EVALUATION OF WATER DEMAND SUPPLY ON TISZA RIVER BASIN

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ABSTRACT

Water scarcity and drought are becoming increasingly challenging for water management, in Europe including Hungary. According to the forecasts, the climate of our country is shifted to the Mediterranean, it becomes warmer and drier, which means that the drought and the water demand of agriculture can increase, impacting the usable water supply. The Great Hungarian Plain (and within this the Tisza-KőrösValley) is the most vulnerable area of the country from a hydrometeorological point of view. The number of drought years are becoming more frequent (2000, 2003, 2007, 2009, 2012, etc.) due to many reasons such as the soil conditions and uneven precipitation distribution. As a result, locally generated surface and ground water and their retention and preservation (storage, water retention, near-natural water management) becomes more important. At the same time, the role of water transfer to water scarcity areas is also increasing.

The Tisza-Körös Valley Co-operative Water Management System is one of the largest water management systems in Europe with the aim of replacing water resources in water-scarce areas and reducing the impact of hydrometeorological extremes. The project consists of two parts: the Tisza Lake and the Tisza-Körös Valley Co-operative Water Management project. The project covers all the areas concerned (agriculture, rural development, land use, water management, nature protection, etc.) and takes into account natural conditions and the effects of changes in them because of the climate. The water shortage remedies include the Kiskőre reservoir (the most significant), the main water supply and distribution network, main waterworks, backwaters and reservoirs. These allow the storage of a total of 201.1 million m^3 of dynamic water resources. The usable water supply for the normal summer water level of Lake Tisza is 155 million m^3. More than 10 million m^3 of water is retained in the main water irrigation works.

In the case of water works this value is 1.5 million m^3. In terms of surface water resources, the current irrigation water abstraction at the river basin level does not cause a deficit, however, it is difficult to estimate due to the lack of irrigation needs. In this study, we reviewed the current situation of drought prevention and water use in Hungary, including the development of water resources, water demand and the possibilities available to replace water shortages.

Keywords: water scarcity, water demand, water management, Tisza River, Hungary

1. HYDROLOGICAL AND CLIMATIC CONDITIONS

The area of Hungary (93000 km^2) belongs to the Danube catchment, which extends to 19 countries and is the second largest in Europe, covering over 800000 km^2. The two largest tributaries of the Danube are the Tisza and the Sava. The Tisza sub-catchment is the largest (157 186 km^2), the longest tributary (966 km) shared among 5 countries: Ukraine, Romania, Slovakia, Hungary and Serbia. Tisza River Basin

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(TRB) is the main water source for Hungary, a significant source for Serbia and an important source for western Romania and southeastern part of the Slovak Republic. The basin gives home to a population of around 14 million people. The Sava, though its basin is only two-third of the Tisza's, has almost double the flow rate (1564 m^3 /s) (ICPDR, 2011).

This publication focuses on the Tisza cathment. Almost half of the country's area is lowland, often without runoff. 60 % of the lowlands are at risk of inland water coverage, 5 % are considered highly vulnerable on the Great Plain. The climate of Hungary is continental, with Atlantic and Mediterranean influences. The mean temperature is 8-11 °C, with large yearly variation (20-25 °C). The yearly precipitation is 500- 900 mm, the lowest values are measured in the Great Plains, while the highest are in Western Hungary. Primary wet periods are in early summer (May-June) and in the autumn (October-November). The natural water balance of Hungary is positive, the total precipitation is 55707 million m^3, while the evapotranspiration is 48 174 million m^3 (Lóczy et al., 2009). As a result of climate change, yearly mean temperature is expected to rise, and the yearly precipitation pattern is expected to change (and the total yearly amount to decrease) and the frequency of extreme weather events is likely to increase. This might lead to increased frequency of floods and inland water accumulation.

The trend of a more variable precipitation pattern is already visible, 2010 was the most humid and 2011 the driest year since 1901, and 2011, 2012 and 2013 were all significantly hotter than average. Climate change is likely to affect the availability and quality of water in Hungary, and the climate is expected to shift towards a Mediterranean climate. Droughts are already prevalent, especially in the Great Plains area. The flow of the Tisza is 170, 800 and 3400 m^3/s in low, medium and high flow conditions, respectively. The Tisza has a high turbidity due to the high particulate matter concentration. Figure 1 shows Tisza water catchment.

