Małgorzata Stępniewska

WATER FOOTPRINT AS AN INDICATOR OF WATER SUPPLY – ECOSYSTEM SERVICES. A CASE STUDY FOR URBAN MUNICIPALITIES OF WIELKOPOLSKA REGION

Malgorzata Stepniewska, Ph.D. – Adam Mickiewicz University

address:
Faculty of Geographical and Geological Sciences
Dzięgielowa 27, 61-680 Poznań, Poland
malgorzata.stepniewska@amu.edu.pl

ŚLAD WODNY JAKO WSKAŹNIK ŚWIADCZEŃ ZAOPATRUJĄCYCH ZWIĄZANYCH Z DOSTARCZENIEM WODY. PRZYKŁAD GMIN MIEJSKICH WOJEWÓDZTWA WIELKOPOLSKIEGO

STRESZCZENIE: Celem artykułu jest ukazanie możliwości oceny świadczeń ekosystemów związanych z zaopatrzeniem w wodę za pomocą wskaźnika, jakim jest ślad wodny regionalnej konsumpcji. Tradycyjnie regionalne bilanse wodne uwzględniają tylko bezpośrednie zużycie wody, wyrażane jako wielkość poboru wód. Jednakże wskaźniki poboru wody nie dostarczają informacji na temat rzeczywistych potrzeb wodnych mieszkańców w relacji do ich konsumpcji. W analizie wzięto pod uwagę także zużycie pośrednie – objętość wody zużytej do wytworzenia dóbr, które są konsumowane przez ludność (wirtualna woda). Jako studium przypadku posłużyły gminy miejskie województwa wielkopolskiego. Całkowity ślad wodny przeciętnego konsumenta na analizowanym obszarze w latach 2008-2009 wynosił 1437 m^3/rok (w tym 73% zielony komponent śladu wodnego, 9% niebieski i 18% szary).
Około 89% całkowitego śladu wodnego było związane z konsumpcją produktów rolniczych, 10% z konsumpcją dóbr przemysłowych, a nieco poniżej 1% z bezpośrednim zużyciem wody w gospodarstwach domowych. Spośród artykułów rolniczych największy wkład do całkowitego śladu wodnego przeciętnego konsumenta miało spożycie mięsa, a następnie produktów zbożowych, kawy, herbaty i kakao. Import wirtualnej wody towarzyszący handlowi produktami rolniczymi i przemysłowymi odgrywa znaczącą rolę w oszczędzaniu zasobów wodnych regionu.

SŁOWA KLUCZOWE: świadczenia zaopatrujące, zaopatrzenie w wodę, ślad wodny, wirtualna woda

Introduction

Water supply is recognized within the provisioning services as a major group of services.[1] Traditionally, water withdrawal indicators are used as indicators of water usage for human consumption. They are used to show the amount of water abstraction with the division into three sectors – the domestic, agricultural and industrial one.[2] This approach reflects the "Proposal for Common International Classification of Ecosystem Services" (CICES).[3] In CICES, within the provisioning services related to water supply, three classes of ecosystem services were distinguished – water supply for household consumption, water for agricultural use and water for industrial and energy uses. The size of services related to water supply is proposed to be expressed by abstracted water in these sectors. However, the water-withdrawal indicators do not give information about the actual water needs of people in relation to their consumption pattern. In addition to tap water consumption, significant amounts of water are used to produce goods that are consumed by the population. In 2002, the water footprint concept was introduced in order to have a consumption-based indicator that could provide useful information, in addition to the classical production-sector-based indicators of water use.[4] The European Parliament proposes the inclusion of water footprint to the basket of four resource use indicators, beside land, material and carbon footprints.[5]

The purposes of the study is to show the possibility of assessment ecosystem services related to water supply using an index which is the water footprint of regional consumption. Urban municipalities of Wielkopolska Region were chosen as the area of study. The total water footprint is considered in division into two components: direct and indirect water footprint. Within each of them, the aim was assumed to determine the blue, green and grey components, taking into

[1] R. Costanza et al., *The value of the world's ecosystem services and natural capital*, "Nature" 1997 No. 387, p. 254; *The Millennium Ecosystem Assessment, Ecosystems and Human Well-being: Synthesis*, Island Press, Washington, 2005, pp. VI; R.S. de Groot, M.A. Wilson, R.M.J. Boumans, *A typology for the classification, description and valuation of ecosystem functions, goods and services*, "Ecological Economics" 2002, No. 41, p. 396.

