ISSN 2070-1292

danube news

Bulletin of the International Association for Danube Research (IAD)
Informationsblatt der Internationalen Arbeitsgemeinschaft Donauforschung (IAD)

donau aktuell

Editorial

Gertrud Haidvogl: Editor DanubeNews, Institute of Hydrobiology and Aquatic Ecosystem Management, University of Natural Resources and Life Sciences Vienna (BOKU), Austria, e-mail: gertrud.haidvogl@boku.ac.at
Bernd Cyffka: Editor DanubeNews, Applied Physical Geography, Catholic University of Eichstätt-Ingolstadt and Aueninstitut Neuburg/Donau, Germany, e-mail: bernd.cyffka@ku.de

Dear readers,

An extraordinary year will end soon. We hope that you have so far passed all the turbulences caused by COVID-19 in good health. Nine months ago, nobody would have thought how fast we would be able to train our skills in home office, video conferencing and distance learning. While this way, working life could at least function halfway indoors, field-work was at least complicated, if not stopped at all due to contact restrictions. The IAD conference, which should have taken place in July 2020, was finally postponed to June 2021 to increase the chances for a much-requested meeting with physical presence of the participants.

We are delighted that so many colleagues have agreed to provide insights into their research activities in our association bulletin "Danube News" during this troubled time. The Tisza, the longest tributary of the Danube, is the focus of the first article in Danube News 42. Dávid Béla Vizi and Tamás Právetz investigated options for improving the river's discharge capacity by restoring flood plains in a section of the Middle Tisza. Their work was part of the EU-funded project Danube "Floodplain". The contribution of Barbara Stammel and her colleagues also originates from a project funded by the Transnational Danube Programme: "Improving Water Quality in the Danube and its tributaries through Integrated Floodplain Management based on Ecosystem Services" (IDES) aims to improve water quality management in the Danube and to identify synergies in the provision of ecosystem services. A short overview of

The Ottheinrichbach, a bypass river of the Bergheim hydropower dam on the Upper Danube in Bavaria, in winter.

investigations of microbial water quality in Serbian rivers is the main topic of the manuscript by Stoimir Kolarević and his colleagues. Finally, Hélène Masliah-Gilkarov presents the WePass project, which represents another milestone in the long-standing efforts to make the hydroelectric dams of the Iron Gates passable for aquatic fish and especially for the Danube sturgeon.

Many aquatic biologists mourn for Elsa Leonore Kusel-Fetzmann. The obituary in our News and Notes section honours her immense oeuvre in hydrobotany. Finally yet importantly, we advertise on our own behalf: On the initiative of IAD President Cristina Sandu, a children's book about Danube sturgeons was created as part of a project. "The Adventures of Starry, the Brave Sturgeon" is available in English, but also in nine different languages spoken in the Danube region.

Many thanks to everyone who contributed to this issue of Danube News. We wish our readers all the best and health for the coming months.

The possibilities of improving the conveyance capacity with restoration measures along the Hungarian Middle Tisza River section, based on a pilot area

Dávid Béla Vizi: Middle Tisza District Water Directorate, Szolnok, Hungary, e-mail: vizi.david.bela@kotivizig.hu

Tamás Právetz: Middle Tisza District Water Directorate, Szolnok, Hungary, e-mail: pravetz.tamas@kotivizig.hu

Abstract

Over the past decades, several extraordinary floods have occurred from rivers in the Danube River Basin. Each of the flooding levels that emerged were one of the centennial flood that caused significant human and economic damage in the affected countries. To handle increasing flood risks within the European Union, the No. 2007/60/EC Directive requires almost all river basin districts to identify areas where there is a significant potential flood risk. The identified flood risks are needed to be reduced as much as

possible to ensure greater human and economic security. This article presents the characteristics of the Tisza River, which are endangered by hydrological extremes. In the case study we attempt to identify the problems with the water conveyance capacity, especially in connection with the land use and forest management practices on the floodplain areas. According to our measurements, these activities have a significant effect on the conveyance ability of the floodplain directly and also indirectly. Land use in the floodplains has changed continuously in the last decades. The increase of forest area resulted in a decrease of the water conveyance capacity in the floodplain. It caused significant negative impact on flow velocity, sediment accumulation and flood levels. Following the remarkable flood events of the early 21st century, dyke sections in the Middle Tisza District were relocated to improve the conveyance in the floodplain area. The other challenge is to develop new practices related to use of the landscape for maintaining the conveyance capacity, taken into consideration the Water Framework Directive and the conservation of ecosystem services. Further aim is to demonstrate the applicability of a two-dimensional hydrodynamic model to study the effects of the restoration measures. In a pilot area, we tested the optimal restoration measures (dyke relocation, land use change and afforestation technique), which can significantly improve conveyance. Based on the modeling results, conveyance capacity of the floodplains can be increased, resulting in flood risk reduction. If the pilot area study gives satisfactory results in practice, it could be applied to other similar river sections in the Danube catchment area.

