The peculiarities of the water use in the Danube-Prut and Black Sea hydrographical district (sector of the Republic of Moldova)

Petru BACAL[1]* and Daniela BURDUJA[1]
[1]Institute of Ecology and Geography, Chişinău, Republic of Moldova

*Correspondence to: Petru BACAL. E-mail: pbacal16@gmail.com.

Vol. 33.1/2023, 1-18

Published:
24 July 2023

DOI:
10.4316/GEOREVIEW.2023.01.01

ABSTRACT: The purpose of present study is the assessment of water use at the hydrographic basins level. The main objectives of this study are: the analysis of volumes of abstracted water by the catchment sources; the evaluation of the volumes of water used by the main usage categories; the dynamics of the volume of abstracted and used water in the years 2003-2021. The study area includes the Danube-Prut and Black Sea Hydrographic District and the related main river basins. The main methods used in this study are: statistical, analytical, comparative, cartographic, as well as consultation of authorities in the field of water use. Despite the large share (43%) of the total area, the Danube-Prut and Black Sea Hydrographic District accounts for only about 4% of the total volume of abstracted and used water from the Republic of Moldova, which is due to the very pronounced rural and agrarian character compared to the Dniester Hydrographic District. During the analyzed period, there is an oscillating evolution of the volume of abstracted and used water, against the background of a general negative trend, interrupted in the years 2007, 2009 and 2020, with longer droughts. In recent years (2015-2021), it was registered a positive dynamic, which is manifested in all the analyzed river basins and categories of water use, which is due especially to the multiple expansion (more than 3 times) of the rural public aqueducts.

KEY WORDS: Danube, Prut, Black Sea, water use, agriculture, households.

1. Introduction

Compared to the Dniester Hydrographic District (HD), the Danube-Prut and Black Sea (DPBS) HD has a much smaller contribution to the water supply of the Republic of Moldova. This hydrographic district accounts for only 4.0% of the total volume of abstracted and used water in the Republic of Moldova and about 20% − on the right side of the Dniester River (RS DR). Despite the much smaller share, DPBS HD has a significant contribution in the water supply to urban and rural localities in the western and in the southern part of the Republic, including the Briceni, Edineț, Glodeni, Fălești, Ungheni, Nisporeni, Hâncești, Cimișlia, Comrat, Ceadâr-Lunga and Cahul towns. Thus, the volume of abstracted and used water is conditioned by the area of the respective districts and by the size of their urban centers, by the degree of access to the Prut riverbed and by the technical capacities

for capturing and transporting of water, as well as by consumption of water for agricultural and household purposes. The border regime of the Prut River significantly limits the access of the population and of companies to this source of quality water. In addition, restricting access has a significant impact on the fishing and recreational uses in the riverside area of the Prut River and considerably diminishes the direct and indirect benefits of this important aquatic objective.

In the former USSR, there were published numerous studies related to the economic assessment of water resources and their role in meeting economic and social needs and in the development of various economic sectors, among which we mention those elaborated by Anuchin (1978), Bevza (1983), Neverov (1990), Belicenco (1990) and Reimers (1990). According to Savina (1990), the rational use of water resources is a system of organizational measures aimed to creating real opportunities for more economic and efficient use of water resources. At international level, there is more research focused on the analysis of water use, especially on domestic water use by Mazzoni et al. (2023), Makki et al. (2013) and on sustainable water use by Freitas et al. (2022), Sebusang (2022).

The present research is based on the Water Framework Directive 2000/60/EC (2000) and its Guideline (2003) regarding to the economic and environmental analysis of water use and of integrated management of river basins. In this context, the authors of present study have focused on the Management Plan of Danube River Basin (2015, 2021), Prut-Bârlad Hydrographic Space (2017) and on the other river basins, which are included in the EU Project Environmental Protection of International River Basins (EPIRB, 2012-2016) and in the European Union Water Initiative Plus for the Eastern Partnership (EUWI+, 2019). Additionally in this paper, it was completed and updated the analysis of water use developed by the authors in the Management Plans of the Districts and hydrographic basins of the Republic of Moldova, including of Dniester (2017) and of Danube Prut and Black Sea Hydrographical Districts (Bejan et al., 2017), the Management Plans of Prut (Bejan et al., 2016), Camenca (Bejan et al., 2019) and Larga (Gâlcă et al., 2020) river basins.

The methodological novelty of this study consists in the complex assessment of water use of a hydrographic district with a very pronounced agrarian and rural character in the context of socio-economic transformations and of intensification of climate change from the last decades.

The present study is a continuation of our researches regarding to the water use analysis on the hydrographic district and river basins from Republic of Moldova, particularly on the Dniester Hydrographic District, recently published by us in the PESD Journal (Bacal et. al, 2022b). Therefore, the main objectives, the informational and methodological support, which are common to both studies, with different research areas and peculiarities of water use. In addition, unlike to the previous article, the present article includes the analysis of abstracted and used water in the 2021 year, with much more abundant rainfall and with a lower consumption of water for agricultural needs than in the 2020 year, with an extreme deficit of rainfall and a maximum water use.

The main objectives of present study are: a) analysis of the volumes of abstracted water by the catchment sources; b) the evaluation of the volumes of water used by the main usage categories; c) the dynamics of the volume of abstracted water by catchment sources; d) the assessment of water consumption trends by the main usage categories and their differences between river basins of this hydrographic districts; e) the identification of the actual problems of water use systems from DPBS HD.

2. Data and Methods

The main informational and statistical support of this study included: 1) Annual Reports of Water Agency from Republic of Moldova "Water use in the Republic of Moldova", 2004-2022; 2) Yearbooks on the quality of environmental factors and on the activity of Ecological Agencies and Inspections, 2004-2022; 3) The Report of National Bureau of Statistics on the public water supply systems and the number of present population, 2022. The study comprised, especially, the 2003-2021 years, but the data at the level of hydrographic district are also analyzed since 1990 year.

The methodological concepts of the present study aimed the complex economic-geographic assessment of the water use in the hydrographic basins. These include the assessment of water consumption and its dynamics by: catchment sources (surface and underground); the main usage categories of water; the river basins and the administrative-territorial units from this hydrographic district. Also, are estimated the current challenges in the field of water use, in particular the deep crisis of traditional agriculture, the massive depopulation of rural areas, accelerated climate changes and the reduced capacities to adapt to them, as well as the opportunities offered by the extension of the key aqueducts and of water distribution networks for household and irrigation purposes, the rational use of water for agriculture and domestic purposes.

The main methods, which are used in this study, are: statistical, analytical, deductive, comparative and cartographical methods. including GIS technique. Statistical method was used in processing of data on the water use by the main river basins and by administrative districts and municipalities from this hydrographic district. The analytical method was used, especially for: a) evaluation the dynamics of the volumes of abstracted and used water, per total, from surface and underground sources and by main categories of use; b) analysis of water use indices at the level of hydrographic district, river basins and administrative-territorial units; c) assessment of problems and perspectives for the development of water supply. The comparative method was applied for evaluating of water use indices in comparison with Dniester HD, as well as for hydrographic spaces and river basins from DPBS HD. The cartographic methods, based on GIS techniques, allowed more relevant spatial representation of water use per general, by catchment sources and by main categories of use on the administrative-territorial units and on river basin from DPBS HD.

3. Study area

The Danube-Prut Black Sea Hydrographic District (DPBS HD) occupies an area of 14.7 thousand km^2 or ≈43% of the area of the Republic of Moldova. The total number of population from DPBS HD is 1.1 million inhabitants or 30% of the total population of the Republic of Moldova. The DPBS HD includes the territory of 17 administrative districts, of which: in full − 8 districts (Briceni, Hâncești, Leova, Cantemir, Cahul, Cimișlia, Basarabeasca, Taraclia) and Autonomous Territorial Unit (ATU) Găgăuzia; almost entirely (without 1-2 villages) − 3 districts (Edineț, Glodeni and Nisporeni). Also, the majority of the territory of Fălești and Ungheni districts (80%), Râșcani (60%) and ½ of Ocnița district is located in the Prut river basin. In addition, the eastern part of the Hâncești district is situated in the Cogâlnic river basin and majority of Stefan Vodă district − in the Hadjider and Sărata river basins (Figure 1), which flows into the estuaries of the Black Sea on the territory of Ukraine.

The majority of the territory from the southern part of Republic of Moldova is situated within the Danube-Black Sea Hydrographic Space (DBS HS), including the basins of the rivers Ialpug (ATU Găgăuzia, Cantemir and Cahul districts), Cogâlnic (Cimișlia, Basarabeasca and Căușeni districts), Sărata and Hadjider rivers (Căușeni and Ștefan-Vodă districts). In the basin of the Prut River are located the absolute majority of the localities of the Leova district, as well as the localities of the

Cantemir and Cahul districts located in the meadow of this river. In the DBS HS are located majority (over 60%) of the Ștefan Vodă district and about ¼ – of the Căușeni district.

