HYDROMORPHOLOGICAL ASSESSMENT OF THE LOWER HUNGARIAN DRAVA SECTION AND ITS FLOODPLAIN

DÉNES LÓCZY* – JÓZSEF DEZSŐ – SZABOLCS CZIGÁNY – ERVIN PIRKHOFFER
Department of Physical and Environmental Geography, Institute of Geography, University of Pécs, H-7624 Pécs, Ifjúság útja 6.
*e-mail: loczyd@gamma.ttk.pte.hu
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Abstract
The hydromorphological properties of rivers and their floodplains receive increased attention both in basic research and water management. A comparison of hydromorphological parameters before and after river regulation (involving floodplain drainage) provides important information for river management, particularly floodplain rehabilitation. The paper assesses a selected reach of the Drava River and the corresponding floodplain utilising two international approaches, the REFORM framework and the Italian Morphological Quality Index.

Keywords: hydromorphology, floodplain, human impact, oxbows, groundwater, rehabilitation, Drava Plain

1. Introduction
River channelisation and the widespread agricultural utilization of floodplains led to landscape degradation, manifested in dropping groundwater table, gradual desiccation of soils, loss of wetlands, reduced floodwater retention capacity (Geilen et al. 2004) and a lower level of landscape diversity (Ward et al. 2002). As a commonly applied approach to river and floodplain management, Natural Water Retention Measures (NWRM) cover multi-purpose interventions: to protect water resources, to promote groundwater recharge through infiltration and regulating baseflow, to restore or maintain ecosystems as well as the close-to-natural state of water bodies (Schwarz 2014). The restored ecosystems equally contribute to the mitigation of and adaptation to climate change (Blanka et al. 2013) as well as to optimal water management (Brierley – Fryirs 2005).

The Drava floodplain belongs to groundwater-dependent ecosystems (GDEs), whose structure and functions basically rely on an adequate supply of groundwater (Kløve et al. 2012). The maintenance of an optimal groundwater table is made difficult by the conflicts between the demands of agriculture, forestry, flood control and nature conservation. For instance, if pre-regulation conditions, favourable for nature conservation and for flood hazard mitigation (FLUVIUS 2007), were restored, permanently high groundwater levels would deteriorate farmlands or make modern farming completely impossible and decrease productivity and yields in general (Kang et al. 2009).

The pre-regulation channel pattern of the Drava River was well-developed meandering and locally anastomosing accompanied by a broad convex floodplain with natural levees, abandoned channels and backswamps (Kiss et al. 2011). Beginning with 1750, river channelization divided the area into an active and a “protected” floodplain. Cutoffs
enhanced channel slope and current velocity and induced channel incision (Lóczy et al. 2014). With water balance fundamentally transformed in the floodplain, drought hazard has remarkably increased. Growing population density and infrastructural development also increased the vulnerability to flood and drought hazards.

Our aim was to provide a comprehensive hydromorphological assessment based on two international approaches. Such an assessment is useful as a background to environmental problems and as a tool to underpin rehabilitation measures (AQUAPROFIT 2005).

2. Methods

The Drava is a border river between Hungary and Croatia with an alluvial plain (morphological floodplain) of 696 km$^2$ area and 15–25 km width (VKKI 2010). On the 75-km long Hungarian section, there are 20 major side-channels, 13 tributary streams and 18 oxbow lakes (of ca 150 hectares total area – Pálfai 2001).

The hydromorphological character of the river and its floodplain along its lower Hungarian section is presented through the indicators of the EU project REFORM (REstoring Rivers FOR Effective Catchment Management) (González del Tánago et al. 2015) (Table 1) combined with another useful approach, the scoring system of the Morphological Quality Index (MQI), which has been successfully applied to the rivers of Italy (Rinaldi et al. 2013, 2015) (Table 2). The contributors of these projects work in close cooperation. The REFORM framework describes changes compared to the conditions prior to river regulation. The MQI refers to an ideal state and is calculated from the equation

$$\text{MQI} = 1 - \frac{S_{\text{tot}}}{S_{\text{max}}}$$

where $S_{\text{tot}}$ is the total score; $S_{\text{max}}$ is the maximum possible score.

The classes of morphological quality are defined as (Rinaldi et al. 2013):
- high: $0.85 \leq \text{MQI} \leq 1$
- good: $0.70 \leq \text{MQI} < 0.85$
- moderate: $0.50 \leq \text{MQI} < 0.70$
- poor: $0.30 \leq \text{MQI} < 0.50$
- extremely poor: $0 \leq \text{MQI} < 0.30$

