

Water use by livestock: A global perspective for a regional issue?

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Implications

- Water scarcity, a function of supply and demand, is a regional issue with global repercussions, given that 1) the increasing human population and demand for animal products will increase water demand and influence international trade in agricultural products and that 2) global climate change is altering rainfall patterns worldwide.
- Water can be divided into the following types: blue (i.e., surface and groundwater), green (i.e., soil water used in evapotranspiration), and gray (i.e., water necessary to dilute pollutants). On a global scale, agriculture represents 70% of blue water use.
- One main difference among all methods for assessing water use is whether and how they include green and gray water. The “water footprint” approach includes green water, whereas life cycle assessment approaches tend to exclude green water or to include only the variation in green water resulting from changes in land use. A second difference is whether water use is reported as a volume of water or as an index of water-use impact (e.g., H₂O equivalents). A third is whether water that returns to the same location (e.g., in urine) is considered to have been consumed.
- Because of these differences and the fact that existing studies have analyzed only a limited number of different livestock production systems, methods give wildly different results for the same livestock product. For example, estimations of water use to produce 1 kg of beef range from 3 to 540 L of H₂O or H₂O equivalents for the life cycle assessment approach and from 10,000 to 200,000 L of H₂O for the water footprint.
- Ultimately, water scarcity depends on blue water use. Decreasing the contribution of livestock to water scarcity can be achieved by decreasing feed irrigation. Livestock farming also has positive impacts on the environment related to water use.

Key words: life cycle assessment, meat, milk, water footprint, water scarcity

Water Scarcity: Is It a Global Issue?

Water scarcity is a function of freshwater supply and demand, both of which vary greatly in time and space around the world. By one definition, human populations face water scarcity when annual renewable water

supplies in a region fall below 1,000 m³/person, which currently occurs throughout most countries in Northern Africa and the Arabian Peninsula (United Nations Environment Programme, 2008). Although such arid and semiarid regions are the most vulnerable to water scarcity, the demand side of the equation can have a strong, if not stronger, influence. Indeed, water stress, defined as annual water withdrawals exceeding 20% of the annual renewable water supply, has occurred in temperate-climate countries such as Belgium, Korea, and the United Kingdom (Organisation for Economic Co-operation and Development, 2004). Thus, a definition of water scarcity that emphasizes the important role of water demand is, “the point at which the aggregate impact of all users impinges on the supply or quality of water . . . to the extent that the demand by all sectors, including the environment, cannot be satisfied fully” (UN-Water/FAO, 2007). Even if water demand does not lead to water scarcity (e.g., in wet regions), it can increase groundwater depth, potentially decreasing water flow to rivers and causing ecosystem changes.

Global water demand is expected to increase greatly in the future, by 50% between 1995 and 2025 (United Nations Environment Programme, 2008), especially in developing countries, not only because of larger human populations, but also because of overall increases in industrial production and human affluence, which lead to greater consumption of energy, consumer goods, and food, especially animal products. This increase in domestic, industrial, and agricultural water use is expected to expand the areas affected by water scarcity (Figure 1). This may happen even in regions with high rainfall, where population density and economic activity are high. Areas suffering from water scarcity may change from year to year. It has been estimated that 64% of the world population will live in water-deprived zones in 2025 (Rosegrant et al., 2002). For the remaining 36%, especially those living in temperate zones, livestock farming could be performed without strong water restrictions. For example, grassland irrigation, a common practice in “wet” countries such as New Zealand and the Netherlands, can be a useful strategy for increasing grass production.