Introduction

The Tisza River Basin *(fig. 1)* drains an area of 156,869 km². Five countries are sharing this largest sub-basin of the Danube River Basin (Romania, Ukraine, Slovakia, Hungary, and Serbia). The Tisza River is the longest tributary of the Danube (966 km), and the second largest by flow, after the Sava River (ICPDR 2019).

The Tisza River itself can be divided into three main sections:

- **The Upper Tisza** upstream from the confluence with the Somes/Szamos River,
- **The Middle Tisza** in Hungary, which receives the largest right-hand tributaries: the Bodrog and Slaná/Sajó Rivers together with the Hornád/Hernád River collect water from the Carpathian Mountains in Slovakia and Ukraine, and the Zagyva River drains the Mátra and Bükk, as well as the largest left-hand tributaries: the Szamos/Somes River, the Körös/Crisuri River System and Maros/Mures River draining Transylvania in Romania,
- **The Lower Tisza** downstream from the mouth of the Maros/Mures River where it receives the Begej/Bega River and other tributaries indirectly through the Danube – Tisza – Danube Canal system.

The river regulation and dyke construction works were finished on the Hungarian section of the Tisza River in the early 20th century. These measures created a new situation for the Hungarian flood protection. Over time, one had to face new problems after the river has been confined between the dykes (Somlyódy 2011). The major challenges are that the river can deposit the transported sediment between the embankments. The other problem is that percentage of floodplain forests has increased tenfold over the last hundred years as a consequence of which morphology and pattern of the watercourse has been changed (Szlávik 2003). One of the largest increases in flood waves is caused by the rise of invasive species, which pose a serious challenge to the water management. The most invasive plant along the Tisza is the *Amorpha fruticosa* (Csiszár et al. 2013). These processes reduce the conveyance capacity of the floodplain areas and also increase flood peaks. As a result of these processes a lower maximum flood discharge can produce the highest ever measured water level *(fig 2.)*

Climate change is also a major cause of increasing weather extremes and affects the hydrological cycle (Mauser et al. 2018). Over the past decades, several extraordinary floods have occurred on the rivers in the Danube River Basin. Each of the flooding levels that emerged caused centennial flood waves and significant human and economic damage in 2000 along the Tisza River. Vizi et al. (2018) studied the

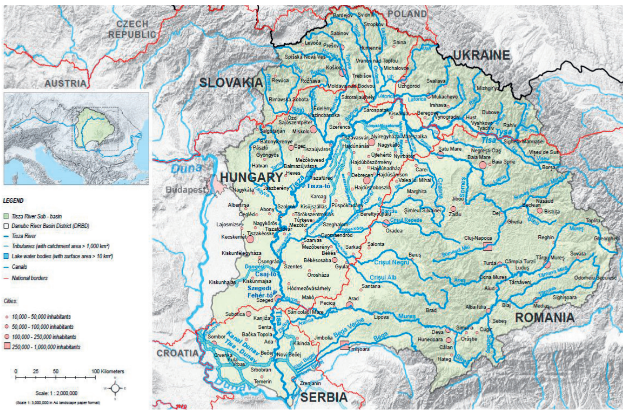

Figure 1: *An overview of the Tisza River Basin. Credit: ICPDR*

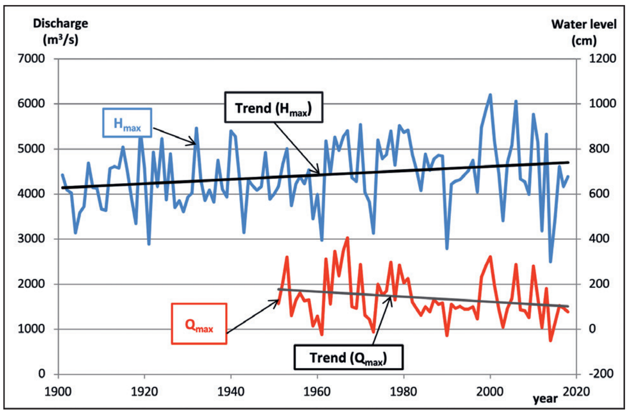

Figure 2: *Maximum discharge and water-level of river Tisza at Szolnok. Credit: Dávid Béla Vizi*

