Indian Journal of Animal Sciences **84** (10): 1090–1094, October 2014/Article

Water requirement estimates of feed and fodder production for Indian livestock vis a vis livestock water productivity

SULTAN SINGH[1], A K MISHRA[2], J B SINGH[3], S K RAI[4], M J BAIG[5], N BIRADAR[6], A KUMAR[7] and O P S VERMA[8]

Indian Grassland and Fodder Research Institute, Jhansi, Uttar Pradesh 284 003 India

Received: 11 November 2013; Accepted: 26 June 2014

ABSTRACT

Water required for feed production accounts the major part of livestock requirement and primarily influences the livestock water productivity. Water requirement to produce a kg DM of common green fodder, protein and energy feeds varied from 267 (sorghum) to 713.3 liter (lucerne), 1,000.0 (linseed) to 2,000.0 liter (soybean) and 690.0 (maize grain) to 850.0 liter (oat grain), respectively. Total water requirement estimated for livestock population 2003 and 2010 were 16.30 and 16.15 MCM, where cattle (both indigenous and crossbred) had highest water requirement (10.11 and 9.51 MCM). To meet the green fodder and concentrate requirement of livestock 151.72, 156.83 and 161.81 and 142.76, 157.67 and 172.04 BCM water required in year 2015, 2020 and 2025, respectively. Livestock water productivity to produce 1 kg milk ranged from 475.0 to 3,751.0 liter depending on the animal rearing system (extensive to intensive system), while to produce a kg of meat water requirement ranges from 8,215.0 to 9,680.0 liter depending on the animal species. Livestock water requirement for drinking and washing is very low (3.6%) than for feed and fodder production, while the livestock water productivity varies widely with their rearing system (extensive vs. intensive system) and animal species.

Key words: Feed, Fodder, Livestock, Water requirement and productivity

Nearly 29% of the water in agriculture is directly or indirectly used for animal production (Hoekstra and Mekonnen 2012). Animal type, activity, feed intake and diet, water quality, water temperature and environment temperature are the main factors influencing water requirement for livestock production (Lardy *et al*. 2008). Feed production constitutes the largest amount of water used in livestock production and the amount of feed produced is growing globally (Deutsch *et al.* 2010). Water needed for drinking, washing and for other services such as cooling and washing, cleaning of production facilities and animal product processing constitutes less than 1%. Livestock water productivity for the unit animal product is influenced by 3 factors namely feed conversion efficiency (amount of feed consumed per unit of meat/milk produced), diet composition (roughage to concentrate ratio), and the feed origin (Gerbens-Leenes *et al.* 2013). To produce the maintenance diet for 1 tropical livestock unit (TLU: measured at 250kg live weight) about 450m^3 of water is required annually. Feeds have highly variable water productivity, ranging from 0.5 kg above-ground dry matter /m^3 water (US grasslands on 300 mm annual rainfall) to 8 kg/m^3 (irrigated forage sorghum, Sudan (Peden *et al*. 2007). Livestock industry across the globe uses about 8% of total water used. The major part of it goes to irrigate the feed crops used for livestock feeding. Zimmer and Renault (2003) demonstrated that a survival diet require 1m^3 of water/head/day, whereas an animal product based diet of humans needs some 10 m^3 water/capita/day. Schlink *et al.* (2010) has discussed global position of water requirement for livestock production in detail. Mekonnen and Hoekstra (2012) carried out a comprehensive global study of the water foot print of farm animals and animal products. Present study was done to estimate the water requirement of Indian livestock for drinking, washing and to produce the feed and fodders based on their availability and demand projections as well as water requirement to produce unit milk and meat.

Present address: [1,2,7]Principal Scientist (singh.sultan @rediffmail.com, asimkmisra@gmail.com, anil.igfri@mail.com), Plant Animal Relationship Division,[3,4,5]Principal Scientist (jbs_igfri@rediffmail.com, baig_igfri@yahoo.co.in, suchitrai67 @yahoo.co.in), Crop Production Division, [8]Principal Scientist (opsverma.igfri@ernet.in), Crop Improvement Division. [6]Principal Scientist (nagratana123@gmail.com), Regional Research Station, Dharwad.