[2] AQUASTAT – FAO's global information system on water and agriculture. Source: http://www.fao.org/nr/water/aquastat/main/index.stm; OECD, Stat Extracts. http://stats.oecd.org; Eurostat. http://epp.eurostat.ec.europa.eu/portal/page/portal/environment/data/database; CSO, Local Data Bank. http://www.stat.gov.pl/bdl [Date of entry: 30-09-2012].

[3] European Environment Agency, *Common International Classification of Ecosystem Services (CICES) version 4 (update July 2012)*, Source: http://unstats.un.org/unsd/envaccounting/seeaLES/egm/Issue8a.pdf [Date of entry: 30-09-2012].

[4] A.Y. Hoekstra, P.Q. Hung, *Virtual water trade: A quantification of virtual water flows between nations in relation to international crop trade*, Value of Water Research Report Series, No.11, UNESCO-IHE 2002. A.Y. Hoekstra (ed.), *Virtual water trade: Proceedings of the International Expert Meeting on Virtual Water Trade*, Value of Water Research Report Series, No.12, UNESCO-IHE 2003;

[5] European Parliament resolution of 24 May 2012 on a resource-efficient Europe (2011/2068(INI), P7_TA-PROV(2012)0223.

account water source (ground or surface) and water pollution. To determine the degree of strain on water resources, the relation between the water demand and water availability is examined.

The water footprint concept

The water footprint has been developed in analogy to the ecological footprint concept, as introduced in the 1990s.[6] The 'ecological footprint' of a population represents the area of productive land and aquatic ecosystems 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 *water* required to sustain a population.

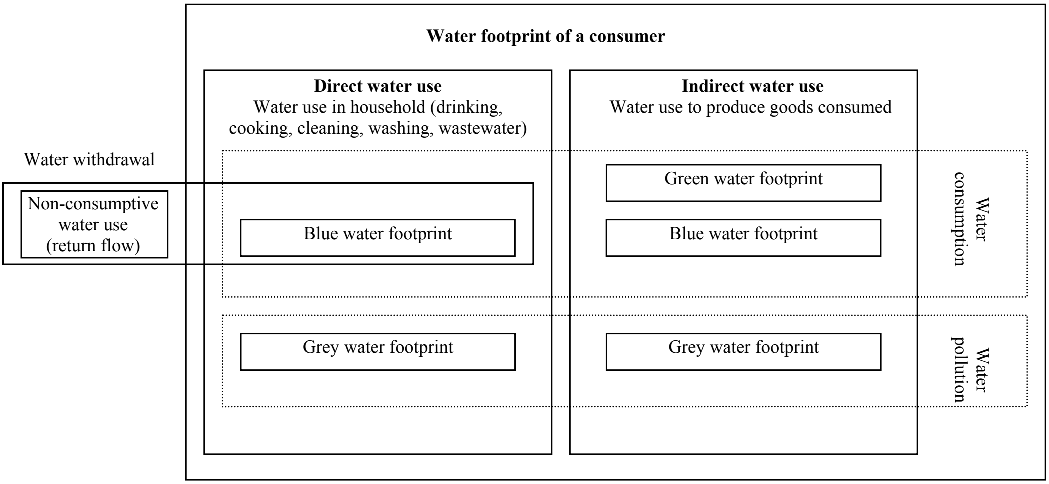
The water footprint is an indicator of freshwater use that examines not only the direct water usage of a consumer, but also the indirect water usage (Fig. 1). The water footprint of a regional consumption is defined as the total volume of freshwater that is used to produce the goods and services consumed by the inhabitants of the region. Water usage is measured in terms of water volumes consumed (evaporated or incorporated into a product) and polluted per unit of time.[7] It is a multi-dimensional indicator, showing water consumption volumes from the source and volumes of polluted water. The blue water footprint refers to consumption of blue water resources (surface and ground water) as a result of the production of a good. Consumption refers to the loss of water from the available ground-surface body of water in a catchment area, which occurs when water evaporates, returns to another catchment area or the sea or is incorporated into a product. The green water footprint is related to the consumption of rainwater, stored in the soil as soil moisture, which is particularly relevant in crop production. The grey water footprint refers to the pollution and is defined as the volume of freshwater that is required to assimilate the load of pollutants based on existing ambient water quality standards.[8]

[6] W. E. Rees, *Ecological footprints and appropriated carrying capacity: what urban economics leaves out*, "Environment and Urbanization" 1992 No. 2(4), p. 120-130; M. Wackernagel, W. Rees, *Our ecological footprint: Reducing human impact on the earth,* New Society Publishers, Gabriola Island, B.C., Canada 1996; M. Wackernagel et al., *Ecological footprints of nations: How much nature do they use? How much nature do they have?* Centre for Sustainability Studies, Universidad Anahuac de Xalapa, Mexico 1997.