Danube-Prut and the Black Sea HD concentrate about 30% of the available surface water resources of the Republic, these being concentrated in rivers, natural lakes and reservoirs. This hydrographic district includes rivers, lakes and ponds, which can be grouped into 3 distinct hydrographic basins: the Prut river basin, the basins of small and medium-sized rivers, with discharge into the Danube estuaries (Cahul, Ialpug, Catlabuh and Kitai) and the rivers of the basins with discharge into the *limans* of the Black Sea (Cogâlnic, Sărata, Hagider, Căplani).

4. Results and discussion

4.1 The volume of abstracted water

In the period of 2003-2021, in the perimeter of DPBS HD, there were abstracted, on average, 33.8 million m^3 of water (Table 1), including 23.1 million m^3 (68%) from the Prut basin and 10.7 million m^3 (32%) from the DBS HS. In the perimeter of Danube Black Sea Hydrographic Space, more than 3/4 of the water is captured from the Ialpug (49% or 5.3 million m^3) and Cogâlnic (29% or 3.1 million m^3) river basins, which is conditioned both by the larger area large, as well as the presence of urban centers in the respective basins: Hâncești and Cimișlia – in the Cogâlnic hydrographic basin (HB); Comrat, Ceadâr-Lunga and Taraclia – in the Ialpug HB. The other rivers from the DBS HS are only a local importance, being used mainly for agricultural and fishing purposes (Bacal, 2017).

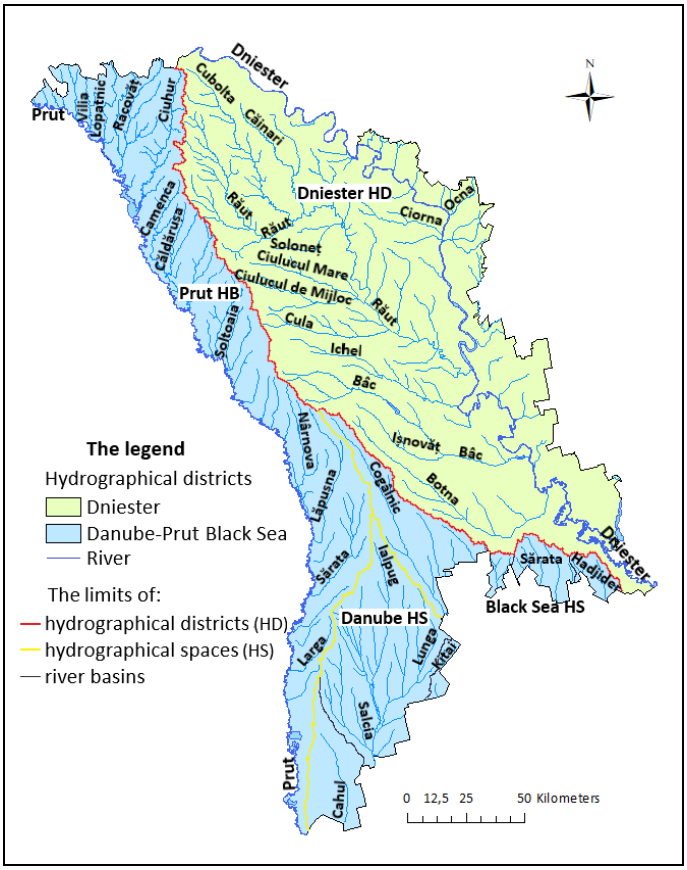

Figure 1 The hydrographical districts of the Republic of Moldova.

The maximum volume of water was abstracted in the districts of Briceni (4.9 million m^3), Cahul (3.8 million m^3), Edineț (3.7 million m^3), Ungheni (3.3 million m^3), in which are located the main water pumping stations from the Prut River and the larger urban centers, as well as in the ATU Găgăuzia with a larger area, a higher level of urbanization and of access to public aqueducts supplied from underground sources (NBS, 2022). The minimum volume of abstracted water can be seen in the districts with smaller sizes and urban centers, but also with lower irrigation capacities, including in districts of Cantemir (1.3 million m^3), Glodeni (1.2 million m^3), Leova (1.1 million m^3), Nisporeni (971 thousand m^3), Basarabeasca (924 thousand m^3) and Ocnița (660 thousand m^3).

Table 1 The volume of abstracted water, by catchement sources, in the DPBS HD and in the its main river basins, in million m^3 (average of 2003-2021 years).

Hydrographic Basins	Total			from surface sources				from underground sources			
	Volume	Share from		Volume	Share from			Volume	Share from		
		RM	RS DR		RM	RS DR	%		RM	RS DR	%
Dniester HD	**816**	**96**	**79**	**708**	**98**	**88**	**87**	**108**	**83**	**61**	**13**
Prut	**23.1**	**2.6**	**14**	**10.3**	**1.4**	**10**	**45**	**12.7**	**10**	**23**	**55**
Prut riverbed	9.2	1.2	6.2	7.4	1.0	7.0	81	1.7	1.3	3.2	19
Ialpug	5.3	0.7	3.8	0.8	0.1	0.8	15	4.5	3.4	8.2	85
Cahul	0.9	0.1	0.4	0.3	0.1	0.4	38	0.5	0.4	1.0	62
Cogâlnic	3.1	0.4	2.3	0.3	0.0	0.3	10	2.8	2.1	5.1	90
Kitai	0.3	0.0	0.2	0.1	0.0	0.1	17	0.3	0.21	0.5	83
Sărata	0.6	0.1	0.4	0.1	0.0	0.1	12	0.5	0.38	0.9	88
Hadjider	0.6	0.1	0.4	0.4	0.1	0.3	66	0.2	0.14	0.3	34
DBS HS	**10.7**	**1.4**	**7.4**	**1.9**	**0.3**	**1.9**	**18**	**8.7**	**7**	**16**	**82**
DPBS HD	**33.8**	**4.0**	**21**	**12.3**	**1.7**	**12**	**36**	**21.5**	**17**	**39**	**64**

Data source: *Water Agency of the Republic of Moldova, 2004-2022*

The maximum volume of water was abstracted in the districts of Briceni (4.9 million m^3), Cahul (3.8 million m^3), Edineț (3.7 million m^3), Ungheni (3.3 million m^3), in which are located the main water pumping stations from the Prut river and the larger urban centers, as well as in the ATU Găgăuzia with a larger area, a higher level of urbanization and of access to public aqueducts supplied from underground sources (NBS, 2022). The minimum volume of abstracted water can be seen in the districts with smaller sizes and urban centers, but also with lower irrigation capacities (Bejan et al., 2017), including in Cantemir (1.3 million m^3), Glodeni (1.2 million m^3), Leova (1.1 million m^3), Nisporeni (971 thousand m^3), Basarabeasca (924 thousand m^3) and Ocnița (660 thousand m^3).

On average, 64% (21.5 mil. m^3) of abstracted water comes from underground sources, including 55% in the Prut river basin and 82% in the DBS HS (Table 1). The maximum share (>80%) of water captured from underground sources is found in the Hâncești and Cimișlia administrative districts (Figure 2), located in the Cogâlnic river basin and in the ATU Găgăuzia, located in the Ialpug river basin. Surface sources predominate only in the Edineț, Ungheni and Cahul administrative districts, with larger urban centers, which are supplied from the Prut riverbed (Bacal, 2016).

The volume of abstracted water from surface sources was, on average, 12.3 million m^3, including 10.3 million m^3 in the Prut river basin and 1.9 million m^3 – in the DBS HS. Due to the low flow and the intensification of climate aridification processes, the exploitation capacity of surface sources is reduced. In addition, groundwater has increased mineralization, which significantly limits the development of irrigated agriculture (Bacal et al., 2017a).

In the DPBS HD, in the 1990-2002 years, there is a reduction about 13 times of the volume of abstracted water (from about 450 million m^3 to only 33.7 million m^3). This situation is mainly due to the similar reduction of water used for irrigation and other agricultural activities which are in the deep crisis. In the period of 2003-2021 years, similar to Dniester HD, there is a general negative dynamic (1.3 times) of the volume of abstracted waters, including in the Kitai (2.0 times), Cahul (1.9 times), Prut (1.4 times) and Ialpug (1.3 times) river basins. At the same time, the increase of the volume of abstracted water is observed in the Hadjider (1.2 times), Sărata (1.3 times) and Cogâlnic (+13%) river basins. A significant reduction is registered in the administrative districts of Edineț (2.0 times), Taraclia (1.9 times), Cantemir (1.8 times), Basarabeasca (1.7 times), Glodeni (1.4 times, as a result of the bankruptcy of the sugar factory). The significant increase of the volume of abstracted water can be seen in the districts of Nisporeni (2.3 times) Leova (1.5

times) and Cimișlia (1.4 times). It is due to the more intense increase of the volume of water abstracted by agricultural companies from these districts.