The supply side of freshwater is a function not only of regional rainfall, which can vary greatly within and between years, but also water management and distribution systems and water pollution, which renders freshwater nonpotable. Unfortunately, global climate change is modifying the supply side of the equation (rainfall patterns), and not in a uniform manner. Simulations of global climate change by the Intergovernmental Panel on Climate Change (IPCC) with 21 different models predicted an average increase of at least 14% in annual rainfall in polar regions (above 60°N) and northern Asia; in contrast, they predicted at least a 12% decrease in annual rainfall in southern Europe and the Mediterranean Basin. Seasonal changes in rainfall are predicted to be even greater, with the greatest increases in December to February in the Tibetan Plateau

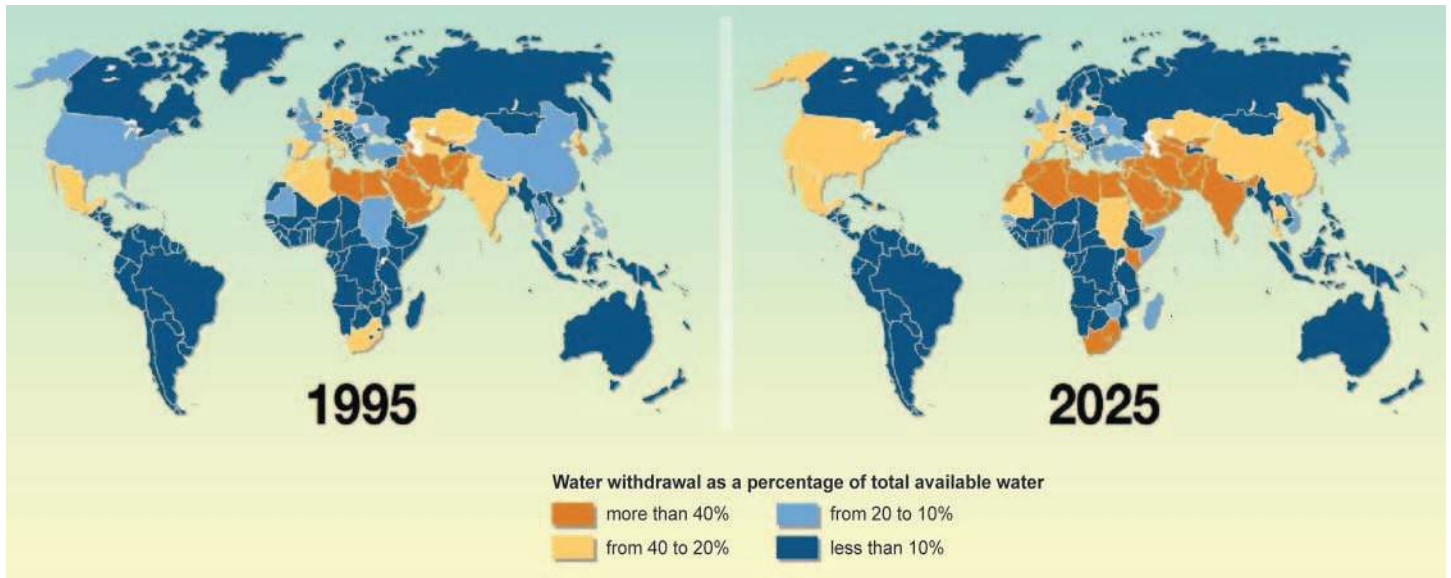


Figure 1. Observed and predicted water withdrawal as a percentage of renewable water stocks in 1995 and 2025, respectively [source: United Nations Environment Programme (UNEP)/GRID-Arendal Maps and Graphics Library, 2009].

(+19%) and northern Europe (+15%) and in June to August in southern Asia (+11%), and the greatest decreases in December to February in the Sahara (−18%) and central America (−14%) and in June to August in the Mediterranean (−29%) and southern Africa (−23%; IPCC, 2007).

Recent studies have highlighted the large amounts of water used for agriculture, especially for livestock production [e.g., Food and Agriculture Organization of the United Nations (FAO), 2006]. No evidence exists that the presence of livestock is related to the risk of water scarcity; for example, in France there is little overlap between regions with high livestock density and those with water-availability problems in summer, some of the latter being areas with irrigated crops (Figure 2). With sustainability becoming or already representing a keystone of resource management and policy in many regions, it is necessary to consider how water use for livestock

production influences water scarcity. However, we recommend a holistic approach, in which the role of livestock in human societies is evaluated as a whole instead of considering the effect on water alone.