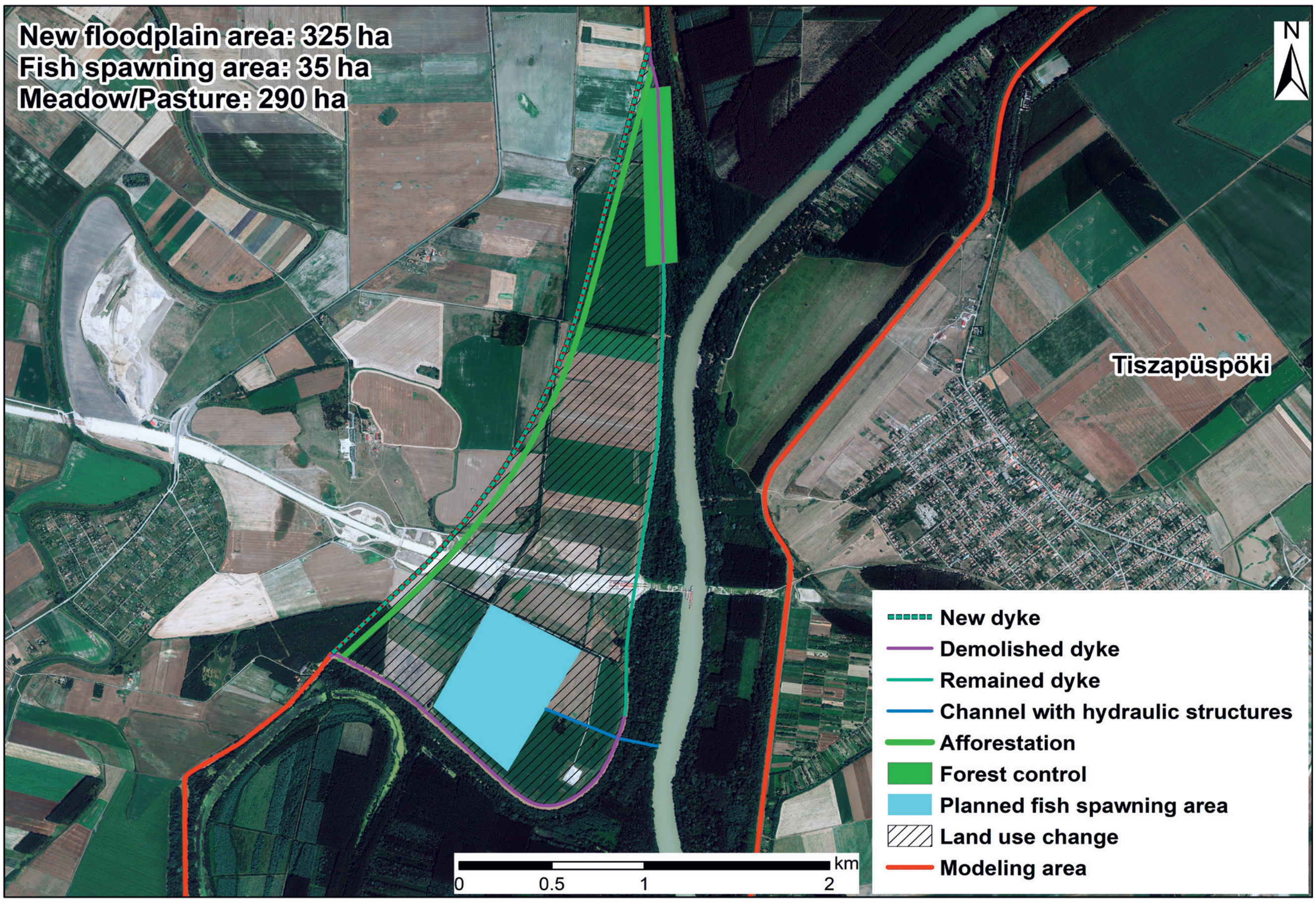

Figure 3: Location of the pilot area near Szolnok, Hungary. Credit: Tamás Právetz

impact of increasing flood peaks caused by climate change, which is further increased by declining conveyance capacity.

To handle increasing flood risks within the European Union the No. 2007/60/EC Directive requires almost all river basin districts to identify areas there is a significant potential flood risk or likely to occur. The identified flood risks are needed to be reduced as much as possible to ensure greater human and economic security. Following the remarkable flood events of the early 21st century, dyke sections in the Middle Tisza District were relocated to improve the conveyance in the floodplain area. The other challenge is to develop new agricultural and forestry practices related to the use of the landscape to improve the conveyance capacity, while taking into consideration the Water Framework Directive and the maintenance of ecosystem services (GDWM 2018).

The tool for this study was the two-dimensional HEC-RAS hydrodynamic modelling software. We had the opportunity to examine the impacts of different types of measures on floods. Hydrodynamic modeling has become an important tool for impact assessments. In addition to flood peak reduction, changes in flow conditions can also be analyzed.

Study area

The project area is Besenyszög-Fokorúpuszta in the floodplain on the left side of the Middle Tisza near Szolnok town *(fig. 3)*. The Tisza's full gradient is 30 m (5 cm/km) in Hungary. Based on the Middle Tisza District Water Directorate (MTDWD)'s hydrometric data, the minimum discharge of the river is 46.9 m^3/s, and the maximum discharge is 2,610 m^3/s at Szolnok. The long-term average discharge is 532 m^3/s at this river section. The highest ever measured water-level was 1040 cm at Szolnok in 2000. The water level fluctuation is 1,320 cm between the highest and lowest values.

