Expl. Agric. (2011), volume 47 (S1), pp. 1–5 © *Cambridge University Press 2011*
doi:10.1017/S0014479710001031

IMPROVING WATER PRODUCTIVITY IN CROP-LIVESTOCK SYSTEMS OF DROUGHT-PRONE REGIONS

EDITORIAL COMMENT

By TILAHUN AMEDE, SHIRLEY TARAWALI *and* DON PEDEN

Crop-livestock systems in sub-Saharan Africa (SSA) are mostly rainfall-dependent and based on fragmented marginal lands that are vulnerable to soil erosion, drought and variable weather conditions. The threat of water scarcity in these systems is real, due to expanding demand for food and feed, climate variability and inappropriate land use (Amede *et al.*, 2009). According to recent estimates, farming, industrial and urban needs in developing countries will increase water demand by 40% by 2030 (FAO, 2009). Water shortage is expected to be severe in areas where the amount of rainfall will decrease due to climate change. The lack of capacity of communities living in drought-prone regions to respond to market opportunities, climatic variability and associated water scarcity also results from very low water storage facilities, poverty and limited institutional capacities to efficiently manage the available water resources at local, national and basin scales. The spiral of watershed degradation causes decline in water budgets (Awlachew and Ayana, 2011), decreases soil fertility and reduces farm incomes in SSA (Amede and Taboge, 2007) and reduces crop and livestock water productivity (Descheemaeker *et al.*, 2011). In areas where irrigated agriculture is feasible, there is an increasing demand for water and competition among different users and uses.

Strategies and policies to reduce rural poverty should not only target increasing food production but should also emphasize improving water productivity (WP) at farm, landscape, sub-basin and higher levels. In drought-prone rural areas, an increase of 1% in crop water productivity makes available at least an extra 24 litres of water a day per person (FAO, 2003). Moreover, farming systems with efficient use of water resources are commonly responsive to external and internal drivers of change. This special issue of *Experimental Agriculture* presents evidence from Ethiopia, Zimbabwe and India, and captures current understanding of strategies to improve water productivity in drought-prone crop-livestock systems.

Molden *et al.* (1997) defined water productivity as the ratio of beneficial outputs and services to water depleted in producing them, which could be expressed in terms of amount (e.g. kg grain per m^3 of water) or value (e.g. USD per m^3 of water). Definitions of WP could vary based on the purpose, scale and domain of analysis. Water productivity enables assessment of interactions between different system elements (e.g. livestock and crop) and creates an enabling environment for a better understanding of system efficiency (Peden *et al.,* 2009; Haileslassie *et al.,* 2011). The volume of water depleted to produce a similar type of animal product also varies among systems (Haileslassie *et al.,* 2011) and is affected by the type of inputs and management practices used. For instance, WP of livestock is strongly linked to that of feeds (Descheemaeker *et al.,* 2011). In the crop-livestock systems of India, Haileslassie *et al.* (2011) noted that the largest component of total water consumption in livestock systems was the production of irrigated fodder while the smallest component was use of crop residues. In fact, the WP of livestock positively correlates with the percentage share of crop residues in the diet (Haileslassie *et al.,* 2011). Water productivity was also higher for intensive systems than extensive systems (Clement *et al*., 2011).

There are proven interventions that would improve water productivity in these systems. Interventions focused on improving feed management, water management and livestock management had a positive effect on improving water productivity (Peden *et al.,* 2009) ranging from a potential 4 to 94% improvement (Descheemaeker *et al.,* 2011). Improved livestock health, leading to lower mortality rates, led to greater animal outputs from the same feed and water consumption. Reducing animal numbers also led to reductions in depleted water, land used and feed produced, but resulted in higher milk and meat production, due to savings in energy for non-productive activities and maintenance (Descheemaeker *et al*., 2011). Descheemaeker *et al.* showed that combining several different interventions using integrated approaches across spatial and temporal scales led to greater improvement in water productivity as compared to any single intervention: the whole was greater than the sum of the parts. Creating fertile spots around houses is a common practice in SSA where farmers grow crops for food security and cash (Amede *et al*., 2011). The homestead plots, which are favoured for application of household refuse, manure and night soil, are also enriched by nutrients coming from the outfields in the form of feed and mulch (Amede and Taboge, 2007) and tend to have higher WP than the less fertile outfields. Introducing *zai* pits, which are small water harvesting holes dug during the dry season and then filled with handfuls of biomass, as an example of water conserving structures in these less fertile and sometimes degraded outfields increased potato yields five-fold and bean yields three-fold compared to the local practices, and WP was 300–700% higher (Amede *et al*., 2011).

