

Investigation of the natural morphodynamic state of a Tisza river section in Hungary

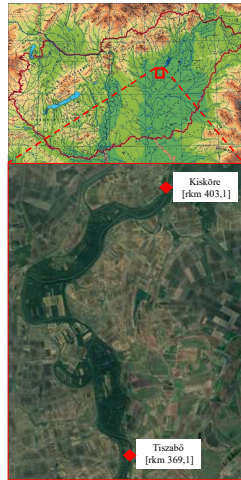
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Introduction

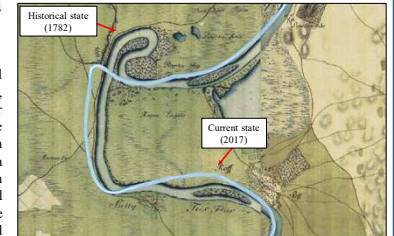
In our study, we investigated the impact of 19th-century regulations on a section of the Middle Tisza in Hungary. In the 19th century, 13% of Hungary's territory was regularly flooded by unregulated rivers. More than half of the flooded area, ~ 2 million ha, is the floodplain of the Tisza and its tributaries. Regulation works started in August 1846. The length of the river before regulation was 1419 km, which was decreased to 962 km after the end of regulation. In addition, 136 km of new riverbed and 589 km of backwater were created.

Another essential part of the research is to describe the natural state of the Tisza before the regulation, as there is not enough data available for the morphodynamic model we have developed so far. The most important question is: Is it possible to estimate the prehistoric state with such a small amount of data using the methodological steps presented? Furthermore, can the results in subsequent studies be used to assess the equilibrium state using sectional averages?



Investigated interventions on a section of the Tisza in Hungary

A key foundation of this research was the analysis of historical literature and data sources. Based on the literature review, minimal data is available from before the 19th-century river regulations, mainly military maps from that era. However, these maps allow us to identify river line changes and channel width between the historical and present-day states. Figure illustrates a preserved meander on the investigated river section (Kisköre [rk 403.1] – Tiszabó [rk 369.1]), highlighting the substantial differences between the two periods (1782 and 2017). The literature review also revealed that the river slope nearly doubled due to the artificial cutoffs.



Methods

The developed methodology is based on several steps. A 2D hydrodynamic model of the Tisza River was required to establish this method. However, due to insufficient data on the riverbed geometry, we applied a novel approach using the tool pyRiverbed. This Python-based tool is designed to estimate riverbed topography and analyze channel morphology. It can predict riverbed shape and profile changes based on various parameters, aiding the analysis of processes such as bed deepening, lateral shifts, or other geomorphological phenomena.

- As a first step, we used the described procedure to generate a synthetic riverbed. The resulting geometry served as the basis for further modeling.

- The riverbed generator used in this study is based on a set of modified Beck (1988) equations:

$$\eta = H - \left(1 - \frac{h_c}{S_t n}\right) \|S_t n, 0\| - \frac{h_c}{S_t n} \exp\left(-S_t \frac{n}{H}\right) \|S_t n, 0\| \quad (1)$$

$$h_c = \frac{4BH[S_t] - S_t^2 B^2}{2B[S_t] + 2H \exp\left(-S_t \frac{n}{H}\right)} \quad (2)$$

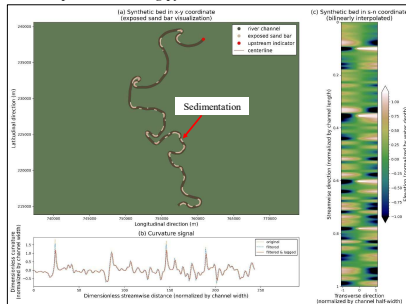
$$S_t = \alpha \cdot AGH, \quad (3)$$

$$A = 3,8 \left[1 + \frac{B}{6,96G} \exp\left(\frac{-6,96H}{B}\right)\right] \quad (4)$$

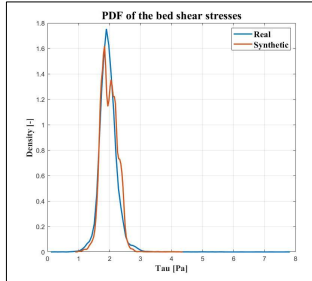
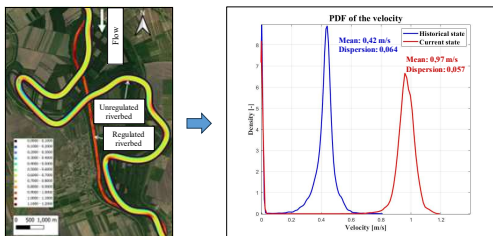
- We applied the generated geometry and mesh in the next step to parameterize the SRH-2D model. We ran the 2D simulations on both the actual geometry (from 2017) and the synthetic model and validated our approach by comparing the results.

Results

- Historical state representation using pyRiverbed:



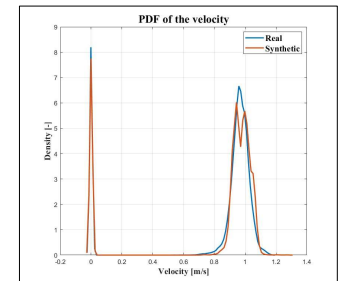
- Analysis of 2D velocity results presented one section (historical - current state):



Comparison of Shear Stresses

- Real and synthetic geometries
- Average shear stress of the real bed: 1.95 Pa
- Average shear stress of the synthetic bed: 1.99 Pa
- Difference: 0.4 Pa, i.e. ~2%

- In comparing the model results, the velocity and shear stress density were taken and validated by evaluating them. During the tests, a section-wise average of water depths was taken and then an overall average water depth was calculated. The total difference between the two conditions was 17 cm, a difference of ~1.5%. After these steps, a methodology was developed that allowed modelling the pre-regulation condition of the section. A similar approach was followed as for the current condition: the pre-regulated riverbed condition was estimated using pyRiverbed and then used to build a 2D model, where the same flow conditions as the riverbed were modelled.



Comparison of velocities

- Real and synthetic geometries
- Average velocity (real geometry): 0.97 m/s
- Average velocity (synthetic geometry): 0.98 m/s
- Difference: 0.01 m/s, i.e. ~1%

Conclusion

In our research, we successfully presented a new methodological approach that enables the estimation of the riverbed geometry before the 19th-century Tisza river regulations and determining flow conditions in the bedload state. By comparing the synthetic riverbed geometry generated with pyRiverbed and the results of the SRH-2D flow model, we validated the approach, which proved suitable for modelling the pre-regulation state.

The studies highlighted that river regulation interventions caused significant changes in channel width and bed slope, transforming the dynamic equilibrium state. The research results can be helpful for underpinning future regulatory works and can also provide relevant data for other scientific fields, such as ecological or habitat studies.

The developed method aids in parameterizing 1D morphodynamic models, thus contributing to more accurate predictions of long-term riverbed changes. With this approach, we move one step closer to reconstructing natural conditions and achieving a deeper understanding of the effects of river regulation.

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