A central element of the restoration is the planned dyke relocation. Approximately 6 km of the dyke will be relocated for a wider active floodplain between the dykes. The result of this relocation will yield an approx. 280 hectares larger floodplain area. For the new dyke construction, a borrow pit in the area will be used, that will be partly filled up with the material from the demolished dyke and used as a fish spawning area for ecological benefit. The planned main land use in the new floodplain area is grassland; lower parts will be left as periodically inundated for wetland habitats without an outlet. The fish spawning area is designed to be connected to the river Tisza with a canal. New forest zones are planned outside the major flood inundation area. In the future, they want to promote grazing in new floodplain areas, in order to help to maintain water conveyance capacity.

In a pilot area, we tried to identify the optimal restoration measures (dyke relocation, land use change and afforestation technique), which can improve runoff. The approach of an integrated river basin management has a high priority in

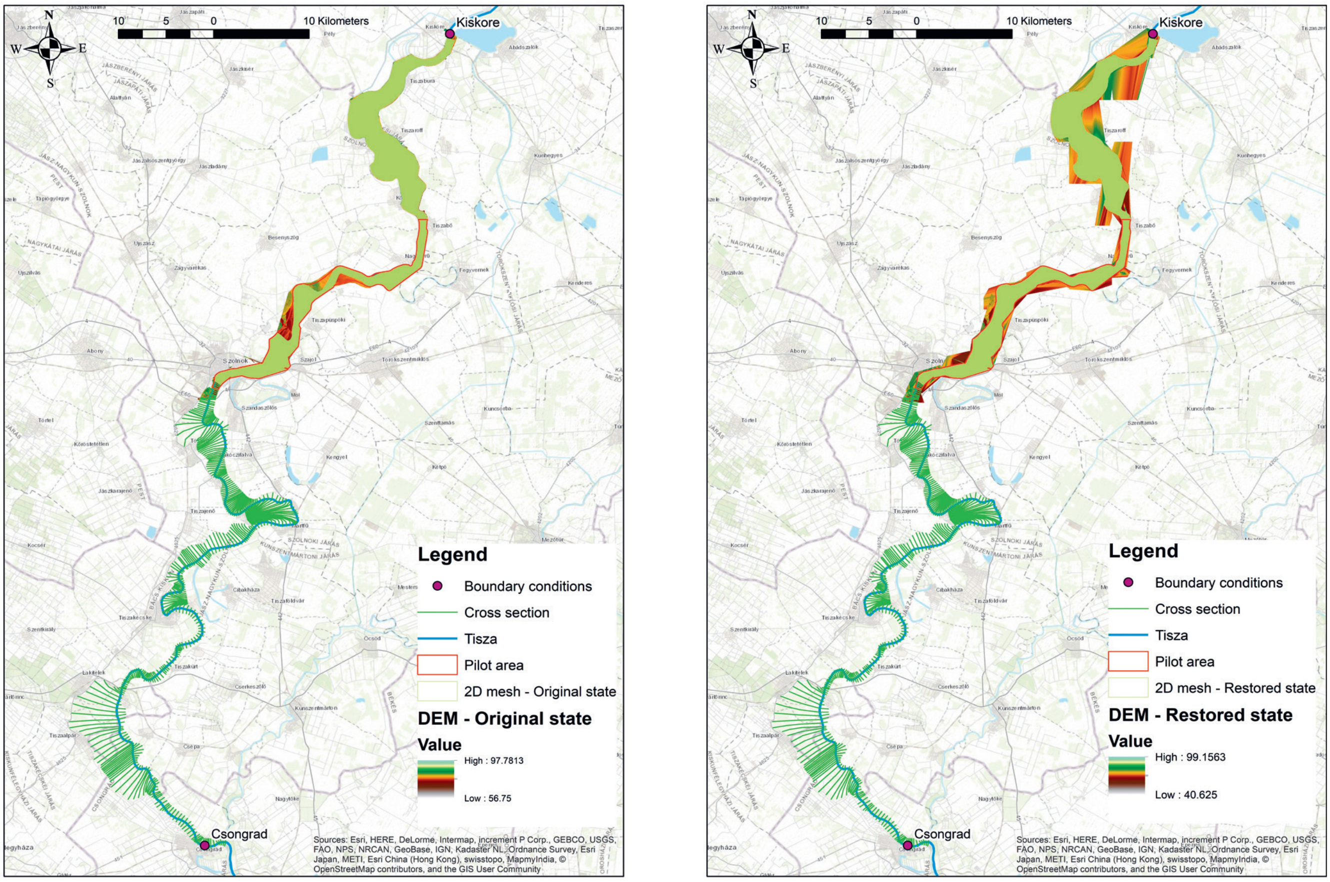

Figure 4: Model versions for original (left) and restored (right) states. Credit: Dávid Béla Vizi

Hungary. By identifying optimal interventions, flood protection can be brought closer to other water-related sectors. The study areas can serve as a good example at river basin level.

