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Water footprint assessment of cattle milk at smallholder farms

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Abstract
With the huge cattle population and poor production management system in the country, environment can be affected by negative factors, including: shortage of water and pollution of water bodies. In context to this problem, a study was performed to estimate Water Footprint (WF) in Hisar district of Haryana from cattle's milk. The information about animal's ration and watering, crops cultivation, irrigation system, etc. was collected by interviewing 50 male farmers (purposive sampling) rearing cattle at smallholder farm, followed by multistage sampling. For estimation of WF of milk, methodology suggested by Water Footprint Network was relied. Both blue and green water estimations were made using both primary and secondary data. The Water Footprint was estimated as 1391.37 Lt. water/ Lt. milk. The indirect blue water constituted major water use with direct water use being estimated as 134.03 Lt./day/lactating animal. The findings of the present article might prepare foundation for other research in future that examine the cause of multi-functionality upon the WF of milk produced at smallholder farms across the country. Sustainable dairy farming may benefit from the WF approach to measuring the amount of water used in milk production. In order to get more accurate readings of the WF of milk, more research will be directed toward the enhancement of the evaluation, which will take into account aspects such as sensitivity analysis, data sources quality, and so on.

Keywords: Water footprint (WF), consumptive water use (CWU), direct water use, indirect water use, cattle

1. Introduction

Studies have shown that livestock raising, together with other agricultural operations like cultivating animal feeding crop or fodder, drinking, washing, and animal products processing, uses a lot of fresh water. Additionally, it is well-known that the availability of water resources and the global hydrological cycle would be impacted by a warming planet. There is a potential for a two- to threefold increase in animal water consumption if temperatures rise, and the livestock industry accounts for around 8% of worldwide human water demand (Nardone *et al*., 2010) [15]. Due to water scarcity and customer worries about the environmental implications of livestock agriculture, quantifying the water usage of animal products has been more popular over the last 2 decades (Legesse *et al.*, 2017) [11]. Because of the growing concern about water shortages, water footprints have been recognised as a crucial indication of the long-term viability of our current methods of producing food. The livestock business has critical shortfalls in providing the food demands of a growing human population without negatively impacting water resources, which is why WF assessment throughout the full value chain of animal products is gaining significance (Zonderland-Thomassen *et al.*, 2014) [21].
Hoekstra and Hung (2002) [9] used the term "Water Footprint" (WF) to describe a method of measuring a person's or a company's freshwater consumption that takes into account both their direct and indirect water usage. The amount of total water used in manufacturing a product is the products WF. It has been argued that, if the Water Footprint for milk is estimated at nation level, China has the maximum Water Footprint 1257 Lt/kg, followed by India 1060 Lt /kg and Netherland has the least Water Footprint 494 Lt /kg (Mekonnen and Hoekstra, 2012) [13]. WF is now widely recognised as a key measure of food production systems' long-term viability. Knowledge of individual farms' freshwater usage is crucial for reducing the dairy industry's

water impact. (Murphy *et al*., 2017) [14]. Due to the availability of very limited literature, we planned to assess the Water Footprint of lactating cow's milk produced at smallholder farms. In view of the foregoing, this manuscript gives a brief account of performed study.

2. Methodology

This study was accomplished in the Hisar district of Haryana, which is categorised as hot arid eco-sub-region lying in transgangetic plain region (western-agro-climatic zone). The volumetric WF technique given by Hoekstra *et al.* (2011) [8] and the Life Cycle Assessment (LCA) established in the ISO standards are two examples of widely acknowledged ideas of WF. The volumetric WF technique is growing in popularity because it provides an all-encompassing evaluation of usage of water, pollution associated with the production or consumption (Owusu-Sekyere *et al.,* 2017) [16], and generates information and aids in water management (Palhares, and Pezzopane, 2015) [17]. Water footprint accounting for smallholder cattle farms was evaluated using the volumetric WF approach proposed by Hoekstra *et al*. (2011) [8]. Green water, grey water, and blue water are the elements that make up a water footprint. Water consumed from groundwater and surface, along the products supply chain refers to the blue water. Usage of rainwater refers to the green water and the non-consumable water due to deteriorative water quality refers to the grey water (Hoekstra A.Y., *et.al*. 2011) [8].

Male cattle rearing farmers were purposively selected for the collection of data. Selection of farmers was completely based on multistage sampling method (5 villages were selected from Hisar district on random basis, further 10 farmers from each village were selected on random basis). For production of milk, both, direct (servicing, drinking and bathing) and indirect (through fodder and feed intake) is used as consumptive water. The parameters estimated were Blue and Green WF of cattle milk (Table 1). This study did not attempt estimation of Grey WF component given the inherent complexities and scope of study.

$$WF_{INDIRECT} + WF_{DIRECT} = WF_{MILK}$$

2.1 Direct water consumption (WF_{DIRECT})

The data on water used for drinking, servicing, mixing with feed and fodder, and bathing (Lt./day) was collected. The estimation of above-mentioned water use at the farm was quite difficult but data was collected by interviews of farmers and observation of farms (the pipe's diameter, time of water run in pipe, animal numbers on the farm, volume of buckets or water trough used and number of times per day these were filled by farmer) for different seasons.

$$WF_{DIRECT} = \text{Drinking water} + \text{Bathing water} + \text{Service water}$$

2.2. Indirect water consumption ($WF_{INDIRECT}$)

$$\text{Indirect water} = \sum_i x_i \times CWU_i$$

x_i = consumption of 'i' concentrate/ roughage (kg) by the cattle. It was measured using the weighing balance. CWU_i = The Consumptive Water Use of 'i' concentrate/ roughage resource expressed in m^3/kg.

