Coordinated water resources allocation in the Hungarian part of the Tisza River Basin

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DOI: 10.5281/zenodo.17691634

Abstract

The Tisza–Körös Valley Integrated Water Management System (TIKEVIR) represents one of Hungary's most complex hydraulic networks, designed to balance the spatial and temporal distribution of water resources across the Great Hungarian Plain. This study analyzes the coordinated operation of the system during the 2025 water scarcity period, focusing on the implementation of the Water Restriction Action Plan and the introduction of system-wide operational scheduling. Based on daily hydrological monitoring and the application of reduction factors (r_t), water allocations were dynamically adjusted to match available discharges and user demands. Despite critical low-flow conditions comparable to the 2022 drought, adaptive management enabled the retention of approximately 15 million m³ of surplus water in Lake Tisza and the transfer of more water to the Körös Valley. The results demonstrate that coordinated scheduling significantly improved the efficiency and equity of water resource distribution under constrained conditions. The applied methodology provides a replicable framework for enhancing drought resilience and sustainable water governance in large-scale lowland hydrosystems.

Introduction

The Tisza Valley is one of Hungary's most significant hydrological and economic regions, covering about 45% of the country's territory. The Tisza River and its tributaries – such as the Bodrog, Sajó, Zagyva, Körös and Maros – shape the natural landscape, agricultural potential, and settlement structure of the Great Hungarian Plain (ICPDR, 2019). Water management in this region is particularly complex, as it must simultaneously address flooding, inland waterlogging, and drought, while ensuring the sustainable use of water resources.

Due to the flat terrain and poor drainage, inland waterlogging is another major issue in the Tisza region, especially during wet winters and springs (Somlyódy, 2011). The total length of inland drainage canals exceeds 30,000 km. However, with the growing impacts of climate change, water retention has become increasingly important. The goal is not only to reduce damage but also to stabilize groundwater levels and support the water needs of natural ecosystems and for irrigation purposes.

The Tisza Valley is among the driest regions of Hungary, and drought has become an increasingly severe economic problem, particularly for agriculture, which depends heavily on irrigation. In recent years, there has been a strong emphasis on irrigation development and efficient water use. The Kisköre Reservoir (also known as Lake Tisza) plays a key role in this system: it regulates water flow, supplies irrigation water, and also serves recreational, fisheries, and environmental protection purposes.

The northeastern region experiences the harshest winters, the central area is the driest, while the southeastern part has the warmest summers. In the southern Great Plain, the mean annual temperature exceeds 11 °C, whereas in the northeast it remains slightly below 10 °C. Summers are the hottest (with a mean July temperature of around 21 °C) and winters the coldest in this area. The annual total of sunshine hours exceeds 2,000 over most of the Great Plain. The lower cloud cover, reduced relative humidity, and limited, highly variable precipitation contribute to the frequent occurrence of summer droughts.

An analysis of the temporal and spatial characteristics of drought events indicates that all major droughts occurring in Europe have historically affected Hungary as well. Projections suggest that approximately 90% of the national territory is likely to be exposed to drought conditions, with the lowland areas exhibiting the highest degree of vulnerability. Nevertheless, the detrimental effects of droughts can be alleviated through the adoption of integrated water management approaches and the application of efficient irrigation technologies (Tamás, 2016).

In Hungary, the regional Water Directorates are responsible for ensuring the provision of water at the appropriate locations and times. To enhance resilience against extreme hydrometeorological phenomena, the Hungarian 'National Water Strategy' prescribes both short- and long-term measures. Achieving these objectives, particularly the adequate water supply for lowland areas even during exceptionally dry years such as 2022, requires a high level of preparedness. The foundation for such efforts lies in the Tisza–Körös Valley Integrated Water Management System (TIKEVIR), which provides the technical and engineering framework for water distribution in the Great Hungarian Plain. The primary purpose of establishing TIKEVIR was to secure water resources, implement regulated water governance, and mitigate the impacts of hydrometeorological extremes across the region (Vizi et al., 2018).

