Review Article

Water Footprint - A Tool for Sustainable Development of Indian Dairy Industry

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Abstract
The increase in the consumption of animal products is likely to put pressure on the world's freshwater resources and water scarcity can pose threat to sustainable development. Dairy farming is a water intensive activity involving not only direct consumptive water use as drinking and cleaning water for animals, but also indirect water embedded in the feed. Water footprint can be used as a tool for sustainable dairy farming. Water footprint calculates the total volume of water used to produce the milk, including direct and indirect use. Water Footprint of milk depends on feed conversion efficiencies, feed composition and feed origin. Feed production contributes maximum to the water footprint. Improving feed conversion efficiencies of dairy animals, improving water use efficiency in milk production and agricultural practices can help in reducing water footprint. Virtual water trade between nations can also be promoted to improve global water use efficiency.

Key words: Dairy Farming, Virtual Water Trade, Water Footprint, Water Use Efficiency

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Introduction

Water is the most essential of all nutrients constituting about 60 to 70 percent of a livestock animal's body. It is essential that dairy cattle consume adequate quantities of water each day to meet their requirements as water is required for digestion and metabolism of energy and nutrients, maintenance of proper ion, fluid and heat balance (Houpt, 1984; Murphy, 1992). Natural resources depletion is causing a significant threat to the sustainability of consumption (Chertow, 2000; Bac *et al.*, 2011). With transition in the nutrition, people are shifting towards more affluent food consumption patterns with more animal products (Bruinsma, 2003; Grigg, 1995; Popkin, 2002). There has been a gradual shift of animal husbandry from subsistence to commercial nature (Sharif *et al*., 2013). With the increase in average per capita income the per capita consumption of meat and other animal products also increases until it reaches some level of satisfaction. (Gerbens-Leenes *et al*., 2010). Dairy farming which is an integrated component of Indian farming system, involves not only direct consumptive water use as drinking and cleaning water for animals, but also indirect water embedded in feed. Climate change, population growth, economic development and demand driven by industry in general and agricultural sector, in particular results in increasing pressure on water resources in recent years. Besides, incidents of groundwater depletion, soil loss, land degradation rivers running dry and increasing levels of pollution form an indication of the growing water scarcity (Meyer and Turner, 1994; Campbell *et al*., 2005; Oago and Odada, 2007). The food production today is by far the largest user of fresh water resources with 70 % compared with only 10 % for household use and 10 % for industry (Molden, 2007). Annually 70% of the used freshwater (not the total freshwater) goes to agriculture (FAO, 2014). In India about 64 per cent of irrigated area relies on groundwater resources (Anon, 2014). Sector-wise global water utilization is shown in Fig. 1.

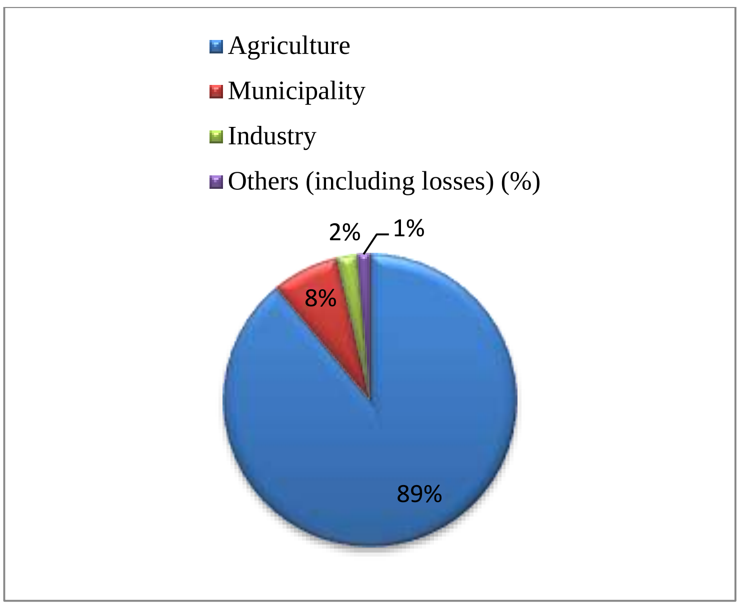

Fig. 1: Water utilization in different sectors in India (Data Adapted from Grail Research, 2009)

