Review Article

Waterfootprint- A distinct vision for water security

ABSTRACT

Due to population growth and decreasing freshwater resources, many countries may face a decline in their ability to be self-sufficient in food production. The issue of freshwater contamination and scarcity needs to be addressed globally because a sizeable majority of the world's population lives in areas where water scarcity occurs for at least one month every year. The world economy plays a role in localized water contamination and depletion, especially as water is increasingly used for exporting goods. The idea of water footprints is a practical way to gauge how much water is needed to produce goods and services and to promote sustainability in industrial and food production.The use of water for various reasons can result in the appropriation of valuable data that can be used to examine the environmental, social, and economic effects and advance conversations about fair and sustainable water use. The idea of a water footprint ultimately aims to encourage wise and effective water use.

Key words: Waterfootprint, Water Scarcity, Agriculture, Sustainability

Introduction

Water scarcity is a major problem for food production, brought on by a combination of factors including population growth, increased demand for agricultural products, and changing consumer preferences. This has led to a significant competition for freshwater resources that has intensified over the years (Davis et al 2017). Roughly 3.2 billion people, or about one-sixth of the world's population, reside in agricultural areas that have significant water scarcities or shortages. More than 2 billion people reside in water-stressed nations, and predictions indicate that by 2040, 600 million children under the age of 18 would reside in countries with the highest levels of water stress (FAO 2020; UN 2018). By 2040, it is predicted that 600 million children under the age of 18 will live in areas with extremely severe water stress (UNICEF, 2017). By 2030, severe water shortages may force 700 million people from their homes globally (Global Water Institute, 2013).A third of the largest groundwater systems on Earth are already having issues, and almost two-thirds of the world's population, or nearly 4 billion people, endure acute water scarcity for at least one month out of the year (Mekonnen and Hoekstra, 2016, Richey et al 2015). Between 4.8 and 5.7 billion people may be residing in areas that may experience water shortages by the year 2050(Burek et al 2016).

Thus, it is common to assume that a water crisis only pertains to water, but it is just the beginning, as water is also essential for a healthy future. The situation in Punjab is also concerning, as the state's grain-producing region is facing a major disaster, with 82% of its land area experiencing a significant decline in underground water levels, and 109 out of 138 administrative blocks being classified as overexploited. The surprising fact is that water has been present on Earth since its inception and is a fixed quantity that moves continually through the hydrological cycle. Although there are plenty of people on the planet, freshwater is not distributed equally and is being used up faster than the hydrological cycle can restore it. Making sure there is a sufficient supply of water that is the proper kind, quantity, and place at the right time is difficult.

Water footprint

It is critical to comprehend how much water we consume and for what purposes if our actions are the primary cause of water scarcity. The idea of a "water footprint" has been established with the intention of making invisible water usage apparent in order to make this understanding more concrete. The concept of "Virtual Water of Product," first presented by Prof. Tony Allan, is the foundation for water footprint. This idea aids in calculating the amount of water needed to make a specific product by taking into account the total water utilised during a product's complete production process, including its creation, distribution, and consumption.This strategy draws attention to the substantial amount of water consumed for food production in addition to routine tasks like drinking, cooking, washing, and dressing(Allan 2003).

Hoekstra and Hung first suggested the idea of a "water footprint" in 2002, and Chapagain and Hoekstra expanded on it in 2004. This idea seeks to increase awareness of the effects that human activity has on the world's water resources. The ultimate goal is to ensure that everyone has access to clean water, which can support local economies and encourage biodiversity. Collaboration between individuals and groups from all around the world, outside the purview of the Water Footprint Network, will be necessary to accomplish this goal. In order to achieve the objective of responsible and sustainable water usage, the Water Footprint approach has a unique contribution to make (Anonymous 2020).Assessments of water footprints provide accurate information on how water is used and distributed for diverse human uses in varied contexts and throughout time. These can be useful in conversations about fair and sustainable water usage and provide a solid foundation for assessing the effects of water consumption on the local environment, community, and economy (Hoekstra et al 2011).

Concept of water footprint

The water footprint is a measurement of freshwater use that accounts for producers' and consumers' direct and indirect water use. Compared to the conventional measure of water withdrawal, it offers a more thorough insight of the utilisation of freshwater resources. The total amount of freshwater utilised throughout a product's manufacture along the whole supply chain is known as its water footprint. It contains details on the place and time that water is used as well as the kinds of pollutants that are present in the water. The water footprint serves as a multidimensional indicator that displays the amounts of water used from various sources as well as the forms of pollution that have an impact on the water (Hoekstra et al 2011).Take the example of pig farming. The industrial method of raising pigs takes 10 months before the animal is ready for slaughter, as shown in Figure 1. The pig is fed grains during this time, and grains require a lot of water to grow. The water is used by the pigs not only for drinking, but also for other tasks like keeping the farm clean, rearing young pigs, and butchering the animals.

