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Review Article

ASSESSMENT OF WATER FOOTPRINT AND ITS SIGNIFICANCE

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Abstract: Water is basis for life on this planet, determining the existence and survivability of every species. However, the availability and sustainability of this natural resource has been questionable since past few years. Any good involves utilization of water during its production process but is generally not assessed or quantified in terms of produce. Therefore, in recent years, the measurement of the water footprint (WFP) in food, agriculture and its related sectors has been recognised as a significant measure of sustainability. Hence this paper signifies the water foot print assessment in livestock and other related products which is essential for determining the water use for production of milk, meat and other products.

Keywords: *Water footprint (WFP), Existence and survivability, Livestock*

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Introduction

Water is the most essential component in every man's day to day life. In the present situation this has become a topic of research due to its scarcity or pollution concern. A significant topic of concern for sustainable growth is the global water shortage scenario, which involves a thorough evaluation of water footprints in all sectors of the economy. The estimated available fresh water is 10,217,120 km^3, of which 42,921 km^3 (0.4%) of freshwater is annually renewed [1]. The amount of earthly fresh water is immense and is renewed every year by a decent amount. However, only 9% of the sustainable freshwater supply is used by human activities [1]. The concern is not that people may run out of water, the real problem is that fresh water may not be always available wherever always required [2], and whenever its available then sustainability becomes doubtful.

The annual supply of per capita water was 5,177 cubic metres in 1951, but this decreased to 1,545 cubic metres in 2011, according to the international water stress threshold of 1,700 cubic metres. However, India's available per capita water supply was registered by the National Institute of Hydrology in 2010 at only 938 cubic metres, and this is predicted to drop to 814 cubic metres by 2025. In India, 395 billion cubic metres of groundwater is available and use of which has risen from 58% in 2004 to 66% in 2015. India's groundwater utilization is estimated to hit an alarming 75% in 2025, as stated by the Central Ground Water Board [3].

In the last five years, the National Pollution Management Board has doubled the number of 'polluted' waterways from 121 to 275. Therefore, in recent years, the measurement of the water footprint (WFP) in food, agriculture and its related sectors has been recognised as a significant measure of sustainability.

Water footprint

'Water' is an universal agent which is used to create everything we use, carry, purchase, sell and consume. Footprints demonstrate the pressure on the ecosystem from humans, not the effects. The water footprint (WFP) thus calculates the quantity of water used to manufacture each of the products and services we use. The water footprint of a considered entity means the consumptive water use (process, product, and nation). The use of consumptive water explains the evaporating groundwater that is introduced into a substance, polluted, or not returning to the same region where it was extracted [4]. It can be measured for a process, such as growing rice, producing a pair of jeans, for the fuel used in vehicles, or for a whole multi-national company. The water footprint can also tell us how much water is being consumed by a particular country from a specific aquifer.

Since Hoekstra proposed the 'water footprint' definition in 2002, the notion of considering the usage of water along supply chains gained attention [5]. The water footprint is a measure of the use of fresh water, and explores not just the actual use of water by the user or manufacturer, but also the indirect use of water.

The concept of ecological footprint is very much related to water footprint. As a result, both striking similarities and variations are seen in the approaches for quantifying both the measures. For example, two distinctions between ecological and water footprints are that ecological footprints are typically measured based on global average productivity, while water footprints are measured on the basis of local productivity. Water footprint projects are spatially explicit while ecological footprints are often not [6].

The water footprint of India is 980 cubic metres per capita, below the global average of 1.243 metres. Collectively, India's population accounts for 12% of the overall global water footprint [7].

Water Footprint Network, which promotes sustainability and efficiency of water use, demonstrated water footprint as a calculation of humanity's appropriation of fresh water through the amounts of water ingested or contaminated. Ruth Mathews, former Water Footprint Network Executive Director, confirmed that it's time not only for large corporations, many of which have already begun to measure their water footprints, but also for people to be aware of the consequences of their use.

Water footprint can be measured in cubic metres per tonne of production, per hectare of cropland, per unit of currency and in other functional units. The water footprint helps us to understand for what purposes our limited freshwater resources are being consumed and polluted. The impact it has depends on where the water is taken from and when. If it comes from a place where water is already scarce, the consequences can be grave and therefore needs immediate action.