Global food production will need to be 70% greater by 2050 than it was in 2000 (Bruinsma, 2003) and 10% increase in cultivated land and a 20% increase in agricultural water demand will occur, even if we use optimum technology and productivity (De Fraiture, Wichelns *et al*., 2007). For growing grain demand more water resources are required. The overall demand for water in livestock production is influenced by several factors such as type of animal, its activity, feed intake and diet, quality of available water, temperature of

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water and ambient temperature (Lardy *et al*., 2008). What kind of animal is used for production, where the animal is kept, what the animal diet constitutes of, where the feed is produced etc. will have an impact on the water requirement of the product (Steinfeld *et al*., 2006). Livestock in itself contains between 5 and 20 times more virtual water per kg product than crop products (Chapagain & Hoekstra, 2003).

The impacts of extreme climatic changes could threaten sustainable water supply for agricultural production (Gosain *et al*., 2006). Food grain supply for human feed and fodder supply for dairy animals will also be affected. 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. The global WF of animal production constitutes almost one third of the WF of total agricultural production. WF of milk in India is 1369 L/Kg while the world average is 990 L/kg (Hoekstra and Chapagain, 2007). The increase in the consumption of animal products is likely to put further pressure on the world's freshwater resources. Moreover, many regions are becoming unsustainable due to dairy farming (Shah, 2009) and water footprint analysis can play an important role is ensuring sustainable agriculture and livestock products (Pretty *et al*., 2010).

What Is Water Footprint?

The concept of 'water footprint' provides an appropriate framework of analysis to find the link between the consumption of animal products and the use of the global water resources. Water footprint accounting is a tool to calculate water use behind consumer products. Water footprint is the total volume of freshwater used to produce the goods and services consumed by the individual, business or nation is known as the water footprint of an individual, business or nation (Chapagain and Hoekstra, 2007). The freshwater that evaporates, is incorporated into a product, is contaminated or is not returned to the same area where it was withdrawn is called as consumptive water use (Dourte & Fraisse, 2012). About 27% of the water footprint of humanity is related to the production of animal products (Mekonnen and Hoekstra, 2011). Water footprint is indicator of water use that looks at both direct and indirect water use by a consumer or producer (Hoekstra, 2003). It varies from place to place, depending on climate, technology adopted for farming and corresponding yields.

The total water depletion in the production process has two components; water depleted within the production area and water embedded in other inputs used in the production process. These are also often referred to as 'internal' and 'external' water footprints (Hoekstra 2003). The latter ('external water footprint') is also called 'virtual water' (Allan 1998).

Water Footprint vs. Life Cycle Assessment

LCA as water footprint also used for identification of so-called 'hot-spots'. The various environmental impacts caused by products from cradle to gravies measured by LCA (Finnveden *et al*., 2009). It is used to

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evaluate the environmental sustainability of products (Dewulf and Van Langenhove 2006). Water consumption has been traditionally omitted in most of LCA studies (Milà i Canals *et al*., 2009).The use of LCA for estimating impacts on water resources is more recent than the use of the water footprint. The total water footprint (adding blue, green, and gray water together) is often considered as the reference value to use to compare the impact of food production on water resources. However blue, green and gray water have completely different natures, and the water footprint estimates only total water use, not its impact on available water resources and thus the risk of water scarcity. The preponderance of green water in the total water footprint (> 90% for plant and animal products, Mekonnen and Hoekstra, 2012) hides the risk of water depletion shown by blue water and of water pollution shown by gray water. Green water accounts for water output from plants but not for their major water input (i.e. rainfall) and thus is not adjusted according to local water balances. The LCA approach is useful for communication purposes and for presenting alongside other environmental impacts while the WFN (Water Footprint Network) approach provides transparent information on water use and related impacts in the appropriate time and spatial scales that could be useful to improve water efficiency and management.