Tisza–Körös Valley Integrated Water Management System (TIKEVIR)

The Tisza–Körös Valley Integrated Water Management System (TIKEVIR) is one of Hungary's most complex and extensive lowland water management systems. Covering an area of approximately 12,000 km² between the Tisza and

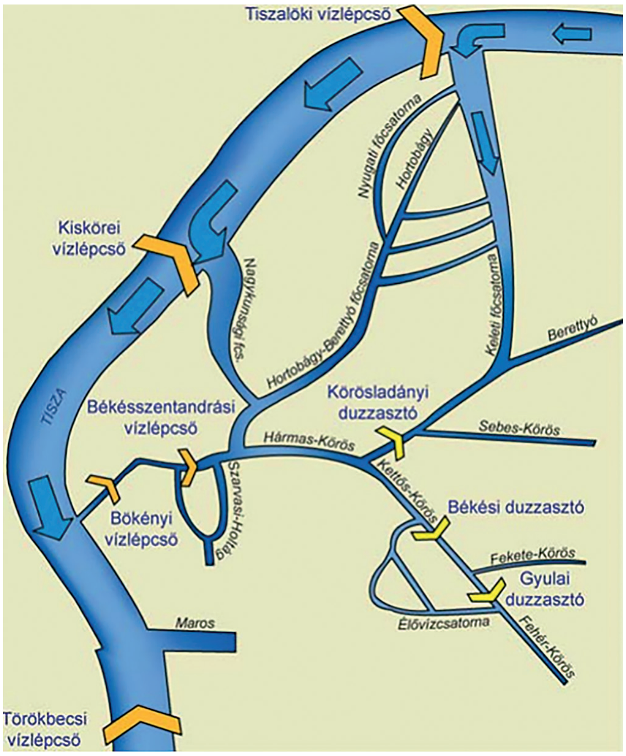

Figure 1. Schematic layout of the Tisza–Körös Valley Integrated Water Management System (TIKEVIR) (source: General Directorate of Water Management).

Körös rivers, its primary objective is to balance the effects of water scarcity and water abundance by enabling the spatial and temporal redistribution of water resources. This regulation serves agricultural production, municipal water supply, as well as ecological and recreational needs in the region.

The central element of TIKEVIR is the Kisköre Dam (Lake Tisza), which regulates the flow of the Tisza River and allows controlled water transfer towards the Körös Valley, the Nagykunság, and the Hortobágy regions. Its main conveyance channels – such as the Nagykunság Main Canal, the Jászság Main Canal, and the Hármas–Körös–Berettyó connection – form an interconnected network that enables multi-directional water movement (*fig. 1*). The operation of the system is supported by automated hydraulic structures, sluices, and pumping stations that ensure precise quantitative and qualitative water regulation.

Beyond irrigation, TIKEVIR performs complex water management functions, including inland drainage, flood control, and ecological water supply to the Körös Valley. In recent years, system development has focused on climate-adaptive water retention, digitalized operational control, and sustainable water resource management. TIKEVIR plays a key role in maintaining water security in the Tisza Valley and preserving the overall hydrological balance of the Great Hungarian Plain.

Hydrology

In certain parts of the TIKEVIR system, the satisfaction of water demands had already become limited by the end of June. In some sections of the Hármas–Körös and Kettős–Körös rivers, the discharge values turned negative, and the rate of evaporation also increased. An important consideration was the establishment of a unified priority ranking, taking into account both licensed and extraordinary water demands. According to the 'Hungarian Act LVII of 1995 on Water Management', ecological water replenishment has priority over agricultural water use, and it was not clearly clarified which water supply belongs to which category.

On the day when the water resources allocation was ordered according to the Water Restriction Action Plan (1 July 2025), the discharge of the Hungarian section of the River Tisza was comparable to the lowest flow conditions observed during the severe water scarcity period of 2022 (Vizi, 2023) (*fig. 1*). On the free-flowing section downstream of the Kisköre Dam, due to the recent developments of the surface water intake facility at Szolnok, maintaining a minimum discharge of 58–61 m³/s was sufficient at Kisköre, instead of the former minimum requirement of 65 m³/s. As a result, approximately 15 million m³ of additional water could be retained in Lake Tisza during the summer period.

Operation under reduced downstream water levels resulted in the establishment of new Low Water Reference (LWR) levels at Kisköre-alsó (-342 cm), Tiszaroff (-383 cm), and Szolnok (-301 cm). To maintain the operational safety of the Szolnok surface water intake facility, a provisional structure was once again constructed during the 2025 water scarcity management period.

