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Analysis of the Water Footprint of Central and Eastern Europe Countries

Analiza śladu wodnego krajów Europy Środkowo-Wschodniej

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Abstract: The article presents an analysis of the water footprint of five Central and Eastern European countries, i.e. Poland, Slovakia, Lithuania, Ukraine and Belarus. The first three are members of the European Union, the other two are not. These countries also differ in terms of climate. The green, blue and grey water footprints of crop production, grazing, animal water supply, industrial production and domestic water supply are analysed. The per capita water footprint is also calculated. It is the highest for the countries of the former Soviet Union, that is Ukraine, Belarus and Lithuania, and half as low for Poland and Slovakia. In the case of virtual water, Poland dominates in the area of import, and Ukraine in export. The index of the net import of virtual water is unfavourable for Ukraine and Lithuania and is much more positive for Poland and Belarus. When calculated per capita, the net import of green virtual water is the highest for Belarus (340 m^3/person/year) and Poland (148 m^3/person/year). A positive value of this index was also recorded for Slovakia and negative for Lithuania and Ukraine (–282 m^3/person/year). Taking into account the exposure of the southern Ukraine steppe to water stress, this is not a favourable situation for greater export of virtual water than its import.

Keywords: water footprint, virtual water, agriculture, industry, households

Streszczenie: Artykuł przedstawia analizę śladu wodnego 5 krajów Europy Środkowo-Wschodniej: Polski, Słowacji, Litwy, Ukrainy i Białorusi. Trzy pierwsze kraje są członkami Unii Europejskiej, pozostałe nie należą do UE. Kraje te różnią się także klimatem. Przeanalizowano zielony, niebieski i szary ślad wodny w uprawie roślin, wypasie, hodowli zwierząt, produkcji przemysłowej i przez gospodarstwa domowe. Następnie obliczono ślad wodny per capita, który jest najwyższy dla krajów byłego Związku Radzieckiego: Ukrainy, Białorusi i Litwy, a połowę mniejszy dla Polski i Słowacji. W przypadku wody wirtualnej Polska dominuje w jej imporcie, a Ukraina w eksporcie. Wskaźnik importu netto wody wirtualnej jest niekorzystny dla Ukrainy i Litwy, a największe dodatnie wartości przyjmuje dla Polski i Białorusi. Po przeliczeniu na mieszkańca, import netto zielonej wody wirtualnej jest najwyższy dla Białorusi (340 m^3/os./rok) i Polski (148 m^3/os./rok). Dodatnią wartość tego wskaźnika odnotowano również dla Słowacji, a ujemne dla Litwy i dla Ukrainy (–282 m^3/os./rok). Biorąc pod uwagę narażenie stepowego południa Ukrainy na stres wodny, nie jest korzystną sytuacja większego eksportu niż importu wody wirtualnej.

Słowa kluczowe: ślad wodny, woda wirtualna, rolnictwo, przemysł, gospodarstwa domowe

Introduction

The countries of Central and Eastern Europe, despite their geographical proximity, differ significantly in terms of climate and economy. The length of Ukraine from north to south (from Pripyat river to Crimea) is 900 km, and from west to east (from the Carpathians mountains to the Central Russian Upland) is over 1,300 km. This results in different biogeographical regions of the country which are mountainous in the Carpathians Mountains, continental in the west and north, steppe (arid agriculture) in the south and east, and Mediterranean on the southern shore of Crimea. Smaller climatic differences occur between Poland and Belarus and Lithuania (partially boreal climate) and Slovakia (mountain climate in most of the country).

Due to their historical and cultural heritage, after 1989, Poland and Slovakia clearly chose the path of integration with the European Union. Lithuania, a former republic of the Soviet Union, followed the same path after 1991 and joined the EU in 2004. The Slavic republics of the USSR, Ukraine and Belarus, did not break off economic and cultural ties with the former Russian Union. Only the illegal annexation of Crimea by Russia and the war in Donbas in 2014 severed Ukraine's strong economic ties with Russia. On the other hand, Russia's open aggression against Ukraine in February 2022 placed Ukraine and Belarus on opposite sides and completely reoriented Ukrainian policy towards the West with the main objective of a quick accession to the European Union.

