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Partnership on Sustainable Agriculture and Mitigation to Climate Change

Report on the Water Footprint Analysis of Braila - Romania

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CONTENT

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1. Introduction

The water footprint (WFP) measures the amount of water used to produce each of the goods and services we use. It can be measured for a single process, such as growing rice, for a product, such as a pair of jeans, for the fuel we put in our car, or for an entire multi-national company. The water footprint can also tell us how much water is being consumed by a particular country – or globally – in a specific river basin or from an aquifer (https://www.waterfootprint.org/water-footprint-2/what-is-a-water-footprint/) .

The water footprint concept was introduced by Hoekstra in 2002 (Hoekstra, 2003) and takes into account both direct and indirect water consumption (embedded in the product life cycle).

The concept has three components:

- **blue water** (water from surface and underground water bodies);
- **green water** (water from precipitation, part of which is lost through evapotranspiration, and part of which is taken over by vegetation or is embedded into products);
- **gray water** (water required for diluting pollutants from industry, household waste water, polluted water from agriculture, etc.).

$$WFP_{Total} = WFP_{Blue} + WFP_{Green} + WFP_{Grey}$$

Blue is the type of water for which issues related to the process of increasing water productivity and saving it under intensive use raise problems at European level. Issues arise especially when blue water is in direct interdependence with soil and surface water reserves, which are exhaustible, thus affecting the environment and being directly involved in the sustainability process (figure 1)

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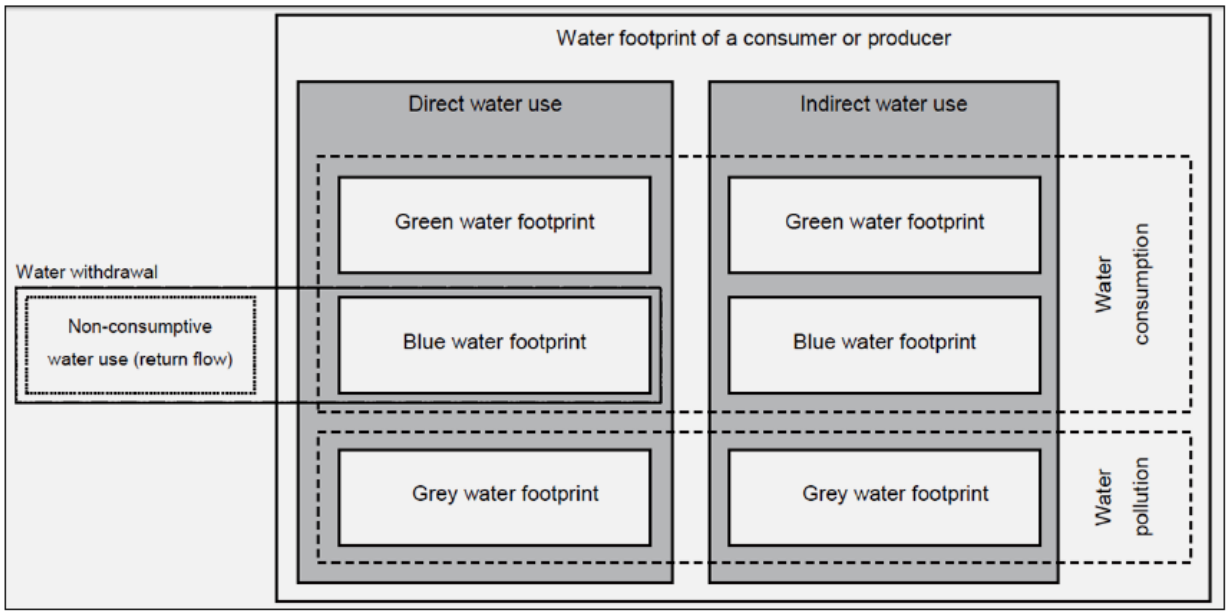

Figure 1 **Concept diagram of water footprint**

In addition, blue water footprint of a given goods or commodity is the volume of freshwater used for production, which in turn depends on the water use in the various steps of the production chain. In case of crops, i.e. crops as they come from the land, without having undergone any secondary processing, and measured in m^3/ton, the estimated amount can be understood as the ratio between the volume of water used (crop water use) during the entire period of crop growth from planting to harvest, and measured as m^3/ha and the corresponding to crop yield in ton/ha. The Blue and Green water can be written as follows :

$$WFP_{Blue} = \frac{CRU_{Blue}}{Y}$$

$$WFP_{Green} = \frac{CRU_{Green}}{Y}$$

Here, *CRU* and *Y* represent crop water use and yield, respectively.