Blue, Green, or Gray Water: Which One Is Critical to Calculate Water Use?

Concepts have been defined in the last 2 decades to differentiate water in the environment depending on its location. Blue water represents surface and groundwater, whereas green water represents water lost from soils by evaporation and transpiration from plants derived directly from rainfall (Falkenmark, 2003). Gray water, a theoretical estimate of the

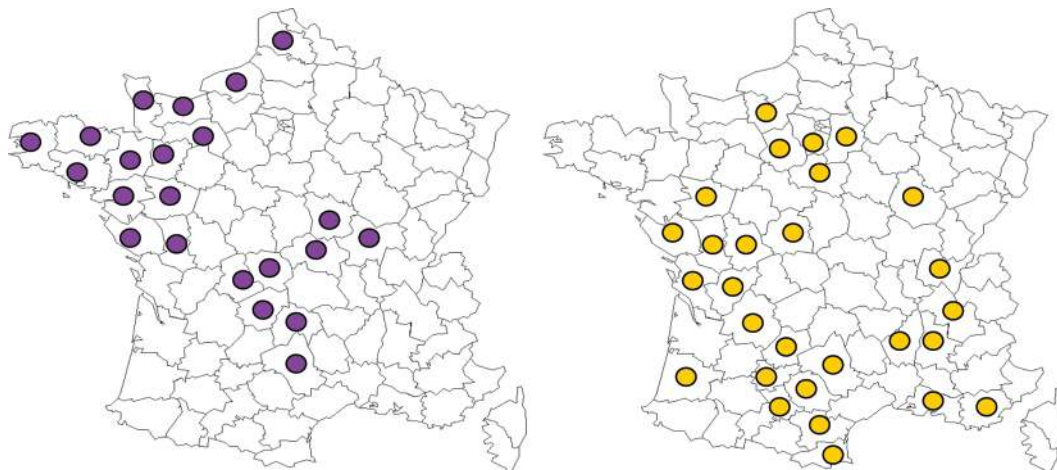


Figure 2. Geographic distribution of cattle and summer water restrictions in France. Purple dots indicate departments with more than 100,000 cattle in January 2009, whereas yellow dots represent departments subject to water restrictions in summer 2008 [source: data from the French BDNI (National Databank for Cattle Identification; <http://www.inst-elevage.asso.fr/>) and Ministry of Ecology (<http://www.eaufrance.fr/>)].

amount of water necessary to dilute pollutants, varies widely depending on the pollutant (e.g., nitrate, synthetic organic chemicals) and the thresholds selected for their concentrations.

The global water cycle is complex. Water evaporated from one location generally returns to the surface as rainfall at another location. On global landmasses, rainfall exceeds evapotranspiration by an average of 70%, whereas on the ocean, evaporation exceeds rainfall. Some blue water returns to the location where it was consumed; for example, a part of the water consumed by livestock (including water contained in feeds) returns to the farm in feces and urine; however, a minor part returns to groundwater by infiltration (Table 1). The remaining water, in animals and their products, leaves the farm. Irrigation water and rainfall are taken up by plants and then transpired, moving to another location via the atmosphere. When rainfall exceeds evapotranspiration, excess water infiltrates into the groundwater and runs off into rivers and then oceans, where it evaporates. Blue and green water are thus closely interwoven. As a theoretical amount of water, gray water does not influence water scarcity. Because this article is devoted to the risks of water shortage, we thus examine only the effects of livestock on blue and green water.