Methods

The HEC-RAS modelling software was developed by the Hydrologic Engineering Center (HEC) of the US Army Corps of Engineers. The program has been successfully used for one- and two-dimensional modelling in the United States of America for all major rivers (US Army Corps of Engineers 2016).

The model for the pilot study was developed by the MTDWD. The model geometry was based on a previous version (current state), which was used for the modelling of the impact of some measures along the Tisza. This model version was updated for the Danube Floodplain project (http://www.interreg-danube.eu/approved-projects/danube-floodplain).

The model includes an approx. 160 km long river section of the Tisza from Kisköre (403 river km) to Csongrád (246 river km). The model has two main parts: a 2D mesh between Kisköre and Szolnok, and a 1D river section between Szolnok and Csongrád. That 1D section was needed to have enough space between the pilot site and the downstream boundary. We did not increase the computation time as much with this solution as if we had increased the 2D mesh. The 2D mesh only included the floodplain area between the dykes, so there were no significant settlements in the pilot area.

We developed three different model geometries (original state, R1, R2). The original state version does not include any dyke relocation and afforestation measure, which were done in the last five years. This calibrated base model geometry represents the condition of the river in the early 2000's. We incorporated the new dyke relocation measure into the R1 and R2 versions. We also modified the roughness in every geometry version in order to reflect land use changes between the scenarios. The R2 geometry included a fish spawning ground and a new runoff area in the floodplain. Figure 4 shows the model versions for original and restored states.

The MTDWD has performed a survey in 2018, which was part of a Hungarian project. The main goal was to update the river geometries along the Tisza valley. The river bed and the floodplain area were measured separately. The Digital Elevation Model (DEM) was composed from the measurement of the river bed and floodplain, which was used in the Danube Floodplain project. The resolution of the geometry is 1 meter.

The geometries have a 2D flow area with 25 x 25 meters wide computation point spacing. The default Manning's value is set during the calibration and validation. The 2D mesh is the same in the R1 and R2 versions. Table 1 contains the relevant information regarding the 2D mesh.

Table 1: Information about the four geometries' 2D mesh. Credit: Dávid Béla Vizi

Geometry	Number of nodes	Nodes distance [m]	Nodes per km²	Average cell size [m²]	Default Manning's value
Original state	158,159	25	1,588	629.66	0.08
Current state	165,057	25	1,597	626.04	0.08
R1 state	170,182	25	1,602	624.19	0.08
R2 state	170,182	25	1,602	624.19	0.08

The cross sections are the basis of the one-dimensional models. The calibration and the roughness coefficient only partly compensate the possible inaccuracies of the cross-sections. The one-dimensional cross sections came from the Hungarian project from 2018. Cross-sections were measured every 100 m in the Middle Tisza district. The model stability is greatly improving if the cross sections are as dense as possible. Based on previous modelling experiences, the optimal distance between cross sections – from model point of view – is 400–800 m for the Tisza. The one-dimensional river section is the same in all model geometries. Between Szolnok and Csongrád (approximately 90 km), 342 cross-sections were integrated into the model.

We determined the land use types in the floodplain by aerial photographs, i.e. by ortho-photographs, as well as by the results of on-site inspections. The roughness factor was changed cross-section wise according to floodplain land use types. The roughness (smoothness) factor assigned was determined on the bases of Hungarian standard, as well as on the bases of values applied also by HEC-RAS and proposed by Chow (1959). The smoothness factors assigned to individual cultivation branches overlap each other as there is no possibility for making sharp difference between the categories of "sparse thicket" and "dense thicket".

The HEC-RAS model applied for the detailed description of the entire river system provided an opportunity for taking into consideration the hydraulic engineering structures, like bridges, barrages, culverts, overflow weirs, floodgates, bottom stages, bottom sills, side overflows and gates, static reservoirs, pump head stations and water intakes.

The model contained the dykes between Kisköre and Csongrád. The dykes were integrated into the DEM for the 2D river section. The cross-sections of the 1D river section also include the right and left dykes. The model also contained two bridges in the 2D mesh and one in the 1D river section near Szolnok. We took into consideration the bridges in the 2D section when we modified the DEM.