The three components of water footprint: The distinction between green and blue water has been introduced by Falkenmark and Rockstrom (1993) [8]. The gray component has been introduced by Chapagain *et al*., (2006) [9].

Green water footprint is the water from precipitation that is stored in the root zone of the soil and evaporated, transpired, or incorporated by plants. It is particularly relevant for agricultural, horticultural and forestry products.

Blue water footprint is water that has been sourced from surface or groundwater resources and is either evaporated, incorporated into a product, or taken from one body of water and returned to another, or returned at a different time. Irrigated agriculture, industry and domestic water use can each have a blue water footprint.

Grey water footprint is the amount of fresh water required to assimilate pollutants to meet specific water quality standards. The grey water footprint considers point-source pollution discharged to a freshwater resource directly through a pipe or indirectly through runoff or leaching from the soil, impervious surfaces, or other diffuse sources.

Direct and/or indirect water footprint

The direct water footprint of a consumer or producer (or a group of consumers or producers) refers to the amount of freshwater consumed and the pollution made as a result of the consumer or producer's water use. It differs from the indirect water footprint, which refers to water consumption and pollution linked with the production of goods and services consumed by consumers or the inputs utilised by producers.

The common consensus is that both direct and indirect water footprints should be considered. While consumers and businesses have traditionally focused on direct water footprints, indirect water footprints are typically substantially bigger. Consumers would overlook the fact that most of their water footprint is related with the things they buy in the supermarket or elsewhere, not the water they consume at home, if they solely addressed their direct water footprint. Depending on the purpose of a particular study, however, one can of course decide to include only the direct or indirect water footprint in the analysis.

A country's entire 'water footprint' is a helpful indicator of its reliance on global water resources. The water footprint provides a more comprehensive view of how a consumer or producer interacts with freshwater systems [10]. It's a statistic for water use and pollution based on volume. It is not a gauge for the severity of local water use, pollution, and environmental impact. The local environmental impact of a certain amount of water consumption and pollution is determined by the local water system's susceptibility and the number of water consumers and polluters who utilise the same system.

The food habits of people have an impact on a country's water footprint. Meat consumption is associated with a substantial water footprint and meanwhile more food is produced from irrigated land contributing towards larger water footprint. Moreover, countries in hot climate zones consume a lot of water for domestic food production, resulting in a greater water footprint.

Comparison between water footprint of crop and animal products

The production of animal products accounts for over one-third of global agriculture's total water footprint [10]. The water footprint of meat from beef cattle (15400 m^3/tonne as a global average) is much larger than the footprints of meat from sheep (10400 m^3/tonne), pig (6000 m^3/tonne), goat (5500 m^3/tonne) or chicken (4300 m^3/tonne) [10]. The global average water footprint of chicken egg is 3300 m^3/tonne, while the water footprint of cow milk amounts to 1000 m^3 /tonne of product. Crop products have a less water footprint than animal products. The same is true when we look at the water footprint per calorie. Compared to crop products, livestock products contain 5 to 20 times more virtual water per kg [11,12]. When it comes to protein water necessities, it's been found that the water footprint per gram of protein for milk, eggs, and chicken meat is around 1.5 times that of pulses [10]. However, as an exception, butter has a relatively much lower water footprint per gram of fat, than oil crops and all other animal products have greater water footprints per gram of fat.

Global animal production requires about 2422 gm^3 of water per year (87.2% green, 6.2% blue, 6.6% grey water). The beef cattle division accounts for one-third of this volume, whereas the dairy cattle division accounts for 19%. Most of the total volume of water (98%) refers to the water footprint of the feed for the animals. Drinking water for the animals, service water and feed mixing water account only for 1.1%, 0.8% and 0.03%, respectively.

Water footprint assessment

Water footprint assessment is essential to quantify and locate the water footprint of a process, product, producer or consumer or to quantify in space and time the water footprint in a specified geographic area. This helps to determine the environmental, social, and economic sustainability of this water footprint and in turn plan response strategy to give attention to the global water crisis.