Direct water consumption by human activities depletes blue water (i.e., makes it less available). This includes all nonagricultural activities, including industry, services, and domestic purposes, as well as some agricultural activities, such as crop irrigation, livestock drinking water use, use in factories producing inputs (e.g., seeds, fertilizers, animal feeds), or those producing animal products (e.g., dairy factories, slaughterhouses, tanneries). In arid areas, water may be sprayed on animals to improve animal performance, but this is a marginal practice. Worldwide, agriculture represents 70% of total blue water use and 86% of blue + green water use (World Water Assessment Programme, 2009), whereas livestock farming uses 15% of the evapotranspiration of irrigated crops, 33% of that of rain-grown crops, and 68% of that of permanent pastures and rangelands (FAO, 2006).

Water scarcity is related to water depletion, not to total water outflow from agricultural systems. Indeed, evapotranspiration, the main water outflow, is positively correlated with rainfall, and areas with high rainfall usually do not suffer from water scarcity problems. Decreasing evapotranspiration (i.e., green water loss) is related to a decrease in photosynthesis and thus in biomass production because transpiration is

related to carbon dioxide uptake, with both exchanges occurring through plant stomata. However, this relationship may weaken when biomass production is low because the proportion of evaporation from soil in total evapotranspiration increases; a decrease in biomass may also be due to a shortage of nutrients, such as nitrogen. This means that a change in green water use for rain-grown crops and forages has no impact on water scarcity. For example, Peters et al. (2010) noted that water flows did not substantially change in Australia from native pastoral systems to the current improved systems, so livestock farming did not influence water scarcity in this case. In conclusion, total water outflow indicates the influence of agriculture on the global water cycle and highlights the role of water in ecosystems, whereas blue water use has an impact on water depletion.

Which Method(s) Should Be Used to Assess Water Use by Livestock?

Knowing how much water livestock species consume directly in food and drinking water is one indicator of their water use, but a more comprehensive indicator comes from estimating how much water was used on or before livestock farms to grow and process their feed or forage and after farms to transform them or their output (e.g., milk, eggs, fleece) into marketable products. Including these “upstream” and “downstream” uses of water by the livestock-product supply chain creates an indicator of the total water used by the production system, which can then be expressed on a per-kilogram basis for each product from that animal. Here we describe 3 methods of classification for water use: 1) “virtual water and water footprints (which include blue, green, and gray water use),” 2) assessments of blue water use only, and 3) assessments of stress-weighted water use. For agricultural systems, blue water “use” can be regarded as any form of consumption (after Owens, 2002), which includes irrigation for crop or forage production, drinking water use, and in some instances, evaporation losses associated with the supply of drinking water. Additionally, differences in which management and environmental processes are included in system boundaries need to be considered when comparing methods. Extensive scientific reviews of methods for estimating virtual water use exist (e.g., Berger and Finkbeiner, 2010), so in this article, we focus on those that target water use of agricultural products (particularly livestock), describe the most recent ones, and highlight their most significant differences.

The Water Footprint

Methods for estimating the virtual water in livestock products began with virtual water accounting in 1993, which focused on imports of agricultural products as one way for water-scarce countries to compensate for a relatively limited potential for agricultural production. This method inspired the appearance of the “water footprint” in 2002 (Hoekstra et al., 2011; Hoekstra, 2012), which expanded the concept to estimate the total domestic- and foreign-based water use of a country and to inform consumers and policy makers about the volumes of water used. Both methods sum blue, green, and gray water use into a single indicator. Green water use by crops is calculated from crop yield and evapotranspiration, which is a function of crop characteristics and climatic parameters in the FAO Penman-Monteith method (Chapagain and Hoekstra, 2004). Deutsch et al. (2010) calculated a modified water footprint by excluding green water from pastures (but not for harvested forages) with grazing-