[7] A.Y. Hoekstra et al., *The water footprint assessment manual: Setting the global standard*, Earthscan, London 2011, p. 195.

[8] M.M. Mekonnen, A.Y. Hoekstra, *National water footprint accounts: the green, blue and grey water footprint of production and consumption*, Value of Water Research Report Series, No. 50, UNESCO-IHE, Delft, the Netherlands 2011.

Figure 1.
Schematic representation of the components of a water footprint



Source: A.Y. Hoekstra et al., *The water footprint assessment manual: Setting the global standard*, op. cit.

The water footprint is closely linked to the virtual water concept. Virtual water is defined as the volume of water required to produce a commodity or service. The concept was introduced by Allan in the early 1990s as a tool to describe the 'virtual' water flows exported from a region as a result of export of water-intensive commodities.[9]

As an indicator of water usage, the water footprint differs from the classical measure of water withdrawal in three respects:

- it is not restricted to blue water use, but also includes green and grey water,
- it is not restricted to direct water usage, but also includes indirect water usage,
- it does not include blue water use if this water is returned to the original catchment.[10]

Water footprint thus offers a wider perspective on how a consumer is related to the usage of limited freshwater resources. Water footprint accounts provide a basis for discussing water allocation and issues related to sustainable, equitable and efficient water use. Besides, the water footprint forms a basis for assess-

[9] J.A. Allan, *Fortunately, there are substitutes for water otherwise our hydro-political futures would be impossible*, in: *Priorities for Water Resources Allocation and Management*, UK: Overseas Development Administration, London 1993, p. 13-26; J.A. Allan, *Overall perspectives on countries and regions*, in: P. Rogers, P. Lydon (ed.), *Water in the Arab World: perspectives and prognoses*, Harvard University Press, Cambridge, Massachusetts 1994, p. 65-100.

[10] A.Y. Hoekstra, A.K. Chapagain, M.M. Aldaya, M.M. Mekonnen, *Water Footprint Manual State of the Art*, Water Footprint Network, Enschede, The Netherlands 2009.

ing the impact of goods and services consumption at local level and formulating strategies to reduce this impact.[11]

Methodology

This study adopts the terminology and calculation methodology as set out in “The Water Footprint Assessment Manual”, which contains the proposal for global standard for water footprint assessment developed by the Water Footprint Network.[12]

The water footprint of regional consumption (in m^3/yr) is calculated by adding the direct water footprint of consumers to two indirect water footprint components:

$$WF_{cons} = WF_{cons,dir} + WF_{cons,indir}\text{(agricultural commodities)} + \\ + WF_{cons,indir}\text{(industrial commodities)} \quad (1)$$

The direct water footprint of consumers within the region ($WF_{cons,dir}$) refers to the consumption and pollution of water related to domestic water supply. The indirect water footprint of consumers ($WF_{cons,indir}$) refers to the water usage by others to make the commodities consumed, with differentiation into agricultural and industrial commodities.

Direct water use – Water footprint of domestic water consumption

The blue water footprint within region related to domestic water supply is estimated using the water withdrawal data from the *Central Statistical Office* of Poland (CSO) database.[13] It is assumed that 10% of the water withdrawn is actual consumption (blue water footprint) and that the remaining fraction is the return flow.

The part of the return flow which is disposed into the environment without prior treatment has been taken as a measure of the grey water footprint.[14] The amount of raw sewage was estimated on the basis of the population not served by sewage treatment plants and the average water consumption per 1 inhabitant in the studied urban municipalities. This data was obtained from the CSO database.[15]

[11] A.Y. Hoekstra et al., *The water footprint assessment manual: Setting the global standard,* op. cit.
[12] Ibidem.
[13] CSO, *Local Data Bank* http://www.stat.gov.pl/bdl [Date of entry: 30-09-2012].
[14] M.M. Mekonnen, A.Y. Hoekstra, *National water ...*, op. cit., p. 12.
[15] CSO, Local Data Bank, op. cit.

Indirect water use

Water footprint of consumption of agriculture products

For agricultural commodities, the water footprint of regional consumption is calculated by multiplying the set of agricultural products consumed by the inhabitants of the region by their respective product water footprint:

$$WF_{cons,indir}\text{(agricultural commodities)} = \sum (C[p]) \times WF_{prod}[p]) \quad (2)$$

$C[p]$ the is consumption of agricultural product p by consumers within the region (ton/yr) and $WF_{prod}[p]$ the water footprint of this product (m^3/ton). The following range of final agricultural goods is considered:

- Cereals – wheat, barley, rye, oat, rice, pasta,
- Coffee, tea, cocoa beans,
- Fruits – grapefruit, bananas, oranges, mandarines, lemons, limes, apples, pineapples, grapes,
- Livestock products – butter, cheese, eggs, milk, yogurt, pork, bovine, poultry,
- Oil crops – ground-nuts, coconut, olives,
- Oil from oil crops – soya-bean oil, ground-nut oil, sunflower-seed oil, rape and mustard oil, palm oil,
- Pulses – beans, peas,
- Roots and tubers – potatoes,
- Vegetables – tomatoes, onions,
- Sweeteners – raw sugar, beet/sugar (raw equivalent),
- Beverages – beer, wine.