At Tiszalök, during the mitigation operations, the diverted discharge temporarily fell below 60 m³/s on two occasions: between 18–20 August (minimum 51 m³/s) and between 9–10 September (minimum 57 m³/s).

Throughout the year, water replenishment of the Körös Valley via the Nagykunság Main Canal exceeded the prescribed discharge of 16 m³/s during several intervals. Between 12–18 July and 21 July–8 August, the combined discharge through the eastern and western branches reached 20–24 m³/s. Conversely, during the period of 18–26 August, reduced transfer rates had to be maintained, with the eastern branch flow decreasing first to 12 m³/s and subsequently to 10 m³/s.

During the flow regulation period (1 July–15 September), approximately 65 million m³ more water was transferred to the Körös Valley compared to the same period in 2022. Throughout the summer, water transfer through the Keleti Main Canal was continuously maintained at the maximum level permitted by technical constraints. Nevertheless, it should be emphasized that increasing the discharge capacity through the Bakonszeg structure would be desirable to enhance future operational efficiency.

To facilitate the most effective execution of water distribution, discharge measurements were carried out across the extended impact area of the TIKEVIR system. The results of these discharge measurements provided essential input data for the daily water balance calculations.

Water resource sharing based on the TIKEVIR Water Restriction Action Plan

The water use restrictions were necessitated by the natural decline in available water resources and the concurrent increase in water demand. The resulting constraints must be borne equitably by all water users within the TIKEVIR system. The degree of restriction applied within the irrigation systems (denoted as rt, the reduction factor) is determined for each subsystem by the ratio between the daily transferable water volume and the total daily water demand.

The efficient allocation of available water resources was greatly facilitated by several moderate increases in discharge that occurred on four occasions during the summer, due to rainfall events in the upper Tisza catchment area. Each of these episodes provided an opportunity to replenish stored water reserves – such as those in Lake Tisza and the irrigation canals. In contrast, no significant runoff-generating precipitation occurred in the Körös catchment area; however, under more favorable hydrological conditions, the water replenishment to the Körös Valley via the Nagykunság Main Canal was temporarily increased by 5–6 m³/s.

Considering the TIKEVIR system as a whole, the highest recorded daily water demand occurred on 24 July 2025, reaching 96.8 m³/s, while the lowest reported demand (39.6 m³/s) was observed on 15 September.

During the 77 days of coordinated water resources allocation, temporary increases in river discharge allowed for 15 days when it was not necessary to reduce the reported water demands through scheduling adjustments. However, during the remaining 62 days of the two-and-a-half-month period, varying levels of demand reduction were required.

The lowest reduction factor was recorded on 30 August, when only 31.2% of the reported water demand could be met within the Tiszalök subsystem, and merely 28.4% within the Kisköre subsystem. By that time, however, the overall reported demand across the TIKEVIR system had already decreased to approximately two-thirds (60.4 m³/s) of the seasonal maximum of 96.8 m³/s.

Water allocation scheduling in the extended TIKEVIR System

The extended TIKEVIR system integrates multiple hydraulic subsystems and irrigation networks across the Tisza River Basin, requiring coordinated operational management during periods of limited water availability. Water allocation scheduling serves as a key component of this management framework, ensuring the equitable and efficient distribution of available water resources among users while maintaining ecological flow requirements. This process relies on continuous hydrological monitoring, dynamic assessment of inflow and demand patterns, and the application of reduction factors (r_t) to balance system-level water use with daily transferable capacities. The methodology applied during the 2025 water scarcity period aimed to optimize the use of constrained water resources

