RESEARCH ARTICLE

Water Footprint of milk production in Andhra Pradesh

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Abstract Highly populous India has huge economy and remarkable economic growth in the last decade. With the booming economy, people's income, expenditure patterns and their lifestyles are changing. Rapid urbanization is also adding fuel to these changes. As a result, food consumption patterns are changing, more towards high income elastic milk, which demands more feed grains and in turn more water resources. This requires better quantification and analysis of nexus between water with milk production which is important for nutritional and livelihood security of Bharat (rural India). Quantification can be done by Water Footprint concept. The average water footprint of milk production in Andhra Pradesh for crossbred cow, buffalo and local cow is 10.50, 6.73 and 2.01 m3/lactating animal. It is correlated with feed requirements of animal, feeding pattern and water footprint of crops fed. Water consumption for it can be reduced by increasing crop and milk productivities.

Keywords : Consumptive water use, crop water requirement, variations

Introduction

Milk production is an integrated component of Indian farming system. It provides food and income security to the rural population especially women. Water plays a significant role in milk production. India has occupied a center stage in global food and water supply and demand projections and the ways how it would meet its increasing food and water demand was the major focus of many recent food and water demand projections at the global scale (Seckler et al., 1998; Rijsberman 2000; Rosegrant et al., 2002) and the national scale (Bhalla et al., 1999; Dyson and Hanchate 2000) with its spatial mismatches of the population and scarce water resources (Amarasinghe et al., 2005). The reasons for India being a focal point are firstly, increasing growth rate of population with existing huge base of 121 crore. Secondly, recent trends indicate that the food consumption pattern in India is changing with increasing share of dairy products in the daily nutritional intake due to changing lifestyles and expenditure patterns and increasing income in the improving economy. Total grain demand increase in the future will be 19.9 kg/month over the next 50 years from 16.7 kg/month due to increase in demand for feed grain (Amarasinghe et al., 2007). More water resources will be required to grow the growing grain demand. Amidst, the impacts of extreme climatic changes could threaten sustainable water supply for agricultural production (Gosain et al., 2006). This may also affect food grain supply for human feed and fodder supply for dairy animals. This is how changing consumption patterns in India and their implications on future food and water demand are linked up. There exist a strong nexus between crop, water and milk production (Amarasinghe et al., 2012); water act as a linkage between crop and livestock as water consumed in crop production will reflect in milk production where these crops are used as fodder and feed ingredients. Therefore, increasing water productivity in crop production would also increase water efficiency in milk production. Gaining a better understanding of the linkages between water use and milk production is vital for influencing the development trajectories of rural areas (Kemp-Benedict et al., 2011). As many regions are becoming unsustainable due to dairy farming (Shah, 2009), analysis like this is important to sustain natural resources to ensure sustainable agricultural production and development in the future (Pretty et al., 2010). Sustainable water use throws light on increasing water productivity which aims at more output from a drop of water. It is discussed that increase in productivity (1% annually) eliminates Consumptive Water Use (CWU) demand increase for gains even under full self sufficiency assumption and a 1.4 % growth eliminates the CWU demand increase of all crops by 2050 (Amarasinghe et al., 2007). Efficient water use can also be achieved by a reciprocal strategy of obtaining same output from relatively less amount of water than existing consumption. It needs a study of quantification of water consumption in the system

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which can be carried out by concept of water footprint. Water footprint explains the quantum of water used by a milking animal or unit of output (milk).

Water Footprint of a process is the volume of water consumed, taking into account the water consumed and polluted in the different steps of the production chain. The process for which water footprint accounting is done in this study is milk production. Based on the nature of water consumption, the water footprint of milk production has divided into components namely direct and indirect which in turn have three sub-components on account of their source (Table 1). Estimation of grey component is beyond the scope.

Similar studies were carried out in India's milk productive states namely Gujarat (Singh et al., 2004), Punjab (Amarasinghe et al., 2010) and Haryana (Janardan, 2012; Sirohi et al., 2013). No such studies were executed in Andhra Pradesh, the third leading state in milk production in the country with a share of 9.45% in national milk production (GoI, 2013). Therefore, the present study aimed at providing first hand information on water consumption in milk production at district level to design water efficient district agricultural plans.