Moreover, the grey water is the pollutant equivalent water consumption for a particular commodity. It calculated (WFP_{grey} , m^3/ton) as the chemical application rate per

hectare (AR, kg/ha), times the leaching factor (α) divided by the maximum acceptable concentration (C_{max} , kg/m^3) minus the natural concentration for pollutant considered (C_{nat} , kg/m^3) and then finally divided by the crop yield (Y, ton/ha).

$$WFP_{Grey} = \frac{(\alpha \times AR)\,(C_{max} - C_{nat})}{Y}$$

The water footprint is an indicator of water use that looks at both direct and indirect water use of a consumer or producer [1].

The *internal water footprint* of a nation is the volume of water used from domestic water resources to produce the goods and services consumed by the inhabitants of the country.

The *external water footprint* of a country is the volume of water used in other countries to produce goods and services imported and consumed by the inhabitants of the country (Chapagain and Hoekstra, 2004) (Figure 2)

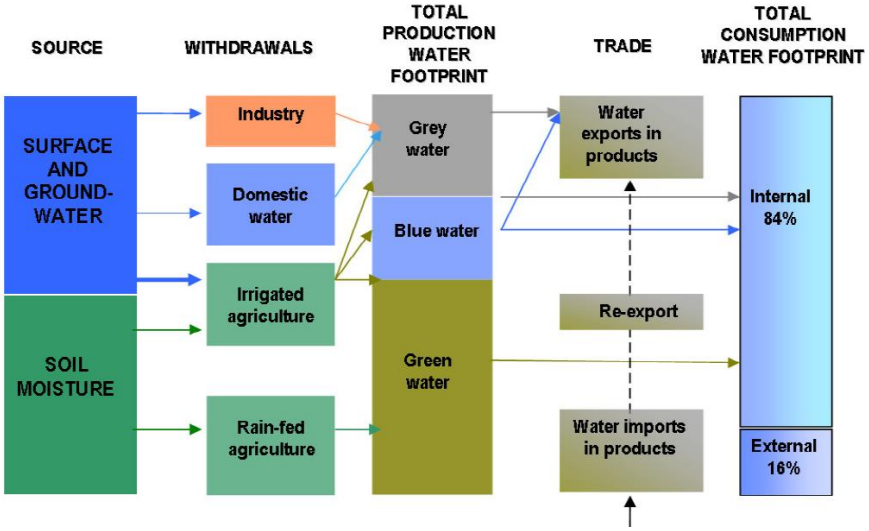

Figure 2Water footprint components [1].

The highest degree of concentration of blue water footprint of per capita national consumption (80,66%) is recorded for agricultural products, according to [2].

The demand for water per product in agriculture concerns both vegetable and animal products. The values take into consideration all the water volume registered at the national level, both from natural process and from irrigation (without losses) and retained in the soil, needed for plant production.

The water content of virtual agricultural products varies from one country to another according to the relief, climate, technology adopted for agriculture, but also to the levels of yields obtained. Thus, on the external component, allocation of green water footprint of per capita consumption of agricultural products per countries, although different from the internal one, still maintains the direction of lack of uniformity.

Within this context, it is noted that the first group includes countries: Romania, Lithuania, Poland, Latvia, Slovakia, Bulgaria, and Hungary. They represent 10,03% of the total number of countries and it receives 25,00% of the total green water footprint of per capita consumption of agricultural products. This group includes the countries with the lowest values of green water footprint of per capita consumption of agricultural products which oscillates between 161,5 – 401,39 m3/yr/cap according to [2].

Agricultural production is the main consumer of water, especially the production of animal foods, which have large WFs.

In 2011, the global water footprint (WF) of agricultural production was 8362 km^3 /year (80% green, 11% blue, and 9% grey) [3]. World water demand is expected to increase by 20%–30% until 2050 [4]. Demand for land and water resources has increased significantly, and these resources are expected to be scarcer in the future. Efficient water management in agriculture is needed to meet the growing demand for food and reduce poverty and hunger in a sustainable manner. The question is how the world will feed the global population without further impacting the freshwater and ecosystems.

Many global studies have assessed the water needed to produce crops at a high spatial resolution [5-11]. Estimates of the global consumptive (green plus blue) WF of crop production range from 5938 to 8508 km^3 /year (Table 1). The differences in the WF estimates are due to differences in the modeling approach, input data, including climate and cultivated area, the number of crops and their specification, and the models used. In terms of product coverage, Mekonnen and Hoekstra [10] explicitly estimated the WF of 146 individual crops, while the other authors included 20 or fewer individual crops and grouped the rest of the crops into two or four major groups. Although the estimated future global WF related to crop production under climate and land use change[12] was within the range of the estimates for the current period, Huang, Hejazi, Tang, Vernon, Liu, Chen, and Calvin [12] , projected that the WF under climate and land use change will crease by as much as 22%. The increase in the

WF is particularly large for the blue WF, which will increase by 70% by 2090, due to expansion in global irrigated area. About 86% of the consumptive WF of crop production was related to the production of crops that can be used directly for human food consumption [10] . The other 14% was for fodder crops, fiber, rubber, and tobacco. Some of the food crops, such as maize, rapeseed, palm oil fruit, soybeans, and sunflower, are also used for biofuel production. This will lower the total WF that is used for human food consumption (Figure 3).