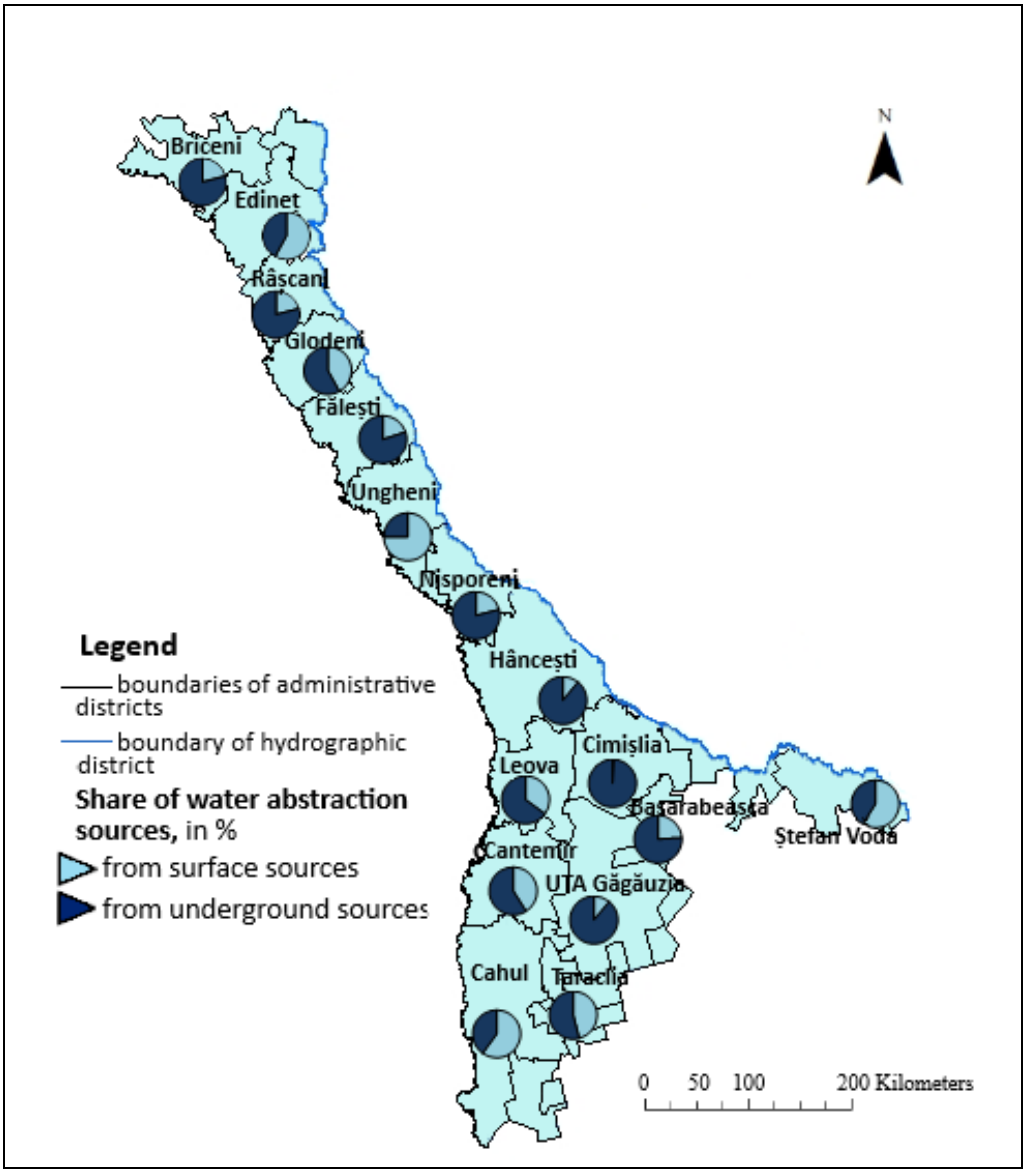

Figure 2 The share of water catchment sources in the administrative districts from the DPBS HD (Average of the 2003-2020 years). *Data sources: Water Agency of the Republic of Moldova, 2004-2022.*

Also, are observed 2 reduction periods (2003-2004 and 2008-2014), the growth period 2015-2020 and the maximum volume in 2007, 2009 and 2020, being conditioned, mainly, by the evolution of the volume of water captured from the sources of surface. At the same time, the negative dynamics from the years 2008-2014 is much more pronounced, especially for water captured from surface sources, especially in the basins of DBS HS, with the exception of the Hadjider HB. In addition, the general reduction trend in the 2008-2014 years is also marked by a more pronounced fluctuating evolution compared to Dniester HD. Also, the positive dynamics from the years 2015-2020 are more intense for waters captured from surface sources (Figure 3).

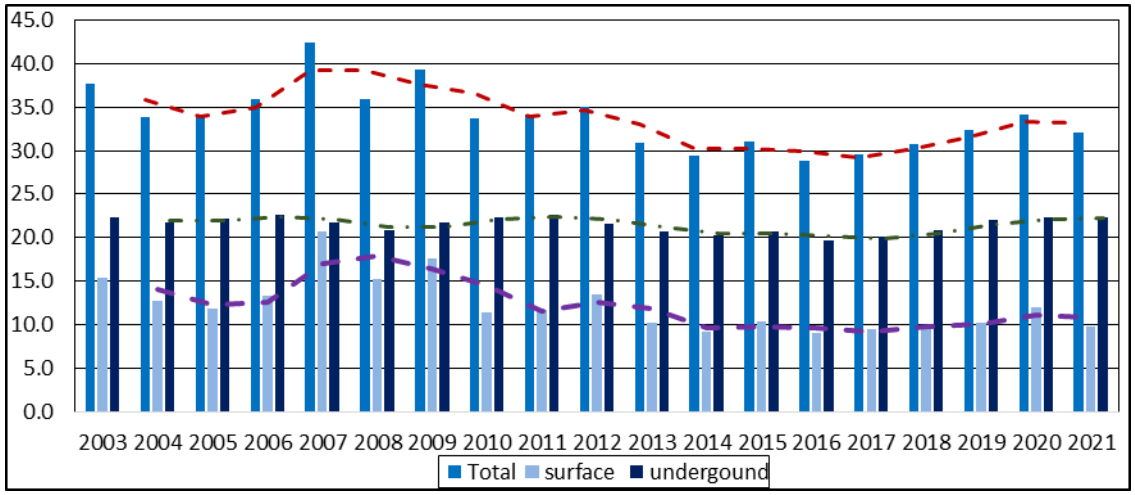

Figure 3 Dynamics of the volume of abstracted water in the DPBS HD by catchment the sources, in mil. m^3. *Data sources: Water Agency of the Republic of Moldova, 2004-2022.*

Overall, the volume of abstracted water from surface sources decreased more than 1.7 times, and in the years 2007-2014, 2.3 times, including in the Prut HB – 2.0 times and in the DBS HS – ≈4 times (from 4.5 million m^3 to only 1.2 million m^3), and the reduction trend was maintained until 2017, being the most pronounced among the all analyzed river basins. The multiple reduction of the volume of water captured from surface sources is recorded in the ATU Găgăuzia, as well as in the Hâncești, Cantemir and Taraclia districts. This trend is due to the massive damage of the state irrigation systems in most districts (Bejan et al., 2017), to the bankruptcy of industrial and agricultural companies, to reducing of urban water consumption.

The volume of abstracted water from underground sources in the 2020-2021 years is identical (22.3 million m^3) to that of 2003, and the oscillation of the respective indicator is insignificant throughout the study period. At the same time, are observed big differences in the evolution of the respective indicator in the Prut river basin and in the DBS HS. Thus, if in the Prut river basin there is, as a whole, a reduction by ≈1.3 times or with 2.0 million m^3, then in the DBS HS the volume of water abstracted from underground sources increases by ¼ or with 1.9 million m^3, and the increase in the volume of abstracted water from underground sources is recorded in the all hydrographic basins. The negative trend in the 2003-2014 years is succeeded by a positive dynamic in the 2015-2021 years (Figure 3), which is manifested in the absolute majority of administrative districts, being conditioned by the rapid expansion of rural public aqueducts (NBS, 2022).