METHODOLOGY

Many workers have included several processes and factors involved in animal rearing while calculating the water requirement. For the present study many assumptions and following factors have been included for determining livestock water productivity.

1. Water requirement for drinking and washing/cleaning
2. Water requirement for feed and fodder (green fodder, straw/stover/crop residues, protein and energy source) production.

Drinking and washing requirements of water were taken from Indian literature (Kidan 1976, Pal *et al.* 1973 and Radadia *et al.* 1980). For calculation it was assumed that only half of the livestock population in India is washed daily. It was further assumed that only female stock of cattle and buffaloes are washed daily. For male stock, calves of less than a year and breeding and working bulls of crossbred cattle and indigenous cattle respectively are washed. For livestock species like sheep, goats, yak, mithun, camel, pigs, donkeys, mules etc. no water was taken into consideration for washing.

Crop residues yield were estimated for different crops (both Rabi and Kharif crops) using their production data from agricultural statistics (MoA, GOI 2003) and grain straw ratio factors (Ramchandra *et al.* 2007, Jain *et al*. 1996). It was assumed that the crop residues had 90% DM contents. Further for green fodder, crop residues and concentrates, dry matter contents of 30, 61.48 and 90 %, respectively were taken into account to estimate the dry matter availability from these feed and fodder resources. To calculate the water requirement for unit (kg) feed and fodder production, total water requirement of crops (green fodder and grain/seed crops) and their yield was taken into account (Menhi lal and Shukla 1988). As the cereal crops are grown mainly for grains which are used as ingredient of livestock concentrate/feed for which the water used was taken into account and to avoid the double accounting no water was accounted for straw and stover production.

Animal population and their categories

India had 185.18 million cattle, 97.92 million buffaloes, 61.47 million sheep, 124.36 million goats and 15.82 million other livestock including pig, donkey, mule, camel, horse, yak and mithun, which constitute about 20% of the world's ruminant population (GOI 2003). Classification of species into different categories, viz. calves below 1 year, between 1–1.5 year, heifers, working, lactating, breeding, breeding plus working and others is based on Livestock Census 2003 of India.

Many assumptions were used to calculate the livestock water productivity (to produce 1liter milk or 1 kg meat) for different ruminant species. For milk production these includes: animal weight (400 kg), dry matter intake (2.2% of body weight), diet composition (concentrate 1/3, roughage 2/3 of which 2/3 dry roughage and 1/3 green fodder), milk yield (7.5 liter) etc. It was also considered that the concentrate mixture consists of 33 parts protein, 65 parts energy source and rest 1 part each of mineral mixture and common salt. Animals producing up to 4 liter of milk/day do not require additional water for milk production. For each 0.453 liter of additional milk production 2.5 liter of extra water is required. Water required for drinking and cleaning mentioned earlier was also taken into account.

In intensive system of rearing animals were fed straw, green fodder and concentrate following thumb rule of 1/3 concentrate and 2/3 roughage. For calculating the water requirement, the mean values of water efficiency mentioned in protein, energy and green fodder were considered assuming this will represent the average water requirement for different sources of protein, energy and green fodder.

In semi extensive system of rearing system, it was assumed that animal is getting 1% (nearly 40% of its DM requirement) of its dry matter requirement from 4 h grazing and rest amount of DM is met through roughage and concentrate distributed in 2/3 and 1/3 parts, respectively. This roughage part consists of dry roughage and green in 2/3 and 1/3 part. For calculating water requirement the green fodder and concentrate offered at stall was taken into account. The DM consumed by animal through grazing was not taken into account for calculating as it was assumed that biomass/dry matter grazed by the animal receives water from rain as no water was supplied to produce that biomass or dry matter. In extensive system, it was assumed that animal is getting 1.5 % (nearly 60% of its DM requirement) of its DM requirement through 8 h grazing. Only 60% to 40% of the balance (4 kg DM) is supplied with nearly 2.0 kg straw/grass and ½ kg of kitchen waste or flour and does not meet the production requirement of the animal. In this system of rearing water requirement was accounted only for ½ kg of feed supplemented to animal in the form of flour. The DM consumed through grazing was not taken into account for calculation assuming that biomass/dry matter grazed by the animal produced from rain water.