Table 1. Nature of blue water used for livestock farming

Type of blue water
Water input by animals
Drinking water
Water contained in forages (including metabolic water)
Water contained in crops (including metabolic water)
Water output by animals
Urine
Water in feces
Milk and meat
Other water inputs
Water for on-farm servicing
Water for crop irrigation
Water for all upstream inputs other than feeds
Water for factories, slaughterhouses, and tanneries

based systems, in particular because grazing systems provide ecosystem services (e.g., grassland biodiversity support) and because there is often no alternative use for grazed grasslands. These indicators, oriented toward estimating total water use by-products, are useful for tallying international trade in virtual water and discussing the use of volumes of blue, green, and gray water in water resource management. When used to indicate the environmental impacts of such water use, however, the relevance of these methods is questionable. For example, the use of green water does not have the same impact on competitive blue water resources in a river system as the direct consumption of blue water has. Additionally, water use may be more detrimental in one region compared with another, depending on the level of water stress in each region (Figure 3). In any case, the conceptual chain from estimating water use to estimating its potential impact is not built explicitly into the water footprint concept. Although this permits multiple interpretations about impacts to be made by those who understand water resource management well, it leaves determination of the potential impacts associated with water footprints open to uncertainty and misinterpretation by those who do not.

Life Cycle Assessment Methods

Research to develop indicators that inherently represent environmental impacts of water use has flourished in the past few years, specifically in the framework of life cycle assessment (LCA). Life cycle assessment is an internationally standardized approach for estimating the environmental impacts (in multiple impact categories) of goods and services throughout their life cycle, from extraction of raw materials and production to (in the most complete studies) their use and disposal (International Organization for Standardization, 2006). Several LCA approaches to estimate water use and its impacts have been developed since 2009, each differing (to greater or lesser extents) in the types of water included, the upstream and downstream processes considered, and the characterization of environmental impacts [e.g., at midpoint(s), endpoint(s), or both in the chain of cause and effect]. A few approaches use water-engineering

models to provide farm-level estimates of water use. Some convergence in methodology has already occurred among LCA approaches, but certain differences remain. Most agricultural LCA studies focus on blue water use only, defined as consumption (evaporative use) at the inventory stage.

All LCA approaches include water used for crop (i.e., feed and forage) production, with some minor differences in which upstream processes are included (some excluding water used in infrastructure or transportation). As with most agricultural LCA, most existing studies stop at the farm gate, some continue to the slaughterhouse or food-processing factory, and at least one continues to the end consumer. All LCA approaches include on-farm water used for irrigation, drinking water, and animal servicing (e.g., cleaning out buildings).

All LCA approaches include blue water (e.g., irrigation), and the most recent (e.g., Ridoutt et al., 2011) focus on consumption of blue water leading to freshwater depletion, meaning that water ingested by livestock but returned to the same location (e.g., as urine) is excluded from the total water use. In contrast, few LCA approaches include gray water, most considering that it is already addressed in the LCA impact indicators for aquatic toxicity (related to pesticide and heavy-metal emissions) and potential eutrophication (related to nitrate and phosphate emissions, among others). In the case of aquaculture, “water dependency” has been considered an “impact” in LCA studies. The amount of water that flows through an aquaculture farm represents the majority of water dependency and can be a management indicator for river-based farms, although it has little practical use for sea-based farms (Aubin and van der Werf, 2009). Life cycle assessment approaches tend either to exclude green water (considering that the evapotranspiration of soil water by crops has no more impact than that by the vegetation they replaced) or to include only the variation in green water attributable to changes in land use (e.g., from pasture to cropland; e.g., de Boer et al., 2011). The effect of on-farm water management is sometimes calculated by comparing it with the effect of natural vegetation, for which evapotranspiration is estimated as a simple function of rainfall (Ridoutt et al., 2011). Most LCA approaches consider that green



Figure 3. Camels drinking from a trough in the an-Nafud Desert (Saudi Arabia). Motorized tankers allow water to be taken directly to animals, rather than vice versa (source: Bernard Faye; used with permission).

water is partially or entirely addressed by the impact indicator for land occupation (considering that soil water, like sunlight or oxygen, is an inherent property of land). As for impact indicators, all LCA approaches define midpoint indicators of water-use impact. Some of these employ characterization factors based on water-stress indices of the catchment from which blue water was taken, which results in virtual water use expressed in H₂O equivalents (e.g., Ridoutt and Pfister, 2010), similar to the CO₂ equivalents of the carbon footprint. Some LCA approaches also include endpoint indicators that estimate the impact on human health, ecosystem quality, or resource depletion (e.g., Milà I Canals et al., 2009).