The data on the average consumption of agricultural products per person in Poland for the period 2008-2009 were taken from CSO[16] and FAO databases[17]. The blue, green and grey water footprints of crop and derived crop products and the blue, green and grey water footprints of farm animals and animal products were obtained from M.M. Mekonnen and A.Y. Hoekstra studies.[18]

Water footprint of consumption of industrial products

The virtual water content of an industrial product can be calculated in a similar manner as described earlier for agricultural products. There are however numerous categories of industrial products with a diverse range of production

[16] CSO, *Statistical yearbook of agriculture 2010*, http://www.stat.gov.pl/gus/5840_6243_PLK_HTML.htm [Date of entry: 30-09-2012].
[17] Food and Agriculture Organization of the United Nations, Faostat, http://faostat.fao.org/site/368/default.aspx#ancor [Date of entry: 30-09-2012].
[18] M.M. Mekonnen, A.Y. Hoekstra, *The green, blue and grey water footprint of crops and derived crop products*, Value of Water Research Report Series, No. 47, UNESCO-IHE, Delft, the Netherlands 2010; M.M. Mekonnen, A.Y. Hoekstra, *The green, blue and grey water footprint of farm animals and animal products*, Value of Water Research Report Series, No. 48, UNESCO-IHE, Delft, the Netherlands 2010.

methods and detailed standardized statistics related to the production and consumption of industrial products are hard to find. For this reason, for the analysis the data was used of the blue and grey water footprint of consumption of industrial products per capita in Poland, presented by M.M. Mekkonen and A.Y. Hoekstra.[19] Their global study contains national water footprint accounts carried out in the configuration of states in a high spatial resolution and taking into account international trade of products. For industrial commodities, they calculated the water footprint of national consumption as the water footprint of industrial processes taking place within the nation plus the virtual-water import related to import of industrial commodities minus the virtual-water export.

Blue water scarcity analysis

The blue water footprint exerts impact on the freshwater system, contributes to water scarcity and associated environmental problems. In order to gather insight into the impact of water consumption, its value was compared to the actually available water resources. As the blue water-scarcity indicator (WS_{blue}), there was used the water consumption-to-availability ratio:

$$WS_{blue} = (W_{cons} / WA_{blue}) \cdot 100 \tag{3}$$

A blue water scarcity of hundred percent means that the available blue water has been fully consumed. As a measure of water availability (WA_{blue}) there were used the capacities of renewable water resources in 16 Groundwater Bodies (GWB) covering the region.[20] Two scenarios were analyzed. In the first of them, as an indicator of water consumption (W_{cons}), the water withdrawal was used, whereas in the second – the total blue water footprint:

1. Scenario 1 (CURRENT) – Water scarcity level by GWB expressed as the ratio of the withdrawal to the total renewable water resources,
2. Scenario 2 (POTENTIAL) – Water scarcity level by GWB expressed as the ratio of the total blue water footprint to the total renewable water resources.

The water footprint of the urban municipalities in Wielkopolska Region

Wielkopolska Region is located in central western Poland and is one of the 16 administrative regions in the country. Urban areas include 28,3 thousand km^2. In 2009, they were inhabited by 1 912 thousand people, concentrated in 109 towns and cities. The most populated urban municipalities of region were Poznań