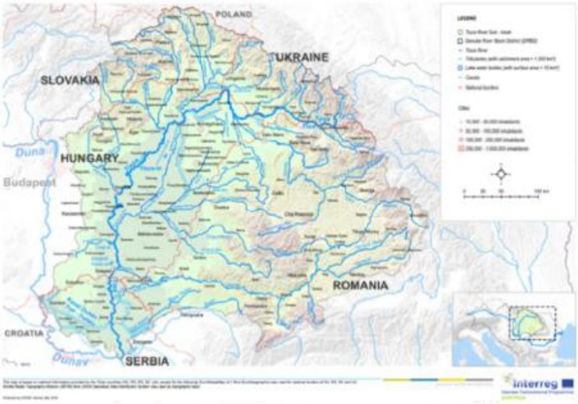

Figure 1. Tisza River catchment (low left sub-map of Danube river basin)
(Source: Interreg Danube GIS by ICPDR, 2011)

The main tributaries are the Túr, Szamos, Kraszna, Bodrog, Sajó, Zagyva, Körös andMaros. Hungarian rivers usually flood twice a year, in early spring due to snowmelt ("icy flood") (Kovács, 1987) and in early summer, due to the precipitation peak of the period ("green flood") (Szlávik, 2001). Per capita surface water resource (11000 m^3 /year) is one of the highest in Europe, but the contribution of the flows within the boundaries is low (600 m^3 /year/person), resulting in unequal geographic and temporal distribution of surface water resources. Watercourses at higher elevations were also regulated and reservoirs were created, significantly affecting the status of the water system (Somlyódy, 2000).

Majority of the land (74000 km^2) is used for agricultural purposes, mostly as cropland (58.7 %) or pastures (10.3 %). Vineyards, orchards and horticultures comprise of only 3.5 %. Forests account for 26 % of cultivated lands, reed and fishfarms 1.4 % (Cegielska et al., 2018).

2. INTEGRATED RIVER BASIN MANAGEMENT PLAN (ITRBMP)

IRBMP is an integrated planning document that describes the characteristics and challenges of a river basin. Its purpose is to outline a comprehensive set of measures to find solutions to complex problems. It follows a structured approach: finding out the facts, deciding on the necessary actions, making a management plan, and carrying out the plan. An essential part of the ITRBMP is the planning of the sustainable use of agricultural water resources (irrigation and drainage water). The process is datedback to 2000, when- EU Water Framework Directive was implemented at the level of river basin and sub-basin in Europe. In the 1st ITRBMP measures are addressed with respect to Significant Water Management Issues within the TRB and in line with EU Water Framework Directive (Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy).

The Joint Tisza ICPDR drives cooperation among the five Tisza-countries water management organizations and stakeholders by promoting common thinking and problem-solving. An elaborated common methodology for water demand and resources status assessment addresses the inter-linkages between the water quantity and quality issues within the Tisza River Basin and contributes to balanced water quantity management, achievement of good water bodies' status and integrated water management within the river basin.

2.1 Water Demand

The water resources of the Tisza River Basin are mainly used for public water supply, irrigation and industrial purposes, but also for other uses such as agriculture, fishing, hydropower production, and recreation. In future, increase in extreme events (severe floods-escess water and draughts) will haveadverse affects on water resources, ecosystems, human health, and economy within the region. Although the reserves of water are sufficient for current users, an increase is expected in water use accompanied with fluctuating climate may have adverse affects on water quantity. It is important that water reservoirs increase to treat the longer and more frequent water scarcity periods. The total number of reservoirs within the TRB is 125 scattered over the basin. The greatest number is located in Romania 77, followed by 23 in the Hungarian share of TRB, 9 in Ukraine and Serbia and 7 in Slovakia. With respect to volume there are 91 reservoirs with water storage ≤ 10 million cubic meters (Mm^3) with a total volume of 241.57 Mm^3 (Table 1).

