Main theses of the PhD dissertation

Doctoral School of Earth Sciences

Hydromorphological assessment of the Hungarian-Croatian section of Drava and Mura rivers

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Introduction

In today's world, the conservation and sustainable use of our natural resources is becoming increasingly important. This is understandable, as the negative consequences of the intensive use of natural resources, civilisation and the often unjustified demand for comfort are increasingly evident in the changes to the natural environment. As one of the most dynamically changing habitats, knowledge of the river processes is very important for the correct method of their management and it’s planning.

The dynamic changes in rivers are also reflected in morphological processes, which involve the shifting of the bed, the continuous transformation of cross-sections. These processes are essentially linked to the characteristics of the transported solid material, the sediment transport. Therefore, it is very important to know the sediment transport of rivers and to monitor the processes involved in sediment transport.

For several years I have been studying the transport of sediment in Hungarian rivers (Danube, Drava, Mura). My dissertation is about the sediment and bedload transport in Drava and Mura rivers. My research area is the joint Hungarian-Croatian section of the two rivers.

Due to their border river character, both river sections are in a special situation, as the water management tasks related to them are shared between the two countries. This makes river management partly difficult, but also has a positive impact on the conservation of ecological values. My research topic is timely and justified considering international efforts to preserve our environmental values in the context of sustainable water management.

In the past, the monitoring of morphological changes and the study of sediment transport was limited to a selected water monitoring section. However, modern measurement techniques allow us to build a new basis for morphological studies, complementing and extending the basic information from the past.

In my dissertation, I present a detailed riverbed survey of the domestic section of the Drava and my baseline studies based on it, supplemented by a 1-dimensional hydrodynamic and sediment transport modelling of the domestic section of the Mura, which I used to investigate the morphological processes of the river section.

Research Aims

The basic aim of the research presented in this thesis is to investigate the current state of the Hungarian-Croatian section of Dráva (between Őrtilos and Drávaszabolcs), using the available state-of-the-art tools and approaches, in order to develope a methodology that will provide a basis for future water management work. During the research I also used and integrated my further research results related to the topic, which prepared the direction and method of the specific research and will have a significant impact on the further use of the results obtained. The sediment transport modelling carried out for the Hungarian section of the Mura River is practically a preliminary study for a morphological study planned for the Drava River. The following questions were addressed and objectives were set:

1. Investigation of sediment transport and bed alteration in the Mura River, a tributary of the Dráva

Modern numerical solutions allow modelling of sediment transport processes. The majority of the sediment arriving in the Hungarian section of the Drava flows via the Mura. As part of the morphological study of the Drava, I have carried out a 1-dimensional sediment transport study of the Hungarian section of the Mura.

2. To present the bend development status of the river section under study, analysing recent changes and predicting future trends.

Since sedimentation is the main factor influencing the morphological changes in a river section, I considered it important to present the current state of the river section based on the latest river bed survey, and to analyse the current morphological changes.

3. To carry out a detailed river basin mapping, which will provide significantly more information on the composition of the river basin in the studied section of the Drava than previous studies.

We had the opportunity to carry out a field survey in the study section of the river, which provided very detailed results for the knowledge of the river section.

4. To analyse the relationship between velocity conditions and the characteristics of the river bed material in the river section under study.

Modern flow measurement offers a new possibility to determine the limiting value of the bedload movement, which I wanted to compare with the classical relation.

5. To confirm - with recent results - the location of the fallout in the Barcs area in relation to the change in the grain size distribution of the sediment.

My aim is to confirm the slope-change identified in previous research and surveys, based on the most recent river bed survey, flow parameters and sediment composition.

Research Methods

In my morphological research I used several interrelated methods.

For the joint Hungarian-Croatian section of the Drava (between Őrtilos and Drávaszabolcs), I have carried out the delineation of bend development using a topography model created in 2018 and prepared a study of bend statistics. Based on the terrain model, I determined the centre line and the main flow line of the bends using geoinformatics tools, and based on this, I analysed the bend parameters and delimited the successive river sections. By comparing the defined centreline with the official register centreline, I determined morphological changes over a seven-year period, which characterise the trend over the last period and allow estimation of future changes. From the field model, I also produced a length section of the river section under study, which I used to investigate the slope characteristics of the river section.