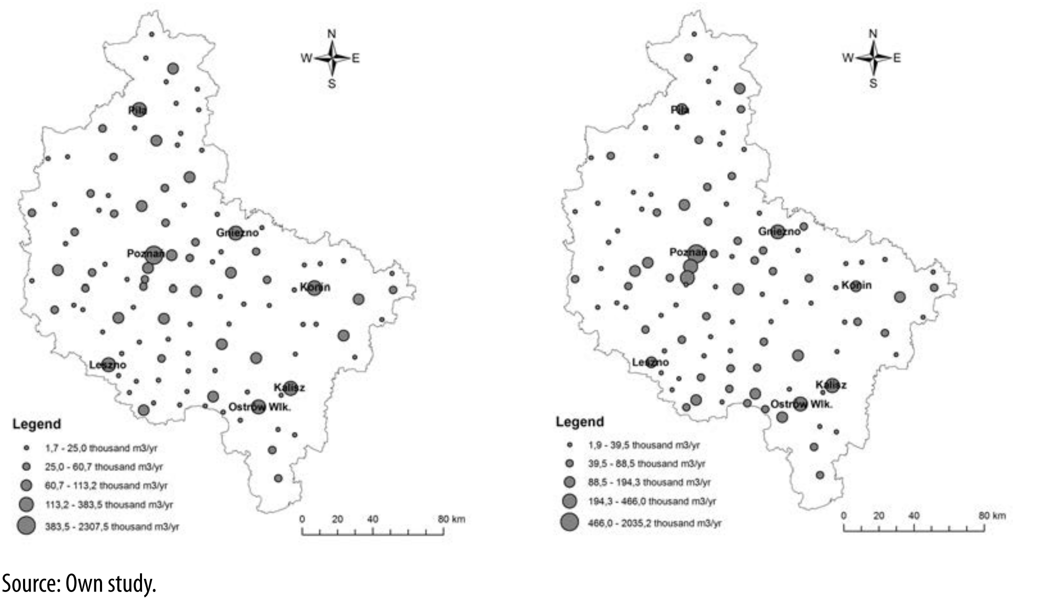
[19] M.M. Mekonnen, A.Y. Hoekstra, *National water ...*, op. cit, p. 14-15.
[20] National Water Management Authority, *Jednolite Części Wód Podziemnych (Groundwater Bodies).*

(554,2 thousand inhabitants), Kalisz (107,0 thousand), Konin (79,5 thousand), Piła (74,6 thousand), Ostrów Wielkopolski (72,4 thousand), Gniezno (69,5 thousand) oraz Leszno (64,3 thousand). Population of 31 other urban centers ranged 10-30 thousand inhabitants, and 71 – below 10 thousand inhabitants.

Direct water footprint

The total water footprint of domestic water consumption in the analyzed region in 2009 was 15,6 million m^3/yr (44% blue, 56% grey). The spatial distribution of its value with the breakdown into blue and grey components is shown in Fig. 2. The blue water footprint was approximately 6,9 million m^3, which constituted only slightly more than 2,5% of the total blue water footprint of regional consumption. Slightly more than half of blue water footprint of domestic water consumption concentrated in the 7 most populated cities in Wielkopolska – Poznań (2308 thousand m^3/year), Kalisz (384 thousand m^3/year), Ostrów Wielkopolski (285 thousand m^3/year), Piła (265 m^3/year), Konin (254 m^3/year), Leszno (224 thousand m^3/year) and Gniezno (213 thousand m^3/year) (Fig. 1). The grey water footprint of domestic water consumption in Wielkopolska urban municipalities in 2009 was approximately 8,7 million m^3. Its highest values were found in Poznan (2035 thousand m^3/year), Kalisz (466 thousand m^3/year), Luboń (311 thousand m^3/year), Gniezno (257 thousand m^3/year), Ostrów Wielkopolski (254 thousand m^3/year) and Puszczykowo (224 thousand m^3/year).

Figure 2.
The water footprint of the domestic water consumption in the urban municipalities of Wielkopolska in 2009
a) The blue water footprint of the domestic water consumption, b) The grey water footprint of the domestic water consumption



Source: Own study.

Indirect water footprint

The total water footprint of the agricultural products consumption in 2009 was 2456,2 million m^3/yr (82% green, 9% blue, 9% grey). The water footprint due to the consumption of agricultural products can be divided into product categories (Table 1). Consumption of livestock products gives the largest contribution to the total water footprint of agricultural products consumption (57%), followed by cereals (21%) and coffee, tea, cocoa beans (6%). The remainder of the footprint is related to other agricultural products (16%).

Table 1.
Water footprint (WF) of consumers related to the consumption of agricultural products in the urban municipalities of Wielkopolska Region in 2009