Table 1 Estimates of the consumptive water footprint (WF) of global crop production

Period	Products Coverage	Global Water Footprint Related to Crop Production (km^3/year)		
		Green	Blue	Total
1997–2001	164 individual crops	5330	1060	6390
1998–2002	20 individual crops and 6 major groups	5505	1180	6685
1998–2002	17 individual crops and 5 major groups	4987	951	5938
1985–1999	Assumed 1 major crop per grid	5550	1530	7080
1998–2002	12 crop functional types	6000	923	6923
1996–2005	146 individual crops	5771	899	6670
1971–2000	12 crop functional types	7250 [1]	600–1258	7850–8508 [1]
1971–2000		4887	1121	6008
2071–2099	12 crop categories	5440	1909	7349

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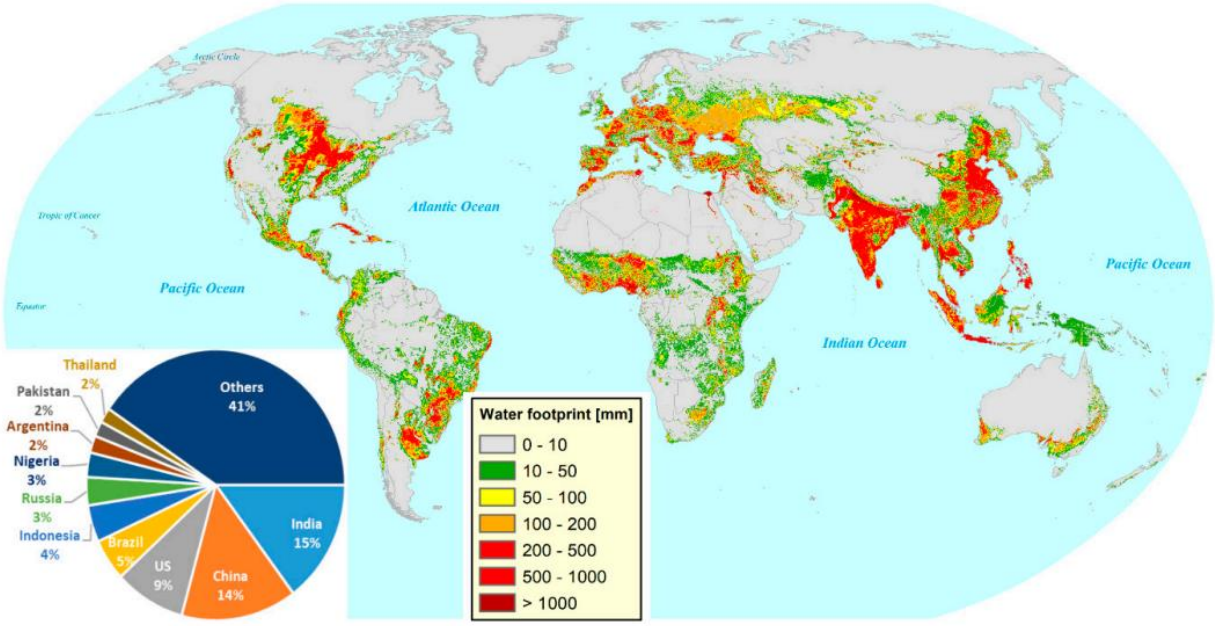

Figure 3 The total (green, blue and grey) water footprint of food crops production. Source from Mekonnen and Hoekstra [10].

2. Assessment on water footprint in Romania

Romania can be considered among the countries with relatively poor water resources (related to the number of inhabitants) as compared with other European countries. Moreover the water resources are unevenly distributed in space.

The Romanian potential of fresh water resources is of 143.8 billions m^3 shared as follows:

- 42 billions m^3 from the inside rivers;
- 90 billions m^3 from the Danube river;
- 1.0 billions m^3 from the natural lakes;
- 10.8 billions m^3 from groundwater.