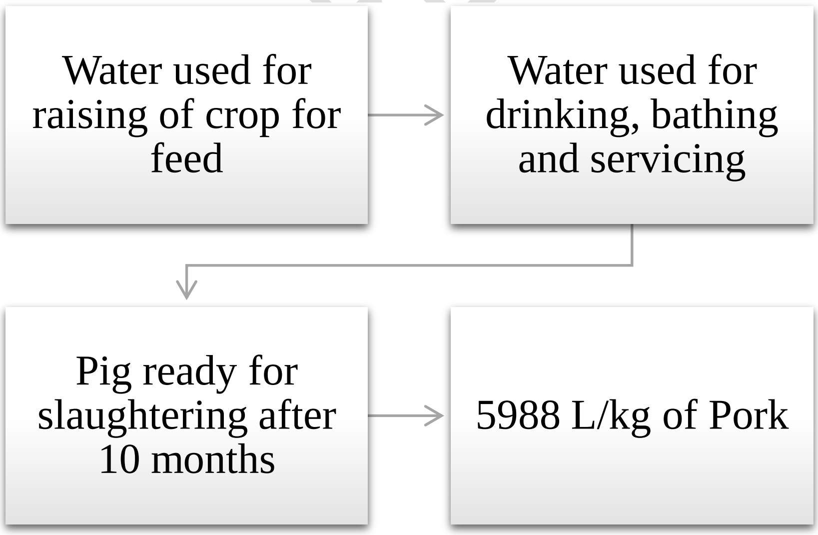


Fig 1: Water footprint of Pork

Components of water footprint

Blue, green, and grey water footprints are the three parts that make up the water footprint. The term "blue water footprint" describes how much surface and groundwater is used in a product's manufacture, with consumption resulting in water loss from the body of accessible ground-surface water. The quantity of rainwater used in the production process that does not end up in runoff is known as the green water footprint. The grey water footprint, on the other hand, relates to the amount of freshwater needed to remove the contaminants from the load, taking into account the current standards for ambient water quality and background concentrations Hoekstra and Chapagain(2008).

What's new about the water footprint?

The water footprint is a measurement that takes into account both direct and indirect water use, as well as the more modern "water withdrawal" measurement. As a result, it provides a more precise and thorough indicator of how a consumer or producer engages with freshwater systems. Instead of evaluating the severity of effects on the local ecology, it concentrates on volumetric measurements of water use and pollution. The local water system's susceptibility, as well as the quantity of water consumers and polluters, determine the local environmental effects of water usage and pollution.

Water footprint assessment

Table 1, as presented in Hoekstra et al. (2011), shows the relationship among different categories of water footprints

Water footprint of commodities

The Water Footprint Network has done an impressive job in determining the water footprint of numerous products. Some of these products are shown in Figure 2 and listed in Table 2.

Water footprint of nation

The total amount of water needed to generate the commodities and services that its residents use is referred to as a country's "water footprint." Internal water footprint and exterior water footprint make up this water footprint. The amount of water utilised within the nation to create goods and services that are consumed by its residents is represented by the internal water footprint. The quantity of water resources utilised in other nations to generate goods and services that are imported and consumed by the nation is represented by the external water footprint, on the other hand.

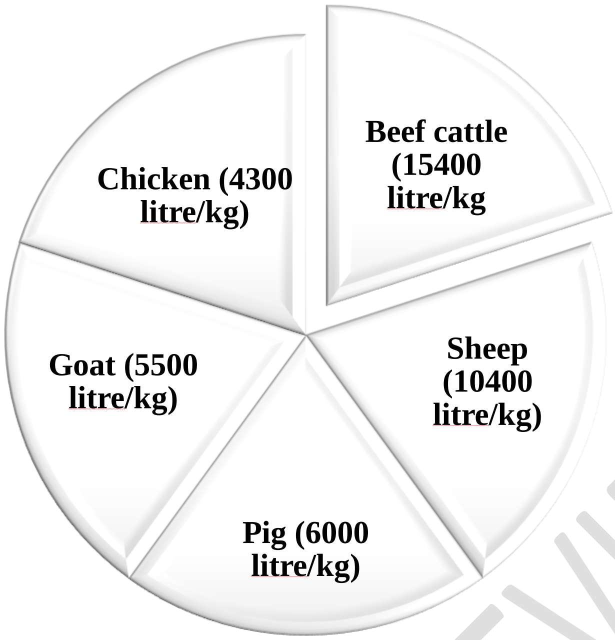


Fig 2: Water footprint of variousmeats

National water footprint =National water use + Virtual water import-Virtual water export

To find water footprint of any nation visit this link *https://www.waterfootprintassessmenttool.org/national-explorer/*

Calculation of water footprint of crop

Crop production generated a global water footprint of 7404 billion cubic metres per year between 1996 and 2005, with a green water footprint of 78%, a blue water footprint of 12%, and a grey water footprint of 10%. The three crops with the biggest overall water footprints were wheat, rice, and maize (1087 Gm^3 yr^{-1}, 992 Gm^3 yr^{-1}, and 770 Gm^3 yr^{-1}, respectively) (Mekonnen and Hoekstra2011). Wheat and rice have the largest combined blue water footprint of all crops, accounting for 45% of the global blue water footprint related to agricultural production. The three nations with the largest total water footprint for agricultural production are India, China, and the United States, with India having the highest total at 1047 Gm^3 per year. Due to grain production, the Indus and Ganges river basins have a combined 25% impact on the global blue water footprint. The worldwide water footprint of rice, a crop with a high water requirement, is 992 Gm^3 yr^{-1} (Bhatt et al 2020a).In order to improve water productivity and encourage sustainable agriculture in water-scarce locations, scientists in the area are attempting to reduce their water footprint, according to study done in 2011 by Mekonnen and Hoekstra. The average amount of water required to produce 1 kg of grains is 3000–4000 litres (McKinsey 2009; Bhatt et al. (2019); Bhatt et al. (2020b)). The sum of the green, blue, and grey water footprints is the total water footprint of the cultivation of a crop or tree (WFproc).