The aim of this paper is to present an analysis of the water footprint and virtual water of five countries of Central and Eastern Europe. Three neighboring countries were selected to extend the earlier water footprint analysis of Poland and Ukraine (Panasiuk 2018). Significant differences in water indicators are related to different economic policies and water resources management.

1. The use of water resources indicators

Various indicators are used to analyze the water resources of individual countries. The most popular but misleading parameter is the average annual per capita river runoff from the territory of the country. In the period 2000-2021, the outflow of surface waters from Poland, including the inflow from abroad, amounted to 57.2 billion m^3, which is about 1,500 m^3/year/person. For Slovakia, lying on the Danube, this parameter reaches 15,000 m^3/year/person and for the less populated Lithuania lying on the Nemunas river it amounted to 7 thousand m^3/year/person (GUS 2022). For non-EU countries total renewable water resources (TRWR) were estimated by FAO (2022) for Ukraine at 3,911 m^3/year/person in year 2015 and for Belarus at 6,097 m^3/year/person in year 2014. In Poland, the capacity of water reservoirs is relatively small (4 billion m^3), It constitutes approximately 6% of the average annual river runoff which does not provide protection against flood or drought (Thier 2017).

The river outflow is often used populistically, because its size for Poland is similar to the value for Egypt and Ethiopia, African countries with a real water stress, despite the fact that they are located on the Nile river its tributaries. In turn, in Ukraine there are deficits of water resources in the river basins of the lower Dnieper, Donets, Boh, Ingulec, as well as in Pryazovia region and the Crimea (Suduk 2018).

Therefore, in the European Union, the river runoff parameter is being abandoned in favor of the Water Exploitation Index. Introduced by the European Environment Agency (EEA 2019), it is used to compare the amount of water abstracted against the total renewable water resources in a given area. The index reduced by the consumption of cooling water (return consumption) in thermal power plants is marked as WEI+. Water scarcity conditions of EU Member States and candidate countries measured with the WEI+ parameter were estimated in year 2017 at 6.9% for Poland and 0.4% for Slovakia and Lithuania, while

the value for southern European countries was 4.4 % for Romania, 23.3% for Turkey; 39.3% for Greece and as much as 70.3% for Cyprus.

A similar indicator is used by FAO (2022). Pressure on water resources in the years 2010-2013, calculated as total freshwater withdrawal of TRWR, was calculated at the following levels:

- 19.0% for Poland (agriculture 1.8% TRWR);
- 11.3% for Lithuania (agriculture 0.2% TRWR);
- 8.4% for Ukraine (agriculture 2.5% TRWR);
- 2.6% for Belarus (agriculture 0.8% TRWR)
- 1.1% for Slovakia (agriculture 0.05% TRWR).

2. Water footprint

The total consumption of water resources and their pollution, as a rule, is considered in the form of the total volume of water, which is necessary to ensure vital activities. Little attention has been paid to water problems related to the structure of the world economy, which ensures the production of various consumer goods and services. As a result, there is almost no information about the fact that the characteristics of production and logistics chains significantly affect the volume of water consumption (distribution of water resources in space and time) and their pollution. Visualization of the hidden use of water according to the life cycle of products will help to understand the global nature of the impact of consumption and trade of fresh water on the qualitative and quantitative indicators of water resources and to make the right strategic decisions to improve the level of water resources management both in terms of a separate production process and at the regional, national and global level (Hoekstra 2020).

The virtual water is a tool that allows a better and broader assessment of the relationship of the consumer or producer to the use of freshwater systems (Schyns 2019). It is the amount of water resources used and/or polluted in the everyday production and use of goods and services. There are three types of the water footprint: green, gray and blue. Each of them defines the source of water as well as the purpose for which it is used (Mekonnen 2011a). The green water footprint describes the rainwater used for vegetation. Its main resources are stored in the unsaturated soil zone from where they get into the atmosphere through the process of evapotranspiration. It is estimated that green areas in the form of forests, meadows and marshes consume about 70% of green water. This indicator is used to measure the amount of water used in agriculture and forestry (Panasiuk 2018). The gray water footprint is water that is polluted by industry. This indicator determines water that is necessary for the assimilation of pollutants in wastewater because it is used to dilute municipal and industrial wastewater discharged into lakes or rivers in order to maintain the required quality standards. If the pollution is significant then the greywater is first directed to the sewage treatment plant. The use of water in the production of goods, animal husbandry and crop production is called the blue water footprint. This water is found in rivers and in natural and artificial water reservoirs as well as in the underground water layer. Through the use in industrial production and agriculture water is lost by being incorporated into the product either by evaporation or by being transported to another catchment area.