Virtual Water Concept and Water Stress Index

The freshwater 'embodied' in the product, not in real sense, but in virtual sense (measured over its full production chain) is called Virtual water. The virtual water content of a commodity as the volume of water that is actually used to produce the commodity, measured at the place where the commodity is actually produced (Allan, 1993, 1994). The 'virtual-water content of a product' is the same as 'the water footprint of a product', but the former refers to the water volume embodied in the product alone, while the latter term refers to that volume, but also to which sort of water is being used and when & where that water is being used. The virtual-water flow between two geographically delineated areas (for example, two nations) is the volume of virtual water that is being transferred from the one to another area as a result of product trade. Virtual water trade between nations can be used as an instrument to improve global water use efficiency, water security in water-poor regions of the world and alleviate the constraints on environment by using best suited production sites (Turton, 2000). Virtual water index was developed by Pfister *et al*. (2009) and is widely applied as a characterization factor at the midpoint level to describe the environmental impact of freshwater consumption in the life cycle of products and processes. WSI index was further incorporated into the water footprint (Ridoutt and Pfister, 2010).

Components of Water Footprint

A water footprint is composed of three components (Fig. 2).

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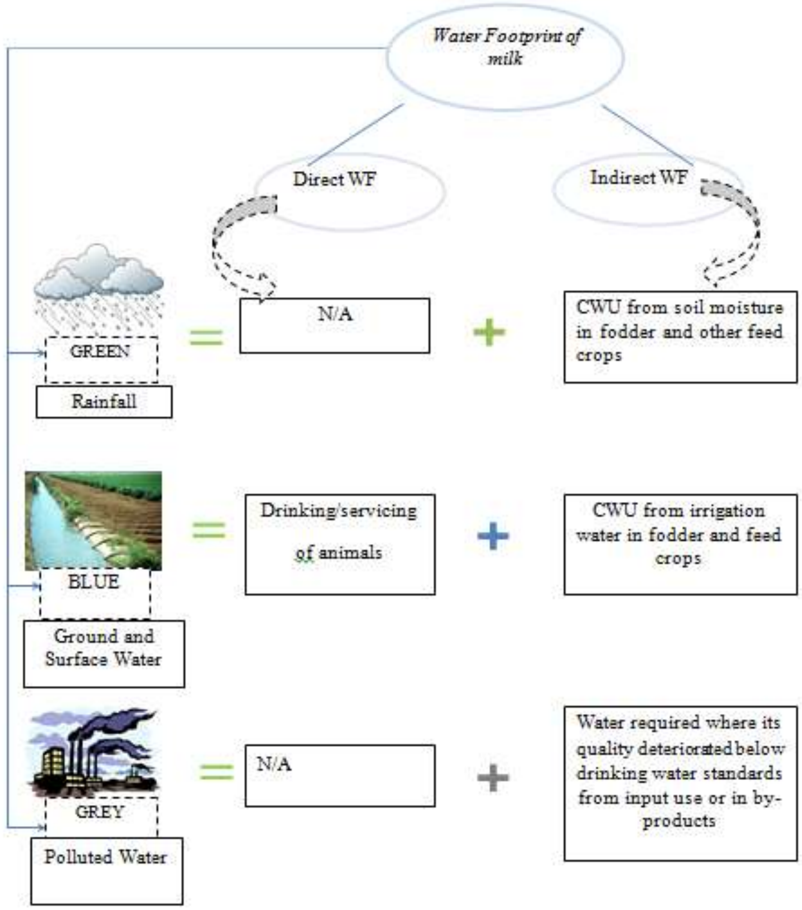

Fig. 2: Flow diagram representing different components of water footprint for milk production

1. Green Water Footprint

Green water is nothing but the precipitation on land that does not run off or recharges the groundwater but is stored in the soil or temporarily stays on top of the soil or vegetation. It includes precipitation and soil water absorbed by crop. All food we eat requires a green water flow as transpiration from plants (Falkenmark & Rockström, 2004).

2. Blue Water Footprint

In the case of agriculture and animal production system, blue water is basically, the volume of water irrigated from various sources like groundwater, river and pond etc. So, blue water footprint is formed of drinking water, irrigation and groundwater and surface water.

3. Grey Water Footprint

The grey water footprint of a product is an indicator of freshwater pollution that can be associated with the production of a product over its full supply chain. It is calculated as the volume of water that is required to dilute pollutants to such an extent that the quality of the water remains above agreed water quality standards.