4.2 The volume of used water

The ***total volume of water used*** in the DPBS HD was, on average, 26.3 million m^3 or only 3.3% of the total volume of water used in the Republic of Moldova and 23% – from the right side of the Dniester River. The insignificant share of DPBS HD is due to the smaller area, the presence of only small and medium-sized cities and to its very pronounced agrarian and rural character (Bejan et al., 2017). In the Prut HB, there were used, on average, 17.3 million m^3 of water, which constitutes only 15% from the total volume of water used in right side of the Dniester River and 2/3 (66%) of DPBS HD, including 6.7 million m^3 (26%) in the perimeter of the Prut riverbed. The total volume of water used in DBS HS was, on average, 8.9 million m^3 or only 7.7% of the total volume of water used on the right bank of the Dniester River and 34% of DPBS HD, including 4.2 million m^3 (16%) in the Ialpug, 2.6 million m^3 (10%) in the Cogâlnic, 791 thousand m^3 in the Cahul, 547 thousand m^3 in the Hadjider, 498 thousand m^3 in the Sărata and 309 thousand m^3 in the Kitai river basins. On

average, from underground sources are abstracted 62% (16.2 million m^3) of water, including 53% in the Prut river basin and 77% in the DBS HS (Table 2).

Table 2 Volume (mil. m^3) of water used and share of usages categories in hidrographic basins, Average of 2003-2021 years.

Hydrographic Bazins	total			households		technological		agriculture					
								total		irrigation		Other agriculture usages	
	mil. m^3	%	%	mil. m^3	%	mil. m^3	%	mil. m^3	%	mil. m^3	%	mil. m^3	%
Dniester HD	**759**	**97**	**77**[1]	**110**	**15**	**580**	**76**	**66,2**	**8,7**	**41,0**	**5,4**	**25,1**	**3,3**
Prut	**17,3**	**2,2**	**15**	**3,8**	**22**	**1,7**	**10**	**11,7**	**67**	**3,6**	21	**8,1**	**47**
Prut riverbed	6,8	0,9	5,9	3,0	44	1,1	16	2,7	39	1,2	18	1,5	22
Ialpug	4,2	0,5	3,6	1,0	24	0,1	3,6	2,8	67	0,4	9,2	2,4	58
Cahul	0,8	0,1	0,7	0,13	17	0,03	4,2	0,5	57	0,2	26	0,3	36
Cogâlnic	2,6	0,3	2,3	0,9	34	0,07	2,7	1,7	63	0,3	12	1,3	51
Kitai	0,3	0,04	0,3	0,06	19	0,02	5,1	0,24	75	0,1	21	0,2	59
Sărata	0,5	0,06	0,4	0,13	25	0,01	2,4	0,4	72	0,1	12	0,3	60
Hadjider	0,5	0,07	0,5	0,03	0	0,04	0,0	0,5	97	0,3	63	0,2	34
DBS HS	**8,9**	**1,1**	**7,7**	**2,2**	**25**	**0,3**	**3,1**	**6,0**	**67**	**1,3**	**15**	**4,7**	**52**
DPBS HD	**26,3**	**3,3**	**23**	**6,1**	**23**	**2,0**	**7,6**	**17,7**	**67**	**4,9**	**19**	**12,8**	**49**

The maximum volume of water was used in the administrative districts with a larger urban centers, with direct access to the Prut river and with high consumption of water for irrigation, including in the districts of Cahul (3.1 million m^3), Ungheni (2.7 million m^3), Edineț (2.4 million m^3) and Briceni (2.0 million m^3), as well as in ATU Găgăuzia (2.6 million m^3), with a higher level of urbanization and access to public aqueducts. The minimum volume was used in the administrative districts with smaller sizes and urban centers, including in Basarabeasca (769 thousand m^3), Nisporeni (954 thousand m^3), Leova (1.0 million m^3) and Cantemir districts (1.2 million m^3).

For ***agricultural needs*** were used, on average, 17.7 million m^3 or 2/3 of the total volume of water used in this hydrographic district (figure 4.a) and ≈40% of agricultural water usages in the right bank of the Dniester. Therefore, in the DPBS HD the amount of water used in agriculture conditioned directly the total volume of water used (Bejan et al., 2017). At the level of hydrographic basins, the maximum share of agriculture can be seen in the Hadjider − 97%, Kitai − 75% and Sărata − 72% river basins, and the average share (67%) − in the Prut and Cogâlnic river basins. The volume of water used in agriculture, especially for irrigation, is conditioned by the surface of the basins and administrative-territorial units located in the perimeter of the respective hydrographic space, by the water sources used, as well as by the presence of large agricultural households (Bacal et al., 2017b).

The maximum consumption of water in agriculture is found in the districts, which have large capacities for distribution and use of water captured from the Prut riverbed, as well as from reservoirs. Also is important the presence of a big agricultural companies, which practice intensive technologies, based inclusively on high water consumption. Thus, maximum volume of water used for agriculture is attested in the administrative districts of Briceni (2,0 million m^3), Cahul (1,6 million m^3), Edineț (1,5 million m^3). The minimum volume of water used in agriculture is observed in administrative districts with small urban centers and with reduced capacities for abstracted and used of water, including Basarabeasca (447 thousand m^3), Cimișlia (703 thousand m^3) Glodeni (759 thousand m^3) and Leova (782 thousand m^3), Nisporeni (804 thousand m^3).

[1] The share from the right side of the Dniester river

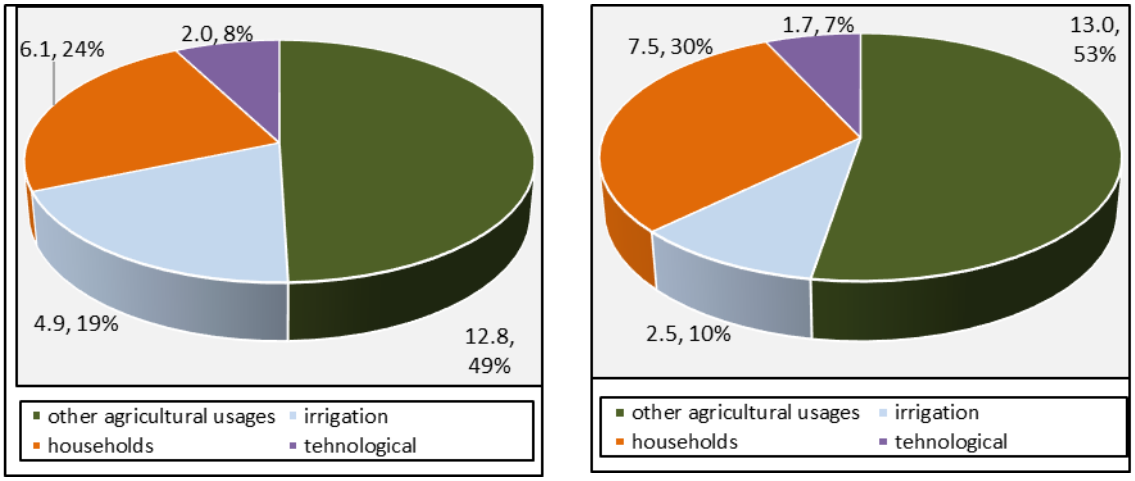

Figure 4 The volume (million m^3) of water used and the share of water use categories in the DPBS HD
a) average of 2003-2021 year **b)** 2021 year
Data source: Water Agency of the Republic of Moldova, 2004-2022.

The maximum share (≥80%) of agriculture is found in the administrative districts of Briceni, Ocnița, Nisporeni, Ștefan Vodă and Cantemir (Figure 5), where operate large agricultural enterprises, and household consumption is lower, as a result of smaller urban centers and the population's reduced access to public aqueducts. The minimum share (≥60%) of agricultural uses is observed in the districts with larger urban centers and with higher consumption for domestic and industrial purposes, including in the districts of Cahul, Ungheni, Edineț, as well as in ATU Gagauzia.

The maximum water consumption is attested at big agricultural companies with a complex profile, especially for growing of technical, fodder and vegetable crops, and the amount of water used depends not only on the need for water for agricultural purposes, but also on the current technical and financial capabilities of agricultural enterprises from this districts (Bejan et al., 2017). Compared to the Dniester HD, in the DPBS HD animal husbandry is much less developed, a fact that is mainly due to the location of the largest cities outside of the respective hydrographic district. At the same time, an average water consumption is recorded at: poultry factories from Fălești, Nisporeni, Cimișlia and Basarabeasca districts; pig complexes from Briceni, Ocnita, Fălești, Hâncești, Cahul and Comrat districts (Inspectorate for Environmental Protection, 2019).