The useable water potential is only about 41- 51 billions m^3 due to the following factors:

- the river flow regime of inside rivers of Romania does not allow to exploit in natural conditions more then 5.0 billions m^3 to which one might add 12.0 billions m^3 released from the reservoirs;
- the requested constrains concerning the navigation along the Danube river which offers about 20-30 billions m^3;
- natural lakes are not intensively used (only for local consumption);
- the technical useable groundwater resources are estimated at about 5.5 billions m^3.

The water resources available are quantitative and qualitative influenced by human activities
(intensives uses closed of the limit of socio-economic resources and discharges of pollutants). According to Chapagain and Hoekstra who studied in 2004 the water footprint of nations, for Romania, water scarcity and water import dependency between 1997-2001 are presented in Table 2, and water footprint of Romania, related to the use of domestic water resources, the use of foreign resources and the water footprint by consumption categories is presented in Table 3 and Table 4 Romania is quite poor in water resources, with 1700 m3/inhabitant/year, ranking it 13th in Europe. Specific mean flow is under 1 l/s.km^2 on the Romanian, Dobrogea, Timis and Arad Plains and 40 L/s.km^2 in the high zones of the Fagaras and Retezat mountains. The river network comprises 78,905 km.

Table 2 Water footprint versus water scarcity, self sufficienty and water import dependency per country between 1997-2001[13]

Country codes FAO-STAT	*Country*	*Total renewable water resources*	*Internal water footprint*	*External water footprint*	*Total water footprint*	*Water scarcity*	*Water self-sufficiency*	*Water import dependency*
		$10^9 m^3$/year	*$10^9 m^3$/year*	*$10^9 m^3$/year*	*$10^9 m^3$/year*	*%*	*%*	*%*
183	Romania	211.93	34.60	4.33	38.92	18	89	11

Table 3 Water footprint of Romania between 19978-2001 [13]

Country codes FAO-STAT	*Country*	*Population*	*Use of domestic water resources*					*Use of foreign water resources*		
			Domestic water withdrawal	*Crop evapotranspiration*		*Industrial water withdrawal*		*For national consumption*		*For re-export of imported products*
				For national consumption	*For export*	*For national consumption*	*For export*	*Agricultural goods*	*Industrial goods*	
			$10^9 m^3$/year	*$10^9 m^3$/year*	*$10^9 m^3$/year*	*$10^9 m^3$/year*	*$10^9 m^3$/year*	*$10^9 m^3$/year*	*$10^9 m^3$/year*	*$10^9 m^3$/year*
183	Romania	22450998	2.04	29.03	2.51	3.527	4.75	3.99	0.34	0.80

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Table 4 Water foot print by consumption category [13]

Country codes FAO-STAT	Country	Water footprint		Water footprint by consumption category				
		Total	Per capita	Consumption of domestic water	Consumption of agricultural goods		Consumption of industrial goods	
				Internal water footprint	Internal water footprint	External water footprint	Internal water footprint	External water footprint
		$10^9 m^3$/year	m^3/cap/year	m^3/cap/year	m^3/cap/year	m^3/cap/year	m^3/cap/year	m^3/cap/year
183	Romania	38.92	1734	91	1293	178	157	15

The agricultural sector plays an important role in Romania, with about 30% of the total population engaged in different agricultural activities, compared to only 3%-14% of the population occupied in agriculture in other European countries[14] [15] . There is a major difference between rural and urban areas, residents living in rural areas are marked by a significantly higher level of poverty and by a lower standard of living compared to residents living in urban areas. Most Romanian farmers suffer from a lack of a clearly defined professional status, which has negative or ambiguous implications for the tax plan and social and health insurance. It is also reflected in the fact that the majority of those involved in agriculture in Romania do not have the necessary professional training to provide them with an adequate level of knowledge and skills suitable for the competitive agricultural sector [16,17].

Therefore, most Romanian farmers rely solely on their practical experience and only 7% of farmers have agricultural training. Although this is not uncommon in the EU, the lack of agricultural education is more severe in Romania [18].

Agriculture in Romania is one of the few branches of the economy that has put Romania at the forefront of the European tops.

For example, in 2016, Romania ranked first in the European Union's sunflower production tops and second in wheat and maize production, after France, according to data from the National Statistics Institute (NSI) [19] . At the national level, agriculture is one of the important branches of the Romanian economy. Thus, the contribution of agriculture, forestry and fish farming to the building up of the Gross Domestic Product (GDP) is around 6% in Romania, while, in the European Member States, the contribution to GDP from agriculture is around 1.7%. However, Romania's agriculture cannot reach its full potential because of the massive fragmentation of agricultural areas, of the lack of technology and of

efficient irrigation systems. These are some aspects for which Romania has fluctuating production per ha in the main crops, compared to the other Member States of the European Union [20] .

