Water footprint of beef production - critical review of current approaches*

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Summary
Beef is one of the most valuable food commodities which is reflected in the high international trade volume. Global demand for beef has been rising consistently over the last five decades. About one third of all agricultural land on the globe is wholly or partially occupied by beef production systems. Beef production is, next to crop irrigation, probably the largest water consumer of all food production systems. It is also reputed to have severe environmental impacts through water depletion, contamination, and negative effects on local and regional hydrology. Current estimates for the embedded water contained in 1 kg of boneless beef range from 10 to 100 m³. Total bovine numbers on the globe are estimated at close to 1.5 billion head with a total live biomass of 500 to 600 million metric tons. 500 million tons live bovine biomass would represent approximately 175 million tons of boneless beef. This would in turn stand for 1.75 million km³ embedded water if the most conservative estimate were used. Life time drinking water of cattle is only 1% or less of this amount. The remainder, aside from some negligible amounts for management and product processing, is water needed for the production of feeds and forages. The wide range of estimates for embedded water (virtual water) is explainable through various factors: biophysical, climatic, production systems related, regional characteristics, or just reflecting the accounting assumptions used. The paper examines these factors and their effects on water demand estimates. A procedure is suggested which allows to evaluate water demand on the production system level in such way that this can be used as a management tool on the enterprise scale. This could open a considerable potential to reduce reputed water demand for beef production.
Key words: water footprint, beef production, rain use efficiency.

Introduction

Global population growth combined with accelerating urbanisation is causing rapidly rising water use worldwide due to the need for increasing food production. Growing industrialisation, spread of irrigation agriculture, change of dietary habits towards a higher proportion of animal produced food in the diet with growing prosperity in emerging countries and the impact of climate change contribute to this. Already an estimated one third of the world's population lives in water-stressed or water water-scarce countries. Fresh water supplies in the biosphere are limited and relatively static. Consequently, the rising demand will cause more and more stress and it can be estimated that by 2025 two thirds of the world population will be severely affected. The major water user worldwide is agriculture. In industrialised countries water withdrawals for agriculture are

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between 30 and 40% of total withdrawals whereas in developing countries this can exceed 90% (FAOSTAT, 2009). Livestock are taking a large share of these withdrawals, not just as drinking water, but also for servicing and product processing and, the largest proportion, for growing of feeds and forages. It is undisputed that the production of meat, eggs, milk, and wool deplete much larger amounts of water per unit weight as the production of cereals, roots and tubers or vegetables. However, various sources give widely varying values, use different units of measurement to describe water use volumes in livestock production, and base calculations on differing assumptions. Beef production is reputed to cause the highest water depletion of all food commodities.

Literature Review

It is well established that daily drinking water demand of cattle ranges between 10 and 20% of the live body weight. Different ambient temperatures, high moisture content in the forage, activity levels of the animals, physiological status of the animals, feed intake, water quality and other factors may lead to higher or lower values. A mature cow of 250 kg live weight in the tropics (1 TLU) will need between 9 to 18 m^3 drinking water per year; her counterpart in the temperate zones weighing twice as much will consume 18 to 36 m^3. The cow in the tropics is more likely to consume near the upper end of the range given whereas the one in the temperate zones will remain closer to the lower end, unless during hot summer days. According to Looper and Waldner (2002) water intake by dairy cows with live body weights of 750 kg in a temperate climate ranges from 84 to 135 l/day depending on daily milk yield (18 to 45 l) and the related daily feed intake (19 to 27 kg DM). This would amount to 30.6 to 49.3 m^3 per year.

Water used for the production of feeds and forages is much greater than the drinking water volumes. Peden et al. (2006) reckon that 1 TLU cattle under tropical conditions ingests about 2% (5 kg) of their live body weight for maintenance and another 2% (5 kg) for nutrient demands relating to thermoregulation, reproduction, parasite infection, growth and motorial activity. Following Peden et al. (2006) in their argument that in average 1 m^3 of water is needed to produce 4 kg DM of feed, water for feed production will vary at maintenance level from 1200 to 2400 l/day or 440 to 880 m^3 per year. Including a moderate production level into the calculation would double these values.

Adding water needed for drinking, for feed production, and for management of the animals, which is another smaller amount, and relating the sum to a unit of product, i.e. one kg of beef, a whole beef carcass, one litre of milk or one unit of animal work will allow to calculate the water cost or water footprint of that particular product. Chapagain and Hoekstra (2003) and Hoekstra and Chapagain (2007) have done this in great detail and found beef to be the food commodity with the highest virtual water content, i.e. the highest water cost per unit product. Depending on the feed base, the production systems, the cattle breeds involved and numerous other factors they arrived at a range of values from 11.7 m^3/kg beef for Netherlands conditions to 37.8 m^3/kg beef for Mexico, which is 3 to 5 times higher than values for pork, and 2 to 3 times higher than for sheep and goat meat. Other authors report even higher values for beef like 50 to 100 m^3/kg (CSIRO, 2009), 15 to 70 m^3/kg (FAO 2008), and 50 m^3/kg (Meyer 1997). These figures are often quoted in an alarmist manner in the media adding to the impression that cattle raising and in particular beef production are exceedingly detrimental to the environment.