For ***regular irrigation*** were used, on average, 4.9 million m^3, which represents 11% of the total volume of water used for these purposes in the Republic of Moldova and 37% in the right side of Dniester river, including 3.6 million m^3 (8% and 27%) in the Prut HB and 1.3 million m^3 (2.9% and 10%) in the DBS HS. In the Ialpug HB for irrigation were used, on average, 383 thousand m^3 of water, in the Cogâlnic HB – 312 thousand m^3, and in the Hadjider HB – 346 thousand m^3. Also, for irrigation is used, on average, 19% of the total volume of water used in DPBS HD, including 21% in the Prut HB and 15% in the DBS HS (Table 2). The maximum share of water used for irrigation is found in the Hadjider (63%), Cahul (26%) and Kitai (21%) river basins. The relatively low volume of water used for irrigation is conditioned both by natural conditions (low flow and insufficient precipitation, increased risk of soil salinization), and by the insufficient technical and economic possibilities of using water for these purposes. The spread of irrigated agriculture has a pronounced azonal character. Thus, despite the fact that the amount of precipitation decreases relatively uniformly from north to south, the volume of water used for irrigation and other agricultural activities is greater in the northern districts (Bejan, 2017). This situation is explained by the much more pronounced commercial nature of agriculture in this region. The maximum volume

of irrigation water was used in the Briceni (1.0 million m^3), Edineț (500 thousand m^3) and Râșcani (400 thousand m^3), with direct access to the Prut riverbed. The maximum share of water used for irrigation is observed in the administrative district of Briceni (≈50%) and Cantemir (Figure 5).

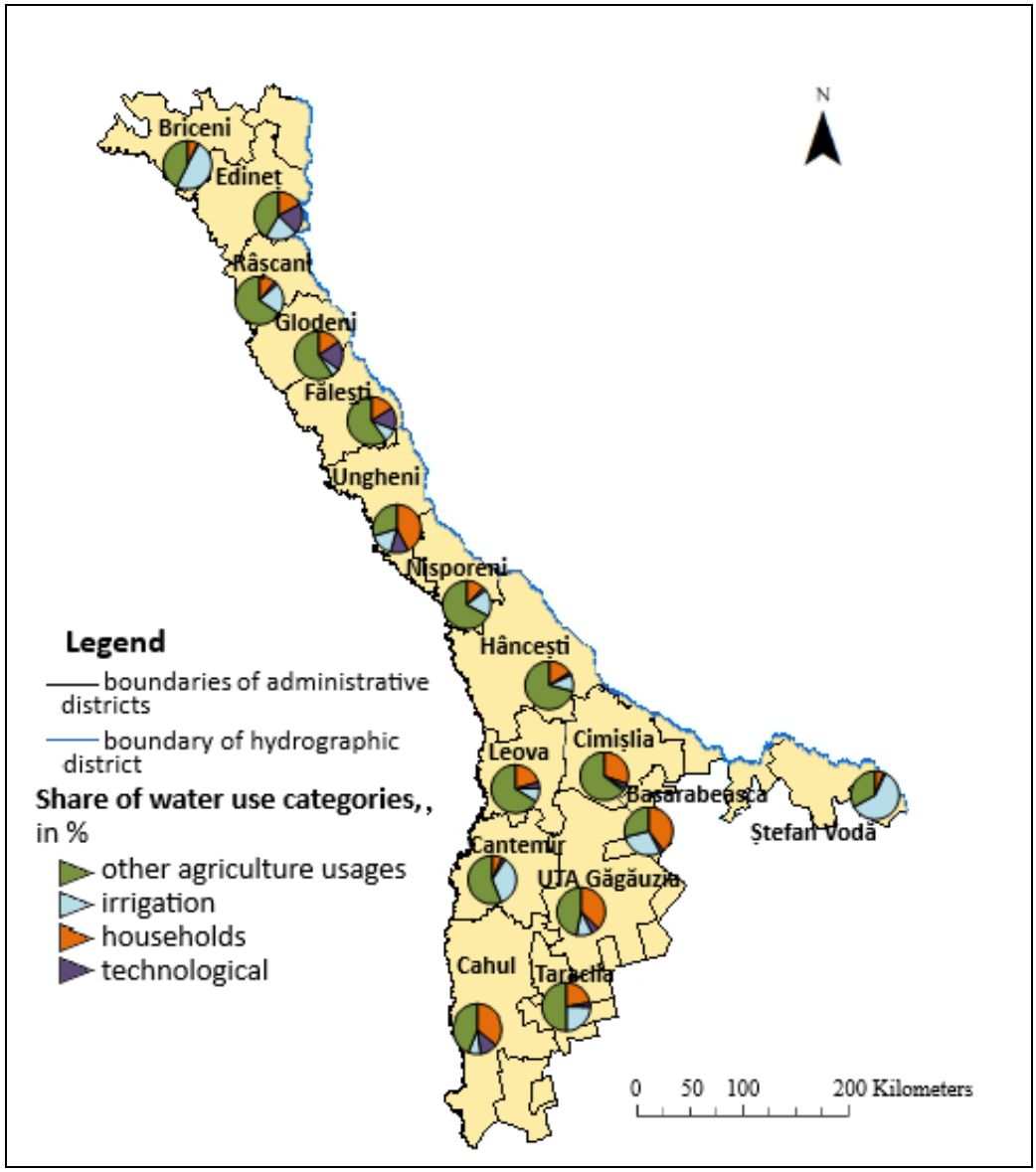

Figure 5 The share (%) of main usage categories of water in the administrative districts from DPBS HD (average of 2003-2021 years) *Data source: Water Agency of the Republic of Moldova, 2004-2022*.

On average, ***for household needs*** were used 6.1 million m^3 of water, which is only 5.2% of the total volume of water used for these purposes in the Republic of Moldova and 11% − in the right bank of the Dniester River, including 3.8 million m^3 in the Prut HB and 2.2 million m^3 in the DBS HS. The volume of water used for these purposes is conditioned by the number and size of the served urban centers, as well as of the rural localities, which have extensive centralized water supply systems and record the use of water (Bacal et. al., 2022a).

The maximum volume of water used for household purposes is found in the perimeter of the Prut riverbed (3.0 million m^3), where are located the most important urban centers (Ungheni and

Cahul) of the DPBS DH. An average volume of water is used in the Ialpug river basin (3.0 million m^3), in which are located Comrat and Ceadâr-Lunga cities and most of the villages from ATU Găgăuzia, with higher access to public aqueducts, as well as in the Cogâlnic river basin (907 thousand m^3), in which are located the Hâncești, Cimișlia and Basarabeasca towns. Minimal volumes of water were used in the hydrographic basins with smaller areas and with a much more pronounced agrarian character, including Sărata (125 thousand m^3), Cahul (134 thousand m^3) and Kitai (60 thousand m^3) river basins. Also, for household purposes were used, on average, 23% of the total volume of water used in the DPBS HD, including 22% in the Prut HB and 25% in DBS HS. The maximum share of household uses is found in the perimeter of the Prut riverbed (44%) and in the Cogâlnic river basin (34%). An average share is observed in the Sărata (25%), Ialpug (24%), Kitai (19%) and Cahul (17%) river basins, and a minimal share – in the Hadjider river basin (0%).

The maximum volume of water for domestic purposes was used in the administrative districts with larger urban centers, including Ungheni and Cahul (1.1 million m^3 each) and with biggest capacities for distribution of potable water captured from the Prut riverbed, as well as in the ATU Găgăuzia with a higher level of urbanization and access to public aqueducts (NBS, 2022). In these administrative units is found a higher share of water need for household purposes (Figure 5). The minimum volume of water for household purposes is found in the administrative districts, with smaller urban centers, which low access to public aqueducts, including Glodeni (182 thousand m^3). Briceni (158 thousand m^3), Nisporeni (126 thousand m^3), Cantemir (91 thousand m^3).

For ***technological purposes*** were used, on average, 2.0 million m^3 or 7.6% of the total volume of water used in the DPBS HD and 14% of water used for these purposes in the right side of Dniester River (Figure 4). The share of water used for technological purposes in the Prut river basin is higher (10%) and is due to the presence of industrial centers, such as Ungheni and Cahul. In the DBS HS, for industry were used, on average, only 280 thousand m^3 or only 3.1% of the total volume of water used in the respective hydrographic space.

The maximum share of water used for technological purposes can be seen in the more industrialized districts, such as Edineț (20%), Glodeni (18%) and Fălești (15%), due to the sugar factories (which no longer work), Cahul (12%). In the absolute majority of districts, especially the southern ones, the share of technological uses of water does not exceed 5% (Figure 5).