To be honest about the decisions taken when conducting water footprint assessment research, one must first clearly define the study's goals and scope. Data is collected and accounts are generated in the phase of water footprint accounting. The next phase is sustainability assessment, in which the water footprint is evaluated from an environmental perspective, as well as from a social and economic perspective. Response choices, tactics, or policies are developed in the final step. A product's water footprint is the sum of the water footprints of the process steps used to create it where in the whole production and supply chain is considered. A consumer's water footprint is the sum of the water footprints of all the things he or she consumes. A community's water footprint is equal to the total of its members' water footprints. Similarly, water footprint of a country's consumption is equal to the sum of its citizens' water footprints.

Water footprint of a product

The total amount of fresh water consumed, either directly or indirectly, in the production of a product is referred to as its water footprint. The term "virtual water content" can be used to refer to a product's water footprint. This term was first coined by Tony Allan in the early nineties. The "virtual-water content" of a product or its embedded, embodied, exogenous, or shadow water are analogous to the "water footprint" of that product [13].

The phrases "water footprint" pertains to not only the volume but also the type of water that was used (green, blue, or grey), as well as when and where the water was used, whereas the terms "virtual-water content" and "embedded water" refer simply to the water volume that is embodied in the product [14]. Thus, as opposed to "virtual-water content" or "embedded water," which only refers to volume, the water footprint of a product is a multidimensional indication. The water footprint is typically defined in units of m^3/ton or litres/kg for agricultural and associated products.

Calculation of a product water footprint

The method of figuring out a product's water footprint is based on the water footprints of the input items required for the processing step to create that product. Obtaining the water footprints of the input products and the water utilised to transform them into the output product is always the first step. The established worldwide water footprint standard has been used as the foundation for water footprint estimates [15]. The water footprint of farm animals and animal products has been calculated by Chapagain and Hoekstra (2003), and Chapagain and Hoekstra (2004) for each nation.

The Water Footprint of an Animal

Combining the feed conversion efficiency and the water footprint of the various feed ingredients based on Chapagain and Hoekstra (2003), and Chapagain and Hoekstra (2004), Mekonnen and Hoekstra (2012) estimated the water footprint of various animals and animal products per production systems and per country. Accordingly, the water footprint of a live animal consists of different components: the indirect water footprint of the feed and the direct water footprint related to the drinking water and service water consumed. The water footprint of an animal is expressed as

$$WF[a,c,s] = WF_{feed}[a,c,s] + WF_{drink}[a,c,s] + WF_{serv}[a,c,s]$$

Where, $WF_{feed}[a,c,s]$, $WF_{drink}[a,c,s]$ and $WF_{serv}[a,c,s]$ represent the water footprint of an animal for animal category 'a' in country 'c' in production systems 's' related to feed, drinking water and service-water consumption, respectively.

Service water refers to the water used to clean the farmyard, wash the animal, and carry out other services necessary to maintain the environment. The water footprint of an animal and its three components are expressed in terms of m^3/y/animal, or, when summed over the lifetime of the animal, in terms of m^3/animal.

The water footprint of pigs, sheep, goats, and broiler chickens, that provide products after slaughter is estimated at the end of its lifetime, because it is this total that will be allocated to the various products. For dairy cattle and layer chickens, the water footprint of the animal per year (averaged over its lifetime) is estimated, because one can easily relate this annual animal water footprint to its average annual production (milk, eggs). The water footprint of an animal related to the feed consumed consists of two parts: the water footprint of the various feed ingredients and the water that is used to mix the feed.

The water footprints of animal products differ significantly between nations and manufacturing methods, according to Chapagain and Hoekstra (2003). The type of production method has a significant impact on the size, makeup, and geographic distribution of an animal product's water footprint. As it determines the feed conversion efficiency, feed composition and origin of feed. It has been reported that the animal production in the dominated by the industrial production system has a smaller total water footprint than grazing and mixed systems. The overall water footprint per unit of product for all farm animal products, aside from dairy products, declines from the grazing system to the mixed production system, and then to the industrial production system.

The rationale is that feed conversion efficiency improves per unit of product when switching from grazing to industrial production methods. In comparison to industrial systems, grazing systems require about three to four times as much feed. When opposed to mixed production systems, the proportion of concentrate feed in the total feed is higher for industrial systems. Meanwhile, it is larger for mixed systems if compared to grazing systems. The water footprint of dairy products is lowest when produced in a mixed system and slightly higher but comparable when produced in a grazing or industrial system.