A series of field measurements was carried out on the joint Hungarian-Croatian section of the Drava, with the aim of investigating the sediment load of the river section by taking bedload samples and measuring the river flow. This monitoring programme, which included detailed sampling, made it possible to verify and refine the results of previous research on the river section. In total, about 90 samples of sediment were taken in 30 cross sections during the monitoring campaign. In all cases, the sampling was accompanied by flow and discharge measurements, both for the sampled cross sections and for the individual sampling points. Such detailed flow and sediment sampling of the river has never been done before. The detailed survey allowed a complete mapping of the morphological status of the river section. This gap-filling research is very important for the future, as

conservation, climate change, ecosystem services, water management and landscape management objectives all require knowledge of possible changes in the river. The results obtained can provide a basis for further detailed morphological studies, spatial planning and landscape management concepts, as well as for the study of the ecosystem services of the river section.

In addition to the research on the Dráva, I also carried out a morphological study of the Hungarian-Croatian section of the Mura River. The Mura's sediment load has a significant influence on the studied section of the Drava, as the Mura receives a significant part of the sediment load of the river section, especially since the installation of the power plants on the upstream section of the river. I have built up a 1-dimensional hydrodynamic and sediment transport model for the Mura river to study the morphological changes (siltation, scouring) of the river section during the flow of the typical floodwaves. In addition, morphometric parameters were analysed and the bend evolution of the river section was studied.

Summary of Results

The aim of the research presented in this thesis was to assess the morphological condition of the Drava. To map the current state of the river, using the available modern tools and approaches, in order to produce a study that will provide a basis for future water management work. I also used and incorporated my research results from Mura, which established the direction and method of the research in Drava, and the methodological experience gained there will provide the basis for further use of the results obtained. Climate change is expected to increase the number and length of mid-water flow periods in the future. One of the aims of my investigations was to help prepare for this by focusing my studies on this hydrological condition. In low-flow conditions, even small differences in river bed slope can affect gravel deposition and armouring of the river bed. This trend is also likely to influence the sediment transport in the riverbed, makeing it important to investigate the current situation in detail.

The sediment regime of the Hungarian-Croatian section of the Drava study is significantly influenced by the amount of sediment coming from the catchment and changes in it, especially the sediment regime of the Mura, a tributary that flows over the study section. My research on this river is also part of my dissertation, which, in addition to the content, also served as a

basis for my research on the Drava. The objectives of my research are presented below, together with the associated theses and their justification:

***1. Investigation of sediment transport and bed alteration in the Mura River, a tributary of the Dráva* – Thesis 1: The siltation of the Mura does not deviate from the typical Hungarian value.**

The slow filling of the floodplain of rivers, due to the deposition of fine sediment during floods, is a well-known phenomenon in our country's watercourses. In order to investigate the process of sedimentation, 1D and 2D hydrodynamic model studies were carried out for the domestic section of the Mura river. During the studies, sediment transport processes were analysed during the 2009 flood as well as during several theoretical (artificially defined) flood waves. My task during the project was a decision-preparation study for this detailed investigation, during which I built, calibrated and validated a 1D sediment transport model, which I then used to analyse several model versions (scenarios). Detailed 2D modelling was performed for four scenarios. The results of the 2D modelling were compared with some floodplain dispersion values found in the Hungarian literature. **Based on these results, the siltation of the Mura does not stand out among the compared values measured on the floodplains of other rivers in Hungary**.

2. Presentation of the bend development status of the river sections, analysis of recent changes and forecasting of future trends.

Based on a detailed terrain model created in 2018, I determined the centerline and main flow line of the river at the time and used this as the basis for a classic bend development study. The analysis reveals the processes that will cause future expected changes in the riverbed. Knowledge of these will also help in planning future river management.

For the entire Hungarian-Croatian section, more than a third of the total length is developed bends and almost a third is undeveloped bends. The real straight section is the least frequent, but the number of pseudo bends is not small. Taking human interventions into account, the results obtained provide good evidence and show the impact of regulation. Over-developed bends are found only in the upper section, and while the most common type here is the

developed bend, the number and length of undeveloped bends is also the highest in the lower section. Examination of the length of each type shows that the lower section typically have larger uniform river sections; all characteristic values (minimum, maximum and average length) are greater in the lower reaches than in the near-natural upper section.

