An Introduction to Water Footprints for Millers**

N Ravi Menon*

INTRODUCTION

This article was extracted from a dialogue session between the public and Ruth Mathews and Arjen Y Hoekstra that appeared in the Wikipedia and summarised to disseminate the important message it contains to the millers. The views expressed in this article are mainly from Ruth Mathews, Executive Director and Arjen Y Hoekstra, Scientific Director of Water Footprint Network (WFN). As the original report is very lengthy, thus only selected sections were extracted for this article.

The millers may have to contribute what they can to implement some of the suggestions given in this article. All of us are aware of the fact that many countries are facing water shortage but no one would have thought that Malaysia also would be one of them. People in Selangor faced the worst water shortage quite recently and that should not have happened in a country blessed with abundant rain water that recently caused the worst floods in the east coast, making thousands of people homeless.

The editor of this *Bulletin* together with other Code of Practice (CoP) auditors were also caught in the midst of a highway that formed an island near Kuantan with all exits cut off by floods for nearly 10 hr. Fortunately there was a restaurant within the isolated island where we sought refuge. All these incidents may point towards a possible human negligence in the proper management of our natural resources. Nature can react with a violent fury at one time but can become calm and soothing at another time. This article gives an insight into the many aspects of water usage and recommends a sensible approach on how to manage water on a global level as it cannot be treated only on a national level because of the international trade of products that give rise to migration of water footprints (WF).

Palm oil millers may find this article useful as they also directly deal with the palm oil mill effluent discharge and pollute the water courses which when not pol-

* *Malaysian Palm Oil Board,*
6 Persiaran Institusi, Bandar Baru Bangi,
43000 Kajang, Selangor, Malaysia.
E-mail: nravi@mpob.gov.my

*Note: ** Compiled and condensed from Water Footprint Network.*

luted are categorised as blue WF but millers can turn them into grey WF. When the mills take in water from the river they are consuming blue WF but if they take in rain water they are consuming green WF. This article was compiled for those mill engineers who have no time to read related material in the website. The palm oil mill engineers would have been hearing a lot about WF as this term appears to be increasingly getting into the limelight these days in an arena that was until recently dominated by the greenhouse gases (GHG) and the carbon footprints. WF are also expected to influence the marketability of palm oil as a factor while the plantation will be dealing with all the three – green, blue and grey WF.

THE CONCEPT OF WATER FOOTPRINTS

The WF concept was introduced in 2002 by Arjen Y Hoekstra from UNESCO-IHE as an alternative indicator of water use. The concept was refined and accounting methods were established with a series of publications from two lead authors, A K Chapagain and A Y Hoekstra from the UNESCO-IHE Institute for Water Education, now at WWF-UK and University of Twente in the Netherlands respectively. In this article, the Global WF Standard developed by the Water Footprint Network was used.

The WF for any nation is defined as the total amount of fresh water that it used to produce the goods and services consumed by the people of that nation. The WF of national consumption can be assessed in two ways.

- The bottom-up approach is to consider the sum of all products consumed multiplied by their respective product WF.

- In the top-down approach, the WF of national consumption is calculated as the total use of domestic water resources plus the gross virtual water import minus the gross virtual water export.

The table in the datasheet section is not a complete list to account for all the items we consume but the full list is available at the website. The definition appears to be reasonable. Since we export a large volume of palm products, our net WF as a nation will diminish to a great extent as only what we consume is debited to our WF account. If a poor country has no exports coupled with low agricultural yield, its WF is bound to be excessively high. High yield through good fertiliser application and agricultural practices coupled with generous export appear to be a good formula for a well-regulated WF which unfortunately does not come within the ambit of many poor nations. But if it does the WF also could rise to negate the gain.