2.1. Water footprint of the economic sectors

Five neighboring countries of Central and Eastern Europe were selected for the comparison. Poland, Slovakia and Lithuania are members of the European Union with a large trade exchange with the countries of Western Europe. However, Lithuania has an economic structure partly inherited from the Soviet Union. Ukraine and Belarus, which are not members of the EU, have less developed economies and are dependent on water-intensive industries. At the same

time, the analyzed countries partly differ in regard to climate (EEA 2020). Poland and half of Lithuania, Belarus and Ukraine lie in the continental climate zone. The southern and eastern part of Ukraine has a steppe climate. The northern and eastern areas of Belarus and Lithuania have a boreal climate. On the other hand, most of the territory of Slovakia covers a mountainous climate with crop production limited to valleys. This affects the use of water in agriculture, greater in the steppe climate, lesser in the mountain.

The water footprint of individual countries, broken down into green, gray and blue, is presented in Table 1. The last available data for all countries in the world comes from 2011 and covers a period of 10 years.

The largest water footprint in all the countries was recorded in crop production. It is dominated by the green water footprint and its highest value (99 billion m^3/year) was achieved by Ukraine with the largest area of cultivation. The lowest value of the green water footprint was recorded for Slovakia (only 5 billion m^3/year). The second significant category is the gray water footprint, which in Poland reached 8 billion m^3/year. Values for other countries are smaller but still significant.

Taking into account the green water footprint in the grazing sector, Ukraine is also in the lead (5 billion m^3/year). Poland is in second place with half the result. The lowest value was again recorded for Slovakia (0.3 billion m^3/year). Animal water supply is the source of the blue water footprint. The largest amount was recorded for Poland and Ukraine (0.4 billion m^3/year), the smallest for Slovakia (0.04 billion m^3/year).

In industrial production, the gray water footprint prevails. Its highest value was recorded for Ukraine (13 billion m^3/year). Poland is in the second with a three-3 times smaller value. The smallest gray water footprint was recorded for Lithuania (0.01 billion m^3/year). The blue water footprint in the industrial sector reaches much smaller amounts. The highest value was also recorded for Slovakia (0.7 billion m^3/year) and Poland (0.6 billion m^3/year), and the lowest for Lithuania (0.002 billion m^3/year).

Domestic water supply is primarily the source of the gray water footprint. The highest value was recorded for Ukraine (4 billion m^3/year). Much smaller, but still significant, was calculated for Poland (2 billion m^3/year). The lowest value of the gray water footprint was recorded for Lithuania (0.1 billion m^3/year). In addition, the blue water footprint appears in the household

Table 1. Comparison of the water footprint of Poland, Slovakia, Lithuania, Belarus and Ukraine in years 1996-2005

[mil. m^3/year]	Water footprint	Poland	Slovakia	Lithuania	Belarus	Ukraine
Crop production	Green	40 857.0	5 008.0	8 660.0	20 857.0	98 614.0
	Blue	108.0	146.0	3.0	110.0	2573.0
	Gray	7 630.0	632.0	192.0	4 547.0	5 161.0
	Total	48 595.0	5 786.0	8 855.0	25 514.0	106 348.0
Grazing	Green	2 452.0	308.0	493.0	1 457.0	4 562.0
Animal water supply	Blue	385.0	37.0	41.0	137.0	378.0
Industrial production	Blue	637.5	30.8	2.0	65.0	664.0
	Gray	4 602.8	251.3	11.4	63.0	12 616.0
	Total	5 240.3	282.1	13.4	128.0	13 280.0
Domestic water supply	Blue	210.0	42.8	21.0	65.0	456.0
	Gray	1 167.7	264.7	100.5	195.5	4 104.0
	Total	1 377.7	307.5	121.5	260.5	4 560.0

Source: Based on Mekonnen (2011b).

sector which, like the gray one, ranks first in Ukraine (0.5 billion m³/year). A half smaller value was recorded for Poland and the lowest for Lithuania. The values for Slovakia and Belarus are slightly higher.

