# The Role of Improved Forages in Solving the Water Scarcity Issue of 4 Billion People

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The XXIV International Grassland Congress / XI International Rangeland Congress (Sustainable Use of Grassland and Rangeland Resources for Improved Livelihoods) takes place virtually from October 25 through October 29, 2021.

Proceedings edited by the National Organizing Committee of 2021 IGC/IRC Congress

Published by the Kenya Agricultural and Livestock Research Organization

# The role of improved forages in solving the water scarcity issue of 4 billion people

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**Key words**: drought tolerance; feed basket; livestock water footprint; tropical forages

## Abstract
Global animal production requires about 2422 $Gm^3$ of water per year. Most of this volume is used by cattle, with 30% used in the beef sector and another 19% in the dairy sector. At the same time, four billion people suffer from severe water scarcity, raising the flag on diverting an important part of the water globally to livestock production. Livestock-water interactions have therefore gained a prominent profile and fuelled discussions on the water footprint of livestock. A series of studies on the most important components of the livestock water footprint have shown that globally more than 90% of the footprint was due to feed production. Despite huge geographical heterogeneity and large differences in terms of livestock production system, feed production thus is a major target to implement water use efficiency strategies. In the tropics, crop-livestock systems and pastoral systems are the most common livestock production systems, and offer several options to diversify the feed basket and increase feed water productivity. Inclusion of improved forages, adapted to specific environments, can further minimize the demands of water for feed production. Indeed, several advantages can be expected: (i) "water saver" forages increase the amount of quality biomass available per drop of water, (ii) synchronization with fertilizer and manure application decreases the contamination of water bodies by a more efficient use of soil available nitrogen, and (iii) growing forages has positive impact on soil water retention through decreased evaporation, improved texture and erosion mitigation, increasing therefore the amount of water available to plants. This is particularly the case in dry seasons, when alternatives would be irrigated or conserved feed, or concentrates. Policies should focus on facilitating the access of farmers to adapted planting materials, and on providing land use guidance to sustainably intensify livestock production in dedicated zones.

## Global water footprint
Global animal production requires about 2422 $Gm^3$ of water per year, composed for 87.2% by green water (effective rainfall stored in the soil), 6.2% by blue water (surface or groundwater resources), and 6.6% by grey water (required to dilute pollutants). One third of this volume is for the beef cattle sector; another 19% for the dairy cattle sector (Mekonnen and Hoekstra, 2010). This water is used for drinking and servicing, for product processing and for feed production. At the same time, four billion people suffer from severe water scarcity (Mekonnen and Hoekstra, 2016), raising the flag on diverting an important part of the fresh water globally available (which decreases due to climate change and pollution) for livestock production. The share of global water withdrawals for livestock use is projected to increase even more (Steinfeld *et al.*, 2006). This has recently heated the debates among animal products consumers, as high meat or high dairy-based diets have higher water footprints (Kim *et al.*, 2019). Therefore livestock-water interactions have gained a prominent profile, and fuelled discussions on the water footprint of livestock, and on the sustainability of the sector (Herrero *et al.*, 2009; Herrero and Thornton, 2013; Herrero *et al.*, 2015).

## Water productivity
### *Systems and boundaries*
Water requirements of livestock vary mainly according to species, growth stage, air temperature, and humidity, level of animal exertion, production levels, and water content in animal diet (Ward and McKague, 2019). The type of production system is therefore playing an important role in determining livestock water productivity (LWP), defined as the ratio of livestock outputs to the amount of water used. For example, from a freshwater perspective, animal products from grazing systems have a smaller blue and grey water

footprint than those from industrial systems (Mekonnen and Hoekstra, 2012). The level of endowment of farmers and where they source their feed also impact the water footprint (Bekele *et al.*, 2017). Methodologically, the assessment of livestock water productivity depends on the system boundaries: assessments focusing on on-farm production will give very different results compared to life cycle analysis, when it comes to feed origins. Indeed, cut and carry systems based on local feed production have a different water footprint than a similar farm using grains produced abroad, depending on the water extraction and scarcity index in each place.

***How to increase livestock water productivity?***

Different options are proposed to increase livestock water productivity from both inputs and outputs sides. Briefly, livestock outputs could be increased through improved feed management, veterinary services and introducing system compatible breeds, and the efficiency of the water inputs could be raised by integrating livestock with crop, water, and landscape management policies and practices (Descheemaeker *et al.*, 2010). Still in many cases, improving feed water productivity by minimising evapotranspiration and other losses is deemed critical, despite a huge geographical heterogeneity and large differences in terms of livestock production system (Rockström and Barron, 2007; Amede *et al.*, 2009a). As highlighted by Mekonnen and Hoekstra (2010), 98% of the total volume of water used by livestock systems refers to the water footprint of the feed for the animals. Drinking water for the animals, service water and feed mixing water account only for 1.1%, 0.8% and 0.03%, respectively (Hoekstra, 2012). Disaggregating meat production by animal species, beef water use is the less efficient, with only 0.065 kg/m$^3$ of water compared to 0.096 kg/m$^3$ for mutton, 0.17 kg/m$^3$ for pig and goat meat and 0.23 kg/m$^3$ for chicken (Mekonnen and Hoekstra, 2010). Ruminants are less efficient in converting feed to meat, because feed quality is lower than for pigs and chicken. However, these values can vary greatly depending on the systems and the location. High water consumption is especially observed in intensive and industrial systems where wastes are not recycled and where cattle are fed with cereals or legumes from intensive agriculture. Extensive livestock systems are usually observed on marginal land where soil moisture is not enough to grow crops, allowing a productive use for an area that would otherwise be lost for food production, while not competing for water and soil with high productive croplands (van Zanten *et al.,* 2016). In the tropics, crop-livestock systems and pastoral systems are the most common livestock production systems, and offer several options to diversify the feed basket and increase the feed water productivity, for example using crop residues (Blummel *et al.*, 2009). The latter is, beside the use of marginal lands, another upgrade option for a biomass stream that humans do not currently consume (van Zanten *et al.,* 2016). In addition, in tropical smallholder systems, cattle provides many more services, including transportation, traction, and manure production for soil fertility, which allows improving water use efficiency (Tarawali *et al*., 2011).