Agriculture has become one of the sectors most vulnerable to climate change and the forecasts say that this trend will increase [21] . The current irrigation system continues to face problems caused by the location and poor technical condition of the irrigation infrastructure, resulting in a high cost of water, which only large farmers can afford to pay. This is the main reason influencing the production of small and medium-sized farmers in terms of the climate conditions of the year. In the years of drought, the farms often record low yields per ha [22].

3. WFP for wheat, corn, sunflower, potato, and tomato crops

3.1 The assessment of main agricultural crops in Romania /Brăila county

The area of Romania is 23,839,071 ha, of which 61% is agricultural land (Figure 4).

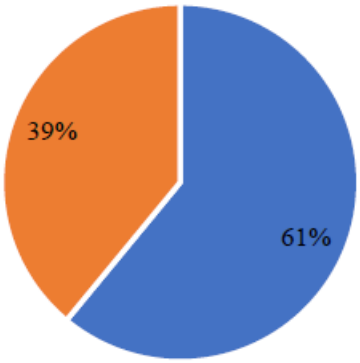

Figure 4 Share of agricultural area of total area of Romania

The largest agricultural areas are arable areas (64% of agricultural land), followed by pastures and meadows (33% of agricultural land). Forests cover an area of 6,800,872 ha, representing 29% of the country's territory, with 0.32 ha of forested land per capita. In 2019, compared to 2018, agricultural crop production increased in grain legumes and decreases in grain cereals, oil plants, sugar beet, fodder beet, tobacco, potatoes – total, vegetables – total, green fodder from arable land, orchards on fruit and vineyards on fruit. Grain crops with significant shares of cereal production in 2019 were grain maize (56.9%), wheat (33.9%), barley and two-row barley (6.5%) (Figure 5).

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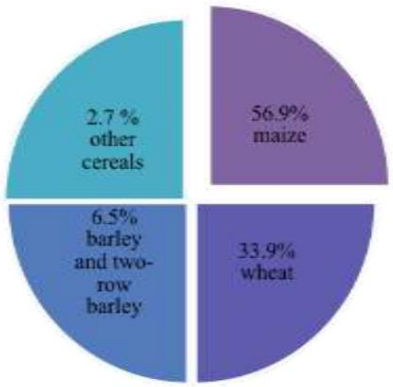


Figure 5 Areas cultivated with the main grain cereals, 2019 according [18]

Counties with a higher share of the total sunflower production were Dolj (9.4%), Timiș (7.8%), Brăila (7.5%), Teleorman (6.6%), and Constanța (6.5%) (Figure 6).

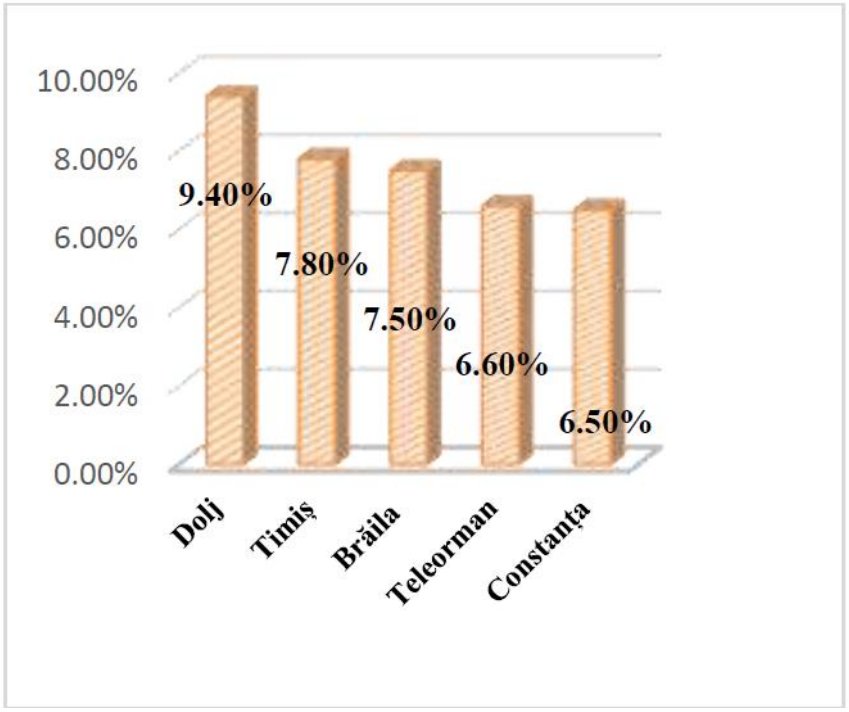


Figure 6 Main sunflower growing counties, 2019 [18]

In terms of wheat cultivation, Romania ranked fourth (8.2%) after France, Germany and Poland, and the share of the European Union's total wheat-cultivated area decreased by 0.1% compared to the previous year (Figure 7).