Product category	WF, million m^3/yr				Total WF
	Green	Blue	Grey	Total	%
Livestock products	1189,66	103,93	116,28	1409,88	57,40
Pork	358,63	33,65	45,50	437,78	17,82
Milk, 1-6% fat	322,12	31,81	27,11	381,05	15,51
Bovine meat and meat offal	162,98	6,19	5,10	174,26	7,09
Poultry, live,over 185g	113,18	9,58	14,90	137,66	5,60
Cheese processed, not grated or powdered	107,24	10,56	8,57	126,37	5,14
Eggs, bird, in shell, fresh, preserved or cooked	56,03	5,27	9,27	70,57	2,87
Butter	37,72	3,74	3,16	44,61	1,82
Yogurt	17,04	1,68	1,43	20,15	0,82
Milk, > 6% fat	14,74	1,46	1,23	17,43	0,71
Cereals	380,86	77,06	52,70	510,61	20,79
Wheat	264,05	70,72	42,80	377,57	15,37
Rye	87,13	1,54	6,08	94,74	3,86
Dry pasta	10,68	2,87	1,74	15,28	0,62
Barley	12,99	0,85	1,40	15,24	0,62
Oat	3,96	0,48	0,34	4,79	0,19
Rice groats and meal	2,04	0,61	0,33	2,99	0,12
Coffee, tea, cocoa beans	149,74	2,39	4,86	157,00	6,39
Coffee, roasted	86,81	0,66	3,03	90,50	3,68
Cocoa Beans	49,10	0,01	0,45	49,55	2,02
Tea	13,83	1,72	1,39	16,94	0,69
Oil from oil crops	89,71	5,45	8,33	103,49	4,21
Rape and Mustard Oil	30,24	4,11	5,96	40,30	1,64
Palm Oil	27,47	0,01	1,04	28,52	1,16
Soya-bean oil	16,75	0,58	0,31	17,63	0,72
Sunflower-sed oil	13,97	0,69	0,93	15,59	0,63
Ground-nut oil	1,28	0,08	0,08	1,44	0,06

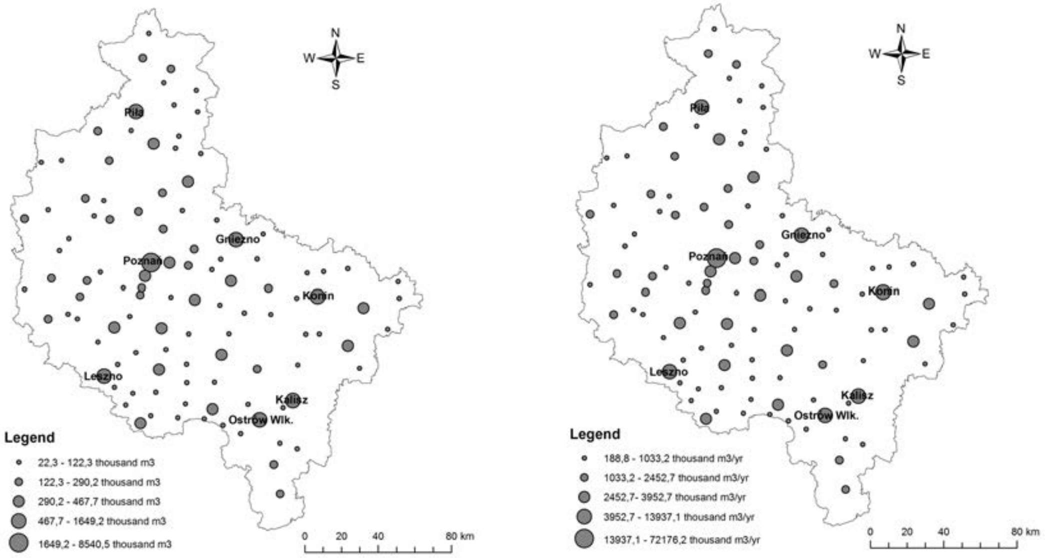
Product category	WF, million m^3/yr				Total WF
	Green	Blue	Grey	Total	%
Sweeteners	43,60	13,61	13,20	70,40	2,87
Raw sugar, beet/Sugar (Raw Equivalent)	43,60	13,61	13,20	70,40	2,87
Roots and tubers	42,71	7,38	14,09	64,18	2,61
Potatoes	42,71	7,38	14,09	64,18	2,61
Fruits	36,12	8,56	7,32	52,00	2,12
Apples	21,14	5,01	4,79	30,94	1,26
Oranges, Mandarines	5,22	1,35	1,19	7,76	0,32
Grapes	3,25	0,74	0,67	4,66	0,19
Bananas	2,65	0,39	0,13	3,17	0,13
Lemons, Limes	1,98	0,70	0,27	2,95	0,12
Grapefruit, fresh or dried	1,54	0,36	0,23	2,13	0,09
Pineapples	0,33	0,01	0,05	0,39	0,02
Beverages	42,09	3,11	4,75	49,95	2,03
Beer made from malt	39,31	2,48	4,18	45,96	1,87
Grape wines	2,79	0,63	0,57	3,99	0,16
Vegetables	9,53	3,88	3,25	16,66	0,68
Tomatoes	4,48	2,62	1,78	8,88	0,36
Onions	5,05	1,26	1,46	7,78	0,32
Pulses	12,31	0,37	3,29	15,97	0,65
Beans	9,81	0,31	2,44	12,57	0,51
Peas, dry	2,50	0,06	0,85	3,41	0,14
Oil crops	5,59	0,32	0,17	6,08	0,25
Ground-nuts shelld	2,02	0,12	0,13	2,28	0,09
Coconut	2,63	0,00	0,01	2,64	0,11
Olives	0,94	0,19	0,02	1,15	0,05
Total	**2001,93**	**226,06**	**228,22**	**2456,21**	**100,00**

Source: Own study.