For meat production it was assumed that birth weight of sheep and goat is 2.5 kg, while that of buffalo and cattle birth weight is 25.0 kg. Slaughter weight and meat yield was assumed 25.0 kg and 22.5 kg for both sheep and goat and 250.kg and 225 kg for both cattle and buffalo, respectively. A dressing per cent of 0.40 and 0.38 was assumed for small and large ruminants, respectively. Feed conversion efficiencies of 14.2, 12.5 and 10 % were assumed for sheep, goat and large ruminants (cattle and buffaloes), respectively. To attain a body weight of 25 kg, goat and sheep consume 200 and 175 kg feed DM, while a buffalo to attain a body weight of 250 kg consumes 2,500 kg feed DM. For buffalo/cattle 30 liter/d water for drinking and another 30 liter/d for other purpose were considered. It was assumed that sheep and goat require 4.0 and 4.5 liter water/d for drinking and 1 liter water for processing of each kg meat.

RESULTS AND DISCUSSION

Water requirement for feed and fodder production: The water requirement of the crop varies mainly with genetic makeup, crop duration and environment conditions during crop growth. Crops like berseem and alfalfa; lucerne and cowpea require more water than sorghum and oat. The water requirement to produce 1 kg of dry matter for different fodder crops is given in Table 1.

Table 1. Water requirements (L) to produce 1 kg dry matter of green fodder, protein and energy feeds*

Green fodder	Water (L)	Protein feeds	Water (L)	Energy feeds	Water (L)
Berseem	454.5	Groundnut	1111.0	Wheat grain	800.0
Lucerne	713.3	Soybean	2000.0	Maize grain	690.0
Oat	312.5	Mustard	1250.0	Barley grain	700.0
Sorghum	267.0	Linseed	1000.0	Oat	850.0
Cowpea	555.0	Mean	1340.0	Mean	760.0
Mean	461.0				

* Values extracted from the data of water applied through irrigation and yield of crop.

Since straw is byproduct of rice and wheat grain, so for straw production no water is accounted for as the wheat and rice crops are primarily grown for grain production and not for straw production. The amount of water required to produce 1 kg of protein and energy source is given in Table 1. The water requirement for soybean production is more than oilseed production. The amount of water required for cereal grain production varied from 690 in maize to 850 L for oat. Renault and Wallender (2000) reported about 1,159, 1,408, 710, 2,547 and 2,860 liter of water/kg of product for wheat, rice, maize, groundnuts and beans, respectively, for intensive system of production. Most of the water consumed is used to grow feed (Oltjen 1991). Barthelemy *et al*. (1993) reported that 2,752, 710, 542, 2,374, 1,159 and 1,910 litre of water is required to produce 1 kg of each soybean, maize, sorghum, oats, wheat and barley grain, respectively. A wide variability in water requirement to produce 1 kg of wheat, barley, sorghum grain and alfalfa hay from different locations was reported (Beckett and Oltjen 1993). Water requirement to produce 1 kg product/grain from wheat, soybean and other agricultural products for developed countries was also reported (Hoekstra and Chapagain 2007).

Livestock water requirement for drinking and washing/ cleaning

Water requirement (drinking and washing) estimated for livestock population of 2003 and 2010 were 16.30 and 16.15 MCM, respectively. Among the livestock species water requirement for cattle (both indigenous and crossbred) was higher (10.11 and 9.51 MCM) followed by buffaloes (4.72 and 5.15 MCM) than other livestock species (Table 2).

Demand and supply of feed/fodders and water

Data revealed that dry matter and green fodder will be deficit by 24.92 and 64.87 %, respectively by year 2025; concentrate will be deficit by the tune of 60.4 % by the year 2025 (Table 3). Likewise 146.74 and 128.12 BCM water is required to produce the green fodder and concentrate for livestock in year 2010 against 161.81 and 172.04 for green fodder and concentrate production, respectively, in year 2025. Thus there is a need of 92.08 and 39.40 BCM water to produce green fodder and concentrate, respectively, to meet livestock needs in year 2010. It is obvious from Table 1 that deficit in green and dry fodder is increasing every year, while for concentrate gap is almost static. But this gap is critical and is going to determine the type of animal and husbandry practices to be followed in future.