The terms blue and green water flows and resources were introduced by Falkenmark (1995). The grey component of water use, expressed as a dilution water requirement, has been recognized by Postel *et al.*

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(1996) and Chapagain *et al*. (2006). The blue water resources are the liquid water found in aquifers, rivers, lakes, dams and wetlands. The blue water flows are the surface run-off, flow of ground water and base flow in rivers. Green water resources is rainfall that has infiltrated in the root zone of the soil also referred to as soil moisture (Deutsch *et al*., 2010). The green water flow consists of both evaporation and transpiration components, often lumped together as evapotranspiration. The grey water footprint is defined as the volume of freshwater that is required to assimilate the load of pollutants based on natural background concentrations and existing ambient water quality standards (Hoekstra *et al*., 2011). Direct consumption of blue water has an impact on the contribution of local water scarcity while green water (i.e. soil water used in evapotranspiration process by plants) is not like blue water which does not limit the availability blue water or environmental flows and has no same impact in a local hydrological system (Berger and Finkbeiner 2010; Ridoutt *et al.*, 2010; Doreau *et al.*, 2012). The environmental impact associated with green water use is relatively minor because it does not alter hydrological systems. However, blue water use in irrigated agriculture has the potential for causing severe environmental problems, such as water depletion, salinization, water-logging or soil degradation (Aldaya *et al*., 2010). A grey footprint is represents only a very small proportion of the footprint per tonne of product and is not carried forward in the analysis.

Estimation Methodology (Data Adapted from Singh *et al.*, 2013)

Dairy farming involves no only direct consumptive water use as drinking and cleaning water for animals, but also indirect water embedded in feed for cattle. Water footprint of milk production includes two components namely direct and indirect.

$$WF_{Milk}= WF_{Direct}+ WF_{Indirect}$$

Direct Water Use

The direct water of a product footprint refers to the freshwater consumption and pollution that is associated to the water use by producer. Direct water use includes drinking, servicing and bathing. Information can be partly obtained from observation and partly through farmer interview. Diameter of pipe used, time period of water flow and number of animals can also be accessed to quantify direct use.

$$WF_{Direct} \text{ or } DWU= DW \text{ (in Litres)} + \text{Bathing (in Litres)} + \text{Servicing (in Litres)}$$

Where DWU is direct water use, DW is drinking water

$$CWU= M^3/ton= WF_{Direct} \text{ or } DWU/ \text{ Av. milk yield (Liters/day)}$$

Where CWU is consumptive water use

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Assuming that agricultural water is allocated specifically for the purpose of producing animal feed, then total livestock use of water will be as much as 100 times greater than that needed for drinking alone (Peden *et al*., 2003). Water intake depends on food intake, nature of the diet, physiological state of the animal and ambient temperature (Matthewan, 1993).

Indirect Water Use

Indirect water footprint, which refers to the water consumption and pollution that can be associated with the (non-water) inputs used by the producer (Hoekstra *et al*., 2011).

$$WF_{Indirect} = (WF_{DF} + WF_{GF} + WF_{Conc.})$$

Water use for feed and fodder crops and calculation of CWU of animals through feed and fodder

Calculation of Crop Water Requirement

The crop water requirement is the actual evapo-transpiration (ETp) in four crop growth periods (initial, development, mid- and late stage). Evapotranspiration of crops, depends on weather, crop and management and environmental parameters.

$$ETp = \Sigma^{4}_{i=1}) k_i \times \Sigma_{\text{month j in ith growth period}} d_{ij} ET_0^{ij}$$

Where, k_i = crop coefficient of ith growth period

d_{ij} = Number of days of the jth month in the ith crop growth period

ET_0^{ij} = Reference evapotranspiration of the jth month in the ith crop growth period

$CWU^{\text{Effective rain}} = \text{Min}(ETa, P_{eff})$ (Allen *et al*., 1998)

P_{eff} is effective part of rainfall at the root zone

The effective rainfall P_{eff} is generated from P_{tot} by CROPWAT (FAO, 2006b)

$P_{tot} \leq 250/30 \rightarrow P_{eff} = P_{tot} * 30/125 * (125/30 - 0.2 * P_{tot})$

$P_{tot} > 250/30 \rightarrow P_{eff} = 125/30 + 0.1 * P_{tot})$

Green Water Footprint is the CWU from rainfall = Min (ET_p, Peff)

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 (ETp) and Effective precipitation (P_{eff}).

$$\text{Blue Water Footprint is CWU from irrigation} = ET_p - P_{eff}$$

$$CWU_{Crop} = CWU_{Green} + CWU_{Blue}$$

The meteorological parameters, like, the monthly data of ET_0 (reference evapotranspiration) and P_{75} (monthly 75% exceedance probability of rainfall) can be taken from World Water and Climate Atlas prepared International Water Management Institute (IWMI, 2000). This database gives the values for a

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large number of locations in India. The data on length of growing period, crop coefficient and yield of feed and fodder crops can be obtained from the regional agricultural stations situated in that particular area.