IMPACT ON PALM OIL MILLS

Fortunately, WF of palm oil at 4971 is reasonable when compared to soyabean at 4190, and groundnut oil, sunflower oil and rapeseed oil at 7529, 6792 and 4301 respectively among some of the edible oils. Palm oil will not be standing alone if there is a battle to fight against any attempt to disqualify it under the WF issue if any. As the plantation industry in the near future will be required to spend a lot of their energy and time on reducing their WF, this article would be of help for the millers to contribute their share of reducing the WF so that eventually wastage of water can be reduced from what it is today although it may not have much impact on the WF of palm oil as a whole. Remember water, air and GHG share global concerns.

Many of us may think that by controlling the water used for taking a shower, watering the lawn or washing the cars will reduce WF of a nation while millers with their massive floor washing exercise on non-processing days would think of curtailing that activity to reduce their mill's WF. The answer is none of these activities would produce any significant solution for cutting down the WF of palm oil. The action front

is not the palm oil mill but the plantation that supports the palms. But as most of our palm oil is exported, our national WF will remain low. The mill may contribute to less than 10% of the water consumed compared to what the estate is contributing. The estate and mill consumptions are mainly from the groundwater that falls under blue WF.

WF COMPUTATION METHOD

Now let us see what the WFN found out in their elaborate study on 250 prominent rivers of the world and about close to three million people associated with these rivers. According to the report, researchers used plots (first assessment) measuring 10 km by 10 km and (second assessment) used 1.5 m x 1.5 m and the nature of water consumption from the groundwater, surface water and rainfall from these plots were recorded. The documentation of WF helped the researchers to allocate the water usage for different types of crops, human consumption, use by the industrial sector, water subjected to pollution, water wasted *etc.* The unexpected results were an eye opener to them. Even though the WF of an agro-based product was observed to be very high in a particular plot, its export results in its non-consumption by the local residents, could result in a welcome reduction of its WF in that plot of land. Many poor countries are reported to have higher WF than the developed nations as the latter export their products along with the WF to the poor nations who now end up with high imported WF. If WF is used as a marketing tool or as a limiting factor for market access poor nations may end up with an additional burden.

WF PER CAPITA

According to the report published by the WFN based on the bottom-up approach, the global average WF is found to be 1385 $m^3\ yr^{-1}$ capita in the period 1996 - 2005 (series of articles published by Mekonnen and Hoekstra, 2011). There are large differences between countries. In the USA, the average WF is 2842 $m^3\ yr^{-1}$ capita whereas in China the average WF is 1071 $m^3\ yr^{-1}$ capita. Crop yield is closely related to WF, but the additional water and fertiliser usage will also raise the WF giving no big advantage in terms of WF.

It is the duty of all nations to ensure that the WF of every product which the country produces is sustainable. According to the report, it can be done by a planned schedule drawn by the government of nations that can spell out the allowable reduction of it's WF in every x-year cycle. This should only be applicable on the products made in a country and not the average WF consumption of that nation derived from the bottom-up approach or top-down approach as these approaches have to import elements the control of which is beyond the jurisdiction of the importing nations.

CASE STUDY ON COCA-COLA

The coca-cola who believed that their WF was very low at about 2% was surprised to know that more than 70% of their WF was in the agricultural ingredients like sweeteners used to make their beverages. They realised that it wasn't enough to look only at their own operations. They also needed to look at their input and the WF of those input.

According to Ruth by seeing a snapshot of their true water use all along the supply chain, they saw how they were linked to watersheds around the world through their product. It really opens up the perspectives of companies to understand their relationship to river basins, water use and sustainability around the world.

WF CAN HELP NATIONAL DECISIONS

Ruth says that by studying the WF, it can be used to help governments to make decisions by identifying the most suitable crop that can produce most efficiently – the high-

est yield with minimum water usage. Ruth proposed two solutions:

(i) If a country wants to preserve its water resources, it can import water-intensive crops instead of growing them in the country, in effect putting the water burden outside or;

(ii) If a country wants to be water independent, this report can help highlight how limited water resources can best be allocated. Ruth believes that the WF of nations report can be used by both individuals and companies. It is particularly valuable to a conservation organisation like the Nature Conservancy and its members, because it offers a more informed understanding of the link between individuals and the health of river basins around the world.

