Final report

Research no K 104552 (”Landscape ecological assessment of rehabilitation potential in sections of the Hungarian Drava River”)

Significance of research and precedents

In most European countries, government bodies and non-governmental conservation organizations make efforts to return rivers to more natural and dynamic conditions and to encourage better management of riparian environments and floodplains (Lóczy 2010). A hydromorphological survey is a comprehensive assessment of ecological river and floodplain status (Tockner et al. 2010) for management purposes. The need for hydromorphological inventories is also underlined in the EU Flood Risk Directive (2007) and by river restoration measures. River types and reaches are also defined in the WFD.

Few studies have been published on the hydromorphology of the Drava River. A hydrogeographical monograph of the Drava-Mura river system was published in 1972 (Lovász 1972). Schwarz & Mohl (1998) applied a specific inventory method for a 40-km long Drava reach and floodplain features like side channels, oxbows and small water bodies (pools, small channels). Later in 2002 the stretch was evaluated according to the five-class system based on the Austrian methodology. Koenzen (2005) developed a floodplain typology and reference conditions for larger rivers in Germany, also applicable for Hungary. A more comprehensive assessment of the Drava and Mura rivers by the Austrian FLUVIUS Bureau, Vienna (FLUVIUS 2007) claims that more than 75% of the morphological floodplain (2,450 km²) is cut off from the channel and active floodplain. Nearly 80% of floodplain suffers from considerable bed incision rates (up to 4 m), hydrographical alterations (flood storage, hydropeaking etc.) and forest cultivation (large hybrid poplar forests along the lower Drava). The Hungarian Aquaprofit Engineering, Advisory and Investment Limited has prepared reports and plans for water and landscape management and regional development (AQUAPROFIT 2007) with the purpose to provide foundations for a large-scale water recharge project for the Drava floodplain, called the ’Old Drava Project’. Implementation began parallel with the here reported research in 2013. The water supply of the Drava floodplain was also investigated from the viewpoint of human settlement (Gyenizse and Lóczy 2010).

Between 2012 and 2014, the SEE River Project (Sustainable Integrated Management of International River Corridors in SEE Countries), funded by the European Commission and the South-East Europe Transnational Cooperation Programme, was directed to the study of river corridor and restoration opportunities in the case study on the Drava (Bizjak et al. 2014).

The staff of the University of Pécs has much experience in floodplain studies along the Drava River. The lateral shifting behaviour of the Drava was compared to that of the Tisza (Lóczy 1997). For the subdivision of floodplains Lóczy et al. (2011) constructed a longitudinal profile index (LPI), which reflects floodplain character. The complex ecological characterization of floodplains, including landform/vegetation relationships have been further developed Ortmann-Ajkai and Horváth (2010). Observations on Mohács Island were aimed at revealing the impact of tillage on the preservation of floodplain microforms (Lóczy et al. 2010). Parallel with the here reported research our staff contributed to the project supported by the Visegrad Fund (31210058), title: Interdisciplinary studies of river channels and UAV mapping in the V4 region (Šulc-Michalková et al. 2016).

Research objectives

1, Clarification of concepts related to floodplain rehabilitation (recovery, restoration, rehabilitation, resilience etc.);

2, Identification of hydrological trade-offs between fluvial landforms, soils, groundwater table and vegetation conditions;

3, Reconstruction of geomorphic evolution of the floodplain with special regard to the date of cutoff for oxbows;

4, Describing the water balance of a selected oxbow lake system (at Cún-Szaporca) based on hydrological monitoring;

5, Evaluation of subsurface river channel/floodplain connectivity based on hydrogeological survey and soil moisture and groundwater monitoring

6, Overall assessment of the rehabilitation potential and the impact of the first water replenishment campaign to the studied oxbow lake; evaluation of the sustainability of ongoing water replenishment and floodplain rehabilitation interventions (recharge of water from the Fekete-víz Stream to Lake Kisinc of the Cún-Szaporca Oxbow);

7, Delineation of the Drava floodway according to the requirements of the Government Decree 83/2014 (March 14).