Table 1. TRB reservoirs with volume ≤ 10 Mm^3 per Country(Matić, 2019)

Tisza Countries	UA	RO	SK	HU	RS
Number of reservoirs	9	48	1	24	9
Percentage of reservoirs per country	10.0	53.33	1.11	26.67	9.89
Volume per country Mm^3	17.703	132.465	2.19	72.665	23.45

From the point of view of agricultural water management, smaller local reservoirs ≤10 Tm^3 are also important, but these are not yet recorded in the international river basin management plan. In the future, these storage capacities will also have to be measured, (Figure 2).

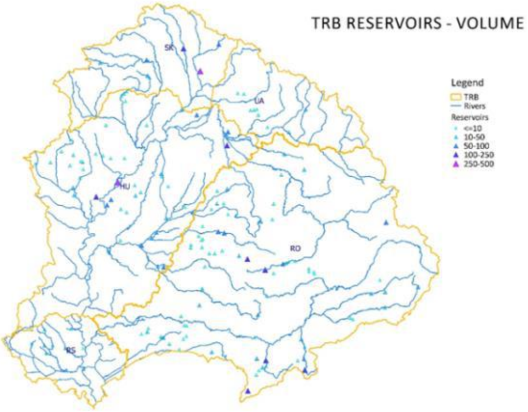

Figure 2. TRB reservoirs and volumes(Matić – Milovanović, 2019)

With respect to reservoirs with single purpose, all 26 reservoirs that serve only for flood protection are located in Romanian share of TRB, and 2 with flood retention purpose only are in Hungary. Nine reservoirs for irrigation are within Serbian share of TRB and 1 is in Hungary. Reservoirs for hydropower generation are located in Romania (5), and those for WS are located in Romania and Hungary, 1 and 2, respectively.

3. HUNGARIAN IRRIGATION STRATEGY

The central part of the River Tisza is the most drought-prone area in Hungary, therefore the current state of water management and the necessary developments are presented hereby focusing on the area of Central Tisza. Since there is no free water supply all over Hungary, it is not possible to irrigate everywhere, in addition, during the implementation of investments related to irrigation development projects besides the conditions of water resource management the conditions of nature conservation, environmental and soil protection must be fulfilled. The prospect of meeting water needs of irrigation is to give priority to surface water abstraction while the use of groundwater is minimised for irrigation purposes.

The hydrological forecasting system (HFS) of the Tisza Valley is based on a rainfall-drainage model Hydrologic Modeling System (HMS) of the Hydrologic Engineering Center (HEC). The HEC-HMS system is designed to model and analyze complete hydrology processes. The HEC-HMS model can be divided into four modules: 1. Basin/sub-basin module, 2. Meteorological module, 3. control module, 4. data storage module. A description of the physical parameters of the river basin (topology, water network, etc.) is set in the basin/sub-basin module. The hydrological processes must be set within this module including the properties of interception, surface storage, infiltration, surface runoff, groundwater migration, etc. The task of the meteorological module is to produce the meteorological boundary conditions needed to run the model. The module can be divided into 4 additional modules: radiation (short and long wave), precipitation, evapotranspiration and snow melting modules. The calculation method of the individual components is also declared in the meteorological module.

The control module contains the run parameters required for the simulation. The data storage module is used to store the input data (precipitation, temperature, etc) required for the simulation. 7180 square kilometer great area of the Central Tisza Region Directorate of Water Management is located in the central part of the Tisza in Hungary, which is almost entirely located in the Great Plain. Since it is lowland, the specific density of water management facilities (canals, embankments, sluices, etc.) is two times greater than the national average. The total length of the water supply channel in the state owned and managed assets of the Central Tisza Region Directorate of Water Management is 912,709 km, of which water distribution and water replenishment channels have a total length of 558,678 km and double-acting channels have a total length of 354,031 km. Water extraction both from groundwater and shallow reservoirs for irrigation purposes show an increase for which 2011and 2012 are good examples. In 2013 further growth with a value of 13,5% was observed due to the impact of the drought in the previous two years. In 2014, a decrease with a value of 7,6% was observed compared to the previous year, but in 2015 the growth was 16.32%. In 2017 the increase in water use for irrigation continued compared to the previous year, with a significant increase with a value of 35,02%.