Data and Methodology

Milk Production is an integrated component of agriculture throughout the state; hence all 22 districts were studied. Exclusion of Hyderabad district was done on account of no agricultural land and dairy farming. The study was based on secondary data sources. The direct water use for drinking, bathing and servicing purposes was assumed as 66 liter/day/animal from earlier studies. To appropriate the volume of water consumed indirectly, feeding patterns (type and quantity) of three types of animals (Buffalo, Local and Crossbred cow) in all districts is required. In addition to this information on fodder production (type, crop duration, time of planting and average yield) and agronomic (time of sowing, duration, crop growth periods etc) and climatic parameters (P75, ETO and Kc) of commercial crops fed as dry fodder and concentrate feed was also used. A clear illustration on data requirements and source has been given in Table 2.

In this study water footprint of milk production was carried out for in-milk animal per day (m^3/animal/day), unit of output (m^3/kg) and unit value of output (m^3/Re). Later duo estimates are derivatives from the first one, hence the starting point of estimation is the water consumed in the milk production (animal/day). Water footprint of milk production includes two components namely direct and indirect. Direct component comprises water required for drinking, bathing and servicing whereas the indirect water consumption constitutes water required from rainfall and irrigation for raising feed and fodder crops viz. dry fodder, concentrate and green fodder.

$$WF_{Milk} = WF_{Direct} + WF_{Indirect} \text{ ....eq (1)}$$

Clearly,

$$WF_{Milk} = (\text{Bathing} + \text{Drinking} + \text{Servicing}) + (WF_{DF} + WF_{GF} + WF_{Conc}) \text{.............eq (2)}$$

The principal source of dry fodder is the straws and stovers of cereal crops. For green fodder, crops like, sorghum, maize, berseem, oats, etc. are cultivated and grasses are collected primarily from fields in case of stall-fed animals. Ingredients of concentrate feed (e.g. groundnut cake, rice bran etc) are derived from main crops raised on farm. Since the diet of milk animals are met by raising crops (fodder and commercial crops), the water consumed by these crops together gives the total water consumed indirectly, which can be estimated using Crop Water Requirement (CWR) and Consumptive Water Use (CWU).

$$ET_p = \Sigma^4_{i=1}) \; k_i \times \Sigma_{\text{month j in ith growth period}} \; d_{ij} ET^{ij}_0 \text{ ....eq(3)}$$

Where,

k_i= crop coefficient of i^{th} growth period

Table 1 Components of Water Footprint in Milk Production

WF_{Milk} =	Direct WF			+	Indirect WF
	Component	Source	Form of use	+	Form of use
	Green	Effective rainfall	N/A	+	CWU from soil moisture in fodder and other feed crops
	Blue	Irrigation	Drinking/servicing of animals	+	CWU from irrigation water in crop production
	Grey	Pollution	Water required where its quality deteriorates below drinking standards due to manure	+	Water required where its quality deteriorated below drinking water standards from input use or in by-products

WF: Water Footprint and N/A: Not Available

Table 2 Data and Source of the Major Variables for Water Footprint of Milk

	Variable	Source
Direct	Drinking, bathing and servicing (66 liter/day/animal)	Farm Level Water Footprints: Concept and Accounting, ICAR
Indirect	Feeding patterns (type and quantity/day/animal)	Integrated Sample Survey, State Animal Husbandry Department 2010-11 - unit record data
	Information on fodder production ● Duration ● Favorable time of planting ● Average Yield	Manual of Regional Station for Forage Production and Demonstration, Pahadisharif, A.P.
	Crops as dry fodder and concentrate feed : Stages of crop growth periods Months and days of crop growth periods Crop coefficients (Kc)	Agronomy Dept of SAU, SMS of KVK 's and DAATTC.
	Planting and harvesting weeks and dates	SMS of KVK's, Agricultural Statistics at a Glance, Andhra Pradesh (2010-11).
	Reference evapotranspiration (ET0)	Online World Water and Climate Atlas of IWMI
	Daily 75% exceedence probability of rainfall (P75) Yields and prices of main crop & by -product for Conversion ratios of crops for apportioning	Comprehensive Scheme for Cost of Cultivation: unit record data
Statistics	District wise crop productivity District wise milk productivity	Season and Crop Report 2010-11 Integrated Sample Survey Report 2011

d_{ij} = Number of days of the j^{th} month in the i^{th} crop growth period

ET_0^{ij} = Reference evapotranspiration of the j^{th} month in the i^{th} crop growth period

$$P_{eff} = \sum_{i=1}^{4} \sum_{month\, j\, in\, i^{th} growth\, period} \frac{d_{ij}}{n_{ij}} P_{eff}^{ij} \text{......................} eq(4)$$

$$P_{eff}^{ij} = \begin{cases} P75^{ij} \times (125 - 0.2 \times P75^{ij})/125 & if\ P75^{ij} \leq 250\ mm \\ 125 + 0.1 \times P75^{ij} & if\ P75^{ij} > 250\ mm \end{cases} \text{..............} eq(5)$$