WF OF NATIONS AND HUMANITY

The WF of consumption in a country depends on two factors: what and how much do consumers consume and what the WF of the products consumed. The latter depends on the production circumstances in the places of origin of the various commodities. Some poor countries have very high WF for national consumption combined with low agricultural yields and high WF per unit of harvested crop for some developing countries.

Both Ruth and Arjen gave their views on the importance of WF of nations in order to assess their WF usage so that they can bring about effective controls among themselves or through intergovernmental discussions for imported goods.

Arjen pointed out that although the WF of a nation might be lower the consumption of imported goods that can contribute towards an increased WF from the food and the goods the nation imports. It might be imported from a high WF nation experiencing poor yield coupled with excessive pollution or water shortage due to drying rivers. The whole supply chain have to be scrutinised to find out a solution to reduce the WF.

Arjen and Mesfin M Mekonnen also conducted a desktop study on the WF of many nations (termed WF of humanity) and segregated and quantified the volume of rain water (green WF), ground water (blue WF) and polluted water (grey WF). The WF of nations took into account the approximate WF involved in the agricultural production as well as the consumption of the people of the nations in this study conducted in 2011 by Arjen and Mesfin M Mekonnen. The WF of nations are given in *Table 1.*

If all the palm oil mills in Malaysia have zero effluent discharge, the grey WF of Malaysia can be brought down by 52 800 m^3 and the virtual WF of our exported palm oil would diminish to some measure.

THE VIRTUAL WF

The virtual WF of 18 of the largest exporters are given in *Table 2*. United States lead with 314 g^3 yr^{-1} with Germany the lowest at 64 g^3 yr^{-1}. WF export also indicates export of agricultural and industrial products.

The results of the study are given in *Tables 2* and *3*. The WF of humanity in the period 1996 - 2005 are given in *Table 3*. The data are shown in millimetre per year on a 1.5 m x 1.5 m grid.

In all countries, the WP related to agricultural production takes the largest share in the total WF within the country. China and the United States have the largest WF in their territory related to industrial production; 22% of the global WF related to industrial production lies in China and 18% in the United States. Belgium is the country in which industrial production

TABLE 1. WATER FOOTPRINTS (WF) OF NATIONS

WF for 1996-2005	Total (g^3)	%	Green (%)	Blue (%)	Grey (%)	Agriculture (%)
Global annual average	9 087	100	74	11	15	92
Production for export	1 817	20	-	-	-	-
Total virtual (trade)	2 320	26	68	13	19	-
Global average	1 385	15	-	-	-	-
USA consumption	2 842	31	-	-	-	-
China consumption	1 071	12	-	-	-	-
India consumption	1 089	12	-	-	-	-
Cereals	2 453	27	-	-	-	-
Meat	2 000	22	-	-	-	-
Milk products	636	7	-	-	-	-

TABLE 2. THE MAIN VIRTUAL WATER EXPORTERS AND IMPORTERS

Largest exporters	$g^3\ yr^{-1}$	Largest importers	$g^3\ yr^{-1}$
United States	314	United States	234
China	143	Japan	127
India	125	Germany	125
Brazil	112	China	121
Argentina	98	Italy	101
Canada	91	Mexico	92
Australia	89	France	78
Indonesia	72	United Kingdom	77
France	65	Netherlands	71
Germany	64		

TABLE 3. THE COUNTRIES WITH THE LARGEST TOTAL WATER FOOTPRINTS (WF)

Largest WFP nations	WF within Territory ($g^3\ yr^{-1}$)	Blue and Grey	Nations	Water footprints
China India	1 207 1 182	Largest blue WFP	India	243 $g^3\ yr^{-1}$ (24% of global blue) Wheat 33%, rice 24%, sugar-cane 16%
United States Brazil	1 053 482	Largest grey WFP	China	360 $g^3\ yr^{-1}$ (26% of global grey)

takes the largest share in the total WF in the country. The WF of industries in Belgium contributes 41% to the total WF in the country; agricultural production still contributes 53% here.

