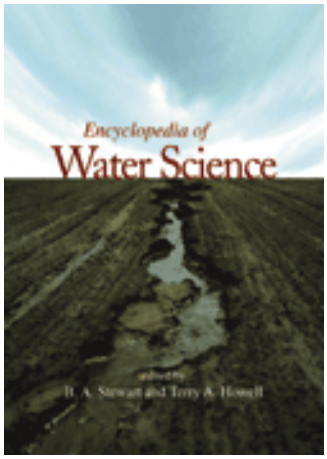

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Water Footprints: The Water Needs of People in Relation to Their Consumption Pattern

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Water Footprints: The Water Needs of People in Relation to Their Consumption Pattern

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Abstract
The water footprint shows the extent and the locations of water use in relation to consumption of people. The water footprint of a country is defined as the volume of water needed for the production of the goods and services consumed by the inhabitants of the country. The internal water footprint is the volume of water used from domestic water resources; the external water footprint is the water used in other countries. Water footprints of individuals or nations can be estimated by multiplying the volumes of goods consumed by their respective water requirement. The United States appears to have an average water footprint of 2480 m^3/cap/yr, while China has an average footprint of 700 m^3/cap/yr. The global average water footprint is 1240 m^3/cap/yr. The four major factors determining the water footprint of a country are: volume of consumption (related to the gross national income); consumption pattern (e.g., high versus low meat consumption); climate (growth conditions); and agricultural practice (water use efficiency).

INTRODUCTION

Worldwide, water demand studies have traditionally taken the perspective of production. Databases and literature on water demand generally show the water withdrawals in the domestic, agricultural, and industrial sector.[1–3] Though providing useful information, these datasets do not tell much about the water needed by people in relation to their consumption. Many goods consumed by the inhabitants of a country are produced in other countries, and this means that the real water demand of a population can be much higher than the national water withdrawals suggest. The reverse can be the case as well—national water withdrawals are substantial, but a large amount of the products are being exported for consumption elsewhere.

The water footprint concept was introduced in 2002 in order to have a consumption-based indicator of water use that could provide useful information in addition to the traditional production-sector-based indicators of water use.[4] The water footprint of a nation is defined as the total volume of freshwater that is used to produce the goods and services consumed by the people of the nation. The concept has been developed in analogy to the ecological footprint concept.[5,6] The ecological footprint of a population represents the area required to produce the resources used and to assimilate the wastes produced by a certain population at a specified material standard of living, wherever on Earth that land may be located. Whereas the ecological footprint thus quantifies the area needed to sustain people's living, the water footprint indicates the volume of water required. A similar type of analysis, not focussing on area or volume of water but on volume of energy, is known under the term "embodied energy analysis" or—in an alternative form—"emergy analysis."[7] Although integration of ecological footprint analysis, water footprint analysis, and embodied energy or emergy analysis into one coherent analytical framework is an obvious challenge, efforts in this direction have not yet been undertaken.

This entry shows how the concept of water footprint can be quantified and mapped and also summarizes current knowledge on the actual water footprints of nations.

ASSESSING THE WATER FOOTPRINT OF A NATION

There are two ways of quantifying the water footprint of a nation. In the bottom-up approach, one multiplies all goods and services consumed by the inhabitants of the nation by their respective virtual water content. Virtual water is the volume of water required to produce a commodity or service (see the entry "Virtual Water: Measuring Flows around the World"). It is termed "virtual" because the water is not really embedded in the commodity or service. The real water content of commodities is generally very small if compared to their virtual water content.

In the top–down approach, the water footprint of a nation is estimated as the national water use plus the virtual water flows that enter the country minus the virtual

Keywords: Water footprint; Consumption; Water demand; Virtual water; Indicators; Water use efficiency.

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Table 1 Global average virtual water content of some selected products, per unit of product.