The water footprint of meat increases from chicken meat (4,300 m^3/ton), goat meat (5,500 m^3/ton), pig Meat (6,000 m^3/ton) and sheep meat (10,400 m^3/ton). The variances can be partially attributed to the animals' various feed conversion rates. The composition of the feed is another crucial element. Because concentrate feed typically has a bigger water footprint than roughages, the percentage of concentrate feed in the total meal is crucial. Poultry birds are efficient from a total feed conversion efficiency point of view, but have a large fraction of concentrates in their feed. From pasture to industrial production methods, the average global blue and grey water footprints of various livestock products rise, except for chicken products. Because the concentrate feed makes up a higher portion of the overall feed in industrial systems compared to grazing systems, items obtained from industrial production systems have larger blue and grey water footprints.

Water Footprint of Animal versus Crop Products per Unit of Nutritional Value

The water footprint increases from milk (1,000 m^3/ton) and egg (3,300 m^3/ton) to beef (15,400 m^3/ton) as reported by Mekonnen and Hoekstra (2011) [16]. Compared to cereals and starchy roots, beef has an average water footprint per calorie that is 20 times higher. Compared to pulses, it was reported that milk, eggs, and chicken meat have 1.5 times larger water footprint per gram of protein. For beef, the water footprint per gram of protein is 6 times larger than for pulses. Mekonnen and Hoekstra (2012); Gupta (2008) has reported that the total water footprint of world is 7,452 Gm^3/year and India is 987.38 Gm^3/year out of which a major share (948.99 Gm^3/year) is used to produce crops and crop products only. Water Footprint of agricultural sector is 92% of the total water print of humanity. Sekyeree *et al*., (2016) [17] in their study observed that 1352 m^3 of water is required to produce one tonne of milk with 4% fat and 3.3% protein in South Africa. Further they also reported that the green water forms the largest component of the total water footprint of milk production from cattle, as it accounts for about 87.65% of the total water footprint. The water footprint of feed ration for lactating cows is about 85% higher than that of non-lactating cows (bulls, dry cows, and heifers). Boguniewicz-Zablocka *et al*., (2019) [18] reported that 1-10 m^3 of water is required for production of 1 m^3 of milk.

Krauss *et al.,* (2016) [19] reported more water usage for cleaning purpose (34 L/cow/day) in conventional herringbone milking parlor (HBP) than automatic milking system (AMS; 29 L/cow/day). Lesser quantity of water usage for cleaning purpose under AMS was also reported by Drastig *et al.,* (2010) [20]. Wankhade *et al.,* (2021) [21] reported that the CWUs per kg of milk production was more in hand milked cows (4.26±0.09 L/kg milk) than machine milked cows (4.06±0.13 L/kg milk).

Conclusion

After a small study based on few articles pertaining to WFP of livestock and related products the following conclusions could be summarized. As the farming system becomes more intensive, the WFP of livestock products declines. Also, it was studied that the WF of meat is higher than that of either milk or eggs. The varied feed conversion ratios can be used to explain the WF variance between various animal products.

Ruminants (cattle, sheep, and goat) have a poor feed conversion ratio compared with monogastric animals (poultry and swine). Farmers and other stakeholders will be able to identify the most water-intensive activities and put plans into place to increase water-use efficiency by estimating the WF of livestock production and conducting economic analyses of water consumption at different stages of production. The main contributor to the WF of livestock production was thus determined to be feed production. Use of low-WF feeds, more efficient irrigation of crops used as livestock feed, and decreased use of animal-sourced protein in human diets through the substitution of plant proteins are all possibilities to lower the WF of livestock production.

Application of research: This study can modify the use of water in various productions, avoiding the wastage and reducing the cost. It throws light on how much water is wasted rather than wisely utilized in agriculture and allied sector.

Research Category: Water footprint

Abbreviations: AMS-Automatic Milking System
CWU-Crop Water Use
Gm^3-billion cubic meters
HBP-Herring Milking Parlour
Km^3-KiloMeterCube
WF-water foot print
WFP-water foot print

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