Irrigation is another important intervention to minimize drought effects and improve rural livelihoods of drought-prone regions. However, the return per irrigation investment in the region has been low to date. In an assessment of irrigation schemes in Ethiopia, Awlachew and Ayana (2011) reported that 87% of all schemes are operating, 74% of the command areas is cultivated but only 47% of the planned beneficiaries benefited from irrigation. Large-scale schemes using pumps show higher water use efficiency than simple gravity diversion types. Understanding the water budgets of the irrigation schemes and water distribution across the different uses is also a prerequisite to minimize water loss and encourage productive use of water. In an attempt to quantify water losses in small-scale irrigation schemes in Ethiopia (Demeku *et al*., 2011) found that about 35% of the applied irrigation was lost as unproductive water with the water loss from the main, secondary and field canals being 26, 4.5 and 4%, respectively. These authors also found that incentives for farmers are critical to improve water management at farm and landscape scales. In situations where farmers were required to rent irrigation pumps, they have minimized unproductive water loss, increased productive water and got higher farm returns. However, financial capacity of farmers, which commonly enables them to gain access and control over water, is highly variable, location specific and dynamic even under a relatively homogenous biophysical and social context (Clement *et al.,* 2011). For instance, in India the better-off farmers who have their own water source and who only need to pay diesel costs to access irrigation water might be more willing to accept changes in water management or cropping practices. The inequities in water access are also commonly deep rooted in land ownership (physical accessibility to water harvesting structure or location relative to the irrigation canal), and are difficult to challenge. Interventions aimed at increasing water productivity do not always necessarily benefit the poorest members of rural communities or the women – rather these might favour the better-off farmers who have access to a wide range of resources and connections (Clement *et al.*, 2011). By excluding women from water users' and livestock producers' associations (e.g. in Zimbabwe), the community commonly loses out on a significant opportunity to increase water productivity and potentially higher returns from crop and livestock investments (Senda *et al.*, 2011). These systems could be more efficient and equitable through capacitating local institutions and improving governance of collectively managed irrigation schemes, grazing lands and hillside exclosures (Deneke *et al.*, 2011).

One of the major drivers in SSA affecting water management has been land use and land cover change as a result of human actions and enterprise choices that, in turn, alter the availability of water resources for various uses. In a detailed study in the Ethiopian highlands, Ali *et al.* (2011) reported that land use change was much faster in relatively water-rich regions compared to dry crop-livestock systems. For instance in Fogera, in the Northern Ethiopian wetlands, land which used to be allocated for livestock rearing up to the mid 1980s has been converted to an intensive rice-based system with the introduction of paddy rice. The consequence was an increased water depletion and intensification of crop-livestock systems, but also increased water productivity through producing food and cash crops three times in a year. On the other hand a drier landscape, Lenche Dima, had undergone minimal change in the same period except for a shift of the livestock population towards small ruminants. Crop-livestock systems that are affected by rapid land use changes, and associated decline in water budgets and nutrient depletion, could be best managed through integrated rainwater management systems.

Rainwater management is an integrated strategy that enables crop-livestock systems to systematically capture, store and efficiently use water and nutrient resources on farms and watersheds in a sustainable way for both agricultural and domestic purposes. It focuses more on the institutions and policies than on the technologies and advocates increased water storage and WP at various scales; in the soils, farms, landscapes, reservoirs and basins. Rainwater management is an effective strategy to manage the consequences of climate change (e.g. floods and drought) by combining water management with land and vegetation management. This is particularly critical for Eastern and Southern Africa where the rate of land degradation is rapid and about 70% of the land falls within drought-prone regions (http://www.un.org/esa/sustdev/csd/csd16/rim/eca_bg3.pdf).

In general, several opportunities exist for increasing agricultural WP in SSA. Integrated research and development focused on improving WP across enterprises, scales and systems can enable communities to improve their capacity to adapt to and enhance their resilience to challenges such as climate change and food insecurity. An interdisciplinary and multi-institutional approach, which recognizes the complexity of water use and management and water governance, would provide strategies to produce more food, feed and income. An inclusive research for development approach, which places poor farmers and women at the centre of water research, is needed. Three strategies that came out of this project are the following:

1. The most important strategy to improve water productivity is increasing productive water use (transpiration) over unproductive water depletion (evaporation and seepage) through adoption of soil and water conservation practices, appropriate choice of crop varieties, improved irrigation efficiency and integrated crop-livestock systems.
2. Adoption of interventions for improving water productivity is mostly governed by socio-economic situations of rural households. Understanding wealth and gender dynamics is a critical tool to target clients. Identifying incentive mechanisms for communities to invest in land and water management and empowering communities to make appropriate decisions in managing land, water and livestock resources would enhance the likelihood of adoption of interventions by farming communities.
3. Interventions for improving water productivity are diverse, ranging from selecting water efficient crop and forage varieties to watershed management, which involves various disciplines and institutions. Achieving water productivity at farm and watershed scales demands closer interaction and linkages among various actors, which could be achieved through skilful facilitation and better communication.