According to the WFN only about 80% of the total WF is available for domestic use *(Table 4)*. The rest are exported.

Gross international virtual water flows (10^9 m^3 yr^{-1}) (1996–2005) is given in *Table 5.*

As a global average, the blue and grey shares in the total WF of internationally traded products are slightly larger than in the case of domestically consumed products, meaning that export goods are more strongly related to water consumption from and pollution of surface and groundwater than non-export goods. The green component in the total WF of internationally traded products is 68%, whereas it is 74% for total global production. The international virtual water flows are given in *Table 6*.

The WF of the national consumption is given in *Table 7.* Agriculture takes most of the WF.

The largest global consumers are China, India and the United States. Their share are given in *Table 8.*

The national consumption being not a benchmark for realistic assessment of a nation's WF was computed on per capita basis, as presented for high WF nations in *Table 9*.

TABLE 4. GLOBAL EXPORT OF WATER FOOTPRINT (WF) (1996 - 2005)

	g^3 yr^{-1}	%
Total WF of all the three sectors	9 087	100
Export of total WF for production of good for export	1 762	19.40
Export of agricultural products	334.78 (19%)	-
Export of industrial products	722.42 (41%)	-
Global domestic WF	7 325	80.60

TABLE 5. INTERNATIONAL VIRTUAL WATER FLOWS

Sectors (1996 - 2005 sensus)	Quantity
Global sum of international virtual water flows related to trade, agricultural and industrial products	2 320 g^3 yr^{-1} (68% green, 135% blue, 19% grey)
Virtual water flows related to international trade in crops and derived crop products	76%
Virtual water flows related to trade in animal products	12%
Virtual water flows related to trade in industrial products	12%
Global virtual water flows related to domestically produced merchandise	1 762 g^3 yr^{-1} (19% of total)

TABLE 6. WATER FOOTPRINT (WF) RELATED TO TRADE AGRICULTURE AND INDUSTRIAL PRODUCT

International virtual water flows related to trade	%
International virtual water flows relate to trade in oil crops (including cotton, soyabean, oil palm, sunflower, rapeseed, and others) and derived products (half of this is cotton products)	43.0
Trade in soyabean product	22.0
Cereals	17.0
Industrial products	12.2
Coffee, tea, and cocoa	7.9
Beef/cattle products	6.7

TABLE 7. THE WATER FOOTPRINT (WF) OF GLOBAL CONSUMPTION IN THE THREE SECTORS

Global consumption over the period 1996 - 2005	$m^3 yr^{-1}$
Global annual average WF related to consumption	1 385
Consumption of agricultural products at 91.5%	1 267
Consumption of industrial products at 4.7%	65
Consumption of domestic water use at 3.8%	53

TABLE 8. THE LARGEST GLOBAL CONSUMERS

Countries	$g^3 yr^{-1}$
China	1 368
India	1 145
United States	821

TABLE 9. WATER FOOTPRINT (WF) BASED ON PER CAPITA OF SOME NATIONS

WF based on per capita of some nations	$g^3 yr^{-1}$
United Kingdom (low due to low WF for beaf at 9 900 m^3yr^1)	1 258
United States (high due the high WF of bovine meat at 14 500 m^3y^{-1})	2 842
Developing nations	
Democratic Republic of Congo	552
Bolivia	3 468
Niger	3 519
Mongolia	3 775

WF for low WF nations with a population exceeding 5 million consumption is shown in *Table 10*, that gives a realistic view of the WF. The global average blue WF of consumption is 153 $m^3 yr^{-1}$ per capita, which is 11% of the total WF. The variation in blue WF per capita across countries is huge, much larger than the variation in total WF per capita whereas the largest total WF per capita (Mongolia) is about seven times the smallest total WF per capita (Democratic Republic Congo), the difference in the case of the blue WF is more than a factor hundred.