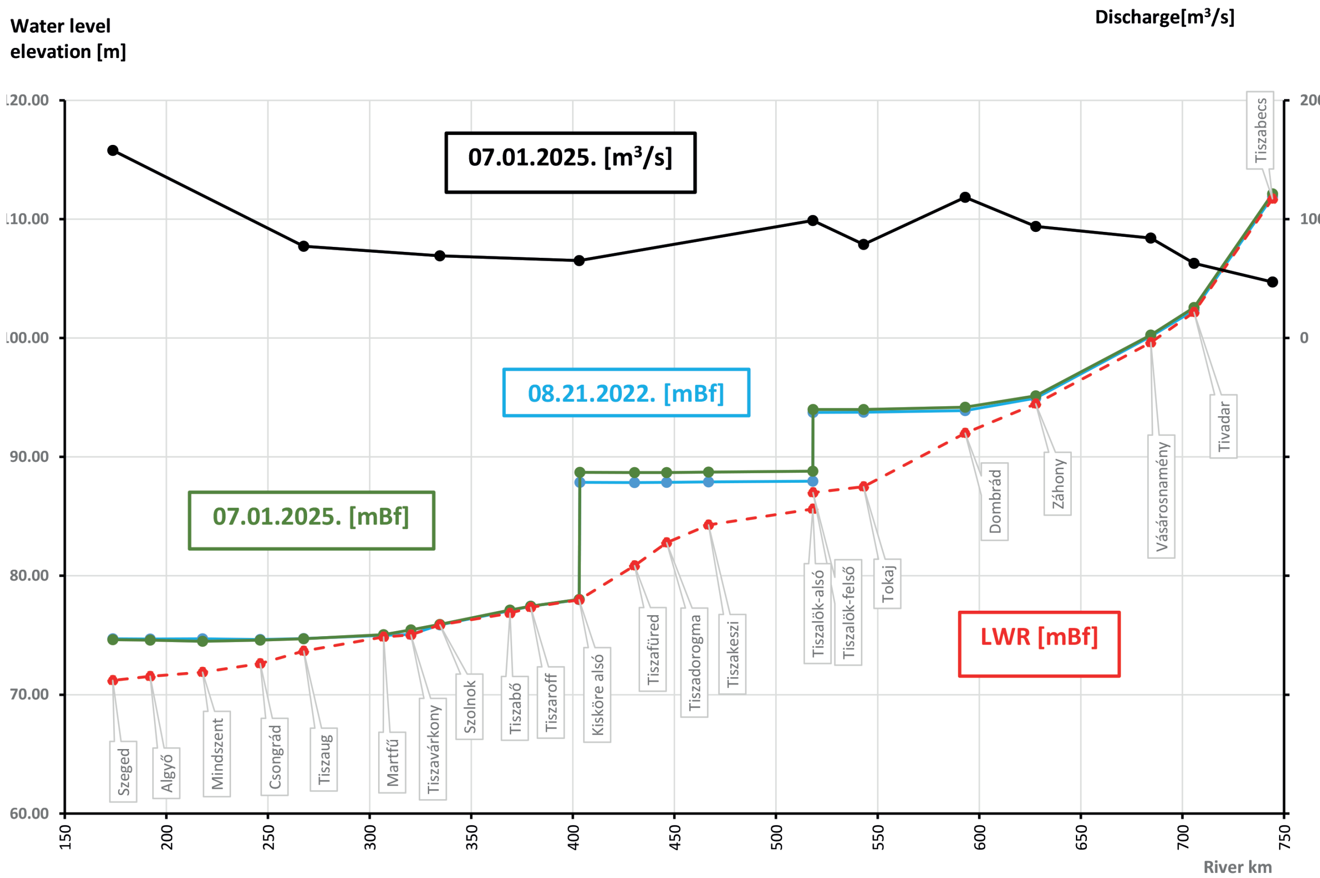

Figure 2. Hydrological situation along the Tisza River compared to the minimum level of 2022. Copyright: Dávid Béla Vizi

while minimizing the adverse impacts on agricultural production and ecosystem services.

In order to ensure the most efficient and economical distribution of available water resources, the regional Water Directorates introduced subsystem-level operational scheduling within their operational area. This approach aimed to reduce the magnitude of simultaneous water withdrawals across the system.

The implementation of scheduling allowed for the limistation of concurrent abstractions, and, when necessary, for the reduction of the maximum withdrawal rate at individual intake points. The scheduling process covering the extended TIKEVIR system required careful coordination and close monitoring. The target discharge values were calculated daily as the product of the reduction factor and the total requested discharge. These values were determined based on the available water resources and the concurrently reported water demands, according to the TIKEVIR Water Restriction Action Plan.

KÖTIVIZIG evaluated the effectiveness of the scheduling each day by comparing the allocated discharges with the quantities of water that could be distributed according to the reduction factor within the extended TIKEVIR system.