$WF_{proc} = WF_{proc,green} + WF_{proc,blue} + WF_{proc,grey}$ [volume/mass]

CWUgreen and CWUblue are divided by crop yield to calculate the green and blue parts of the process water footprint of growing a crop or tree. The yields of annual crops can be calculated using yield statistics. The grey component is determined by multiplying the chemical application rate per hectare to the field by the leaching-runoff proportion, dividing this by the gap between the maximum allowable concentration and the pollutant's natural concentration, and finally multiplying by the crop yield. Pesticides, insecticides, and fertilisers are examples of the contaminants. By adding up the daily evapotranspiration over the full growing season, CWUgreen and CWUblue are computed.

In this context, ETgreen and ETblue refer to the evapotranspiration of green and blue water, respectively. Water depths in millimetres are converted to water volumes per acre using a ratio of 10. Day 1 of planting through Day 1 of harvest is used to calculate the total (lgp represents the length of the growing period in days). The "blue" crop water use represents the total amount of irrigation water that evaporates from the field, whereas the "green" crop water use represents the total amount of rainwater that evaporates from the field during the growing season. A model based on empirical formulas can be used to calculate or estimate evapotranspiration from a field.Generally, indirect estimation of evapotranspiration is done by running a model using inputs of climate, soil, and crop variables. The modelling of crop growth and evapotranspiration can be done in a variety of ways. For this reason, the EPIC model, which is available in grid-based form, is frequently employed. Williams et al. (1989) first presented it, while Williams et al. (1993) later improved it (1995). The model was also created using a grid by Liu et al. (2007).

$$WF_{proc} = WF_{proc\text{-}green} + WF_{proc\text{-}blue} + WF_{proc\text{-}grey}$$

$$WF_{proc\text{-}green} = \frac{CWU\ green}{Y}$$

$$WF_{proc\text{-}blue} = \frac{CWU\ blue}{Y}$$

$$WF_{proc\text{-}grey} = \frac{(x\ X\ AR)/\ (Cmax - Cnat)}{Y}$$

$$CWU_{green} = 10\ X \sum_{d=1}^{lgp} ETgreen$$

$$CWU_{blue} = 10\ X \sum_{d=1}^{lgp} ETblue$$

Where, WF_{proc} (vol/mass, m^3/ton) = Water footprint of the process
CWU (vol/area, m^3/ha) = Crop water use

Y (ton/ha) = Yield of the crop
X = Leaching fraction
AR (kg/ha) = Chemical application rate
Cmax (kg/m^3) = Maximum acceptable concentration in water
Cnat (kg/m^3) = Natural concentration in water
ET (mm/day) = Evapotranspiration
lgp (days) = Length of growing period

Assessment of water footprint for various crops was done for different states of India by Suhail (2017) as shown in Fig 3 to Fig 8.

Reducing the water footprint of crop production through technology and practices

Use of Tensiometers

Tensiometers were recommended by Bhatt (2020) as a means of reducing the water footprint of rice. Rice uses more water than cereals in Punjab, 992 billion m3y-1. In the northwestern Indian Punjab, additional water worth US$39 million is removed each year to feed crops, mainly rice. Tensiometer can be used to apply irrigation water sparingly as it reduces water footprint by 18 to 22%.

Direct seeded rice (DSR)

Transplanted rice had a 41% blue water footprint and a 34% green water footprint, per Chakrabarti et al. (2014). Yet, the green water footprint rose to 53% and the blue water footprint fell to 27% when rice was directly sown. The crop used more rainwater, which was already present in the soil as soil moisture, leading to an increase in the green water footprint for direct seeded rice. As a result, irrigation water's share of the overall water footprint dropped to 27%. Also, as less irrigation water was used, less nitrogen was leached, and the grey water footprint of direct-seeded rice was lower (20%) than that of transplanted rice (25%).

Cropping pattern

Chouchane et al. (2020) identified the nation with the worst water scarcity and adjusted the worldwide crop pattern using the MATLAB linear-optimization technique. The goal was to minimise the most water-scarce countries while reducing and balancing blue water scarcity in the most water-scarce countries. 125 crops from main categories such cereals, fibres, fruits, nuts, oil crops, pulses, roots, spices, stimulants, sugar crops, and vegetables were included in the study. A global blue water savings of 17 1010 m3 yr1 (equal to 21% of the existing global blue water footprint) was made possible by allowing a maximum 10% expansion in harvested area per crop and per country while avoiding an increase in the total amount of rainfed or irrigated crop land per country. As a result, blue water scarcity decreased to 39% or less in the seven countries with the highest national water scarcity, including Libya and Saudi Arabia.

Mulching and drip irrigation

According to Nouri et al. (2019), adopting drip irrigation and mulching techniques decreased the Upper Litani Basin's blue water footprint by 5%. (ULB). The best method for minimising the water footprint of crops was found to be the combination of mulching and drip irrigation. Drip irrigation using a residue retention system significantly increased grain yields for maize and wheat by 13.7% and 23.1%, respectively, as compared to furrow irrigation with no residue, according to Sandhu et al (2019)'s study. When compared to conventional furrow irrigation systems with residue removal, surface drip irrigation with residue retention increased water production in wheat and maize cultivated on permanent beds by 66% and 259%, respectively.Additionally, fertigation with five splits in wheat and seven splits in maize at intervals of 10 days under a drip irrigation system increased the mean N recovery efficiency in wheat and maize by 16.5% and 29%, respectively, over furrow irrigation.