$P75^{ij}$ = daily 75% exceedence probability of rainfall
n_{ij} = total number of days in the j^{th} month of the i^{th} crop growth period

$$CWU_{Green} = Min\ (ETp, P_{eff}) \text{……………………} eq(6)$$

When irrigation meets part of the deficit crop water requirement, the irrigation CWU is the net evapotranspiration, which is the difference between the actual evapotranspiration (ET_p) and Effective precipitation (P_{eff}).

$$CWU_{Blue} = ET_p - P_{eff} \text{…………………………} eq(7)$$

$$CWU_{Crop} = CWU_{Green} + CWU_{Blue} \text{…………………} eq(8)$$

In dry fodder and concentrates only the left-over residues and by-product respectively are fed to animals, unlike in green fodder. Therefore water footprinting of dry fodder and feed concentrate takes into account of their corresponding straws and by-product share solely. For the above purpose CWU of crop has to be apportioned in to CWU of main crop and by-product. Apportioning can be done employing prices and conversion ratio of main crop and by-product. Obtain the ratio of main product and by-product using equation (8).

$$\alpha_i = q_i p_i / \Sigma_j q_j p_j \text{ ………..……………………...} eq(9)$$

Where q_i and p_i are conversion ratios and prices of main product or by-products. Conversion ratio of the main product is taken as 1. CWR of product (main crop or by-product) can be obtained by multiplying α_i value with CWR of total crop as given in equation (9).

$$CWR^{product} = (\alpha_i\ CWR^{crop}) \text{ …………………...} eq(10)$$

In case of green fodder (fodder crops and grasses) whole vegetation is used to feed and no by-product, hence no apportioning is required. The estimation of water consumed by grasses was done using the information of commercial cultivation of these grasses, albeit taking into account only the rainwater use.

Water consumed by quantity of green, dry fodder and concentrate used for feed constitutes indirect water footprint as shown in equation (11).

$$WF_{Milk}(m^3/Animal/day) = (Bathing + Drinking + Servicing) + (Ax + By + Cz) \ldots\ldots eq(11)$$

where A, B, C are water consumed (in m3) by a kilogram of green fodder, dry fodder and concentrate respectively and x, y, z are corresponding quantity of green fodder, dry fodder and concentrate fed to animal in a day (in kg). Water footprint in terms of yield is then obtained by dividing the CWU by the milk yield of the animal.

$$\text{Water Footprint of milk yield}\left(\frac{m3}{liter}\right) = \frac{\text{Total CWU(m3 per animal per day)}}{\text{Daily milk yield (liter per animal per day)}} \ldots\ldots eq(15)$$

In monetary terms, the Water footprint for each of the three types of animals is,

$$\text{Water Footprint of value output}\left(\frac{m3}{Rs}\right) = \frac{\text{Total CWU(m3 per animal per day)}}{\text{Value of milk output (Rs per animal per day)}} \ldots\ldots eq(16)$$

Results and Discussion

Estimation of water footprint in milk production was conducted for local cow, cross bred cow and buffalo across the districts in the state. The results of analysis are organized under three sub-heads namely; milk production (per lactating animal), per unit yield (physical value) and per unit value of output (monetary value).

Milk Production

The average water footprint of milk production (in m3/ lactating animal) of Andhra Pradesh is 10.50, 6.73 and 2.01 for Crossbred cow, buffalo and local cow correspondingly. In simpler words a crossbred cow consumes 10500 liter and for buffalo it is 6730 liter whereas the same for local cow is 2010 liter a day directly and through feed. At state, regional and district water footprint is in order of Crossbred>Buffalo>Local cow. The regional average water footprint of three regions are close to each other for local cow but Rayalaseema region's average is higher than other two by 2 m3 (2000 liter) each in case of crossbred and buffalo. Inter-district variation (Andhra Pradesh variation) in the state is close (26 %) in case of local cow and crossbred cow but slightly higher in buffalo by 2 %. From the two-directional analysis of the results obtained across districts and animal category, profound variations are observed and a valid accountability is given. Hence the variation study focuses on the estimation and factors of differences as well.