Calculation of CWU of Animals through Feed and Fodder

a) Data should be collected on seasonal basis, preferable for three seasons i.e. hot humid/rainy, winter and summer
b) Intake of each type of feed and fodder is then multiplied by the CWU (in m^3/kg) of respective crop to get the indirect water use by animals.

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

x_i is intake of 'i' feed/fodder by the animal
CWU_i is the consumptive water use of 'i' feed/fodder resource

Dairy cattle get their water from three sources- drinking water, water contained in feeds and metabolic water (Kijne, 2005). Water contained in feeds consumed (performed water) is highly variable from feed to feed according to the moisture content, which can range from as low as 5% in dry feeds to as high as 90% or more in succulent feeds (Zinash *et al*., 2002).

Factors Affecting Water Footprints of Animal Products

The global WF of animal production constitutes almost one third of the WF of total agricultural production (Mekonnen and Hoekstra, 2012). From total water used for milk production from buffalo, crossbred cow and indigenous cow, the share of drinking water is less than 1 %, while embedded water accounts for the rest (Singh *et al*., 2004). Main factors involved in WF of milk are-

a) Feed conversion efficiencies
b) Feed composition and Feed origin

Feed Conversion Efficiencies

The feed conversion efficiency, that is the amount of feed required to produce one unit of animal product, strongly affects the water footprint. Cattle's relatively low conversion efficiency leads to a large water footprint. In spite of favorable feed conversion efficiencies, chicken and pig have relatively large fractions of cereals and oil meal in their feed, which results in relatively large water footprints. Efficiency improves from grazing to mixed to industrial systems, because animals in industrial systems get more concentrated feed, move less, are bred to grow faster. If the feed conversion efficiencies are unfavorable it will result in larger water footprint

Feed Composition and Feed Origin

Feed constitute 98%, drinking 1.1%, service water 0.8% and feed mixing water 0.03% of the total WF (Mekonnen *et al*., 2010; (Mekonnen and Hoekstra, 2010). Chapagain and Hoekstra, 2003 reported water

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usage by different milk production components. In general, concentrates have a larger WF than roughage. Green fodder, dry fodder and feed concentrates are the main types of feed for indigenous and crossbred cows and buffaloes, constituting 1, 28 and 71%, respectively, of the milking animal population. The differences in climate and agricultural practices in the regions from which the various feed components are obtained also influence the water footprint of a specific animal product. The total mixture of roughages (grass, crop residues and fodder crops) has a WF of around 200 m^3/tonne (global average); this is about 1000 m^3/tonne for the package of ingredients contained in concentrates (Gerbens-Lenes *et al*., 2013). The sorghum+maize+berseem+oats and sorghum+maize+berseem are the other two fodder cropping patterns with slightly higher CWU (Amarsinghe *et al.,* 2010). The amount of green and blue water evaporated through feed crop land are enormous and estimated to be as much as 45 % of the water used for food production globally (Zimmer & Renault, 2003). Amount of irrigated crops or forages, the proportion of supplementary feed purchased, the water content of forages and evaporation from watering ponds also influences the total water footprint of product (Zonderland Thomassen and Ledgard, 2012)

Effect of Production System on Water Footprint

Livestock industries consume 8% of the global water supply, with most of that water being used for intensive, feed-based production (Schlink *et al*., 2010) the water footprint of concentrate is more than that of roughage so it is a disadvantage of the total water footprint of animals raised in industrial system and advantage in Grazing system rearing. The contribution of blue water footprint to the total water footprint per ton of milk produced ranged from 2% to 19% across all production systems (Irfan and Mondal, 2016). Generally, the fraction of feed consumed is larger in industrial but the favorable higher feed conversion efficiencies leads to lower water footprint in industrial system. But for dairy products, the water footprint happens to be the smallest when derived from a mixed system and a bit larger but comparable when obtained from a grazing or industrial system (Fig. 3). Blue and grey water footprint is generally higher in industrial system as compared to mixed and grazing due to larger component of concentrate feed for animals and high use of fertilizers and agro-chemicals. Trend in global production do not hold same for all the countries. Fresh water problems generally arise due to blue and grey water footprint therefore industrial system placing great pressure on ground and surface water sources. In India cattle are generally fed with pasture and crop residues that have no blue and grey water footprint.