### Table 1. Reach-scale hydromorphological indicators in the REFORM framework (simplified and supplemented after González del Tánago et al. 2015)

| Key process/ features                                      | Indicator                                                                 | Literature source                          |
|-------------------------------------------------------------|---------------------------------------------------------------------------|--------------------------------------------|
| 1. Channel/ floodplain types and dimensions                 | 1.1. Basic river type (BRT)                                               | Rinaldi et al. 2015                        |
|                                                             | 1.2. Extended river type (ERT)                                            | Rinaldi et al. 2015                        |
|                                                             | 1.3. Floodplain type                                                     | Rinaldi et al. 2015                        |
|                                                             | 1.4. Planform                                                             | Nanson and Croke 1992                      |
|                                                             | 1.5. Channel bankfull width                                               | Richards 1982                              |
|                                                             | 1.6. Channel bankfull depth                                               |                                            |
|                                                             | 1.7. Channel slope                                                        |                                            |
| 2. Flooding extent                                          | 2.1. Morphological floodplain accessible by flood                         | Ward et al. 2002                           |
|                                                             | 2.2. Floodplain inundation frequency                                      |                                            |
| 3. River energy                                             | 3.1. Specific stream power at bankfull discharge                          |                                            |
|                                                             | 3.2. Floodplain inundation frequency                                      |                                            |
| 4. Channel adjustment                                      | 4.1. Eroding/aggrading channel banks                                      | Britonley and Fryirs 2005                  |
|                                                             | 4.2. Lateral bank movement                                                |                                            |
|                                                             | 4.3. Bed incision                                                         |                                            |
| 5. Riparian vegetation                                     | 5.1. Riparian corridor                                                    | Corenblit et al. 2007                      |
|                                                             | 5.2. Age structure                                                       | Corenblit et al. 2007                      |
|                                                             | 5.3. Dominant plant associations                                          |                                            |
| 6. Aquatic vegetation                                      | 6.1. Aquatic plant coverage                                               | Gurnell et al. 2015                        |
| 7. Constraints on channel adjustment                       | 7.1. Bank revetments, embankments, artificial levees                      | Piégay et al. 2005                         |
|                                                             | 7.2. Average width of erodible corridor for 50 years                      |                                            |
Table 2. Principal hydromorphological indicators in the Morphological Quality Index (simplified after Rinaldi et al. 2013, 2015)

| no | Indicator | Main parameters | Mode of data acquisition |
|----|-----------|-----------------|--------------------------|
|    |           | Geomorphological functionality |                      |
| F1 | longitudinal continuity | crossing structures (e.g. weirs) | RS, field survey |
| F2 | modern floodplain | dimensions (width) | RS, GIS, field survey |
| F3 | hillslope-river corridor connectivity | elements of disconnection | RS, GIS, field survey |
| F4 | bank retreat | processes, rate | RS, field survey |
| F5 | potential erodible corridor (Piégay et al. 2005) | width, length | RS, GIS |
| F6 | bed configuration + valley slope | bed features, valley slope | topographic maps |
| F7 | channel pattern | length of altered portions | RS, GIS, field survey |
| F8 | fluvial landforms in floodplain | presence of oxbow lakes etc. | RS, field survey |
| F9 | cross section | alteration | field survey, RS, GIS |
| F10 | bed structure | armouring, clogging etc. | field survey |
| F11 | in-channel large wood | amount of large wood | field survey |
| F12 | width of functional vegetation | (Gurnell et al. 2015) | RS, GIS |
| F13 | length of functional vegetation | (Gurnell et al. 2015) | RS, GIS |

|    | Artificiality |                      |
|----|--------------|----------------------|
| A1 | upstream alteration of flow | dams, diversions etc. | hydrological data |
| A2 | upstream alteration of sediment discharge | dams, check dams etc. | RS, GIS |
| A3 | flow alteration in reach | human interventions | RS, GIS, database of interventions |
| A4 | sediment alteration in reach | check-dams, weirs | RS, GIS, database of interventions |
| A5 | crossing structures | bridges, fords, culverts | RS, GIS, database of interventions |
| A6 | bank protection | walls, rip-rap, gabion | RS, GIS, database of interventions |
| A7 | artificial levees | length, position | RS, GIS, database of interventions |
| A8 | changes of course | cutoff, relocation etc. | historical information |
| A9 | bed stabilisation | sills, ramps etc. | RS, GIS, database of interventions |
| A10 | sediment removal |                       | database of interventions, RS, GIS |
| A11 | wood removal |                       | database of interventions, field survey |
| A12 | vegetation management | intensity of cuts | RS, GIS |

|    | Channel adjustment |                      |
|----|-------------------|----------------------|
| CA1 | adjustments in channel pattern |                      |
| CA2 | adjustments in channel width | RS, GIS |
| CA3 | bed-level adjustments | field survey |
Since both methods were elaborated for reach-scale analysis, we selected a typical reach of the Lower Drava Plain, the environs of the Cün-Szaporca cutoff meander with oxbow lakes (Fig. 1), which are also in the focus of rehabilitation efforts within the Old Drava Programme (AQUAPROFIT 2005; DDKÖVÍZIG 2012).

In addition to our data acquisition data sources were water management documents (among others AQUAPROFIT 2005; VKKI 2010; DDKÖVÍZIG 2012), archive maps (Military Survey maps, river regulation map from 1833, extents of inundation in 1827 and 1972 etc.) and GoogleEarth images.