## The role of forages and potential gains

Inclusion of improved forages adapted to specific environments can further minimize the demands of water for feed production. Although this has been until now barely mentioned in the literature, and largely absent from the most extensive livestock environmental impacts assessments, like the book "Livestock's long shadow" (Steinfeld *et al.*, 2006), several advantages can be expected, and are detailed here.

***Water savers vs. water spenders***

From an agronomic and physiological point of view, plants can be categorised as water savers or water spenders. Such categorization allows the targeting of different forages to environments with different precipitation patterns. Water-spending forages might be better used in environments with short droughts, whereas water-saving forages would be better off under longer drought conditions. Each category has potential benefits and drawbacks (Table 1; Cardoso and Rao, 2019). One advantage of water savers is the increase of quality biomass available per drop of water. This is particularly important in dry seasons, when alternatives would be irrigated materials, conserved materials or concentrates.

Table 1. Water use strategies

| Water use strategy | Water-spending | Water-saving |
|---|---|---|
| Benefit | Maximize growth when water is available | Reserved water in soil for later use |
| Trade-off | Faster desiccation of plants | Save water at expense of growth |
| Target-environment based on precipitation patterns | Intermittent or shot seasonal drought (1-4 months) | Long seasonal drought (> 4 months) |
| Recommended use | Cut and carry systems and forage conservation (e.g., hay) | Grazing systems |

In dry climates, the water content of forages decreases from 90 percent during the growing season to about 10 to 15 percent during the dry season (Pallas, 1986): there is therefore a trade-off with water for drinking, as the water content of feed determines the amount of water intake through drinking.

***Synchronization of nutrient applications***

Synchronization of nutrient demand with fertilizer and manure application decreases the contamination of water bodies by a more efficient use of soil available nitrogen, and therefore decreases the grey water footprint. This synchronization is a temporal, locational, and quantity question: it implies that the rate of release of a nutrient into a plant-available form is closely related to the rate at which it is needed by the plant, and that the location of released nutrients is close to plant roots (Myers *et al.*, 1994). Simple management practices around the control of quantity and quality of both mineral and organic fertilizers application can support synchronization.

***Soil water conservation***

Growing forages have positive impact on soil water retention through decreased evaporation, improved soil structure (size and stability of the aggregates, pores size and distribution etc.), and erosion mitigation, therefore increasing the amount of green water available. Different types of forages are available for different types of systems. The highest benefits at farming system level are obtained when forages are integrated in rotations or in areas not suitable for crops, so as to not replace staple or other high value crops. Grasses can be used on contour lines, or in improved pastures and silvopastoral systems (e.g. Central America and the Caribbean; Alonso, 2011). Legumes have been used to reclaim degraded soils, to enhance soil fertility, and to improve water use efficiency in different locations (Bell *et al.,* 2012; Douxchamps *et al.*, 2014; Muhr *et al.*, 1999). In general, the availability of more biomass produced with limited amounts of water on the farm allows for multiple uses, all increasing water use efficiency at farm level: feeding forages to pigs allows to redirect part of the household wastes for composting, which improves soil texture and therefore soil water retention.

## Implications

Although forage species adapted to different edaphic stresses and different systems have been developed, these species are not always accessible, available and/or affordable for smallholder farmers in tropical zones. Few– mostly grasses–are commercialized and available, while many options remain in gene banks and seed stores due to complicated import and release processes, or lack of informal seed production systems. Lack of knowledge about their benefits and their management, and lack of access to planting material are major constraints for adoption. Livestock innovation is a social process, and it will not be possible to achieve a substantial reduction of the global livestock water footprint unless close attention is paid to policies, institutions and their associated processes (Amede *et al.*, 2009a). Unfortunately, this domain so far stays a blind spot, as findings from livestock water productivity studies are not taken forward in national water policies that used to concentrate on increasing water-use efficiency in crop production and feed conversion efficiency in the livestock sector (Hoekstra, 2014). It is key aspect to improve the dialogue between professionals of the water livestock sectors. Policies should focus on facilitating the access of farmers to adapted planting materials, and on providing land use guidance to sustainably intensify livestock production in dedicated zones.

## Acknowledgements

The work was undertaken as part of the CGIAR Research Program on Livestock and the CGIAR Research Program on Water, Land and Ecosystems, which are supported by the CGIAR Fund Donors and bilateral funding agreements.

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