Entry Points to Improve Livestock Water Productivity in Selected Forage Based Livestock Systems

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Abstract
Agricultural production is challenged by increasing water scarcity and simultaneously growing demands for food and feed. Globally livestock feed sourcing is seen as one of the major causes for water depletion, and therefore increasing livestock water productivity (LWP) is necessary. Feed sources in Forage Based Livestock Production Systems [FLPS (grazing, mixed-irrigated and mixed-rain-fed)] largely consist of pasture, crop residue, or immature cereal crops, and also plants cut for fodder and carried to the animals. In drylands (arid and semi-arid) eco-regions, FLPS are generally extensive and thus the scale of water depletion for feed production is a major concern. This paper synthesizes LWP-knowledge generated across different FLPS over time and systematically identifies entry points to enhance productive uses of fresh water resources. It draws on examples of grazing systems in Uganda (Nile basin), mixed-rainfed systems in Ethiopia (Nile basin), mixed-irrigated systems in Sudan (Nile basin), and mixed-irrigated systems in India (Indio-Gangetic basin). Although these systems vary by their degree of intensification, scale of water related problems, and therefore in their values of LWP, a number of common entry points to increase LWP can be identified. Based on empirical evidence from these systems, we systematically clustered these entry points as: i) improving the water productivity of feed; ii) improving livestock feed sourcing and feeding; iii) enhancing livestock feed use efficiencies; iv) enabling institutions and market linkages to facilitate adoption of relevant technologies. The paper concludes by discussing a comprehensive framework for entry points to improve water productivity in FLPS.
Key words: Water productivity of feed; Feed use efficiencies; Unproductive water use.

1. Introduction

In view of current demographic trends and predicted dietary transition, global water use will increase to 12,000-13,000 km^3 yr^{-1} in the next few decades (Peden 2007). In spite of their apparent role in supporting rural livelihoods, there are growing debates emphasizing livestock as one of the major agricultural enterprises for depletion of water and thus adding extra pressure on already scarce resources. Feed sources of Forage Based Livestock Production Systems [FLPS (grazing, mixed-irrigated and mixed-rain fed)] largely consist of pasture, crop residue, or immature cereal crops, and also plants cut for fodder and carried to the animals. In drylands (arid and semi-arid) eco-regions FLPS are dominantly extensive and thus the volume of water depletion for feed production is a major concern. This compels the need for better understanding of livestock water interactions and designs for comprehensive entry points to improve Livestock Water Productivity (LWP).

Biophysical and socioeconomic diversity in FLPS, however, generally are a challenge to develop comprehensive entry points to improve LWP. To address these diversities, ILRI and partners have been developing a systems based LWP framework and testing entry points across the different FLPS. For example, grazing systems in Uganda (Nile basin), mixed-rainfed system in Ethiopia (Nile basin), mixed-irrigated system in Sudan (Nile basin) and mixed-irrigated system in India (Indio-Gangetic basin) have been investigated in this respect (Descheemaeker et al., 2011; Haileslassie et al., 2011a and b)]. This paper uses this information to synthesize major LWP related problems and entry points to improve LWP in FLPS.

2. LWP in forage based livestock systems: challenges and opportunities

According to Seré and Steinfeld (1996) grazing, mixed-rainfed and mixed-irrigated systems are the major FLPS in dryland production environments, the intensity and purposes of production vary greatly within and among these systems. This diversity has implications for the challenges FLPS face and the prospects they have to improve LWP. For example, dry fodder (mainly crop residues) and green fodder (planted fodder and fodder from grazing) constitute the major feed ingredients in these systems. Concentrate use, even in the most intensive systems (e.g. mixed-irrigated, India), does not exceed 10% (e.g. Haileslassie et al., 2011b). Depending on the level of intensity and crop-livestock integration the proportion of dry and green fodder also varies. As feed is an interface between water and livestock these intra- and inter-FLPS differences in feed sourcing and feeding strategy have implications for the type and the scale of importance of LWP related problem. Out of the 12 LWP related problems, identified from the literature [Descheemaeker et al., 2011; Haileslassie et al., 2011a; Peden et al., 2007 (Table 1)] and informally discussed with experts in these systems, 85, 66 and 16% of the problems were suggested as very important for grazing, mixed-rainfed and mixed-irrigated, respectively (Table 1). Despite these differences, all FLPS have ineffcient uses of available water as their common denominator (Table 1).