Planting mehod

According to Brar et al. (2019), drip irrigation of beds and ridges boosted tuber yields by 34.9% and 26.4%, respectively, while using 23.3 and 53.3 millimetres less irrigation water. When compared to crops that were watered with furrows, the seasonal transpiration of the crops planted in drip-irrigated beds and ridges was greater by 31.0% and 31.7%, respectively. Crops that were drip-irrigated had higher perceived and actual water productivity than those that were furrow-irrigated. Kaur and Brar (2016) discovered that straw mulch increased the crop's apparent water productivity and cured rhizome production in their investigation on the effects of mulch on turmeric irrigation, yield, and water productivity.

Impact of anti-transpirants

In a study on soybean production and rainfall use efficiency, Sanbagavalli et al. (2016) found that applying potassium nitrate at a concentration of 1% as an anti-transpirant increased both soybean yield and rainfall use efficiency.

Water saving by trade

Several nations are able to preserve their local water supply by importing commodities that use a lot of water and exporting goods that use little water. A national water saving through the import of a good can imply water conservation on a worldwide scale if the movement is from areas with relatively high water productivity (i.e., commodities with a small water footprint) to areas with low water production (commodities with a large water footprint). The importing countries would have required 2407 billion cubic metres of water annually if all agricultural imports had been produced domestically. But, only 2038 billion cubic metres of water are required annually in the exporting countries to produce these items, saving 369 billion cubic metres.This decrease accounts for 4% of the global water footprint of agricultural production (which is 8363 billion cubic metres per year). In countries with limited water supplies, national policy makers are probably more interested in domestic water savings than global water savings (Mekonnen and Hoekstra 2011).

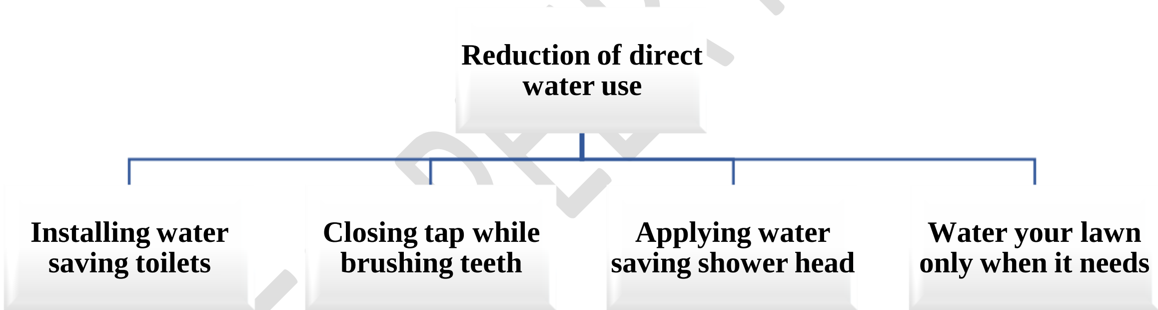
According to Zhuo et al. (2019), the environmental cost of producing pork is transferred to the North by producing feed maize in the North and importing it to the South for consumption. While boosting feed and hog production in the North would increase local income in line with government goals, it might also make the area's water shortage worse.

Personal water footprint

To calculate your personal water footprint, you have to visit *www.waterfootprintnetwork.org*and click over personal water footprint calculator.

How to reduce your water footprint?

Reduction of direct water use:



Reduction of indirect water use:

