Improving the water productivity of livestock: An opportunity for poverty reduction

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Abstract

In Ethiopia, intensification of agricultural production is the primary focus of the government's poverty reduction strategy. Livestock constitute an invaluable resource providing essential goods and services to small-scale poor farmers and their families and communities. Production of high valued livestock products provides a route out of poverty especially where growing urban demand fuels the markets. Water security is a requisite input for livestock production and its resultant contribution to poverty reduction. Typically, one tropical livestock unit (TLU = 250 kg live weight) requires less than 50 litres/day derived from drinking water and moisture in animal feeds. Assuming annual rainfall of 500 to 1000 mm and a stocking rate of one TLU/ha, the drinking water required by livestock is less than 0.2% of the intercepted precipitation. While sufficient high quality water is essential to sustaining livestock production, direct water intake is only of minor significance in terms of livestock water budgets in farming systems and watersheds where the water required for feed production can be up to 5000 litres/TLU per day or 100 times the amount directly consumed.

Water productivity of livestock may be high or low depending on the context within which livestock production is evaluated. Livestock produced solely with irrigated forage and grain crops may be very inefficient in terms of water consumed for food produced. However, 'cut-and-carry' and grazing production relying on consumption of crop residues and tree fodder can be very efficient since the water used for plant production would have been used with or without livestock feeding on it. The stover or feed is simply a by-product of growing crops and does not require additional water for its production. Livestock also provide rural farmers with additional value in terms of consumable and marketable outputs without incurring significant demand for water. Understanding and managing water productivity of livestock presents opportunities to contribute to poverty reduction.

Water productivity varies according to the geographic scale being considered and depends largely on the degree to which water is depleted or available to other users or ecosystem services. Livestock have a profound impact on downstream water resources. In urban and peri-urban areas, livestock production may be an ideal agricultural practice in terms of water productivity if downstream contamination can be avoided. Increasing

demand for livestock products implies increased future demand for water that can be expected to rival the water requirements for production of all other food products consumed by the urban population. In many cases, livestock management practices jeopardise water quality, human health and aggravate water mediated land degradation. Research is needed to develop practical strategies to enable poor people in rural, peri-urban and urban areas to better manage livestock so that they can realise poverty reducing benefits and minimise harmful effects on themselves and others. An utmost need exists for community based natural resources management, a critical issue of interest to water and livestock managers. Given the paucity of literature on livestock–water interactions, key areas for future research are highlighted.

Introduction

Poverty is the pronounced deprivation in human well-being encompassing not only material deprivation but also poor health, literacy and nutrition, vulnerability to shocks and changes, and having little or no control over key decisions (ILRI 2002).

About 1.3 billion people or one-fifth of the world's population live on less than US$ 1 per day. Women constitute 70% of the poorest of the poor. They provide more than half the labour force required to produce food in the developing world. In Africa, close to 70% of the staple foods are produced by women. Women typically spend a higher proportion of their income on food and health care for children (Ashby 1999).

Ethiopia ranks near the bottom of the global poverty scale. About 45% of the people live on less than US$ 1/day, and life expectancy is about 47 years and falling. Diseases of poverty such as malaria, tuberculosis (TB), Human immunodeficiency virus/Acquired immuno-deficiency syndrome (HIV/AIDS), parasites, blindness, respiratory infections and diarrhoea are widespread (WHO 2002). Safe drinking water and sanitation are woefully inadequate particularly in rural areas. Chronic food insecurity evidenced by high prevalence of stunting and wasting in children trap future generations into continued poverty. Efforts by the poor to sustain themselves contribute directly to land and water degradation. For example, collection of wood and manure for fuel renders land vulnerable to erosion resulting in flooding, soil loss and sedimentation of water bodies.

Poverty reduction is the driving goal of Ethiopian development strategies. The International Livestock Research Institute (ILRI) and its partners are committed to reducing poverty and making sustainable development possible for poor livestock keepers, their families and the communities in which they live. In Ethiopia, the Ethiopian Agricultural Research Organization (EARO) is ILRI's traditional and primary partner in promoting effective use of animal agriculture for poverty reduction. Through new partnerships, this workshop affords the opportunity to integrate animal agriculture into the wider poverty reduction strategy including the integration of diverse livelihood strategies within watershed and river basin systems. Indeed, the moral imperative of today is to sustainably reduce poverty with particular emphasis on improving the lives of women and children.