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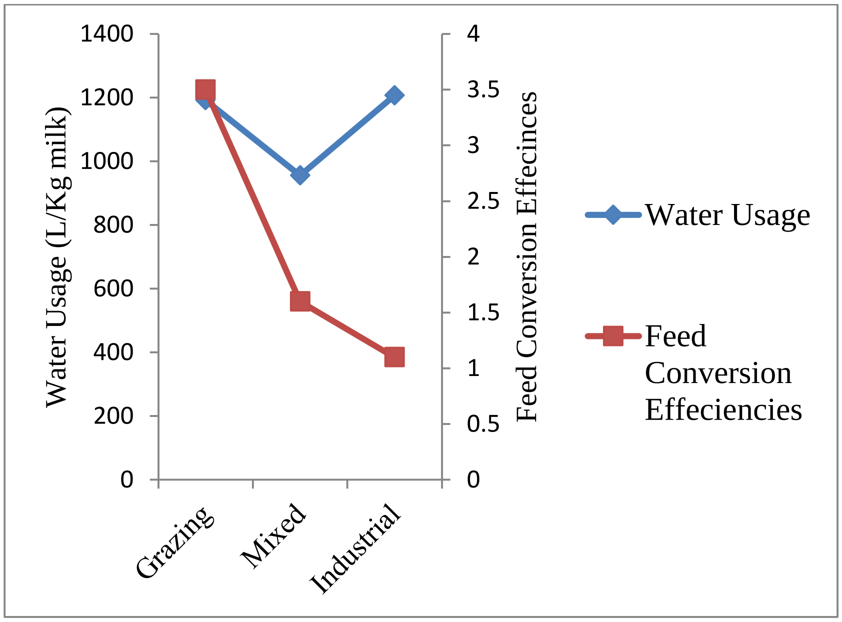

Fig. 3: Chart represnting varition of water usage and feed conversion effeciencies with different livestock production system (Adapted from : Mekonnen *et al.*, 2012).

Water Footprint of Milk Production in India

With the increase in human population demand for milk is also increasing and people are shifting to market oriented organized dairy farming (Fig. 4). India rank 1st in milk production and contributing 18.5% of the total world milk production with a growth of 6.26% whereas world milk production increases by 3.1% (Economic Survey 2015-16). Milk production from 2015-2016 is 155.5 million tonnes (NDDB) while projected demand for 2020 with GDP growth low(6%), moderate (7%) and high (8%) is 216.1 million tonnes, 227.7 million tonnes and 270.2 million tonnes (Shah and Dave, 2010). While in 2020 India will be 64.21% and 24.81% deficit in Green and dry respectively (IGFRI vision 2030). Climatic change will also hit this projected milk production. Considering all this there is a strong need for reducing water footprint and aiming towards sustainable dairy farming. Singh and Avinash (2004) in the Gujarat dairy study of India have shown that the water productivity was as low as 0.3 L of milk per 1 m^3 of water. However, the global water requirement for milk production is reported to be 1.1 l per m^3 of water, which is three times as high as in Gujarat (Chapagain and Hoekstra, 2003).