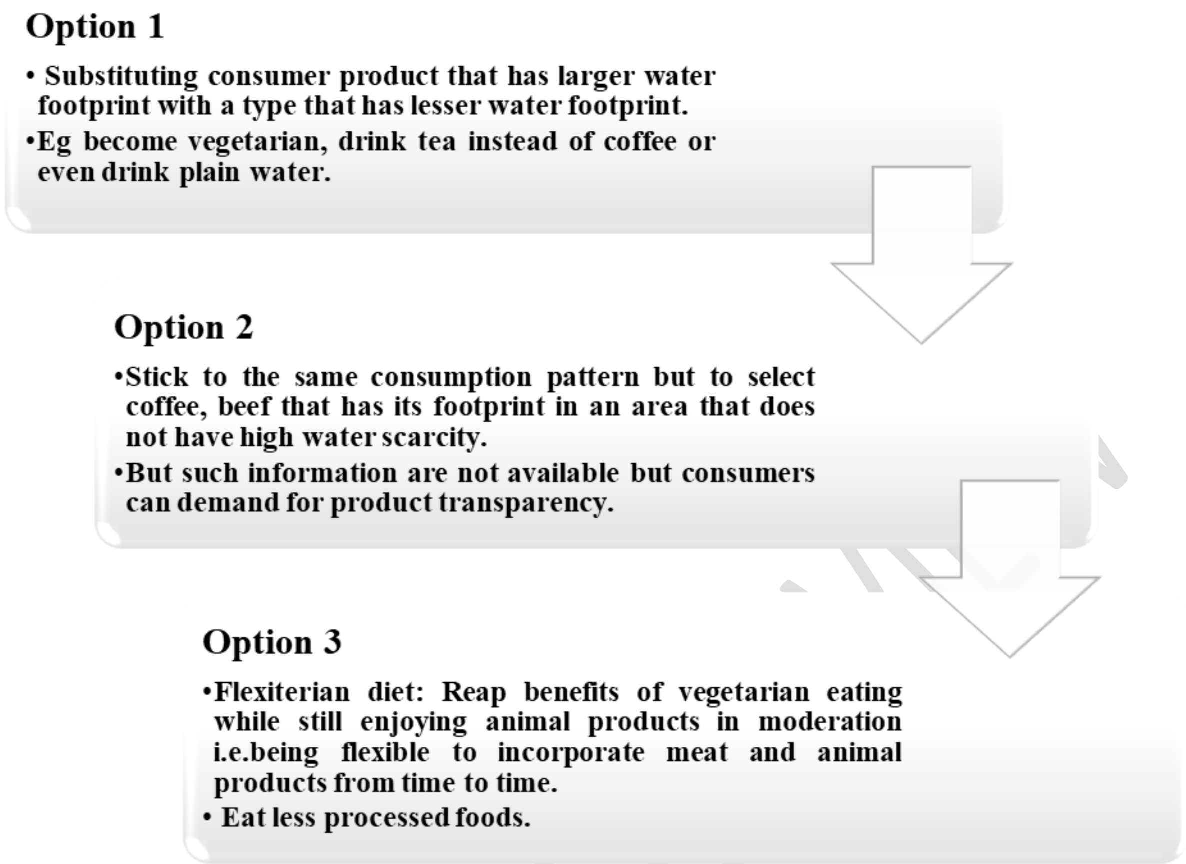


Fig 9: Reduction of personal water footprint

When is my water footprint environmentally sound?

Consumer's water footprint can be deemed sustainable if it does not go above his fair share of the world's freshwater resources and does not contribute to violating environmental flow standards in specific locations or at specific times..

What actions can businesses take to lessen their water footprint?

By using less water and taking precautions to prevent water contamination, businesses can reduce their operational water footprint. Reduce, recycle, and treat water before disposal are the three main strategies. Yet, the majority of a company's water footprint comes from their supply chain, which can be more challenging to manage.To address this, companies can establish supply agreements with their suppliers that meet specific requirements, switch to a different supplier, set measurable goals for reducing water footprint, benchmark their progress, label products with water footprint information, obtain certification, and report their water footprint. Hoekstra provides suggestions for tools to help businesses and governments manage water resources effectively in his recent work, "The Water Footprint of Modern Consumer Society."