The purpose of this paper is to highlight a few key principles related to the role of livestock keeping as an important pathway out of poverty taking into account both beneficial and harmful livestock management practices associated with integrated watershed and river basin management. Global issues and principles are discussed with reference to the Ethiopian context for development, integrated natural resource management (INRM) and the improvement of water productivity through effective water management.

Livestock and poverty reduction

The potential of livestock to reduce poverty is enormous. Livestock contribute to the livelihoods of more than two-thirds of the world's rural poor and to a significant minority of the peri-urban poor. The poorest of the poor often do not have livestock, but if they can acquire animals, their livestock can help start them along a pathway out of poverty. Livestock also play many other important roles in people's lives. They contribute to food and nutritional security; they generate income and are an important, mobile means of storing wealth; they provide transport and on-farm power; their manure helps maintain soil fertility; and they fulfil a wide range of socio-cultural roles (ILRI 2002).

A predicted increase in demand for animal food products in developing countries offers the poor, including the landless, a rare opportunity to benefit from a rapidly growing market (Delgado et al. 1999). In brief, the global process of urbanisation creates expanding market opportunities for food products. Increasing disposable income enables people to increase the proportion of their diet comprised of meat, eggs and milk products including milk, butter and cheese. Consequently, urbanisation leads to a consumer driven increase in the demand for animal products relative to the demand for plant based components. Satisfying this demand provides a great opportunity for poor farming families to rise out of poverty. Mismanaging the production of animal products places unnecessary demands on water resources and can result in enhanced degradation of water and land resources.

Water requirements of livestock

Water contributes up to 80% of an animal's body weight. Deprivation of water more than any other nutrient quickly leads to reduced feed intake, production, reproduction, poor health, and death. Water intake depends upon the size of animal, feed and salt ingested, lactation, and ambient temperature and an animal's genetic adaptation to its environment. For example, indicative water intake by dairy cows could be estimated by the following equation (after Pallas 1986):

$$y = 16.0 + 0.71i + 0.41m + 0.05s + 1.2t$$

where, y is the daily water intake (litres per day assuming l litre, and weights = 1 kg), where i is the daily dry matter feed intake (kg/day), m is the daily milk production (kg/day), s is the sodium intake (g/day) and t is the mean weekly mean minimum temperature (°C).

Indicative water intake levels of livestock range from about 5 litre/TLU in cool wet weather to about 50 litre/TLU in hot dry conditions (Table 1). Although much effort has been devoted to the important task of providing drinking water for animals, the actual water required to produce daily feed for livestock is about 100 times the actual daily requirements for drinking water. Livestock typically require daily feed intake of dry matter amounting to about 3% of their weight, but about 1 m^3 or 500 litres of water is required to produce 1 kg dry matter. One TLU of small livestock such as sheep and goats would require up to 5000 litres of water a day to produce the feed required, and larger animals such as camels will require at least half of this amount.

Table 1. *Indicative water requirements for drinking and feed production necessary to sustain animal production.*

Species	Mean live weight (kg)[1]	Tropical livestock units (TLU/head)	Daily dry matter intake		Water needed to produce daily dry matter intake[2]		Voluntary daily water intake by season and average temperature (litre/TLU)[3]		
			Kg	Kg/TLU	Litre	Litre/TLU	Wet (27°C)	Dry (15–21°C)	Dry hot (27°C)
Camels	410	1.6	9	5.6	4500	2813	9.4	21.9	31.3
Cattle	180	0.7	5	7.1	2500	3571	14.3	27.1	38.6
Sheep	25	0.1	1	10.0	500	5000	20.0	40.0	50.0
Goats	25	0.1	1	10.0	500	5000	20.0	40.0	50.0
Donkeys	105	0.4	3	7.5	1500	3750	5.0	27.4	40.0

1. One TLU = 250 kg.
2. Assuming 2 kg/m^3 (Kijne et al. 2002).
3. Pallas (1986).

Water productivity—General principles

Popular literature often criticises the use of livestock in agricultural production because of their apparently high water requirements (e.g. Goodland and Pimental 2000; Postel 2001). Water requirements of various agricultural commodities varies (Table 2) with beef production reportedly requiring 200 times more water than potatoes. Many details are missing from such summaries. For example, the food items listed have highly variable water contents. The figures do not take into account market values of the commodities. The requirements do not clearly explain how the water was used in the production process and how much could have been re-used for other purposes. The example in Table 2 for example could have come from a North American feed lot where the feed is irrigated maize and where large quantities of water are used during the slaughter, processing, and packaging of animal products. It probably does not represent livestock keeping and production in the sub-Saharan African context. Despite these, the reported differences cannot be ignored.