Estimates of livestock water productivity to produce an unit animal product

Estimated water requirement were 475, 2,451 and 3,751 liter for production of 1 liter milk in extensive, semi-extensive and intensive system of livestock rearing. This variation may be attributed to types of feed ingredients of ration fed to animals/livestock and slaughter weight of the animal. Animal products from industrial systems generally consume and pollute more ground- and surface-water resources than animal products from grazing or mixed systems (Mekonnen and Hoekstra 2012). Reports of Gerbens-Leens (2013) that globally industrial systems have the largest blue and grey water foot prints for beef, and grazing systems have the smallest blue and grey water foot prints, are on the pattern of present observations. Water productivity was as low as 0.3 L of milk / m^3 of water; however global water requirement for milk production is reported to be 1.1 liter/m^3 of water (Singh and Kishore 2004). Water productivity estimates in terms of water requirement were 8,215, 9,338 and 9,680 liter for sheep, goat and buffalo for 1 kg of meat production. For meat production the reported water productivity ranged from 0.04–0.07kg/m^3 of water (Zimmer and Renult 2003, Chapagain and Hoekstra 2003, Oki *et al.* 2003). They reported requirement of 15,497, 4,043, 6,143 and 900 liter of water /kg of product from beef, chevon, mutton and milk production, respectively, in developed countries. The water requirement to produce animal product i.e. beef and milk was 13,500 and 790 liters, respectively. This water requirement to produce 1 kg of food/fodder crop and milk product varies between the countries. In developing and underdeveloped world livestock are usually fed on crop residues requiring less water than those fed on high grain and green fodder based diet in developed countries. Use of irrigation water under intensive system of rearing increases the water requirement to produce animal product. Water requirement estimates for beef production was 20,864 litre/ kg of meat (Robbins 1987) and 20,559 litre/kg of boneless beef (Kreith 1991). Water used for beef cattle can be divided into that drunk by animals that used for producing feed, and that used for processing the cattle into beef. As per estimate (Barthelemy *et al*. 1993) 13,500 litre water is

Table 2. Estimates of drinking and washing/cleaning water requirements for different categories of livestock