The current study captured and crystallized the following factors of variations in the water consumption by a lactating animal. Firstly, the water footprint of milk production is varies with type of animal (crossbred, local cow and buffalo). This can be shown from similar pattern of trend between water footprint (10.50, 6.73 and 2.01 m3) and dry matter intake (12.79, 10.5 and 5.34 kg/animal) in case of crossbred cow, buffalo and local cow respectively. So, water consumption is positively related with feed requirements which in turn relay on genetic potential of the animal. Secondly, feeding pattern is found to influence the water footprint when studied within each animal category across districts. This is evident from Visakhapatnam, Vizianagaram and Srikakulam districts of Coastal Andhra, where low water embedded composite feed-mix is used rather high water intensive rice bran (as in remaining districts). Hence the estimations of above three districts is on lower side, especially crossbreds. Similarly Kurnool district has low water footprint than other districts of the region due to adoption of low water consuming sorghum straw (0.06 m3/kg straw) than paddy straw (0.48 m3/ kg straw). Thirdly, water consumption is highly related with spatial differences in water footprint of same crop due to variation in location specific water requirement of a crop. Due to high amount of water embedded in rice straw and rice bran in Ananthpur and Cuddapah districts of Rayalaseema recorded high water footprint, peculiar in buffalo. Fourthly, differences in proportion of dry, green and concentrate feed may also yield in variations. In Mahabubnagar, Nalgonda and Ranga Reddy districts of Telangana, higher proportion of water intensive feed concentrate (rice bran) were found than other districts in region, which resulted in higher water consumption for milk production in case of all three categories of animal. The virtual water of one kg rice bran in these three districts is Mahabubnagar (2.25 m3), Nalgonda (2.19 m3) and Ranga Reddy (2.60 m3).

Per Unit of Milk Yield

On the basis of milk output, the water footprints are higher for buffalo than cow at the state level and Rayalaseema and Telangana region as well. In Coastal Andhra, the water footprint of buffalo and local cows are more or less same. The state average of water use for buffalo milk production is 2000 liter (2 m3/kg) ranging from 0.96 m3 in Vizianagaram to 5.27 m3 in Medak district (Table3). These high water footprints were due to more water consumption through feed and fodder and comparatively lower yields (3.6liter/day) than crossbred cow (7.0liter/day). Water consumed per kg of milk is relatively lesser in case of crossbred cow due to their higher productivity. Milk productivity and water footprint per unit milk yield is inversely correlated. It is evident from the earlier studies, in organized farms of Karnal district of Haryana water consumed (in m3/kg of milk) by Karan Fries (1.21), Murrah (1.27)) and Sahiwal&Tharparkar (1.58) is in inverse trend of its corresponding productivity 9.0, 7.4 and 7.2 kg/ day. Though the milk production in Moga district of Punjab is water intensive, its water footprint 0.94 m3/kg than national average 1.37m3/kg (Chapagain and Hoekstra, 2004). This is

Table 3 District-wise Water Footprint of Milk Production in Andhra Pradesh: Types of Animal