Understanding their implication and managing them for integrated natural resource management requires analysis of innovative new research on water productivity of livestock.

Table 2. *Estimates of water required to produce diverse food products.*

Food product	Litres of water required to produce 1 kg of food item
Potatoes	500
Wheat	900
Alfalfa	900
Sorghum	1110
Maize	1400
Rice	1910
Soybeans	2000
Chicken	3500
Beef	100,000

Source: Goodland and Pimental (2000).

Water productivity of livestock is a measure of the ratio of outputs such as meat, milk, eggs, or traction to water depleted (i.e. used as an input and subsequently not available for other uses). When multiple outputs such as milk (litres), meat (kg), and traction (ox-days) are involved, productivity must be expressed using a common measure such as US dollars or Ethiopian Birr per unit of water depleted. Degraded water can be viewed as water depleted for high value purposes. Water productivity can be estimated by the following equation:

$$\textit{Water productivity of livestock} = \sum \left[\frac{\textit{livestock outputs and services}}{\textit{Depleted water}} \right]$$

Water productivity measures are scale dependent (Table 3), and water considered depleted at one scale may not be considered as such at a different scale if it has been or can be used for additional purposes. At the level of the individual animal, water lost through evaporation and respiration are no longer available to the animal or to any other users. This is depleted water. Losses such as those in urine and milk have no further value to the individual, but may be of use to other users. Degraded water is partially depleted water that can have lower value uses. A clear research challenge is to develop livestock management practices that increase water productivity and reduce depletion and degradation. Applicability of interventions will be scale-specific as suggested in Table 3. For example, urine provides nutrients to the forage crops on which animals feed and contributes to soil moisture. This is depleted water from the perspective of the individual animal but not to larger systems (e.g. a pasture).

Estimating water productivity of livestock can be tricky. For example, Goodland and Pimental (2000) suggested that 100 thousand litres of water are needed to produce 1 kg of beef. In contrast, let us assume that one head of cattle consumes 25 litre/day over a two-year period to produce 125 kg (the approximate dress weight of one TLU). This implies that it will drink up to 18,250 litres over a two-year period. Let us also assume that all of the feed comes from crop residues for which no additional water input was required. Then productivity of beef production would be about (18,250 litres)/(125 kg) or 146 litres/kg, an amount far more efficient than the figure given for potatoes (Table 2). In addition, much of the water consumed by livestock is released into the soil as urine providing soil nutrients and soil moisture. From this example, it is clear that livestock production could be viewed as either one of the most efficient or inefficient means of producing food for people depending on the system in which the livestock are raised. The difference between the two water productivity scenarios of 100 thousand and 148 litres/kg of beef, that we must assume that we know very little about the true water productivity of livestock keeping. Understanding water productivity of livestock is lacking, especially at a watershed or river basin level, and must be given priority in future research and development.

Table 3. *Examples of depleted and degraded water with mitigation approaches for different scales of livestock production.*

Scale or type of livestock system	Forms of depleted and degraded water linked to livestock management at lowest scale of importance	Examples of livestock related methods to reduce depletion and degradation linked to system scale where applied
Biosphere	None	Implies that water is never lost and is always recycled so that interventions operate at regional or local scales
River basin	River discharge Contaminated ground and open water	Replenish ground water Manage upper catchment Manage manure, and animal by-products International financing mechanisms
Watershed that includes many farming systems	Runoff Contaminated ground water Downstream flow beyond watershed boundary	Reduce contamination by urine and manure Increase ground cover and infiltration Create incentives for downstream users to assist upstream water and soil conservation Improve common property and community based natural resources management (NRM)
Household including livestock and crop production	Transpiration, evaporation and runoff Export of agricultural products containing water Infiltration below roots	Increase ground cover and infiltration Increase soil water holding capacity Construct contour erosion barriers
Livestock grazing and feeding of crop residues (pasture or crop land)	Transpiration, evaporation and runoff Infiltration below root layers Removal of agricultural products containing water	Maintain ground cover and increase soil water holding capacity Plant deep-rooted fodder species (e.g. tree fodder) Use drought tolerant plants (e.g. C4 forages) Increase water holding capacity of soil (e.g. adding manure)
Individual animals	Respiratory loss Lactation, urination and defecation Evaporation (thermoregulation)	Use of drought and heat tolerant animals Provide shade Provide non-saline drinking water