The crop water requirement by crop is required to calculate the indirect WF (blue and green water components). Crop water demand is the sum of ETp across a crop's four-stage development cycle. (Allen *et al*., 1998) [1]. For the present study, data reported from Sirohi *et al.* (2013) [19] for Haryana specific feed and fodder crops was selected as Secondary data source.

$$WF_{INDIRECT} = WF_{DRY\text{-}FODDER} + WF_{GREEN\text{-}FODDER} + WF_{CONCENTRATE}$$

3. Results and Discussion

3.1. The Production System

Male farmers selection was done purposively because males of the family are responsible to take decisions and actions for animal rearing practices in the research area. Significant aspects of farms and homes are summarised in Table 2. Adequate quantity of concentrates, agricultural by-product, green grass and fodder as feed was available in animals' stalls. Availability of green forage was totally dependent on the season. Lactating cattle were the potent recipients of the more costly food like concentrates.

3.2 Direct Water Use

In order to have sensible estimates of the direct water consumption, the information was collected for summer, humid and winter season (Table 3). The total direct water use was calculated 134 $Lt.day^{-1}$. However, the previous study judged the wide volumes of direct water use from 100 $Lt.day^{-1}$ (Singh *et al*., 2004) to 64 $Lt.day^{-1}$ (Chapagain and Hoekstra, 2003) [5] for lactating Indian dairy cattle. Similarly, Sirohi *et al*., (2013) [19] reported blue WF from direct use of 85 $Lt.day^{-1}$from Karan Fries and 80 $Lt.day^{-1}$ from Sahiwal and Tharparkar at organized dairy farms. The researchers also estimated direct water use for unorganized dairy farms being 66 $Lt.day^{-1}$ for local and cross bred cattle (*ibid*). Although, different practices, species, recall errors etc, can be considered as sources of variation, but suggesting the reasons for varying reports will be merely speculative, at least, at this stage. Therefore, further studies to accurately estimate water use are advocated. Interestingly, it was found that no water was used for service during summer season as owner shifted their animals to dry and sandy land. This, perhaps, is a sign of lack of adequate water availability. The respondent farmers preferred not to bathe their animals in winter season. Although the variations in the available literature and findings of the study are not very wide, but there is scope of further studies or larger scale to estimate water usage for animals in different parts of the state and country which will pave way for appropriate water management steps.

3.3 Indirect water use

The term "indirect WF" usually relates to the water use as well as pollution which may be linked to the producer's other (non-water) inputs. (Hoekstra *et al*., 2011) [8]. In this study, grey component of WF was not studied. Many other researchers have earlier avoided estimating grey component (Example, Murphy *et al*., 2017; Ibidhi and Salem, 2020; and Bansod, 2012) [14, 10, 4]. Perhaps, the complexities involved in estimating the grey component makes it a difficult task. However, it cannot be ignored that water pollution due to animal and their product is an area of concern. Therefore, it is suggested that attempts should be made for estimating grey water component also.

The estimation of Indirect water uses attributable to feed and fodder consumed was done by using secondary data reported by Sirohi *et al.* (2013) [19]. There is a wide variety in the amount of water found in the foods eaten (performed water) based on the feed's moisture content, 90% or more in succulent crops or little as 5% in dry crops (Zinash *et al*., 2002) [20]. A crop's water needs are based on the average ETp throughout the course of its 4 growth stages (initial, development, mid and late stage). Environmental factors, management, crop, and weather, all influence the evapotranspiration of crops. Table 4 summarizes the estimated green and blue WF of on the basis of feed and fodder consumed by cattle. In the present study, the crop water requirement was highest for cotton crop due to high ETp for the locale of the study. The CWU of crops were furnished to primary and by-products (Ground nut cake, wheat straw, paddy straw, cotton seed and cotton seed cake).

When the values reported by Sirohi *et al*., (2013) [19] are taken into account, the consumptive water use by crop has contribution of 4.684 and 5.659 m^3 $day^{-1}$from green and blue water use, respectively. Thus, the estimated total indirect water use was 10.343 m^3 day^{-1}. In term of percentage, it is 45% as green and 55% as blue water use. However, methodological problems confound the issue of CWU by the cotton crop. Further studies to reliably estimate water use in cotton crops are thus advocated.