Methods

1, A detailed survey of international professional literature and comparison of definitions

2, For the study of fluvial landforms, satellite and UAV images were used, checked in the field and supplemented by Ground Penetrating Radar (GDR) surveys (led by György Sipos, University of Szeged, and Marcin Słowik, Adam Mickiewicz University in Poznań). Soil parameters were established using the AGROTOPO map, additional field surveys and laboratory analyses (grain size from repeated sieving (manufacturer: Fritsch GmbH) and Malvern Mastersizer 3000 Hydro LW laser analyzer (Malvern Inc., Malvern, UK) in the range of 0.02 μm to 2 mm. The hydraulic properties of sediments are established by well (pumping) tests, conductivity estimated from refill curves. In the laboratory undisturbed samples are used for seepage analyses. The connectivity of the hydrological system was also studied in the laboratory (determination of saturated hydraulic conductivity with the falling head method).

3. The historic evolution of meanders and their cutoffs were reconstructed from archive maps (Military Survey map sheets, river regulation plans, land property inventory maps etc.).

4. Hydrological monitoring was based on the groundwater obervation network of the South Transdanubian Water Management Directorate (DDVÍZIG) supplemented with two monitoring stations operated by the Department of Physical and Environmental Geography, monitoring infiltration (measured by Drain Gauge G2 Passive Capillary Lysimeter); water potential (MPS-2); soil temperature; soil moisture content (5TM) at various depths (25 cm and 70 cm from ground surface (sensors manufactured by Decagon Devices, Pullmann, WA, USA); depth to groundwater table (monitored by Dataqua LB 601 instruments – Dataqua Co., Balatonalmadi, Hungary).

5. Monitoring data and river regime information (from DDVÍZIG) were evaluated to reconstruct surface communication between floodplain lakes and the main channel as well as groundwater flow (hyporheic flow).

6. Overall rehabilitation potential was semiquantitatively estimated using a scoring system based on the overview of foreseeable improvements in the provision of (altogether 20) ecosystem services (two different lists). The potential to improve provision is expressed by the difference between the present rating and full provision (5-sp). The actual attainable improvement (or possible deterioration) is calculated for services arranged and weighted in ranked order of significance: flood control (weight: 1), water generation (0.75), water quality (0.5), biodiversity (0.25) and social services (0.1). The percentage change in cumulative rehabilitation potential (ΔRP) is defined by the formula:

$$\Delta RP = \left(\frac{\sum_{i=1}^{n} w_i(5 - s_{pi})}{\sum_{i=1}^{n} w_i \cdot 5} - \frac{\sum_{i=1}^{n} w_i(5 - s_{fi})}{\sum_{i=1}^{n} w_i \cdot 5}\right) \cdot 100$$

The feasibility of the implemented water replenishment into the Cún-Szaporca oxbow is judged from the findings of water balance analysis compared to the figures contained in the planning documents of the Old Drava Programme. During the first water replenishment campaign (3–13 March 2016), discharge of the feeder canal and lake level rise were recorded by Dataqua tensiometer. Losses calculated using several approaches (Chézy equation, Strickler-Manning equation, Mayer etc.).

7. The 2D hydrodynamic modelling of the selected Drava floodplain segment was performed by the MIKE 21 Flexible Mesh Model (DHI 2014). This model is composed of shallow-water equations, vertically averaging the set of the three-dimensional Navier-Stokes equations, which describes fluid flow but cannot be solved analytically. The base equations are solved using an unstructured discretization mesh, which equally includes elements of a triangular irregular network (TIN) and a quandrangular network. Thus, the sizes and shapes of the individual elements are variable. The model relies on the Finite Volume Method (Chen 2010) for the solution of partial differential equation system, which calculates water depth and specific flow values in x and y directions. Further derived values include water level, current velocity and shear stress on the channel floor.

Results

1. Clarification of terms

River *recovery* is defined as a sequence of stages of geomorphic adjustment governed by the nature of the landscape and its sensitivity to floods following disturbance (Fryirs and Brierley 2000). The space available for regulated rivers as geomorphic agents, however, does not normally allow recovery. If river *restoration* conceived as “the complete structural and functional return to a predisturbance state” (Cairns 1991, p. 187), it is another goal not commonly achievable or even desirable. *Rehabilitation* means “the partial structural and functional return to a pre-disturbance state" (Cairns 1991) or, in a holistic sense, “the return of an ecosystem to a close approximation of its condition prior to disturbance” and this can never be perfect (National Research Council 1992, p. 18). For the Drava and its Hungarian floodplain the concept of rehabilitation seems appropriate, denoting measures towards improved ecological (environmental) functioning of the system (Lóczy 2012). *Rehabilitation potential* is a measure used to reveal the opportunities for re-establishing ecosystem services/landscape functions. In this respect, the target of rehabilitation (e.g. with view of future water availability or species composition) is markedly different from that of restoration in a strict sense (Jennings and Harman 1999).