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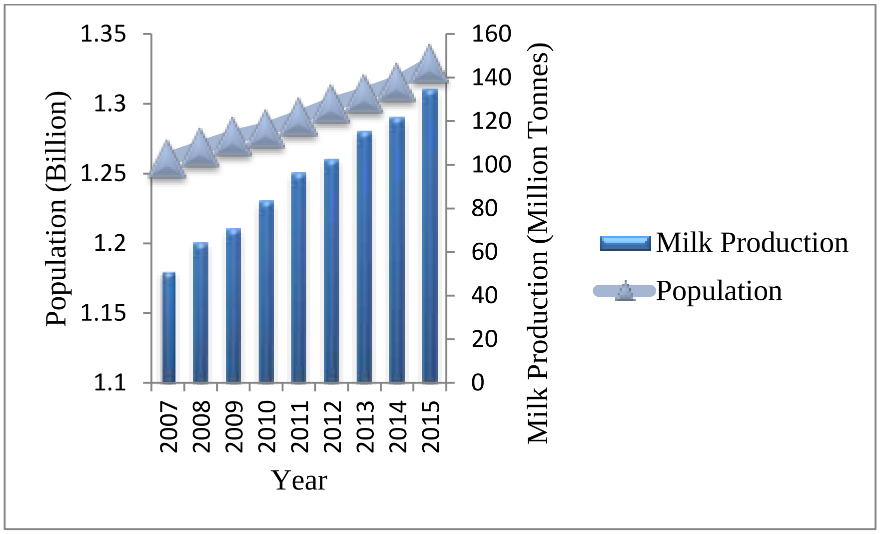

Fig. 4: Chart representing growth of population and milk production with years (NDDB, World Bank)

Water productivity (milk yield produced per cow/virtual water used for 1L milk per day) of crossbred cow is more than the indigenous cow whereas water intensity (1/water productivity) of crossbred cow is less than the indigenous cow (Irfan and Mondal, 2016). Sirohi *et al.*, 2013 also concluded that the total consumptive water use for milk production in Karan fries, Murrah and Sahiwal and Tharparker is 1212, 1269 and 1583 m^3/ton. This is the inverse of their milk production (Karan Fries 9.0, Murrah 7.4 and Sahiwal and Tharparker 7.2 kg/day.) Janardan *et al.*, 2012 found that water footprint of Sahiwal, Karan Fries, Tharparkar and buffalo is 8742.68, 9169.77, 10557.37 and 11484.60 L/ton. Murrah is less adaptive to climatic change because of high water footprint per ton of milk production. Sahiwal and Tharparker can be beneficial if their productivity is increased**.** 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 m^3/ lactating animal (Harika *et al*., 2015). Water (both direct and indirect) consumed by buffaloes, crossbreds and cows ranged from 6.1 to 11.81, 5.51 to 11.63 and 6.71 to 7.11 m3/day/animal respectively (Singh *et al*., 2009). Milk productivity and water footprint per unit milk yield is inversely correlated. Therefore, water consumed per kg of milk is relatively lesser in case of crossbred cow than buffalo and indigenous cattle due to their higher productivity. Higher the milk productivity of an animal the less will be its contribution to water footprint. Different studies conducted on water footprint of milk production in India are represented in Table 1.

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Table 1: Studies on water footprint of milk in India

References	Location of Study	Breeds	Water Footprint (m3/kg)
Chapagain and Hoekstra, 2004	Global average	-	1.02
Chapagain and Hoekstra, 2004	India average	-	1.37
Amarsinghe *et al.*, 2010	Moga, Punjab	-	0.94
Amarsinghe *et al.*, 2011	India average	-	1.79
Janardan *et al.*, 2012	Karnal, Haryana	Karan Fries	1.02
		Sahiwal	1.21
		Buffalo	1.55
Sirohi *et al.*, 2013	Karnal, Haryana (Organized Farms)	Karan Fries	1.21
		Sahiwal and Tharparker	1.58
		Murrah	1.27
Singh *et al.*, 2014	Gujrat	Crossbred cow	2.18
		Indigenous cow	2.3
	Punjab	Buffalo	3.27
		Crossbred cow	3.01
		Indigenous cow	2.3
	Kerala	Buffalo	4.86
		Crossbred cow	2.51
		Indigenous cow	3.49
		Buffalo	3.9
Harika *et al.*, 2015	Andhra Pradesh	Cross bred	1.48
		Local	1.6
		Buffalo	1.99
Sharif and Dixit, 2015	Karnataka	Crossbred cow (S)	1.84
		(SC)	1.13
		(C)	0.84
		(OE)	0.73
		Local cows (S)	1.92
		(SC)	1.88
		(C)	1.77
		(OE)	1.23
		Buffaloes (S)	2.66
		(SC)	2.48
		(C)	1.87
		(OE)	1.14
Irfan and Mondal, 2016	India average	Crossbreed cow	1.07
		Indigenous cow	1.47+A12:D37