Discussion

Most of the calculations presented above are based on beef production in industrialised farming system. Hoekstra and Chapagain (2007) in one example assume that the production one kg boneless beef requires about 6.5 kg of grain, 36 kg of roughages (pasture, hay, silage and other roughages), and 155 l of water (only for drinking and servicing). Producing this volume of feed requires about 15340 l of water in average. However, grain based beef production is mostly limited to industrialised countries, i.e. Europe and North America. Here we find 12.9 and 12.5% of the world cattle population respectively, but 24.7 and 27.2% of world beef production, and 46.3 and 19.3% of the world milk production (FAO Production Yearbook, 2007). Out of the worldwide more than 3.3 billion ha of permanent pastures approximately one third are managed and improved pastures with higher productivity whereas the remainder are extensive natural pastures with relatively low productivity. According to Gerber et al. (2007) an additional 0.5 billion ha arable land are used to produce feeds and forages for livestock production. However, most of this is dedicated to feed production of poultry and pigs. Most of the improved pastures are found in Europe and North America, just as the major proportion of the 0.5 billion ha arable land used for feed and forage crops (Table 1).

Approximately 75% of all cattle are kept in the less developed countries of Africa, South America and Asia. Here the feed base is primarily unimproved natural pastures, followed by crop residues in mixed farming systems, domestic and agro-industrial by-products, and forage crops in that order of importance (Table 2).

Schwartz and Walsh (1991) calculated that 1 TLU cattle on a semi-arid natural pasture in East Africa needs about 4.8 kg dry forage for maintenance and 6.4 kg for maintenance plus a moderate production performance, i.e. 300 gm daily gain or 2.5 l milk/day. That is 2336 kg DM per year. Based on 300 mm annual rainfall, rain use efficiency (RUE) of 5.7 kg DM/ha/year/mm in the herb layer and a sustainable off-take of 30% ANPP, this translates into 4.57 ha pasture er TLU cattle.

Table 1: Arable land, permanent pastures, and other land [million ha] by continent in 2005.

	Africa	N America	S America	Asia	Europe	Oceania
Arable Land	239.3	229.0	121.9	577.1	296.4	54.7
Pastures	906.6	253.2	459.4	1097.8	181.7	409.9
Other Land	1184.9	77.1	350.4	844.0	729.4	177.6

Source: http://faostat.fao.org/site/377/ downloaded 03.04.2009

Table 2: Rain use efficiency (RUE) of arid and semi-arid natural pastures in Northern Kenya (Schwartz & Walsh 1991)

Seasonal/annual Rainfall [mm]	Herb layer production [kg TDM/ha]	Shrub layer production [kg TDM/ha]	RUE herb layer [kg /ha/year/mm]	RUE shrub layer [kg /ha/year/mm]
100	450	150	4.5	1.5
200	1080	520	5.4	2.6
300	1710	890	5.7	2.97
400	2340	1260	5.85	3.15

At 0.3 kg daily gain, half of which is boneless beef, the RUE for boneless beef is 0.04 kg/ha/year/mm. This in turn would amount to a virtual water content of ~25 m^3/kg. However, pastures of this quality are utilised at zero opportunity cost since there is no alternative use option. Since ANPP remains the same whether the pasture is grazed or not this has to be considered a water neutral system.

A similar approach needs to be taken where forage from unimproved pastures is augmented by crop residues. Cereal straws as well as legume straws, which are available without any additional water demand over the main crop, usually have 2 to 4 times the volume or weight of the grain yield. In contrast the monetary value is usually less than 10% of that of the main crop. If at all, only that portion should be considered in calculating water costs of beef in the mixed farming systems in developing countries. Domestic by-products (household offal) need to be seen in the same light, whereas agro-industrial by-products like oil cakes, molasses, industrials brans, etc. usually have higher commercial values.

For example in seed cotton (UNCTAD, 2009) ~ 42% of the weight are fibre and ~ 58% are seeds representing 80 and 20% of the monetary value respectively. Seeds are either processed into cotton seed meal directly or, after oil extraction into cotton seed oil cakes as livestock feed. In both cases some water costs are associated with the processing and some allocation has to be made, if used for beef production. It is still much less than what is estimated for grain based beef cattle diets.

Conclusion

It can be stated that beef production based on pastures, crop residues and crop processing by-products incurs no or very limited water costs. This comprises ~75% of the world's cattle population. Grain based beef production systems need to be examined critically for the possible replacement of higher amounts of whole grain by crop residues and by-products to reduce their water costs.

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