An examination of the current official and river basin survey centre line of the Drava illustrates the morphological changes that have occurred in the past. The different dynamics of bed changes in the regulated and near-natural sections of the river can be observed already in this short period of time. My study has revealed a significant, almost visible, bed migration in the less regulated upper section, which can be used to define the areas of the floodplain and river banks where erosion is expected in the future. The lower, regulated section is in a relatively stable condition.

I also studied the river development of a typical stretch of the Mura from the 18th century to the present day. The available surveys have given me the opportunity to investigate the long-term impact of river regulation works: detecting dynamic morphological changes.

***3. Preparation of a detailed river bed mapping, which will provide significantly more information on the composition of the river bed in the studied section of the Drava than previous studies.* – Thesis 2: The armouring process caused by the regulatory works below Barcs has been completed.**

We were able to carry out a field survey of the river section, which provided very detailed results for the understanding of the river section. In all cases, the sampling was accompanied by discharge and flow measurements, both for the sampled cross-section and at each sampling dependency. The detailed survey allowed a complete mapping of the morphological status of the river section. I also prepared a grain size distribution analysis of the river bed material samples taken and, on this basis, a sediment length section of the section under study. Using previous research results, I examined whether the resulting grain composition had changed over time. Overall, our measurements indicated slightly finer sediment than previous studies. Downstream of Barcs, in contrast to previous results, the gravel fraction had almost completely disappeared (only locally present) and coarse sand dominated all observed cross sections. ***Although the modified slope conditions in the riverbed cut during the regulation works caused***

armouring, this process slowed down and stopped after the energetic rearrangement of the river section, as indicated by the dominance of the sand fraction in the river bed.

4. Analysis of the relationship between velocity conditions and bedload characteristics for a river section. **– Thesis 3: Shields parameter derived from measurement results is consistent with the results of theoretical calculations.**

Based on the field survey, I generated and analysed the longitudinal variation of the typical flow and bedload parameters. An sudden decrease in flow velocity was observed between 175 and 170 fkm in the zone of change in slope-changeing. Shear rates showed a more heterogeneous picture. The correlation between the average flow velocity of the cross sections studied and the typical grainsize diameter (d60) of the samples taken can be described by a power function and shows a moderately strong correlation. The measured velocity distribution at depth was quite noisy, indicating the highly turbulent nature of the flow.

Modern flow measurement offers a new possibility to determine the limiting value (Shield number) of the bedload movement. Classically, this value is determined on the basis of the general hydraulic characteristics of a basin section. However, ADCP flow measurement allows the estimation of shear stress to be estimated from the measured flow parameters. The use of the measurement results may open up new possibilities in the analysis of sediment transport, so I have examined how the results of the classical and the possible new calculation method compare. ***The results showed a significant difference between the two calculation methods. Further measurements and a comparative study are needed to clarify the relationship.***

5. Verification and refinement of the location of the slope-changing in the Barcs area with recent results, also compared with the change in the grain size distribution of the sediment. **– Thesis 4: The slope-changing can be detected in flow and sediment transport parameters.**

Based on the recent river bed survey, I also examined the slope of the river section along the middle line. By connecting the deepest river bed points of

the characteristic sections (inflectional and top sections of bends), I determined the river bed line of the river section.

The resulting bottom line confirmed the location of the breaking of the slope from previous investigations, which is now located in the region of 175 fkm. This local variation within the entirely alluvial river section reduces the slope of the upper from around 0.4 thousandths to around 0.1 thousandths. Detailed analysis of the terrain model also shows that, although river control in the lower section limits lateral displacement of the bed, but the vertical variation of the river bed in this sections is greater than in sections not affected by interventions.

Comparing the longitudinal section of the bed with the longitudinal section of the bed material, the consistency cen be demonstrated: typical bed material is the gravel in the upper reachis and in the immediate region of the slope-changing, and sand in the river below slope-changing.

The location of the slope-changing can also be detected in the longitudinal evolution of other flow and bedload transport parameters: there is a distinct, pronounced sinuosity in the topographic contours of the main river bed along this section; similarly, the effect of the slope-changing on the typical grain diameter, average velocity and the movement of the bed material is also noticable

List of Publications on this Topic

Ficsor, J. & Engi, Zs. (2024). Morfológiai vizsgáltatok Magyarország délinyugati határfolyóin. *Modern Geográfia, 19*(3), (megjelenés alatt).

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