As illustrated in figure 3, throughout the period between 1 July and 15 September, the total discharge released for water replenishment under the scheduling regime only persistently exceeded the reduction-factor-adjusted target between 13 and 21 August. This corresponded to the period when the required water quantities could only be supplied by utilizing the surplus water stored in Lake Tisza, resulting in a notable decrease in upstream water level – up to 3–4 cm per day. During the entire mitigation period, the total actual discharge released through the scheduling process remained significantly lower than the total reported demand (blue columns in *fig. 3*) on a system-wide scale.

There were certain periods during which individual Water Directorates exceeded the water volumes calculated for them based on the respective reduction factors. However, apart from the previously mentioned interval, these deviations did not result in sustained overuse at the overall TIKEVIR system level, as other Directorates simultaneously utilized considerably less water than their allocated quotas.

At the TIKEVIR system scale, the highest recorded discharge occurred on 25 July 2025, amounting to 56.0 m³/s, which represented 58.3% of the total reported demand on that day (96.1 m³/s).

It can be concluded that the coordinated and system-wide implementation of operational scheduling enabled a substantially more efficient and balanced distribution of available water resources.

Conclusions

Water management in the Tisza Valley is one of Hungary's most complex and vital environmental, economic, and social issues. The 19th-century river regulations created safer living