In the DPBS HD, *the total volume of water used* during 1990-2002 was reduced by about 7 times, or from 220 million m^3 to about 30 million m^3, a fact that is due to the more pronounced agrarian and rural character in comparison with Dniester HD. In addition, the decline of the agro-industrial complex and the financial shortage manifested, on a larger scale and with much more serious socio-economic consequences, which significantly limited the capacity to capture, distribute and use of water resources. In the 2003-2021 years, the oscillating dynamics of the volume of water used in the DPBS HD (Figure 6) is similar to that in Dniester HD (Bacal, 2022b), and the total volume of water used decreased by about 1.2 times, including in the Prut river basin − 1.2 times and in the DBS HS – 1.3 times. There are also 2 reduction periods (2003-2005 and 2008-2014), the growth period 2015-2020 and the maximum volume in 2007, 2009 and 2020, being conditioned, mainly, by the dynamics of the volume of water used for irrigation.

At the same time, the negative dynamics from 2008-2014 years is much more pronounced, especially in the basins of DBS HS (Bacal et al., 2017a). In the 2003-2005 years, the total volume of water used in the DPBS HD decreased ≈1.3 times (by 3.8 million m^3), including in the Prut HB − ≈1.2 times (with 1.6 million m^3). In the DBS HS there is a 1.4 times reduction (with 2.2 million m^3), including 1.7 times (with 2.0 million m^3) in the Ialpug HB and 1.2 times in the Cogâlnic (with 200 thousand m^3) and Sărata (with 40 thousand m^3) river basins. The increase of the total volume of water used is observed in the Hadjider (+18%), Cahul (+4%) and Kitai (+2%) river basins.

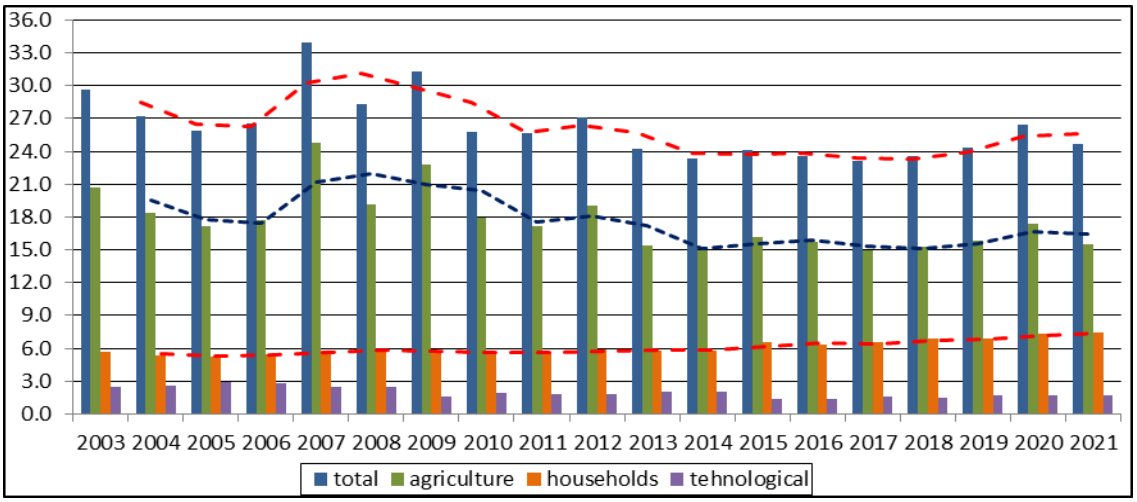

Figure 6 Dynamics of the volume of water used in DPBS HD (per total and by usage categories), in million m3 (average of 2003-2021 years). *Data source: Water Agency of the Republic of Moldova*, *2004-2022.*

In 2007, was used a maximum volume of water (34.0 million m^3), which is due to the manifestation of the very strong drought in this year. In the 2008-2014 years (with an interruption in 2009), is registered a very pronounced negative dynamic, which is manifested in the all analyzed river basins from the DPBS HD. The total volume of water used decreased by more than 1.6 times or with 10.6 million m^3, including with ≈7 million m^3 in the Prut river basin and with 3.8 million m^3 in the DBS HS. The maximum reduction is found in the Danube HS, including in the Cahul (by 4.0 times) and Kitai (by 2.0 times) river basins, where predominates irrigation use and it is a more difficult economic situation, and the territory is more affected by the climate changes process (Bacal, 2010, 2017b). In the Prut and Cogâlnic river basins the total volume of water used was reduced by 1.6 times, and in the Ialpug river basin – by 1.5 times.

In the years 2015-2020, it was registered a positive dynamic (Figure 6), which is manifested in all the analyzed river basins from the DPBS HD, and the maximum consumption of water is observed in 2020, as a result of the strong drought. The total volume of water used in the years 2015-2020 increased with 3.2 million m^3 (+13%), including with 1.4 million m^3 (+9%) in the Prut HB and with 1.8 million m^3 (23%) – in the DBS HS. The highest growth rates can be seen in the Prut riverbed (+26%), as well as in the Hadjider (+33%), Ialpug (+24%), Cogâlnic (+23%) and Sărata (+19%) river basins. This trend is due to the increase of the volume of water used for irrigation, especially in 2020 year, as well as to the rapid increase of the volume of water delivered by rural public aqueducts. In the 2021 year, the total volume of water used in the DPBS HD was with 1.8 million m^3 lower than in the 2020 year, including with 1.3 million m^3 – in the Prut HB and with 460 thousand m^3 – in the DBS HS.

As a result of the absolute predominance of agricultural uses, the *dynamics of the volume of water used for agriculture* is almost identical to that of the total volume of water used, but positive and negative oscillations are more frequent and more pronounced (Figure 6). In the 1990-2002 years, the total volume of water used for these purposes in the DPBS HD decreased by about 7.5 times (from 150 million m^3 to 20 million m^3). In the 2003-2020 years, is recorded an oscillating evolution, against the background of a general negative trend until 2017, which was interrupted in 2007 and 2009 years. The total volume of water used for agriculture in the 2003-2019 years decreased by ≈1.5 times or with 5.2 million m^3, including by 1.4 times (with 2.7 million m^3) in the Prut HB and by

1.5 times (with 2.5 million m^3) in the DBS HS. The reduction of the volume of water used for agriculture is attested in all the hydrographic basins of the respective district, with the exception of the Sărata and Hadjider river basins, where is registered a general positive trend, which is due to the increase of the production capacities of some large agricultural enterprises in the Ștefan Voda and Causeni administrative districts. In the 2003-2005 years, the volume of water used in agriculture also decreased by ≈1.3 times (with 3.5 million m^3), including in the Prut HB − by 1.3 times (with 1.9 million m^3) and by 1.5 times of the water used from the Prut riverbed. In the DBS HS there is a 1.4 times reduction (with 1.7 million m^3), including by 1.8 times (with 1.8 million m^3) in the Ialpug river basin. At the same time, the increase of the total volume of water used is observed in the Hadjider (+18%) and Cahul (+53%) river basins, but the amount is insignificant (several tens of thousands of m^3). In 2007, in agriculture a maximum volume (24.8 million m^3) of water was used, a fact that is due to the manifestation of the very strong drought in this year.

In the 2008-2014 years (with an interruption in 2009), is registered a particularly pronounced negative dynamic, which is manifested in the all analyzed river basins from the DPBS HD (Bejan et al., 2017). The total volume of water used in agriculture decreased in the respective period by 1.8 times or with ≈10 million m^3, including with 6.5 million m^3 in the Prut HB and with 3.5 million m^3 in the DBS HS. The maximum reduction is found in the Danube river basins, including Kitai (by 7.0 times) and Cahul (by 4.0 times), where irrigation use predominates, and the territory is more affected by the climate aridification process. Also, the volume of water used for agricultural purposes from the Prut riverbed decreased by 2.6 times (with 2.8 million m^3). In the Prut and Cogâlnic river basins the volumes of water used for agriculture were reduced 1.7 times (with 0.7 million m^3), and 1.8 times in the Ialpug river basin (with 1.3 million m^3). In the years 2015-2020, it was registered a positive dynamic, which is manifested in the all analyzed hydrographic basins from the DPBS HD, with the exception of Cahul river basin. The maximum water consumption is observed in the 2020 year, as a result of the manifestation of the strong and long drought. The total volume of water used in the 2015-2020 years increased with 2.5 million m^3 (+17%), including with 1.1 million m^3 (+10%) in the Prut HB and with 1.4 million m^3 (+30%) – in the DBS HS. The highest growth rates can be seen in the Prut riverbed (+66%), as well as in the Ialpug (+44%), Kitai (+40%), Hadjider (+33%), Cogâlnic (+17%) and Sărata (+18%) river basins. This trend is due to the increase the volume of water used for irrigation, especially in 2020, but also to the significant increase in the volume of water delivered by rural public aqueducts (NBS, 2022). In 2021, for agricultural purposes was used with 1.4 million m^3 of water less compared to 2020 year (Figure 6), a fact that is exclusively due to the similar reduction in the volume of water used for irrigation.