Table 1 Problem matrix showing the scale of importance of LWP related problems across FLPS

Key LWP related problems	Forage Based Livestock Systems (FLPS)								
	Grazing			Rainfed-mixed			Irrigated- mixed		
	1	2	3	1	2	3	1	2	3
Scarcity of water (spatio-temporal) for livestock drinking			**x**		**x**		**x**		
Scarcity of water (spatio-temporal) for feed production			**x**		**x**			**x**	
Inefficient use of available water			**x**			**x**			**x**
Soil nutrient depletion		**x**				**x**	**x**		
Poor feed quality			**x**			**x**		**x**	
High feed gap			**x**			**x**	**x**		
Over grazing			**x**			**x**	**x**		
Open grazing on common property resources			**x**		**x**		**x**		
Post-harvest feed quality & quantity	**x**					**x**			**x**

loss					
High mortality and morbidity	**x**		**x**		**x**
Mainly poor-productivity genotype	**x**		**x**		**x**
Poor access to input and output markets	**x**	**x**		**x**	

1 is for less important, **2** is for rather important and 3 is for very important. The importance of the problem is scaled in relative terms to the FLPS (experts' opinion).

LWP is theoretically defined as the ratio of livestock products and services to the amount of water depleted and degraded in producing these products and services, usually expressed at \$ m^{-3} (Peden *et al.* 2007). Since 2002 LWP has been analysed across scales: regions, systems, farm-herd and animal. Generally the values of LWP range between 0.1-0.65 USD m^{-3} (Descheemaeker et al., 2011) and with increasing intensification and integration of crop-and livestock systems LWP value tends to increase. But this may not always guarantee system sustainability. Comparison between these values might not be relevant as the studies were based on different data sources and addressing different scales. What is more appealing here is the enormous gap between minimum and maximum values of LWP, illustrating potential for improvement. Therefore a priority is to identify entry points and systematically organize them to facilitate harnessing these potentials.

3. Framework for a comprehensive entry points to improve LWP

Rockström and Barron (2007) suggest the challenges to improve agricultural water productivity (WP) in mixed-rainfed systems are: i) improving water availability for crops and ii) enhancing plant water uptake capacity. With respect to livestock system this is widely comprehended as synonymous to feed WP improvement. However FLPS are a combination of forage plants, livestock and their complex interactions, and despite of the fact that livestock feed production depletes by far a significant proportion of water invested in livestock business, improving WP of feed is only one part of the solution. It must be accompanied by livestock feed use efficiency (Figure 1).

Currently in most parts of FLPS unproductive water loss (evaporation, run off) is common. Entry points such as mulching (mixed-rainfed and mixed-irrigated) and water harvesting measures [mixed-rainfed, Descheemaeker et al., (2011)] reduce runoff and create opportunities for better water infiltration and thus increasing plant water availability across time and space (Figure 1) . When water availability is combined with increased plant water uptake through improved soil fertility and crop management, it increases the proportion of water flowing as productive transpiration.