Because animal products have high value compared with most staple plant based foods, livestock production will likely be increasingly valued as an effective strategy to alleviate poverty in situations where market opportunities exist. Following on the argument that water productivity of animal products derived from consumption of crop residues is competitive with crop production, it follows that in terms of water productivity, livestock can make an important contribution to poverty alleviation.

The case of urban and peri-urban livestock production

Globally, urban demand for livestock products is growing rapidly because of the combined effects of migration and increased income (Delgado et al. 1999; ILRI 2002). Assume that animal products will make up 10% of the future urban diet, and that feed conversion efficiency of animal feed is about 10%, and that water requirements for production of animal and plant food are about the same. Then the water required to meet the future urban demand of animal products would be about the same as that required to produce all other food for the urban population. Urbanisation often leads to the re-allocation of water from agriculture to urban demands for domestic water and industry (Molden 2002). This suggests that future competition for water between livestock and other water users will intensify. However, urban and peri-urban livestock production systems can give high value products for relatively little use of urban water if water requirements for feed production are not drawn from the urban and peri-urban areas where water demand is high. By importing feed from outside of the source area for urban water supplies, urban livestock producers can avoid having to compete with urban demand for this essential input. This is a form of 'virtual water' (Meissner 2002) that provides a mechanism to improve water productivity within urban and peri-urban agriculture. It also reduces the land area required for production.

Non-consumptive interactions of livestock and water resources

As Steinfield et al. (1997) observed, livestock do not degrade the environment—humans do. The decisions and actions of people who manage livestock rather than the livestock themselves are primarily responsible for the mix of positive and negative impacts that they have on environmental and human health. In Ethiopia, many farmers would fail to harvest crops without access to oxen to plow and drain waterlogged vertisols (e.g. Astatke and Saleem 1997). The water required by the oxen must be factored into the productivity of these crops. When poorly managed, livestock keeping can contribute to degradation and depletion of water resources. Yet, studies in Ethiopia demonstrate that conversion of cropland to grassland reduces annual soil loss from 42 to 5 t/ha presumably with an accompanying decrease in runoff because well-maintained grass cover is perhaps the best natural method of erosion and runoff control. Establishing watering points for livestock creates foci for high human and animal populations and unleashes unsustainable pressure on natural vegetation (Steinfield et al. 1997). In some savannah systems, scarcities of vegetation are caused by drought and not grazing pressure (Ellis and Swift 1988; Cavendish

1995) where livestock numbers are determined by rainfall levels, and attempting to revive grassland through manipulating livestock numbers is thus misguided. Livestock management has a major impact on river basin hydrology and on the sustainability of livelihoods of the inhabitants. Integrated watershed management will need to integrate effective livestock management to attain sustainable poverty reduction. Finding optimal livestock keeping practices and feeding systems for different species and conditions is a primary need for future research and for development of watersheds and river basins.

Human health is a fundamental aspect of poverty (ILRI 2002) and significant health issues are linked to both livestock and water management. For example, clean water is essential to ensure hygiene in processing dairy and meat products. Without quality water, food safety is jeopardised and market opportunities are lost.

Malaria, the number one cause of mortality in Ethiopia (WHO 2002), exists where water provides suitable habitat for larval *Anopheles* mosquitoes. Some vector species prefer blood meals taken from livestock raising the prospect that livestock treated with insecticides such as deltamethrine could attract mosquitoes and control malaria (Habtewold et al. 2001; Rowland 2001). However, watering practices for livestock may generate breeding sites for the vector and contribute to increased prevalence of malaria. Land use changes such as converting papyrus swamps to pasture and crop appear to increase temperatures and enable survival of anopheline populations in African highlands (Lindblade et al. 2000).