We used real events as a basis of our hydrological data. The MTDWD has made monitoring along the Tisza River. The

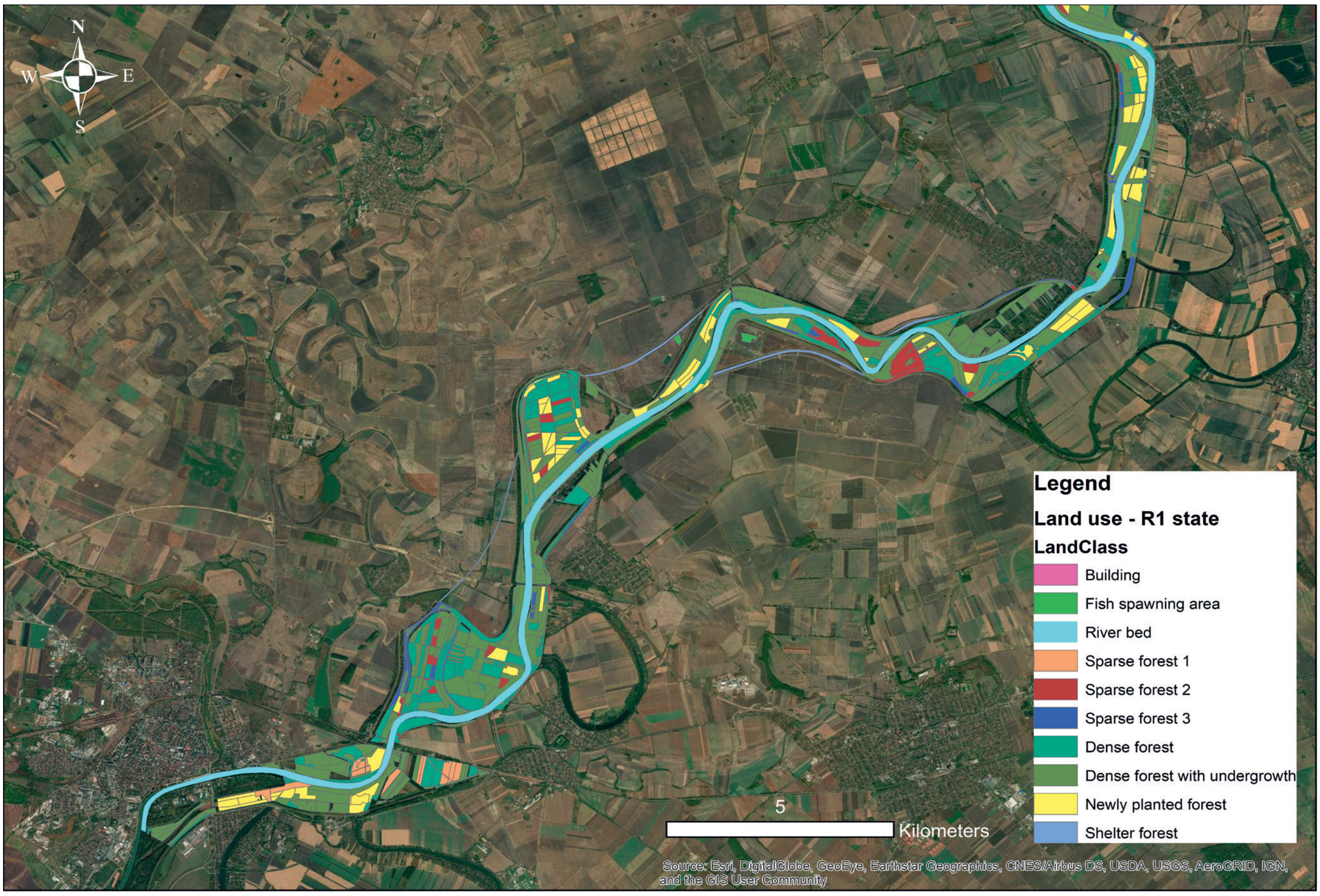

Figure 5: Land use in the R1 scenario. Credit: Dávid Béla Vizi

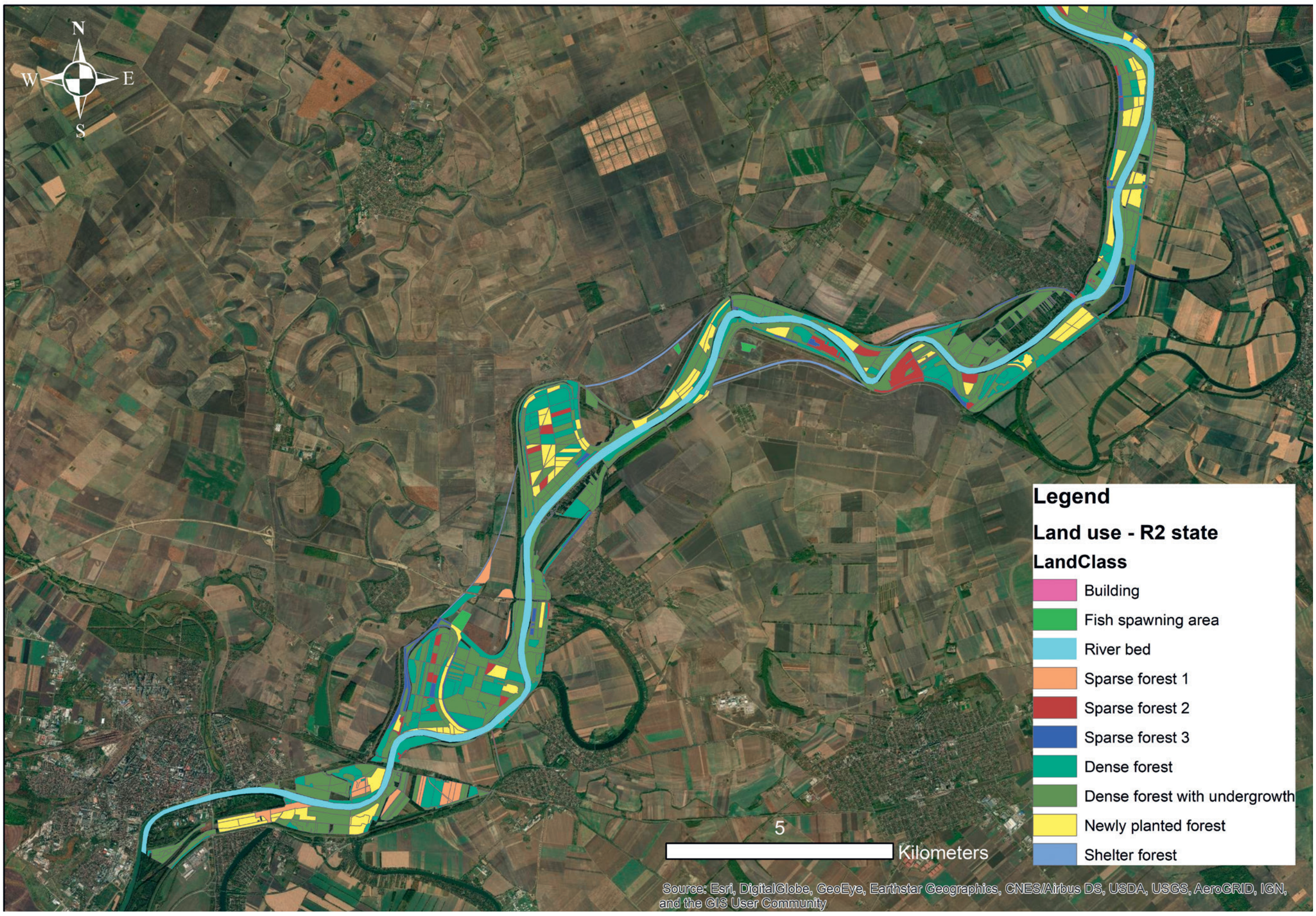

Figure 6: *Land use in the R2 scenario. Credit: Dávid Béla Vizi*

following events were simulated: HQ2, HQ10, HQ100. Each HQ is based on the same flood wave. We have the official HQ values for Kisköre, which is the upstream boundary condition in the model *(tab. 2)*.

We modified the flood peak according to the official HQ values for each HQ. Every model run had a one month long "warmup" period with a steady state value. We made that to have a more stable unsteady flow simulation. The steady state value was 512 m^3/s at Kisköre.

Each restoration scenario included dyke relocation measures. The new dyke course was integrated into the geometry. The R1 version considered the new floodplain area as a pasture (change in land use) *(fig. 5)*. There is an 80 m wide shelter forest next to the new dyke (change in land use).

Our main aim with R2 is to increase the effects of the restoration measures without harming the flood protection *(fig. 6).* The R2 version has a new fish spawning area in the pilot site (change in land use). There are some forest regulation measures in this scenario: shelter forest next to the dyke, and new floodplain forests in the floodplain areas where the water flow is negligible. The runoff is increased with removing the invasive species in an area where the vegetation is quite dense (change in land use).