Water table levels of groundwater can be significantly affected by evaporation, evapotranspiration and temperature fluctuations. In most parts of the Great Plain, the depth of the groundwater has an average value ranging 3-5 meters. Annual cyclicality is observed in the change of groundwater level, from autumn to spring growth while from spring to autumn decrease can be detected. Rivers or irrigation channels nearby can also significantly affect the water level. The most common situation in the Great Plain is when the groundwater level is directly connected to a river basin, resulting in two situations. Situation one is when the river feeds groundwater, since the water level of the river is higher than groundwater table. The other situation is the opposite, when the ground water feeds the river. In this case, the draining and trapping effect of the river prevails.

These processes show the greatest intensity along the riverside bar. Other artificial processes such as the operation of an irrigation channel can influence groundwater trends, as well. The channels located within the area of a certain Directorate are artificially created watercourses in order to drain the precipitation or to replace it in a water shortage period. During the irrigation period, there is a certain groundwater level increase in nearby channels, since this “artificial rainfall” also affects its environment. This effect is highly dependent on the operating scheme of the irrigation channel. The difference in groundwater levels can be used to estimate the amount of water by which the water amount of groundwater reservoirs reduces or increases, taking into account the porosity properties of the aquitards. In most of the groundwater monitoring wells the maximum water level was observed in April, while the minimum water level was observed in November, and the difference of these two was 2,82 km^3 (Figure 3).

In addition to natural factors, groundwater use can be increasingly modified by the use of groundwater for irrigation purposes. Groundwater was used primarily for irrigation in 2016 with a total amount of 539 356 m^3 and 2017 with a total amount of 486 397 m^3.

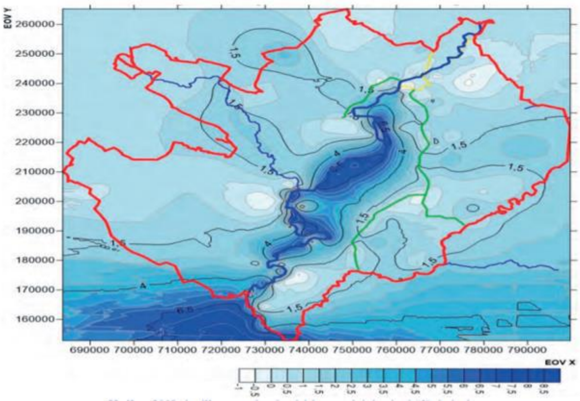

Figure 3. Average groundwater table value differences between April and November 2018 (Matić, 2019)

The consumption of groundwater without permissions can take place typically in two different ways: water production from illegal irrigation wells as well as from private wells, which are established for mainly watering purposes. There is no accurate data related to the mentioned consumption of wells, they can only be estimated. The consumption value for smaller private wells is 11.749.900 m^3/year. The irrigation of arable lands from illegal wells is typical, where there is no available surface water supply. Since the water consumption of irrigated arable lands can reach the value of thousands of m^3 per year from each well, therefore the total consumption can result in hundreds of thousands or millions of m^3 water per year. However, this is just a rough estimation, which is quite uncertain. The number of illegal wells is high because the official permission is still expensive. Reducing the fees could also encourage the resident population to create wells with permission. The legalisation of wells was free in 2018, the positive impact can be expected after 6-7 years.

In 2018, a drought monitoring system was put into operation based on the meteorological measurement network of the General Directorate of Water Management. The Pálfai drought index was calculated based on the measured data, therefore the length of the drought periods had to be established between 15 August and 30 November 2018, which resulted the average value of 5.73 ˚C/100 mm (Figure 4). Water fees were waived for irrigation farmers for this period, as the expected loss of crop yields could reach 30-40%.

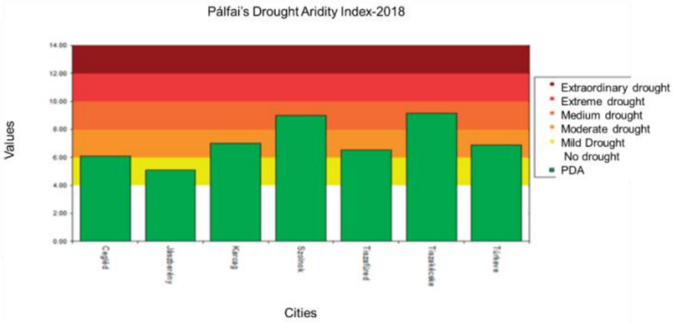

Figure 4. Pálfai drought index, 2018 (TIVIZIG, 2009)

Some of the irrigation systems built in the 70's and 80's had been out of service in the early 90's. The re-commissioning of these irrigation channels can be only achieved through reconstruction or developments, considering that these systems have been mostly floating water extraction objects, which have been ceased.