The 2 groups of methods thus differ greatly. The water footprint takes into account different types of water, including virtual water, but is limited to on-farm flows, whereas LCA is limited mainly to blue water but includes off-farm uses (e.g., “from cradle to farm gate”).

Does Livestock Production Contribute to Water Scarcity?

The total water used to produce human foods is generally calculated per unit of product, the most common of which are kilograms, kilocalories, or a monetary unit. Because one of the main roles in animal products is to provide protein, kilograms of protein may be a more relevant unit when several foods are compared. However, the main criticism of between-food comparisons is that each food has specific nutritional (e.g., hemic iron in beef, lycopene in tomatoes), hedonic, or cultural properties that are difficult to compare.

At the global scale, when total water use is expressed per kilograms of product, crop products almost always have less use than animal products (Hoekstra and Chapagain, 2007). The same pattern holds for total use of other resources, such as fossil energy, phosphorus, or land. However, the present trend in food consumption is a rapid increase in animal products

at the expense of crops in emerging and developing countries (Food and Agriculture Organization of the United Nations, 2009). This is due mainly to demography and a change in consumer habits. It is likely that the growing idea in developed countries that animal-product consumption should decrease will not influence this trend.

Because freshwater availability depends greatly on geographic location (Figure 4), water use should be calculated for a specific area, either per hectare or per kilogram of product within that area. In the same location, crops and pastures have similar evapotranspiration rates, related to net primary production, which is less than that for forest. For this reason, land use (e.g., crops vs. pastures) is not a major determinant of water scarcity. Among existing studies, water use per kilogram of beef ranges from 27 to 200,000 L (Peters et al., 2010; Wiedemann et al., 2010). As described above, the results depend on the methodology and the coefficients used (e.g., for evapotranspiration). For the same methodology, results also depend on the boundaries of the systems; for example, the total water use for 1 kg of beef may or may not include the contribution of nursing cows. Pimentel et al. (1997), who reported 200,000 L/kg of beef, did not specify the method used, but the calculation was based on extensive rangeland systems, which require a large area for animal production. If this value is considered, the total water used to produce the 60 million tons of beef every year is greater than the total freshwater reserves of the planet. Hoekstra and Chapagain (2007) estimated a water footprint of approximately 15,000 L/kg of beef. If green water is included in estimates (as in water footprints), the total water used by low-producing animals in pastoral rangelands, such as those in arid plains or high mountains, would be extremely high. For pastures with similar evapotranspiration per hectare, if animal productivity (e.g., daily body weight gain) is divided by 10 and grazing area per animal is multiplied by 10, the water footprint of the animal could increase 50 to 100 times, whereas the true impact of animals on water scarcity would be relatively low. When less



Figure 4. Zebus drinking at a reservoir in the Garissa region (northern Kenya). Unlike camels, which can drink once a week, cattle must drink at least every other day (source: Bernard Faye; used with permission).

extreme cases are considered, between-country differences exist, for example, ranging from 11,000 L/kg of beef in Japan to 37,800 L/kg of beef in Mexico. The variation probably arises from differences in local evapotranspiration, production systems, and animal productivity. Because food sovereignty should be a target for each country, an increase in animal productivity can be an objective; however, this is often difficult to achieve because of environmental, social, and economic constraints. For the same region, total water uses for beef depend greatly on the production system. When beef is produced by culled cows from a dairy herd, the amount of water necessary to produce 1 kg of beef is divided between milk and beef products. In contrast, because beef meat is the only product of a beef herd, the calculation of total water use of 1 kg of beef includes the water use by both bulls and steers, but also that of nursing cows. As a consequence, livestock in these systems use significantly different amounts of water.