REFERENCES

Ali, H., Descheemaeker, K., Steenhuis, T. S. and Pandy, S. (2010). Comparison of landuse and landcover changes, drivers and impacts for moisture-sufficient and drought-prone regions in the Ethiopian Highlands. *Experimental Agriculture* 47 (Suppl. 1): 71–83.

Amede, T., Menza, M. and Awlachew, S. B. (2010). *Zai* improves nutrient and water productivity in the Ethiopian highlands. *Experimental Agriculture* 47 (Suppl. 1): 7–20.

Amede, T., Katrien Descheemaeker, K., Peden, D. and van Rooyen, A. (2009). Harnessing benefits from improved livestock water productivity in crop–livestock systems of sub-Saharan Africa: synthesis. *The Rangeland Journal* 31: 169–178.

Amede, T. and Endale Taboge (2007). Optimizing soil fertility gradients in the Enset (*Enset ventricosum*) systems of the Ethiopian highlands: Trade-offs and local innovations. In *Advances in Integrated Soil Fertility management in Sub-Saharan Africa: Challenges and Opportunities*, 289–297. (Ed. A. Bationo). Dordrecht: Springer Verlag.

https://doi.org/10.1017/S0014479710001031 Published online by Cambridge University Press

Awlachew, S. B. and Ayana, M. (2010). Performance of irrigation: Assessment at different scales in Ethiopia. *Experimental Agriculture* 47 (Suppl. 1): 57–69.

Clement, F., Haileslassie, A., Ishaq, S., Blümmel, M., Murty, M. V. R., Samad, M., Day, S., Himagushu Das and Khan, M. A. (2010). Enhancing water productivity for poverty alleviation: Roles of capital and institutions in the Ganga basin. *Experimental Agriculture* 47 (Suppl. 1): 133–151.

Demeku, S. D., Descheemaeker, K., Haileslassie, A. and Amede, T. (2010). Irrigation water productivity as affected by water management in a small scale irrigation scheme in the Blue Nile Basin, Ethiopia. *Experimental Agriculture* 47 (Suppl. 1): 39–55.

Deneke, T. T., Mapedza, E. and Amede, T. (2010). Institutional implications of governance of local common pool resources on livestock-water productivity in Ethiopia. *Experimental Agriculture* 47 (Suppl. 1): 99–111.

Descheemaeker, K., Amede, T., Haileslassie, A. and Bossio, D. (2010). Analysis of gaps and possible interventions for improving water productivity in crop-livestock systems of Ethiopia. *Experimental Agriculture* 47 (Suppl. 1): 21–38.

FAOSTAT (2009). *FAO statistical database*. Retrieved 11 December 2009, from http://faostat.fao.org/default.aspx.

Food and Agricultural Organization (FAO) (2003) *Raising Water Productivity*. Available from: http://www.fao.org/ag/magazine/0303sp2.htm [Accessed 6 December 2010].

Haileslassie, A., Blümmel, M., Clement, F., Descheemaeker, K., Amede, T., Samireddypalle, A., Acharya, N. S., Radha, V., Ishaq, S., Samad, M., Murty, M. V. R. and Khan, M. A. (2011). Assessment of the livestock-feed and water nexus across a mixed crop livestock systems intensification gradient: An example from the Indo-Ganga basin. *Experimental Agriculture* 47 (Suppl. 1): 113–132.

Peden, D., Taddesse, G. and Haileslassie, A. (2009). Livestock water productivity: Implications for sub-Saharan Africa. *The Rangeland Journal* 31:187–193.

Molden, D. (1997). *Accounting for Water Use and Productivity*. Colombo, Sri Lanka: International Irrigation Management Institute.

Senda, T. S., Peden, D., Homann-Kee Tui, S., Sisito, G., van Rooyen, A. and Sikosana, J. L. N. (2011). Gendered livelihood implications for improvements of livestock-water productivity in Zimbabwe. *Experimental Agriculture* 47 (Suppl. 1): 169–181.