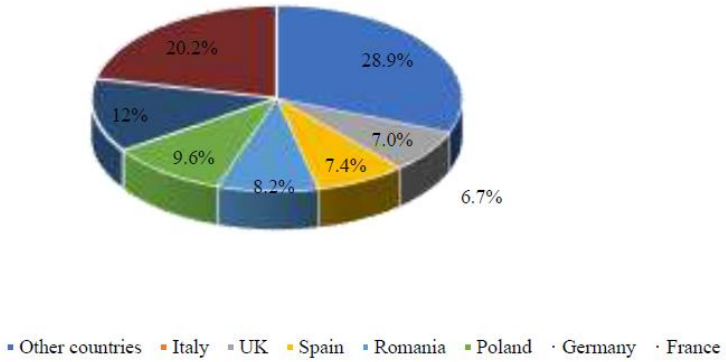
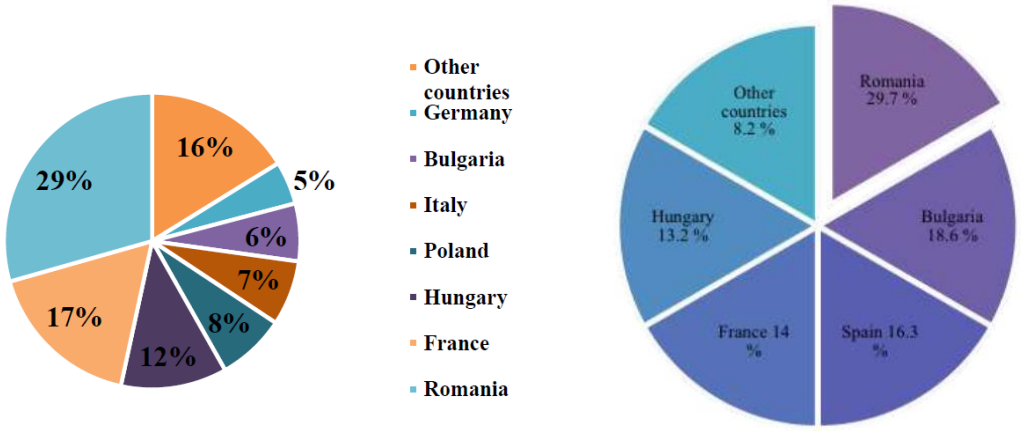


Figure 7 Areas cultivated with wheat in the EU, 2019
Source: Data processed after Eurostat[21]

Romania, the largest grain maize grower in 2018 and 2019 in the European Union (more than one-fourth) (Fig. 8). In 2018, its share in the EU cultivated area with maize was 29% and in 2019 it increased at 29.7%. In 2018, Romania was followed by France whise share in the EU-28 cultivated area accounted for 17%, and Italy with 16% (Figure 8a). In 2019, Romania was followed by Bulgaria which kept 18.6% and Spain with 16.3% (Figure 8b).



(b)

(a)

Figure 8 Areas cultivated with grain maize in the EU : (a) 2018, (b) 2019

In Romania, 6.5% of the total wheat production of the European Union was obtained in 2019, with our country ranking fifth among Member States, after countries such as France, Germany, the United Kingdom, and Poland. In 2019, Romania cultivated the largest area with grain maize in the European Union and also obtained the largest production. As regards sunflower production, Romania ranked first among Member States, followed by Bulgaria, Hungary, France, and Spain. Rape production placed Romania in the top seven Member States.

3.2 Water Consumption in Romanian Agriculture

A survey on the consumption of water from the irrigation of the main crops in Romania, in the sectors as fruits and vegetables, crops, plants and medicinal herbs and medicinal and aromatic plants emphasized that in during 2007-2011 the consumption of water for the crops was about 40730920 thousand m^3/ha, the plants with the highest consumption of water as plants vegetables, followed by field crops [23].

In the year 2011, the area cultivated with vegetables, and solariums in the field was 232,9 hectares and the production was of 3302,5 thousand tons. Data on the evolution of the area and production are showed in the tables 5, 6 and 7.