Yet, it can be seen that it is the indirect water use that largely accounts for greater proportion water use for animals. Deutsch *et al*., (2010) [6] have also argued that globaly rise in animals feed production will further lead to much higher water consumption as majority of water consumption is associated with feed and fodder production for farm animals. Mekonnen and Hoekstra (2011) [12] assessed that for the period 1996–2005, WF for the global crop production was 7404 Gm^3yr^{-1}.

3.4. Total water footprint

The present research work revealed that the total consumptive water for lactating cattle was 1391.37 Lt.water/Lt.milk. In the estimates, major share is due to indirect blue water use (Table 3). This is probably due to the fact that Hisar is classified as hot arid district of Haryana and receives low rainfall. The average rainfall is ≤ 450 mm/year. Because of which, a greater reliance on irrigation for crops becomes crucial. However, the WF per tonne of feed is higher in Netherlands and the United States, and this fact cannot be overlooked. (Mekonnen and Hoekstra, 2012) [13]. The worldwide average of total WF of milk for grazing system was 1191 m^3/ton, with 1087 m^3/ton contribution from green water, and 56 m^3/ton from blue water (*ibid*). Contrarily, Amarsinghe *et al*. (2011) [3] have reported all India average of total Water Footprint of milk to be 1369 and 1789 m^3/ton, respectively.

The question of how India will satisfy its rapidly growing need for food and water has risen to the forefront of global supply and demand estimates in recent years. The consequences of severe weather occurrence heavily affect the water availability for agricultural production. Fodder and Feed may be impacted as a result of this. Ninety percent of India's water withdrawals go to agriculture (Amarasinghe *et al*., 2007) [2], with groundwater being the source of irrigation for sixty-three percent of the irrigated land (GOI, 2010) [7]. Groundwater consumption has become unsustainable in several locations, threatening the viability of the high efficient feed crops and milk yield. There is a compelling argument for reducing the WF of milk to increase sustainability as milk production in the nation becomes more water-intensive and demanding.

If integrated research and development doesn't lead to much greater water-use efficiency, then the projected growth in food consumption in developing nations over the future years would require a considerable need for extra agricultural water. Lately, it is advised that prime target should be to achieve high productivity in Indian lactating dairy cattle. But it must also ensure that this doesn't disturb the smallholder production systems being practised at village level, also careful consideration must be given to other environmental concerns. There is huge requirement for vast assessment of such environmental impacts in order to reach at reliable solutions and it is believed that the easiest ways are tough to find.

Table 1: Components of Water Footprint in Milk Production.

WF_{MILK}	Direct water footprint (WF_{DIRECT})		Indirect water footprint ($WF_{INDIRECT}$)
Element	**Source**	**Type of use**	**Type of use**
Green Water	Effective rainfall	—	CWU from soil moisture in fodder and other feed crops
Blue Water	Irrigation	Drinking, bathing, servicing and mixing with feed and fodder.	CWU from irrigation water in crop production.

Table 2: Farms milk production and respondents' family status.

Sr. No.	Characteristics	Mean ± SD
1	Cultivable land (acres)	3.33±1.32
2	Animal's Lactation Number	2.81±0.22
3	Family member strength	5.8±0.21
4	Average Milk Yeild (Lt. / animal /day)	7.51±0.91
5	Animal's Age (years)	5.33±0.15

Table 3: Total consumptive water for lactating cattle (Lt. $head^{-1}$ day^{-1})

WF Component	Type	Water use	Season (Lt. $head^{-1}$ day^{-1}) (Mean ± SD)			Estimated average (Lt. $head^{-1}$ day^{-1})
			Summer	Humid	Winter	
Blue Water	Direct	Drinking water	72.48±25.95	34.66±12.79	48.85±18.64	51.99
		Bathing water	40.09±20.89	56.5±26.11	0	51.48
		Servicing water	0	7.36±6.78	13.36±6.49	13.84
		Water in feed	-	-	-	16.72
	Indirect	Irrigation water	-	-	-	5659
Green Water	Indirect	Soil moisture	-	-	-	4684
Total						10477.03

Table 4: Blue and Green Water Footprint of feed and fodder crops for lactating cattle.

Sr. No.	Feed type	Crop	GWP (m^3)	BWP (m^3)
1	Dry fodder	Wheat straw	0.009	0.394
		Paddy straw	0.009	0.021
2	Green fodder	Sorghum	0.036	0.029
		Barseem	0.0003	0.031
		Maize	0.004	0.006
		Oats	0.0006	0.026
		Local grass	0.0005	0.020
3	Concentrate	Cotton seed	0.0051	0.276
		Ground nut cake	1.080	0.377
		Wheat bran	0.022	1.07
		Cotton seed cake	3.514	3.13
		Pearl millet grain	0.003	0.186
		Wheat flour	0.001	0.093
Total			4.684	5.659

4. Conclusion

Dairy farmers have started to worry about climate change since it is altering rainfall patterns and water availability. The most significant indirect contributor is agricultural water usage, which may be drastically decreased. Milk production could be possible in a more water-sustainable manner if certain conditions are met, such as high agricultural productivity, low CWU, good nutritional value forage/fodder crops, optimal pattern of animals feeding, and procedures that save water. This would result in a lesser WF.

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