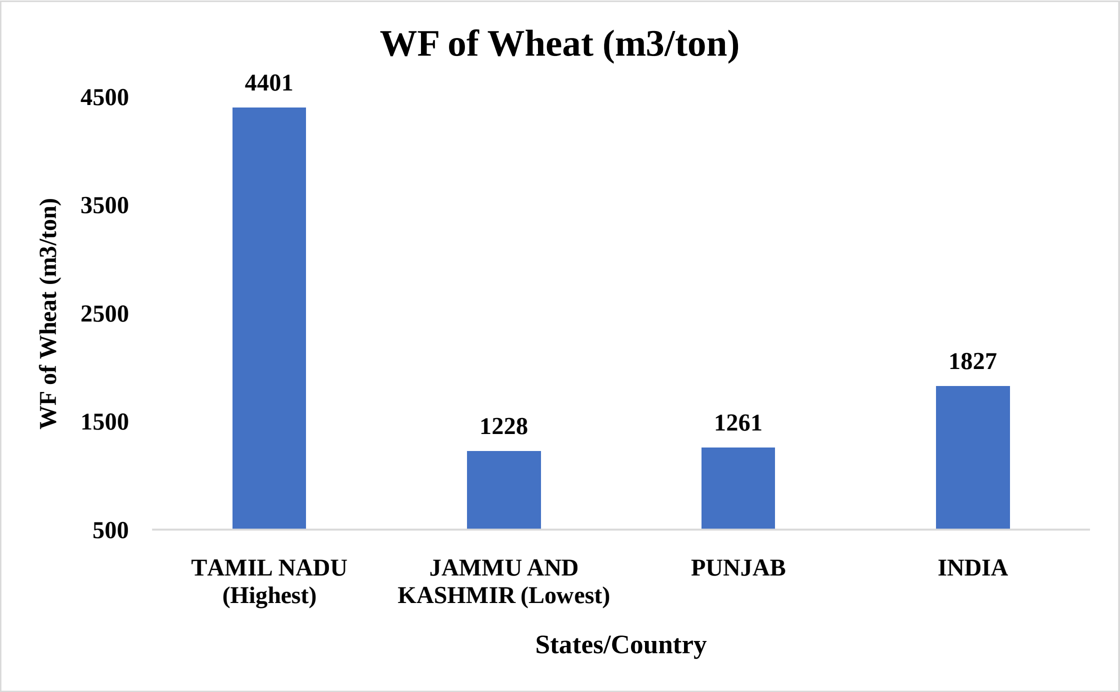


Fig 3: Water footprint of wheat

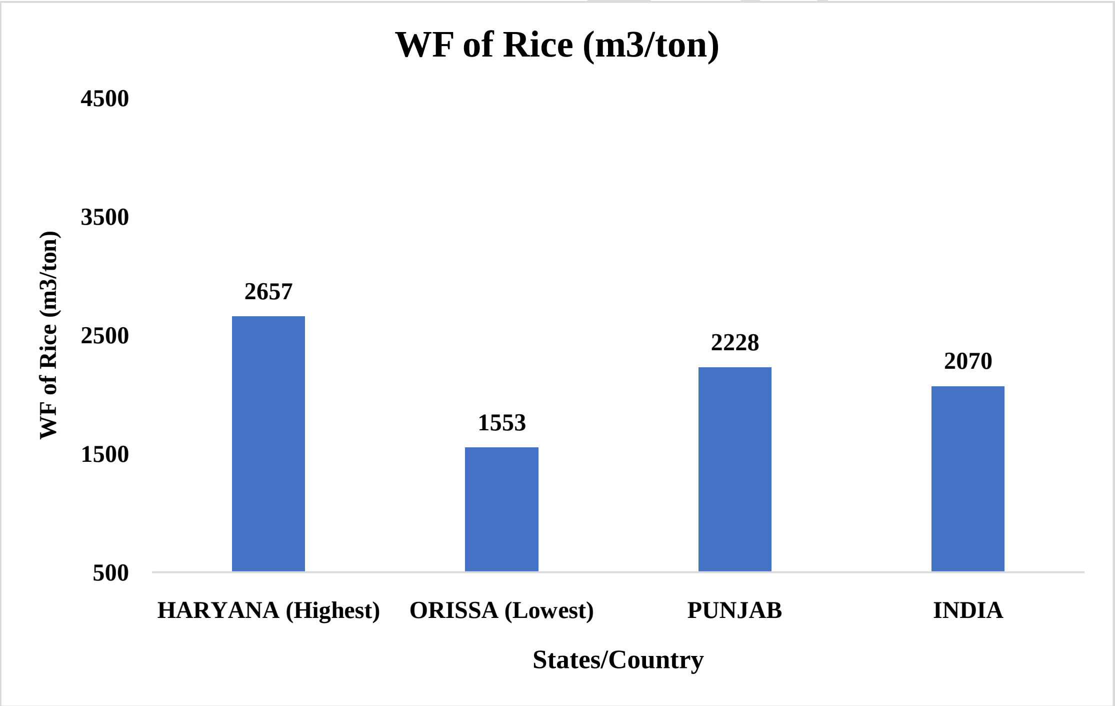


Fig 4: Water footprint of rice

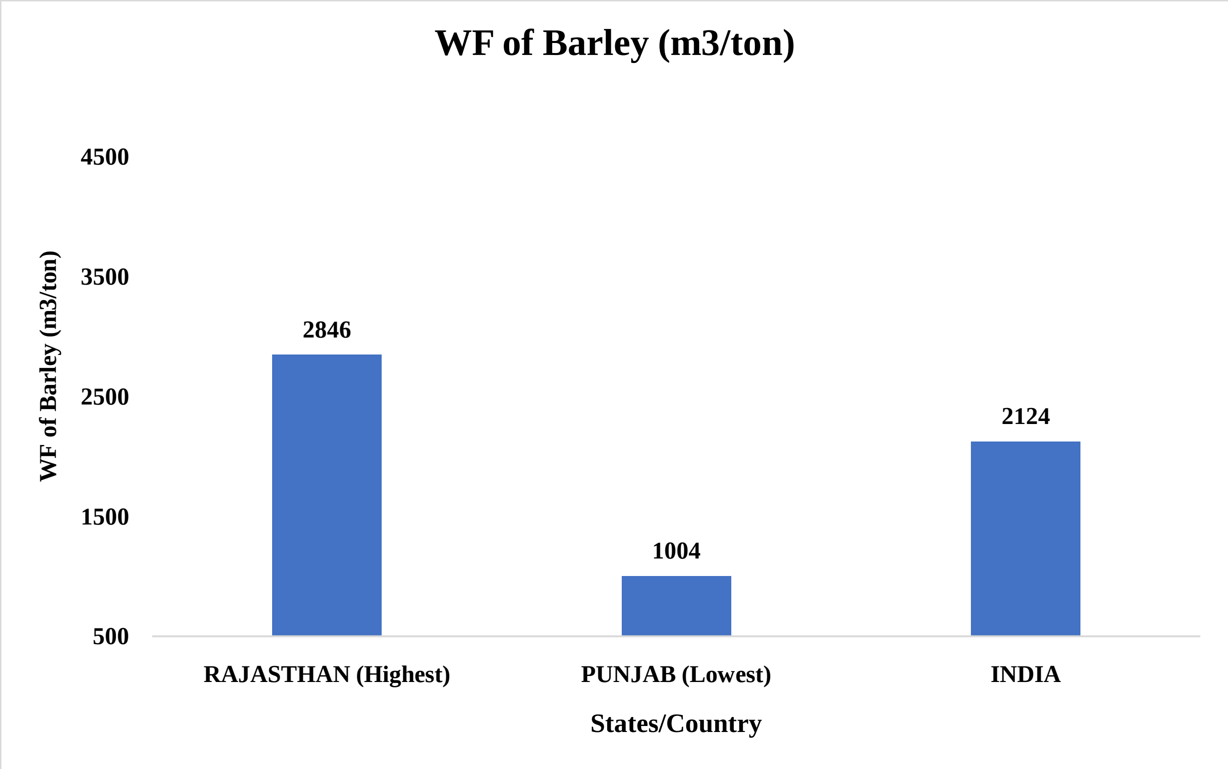


Fig 5: Water footprint of barley

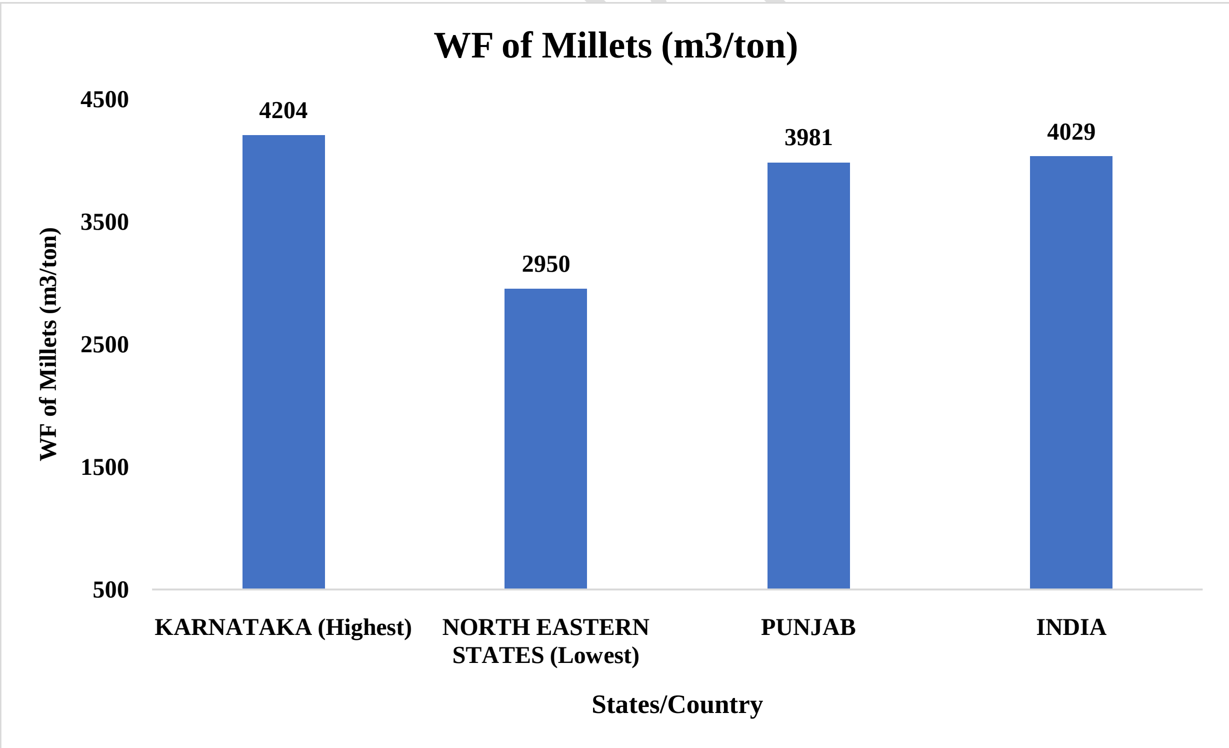


Fig 6: Water footprint of millets

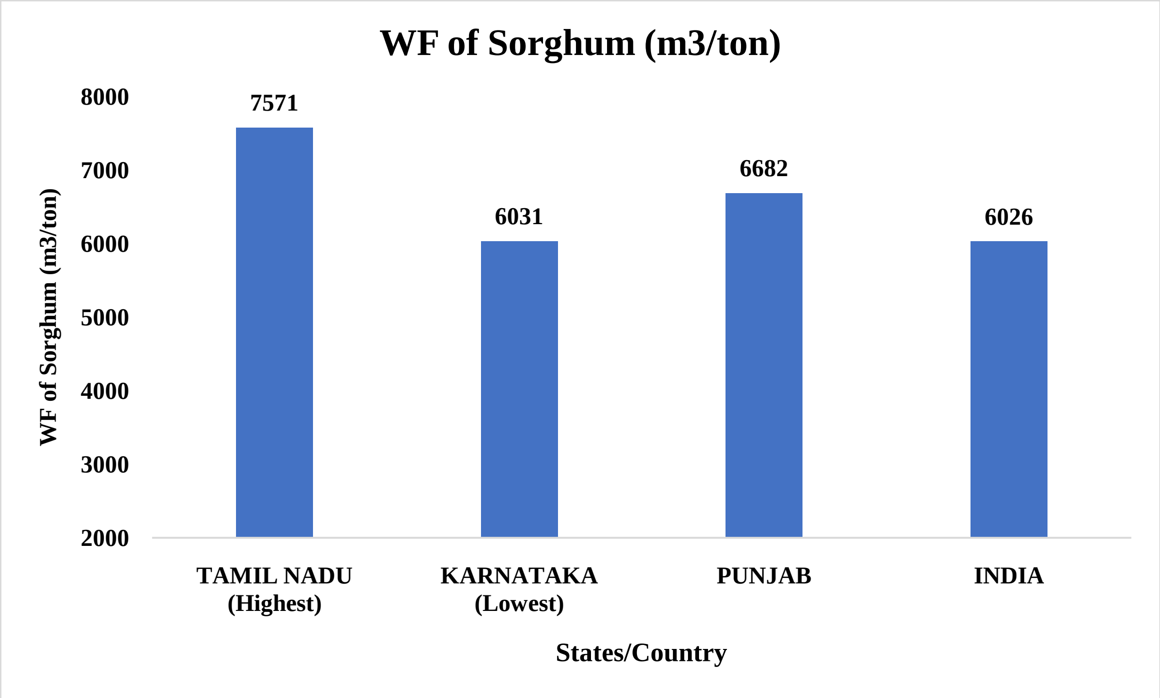


Fig 7: Water footprint of Sorghum

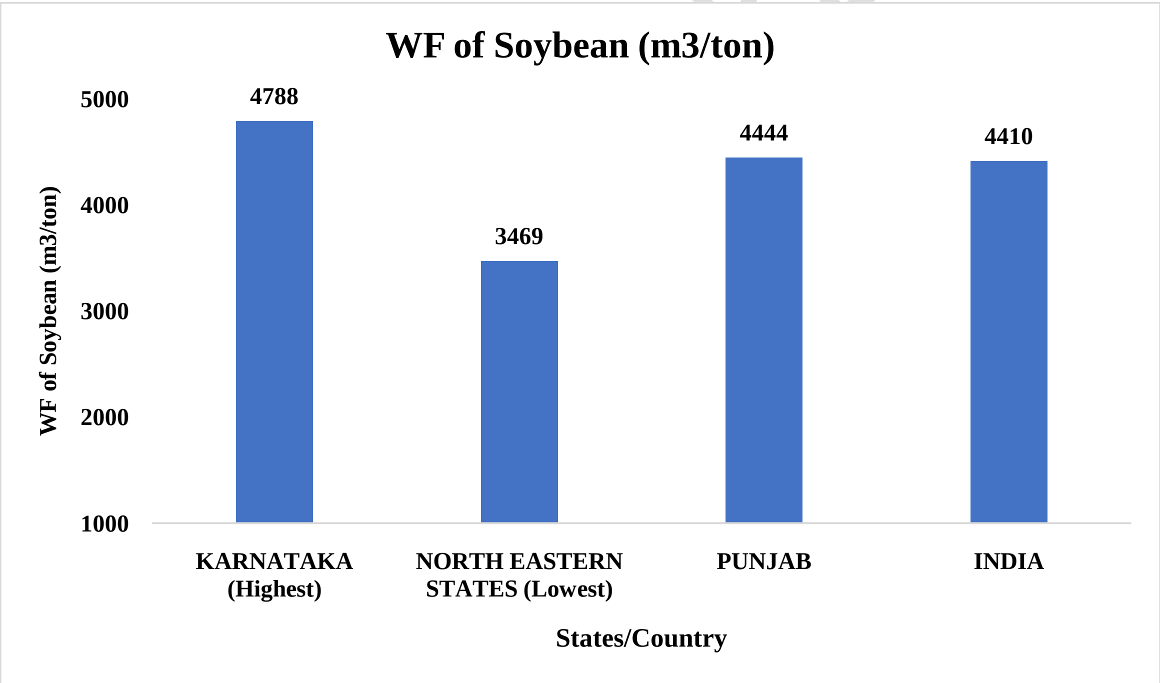


Fig 8: Water footprint of Soybean

Conclusions

The water footprint is an indicator of the escalating water stress caused by the rising population pressure and is not a solution in itself. Although industrialization amplifies a nation's water footprint, agriculture accounts for the majority of it. The water footprint and water productivity have an inverse relationship; therefore, increasing water productivity can decrease the water footprint. The use of tensiometers, drip irrigation, and deficit irrigation can help to minimize the water footprint in agriculture.

Table 1: Relationship between different sorts of water footprint