Table 5. The evolution of the area and vegetables production

Specification	UM	2007	2008	2009	2010	2011*
Area	thousands ha	253.4	268.6	267.1	262.7	232.9
Total production	thousands t	3116.8	3819.9	3901.9	3863.6	3302.5

*Source: INS - Statistical Yearbook of Romania, 2007-2010 * Dates MASR-AGR 2B* [24]

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Table 6. Data on the evolution of the area and production of tomatoes, onions, cabbage, peppers and other vegetables

Culture	Specification	UM	2007	2008	2009	2010	2011*
Tomatoes	Surface	thousands ha	46.0	51.5	49.1	49.8	47.1
	Total production	thousands t	640.8	814.4	755.6	768.5	809.4
Cheap	Surface	thousands ha	34.1	35.0	35.2	33.8	32.7
	Total production	thousands t	325.0	395.6	378.1	369.1	387.9
Bars	Surface	thousands ha	46.1	49.0	48.3	47.0	43.6
	Total production	thousands t	893.2	964.6	1001.9	981.2	1037.2
Arden	Surface	thousands ha	18.6	20.2	20.0	21.0	19.4
	Total production	thousands t	184.9	238.7	245.7	243.5	245.2
Other	Surface	thousands ha	108.6	112.9	114.5	111.1	90.1
	Total production	thousands t	1072.9	1406.6	1520.6	1501.3	822.8

*Source: INS - Statistical Yearbook of Romania, 2007-2010 * Dates MASR-AGR 2B* [24]

In terms of irrigating vegetables in table 3 it could seen the amount of water needed for cultivation of vegetables.

Table 7. The number of watering and norms appropriate for different vegetal cultures

No.	Specie	No. of watering [23]	Norm of watering [m^3/ha]
1.	Tomatoes	7 - 8	300 - 350
2.	Onion	7 - 8	300 - 350
3.	Cabbage	5 - 6	300 - 400
4.	Pepper	9 - 10	350 - 400
5.	Eggplant	9 - 10	400
6.	Garlic	3 - 5	300 - 350
7.	Beans	3 - 4	300
8.	Leeks	5 - 8	300 - 350
9.	Peas	3	300
10.	Carrots	7 - 9	300 - 350
11.	Beetroot	5 - 6	300 - 350
12.	Cucumbers	4 - 5	300
13.	Zucchini	4 - 5	300
14.	Melons	3 - 4	300
15.	Watermelons	3 - 4	300
16.	Cauliflower	7 - 8	400
17.	Salad	2 - 3	200 - 250

According to the data from table 7, one can calculate the amount of water to the vegetable plants in the period 2007 - 2011 (figure 9).

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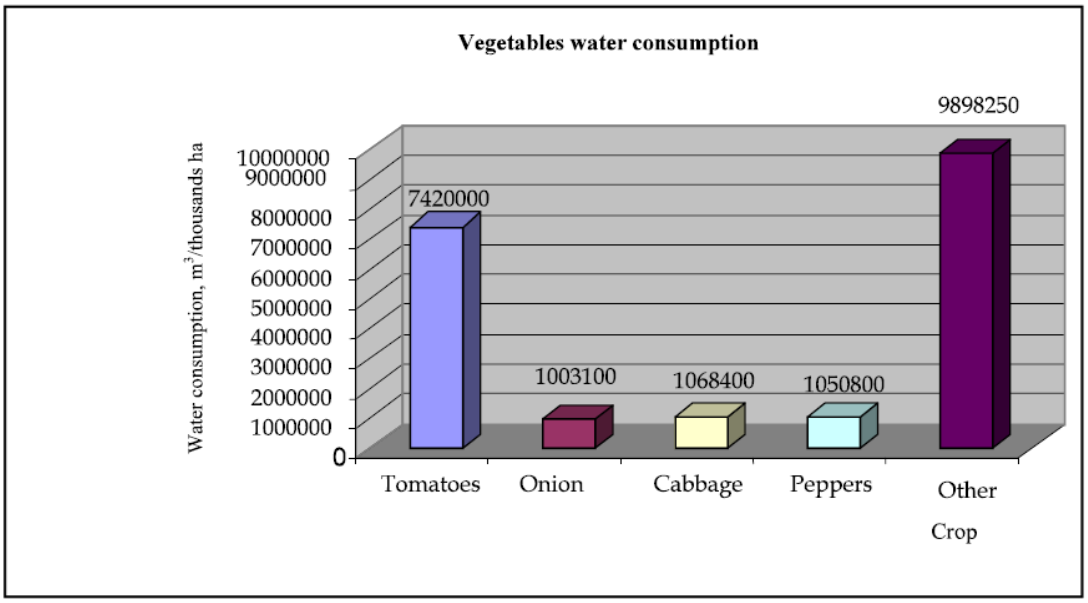

Figure 9. Water consumption of vegetable in Romania (m^3/thousands ha) during the period 2007 - 2011

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3.3 The field crops

The field crops may be framed into several categories, namely: cereal, technical plants and herbs and medicinal herbs (figure 10)