The total volume of *water used for irrigation* decreased in the 1990s about 10 times (from 100 mil. m^3 to 10 mil. m^3), which determined the reduction of the total volume of water used, especially from surface sources. Similar to Dniester HD, in the years 2003-2021, it was registered an oscillating evolution, against the background of a general negative trend, which was recorded until 2017, being interrupted in the 2007 and 2009 years (Figures 6). In the 2003-2005 years, the volume of water used for irrigation in the DPBS HD decreased by 1.8 times (from 8.6 million m^3 to 5.2 million m^3), including by 1.7 times in the Prut HB. In the DBS HS, the volume of water used for irrigation decreased, in the respective period, by ≈2 times (from 3.5 million m^3 to 1.8 million m^3), including by 4 times in the Ialpug and Sărata river basins and by 1.3 times − in the Cogâlnic and Kitai river basins. At the same time, the increase the volume of water for irrigation is registered in the Cahul (by 3.4 times) and Hadjider (+26%) river basins. After the maximum of 2007 year (12.5 million m^3), it was observed a very pronounced negative dynamics, which is manifested in the all analyzed hydrographic basins from the DPBS HD (Bejan et al., 2017).

The total volume of water used for irrigation in the 2008-2017 years decreased by 5.0 times (from 12.5 million m^3 to 2.5 million m^3), including more than 4 times in the Prut HB and more than 8 times in the DBS HS. This trend is caused both by the worsening of the situation in agriculture, by the intensification of aridization processes, and by the spread of the phenomenon of incomplete records of water consumption for these purposes (Bacal & Burduja, 2017). The highest reduction of the volume of water used for irrigation can be seen in the basins of the small rivers Cahul and Kitai, as well as in the Ialpug HB, where, according to the data of the Moldavian Water Agency, the amount of water used for irrigation is zero or of only 20-30 thousand m^3. The volumes of water used for irrigation from the Prut riverbed and in the Cogâlnic HB have been reduced by 5 times.

In the years 2018-2020, there is a significant increase (≈1.7 times or with 1.7 million m^3) of the total volume of water used for irrigation, including 2.1 times (with 500 thousand m^3) in the DBS HS and 1.6 times (with 1.5 million m^3) − in the Prut river basin. The maximum consumption of water for these purposes is observed in the year 2020, as a result of the manifestation of the strong drought, as well as to the efficiency of statistical reporting in this field. The maximum increase is observed in the Hadjider HB (3.3 times), in the Prut riverbed (2.5 times) and in the Cogâlnic HB (1.7 times). At the same time, in the Ialpug river basin, the volume of water used for irrigation (20 thousand m^3) remained unchanged, and in the Kitai and Cahul river basins the water was not used for regular irrigation, as a result of the clogging and drying of the reservoirs. In the year 2021, with abundant rainfall, the negative difference compared to the dry year 2020 is observed in the all analyzed hydrographic basins from DPBS HD.

The volume of water used for domestic purposes in the years 1990-2000 decreased by about 1.8 times (from about 10 million m^3 to 5.7 million m^3), being caused by the significant decrease of water consumption in the urban centers, especially those located in the Prut HD (Edineț, Glodeni, Briceni), as well as in the cities of Hâncești, Cimișlia and Basarabeasca located in the Cogâlnic river valley. In the years 2003-2021, it was registered, on overall, an oscillating evolution, against the background of a positive and well-pronounced general trend, which is manifested both in the Prut HB and in the DBS HS (Figure 6). The total volume of water used for these purposes increased 1.3 times (with 1.7 million m^3), including a 26% increase (with 0.9 million m^3) in the Prut HB and 37% (0.8 million m^3) in the DBS HS. The highest growth rates can be seen in the Kitai (13 times), Sărata (2.4 times) and Cahul (2.2 times) river basins, but the amount of water used is insignificant (only a few tens of thousands m^3). Also, a significant increase is observed in the Ialpug HB (1.4 times or with 600 thousand m^3 more than in 2005). The positive dynamics due to the expansion of public aqueducts and the increase of the volume of water delivered through them. In the Cogâlnic HB can be seen, on overall, an insignificant increase (4%), and in the years 2009-2014, the respective indicator fluctuates significantly, reaching minimum values of 740-760 thousand m^3.

In the years 2003-2005, the volume of water used for household purposes in the DPBS HD decreased with 400 thousand m^3, including 250 thousand m^3 (1.2 times) in the DBS HS. This fact is due exclusively to the decrease of the volume of water used for these purposes in the Ialpug and Cogâlnic river basins, where there are concentrated the absolute majority of urban centers and which account for over 90% of the total volume of household water used in the DBS HS. In the years 2006-2014, it was recorded a fluctuating evolution, with insignificant positive or negative deviations, against the background of a more pronounced positive trend in the DBS HS (Bacal et all., 2017a). The highest rates of growth can be seen in the small river basins, but with insignificant amounts, as well as in the Ialpug HB (+27% or by 220 thousand m^3). In the Cogâlnic river basin there is a significant reduction (1.5 times or with 270 thousand m^3). In the years 2015-2021, it was registered a very pronounced positive dynamic, which is manifested in the all analyzed river basins from the DPBS HD. The total volume of water used for domestic purposes increased during this

period, on average, 1.3 times or with 1.7 million m^3, including by 25% in the Prut HB and by 34% in the DBS HS. The highest growth rates are recorded in the basins of the middle rivers − Cogâlnic (by 34% or with 250 thousand m^3) and Ialpug (by 35% or with 360 thousand m^3).

The total volume of water used for technological purposes registers an oscillating evolution against the background of a general negative trend, marked by the decline in the agro-industrial complex, which occurred with a much greater intensity compared to the Dniester HD. In the years 1990-2002, the total volume of water used for these purposes decreased by about 4 times (from 10 million m^3 to 2.5 million m^3). In the years 2003-2021, the dynamics of the volume of water used for technological purposes had an oscillating character against the background of a general negative trend (Figure 6), which is observed in the all river basins from the DPBS HD, with the exception of the Kitai HB, but the amount of water is insignificant (10-20 thousand m^3). Thus, the total volume of water used for industry decreased 1.6 times (with 760 thousand m^3), both in the Prut HB (with 620 thousand m^3) and in DBS HS (by 130 thousand m^3). The maximum reduction is registered in the basins of the small rivers Cahul (2.6 times) and Sărata (2.0 times). Also, a significant reduction is also observed in the basins of the middle rivers − Cogâlnic and Ialpug (1.7 times), where there are concentrated most of the cities from the DBS HS.

In the years 2003-2005, unlike the waters used for agricultural and domestic purposes, the volume of waters used in industry registered a positive dynamic that is manifested in the all analyzed hydrographic basins (Bacal, 2010). The total volume of water used for technological purposes in the DPBS HD increased by 17% or with 410 thousand m^3, including by 17% (with 360 thousand m^3) in the Prut HB and by 13% (with 50 thousand m^3) in the DBS HS. The increase of water use for industry can be seen in the Ialpug HB (by 20% or with 40 thousand m^3), in the Prut riverbed (by 6% or with 70 thousand m^3). In the Cogâlnic, Sărata and Cahul river basins, the volume of water used for these purposes has not changed.

In the years 2006-2016, the volume of water used for industry decreased in the DPBS HD ≈2.0 times (with 1.5 million m^3), including 2.0 times in the Prut HB (with 1.2 million m^3) and 1.8 times (with 240 thousand m^3) − in the DBS HS. In the Cogâlnic and Sărata river basins, the volume of water used for technological purposes decreased, in the respective period, 2.0 times, and in the Ialpug river basin − 1.9 times (with 140 thousand m^3).

In the years 2017-2021, it was found a positive trend (figure 6), which is manifested in the all analyzed hydrographic basins, except of the Cahul river basin, but the amount of water is insignificant (10 thousand m^3). The total volume of water used for technological purposes in the DPBS HD increased by 22% or with 310 thousand m^3, including by 22% (260 thousand m^3) in the Prut HB and by 30% (60 thousand m^3) in the DBS HS. The increase of technological water use is also attested in the basins of the middle rivers Cogâlnic and Ialpug (1.4 times), as well as in the valley of the Prut River, where there are concentrated most of the cities and industrial enterprises from DPBS HD.