Product	Virtual water content (litres)
1 sheet of A4-paper (80 g/m^2)	10
1 tomato (70 g)	13
1 potato (100 g)	25
1 microchip (2 g)	32
1 cup of tea (250 ml)	35
1 slice of bread (30 g)	40
1 orange (100 g)	50
1 apple (100 g)	70
1 glass of beer (250 ml)	75
1 slice of bread (30 g) with cheese(10 g)	90
1 glass of wine (125 ml)	120
1 egg (40 g)	135
1 cup of coffee (125 ml)	140
1 glass of orange juice (200 ml)	170
1 bag of potato crisps (200 g)	185
1 glass of apple juice (200 ml)	190
1 glass of milk (200 ml)	200
1 cotton T-shirt (250 g)	2300
1 hamburger (150 g)	2400
1 pair of shoes (bovine leather)	8000

Source: From UNESCO-IHE (see Ref. 8).

water flows that leave the country. A nation's water footprint has two components—the internal and the external water footprint. The first component is defined as the use of domestic water resources to produce goods and services consumed by inhabitants of the country. It is the sum of the total water volume used from the domestic water resources in the national economy minus the volume of virtual water export to other countries insofar related to export of domestically produced products. The external water footprint of a country is defined as the annual volume of water resources used in other countries to produce goods and services consumed by the inhabitants of the country concerned. It is equal to the so-called virtual water import into the country minus the volume of virtual water exported to other countries as a result of the re-export of imported products. Virtual water flows (m^3/yr) between nations can be estimated by multiplying commodity trade flows (tn/yr) by their associated virtual water content (m^3/tn).

WATER NEEDS BY PRODUCT

Total crop production in the world requires 6390 billion m^3 of water per year at field level.[8] This volume includes both the use of blue water (ground and surface water) and the use of green water (moisture stored in soil strata). Adding irrigation losses, which globally add up to 1590 billion m^3/yr, the total volume of water used in agriculture becomes 7980 billion m^3/yr. About one-third of this amount is blue water withdrawn for irrigation and the remaining two-thirds is green water (soil water). Rice is

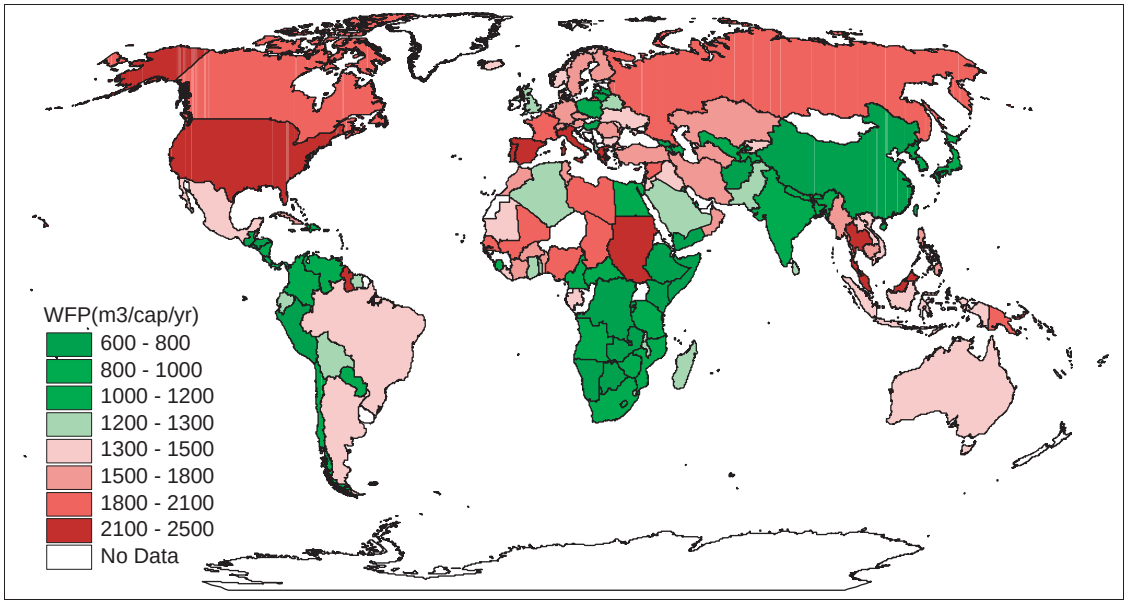

Fig. 1 Average national water footprint per capita (m^3/capita/yr). Green means that the nation's water footprint is equal to or smaller than global average. Countries with red have a water footprint beyond the global average.

