reseeding with manure was the key to controlling termites and opening up opportunities to increase LWP through the strategies of better water conservation and sustainable provision of livestock drinking water.

Conclusions

Research on options to improve livestock water productivity in the Nile Basin is still in its infancy and many questions and issues remain unanswered. However, this initial CPWF research confirms that livestock numbers and densities are high and vary spatially in the Basin with Sudan, Ethiopia, and Egypt having most animals but high densities also occur in some smaller countries. Basin-wide, these animals require as much feed as the food people need. Water to produce animal feed is a major use of agricultural water. There is need to use this water more productively. The livestock water assessment framework (Figure 1) identified four basic strategies that can help increase livestock water productivity. These are sourcing feeds that require relatively little water for production, adoptions of animal sciences that can help increase the productive benefits people derive from multiple animal products and services, conservation of water through better management of animal watering sites and vegetation on both crop and pasture lands, and strategically optimal spatial allocation of watering sites accompanied by limits on animal densities to bring about a better balance between livestock demands for and availability of water and feed resources. Case studies from Ethiopia, Sudan and Uganda confirm this viewpoint. In the temperate highland mixed crop-livestock systems, water is relatively abundant but intermittent shortages and water depletion through run-off are problematic. In Ugandan rangelands, severe land and water degradation has made much land unproductive. In Sudan, physical drinking water shortage concentrates large numbers of animals into small areas leaving large area with surplus pasture underutilized. In all cases, water conservation, improved feed sourcing, improved veterinary care, nutrition and management, and strategic provisioning of drinking water can help increase LWP. However, the specific appropriate intervention options will vary among countries and production systems. One way to increase LWP is effective involvement of communities enabling them to take collective action in managing their common property natural resources. Evidence suggests that reducing poverty endows farmers with greater resources enabling them to invest in agricultural inputs that can increase water productivity. Overall, there appears to be ample opportunity to increase the water productivity of livestock in the Nile basin but the first step must be effective integration of livestock, water and land management.

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References

Alemayehu, M., D. Peden, G. Taddesse, A. Haileslassie and W. Ayalneh. 2008. *Livestock water productivity in relation to natural resource management in mixed crop-livestock production system of the Blue Nile river basin, Ethiopia*. Proceedings of the CPWF 2nd International Forum on Water and Food, Addis Ababa, Ethiopia, 9-14 November 2008.

Amede, T. (ed.). 2003. *Natural Resource degradation and Environmental Concerns in the Amhara Regional State, Ethiopia: Impact on Food Security*. Bahir Dar, Ethiopia: Ethiopian Society of Soil Sciences. 278 p.

Amede, T., R. Kirkby, and A. Stroud. 2006. *Intensification pathways from farmer strategies to sustainable livelihoods: AHIs experience.* Currents: 40/41: 30-37. SLU, Sweden. September 2006.

Faki, H., I. El-Dukheri, M. Mekki and D. Peden. 2008. *Opportunities for increasing livestock water productivity in Sudan*. Proceedings of the CPWF 2nd International Forum on Water and Food, Addis Ababa, Ethiopia, 9-14 November 2008.

Fathelbari, M.O. and M. T. Musa. 2008. *Water production systems and methods of their improvement in Al Gedarif State, Eastern Sudan.* Proceedings of the CPWF 2nd International Forum on Water and Food, Addis Ababa, Ethiopia, 9-14 November 2008.

Gebreselassie, S., D. Peden, A. Haileslassie and D. Mpairwe. 2008. *Cost-effective assessments of livestock-water productivity using previous animal feeding trials.* Proceedings of the CPWF 2nd International Forum on Water and Food, Addis Ababa, Ethiopia, 9-14 November 2008.

Goreish, I.A. and M.T. Musa. 2008. *Prevalence of snail-borne diseases in irrigated areas of the Sudan.* Proceedings of the CPWF 2nd International Forum on Water and Food, Addis Ababa, Ethiopia, 9-14 November 2008.

Haileslassie, A., Priess, J., Veldkamp, E., Teketay, D. and Lesschen, J.P., 2005. *Assessment of soil nutrient depletion and its spatial variability on smallholders' mixed farming systems in Ethiopia using partial versus full nutrient balances.* Agriculture, Ecosystems and Environment, 108(1): 1-16.

Haileslassie A., S. Gebreselassie, D. Peden, Amede T. and K. Descheemaeker. 2008. *Impacts of Poverty on Water Productivity: the case of the Blue-Nile.* Proceedings of the CPWF 2nd International Forum on Water and Food, Addis Ababa, Ethiopia, 9-14 November 2008.

Hurni H. 1990. *Degradation and conservation of soil resources in the Ethiopian highlands*. In B. Messerli and H. Hurni, eds. African Mountains and Highlands: Problems and perspectives. Marceline, Miss: African Mountains Association.

MoARF (Sudan Ministry of Animal Resources and Fisheries). 2006. *Statistical bulletin for animal resources*. Issue no. 15-16, General Administration for Planning and Economics of Animal Resources, Animal Resources Economics Administration, Khartoum.

Mpairwe, D., D. Mutetikka, G. Kiwuwa, S. Mugerwa, B. Owoyesigire, E. Zziwa, and D. Peden. 2008. *Options to improve livestock-water productivity in the Cattle Corridor within the White Nile sub-basin in Uganda.* Proceedings of the CPWF 2nd International Forum on Water and Food, Addis Ababa, Ethiopia, 9-14 November 2008.

Peden, D., Taddesse, G., Misra, A.K. 2007. *Water and livestock for human development.* In: Molden, D. (Ed), Water for food, water for life: A comprehensive assessment of water management in agriculture. London: Earthscan and Colombo: International Water Management Institute.

Thornton, P., R. Kruska, N. Henninger, P. Kristjanson, R. Reid, F. Atieno, A. Odero and T. Ndegwa. 2002. *Mapping poverty and livestock in the developing world.* Nairobi: ILRI.

Van Breugel, P., M. Herrero, J.A. van de Steeg and D. Peden. 2008. *Recommendation domains and key aspects of livestock-water productivity in the Nile basin.* Proceedings of the CPWF 2nd International Forum on Water and Food, Addis Ababa, Ethiopia, 9-14 November 2008.