The main challenge was that there was no substantial flood wave since the dyke relocations were finished on the Middle Tisza region. The original state scenario was needed for that purpose. We used the flood wave of 2000 for calibration with an old geometry, representing the characteristic of the early 2000's. This flood wave produced the highest water levels in the Middle Tisza. The calibration of the model was accomplished gradually, starting with the shorter sections (1D and 2D separately). We assembled the individual sections and then performed the river sections. We had 3 calibration station: Tiszaroff, Tiszabő and Martfű. The average difference between the computed and the observed data is 5–10 cm at each control point which was considered as a good result.

Table 2:
Discharge values for each HQ scenario

Scenario	Discharge [m^3/s]
HQ5	2,107
HQ10	2,363
HQ100	3,012

Results

The hydraulic simulations of the different scenarios in the Middle Tisza pilot area reveal neglectable effects in the peak discharge of the flood waves of below +/- 0.5 %. The time lag of the flood peak is notable in all events in the R1 scenario with a maximum 15 hours peak delay in the HQ100 event. The time difference is lower in the R2 scenario and there is no change in the HQ10 event.

The flooded area has increased through the dyke relocation by ca. 4.4 to 6.2 % and thus the storage volume is 3.9 to 5.0 % higher compared to the current state (CS). The average water depth can be increased through this augmentation of the flooded area by more than 6% in both restoration scenarios in all investigated hydrological scenarios.