Categories	Formula
Water footprint of a product	This refers to the total amount of water used throughout the entire process of producing a product, including all steps involved in the production and supply chain.
Water footprint of a consumer	This refers to the total amount of water used to produce all the products that a consumer has consumed.
Water footprint of a community	This refers to the total amount of water used by all the members of a group or organization, when considering the water footprints of each individual member.
Water footprint of national consumption	This refers to the total amount of water used by all the people living in a certain place, when considering the water footprints of each individual.
Water footprint of a business	This refers to the total amount of water used to produce the final products of a business, when considering the water footprints of each product.
Geographically defined area's water footprint (for example, a municipality, province, state, nation, catchment or river basin)	This refers to the total amount of water used in all the processes that are taking place in a certain area, when considering the process water footprints of each individual process.

Table 2: Water footprints of different products

Product	Global average WF	Blue WF (%)	Green WF (%)	Grey WF (%)
Pork	5988 L/kg	8	82	10
Beef cattle	15400 litre/kg	4	94	3
Sheep	10400 litre/kg	5	94	1
Goat	5500 litre/kg	6	94	0
Chicken	4300 litre/kg	7	82	11
Egg	196 L/ 60g	7	79	13
Milk	255 L/L	8	85	7
Leather	17093 L/kg	4	93	13
Sugar from	1782 L/kg	27	66	6

Sugarcane				
Sugar from Sugarbeet	920 L/kg	19	62	19
Coffee	264 L for 250 mL	1	96	3
Tea	27 L for 250 mL	10	82	8
Bio-ethanol from Sugarcane	2107 L/ litre	27	66	6
Bio-ethanol from Soybean	11397 L/ litre bio-ethanol	3	95	2
Bio-ethanol from Maize	2854 L/ litre bio-ethanol	7	77	16
Bio-ethanol from Sugarbeet	1188 L/ litre bio-ethanol	19	62	19
Beer (Barley)	74 L for glass of 250 mL	6	85	9
Wine (Grapes)	218 L for 250 mL glass	16	70	14
Shirt	2495 L for 250g shirt	33	54	13
Pizza	1259 L/725 g	14	76	10

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