2.2. Total per capita water footprint

The highest total water footprint values were achieved by the green water footprint, followed by the gray water footprint and the lowest by the blue water footprint (see table 3). The total values of the water footprint depend largely on the size of the country: Ukraine – 44 million inhabitants, Poland – 38 million, Belarus – 9 million, Slovakia – 5 million and Lithuania – 3 million (CIA 2022). Therefore, it is worth looking at the per capita values calculated on the basis of Mekonnen's (2011b) data.

The green per capita water footprint reaches the highest value in Lithuania (2.6 thousand m³/year). The second position is occupied by Ukraine (2.3 thousand m³/year), followed by Belarus (2.2 thousand m³/year), Poland (1.1 thousand m³/year) and Slovakia (1.0 thousand m³/year). With regard to the gray per capita water footprint, the largest share was achieved by Belarus (482 m³/year) and Ukraine (448 m³/year), the smallest in Lithuania (87 m³/year). The lowest values are achieved by the blue per capita water footprint – 91 m³/year for Ukraine and 49 m³/year for Slovakia, and only 19 m³/year for Lithuania.

Comparing the total per capita water footprint, it is observed that it is the highest for the countries of the former Soviet Union: Ukraine, Belarus and Lithuania (2.7-2.8 thousand m³/year) and half as much for Poland and Slovakia (1.3-1.5 thousand m³/year). These relationships result mainly from the green water footprint, i.e. the amount of water used in agriculture. Looking at the blue water footprint, high water consumption is observed in Ukraine in industry, waterworks and agricultural irrigation. In turn, data on the gray water footprint, indicate unresolved waste water management in Belarus and Ukraine.

3. Virtual water

The concept of virtual water is closely related to the concept of water footprint and covers water consumption at all stages of production or service (Skrypchuk 2013). The term was introduced by J.A. Allan to describe virtual water flows as a result of the export of water-intensive goods (Stępniewska 2014). It is the water 'embodied' in products, not in reality, but in a virtual sense. It refers to the amount of water used to manufacture a product or contaminated during its production, taking into account the complete production chain. Such ‚exogenous water' should be added to the country's ‚indigenous water' (Hoekstra 2003).

3.1. Virtual water import

An alternative to saving water consumption in Ukraine can be a strategy to minimize consumption by importing water-intensive products – both agricultural and industrial.

Table 2. Total water footprint and total per capita water footprint of Poland, Slovakia, Lithuania, Belarus and Ukraine in years 1996-2005

	Water footprint	Poland	Slovakia	Lithuania	Belarus	Ukraine
Total water footprint [mil. m³/year]	Green	43 310.0	5 317.0	9 153.0	22 315.0	103 177.0
	Blue	1 341.0	256.0	67.0	377.0	4071.0
	Gray	13 400.0	1145.0	304.0	4 805.0	21 881.0
	Total	58 051.0	6 718.0	9 524.0	27 497.0	129 129.0
Total water footprint per capita [m³/person/year]	Green	1 121.0	1 022.5	2 615.1	2 236.0	2 302.0
	Blue	35.0	49.2	19.1	37.8	91.0
	Gray	347.0	220.2	86.9	481.5	448.0
	Total	1 503.0	1 291.9	2 721.1	2 755.3	2 841.0

Source: Based on Mekonnen (2011b).

The water situation in a scarce region can be significantly improved by importing products that require large volumes of water for production, instead of producing them independently, that is, by importing virtual water (Skrypchuk 2020). Table 3 presents the import of virtual water to five countries of Central and Eastern Europe for individual sectors of the national economy.

In the crop production sector, import of green virtual water prevails. Poland is in the first place with a huge advantage, with a value of 11.5 billion m³/year. The second place is occupied by Ukraine with the value of 4.6 billion m³/year, followed by Belarus and Slovakia. The lowest value was achieved by Lithuania (1.6 billion m³/year). The blue trace of virtual water reaches much lower values. The highest value in this category was again occupied by Poland (2.2 billion m³/year). For the remaining countries, imports ranged from 0.3-0.7 billion m³/year. Gray virtual water has the smallest share in the plant cultivation sector, with the highest value for Poland (1.1 billion m³/year). Poland, as a relatively wealthy country, imports a large amount of virtual water along with food imports from other European Union and non-European countries, e.g. citrus fruits.