3. Results and discussion

Significant impact of human activities is manifested in the hydromorphological parameters of the river and its floodplain. The REFORM framework (Table 3) and in the MQI approach (Table 4) both point out fundamental changes (degradation) in river mechanism and floodplain connectivity, the role of aquatic and riparian vegetation and
opportunities for channel adjustment.

The comparison of pre-regulation and present conditions based on the REFORM method reveals a heavy modification of the river channel (geomorphological type, sinuosity, rate of incision) with severe impact on the floodplain too, manifested in both positive (reduction of flood-prone areas) and negative changes (degradation of riparian forests).

The MQI value for the studied Drava reach describes actual conditions. Its value was found to be 0.41, which qualifies poor in comparison with most Italian rivers. However, in Hungarian comparison this index value is suspected to be close to the national average for major rivers and floodplains.

4. Conclusions

Both hydromorphological assessment approaches have highlighted a high degree of transformation for the river and its floodplain compared to reference conditions (pre-regulation in the case of the REFORM framework or theoretical maximum scores in the case of the MQI). Further investigations are necessary to prove the applicability of the methods for the rivers of the Carpathian Basin.

Although these methods do not provide an envisioned target for rehabilitation efforts, detailed information are supplied for planners of such interventions.
Table 4. Assessment of the present conditions of the selected reach by the scoring system of the Morphological Quality Index. The range of scores is variable.

| No  | Indicator                                      | Description                                                                 | Range of scores | Score for the Cün-Szaporca cutoff meander |
|-----|-----------------------------------------------|----------------------------------------------------------------------------|-----------------|-------------------------------------------|
| F1  | longitudinal continuity                       | slight interception of sediment and wood                                   | 0–5             | 1                                         |
| F2  | modern floodplain                             | floodplain narrowed down to <25% of width                                 | 0–5             | 2                                         |
| F3  | hillslope-river corridor connectivity         | connection prevented by artificial levee                                   | 0–5             | 5                                         |
| F4  | bank retreat                                  | bank retreat prevented by revetment                                        | 0–3             | 3                                         |
| F5  | potential erodible corridor (Prégy et al. 2005) | no corridor along main channel, narrow corridor along oxbow lakes          | 0–3             | 3                                         |
| F6  | bed configuration + valley slope              | bed forms consistent with mean valley slope                               | 0–5             | 2                                         |
| F7  | channel pattern                               | consistent alteration for the whole reach, preservation of cutoff meander  | 0–5             | 3                                         |
| F8  | fluvial landforms in floodplain               | series of oxbow lakes in cutoff meander                                   | 0–3             | 0                                         |
| F9  | cross section                                | moderate alteration                                                       | 0–5             | 3                                         |
| F10 | bed structure                                 | evident and widespread armouring                                          | 0–6             | 4                                         |
| F11 | in-channel large wood width of functional     | small amounts of large wood                                               | 0–3             | 2                                         |
|     | vegetation (Gurnell et al. 2015)             | wide strip of functional vegetation                                       | 0–3             | 1                                         |
| F12 | vegetation (Gurnell et al. 2015)             | functional vegetation all along the reach                                 | 0–5             | 0                                         |
| A1  | upstream alteration of flow                   | significant alteration of flow by dams in upstream countries              | 0–6             | 5                                         |
| A2  | upstream alteration of sediment discharge     | significant reduction of sediment discharge by dams in upstream countries | 0–6             | 6                                         |
| A3  | flow alteration in reach                      | significant reduction of channel forming discharges                       | 0–6             | 4                                         |
| A4  | sediment alteration in reach                 | absence of sediment flux interception                                     | 0–6             | 0                                         |
| A5  | crossing structures                           | no bridge in upstream vicinity (<1000 m) of reach                         | 0–3             | 0                                         |
| A6  | bank protection                               | rip-rap protection along the whole reach                                  | 0–12            | 12                                        |
| A7  | artificial levees                             | levee along the whole reach                                               | 0–12            | 12                                        |
| A8  | changes of course meander cutoff             | meander cutoff                                                            | 0–3             | 3                                         |
| A9  | bed stabilisation                             | limited bed revetments                                                    | 0–8             | 3                                         |
| A10 | sediment removal                              | localised dredging in the past 20 years                                   | 0–6             | 3                                         |
| A11 | wood removal                                  | selective removal in the past 20 years                                     | 0–5             | 2                                         |
| A12 | vegetation management                         | selective cuts in the past 20 years                                       | 0–5             | 2                                         |
| CA1 | adjustments in channel pattern                | major changes in channel pattern since 1950                              | 0–6             | 4                                         |
| CA2 | adjustments in channel width                 | limited changes since 1950                                                | 0–6             | 2                                         |
| CA3 | bed-level adjustments                         | 2.4 m bed level change in 100 years                                       | 0–12            | 7                                         |

**maximum score** 158

**Total score** 94
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