When blue water alone is considered, total water use is much less: 27 to 540 L/kg of carcass-weight beef produced in Australia (Peters et al., 2010). These differences are mainly due to characteristics of the production systems (i.e., an organic system without irrigation vs. a more intensive system with irrigation), and significant between-year differences were observed. Similar ranges (25 to 234 L/kg of body weight of beef) were observed by Ridoutt et al. (2012) for 6 Australian beef systems, which correspond to blue water use, weighted by water-stress indices, ranging from 3 to 221 L/kg of body weight of beef. Similarly, Ridoutt et al. (2010) estimated weighted blue water use of milk solids as 108 and 14 L/kg (i.e., approximately 830 and 108 L/kg of milk, respectively). Under Dutch conditions, de Boer et al. (2011) estimated weighted blue water use as 61 L, of which 75% arose from on-farm forage irrigation. Such weighted values in blue water use for livestock products, although sometimes much less than the amount of water they drink during their lifetimes, have been designed to reflect the impact of livestock on water scarcity. The blue water uses calculated by Mekonnen and Hoekstra (2010) represent approximately 3% of the green water use of beef, and 10% of the green water use of pork, chicken, eggs, and milk (Table 2), but the average values hide large differences between countries and between systems. For example, the mean blue water use for chicken meat equals 30 L/kg in Brazil and 873 L/kg in India. For pork, the system that requires the most blue water in Brazil and Australia is grazing, whereas in India, it is industrial production. Large differences are observed for beef blue water use: 1,471 L/kg for industrial systems in India and 0 for grazing in India and China. The absence of blue water is due to the estimation method, which does not account for uses besides direct use by animals and the feeds they consumed. Despite a huge variability in estimates according to the method used, it is clear that blue water use is the best criterion for estimating the contribution of livestock to the risk of water scarcity.

Which Livestock Farming Practices Help Decrease Water Use?

Numerous reports describe ways to conserve green water with cropping and management practices. Among others, agronomic and genetic improvements have been detailed in an expert evaluation by INRA (2006). Improvements in livestock management, such as crop-livestock integration with the use of crop by-products by livestock, have been proposed (Food and Agriculture Organization of the United Nations, 2006; van Breugel et al., 2010). These techniques can increase water recycling or percolation in soils and decrease runoff. Despite these

possible improvements, it is noteworthy that the green water content of grasslands and crops used for animals lies in the same range as that of crops used for human food or biofuels. Because the risk of water scarcity in agriculture is related to blue water use, we have focused on how it can be decreased in livestock farming, from cradle to farm gate. The 2 main options include decreasing the amount of irrigated feeds and reducing water intake by animals.

The most efficient practice may be to decrease irrigation of feeds grown in areas where rainfall is too low to avoid freshwater depletion, at least during certain periods of the year (Figure 5). Irrigation increases human food security in many countries, but may deplete groundwater and, in extreme cases, lower water levels of inland seas and increase their salinity. Several possibilities exist for increasing irrigation efficiency by optimizing the timing and amount of water application or by applying technological improvements (Food and Agriculture Organization of the United Nations, 2003, 2006). For example, corn, which is widely used for livestock feeding, is highly sensitive to water scarcity, requiring irrigation for maximum biomass production when rainfall is insufficient. Several solutions have been proposed to reduce corn irrigation. Early-maturity varieties may be sown to synchronize maximal growth with freshwater availability, but their yields are less than those of normal varieties. Crop-breeding companies have been working for years to develop corn with better drought resistance, using either genetic engineering or traditional selection in dry countries, but these varieties are not expected to be available on the market in the near future. Alternately, farmers could purchase corn from regions where it requires no irrigation, but other environmental impacts may increase because of changes in land use and, to a lesser extent, increased transportation distances. Another possibility is to replace corn with other cereals, although their nutritional characteristics (e.g., amino acid composition) may differ. Corn can be replaced by sorghum, which grows in the same area and produces more biomass in the absence of irrigation; consequently, sorghum has a greater green water footprint than corn (Hoekstra and Chapagain, 2007).