In the animal products sector, the import of green virtual water also has the largest share, with the highest value for Poland (0.7 billion m³/year) and the second position for Slovakia (0.4 billion m³/year). The blue and gray traces of virtual water have a small share. These values oscillate between 19-77 million m³/year. Poland and Slovakia, as the richer countries in the region, lead in these statistics due to the import of meat and dairy products.

An important sector is industrial production, where gray virtual water imports prevail. The highest values were achieved by Poland (2.9 billion m³/year) and Ukraine (2.8 billion m³/year). They were followed by Belarus and Slovakia. In this sector, there is also import of the blue trace of virtual water. The highest value of this indicator was achieved by Poland and Ukraine (0.2 billion m³/year). The lowest value was again recorded in Lithuania. Per capita, Belarus, Slovakia and Lithuania achieve high values of virtual water imports in the industrial sector because, as countries with smaller economies, they produce less industrial products and some of them have to be imported.

3.2. Virtual water export

In total, 16% of the water used in the world for agricultural and industrial production is

Table 3. Import of virtual water to Poland, Slovakia, Lithuania, Belarus and Ukraine in years 1996-2005

Sector	Water footprint [mil. m³/year]	Poland	Slovakia	Lithuania	Belarus	Ukraine
Crop products	Green	11 501.5	1 812.4	1 579.1	3 773.1	4 585.8
	Blue	2 229.6	534.8	341.1	519.1	677.3
	Gray	1 121.7	234.1	170.5	224.1	347.6
	Total	14 852.8	2 581.3	2 090.7	4 516.3	5 610.7
Animal products	Green	715.6	392.5	223.9	351.1	349.3
	Blue	77.5	52.7	19.4	28.8	26.1
	Gray	64.7	40.0	15.4	21.5	19.3
	Total	857.8	485.2	258.7	401.4	394.7
Industrial products	Blue	223.1	79.1	43.4	83.7	154.6
	Gray	2 870.2	1 088.2	684.3	1 545.9	2 750.0
	Total	3 093.3	1 167.3	727.7	1 629.6	2 904.6

Source: Based on Mekonnen (2011b).

exported as virtual water. At the same time, the annual global volume of virtual water flow is about 1.6 trillion m³/year (Schyns 2019). The total water savings resulting from the international trade of virtual water in the form of agricultural products is equivalent to 6% of the total volume of water used in agriculture (Zhuo 2019). Table 4 presents the export of virtual water from selected countries of Central and Eastern Europe.

When analyzing the export of virtual water in the plant production sector, the green water footprint achieved the highest values. In Ukraine it amounted to as much as 15.3 billion m³/year, and in Poland only 3.9 billion m³/year. In Lithuania and Slovakia it was at the level of 1.5 billion m³/year and the lowest value was recorded in Belarus (0.6 billion m³/year). Ukraine, as a country with great steppe areas, exports large amounts of cereals and corn. The export of blue virtual water in this sector is much lower (the largest for Poland – 0.9 billion m³/year). The lowest values are related to the export of gray virtual water.

In the animal production sector, the highest values in the export of green virtual water were achieved this time in Poland (2.6 billion m³/year). Ukraine was in second place (2.3 billion m³/year). The lowest export was recorded in Belarus (0.2 billion m³/year). Significantly lower values are recorded for the blue and gray traces of virtual water. Poland is definitely the leader in this sector. This is due to the export of large amounts of meat and dairy products.

In the industrial manufacturing sector, the gray footprint of virtual water prevails. The highest values were recorded in Ukraine (5.9 billion m³/year). Poland achieved almost half of this level (2.5 billion m³/year). The next places were occupied by Slovakia, Belarus and Lithuania. In this sector, there is also the export of blue virtual water, with the highest values recorded for Ukraine and Poland (0.3 billion m³/year). A large share of water-intensive and polluting heavy industry in Ukraine may be observed in industrial production. The country exported large quantities of steel products to Russia and other countries.