Conceptual issues are treated in detail in the following publications:

Lóczy, D. Dezső, J., Ronczyk, L., Czigány, Sz., Pirkhoffer, E., Gyenizse, P., Halász, A., Ortmann-Ajkai, A. 2016. Floodplain degradation an dpossible rehabilitation along the Hungarian Drava section. In: Šulc-Michalková, M., Miřijovský, J., Lóczy, D., Zgłobicki, W. (eds), Interdisciplinary studies of river channels and UAV mapping in the V4 region. Comenius University in Bratislava. 127–176.

Lóczy D. 2017. Tájfunkciók, ökoszisztéma szolgáltatások, tájrehabilitáció. A Magyar Földrajzi Társaság 2016. évi Vándorgyűlésének előadásai, Eger

Lóczy, D. Dezső, J., Gyenizse, P., Ronczyk, L., Czigány, Sz., Pirkhoffer, E., Ortmann-Ajkai, A. An ecosystem service based evaluation system for floodplain rehabilitation projects. River Research and Applications (submitted)

2. Hydrological trade-offs

The lakebed was divided into two zones, one shallow (less than 1.5 m) and an area of larger depth (1.5 to 2.4 m). The hydraulic conductivities of the recently flooded shoreline areas are similar to the relevant values obtained from the pumping tests. The hydraulic analyses of the undisturbed samples indicate very different hydraulic conductivity values. The deeper zone, where the median particle size 10 μm, has an order of magnitude lower hydraulic conductivity (k ~ 10-8 m s^{-1}), while the shallow zone, where D_{med} = 80 μm has a k ~ 10-7 m s^{-1}. The additionally inundated areas have an even higher conductivity (k ~ 10-5 m s^{-1}). Due to the increasing total seepage area, an increasing volume of added water is lost due to the increased seepage surface area.

Reflecting the heterogeneity of physical habitats, the diversity of plant communities is also high. According to the Landscape Ecological Vegetation Database and Map of Hungary (MÉTA – Molnár et al. 2007), natural and semi-natural vegetation covers about 20% of the Dráva Plain. Most characteristic habitats are wetlands, wet and mesophilous forests (mostly hornbeam-pedunculate oak and oak-ash-elm gallery forests) and meadows (Ortmann-Ajkai and Horváth 2010), including some habitats of European Community Interest. Aquatic and riparian vegetation represents about 4% of the total natual and semi-natural vegetation, but very diverse. It is found in the lentic side arms and cut-off oxbows. Floating pondweeds include Lemna and Ceratophyllum species with rare protected plants. Softwood groves are largely replaced by regularly mown or grazed swamp meadows, repeatedly inundated during floods.

For more details: Dezső, J. et al. (accepted for publication) Monitoring of soil moisture dynamics in floodplain Entisols under drought. Vadose Zone Journal

3. Geomorphic evolution

By geomorphic evolution, an older and a younger oxbow row were identified. Accepting the gradual shift of the meander belt in southwestern direction over the Quaternary (Lovász 1964), this allows the conclusion that oxbows in the distal zone were cut off through natural processes during the lateral migration of the Old Drava in the Late Holocene. In lack of absolute dating of oxbow deposits, no estimates can be made for the date of cutoff in the case of old oxbows. Their morphology (e.g. water depth, 'freshness' of banks and sediment plugs), thickness of organic fill and sporadic archaeological (human settlement) data (Bándi 1979) suggest that they lost communication with the Drava by neck cutoff some millenia ago. Most of the oxbows in the close neighbourhood of the present-day Drava channel, however, were detached from the main channel during river regulation works in the 19th century. The approximate dates of cutoff can only be estimated for the younger oxbows using map sheets of the three Military Surveys as well as other archive maps.