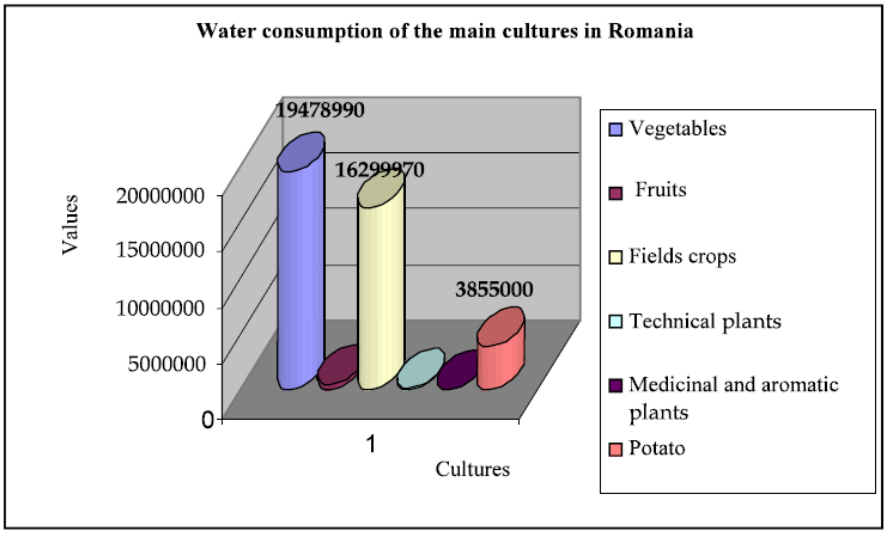

Figure 10. Crop water consumption in Romania (m^3/hectares) during the period 2007 - 2011

For this reason, we treated the watering issue accordingly (tables 8 - 11). Wheat and corn are the concerned cereals in this study.

The norm for watering is 300 - 400 m^3 water/hectare and is made only in dry areas (southern Romania), in the Transylvania irrigate less often, in very dry periods. At a rate of 350 watering m^3/ha, water requirements (table 8) will be 10,277,470 m^3/thousands ha by watering. If the planting soil moisture is low sin u ensure a smooth East, will be applied after planting to watering of 200 - 250 m^3/ha. The rules of watering will be 500 m^3/ha and will be applied whenever the need arises. At a rate of 250 watering m^3/ha, water requirements will be of 6,022,500 m^3/hectares by watering in the period 2007 - 2011.

Table 8. Data on the evolution of the area and wheat production in Romania [25]

Specification	UM	2007	2008	2009	2010	2011*
Area	thousands ha	1975.0	2110.3	2148.8	2162.4	1977.7
Average production	Kg/ha	1541	3403	2421	2688	3637
Total production	thousands t	3044.5	7181.0	5202.5	5811.8	7192.2

Table 9. Data on the water requirements for wheat

Specification	UM	2007	2008	2009	2010	2011*	Total
Area	thousands ha	1975.0	2110.3	2148.8	2162.4	1977.7	
Water requirements	m^3/thousands ha	691250	7385105	752080	756840	692195	10277470

Table 10. Data on the evolution of the area and corn production in Romania [25]

Specification	UM	2007	2008	2009	2010	2011*
Area	thousands ha	2525.8	2449.5	2344.9	2108.7	2616.1
Average production	Kg/ha	1526	3213	3406	4297	4480
Total production	thousands t	3855.1	7870.0	7987.7	9060.7	11720.2

Table 11. Data on the water requirements for corn [25]

Specification	UM	2007	2008	2009	2010	2011*	Total
Area	thousands ha	2525.8	2449.5	2344.9	2108.7	2616.1	
Water requirements	m^3/thousands ha	1262900	1224750	1172450	1054350	1308050	6022500

3.4 The potato culture

Potato is a very extensive culture in Romania. The norm of watering is 500-700 m^3/ha, 5 - 6 watering/ year. At a watering rate of 600 m^3/ha/year, 5 watering, water consumption in the period 2007 - 2011 is going to be 3855000 thousand m^3/ha (table 12, 13). The water consumption in analyzed crop cultures (vegetables, fruits, field crops, technical plants, medicinal and aromatic plants, potato) is presented in figure 10.

Table 12 Data on evolution of the area and potato production in Romania [25]

Specification	UM	2007	2008	2009	2010	2011*	Total
Area	thousands ha	253.4	268.6	267.1	262.7	232.9	1284.7

Table 13 Data on the water requirement for potato crops [25]

Specification	UM	2007	2008	2009	2010	2011*	Total
Area	thousands ha	253.4	268.6	267.1	262.7	232.9	1284.7
Water requirements	m^3/thousands ha	761100	805800	801300	788100	698700	3855000

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