3.3. Net virtual water import

The tables above show that there are significant export and import flows of virtual water. To get a broader perspective, it is necessary to calculate the balance of virtual water exported from each country. Table 5 shows the net virtual water import for the analyzed countries of Central and Eastern Europe.

Poland imports the largest amount of virtual water, followed by Ukraine and Belarus. The largest export of products, along with the associated virtual water, comes from

Table 4. Export of virtual water from Poland, Slovakia, Lithuania, Belarus and Ukraine in years 1996-2005

Sector	Water footprint [mil. m³/year]	Poland	Slovakia	Lithuania	Belarus	Ukraine
Crop products	Green	3 946.3	1 482.6	1522.0	563.0	15 289.2
	Blue	909.0	246.8	262.6	104.6	545.6
	Gray	881.2	194.0	118.6	73.6	691.4
	Total	5 736.5	1 923.4	1 903.2	741.2	16 526.2
Animal products	Green	2 569.4	266.8	524.8	170.3	2 303.1
	Blue	230.3	47.4	59.2	20.7	227.5
	Gray	195.2	23.1	10.6	16.4	78.0
	Total	2 994.9	337.3	594.6	207.4	2 608.6
Industrial products	Blue	268.6	55.9	14.2	27.4	292.5
	Gray	2 471.2	852.6	309.9	428.8	5 888.6
	Total	2 739.8	908.5	324.1	456.2	6 181.1

Source: Based on Mekonnen (2011b).

Table 5. Net virtual water import to Poland, Slovakia, Lithuania, Belarus and Ukraine in years 1996-2005

Import/export	Water footprint [mil. m³/year]	Poland	Slovakia	Lithuania	Belarus	Ukraine
Import	Green	12 217.1	2 205.0	1 803.0	4 124.2	4 935.1
	Blue	2 530.1	666.6	403.9	631.6	858.1
	Gray	4 056.7	1 362.3	870.2	1 791.6	3 116.9
	Total	16 273.8	4 233.9	3 077.1	6 547.4	8 910.1
Export	Green	6 515.7	1 749.4	2 046.9	733.3	17 592.8
	Blue	1 407.9	350.1	336.0	152.7	1 065.7
	Gray	3 547.7	1 069.7	439.1	518.8	6 658.0
	Total	11 471.3	2 099.5	2 822.0	1 404.8	25 316.5
Net virtual water import	Green	5 701.4	455.5	- 243.9	3 390.9	- 12 658.0
	Blue	1 122.2	316.5	67.8	479.0	- 207.6
	Gray	509.0	292.5	431.0	1 272.8	- 3 541.1
	Total	7 332.6	1 064.5	254.9	5 142.7	- 16 406.7
Net green virtual water import per capita [m³/person/year]		147,7	87.6	- 69.7	339.8	- 282.4

Source: Based on Mekonnen (2011b).

Ukraine. This value differs significantly from that of other countries. The second place is occupied by Poland and the remaining countries have a much smaller export of virtual water.

It is expected that no more water is exported than imported from countries exposed to water stress, e.g. steppe climate. On the other hand, countries with rich water resources, e.g. mountain ones, export products with 'exogenous water'. In practice, it is just the opposite. In case of the green footprint, the largest net import of virtual water was recorded for Poland with a continental climate (5.7 billion m³/year). The next place was taken by Belarus (3.4 billion m³/year) and Slovakia (0.5 billion m³/year). More green virtual water is imported to these countries than exported to other countries. The opposite situation is in Lithuania, where net imports reached the value of -0.2 billion m³/year. The worst situation, however, is in Ukraine, where the value of -12.6 billion m³/year was recorded.

Analyzing the net import of blue virtual water, Poland again achieved the highest value (1.1 billion m³/year). The next place was taken by Belarus, Slovakia and Lithuania. Negative value occurred only in Ukraine (-0.2 billion m³/year). The net import of gray virtual water was the largest in Belarus (1.2 billion m³/year). The next place was assigned to Poland, Lithuania and Slovakia. Again, in Ukraine, the net import of virtual water reached a negative value (-3.5 billion m³/year).