EXTERNAL WATER DEPENDENCY OF COUNTRIES

All external WF of nations together constitute 22% of the total global WF. The share of external WF, however, varies from country to country. Some European countries, such as Italy, Germany, the United Kingdom, and the Netherlands have external WF contributing 60% - 95% to the total WF. On the other hand, some countries, such as Chad, Ethiopia, India, Niger, Democratic Republic of Congo, Mali, Argentina, and Sudan have very small external WF, smaller than 4% of the total footprint. The water scarce countries and their external dependency rate are given in *Table 11.*

Notes by the Authors

In the estimation of the WF of consumer products, we considered a huge amount of different agricultural commodities separately, whereas industrial commodities were treated as one whole category. Although in this way, the study shows no detail within the estimation of the WF of production and consumption of industrial products, we justify the choice in this global study based on the fact that most of the WF of humanity is within the agricultural sector.

The data presented in this article are derived on the basis of a great number of underlying statistics, maps, and assumptions. Due to all basic sources include uncertainties and possible errors, the presented WF data should be taken and interpreted with extreme caution, particularly when zooming in on specific locations on a map or when focusing on specific products. Basic sources of uncertainties are, for example, the global precipitation, temperature, crop, and irrigation maps that we have used and the yield, production, consumption, trade, and wastewater treatment statistics on which we relied. Underlying assumptions refer, for example, to planting and harvesting dates per crop per region and feed composition per farm animal type per country and production system.

TABLE 10. WATER FOOTPRINT (WF) OF NATIONAL CONSUMPTION: POPULATION LARGER THAN 5 MILLION

WF based on per capita of some nations	$m^3 yr^{-1}$
Turkmenistan	740
Iran	589
United Arab Emirates	571
Egypt	527
Libya	511
Tajikistan	474
Saudi Arabia	447
Pakistan	422
Global average	153

See page 33

see page 26

TABLE 11. WATER SCARCE COUNTRIES AND EXTERNAL WATER FOOTPRINT (WF)

	External dependency (%)
Malta	92
Kuwait	90
Jordan	86
Israel	82
United Arab Emirates	76
Yemen	76
Mauritius	74
Lebanon	73
Cyprus	71

Another assumption has been that WF of industrial production and domestic water supply are geographically spread according to population densities. The reporting about uncertainties in the basic datasets that we had to rely on is very poor, particularly if we want to get a quantitative picture of the uncertainties. The basic datasets we have used together with our own assumptions do not give rise to the expectation that our data include a specific bias in some direction. Our estimates of global crop water consumption are in the middle of the range that one gets if considering different studies for consumption and international trade data, there are no alternative global databases than the ones we used. These databases do not yet include uncertainly information. Despite the uncertainties, we think that the current study forms a good basis for rough comparisons and to guide further analysis.

CONCLUSION

The study provides important information on the WF of nations, disaggregated into the type of WF (green, blue, or grey) and mapped at a high spatial resolution. This article shows how different products and national communities contribute to water consumption and pollution in different places. The figures can thus form an important basis for further assessment of how products and consumers contribute to the global problem of increasing freshwater appropriation against the background of limited supplies and to local problems of overexploitation and deterioration of freshwater bodies or conflict over water. Once one starts overlaying localised WF of products or consumers with maps that show environmental or social water conflict, a link has been established between final products and consumers on the one hand and local water problems on the other hand. Establishing such links can help the dialogue between consumers, producers, intermediates (like food processors and retailers), and governments about how to take and share responsibilities to reduce the WF where most necessary.