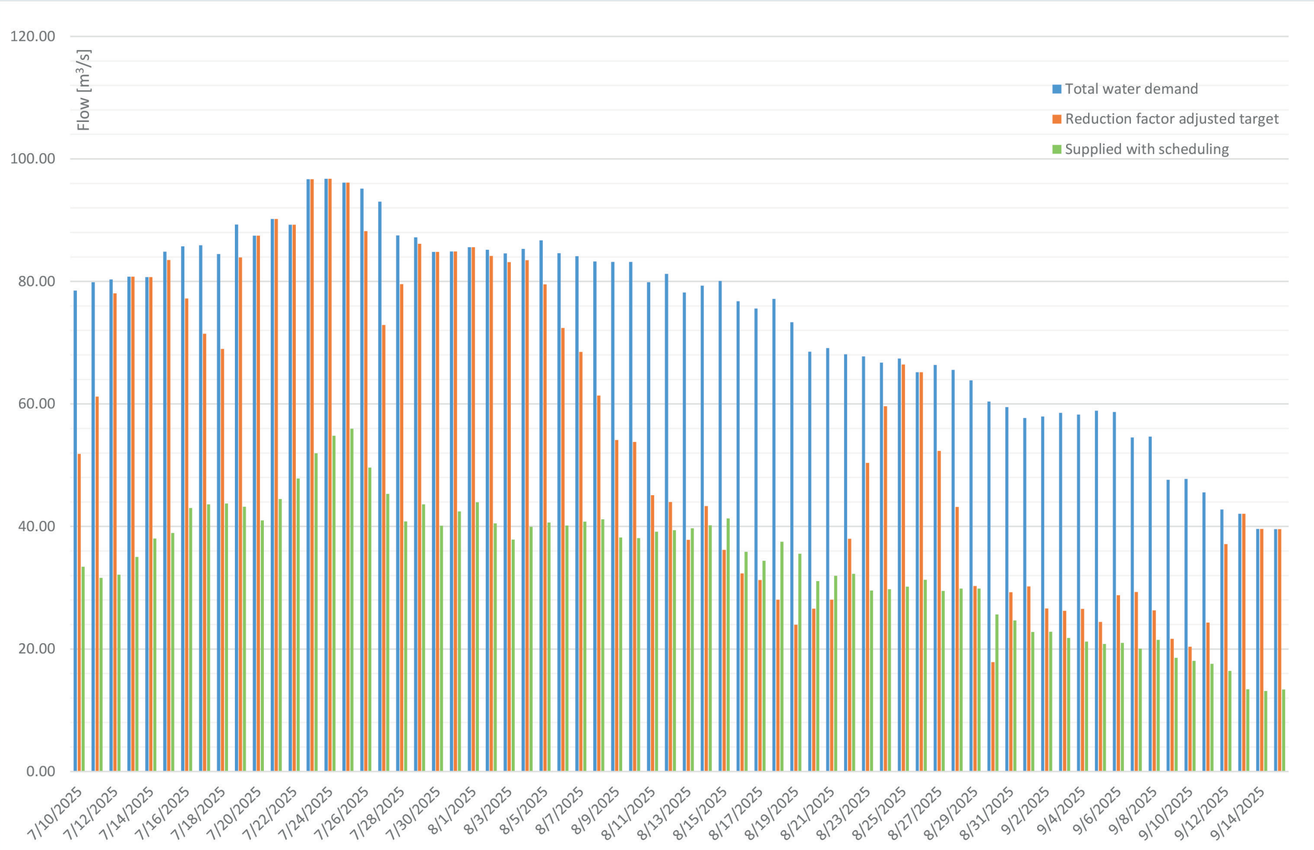

Figure 3. Total water demand and the reduced value by the reduction factor compared to the water volumes delivered by scheduling.
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conditions, but the modern challenges of climate change, drought, and water quality require new, flexible, adaptive solutions. The future of water management in the region lies in water retention, maintaining ecological balance, and strengthening cooperation between regions and countries.

The research analyzes the implementation of the Water Restriction Action Plan, which established a regulated framework for equitable water distribution among irrigation, municipal, and ecological users. The study emphasizes the introduction of operational scheduling within the extended TIKEVIR system, designed to harmonize subsystem-level water abstractions and to optimize the utilization of limited water resources through the application of reduction factors (r_t). Daily discharge targets were dynamically adjusted in accordance with the available water stocks and concurrent demands, enabling responsive and data-driven system management.

Hydrological observations revealed that, by late June, several sections of the system experienced restricted water availability, with minimum discharges comparable to those recorded during the 2022 drought. Despite this, effective coordination allowed the maintenance of critical ecological flows and the retention of approximately 15 million m³ of additional water in Lake Tisza. During the 77-day allocation period, 65 million m³ more water was transferred to the Körös Valley compared to 2022, while demand reductions were necessary on most days to ensure sustainability.

Overall, the study demonstrates that coordinated, system-wide scheduling significantly enhanced the efficiency and fairness of water allocation within the TIKEVIR network. The adaptive management framework applied in 2025 provides a model for future drought resilience and sustainable water governance in large-scale lowland hydrosystems such as the Tisza Basin.

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The Tisza Basin – Source of Innovative Solutions to Plastic Pollution in Rivers

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DOI: 10.5281/zenodo.17691671

Plastic pollution in the Tisza River Basin

The Tisza (Тіша/Tisa/тиша/Theiss) is the Danube's longest tributary, stretching over 960 kilometers. Like the Danube, it is an international river, collecting water from five countries (Ukraine, Romania, Hungary, Slovakia, and Serbia) before joining the Danube. It drains the largest sub-basin of the Danube River Basin, covering a catchment area of more than 157,000 km². The Tisza River Basin lies within the Mid-Danube or Pannonian Basin – an area of almost 300,000 km² where four of the Danube's largest tributaries meet: the Morava, Drava, Sava, and Tisza. Historically, about 10% of the basin was covered by rivers, lakes, and wetlands, a landscape comparable to present-day Finland (Bódi, 2014; Jurvelius, 1983). During flood periods, the water-covered area could double or even triple, the extent and structure of surface waters in the medieval Pannonian Basin were visualised with the help of artificial intelligence (Jakab et al., 2025). By the mid-19th century, however, extensive river regulation and drainage works radically transformed the basin. Approximately 85–90% of surface freshwater has been lost since then (Werners et al., 2010), making it the second-largest loss of surface waters in the world after Ireland (Fluet-Chouinard et al., 2023). River meanders were cut off, and almost all natural watercourses were confined between levees. The Tisza alone lost 112 of its meanders, shortening its length from 1,419 to 962 km, while its floodplain shrank to less than 10% of its original size (Lászlóffy, 1982). This transformation disrupted local water cycles, intensified droughts, and increased the impacts of climate change – including extreme floods, water scarcity, and desertification. It also unintentionally worsened plastic pollution. The faster flood waves and higher flow velocities of regulated rivers now transport massive amounts of floating waste. In effect, during every flood, the river flushes out its accumulated pollution, sweeping plastic from floodplains downstream. Although the EU Water Framework Directive and the EU Mission Restore Our Ocean and Waters have improved water quality in EU countries, transboundary rivers such as the Tisza, with its source lying outside the EU, remain difficult to manage.

Today, the Tisza is among the most plastic-polluted tributaries of the Danube, the abundance of passing PET bottles often exceeding the 50 items/minute threshold (*fig. 1 & 2*).

Floating riverine litter accumulations – the riverine counterparts of marine garbage patches – can reach considerable