4. Oxbow water balance

Infiltration into the vadose and root zones is limited in the area and, thus, drought hazard is maintained. On sandy-loamy soils rainwater only slightly contributes to groundwater levels and groundwater flow does not improve significantly the water balance of the lake. In the critical summer periods high evapotranspiration from agricultural fields inhibits the recharge of groundwater. Water levels in the oxbow lakes are primarily influenced by the adjacent groundwater levels, which are regulated by the hyporheic flow of the Drava River. The rising water level in the oxbow triggers an increasing hydraulic pressure difference compared to the adjacent areas. With the increasing volume in the oxbow, the potential contact surface and seepage area also increases and this leads to heavy losses by seepage.

In more detail: see Lóczy et al. 2017. (Journal of Environmental Management)

Table 1 Important controls on the water balance of floodplain lakes

	importance	*source*	*response assessed*	*research approach*	*principal literary reference*
input					

hyporheic flow	primary	river backwater effect at high flow	monthly	monitoring in observation wells	EA 2009
subsurface inflow	primary	from deposits	monthly	monitoring in observation wells	EA 2006, Alley et al. 2002
direct precipitation	secondary	precipitation fallen on lake surface	daily	calculation based on rain gauge measurement	
output					
evaporation	primary	from lake surface	seasonally	calculation of evaporation	Antal and Kozmáné Tóth 1976; VITUKI 1986
transpiration	secondary	from riparian forest	seasonally	estimation from forestry literature	Hall et al. 1998; Čermák and Prax 2001
seepage	primary	from lake into deposits	monthly	estimation from lake level drop	

5. Subsurface river channel/floodplain connectivity

With reduced surface connectivity, groundwater flow becomes the main driver of connecting processes. Effective porosity and hydraulic conductivity of alluvial deposits and seepage from an oxbow lake (the degree of clogging of floor deposits) control groundwater movements. The influence of hyporheic flow is evidenced by groundwater table observations.

Further details in Dezső, J., Lóczy D., Nagy, G. (in preparation): Chapter 14 Floodplain connectivity. In: Lóczy, D. (ed.): The Drava River: Environmental Problems and Solutions. Springer, Cham, Switzerland

6. Evaluation of rehabilitation potential and water replenishment campaign

The semi-quantitative method shows a clear improvement in the provision of ecosystem services (floodplain functions): concerning the USACE list: the present-day provision level is estimated at 61.9% and a growth to 89.7% is expected. This means a rise of 27.8%. For rehabilitation potential calculated from the above equation 62.4 – 35.1 = 27.3% is received. In the other approach applied (Ramsar Convention Secretariat 2010), the most striking improvement is expected for water-related services. The present level of provision (48.3%) is foreseen to increase to 69.1%, which means a rise of 20.8%. Overall rehabilitation potential is calculated to grow from 45.4 to 67.9%, a change of +22.5%.

Our research shows that the critical factor in water retention is the transmissivity of lakebed deposits. Based on the laboratory hydraulic analyses of the undisturbed sediment samples highly different conductivity values were found for the middle and offshore parts of the oxbow lakes. Relatively coarse fraction (~80 μm) dominates the shoreline zone and allows higher seepage rate from the oxbow lake. The water level drop observed after the first replenishment campaign demonstrates that the oxbow lakes are unable to retain the water input. High proportions are lost partly due to the pressure differences between the lake water and the surrounding groundwater and partly due to evaporation.

For more details: Lóczy et al. 2017. (Journal of Environmental Management)

Lóczy, D. (in preparation): Chapter 20 Landscape Rehabilitation: the Old Drava Programme. In: Lóczy, D. (ed.): The Drava River: Environmental Problems and Solutions. Springer, Cham, Switzerland

7. Floodway modelling

Four zones were delineated upstream Barcs, and three between Barcs and Drávaszabolcs. Due to the confined floodplain downstream Barcs, no stagnant water area was delimited there. Specific velocities were markedly lower than stated in the Government Decree (0.2 to 6.0 $m^2 s^{-1}$), and ranged between 0.089 and 3.476 $m^2 s^{-1}$, and 0.075 and 2.01 $m^2 s^{-1}$, upstream and downstream Barcs, respectively. The primary and secondary conveyance zones covered a combined area of about 40% of the entire floodplain, while the remaining 60% included both the transitional and stagnant water zones upstream Barcs and solely the transitional zone downstream Barcs.

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