There are practically four types of results for environmental assessment of irrigation development:

(i) Water requirements for irrigation development are not significant as well as the expected cumulative effect.

(ii) Water requirements for irrigation development are significant, but the expected cumulative effect is not significant because sufficient free water supply is available.

(iii) Water requirements for irrigation development are significant as well as the expected cumulative effect, but water demands can be satisfied without any environmental risk by applying mitigation measures.

(iv) Water requirements for irrigation development are significant as well as the expected cumulative effect, moreover the water demand cannot be satisfied without any environmental risk by applying mitigation measures, and therefore an exemption procedure is required or the water demand can be only satisfied to an extent that does not yet cause significant impact on the environment (b version).

4. ALTERNATIVES IN DEVELOPMENT

Version 1: minimal development on water demand: The specified water yield which can be utilized for agricultural purposes from the Lake Tisza to the local environmental authority (KÖTIVIZIG) in case of the main irrigation channel of Jászság is 8,0 m^3/s, while in case of the main irrigation channel of Nagykunság and Tiszafüred it represents 38,3 m^3/s and 3,0 m^3/s, in total: 49,3 m^3/s. The total amount of the permitted water yields and the system losses in the „0" state indicate 41.467 m^3/s, while the free water supply is 7.833 m^3/s. The surface of the permitted area is 31.393 hectares. In the first version, the development on water yield is 4.009 m^3/s, however the development on area represents 3.023,8 hectares. The increase in water yield is approximately 9.7%, while the change in area shows 9.6%. These results are not considered to be significant from a professional point of view, since these irrigation systems had 60-70 thousandhectares of authorized area at the beginning of the 1980s. The planned developments do not have a significant impact.

Version 2: maximal development on water demand:After the implementation of version 1 (version 2), the available free water supply is 4.249 m^3/s from Tisza lake and 5.779 m^3/s from Hortobágy-Berettyó main channel, taking into account the defined water contingent, additionally 27.000 hectares of irrigation-development can be planned.

In the irrigation systems of Nagykunság, Jászság and Tiszafüred, approximately 12.000 hectares, along the Hortobágy-Berettyó main channel more than 15.000 hectares would be irrigated. In practice, the permissions have shown a significant amount of inaccessible water supply. The quality of irrigation can be still adequately ensured in the existing irrigation areas by releasing the inaccessible water supply, while new developments can be planned based on the additional water resources. The amount of unnecessarily inaccessible water yields can be estimated for 14.5 m^3/s, while the area that can be provided in this way can be estimated for 40,000 hectares. Filling up the fish ponds and the first floods of rice plants usually occur in the period of April-May, while irrigation and water resupply of fish ponds and rice ponds take place typically in from June to August.

5. CONCLUSIONS

According to data reported by Tisza countries, total water quantity for present uses (irrigation, other agricultural use, public water supply, industrial water supply, other uses) is 1,409.84 Mm3, regardless of the source of water being significantly smaller than planned water demand by the end of the next planning period 2,585.67 Mm3, e.g., approximately 54 %. The most significant water demand increase within the TRB is planned for irrigation – 67 %, and according to provided data with respect to water source the majority of water intake increase is planned from surface water.

For other agricultural use, water intake increase is planned both for surface and groundwater sources. Although the quantity of water for public water supply is higher at the present than future demand, there is a planned increase of intake from groundwater. Based on data and information reported by Tisza countries, it is obvious that planned increase in water demand refer to both surface and ground water sources, from 566.57 to 805.61 Mm^3 and from 75.51 to 91.99 Mm^3, respectively.

6. ACKNOWLEDGEMENT

This research was supported by EFOP-3.6.2-16-2017-00001 project (Research of complex rural economic and sustainable development, elaboration of its service networks in the Carpathian basin).

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