The total water footprint related to the consumption of industrial products in 2009 was 278,6 million m^3/yr (11% blue, 89% grey). It was calculated by assuming the values for the blue and grey water footprint per capita respectively as 15,4 m^3/year and 130,2 m^3/year in the period 1996-2005. Variation of the analyzed indicator in the urban municipalities of Wielkopolska is shown in Fig. 3. The highest values of the total water footprint of industrial products consumption were recorded in Poznań (80,7 million m^3/year), Kalisz (15,6 million m^3/year), Konin (11,6 million m^3/year), Piła (10,9 million m^3/year), Ostrów Wielkopolski (10,5 million m^3/year), Gniezno (10,1 million m^3/year) and Leszno (9,4 million m^3/year). These cities, with a total population of 957 thousand people, were characterized by the total blue water footprint of industrial products consumption at the level of 148,8 million m^3/year.

Figure 3.
The water footprint of the industrial products consumption in the urban municipalities of Wielkopolska in 2009

a) The blue water footprint of the industrial products consumption b) The grey water footprint of the industrial products consumption



Source: Own study.

The total water footprint

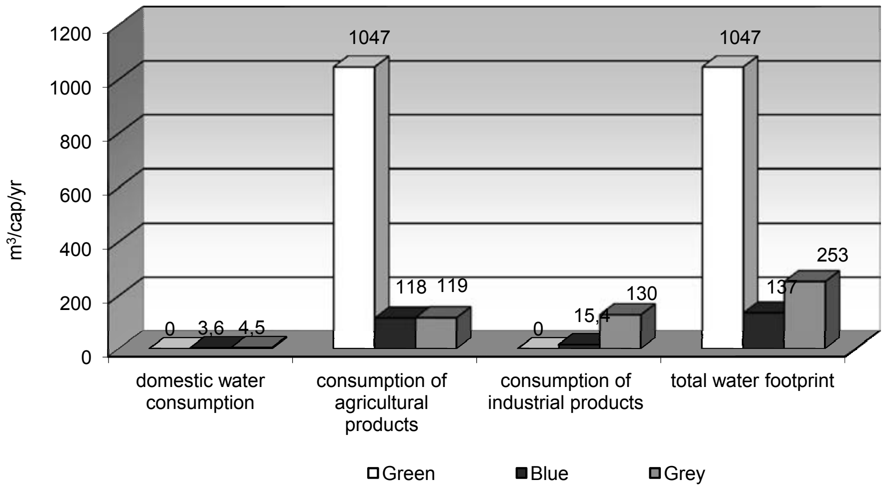
The total water footprint of regional consumption in the period 2008-2009 was 2750,4 million m^3/yr (73% green, 10% blue, 18% grey). The average consumer in the Wielkopolska Region had a water footprint of 1437,5 m^3/yr. A detailed overview of the individual contribution of consumption categories to the water footprint of Wielkopolska consumers is given in Figure 4. Agricultural goods are responsible for the largest part of the total water footprint (1284,0 m^3/person/year), industrial goods are responsible for 145,4 m^3/person/year and domestic water usage for approximately 8,1 m^3/person/year.

Table 2 summarizes the values of water footprint of regional consumption from the results of two global water footprint studies. In the case of M.M. Mekonnen and A.Y. Hoekstra study[21] it is possible to compare the results directly, because the same method and assumptions are applied. The calculated values of the water footprint are close to the average values for Poland given by these authors. The exception is the water footprint of domestic water consumption, which for the urban municipalities of Wielkopolska is significantly lower than the national average. It is mainly determined by the grey component, relatively

[21] M.M. Mekonnen, A.Y. Hoekstra, *National water ...*, op. cit.

low due to the high (89%) share of population using sewage treatment plants in the urban municipalities. Whereas as compared to global averages, the studied area is characterized by much higher water footprint of industrial product con-

Figure 4.
The total water footprint of consumption per capita in the urban municipalities of Wielkopolska



Region in the years 2008-2009

Source: Own study.