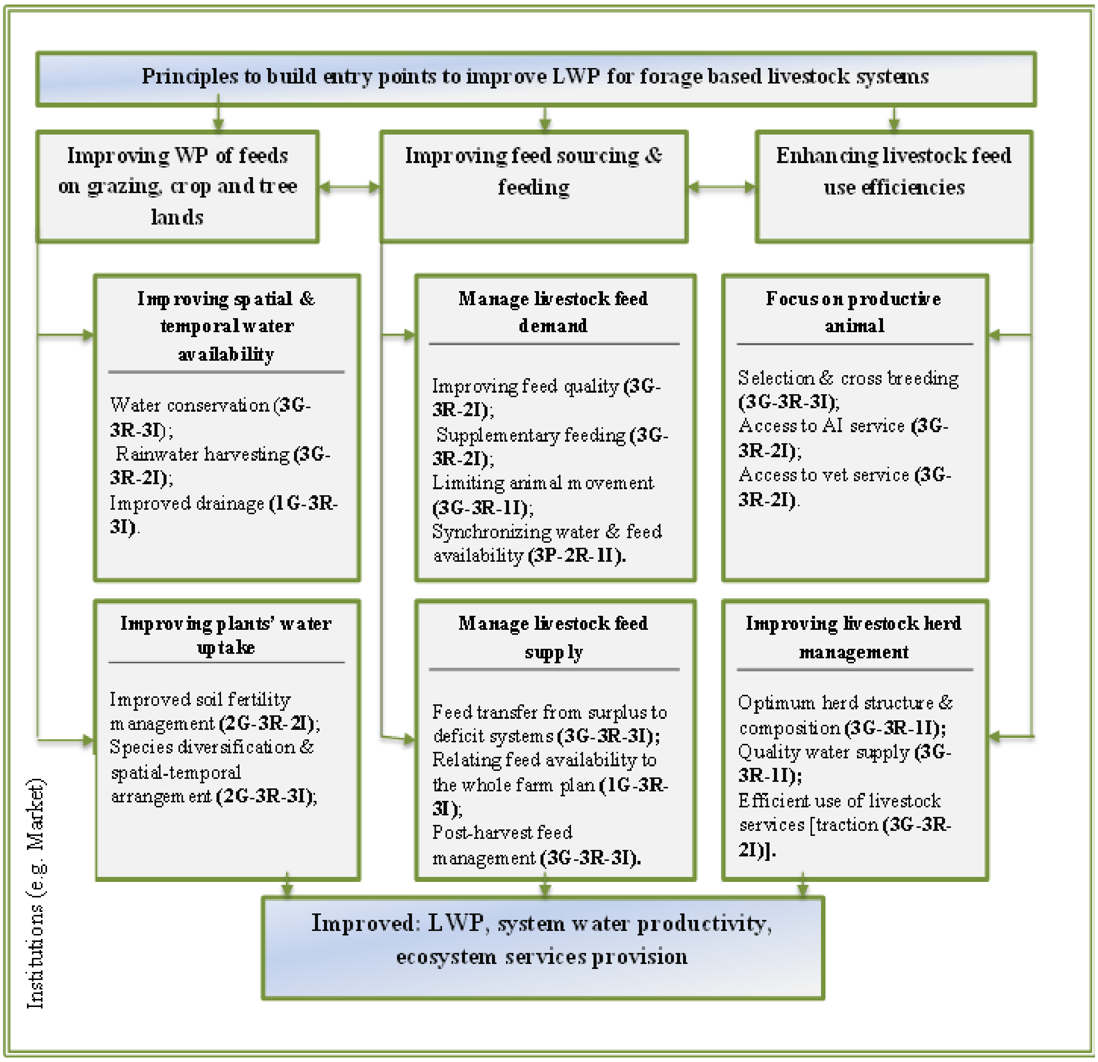

Figure 1 Framework of entry points to improve LWP in FLPS (in brackets G is for grazing, **R** is for rainfed-mixed and **I** is for irrigated mixed. Numbers in prefix represent scale of relevance for entry points**: 1** low and **3** high).

To improve LWP, we need to increase the quality of locally available feed and the way we feed the animal. Such activities may involve selection, intercropping, urea treatment, chopping of coarse residues etc. For example, Haileslassie et al. (2011b) in mixed-irrigated systems showed that by improving feed quality (from 7 to 8.5 ME MJ kg^{-1}) >50 m^{-3} of water cow^{-1} yr^{-1} can be saved. For mixed-rainfed systems, Descheemaeker et al. (2011) reported an improvement in LWP when crop residues were treated with urea.

By limiting animal movement it is also possible to reduce the amount of energy livestock requires, leading to higher LWP values. For mixed-rainfed systems Descheemaeker et al. (2011) reported ~12% of the metabolizable energy (ME) in animals are spent walking in search of feed and water. If we assume the average ME demand of 60 MJ TLU^{-1} day^{-1} for a mixed herd model and ME density of feed resources at 8 MJ Kg^{-1}, the energy needed for walking is roughly equivalent to 1 kg DM. Assuming feed WP of 0.89kg m^{-3} and 3.5 TLU per household into account, the water invested in walking would be 1295 m^{-3} per household per year (Figure 1).

Generally, reproductive /productive performance of indigenous breeds are inferior compared with the cross breeds [e.g. in mixed-rainfed, mixed-irrigated) Descheemaeker et al., (2011); Haileslassie et al., 2011a]. Haileslassie et al., (2011b) also emphasized strong intra and interbreed variability. Two lessons can be drawn from these examples: firstly it is important that future livestock management interventions include the introduction of productive animals through crossing of indigenous with foreign blood animals. Secondly, opportunities for selective crossing of local breeds and within breed selection must be practiced.

Livestock mortality and morbidity are the major causes of economic loss and low productivity, mainly in grazing, and in mixed-rainfed systems. For example in mixed, rainfed systems in Ethiopia the estimated mortality rate, at a national level, reaches 8-10% in adult cattle; 14-16% in sheep 14-16% and 11-13% in goats. In financial terms losses due to mortality alone exceed 43 million USD yr^{-1}. Using the lower value of LWP (0.09 USD m^{-3} of water, Descheemaeker et al., (2011); this will be equivalent to a loss of 479 million m^3 of water.

Generally, despite differences in their scale of importance across FLPS, entry points to improve LWP needs to be built on key principles indicated in the framework (Fig 1) and to achieve higher LWP values and enhance ecosystems service provision these entry points need be integrated and contextualized.

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