S= safe, SC= semi-critical, C= critical, OE= overexploited

Milk Production under Different Groundwater Exploitation

Milk production under different levels of groundwater exploitation i.e. safe, semi-critical, critical and overexploited were analyzed by Sharif and Dixit (2013). In overexploited area this ratio exceeds 100 %; in critical areas 90-100 %, in semi-critical 70-90% and less than 70 per cent in the safe areas. Due to high milk yield, higher water productivity of dry and green fodder and composition of feed fodder, milk production

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is highest per unit of ground water in overexploited areas irrespective of animal species. Groundwater irrigated is lowest in overexploited village for the production of green and dry fodder followed by critical and semi critical villages. It can conclude that water scarce regions use water judiciously. Farmers are adopting water saving technologies like drip and sprinkler irrigation in these areas and they are also aware of the critical stages of crop irrigation and they irrigate during this critical period and able to reap good yield for dry and green fodder. Milk production from local cows was a losing proposition, irrespective of the different groundwater regime, and amount of loss was highest in critical and over exploited areas. Farmers of groundwater abundant (safe and semi-critical) region made marginal net profit from milk production of buffaloes and it was a net loss in critical and overexploited) regions.

How to Increase Water Use Efficiency?

a) Monitoring water use
b) Losses from leaky tubes and watering should be minimized. Install a float with a shut-off. to prevent loss of water overflow
c) Waste wash water can be reused (for collecting yards wash-down)
d) Roof water collection
e) Plate cooler water can be recycled for wash down/drinking water
f) Cow cooling doesn't need water spraying continuously, cycle the unit off and on in coordination with a fan system
g) Use high-pressure, low-volume cleaning systems
h) Use a scraper or a chain break up dung before hosing
i) Recycling green water (from effluent) to flood wash the yard

Water Conservation Strategies in Crop Production

a) Adjust planting time of crop in accordance with weather changes.
b) Irrigation method like drip and sprinkler. Drip irrigation is most efficient with respect to water (Raes *et al*. 2009; Zegada-Lizarazu, 2011).
c) Precision land levelling resulted in irrigation water savings of 15-30% accompanied by increases in crop yields by 4-6% compared to traditional levelled fields (Sidhu *et al*., 2010; Kaur *et al*., 2012).
d) Mulches produced 13-21% higher grain yield and more roots (25 and 40% higher root weight and root length densities) in sub-surface (>0.15 m) layers (Chakraborty *et al*., 2010).

Water Footprint Role in Trade

Virtual water trade between nations can be used as an instrument to improve global water use efficiency. Trade of real water between water-rich and water-poor regions is generally impossible due to the large distances and associated costs, but trade in water-intensive products (virtual water trade) is realistic (Hoekstra and Hung, 2002). Water-scarce countries are importing virtual water (through import of water-intensive products), are relieving the pressure on the domestic water resources. With the current water

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productivity in India and the food demand scenario for the year 2050, it seems inevitable for India to become an importer of virtual water (Falkenmark, 1997; Yang *et al*., 2003; Falkenmark & Lannerstad, 2005).

Conclusion

Water footprint can act as a tool for sustainable dairy farming which can be used to calculate water in milk production. It can be mainly reduced by reducing water use for crop production as it is the major indirect component. High crop productivity (irrigation method like drip and sprinkler, precision land leveling, mulches), low water consuming high nutrition value feed crops, suitable feeding patterns, water saving techniques (water budget, using waste wash water for collecting yards wash down, roof water collection) and increasing milk productivity by shifting to greater-volume producing cows may allow the production of milk in a more water sustainable way, reducing its water footprint.

Authors' Contributions

Ankaj Thakur, Anshuman Kumar and Brij Vanita hypothesized the concept of this review paper. Ankaj Thakur, Anshuman Kumar, Brij Vanita, Girish Panchbhai prepared the manuscript. Ankaj Thakur, Narender Kumar, Anjali Kumari and Pardeep Kumar Dogra assisted in collecting and compiling the resource material and in manuscript preparation. All authors read and approved the final manuscript.

Conflict of Interest

The authors declare that they have no conflict of interest.

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