The total net virtual water import amounted to 7.3 billion m³/year for Poland; 5.1 billion m³/year for Belarus; 1.1 billion m³/year for Slovakia, 0.3 billion m³/year for Lithuania and a negative value of -16.4 billion m³/year for Ukraine. The values of net virtual water imports have also been recalculated in relation to the number of inhabitants in each country. The per capita net imports of green virtual water in the five surveyed countries are shown in Figure 1.

The highest per capita net import of green virtual water were recorded in Belarus (340 m³/person/year) and in Poland (148 m³/person/year). A positive value of this indicator was also recorded for Slovakia (88 m³/person/year). Other countries described here had negative values: -70 m³/

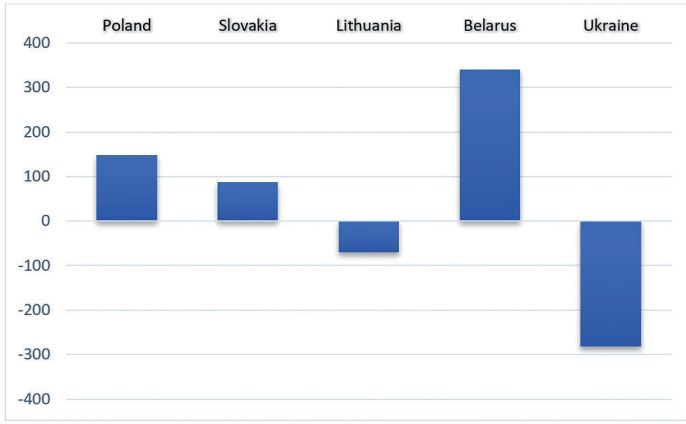

Figure 1. The per capita net imports of green virtual water in Poland, Slovakia, Lithuania, Belarus and Ukraine in the years 1996-2005 in m³/person/year (Gołaszewska 2021)

person/year for Lithuania and -282 m³/person/year for Ukraine. Belarus has achieved the highest value of the per capita net import of green virtual water because, as a country with a smaller economy, it has to import a great many goods from abroad. Poland also achieved a high value of net imports of green virtual water through import of fruit, vegetables, coffee and tea. Poland exports dairy and meat products but these values do not exceed the value of virtual water import. The third place is occupied by Slovakia which, as a richer country, can afford a wider import of products from abroad. Lithuania, as a country with a less developed economy, has a negative per capita net import of virtual water.

Ukraine is in the least favorable situation exporting much more green virtual water than it imports. Taking into account Ukraine's exposure to water stress, this is very risky and destructive for the environment and economy. The country exports mainly products grown in the steppes. Before Russia's aggression in 2022, an additional and very significant burden for this country was heavy industry and the export of steel products. In addition, this sector also generated significant environmental pollution.

Therefore, countries that import virtual water are not sufficiently supplied with water resources. Countries with sufficient and excess supply, i.e. with a supply of more than 25 thousand m³ per capita, export virtual water in the form of agricultural products and industrial goods. The group of largest exporters of virtual water also includes countries with an average supply (5-25 thousand m³ per capita). Thus, it is possible to solve the problem of shortage of water resources by taking advantage of the global economy. International trade can provide water savings on a global scale by selling water-intensive goods from countries with high water availability to countries with low water availability.

Summary and Conclusions

The Central and Eastern European countries described in this paper differ geographically and economically. Taking into account their total water footprint, Ukraine achieved the highest values. The import of virtual water there is much lower than the export. The country disposes of water together with the agricultural goods it exports. In Poland, a country with a similar number of inhabitants and better developed economy, the value of the water footprint was less than half that of Ukraine. The net import of virtual water here reaches the highest value among the described Central and Eastern European countries. The reason for this is

probably the significant import of fruit and vegetables from the Mediterranean region and tropical countries. Another country with a high water footprint is Belarus. There, the net import of virtual water reaches the second highest value. Such a state and regional policy leads to a violation of security in the agricultural sector of Ukraine and requires an immediate review of the strategic goals of the development of agrarian nature management. Lithuania and Slovakia are countries with a similar area and population. They also have a similar total water footprint. However, in Slovakia the net import of virtual water is much higher than in Lithuania.

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