We decreased the water level with the dyke relocation and land use change in R1 compared to the current scenario. The difference is 5-15 cm near to the pilot site. The R2 version did not cause further reduction in the water level. The aim was to increase the ecological status while the flood risk is not rising.

Locally the effect was visible in a decreased water depth upstream of the dyke relocation up to 0.5 m up to the upper model boundary. Downstream of the dyke relocation there is no change in the water depth. Looking at the velocity, the flow speed in the Tisza riverbed is decreased, but this reduction is just visible for ca. 7 km of the river length.

Table 3: Results of the 2D simulations. Credit: Dávid Béla Vizi

		HQ5	HQ10	HQ100
Q_{max} [m³/s]	out CS	1,929	2,273	2,904
	out R1	1,927	2,275	2,905
	out R2	1,937	2,275	2,906
Delta Q_{max} [m³/s]	R1-CS	-2	2	1
	R2-CS	8	2	2
Delta t [h]	R1-CS	8	4	15
	R2-CS	7	0	6
Change in flooded area [%]	R1-CS	6.2	5.0	6.2
	R2-CS	6.1	4.4	6.1
Change in volume [%]	R1-CS	4.5	5.0	5.0
	R2-CS	3.9	4.4	5.0
Average water depth [m]	CS	3.70	5.20	5.97
	R1	3.63	5.14	5.90
	R2	3.61	5.12	5.90
Average flow velocity [m/s]	CS	0.150	0.200	0.220
	R1	0.140	0.180	0.210
	R2	0.150	0.190	0.220

Conclusions

The flood peaks along the river Tisza have shown an increasing trend over the last decades. The process began during the dyke construction works in the 19th century. The river was confined in a narrower floodplain area between the dykes. That is the only area where the river can deposit the carried sediment. Due to this process and the increasing size of the dense forest areas, the water conveyance capacity of the floodplain was reduced. In response to these processes, the MTDWD started dyke relocations. The integrated water management practice was also promoted on the new floodplain areas.

In addition to increasing the conveyance capacity, more emphasis was placed on the design of optimal land uses. Primary runoff areas continue to serve the purpose of flood protection in the floodplain with increased conveyance. On the other hand, creating the fish spawning areas were both ecologically and economically beneficial and did not pose any flood risk.

During the pilot study, different measures could be taken into account in determining geometry (e.g. dyke) and land use (forest areas, grassland). The main challenge was to calibrate the model sufficiently. The last significant flood wave was in 2013 along the Tisza. The dyke relocations were finished after this flood wave, so we did not have a new flood wave with the current dyke course to calibrate or validate for the current status. That is why we created an original state version with the old dykes along the pilot area. We could calibrate the model for this version, and compare the new geometries with this.

The initially specified purposes of restoration were partly met: the conveyance capacity and the floodplain area were increased and show the significant effect in flood volume storage. However, the decrease of the flood hazard with the two restoration scenarios only can be considered as a local effect. The impact of ecological measurements should be determined by other tools (e.g. cost-benefit analysis).

Acknowledgements

The Danube Floodplain project is co-funded by the European Union ERDF and IPA funds focuses on interactions of two key aspects, improving transnational water management and flood risk prevention while maximizing benefits for biodiversity conservation.

References

2007/60/EC Directive of the European Parliament and of the Council on the assessment and management of flood risks.

Chow VT (1959): Open-channel hydraulics, McGraw-Hill Book Co, 680 p, New York.

General Directorate of Water Management (GDWM) (2018): National Water Strategy. In: OVF (ed.) Nemzeti Vízstratégia.

ICPDR (2019): Integrated Tisza River Basin Management Plan – Update.

Csiszár Á, Korda M, Schmidt D, Sporcic D, Süle P, Teleki B et al. (2013): Allelopathic potential of some invasive plant species occurring in Hungary. Allelopathy J. 31, 309–318.

Mauser W, Stolz R, Weber M, Ebner M (2018): Danube River Basin Climate Change Adaptation – Final Report, Germany.

Somlyódy L (2011): Water management of Hungary: situation and strategic tasks. MTA, Budapest. In: Somlyódy L (ed.): Magyarország vízgazdálkodása: helyzetkép és stratégiai feladatok.

Szlávik L (2003): The extension of Vásárhelyi's Project. Forestry Journal, Vol. 138, No 12, Budapest. In: Szlávik L. (ed.) Vásárhelyi-terv továbbfejlesztése: árvízvédelem, terület- és vidékfejlesztés a Tisza mentén.

US Army Corps of Engineers (2016): HEC-RAS River Analysis System – User's Manual, USA.

Vizi DB, Fehér J, Lovas A, Kovács S (2018): Modelling of extreme hydrological events on a Tisza River Basin pilot area, Hungary, Journal of Environmental Geography, XI(3-4), 55-64. DOI: 10.2478/jengeo-2018-0012