Waterborne human illnesses often arise from contamination of domestic water by poorly managed livestock. For example, Cryptosporidium, a parasite whose oocysts are common in livestock, has been associated with various outbreaks of human illness in recent years and is thought to aggravate the impact of HIV/AIDS (FAO 1977).

To ensure that productivity gains to reduce poverty are not offset by an associated poor human health, there is a need to integrate human health into R&D related to water and livestock management.

Conclusion: Emerging research priorities

Livestock are valued assets for the rural poor and marketing of livestock products is a practical and effective pathway out of poverty. Opportunities exist to increase the water productivity of livestock at scales ranging from households to river basins. However, surprisingly little integrated research has been done on this subject, and little of the existing knowledge has been translated into policy and technology to improve the livelihoods of the poor. Livestock interact both positively and negatively with the management of water and other natural resources. A number of critical human health issues are linked to water and livestock management. Research is needed to better understand the role of livestock in integrated water management, and strong evidence exists to suggest that this must be addressed in the implementation of Ethiopia's poverty reduction strategy.

References

Ashby J. 1999. *Poverty and gender: A proposal for action research*. CGIAR conference on poverty, San José, Costa Rica. CGIAR (Consultative Group on International Agricultural Research), Washington, DC, USA.

Astatke A. and Saleem M. 1997. Effects of different cropping options on plant-available water of surface-drained vertisols in the Ethiopian highlands. *Agricultural Water Management* 36:111–120.

Cavendish W. 1995. Economics and ecosystems: The case of Zimbabwean peasant household. In: Bhaskar V. and Glyn A. (eds), *The North, the South and the environment: Ecological constraints and the global economy*. UNU Press, Tokyo, Japan.

Delgado C., Rosegrant M., Steinfeld H., Ehui S. and Courbois C. 1999. *Livestock to 2020: The next food revolution*. Food, Agriculture and the Environment Discussion Paper 28. IFPRI (International Food Policy Research Institute), Washington, DC, USA. 72 pp.

Ellis J. and Swift D. 1988. Stability of African pastoral ecosystems: Alternate paradigms and implications for development. *Journal of Range Management* 4:450–459.

Goodland R. and Pimental D. 2000. Environmental sustainability and integrity in natural resource systems. In: Pimental D., Westra L. and Noss R. (eds), *Ecological integrity*. Island Press, Washington, DC, USA.

Habtewold T., Walker A., Curtis C., Osir E. and Thapa N. 2001. The feeding behaviour and Plasmodium infection of Anopheles mosquitoes in southern Ethiopia in relation to use of insecticide-treated livestock for malaria control. *Transaction of the Royal Society of Tropical Medicine and Hygiene* 95(6):584–586.

ILRI (International Livestock Research Institute). 2002. *Livestock–A pathway out of poverty: ILRI's strategy to 2010*. ILRI, Nairobi, Kenya.

Kijne J., Tuong T., Bennett J. and Oweis T. 2002. *Ensuring food security via improvement in crop water productivity*. Challenge Program on Water and Food: Background Paper 1. IWMI (International Water Management Institute), Colombo, Sri Lanka. pp. 1–42.

Lindblade K., Walker E., Onapa A., Katungu J. and Wilson M. 2000. Land use change alters malaria transmission parameters by modifying temperature in a highland area of Uganda. *Tropical Medical Institute of Health* 5(4):263–274.

Meissner R. 2002. Regional food security: Using the concept of virtual water. *African Security Review* 11(3).

Molden D. 2002. *Integrating research in water, food and environment*. Challenge Program on Water and Food: Background Paper 4. IWMI (International Water Management Institute), Colombo, Sri Lanka. pp. 115–160.

Pallas P. 1986. *Water for animals*. Land and Water Development Division. FAO (Food and Agriculture Organization of the United Nations), Rome, Italy.

Postel S. 2001. Growing more food with less water. *Scientific American* 284(2):46.

Rowland M. 2001. Control of malaria in Pakistan by applying deltamethrin insecticide to cattle: A community randomised trial. *The Lancet* 357:1837–1841.

Steinfield H., de Haan C. and Blackburn H. 1997. *Livestock–environment interactions: Issues and options*. FAO (Food and Agriculture Organization of the United Nations), Rome, Italy.

WHO (World Health Organization). 2002. *WHO country cooperation strategy in Ethiopia: Investing for healthy generation*. WHO, Addis Ababa, Ethiopia.