Livestock	Category	Year 2003		Year 2010 Projections	
		Numbers '000	Water requirement (MCM)	Numbers '000	Water requirement (MCM)
Cattle					
Crossbred male	0–1 year	1505.92	0.04	1849.30	0.05
	1– 3 Years	1493.72	0.06	1834.30	0.08
	> 3 Years	188.20	0.01	231.10	0.01
	Working	3396.21	0.18	4170.50	0.22
	Breeding + Work	475.31	0.03	583.70	0.04
	Others	147.64	0.01	181.30	0.01
Crossbred female	4–12 month	2849.67	0.08	3500.40	0.10
	1–3 years	3312.91	0.20	4069.40	0.24
	Milking	6957.38	0.47	8546.10	0.57
	Dry	3132.21	0.16	3847.50	0.20
	Heifers	987.51	0.07	1213.00	0.08
	Others	236.78	0.01	293.00	0.02
Indigenous male	0–12 months	6743.50	0.17	6053.60	0.15
	1–3 years	12515.49	0.52	11235.00	0.47
	<3 Years breeding	7750.15	0.40	6957.20	0.36
	Working	47728.49	3.20	42845.40	2.87
	Breeding + work	7362.62	0.38	6609.30	0.34
	Others	667.80	0.03	599.50	0.03
Indigenous female	4–12 month	9313.22	0.28	8360.60	0.25
	1–3 years	17341.46	0.72	15567.70	0.65
	Milking	24437.86	1.64	21938.20	1.47
	Dry	21292.49	1.11	19114.60	1.00
	Heifers	3754.54	0.25	3370.50	0.23
	Others	1586.44	0.08	1424.20	0.07
Total cattle		185177.52	10.11	174395.30	9.51
Buffaloes					
Buffalo males	0–12 months	5109.94	0.15	5565.60	0.16
	1–3 years	4518.15	0.27	4921.10	0.29
	<3 Years breeding	607.06	0.04	661.20	0.04
	Working	6603.68	0.44	7192.60	0.48
	Breeding + work	2545.29	0.17	2772.30	0.19
	Others	212.76	0.01	231.70	0.01
Buffaloes Female	0–1 years	11091.34	0.33	12069.30	0.36
	1–3 Years	13358.65	0.79	14546.80	0.87
	Milking	31827.80	2.14	34667.10	2.33
	Dry	17749.56	1.19	19328.20	1.30
	Heifers	3471.66	0.23	3780.40	0.25
	Others	832.98	0.04	907.10	0.05
Total buffaloes		97928.87	4.72	106643.30	5.15
Goat					
	<1 year	56222.84	0.14	56970.00	0.14
	> 1 year	68134.16	0.48	69041.90	0.48
Total goat	Total	124357.00	0.62	126011.90	0.63
Sheep		61469.00	0.43	65716.50	0.46
Pigs		13518.00	0.30	13751.50	0.30
Yaks		65.00	0.00	71.60	0.001
Mithuns		682.00	0.01	436.60	0.01
Horses and ponies		751.00	0.03	682.00	0.03
Mules		176.00	0.01	140.20	0.006
Donkeys		650.00	0.02	479.10	0.01
Camels		488760.20	0.05	438.00	0.03
Total livestock		485002.39	16.30	488760.2	16.15

Table 3. Water requirement for crop residue, green forage and concentrate feeds production (projections)

Year	Requirement		Availability	
	DM	Water (BCM)	DM	Water (BCM)
Crop residues (DM basis)				
2000	337.53	156.78	263.13	122.23
2005	349.82	162.49	272.36	126.51
2010	362.12	168.20	277.27	128.79
2015	374.41	173.91	286.50	133.08
2020	387.32	179.91	290.80	135.08
2025	399.62	185.62	300.02	139.36
Green forages (DM basis)				
2000	296.40	136.64	115.35	53.18
2005	307.50	141.76	116.97	53.92
2010	318.30	146.74	118.56	54.66
2015	329.10	151.72	120.18	55.40
2020	340.20	156.83	121.77	56.14
2025	351.00	161.81	123.39	56.88
Concentrate feeds (DM basis)				
2000	99.63	98.83	34.74	34.46
2005	114.38	113.47	41.54	41.20
2010	129.15	128.12	48.33	47.94
2015	143.91	142.76	55.13	54.69
2020	158.94	157.67	61.94	61.44
2025	173.43	172.04	68.76	68.21

BCM, Billion cubic meters.

required to produce 1 kg meat from bovine, sheep and goat, which is higher than the present values. Dressing per cent and per cent of the boneless yield in carcass influence the water requirement for meat production.

REFERENCES

Barthélemy F, Renault D, Wallender W. 1993. *Water for Sustainable Human Nutrition: Inputs and Resources Analysis for Arid Areas*. pp.70.UC Davis Internal Report.

Beckett J L and Oltjen J W. 1993. Estimation of the water requirement for beef production in the United States. *Journal of Animal Sciences* **71**: 818–26.

Chapagain A K and Hoekstra A Y. 2003. Virtual water trade: a quantification of virtual water flows between nations in relation to international trade of livestock and livestock products. *International Expert Meeting on Virtual Water Trade.* (Ed.) Hoekstra A Y. Value of Water Research Report Series, **12**, IHE, Delft, Netherlands.

Deutsch L, Falkenmark M, Gordon L, Rockström J and Folke C. 2010. Water-mediated ecological consequences of intensification and expansion of livestock production. *Livestock in a Changing Landscape*. pp 97– 111. (Eds) Steinfeld H, Mooney H A, Schneider F and Neville L E. Washington DC, USA.