Districts Units	WF of Milk Production m^3/animal/day			WF of Unit Yield m^3/kg			WF of Unit Value of Output m^3/Re			
Coastal Andhra	LC	CB	Buff	LC	CB	Buff	LC	CB	Buff	Milk
East Godavari	1.52	11.06	6.45	1.88	1.51	1.48	0.09	0.07	0.07	0.06
Guntur	2.45	13.65	7.89	1.46	1.75	1.72	0.07	0.08	0.07	0.04
Krishna	2.05	11.74	7.70	1.46	1.51	1.42	0.07	0.08	0.07	0.05
Nellore	1.99	13.68	7.47	2.04	1.87	1.93	0.06	0.06	0.08	0.04
Prakasham	2.27	14.04	8.29	1.82	1.97	1.95	0.06	0.06	0.08	0.04
Srikakulam	2.68	6.05	5.97	1.74	0.90	1.90	0.10	0.05	0.11	0.07
Vishakhapatnam	1.89	5.57	5.94	2.27	0.85	1.54	0.12	0.04	0.07	0.05
Vizianagaram	1.14	4.52	3.48	1.24	0.66	0.96	0.07	0.04	0.05	0.05
West Godavari	1.98	10.98	7.05	1.37	1.52	1.51	0.08	0.09	0.08	0.06
Coastal Andhra Average	2.00	10.14	6.69	1.71	1.39	1.65	0.08	0.06	0.08	0.05
Coastal Andhra C.V.	23.28	37.10	21.91	18.89	32.18	20.49	23.52	27.17	23.25	15.03
Rayalaseema										
Ananthapur	2.76	13.07	10.47	2.27	2.07	3.59	0.15	0.14	0.20	0.08
Chittoor	1.94	11.69	6.26	1.56	1.50	1.57	0.08	0.08	0.08	0.08
Cuddapah	2.56	13.56	10.59	2.33	2.11	3.29	0.12	0.11	0.19	0.07
Kurnool	1.27	10.09	6.06	0.82	1.45	1.66	0.04	0.07	0.09	0.05
Rayalaseema Average	2.13	12.10	8.34	1.75	1.78	2.53	0.10	0.10	0.14	0.07
Rayalaseema C.V.	31.48	12.86	30.26	40.53	20.05	41.88	46.97	28.67	46.93	19.18
Telangana										
Adilabad	1.14	8.76	4.29	0.81	1.47	1.58	0.04	0.08	0.08	0.05
Karimnagar	1.37	8.26	4.12	1.22	1.13	1.14	0.07	0.06	0.07	0.06
Khammam	2.36	9.16	7.69	1.78	1.37	2.11	0.08	0.06	0.10	0.05
Mahabubnagar	2.66	11.73	7.70	2.02	1.83	2.37	0.10	0.09	0.12	0.06
Medak	2.15	9.86	4.19	1.37	1.44	5.27	0.06	0.06	0.23	0.05
Nalgonda	2.09	11.57	5.86	1.35	1.22	1.72	0.07	0.06	0.09	0.05
Nizamabad	1.15	8.91	5.36	0.83	1.11	1.21	0.03	0.05	0.06	0.05
Ranga Reddy	2.53	14.24	8.74	1.98	2.00	2.00	0.08	0.08	0.08	0.05
Warangal	2.28	8.80	6.53	1.48	1.27	1.95	0.06	0.05	0.08	0.04
Telangana Average	1.97	10.14	6.06	1.38	1.43	2.15	0.06	0.07	0.10	0.05
Telangana C.V.	30.08	19.45	28.42	32.67	22.79	61.42	32.50	22.92	55.10	13.47
Andhra Pradesh Average	2.01	10.50	6.73	1.60	1.48	1.99	0.08	0.07	0.10	0.06
Andhra Pradesh C.V.	26.51	26.64	27.99	28.81	27.19	47.92	35.06	31.29	49.14	19.77

LC- Local Cow, CB- Crossbred cow and Buff-Buffalo.

accounted to higher average milk productivity of 10.4 and 6.5 liters/day/animal for cow and buffalo respectively, are significantly higher than the national average of 6.5 and 2.2 liters/day/animal. Hence variations are due to differences in type and water embedded in feed, fodder and productivity of milk animals across districts.

Per Unit Value of Milk

The observed differences in water footprint in terms of milk production and productivity are also reflected in the water footprints in monetary terms. Since the average farmgate prices of both, cow and buffalo milk were more or less similar in the state (Rs19/liter), unlike in northern India, where buffalo milk is price higher than cow milk. Hence, across the type of animals higher water footprint is found in case of buffalo followed by local cow and crossbred cow (Table 3). Taking weighted average of consumptive water use per unit of value of milk production of all three types of animals, the weights being the total production of milk from each animal type in the district, the average water footprint works out to be 0.06 m3/Re that is, 60 liter of water is consumed to produce a rupee worth of milk output in Andhra Pradesh. The differences in yield and feeding pattern across districts that was reflected in water footprint by type of animal, seems to be neutralized by the differences in composition of milch herd when weighted averages were taken. Hence, the spatial variations in water footprint of total milk production have narrowed down considerably.

Conclusions

Milk production is becoming water-intensive and exhaustive in the state, so there is strong need for bringing down the water footprint of milk for sustainable dairy farming. Indirect component is the major part, key role of feed and fodder crops made it point of check. Hence water footprint of milk can be lowered by reducing water footprint of animal feed crops. This requires water use efficiency in crop production. Crop productivity can be increased by better farm management and agronomic practices, harvesting of green water and water efficient irrigation systems. Emphasis is needed in identifying pockets of high crop productivity, low water consuming high nutrition value feed crops, suitable feeding patterns, water saving techniques and increasing milk productivity. Virtual trade between low and high water efficient districts is a better option than using scarce irrigation water resources inefficiently.

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