HISTORY

The WFN is an international learning community (non-profit foundation under Dutch law) that serves as a platform for connecting communities interested in sustainability, equitability and efficiency of water use. The organisation has two work programmes: a technical work programme and a policy work programme. In addition, there is a Partner Forum which offer

partners of the WFN a way of receiving, contributing and exchanging knowledge and experience on WF.

The blue WF is the volume of freshwater that evaporated from the global blue water resources (surface water and ground water) to produce the goods and services consumed by the individual or community. The green WF is the volume of water evaporated from the global green water resources (rainwater stored in the soil as soil moisture). The grey WF is the volume of polluted water that associates with the production of all goods and services for the individual or community. The latter can be estimated as the volume of water that is required to dilute pollutants to such an extent that the quality of the water remains at or above agreed water quality standards.

Being sustainable means using blue water wisely and not making grey water. Humans have polluted much water. Some rivers have so much rubbish in places that boats are pushing its way through the rubbish, for example, the Lake Karachay in Russia. It was the dumping site for radioactive waste, the water under the rubbish has chemicals from factories and toilets.

International Standard

In February 2011, the WFN, in a global collaborative effort of environmental organisations, companies, research institutions and the United Nation, launched the Global WF Standard. ISO is working on a procedural standard on how to incorporate WF in a product life cycle analysis. This ISO standard will be linked to the Global WF Standard, which can be applied for different sorts of WF assessment: for products, companies, countries or river basins.

Life Cycle Analysis (LCA) of Water Use

LCA is a systematic, phased approach to assess the environmental aspects and potential impacts that are associated with a product, process or service. Life cycle refers to the major activities in the course of the product's life-span from its manufacture, use, and maintenance, to its final disposal, including the raw material acquisition required to manufacture the product. Thus, a method for assessing the environmental impacts of freshwater consumption was developed. It specifically looks at the damage to three areas of protection: human health, ecosystem quality, and resources. The consideration of water consumption is crucial where water-intensive products (for example agricultural goods) are concerned and need therefore to undergo a LCA. In addition, regional assessments are equally necessary as the impact of water use depends on its location. In short, LCA is important as it identifies the impact of water use in certain products, consumers, companies, nations, *etc,* which can help reduce the amount of water used.

Water Footprint of Products

The WF of a product is the total volume of freshwater used to produce the product, summed over the various steps of the production chain. The WF of a product refers not only to the total volume of water used; it also refers to where and when the water is used. The WFN maintains a global database on the water footprint of products: WaterStat.

An individual's daily diet of fruits, vegetables and grains requires more than 1500 litres (396.3 US gal) of water, as compared to 3400 litres (898.2 US gal) needed for a daily diet rich in animal protein. Research by the Cranfield University calculated the amount of water required to produce various common foods in the United Kingdom are given in *Table 12.*

Water Footprint of Individual Consumers

The WF of an individual refers to the sum of his or her direct and indirect freshwater use. The direct water use is the water used at home, while the indirect water use relates to the total volume of freshwater that is used to produce the goods and services consumed. The average WF of the individuals in some countries are given in *Table 13*.

TABLE 12. THE HOUSEHOLD WATER USAGE OF COMMON ITEMS IN THE UNITED KINGDOM

Product	Litres	US gallons
1 cup of tea	32.4	8.6
1 imperial pint of beer	160	42.3
1 glass of wine	120	31.7
1 glass of milk	200	52.8
1 kg (2.2 lb) of beef	15 000	3 963
1 kg (2.2 lb) of poultry	6 000	11 585.1
250 g (8.8 oz) packet of M&M's	1 153	1 304.6
575 g (20.3 oz) jar of Dolmio pasta sauce	202	153.4

TABLE 13. THE AVERAGE WATER FOOTPRINTS (WF) OF SELECTED NATIONS

Average WF for global and some nations	Per person/year (m^3)
Average resident (global)	1 385
Average resident in the United States	2 842
Average resident in China	1 071
Average resident in India	1 089
Average resident in United Kingdom	1 695