Table 2 Composition of the water footprint for some selected countries. Period: 1997–2001.

		Use of domestic water resources					Use of foreign water resources			Water footprint		Water footprint by consumption category				
			Crop evapotranspiration[a]		Industrial water withdrawal		For national consumption					Domestic water	Agricultural goods		Industrial goods	
Country	Population ×1000	Domestic water withdrawal Gm^3/yr	For national consumption Gm^3/yr	For export Gm^3/yr	For national consumption Gm^3/yr	For export Gm^3/yr	Agricultural goods Gm^3/yr	Industrial goods Gm^3/yr	For re-export of imported products Gm^3/yr	Total Gm^3/yr	Per capita $m^3/cap/yr$	Internal water footprint $m^3/cap/yr$	Internal water footprint $m^3/cap/yr$	External water footprint $m^3/cap/yr$	Internal water footprint $m^3/cap/yr$	External water footprint $m^3/cap/yr$
Australia	19,071	6.51	14.03	68.67	1.229	0.12	0.78	4.02	4.21	26.56	1393	341	736	41	64	211
Bangladesh	129,942	2.12	109.98	1.38	0.344	0.08	3.71	0.34	0.13	116.49	896	16	846	29	3	3
Brazil	169,109	11.76	195.29	61.01	8.666	1.63	14.76	3.11	5.20	233.59	1381	70	1155	87	51	18
Canada	30,649	8.55	30.22	52.34	11.211	20.36	7.74	5.07	22.62	62.80	2049	279	986	252	366	166
China	1,257,521	33.32	711.10	21.55	81.531	45.73	49.99	7.45	5.69	883.39	702	26	565	40	65	6
Egypt	63,375	4.16	45.78	1.55	6.423	0.66	12.49	0.64	0.49	69.50	1097	66	722	197	101	10
France	58,775	6.16	47.84	34.63	15.094	12.80	30.40	10.69	31.07	110.19	1875	105	814	517	257	182
Germany	82,169	5.45	35.64	18.84	18.771	13.15	49.59	17.50	38.48	126.95	1545	66	434	604	228	213
India	1,007,369	38.62	913.70	35.29	19.065	6.04	13.75	2.24	1.24	987.38	980	38	907	14	19	2
Indonesia	204,920	5.67	236.22	22.62	0.404	0.06	26.09	1.58	2.74	269.96	1317	28	1153	127	2	8
Italy	57,718	7.97	47.82	12.35	10.133	5.60	59.97	8.69	20.29	134.59	2332	138	829	1039	176	151
Japan	126,741	17.20	20.97	0.40	13.702	2.10	77.84	16.38	4.01	146.09	1153	136	165	614	108	129
Jordan	4,813	0.21	1.45	0.07	0.035	0.00	4.37	0.21	0.22	6.27	1303	44	301	908	7	43
Mexico	97,291	13.55	81.48	12.26	2.998	1.13	35.09	7.05	7.94	140.16	1441	139	837	361	31	72
Netherlands	15,865	0.44	0.50	2.51	2.562	2.20	9.30	6.61	52.84	19.40	1223	28	31	586	161	417
Pakistan	136,475	2.88	152.75	7.57	1.706	1.28	8.55	0.33	0.67	166.22	1218	21	1119	63	12	2
Russia	145,878	14.34	201.26	8.96	13.251	34.83	41.33	0.80	3.94	270.98	1858	98	1380	283	91	5
South Africa	42,387	2.43	27.32	6.05	1.123	0.40	7.18	1.42	2.10	39.47	931	57	644	169	26	33
Thailand	60,487	1.83	120.17	38.49	1.239	0.55	8.73	2.49	3.90	134.46	2223	30	1987	144	20	41
United Kingdom	58,669	2.21	12.79	3.38	6.673	1.46	34.73	16.67	12.83	73.07	1245	38	218	592	114	284
U.S.A	280,343	60.80	334.24	138.96	170.777	44.72	74.91	55.29	45.62	696.01	2483	217	1192	267	609	197
Global total/ average	5,994,251	344	5434	957	476	240	957	240	427	7452	1243	57	907	160	79	40

[a]Includes both blue and green water use in agriculture.