Table 2.
Water footprint of consumer (m^3/person/year) in Wielkopolska Region urban municipalities as compared to average values for Poland and the World

Total WF components	Period 2008-2009[a] Wielkopolska Region	Period 1996-2005[b]		Period 1997-2001[c]	
		Poland	World	Poland	World
WF $_{\text{domestic water consumption}}$	8,1	35,9	52,6	48,0	57,0
WF $_{\text{agricultural commodities}}$	1284,0	1223,9	1267,4	828,0	1067,0
WF $_{\text{industrial commodities}}$	145,4	145,6	65,0	226,0	119,0
Total WF	**1437,5**	**1405,4**	**1385,0**	**1102,0**	**1243,0**

[a] own study.
[b] M.M. Mekonnen, A.Y. Hoekstra, *National water footprint accounts: the green, blue and grey water footprint of production and consumption*, op. cit.
[c] A.K. Chapagain, A.Y. Hoekstra, *Water footprints of nations*, op. cit.

sumption. In the case of A.K. Chapagain and A.Y. Hoekstra study[22] when comparing the results, methodological differences should be taken into account. Their study excludes the grey water footprint component and is restricted to the analysis of the blue and green water footprints. Moreover, in that study, the water footprint of domestic water consumption represents the total water withdrawal in the domestic sector. Whereas in the study for Wielkopolska Region, the non-consumptive part of water withdrawal (the return flow) is not the part of the water footprint.

Blue water scarcity

In scenario 1, the current pressure on water resources arising from direct water usage was specified. The average share of water withdrawal in the total renewable groundwater resources in the region was 3,6% in 2009. The values of this ratio were characterized by large regional variations, from below 0,5% (GWB no 43, 71 and 79) to 17,7% for GWB no 62, located within Poznań agglomeration. Scenario 2 reflects a hypothetical situation in which the total water needs of residents (both direct and indirect water use) would be satisfied from the groundwater resources available in the region. In this scenario, the average value of „blue water scarcity" is 16,8%, therefore it is almost 5-fold higher than in current state. This shows the scale of water saving as a result of the trade of commodities. Use of regional water resources is significantly reduced through the import of water contained in agricultural and industrial products.

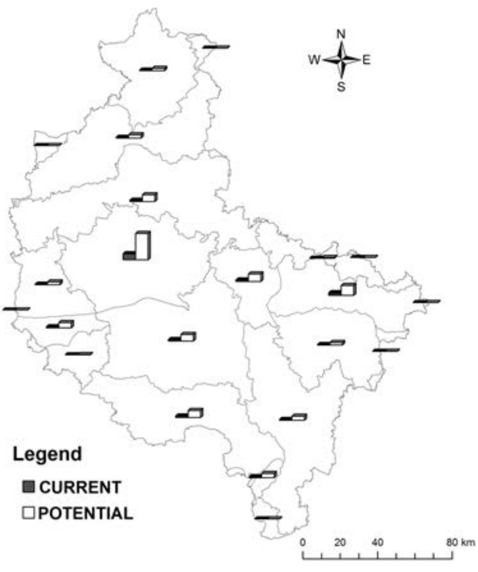


Figure 5.
The degree of strain on groundwater resources caused by addressing water needs of the urban municipalities of Wielkopolska in 2009 (%)

CURRENT: the water demand equals the water withdrawal

POTENTIAL: the water demand equals the total blue water footprint of regional consumption

Source: Own study.

[22] A.K. Chapagain, A.Y. Hoekstra, *Water footprints of nations*, Value of Water Research Report Series, No. 16, UNESCO-IHE, Delft, the Netherlands 2004.

Conclusion

The study illustrates the possibility of assessing water supply ecosystem services by using the water footprint as an indicator of water use in relation to the volume and pattern of consumption by the people. The total water footprint of the urban municipalities of Wielkopolska Region in the period 2008-2009 was 2750 million m^3/yr, which is in average 1437 m^3/cap/yr. The largest contribution to the total water footprint was the consumption of agricultural products (2456 million m^3/yr). In particular, the consumption of livestock products significantly contributes to the total water footprint. Next to agricultural products, the consumption of industrial goods plays an important role in the total water footprint of the region. The total water footprint related to the consumption of these products in the period 2008-2009 was 278,6 million m^3/yr. Whereas the domestic water withdrawal was responsible for slightly below 1% (15,6 million m^3/yr) of the total water footprint.

As an aggregated indicator, the water footprint shows the total water demand of inhabitants, and it is a rough measure of the impact of human consumption on the water environment. However, further detailed study is necessary, including more precise analysis of the components and characteristics of the total water footprint, the analysis of the blue versus the green water use, as well as the analysis of the international and interregional virtual water flows and water dependency.