5. Conclusion

The volume of abstracted and used water is conditioned by the area of the river basins and of administrative districts from the DPBS HD and by the size of their urban centers, by the degree of access to the Prut riverbed and by the technical capacities for capturing and transporting water, as well as by the consumption for agricultural and household purposes.

In the period of the years 2003-2021, in the perimeter of DPBS HD, there were abstracted, on average, 33.8 million m^3 of water, including 2/3 from the Prut river basin. Also, ≈2/3 of the abstracted water come from underground sources, including 55% in the Prut river basin and 82%

in the DBS HS. Surface sources predominate only in the Edineț, Ungheni and Cahul administrative districts, with larger urban centers, which are supplied from the Prut riverbed.

The total volume of water used in the DPBS HD was, on average, only 26.3 million m^3 or only 3.3% of the total volume of water used in the Republic of Moldova and 23% − from the right side of the Dniester River. The insignificant share of DPBS HD from total volume of abstracted and used water in the Republic of Moldova is due to the presence of only small and medium-sized cities and to its very pronounced agrarian and rural character.

For agricultural needs, it was used ≈2/3 of the total volume, including 19% for regular irrigation, for households - ≈1/4 (23%) and for technological purposes – only 7.6% of total volume of water used in the DPBS HD. The amount of water used in agriculture conditioned directly the total volume of water used in the absolute majority of river basins and of administrative districts from DPBS HD, except of Ungheni and Cahul districts, with biggest urban centers and a large water use for households and industry.

In the years 1990-2002, there is an about 13 times reduction of the total volume of abstracted water and a 7 times reduction of the total volume of used water, which is due to the more pronounced agrarian and rural characteristic than Dniester HD. In the years 2003-2021, it was registered an oscillating evolution on the background of a general negative trend (1.2 times), which is manifested in the absolute majority of river basins and of administrative districts from DPBS HD. The negative dynamics from the years 2003-2014 is succeeded by the positive trend, and the maximum water use was recorded in the years 2007, 2009 and 2020, in which there were manifested the strongest droughts.

Acknowledgments: This article is elaborated within the Research Project 20.80009.7007.11 "Assessment of urban and rural ecosystems stability in order to ensure sustainable development" of the Institute of Ecology and Geography from Chișinău. Also, the results presented in this article were obtained within the UNDP Moldova Project "Study of the social and environmental impact of the Nistrean CHP" (2020-2021), as well as in the Doctoral project "Economic-geographical aspects of the use and management of water resources in the Republic of Moldova".

References

Administrația Națională Apele Române, 2017. Planul de management al spațiului hidrografic Prut Bârlad. Ciclul II, 2017. Available online: http://www.rowater.ro/daprut/default.aspx.

Agenţia Apele Moldovei, 2004-2022. Rapoartele anuale (2003-2021) generalizate „Utilizarea apelor în Republica Moldova”. Preprint.

Anuchin, V., 1978. Osnovy prirodopolzovaniya. Moskva: Nauka. 293 p. (in Russian).

Bacal, P., 2010. Gestiunea protecţiei mediului înconjurător în Republica Moldova (Aspecte teoretice şi aplicative). Chişinău: ASEM. 240 p.

Bacal, P., 2016. Economic and geographical aspects of water use in the Prut river basin (The sector of the Republic of Moldova). Present Environment and Sustainable Development, Volume 10, no. 2, pp. 77-94. DOI : 10.1515/pesd-2016-0027.

Bacal P., Bejan. Iu. The particularities of use and management of water resources in the Danube-Black Sea Hydrographical Space. În: Lucrările Seminarului Geografic Internațional „D. Cantemir”, Vol. 45, Iași 2017, p. 33-43. DOI: http://dx.doi.org/10.15551/lsgdc.v45i0.03.

Bacal, P., Burduja, D., 2017. Dynamics and branch structure of water consumption in the Republic of Moldova. In: Present Environment and Sustainable Development. Vol 11, no. 2, 2017. p. 187-201. DOI 10.1515/pesd-2017-0036.

Bacal, P., Jeleapov, A., Burduja, D., 2022. Status and use of water supply and sewerage systems in the Northern Development Region of the Republic of Moldova. In: Central European Journal of Geography and Sustainable Development, 2022, Volume 4, p. 23-40. Available online: https://doi.org/10.47246/CEJGSD.2022.4.1.2.

Bacal, P., Burduja, D., 2022. The pecularities of the use of water resources in the Dniester Hydrographical District (sector of the Republic of Moldova). Present Environment and Sustainable Development, Volume 16, No. 2, 2022. pp. 159-171. DOI: https://doi.org/10.47743/pesd2022162012.

Bejan, I., Boboc, N., Bacal, P. et al. Planul de Gestionare a Bazinului Hidrografic Prut. Ciclul I, 2017-2022. Chișinău, 2016. 116 p.

Bejan, I., Nedealcov, M., Boboc, N.; Bacal, P. Melniciuc, O., Jeleapov, A,, Tăbăcaru, A., 2017. Planul de Gestionare a Districtului Bazinului Hidrografic Dunărea-Prut și Marea Neagră. Ciclul I, Chișinău, 2017. 150 p.

Bejan, I., Bacal, P., Nedealcov N., Jeleapov, A., Jeleapov, V., Zgîrcu, N., 2019. Planul de Gestionare a Bazinului Hidrografic Camenca. Ciclul II, 2019-2024. Chișinău, 2019. 98 p.

Belichenko, Yu., 1990. Ratsionalnoe ispolzovanie vodnykh resursov.174 p. (in Russian).

Bevza, G., 1983. Vodnye resursy-natsionalnoe dostoyanie. Kishinev: Shtiintsa. (in Russian).

Biroul Național de Statistică, 2022. Statistici pe domenii. Sisteme publice de alimentare cu apă și de canalizare. Available online: http//www.statistica.gov. md.

Biroul Național de Statistică. Numărul populației prezente pe grupe de vârstă la nivel de comune la 01.01.2022. Available online: https://statbank.statistica.md/.

Danube River Basin Management Plan 2015-2021. Available online: https://www.icpdr.org/main/sites/brochure2015.pdf.

Directive 2000/60/EC of 23 October 2000 establishing a framework for Community action in the field of water policy. Official Journal of the European Communities.

Environmental Protection of International River Basins (2012-2016). Available online: https://www.euneighbours.eu/en/east/stay-informed/projects.

Freitas, M. et al., 2022. A composite indicator to measure sustainable water use in Portugal: A compromise programming approach. Journal of Environmental Management. Volume 311, Article no. 114791. Available online: https://doi.org/10.1016/j.jenvman.2022.114791.

Gîlcă, G., Zgîrcu, N., Jeleapov, A., Iurcu, V., Bacal, P., Burduja, D., Știrbu, S., 2020. Planul de Gestionare a bazinului hidrografic al râului Larga. Ciclul I. (2019-2024). Chișinău, 2020, 76 p.

Guidance document no. 1. Economics and the Environment. The Implementation Challenge of the Water Framework Directive., 2003. Luxembourg: Available online: https://circabc.europa.eu/.

HG nr. 814 din 17.10.2017 cu privire la aprobarea Planului de gestionare a districtului bazinului hidrografic Nistru. În: Monitorul Oficial nr. 371-382 din 27.10.2017. Available online: https://www.legis.md/cautare/get.

Inspectoratul pentru Protecția Mediului, 2004-2022. Anuarele (2003-2021) privind calitatea factorilor de mediu şi activitatea Inspecţiilor Ecologice. Preprint.

Makki, A. et al., 2013. Revealing the determinants of shower water end use consumption: enabling better targeted urban water conservation strategies. Journal of Cleaner Production, Volume 60, pp. 129-146. Available online: https://doi.org/10.1016/j.jclepro.2011.08.007.

Mazzoni, F. et al., 2023. Investigating the characteristics of residential end uses of water: A worldwide review. Water Research, Volume 230, Article no. 119500. Available online: https://doi.org/10.1016/j.watres.2022.119500.

Reymers, N., 1990. Prirodopolzovanie. Slovar-spravochnik. Moskva. 637 p. (in Russian).

Savina, A., 2004. Ratsionalnoe ispolzovanie vodnykh resursov kak faktor regionalnogo razvitiya: Dis. d-ra. ekon. nauk. Orenburg. 166 p. (in Russian).

Sebusang, N., Basupi, I., 2022. Household water use efficiency: Current trends, opportunities and constraints in Gaborone, Botswana. Physics and Chemistry of the Earth. Volume 125, Article no. 103076. Available online: https://doi.org/10.1016/j.pce.2021.103076