Source: From UNESCO-IHE (see Ref. 8).

the largest water consumer. It takes about 1359 billion m^3/yr, which is about 21% of the total volume of water used for crop production at field level. The second largest water consumer is wheat (12%). Although the total volume of the world rice production is about equal to the wheat production, rice consumes much more water per ton of production. The difference is due to higher evaporative demand for rice production and lower yields in comparison to wheat production. As a result, the global average virtual water content of rice (paddy) is 2291 m^3/tn and the average for wheat is 1334 m^3/tn.

The virtual water content of rice (broken) that a consumer buys in the shop is 3420 m^3/tn on average. This is larger than the virtual water content of paddy rice as harvested from the field because of the weight loss as paddy rice is processed into broken rice. Table 1 shows the virtual water content of a few consumer products. In general, livestock products have higher virtual water contents than crop products. This is because a live animal consumes a lot of feed crops, drinking water, and service water in its lifetime before it produces some output. The higher up in the product chain the greater the virtual water content of the product. For example, the global average virtual water content of maize, wheat, and rice (husked) is 900, 1300, and 3000 m^3/tn, respectively, whereas the virtual water content of chicken meat, pork, and beef is 3900, 4900, and 15,500 m^3/tn, respectively. However, the virtual water content of products varies greatly from place to place, depending upon the climate and technology adopted for farming and corresponding yields.

WATER FOOTPRINTS OF NATIONS

The global water footprint is 7450 billion m^3/yr, which is 1240 m^3/cap/yr in average.[8] About 86% of the global water footprint relates to the consumption of food and other agricultural products. Eight countries—India, China, the United States, the Russian Federation, Indonesia, Nigeria, Brazil, and Pakistan—together contribute 50% to the total global water footprint. In absolute terms, India is the country with the largest footprint in the world, with a total footprint of 987 billion m^3/yr. But on a relative basis, the United State's citizens have the largest water footprint, with 2480 m^3/yr per capita, followed by the people in south European countries such as Greece, Italy, and Spain (2300–2400 m^3/yr per capita). Large water footprints can also be found in Malaysia and Thailand. The Chinese people have a relatively low water footprint, with an average of 700 m^3/yr per capita. The average per capita water footprints of nations are shown in Fig. 1. Table 2 shows the composition of the water footprint for a few selected countries.

The explanatory factors behind the size of a national water footprint are the volume of consumption, consumption patterns, climate, and agricultural practice. In rich countries, people generally consume more goods and services, which immediately translate into increased water footprints. This partially explains the high water footprints of, for instance, the United States, Italy, and Switzerland. The composition of the consumption package is relevant, too, because some goods (bovine meat, rice) require more water than others. The high consumption of meat significantly contributes to larger water footprints in countries like the United States, Canada, France, Spain, Portugal, Italy, and Greece. The average meat consumption in the United States is, for instance, 120 kg/yr—more than three times the world average. In regions with unfavorable climatic conditions (high evaporative demand), the water requirement per unit of crop production is relatively large, lending to higher water footprints in countries such as Senegal, Mali, Sudan, Chad, Nigeria, and Syria. A fourth factor that determines larger water footprints is water-inefficient agricultural practice that increases water requirements in production, as evident in countries such as Thailand, Cambodia, Turkmenistan, Sudan, Mali, and Nigeria. In Thailand, for instance, rice yields averaged 2.5 tn/ha in the period of 1997–2001, while the global average in the same period was 3.9 tn/ha.

CONCLUSION

The water footprint of a nation is a rough indicator of the effects of national consumption on worldwide water resources. The ratio of internal to external water footprint is relevant because externalising the water footprint means externalising the environmental impacts. Some European countries (Italy, Germany, the United Kingdom, and the Netherlands) have external water footprints, contributing 50%–80% to the total water footprint.[8] The ratio of blue to green water footprint is relevant because blue water abstractions affect the environment generally more than green water use.[9] Finally, some components of the water footprint involve the use of water for which no alternative use is possible, while other parts relate to water that could have been used for other purposes with higher value added. There is a difference, for instance, between beef produced in extensively grazed grasslands of Botswana (use of green water without alternative use) and beef produced in an industrial livestock farm in the Netherlands (partially fed with imported irrigated feed crops).

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