Direct water intake by animals is composed of drinking water, water contained in feeds, and a small amount of metabolic water produced by nutrient metabolism. For ruminants, total water intake is generally between 3.5 and 5.5 L/kg of dry matter intake in temperate countries; it is greater for dairy cows than for growing animals or animals at maintenance. The greater the water content of feed, the less drinking water they require. For example, when early-stage fresh grass is fed, animals do not require drinking water. Increasing the proportion of fresh grass or silage in the diet thus decreases drinking water intake. Water intake can be 50% greater

Table 2. Total green and blue water use per kilogram of animal product¹

Product	Average ² green water use, L/kg	Average blue water use, L/kg	Range of blue water use, ³ L/kg
Beef	14,414	550	0 to 1,471
Pork	4,907	459	205 to 3,721
Chicken	3,545	313	24 to 995
Eggs	2,592	244	24 to 1,360
Milk	863	86	0 to 147

¹Data from Mekonnen and Hoekstra (2010).

²Average = weighted average for 7 countries (Australia, Brazil, China, India, the Netherlands, Russia, United States) and 3 systems (grazing, mixed, industrial).

³Range = least to greatest footprint among the 21 countries or systems.



Figure 5. Irrigation of a sunflower crop in France (source: © 2007 iStockphoto.com/Donald Gruener).

in tropical countries than in temperate countries, especially for chickens. Water intake is also increased by the consumption of salty feeds. There are several means to decrease water intake. Some breeds adapted to drought, such as goats and camels, consume less water because of better water recycling. In hot countries, the use of shelters reduces heat stress and leads to a decrease in water intake (Morand-Fehr and Doreau, 2001). When an LCA approach is considered, an efficient way to decrease water intake per kilogram of product is to decrease the total amount of feeds necessary to obtain the final product or to improve the productivity of the animal production system. Thus, water intake per kilogram of meat decreases when age at slaughter, and thus total feed intake, decreases, such as for chicken or for beef produced from culled dairy cows rather than from young beef cattle. But this approach is sectorial and does not account for other criteria of livestock sustainability or land use for animal production. For example, extensive beef-cattle systems generate animal products by using rainfall on land that is suitable for few other agricultural purposes (except for forests in mountain regions). Nonetheless, the methods mentioned in this paragraph may decrease water intake by animals only slightly.

Conclusion

Water is a precious resource that must be conserved globally by all sectors of the economy, including agriculture and thus livestock farming. Tools such as the water footprint and LCA are available, but their interpretation by policy makers has to be refined. In addition, it is necessary to remember that freshwater availability is only one of the major environmental issues for the planet. Fossil fuel depletion and greenhouse gas emissions are other urgent priorities that have to be taken into account in a global approach for assessing environmental impacts of farming systems. This multiple-criteria approach is one of the advantages of LCA.

In this article, we have focused on negative impacts of livestock on water reserves; however, livestock can also have neutral or positive influences on water resources. For example, animal use of marshes damages biodiversity less than draining marshes to convert them to agriculture. In arid zones, the use of draft animals for drilling, hydraulic works, water extraction, and transport supports human settlements (Blanfort et al., 2011). More than 1 billion people depend on livestock farming, and animal products are an essential component of human diets. Livestock farming plays a major role in many communities, especially for smallholders in developing countries. Although the debate on the consumption of animal products in developed countries remains open, the interaction between livestock and water resources should be considered with the objective of establishing sustainable farming systems.

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