Gerbens-Leenes P W, Mekonnen M M and Hoekstra A Y. 2013. The water foot prints of poultry, pork and beef: A comparative study in different countries and production systems. *Water Resources and Industry* **1–2**: 25–36.

GOI. 2003. *17th Livestock Census*, Ministry of Agriculture. Government of India 2005, New Delhi.

Hoekstra A Y and Chapagain A K. 2007. Water footprints of nations: water use by people as a function of their consumption pattern. *Water Resource Management* **21**: 35–48.

Hoekstra A Y and Mekonnen M M. 2012. The water foot prints of humanity. *Proceedings of the National Academy of Sciences* **109** (9): 3232–37.

Jain D K, Sharma K N S, Walli T K and Rai S N. 1996. *Estimates of nutrition requirements and availability for bovine population across major states of India*. Dairy Economics, Statistics and Management Division, NDRI, Karnal, ICAR New Delhi.

Kidan N B.1976. 'Water requirements for young buffalo calves and heifers and other operations at the farm.' M Sc Thesis, Haryana Agricultural University, Hisar, Haryana, India.

Kreith M. 1991. *Water Inputs in California Food Production*. Water Education Foundation, Sacramento, CA.

Lardy G, Stoltenhow C and Johnson R. 2008. *Livestock and Water*. North Dakota State University, Fargo, North Dakota.

Mekonnen M M and Hoekstra A Y. 2012. A global assessment of the water foot prints of farm animal products. *Ecosystems* **15** (3) 401–15.

Menhi Lal and Shukla N P. 1988. Water management in forage crops. *Pasture and Forage Crop Research. A State of Knowledge Report*. pp. 211–20. (Ed.) Singh P. Range management Society of India, Indian Grassland and Fodder Research Institute, Jhansi, UP, India

Oki T, Sato M, Kawamura A, Miyake M, Kane S and Musiake K. 2003. Virtual water trade to Japan and in the world. *International Expert Meeting on Virtual Water Trade.* (Ed.) Hoekstra A Y. Value of Water Research Report Series, **12**, IHE, Delft, Netherlands.

Oltjen W. 1991. Water needs for meat production. *Journal of Animal Science* **69** (Suppl 1): 227 (Abstract).

Pal S, Pal R N and Thomas C K. 1973. Water intake by Murrah buffalo cows. *Indian Journal of Dairy Science* **26**: 253.

Peden D, Tadesse G and Misra A. 2007. Water and livestock for human development. *Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture.* pp.485–514. (Ed.) Molden D. London, UK: Earthscan; Colombo, Sri Lanka: IWMI.

Radadia N S, Pal R N, Juneja I J and Sastry S N R.1980. Studies on the effect of certain in summer managemental practices on lactating Murrah buffaloes. 3. Physiological reactions and some attributes of blood. *Haryana Agricultural University Journal of Research* **10**: 142–47.

Ramchandra K S, Taneja V K, Anandan S and Angadi. 2007. *Livestock feed resources in different agro ecosystems of India: Availability, requirement and their management*. National Institute of Animal Nutrition and Physiology, Bengaluru, ICAR, New Delhi.

Renault D and Wallender W. 2000. Nutritional water productivity and diets. *Agriculture Water Management* **45**: 275–96.

Robbins J. 1987. *Diet for a New America*. Still point Press, Walpole, NH.

Schlink A C, Nguyen M L and Viljoen J. 2010. Water requirements for livestock production: a global perspective. *Revue scientifique et technique (International Office of Epizootics)* **29** (3): 603–19.

Singh O P and Kishore A. 2004. Groundwater Intensity of North Gujarat's Dairy Industry: Why Should Dairy Industry Take a Serious Look at Irrigation? *Water and Welfare: Critical Issues in India's Water Furue.* IWMI-Tata Annual Partners' Meet, 17–19 February, Anand, India.

Zimmer D and Renault D. 2003. Virtual water in food production and global trade. Review of methodological issues and preliminary results. *International Expert Meeting on Virtual Water Trade* (Ed.) Hoekstra A Y. Value of Water Research Report Series, **12**, IHE, Delft, Netherlands pp. 93–109.