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HYDROMORPHOLOGICAL ASSESSMENT OF THE LOWER HUNGARIAN DRAVA SECTION AND ITS FLOODPLAIN

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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

$$\mathrm{MQI} = 1 - S_{tot}/S_{max},$$

where S_{tot} is the total score;

S_{max} is the maximum possible score.

The classes of morphological quality are defined as (Rinaldi et al. 2013):

- high: $0.85 \leq \mathrm{MQI} \leq 1$;
- good: $0.70 \leq \mathrm{MQI} < 0.85$;
- moderate: $0.50 \leq \mathrm{MQI} < 0.70$;
- poor: $0.30 \leq \mathrm{MQI} < 0.50$;
- extremely poor: $0 \leq \mathrm{MQI} < 0.30$.

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 Nanson and Croke 1992
		1.4. Planform	Richards 1982
		1.5. Channel bankfull width	
		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	
4.	Channel adjustment	4.1. Eroding/aggrading channel banks	
		4.2. Lateral bank movement	Brierley and Fryirs 2005
		4.3. Bed incision	
5.	Riparian vegetation	5.1. Riparian corridor	
		5.2. Age structure	Corenblit et al. 2007
		5.3. Dominant plant associations	Corenblit et al. 2007
6.	Aquatic vegetation	6.1. Aquatic plant coverage	Gurnell et al. 2015
7.	Constraints on channel adjustment	7.1. Bank revetments, embankments, artificial levees	
		7.2. Average width of erodible corridor for 50 years	Piégay et al. 2005

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

Table 3. Classification and assessment of the pre-regulation and present conditions for the selected reach according to the REFORM framework

Indicator	*Unit*	*Class/value at Cún-Szaporca cutoff meander*	
		Pre-regulation (early 19th cent.)	Present (21st cent.)
1.1. Basic river type (BRT)		single-thread: meandering (4)	heavily artificial (0)
1.2. Extended river type (ERT)		unconfined, sand (+ fine gravel) bed, meandering (18)	heavily artificial (0)
1.3. Rinaldi floodplain type		(sinuous/meandering) lateral migration (G)	
Nanson/Croke floodplain type		meandering with lateral migration (2b)	
1.4. Planform	dimensionless sinuosity index	3.8	1.1
1.5. Channel bankfull width	metres	active channel: 350	oxbow lakes: 200
1.6. Channel bankfull depth	metres	active channel: ca 5.5	oxbow lakes: 3.3
1.7. Channel slope	$m\ m^{-1}$	0.00023	0.000114
2.1. Morphological floodplain accessible by flood	%	80	7
2.2. Floodplain inundation frequency	times per decade	>10	1
3.1. Specific stream power at bankfull discharge	$W\ m^{-2}$	ca 10	35 (FLUVIUS 2007)
4.1. Eroding/ aggrading channel banks	% of active channel length	ca 50/50	90/10
4.2. Lateral bank movement	$m\ year^{-1}$	>1	<0.1
4.3. Bed incision	$cm\ year^{-1}$	n.a.	2.4
5.1. Riparian corridor	average width (m)	>80	20
5.2. Age structure of riparian vegetation	% of old, mature and young forests	old forest >50%	old forest: 20%; mature forest: 70%; young forest: 10%
5.3. Dominant plant associations	association type	softwood and hardwood forests	alluvial and mixed riparian forests
6.1. Aquatic plant coverage	% of channel bed	n.a.	in oxbow lake: <10
7.1. Bank revetments, embankments, artificial levees	% of channel length	<10	100
7.2. Average width of erodible corridor for 50 years	channel widths	n.a.	1.5 (Kiss et al. 2011)

Since both methods were elaborated for reach-scale analysis, we selected a typical reach of the Lower Drava Plain, the environs of the Cún-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, extentions 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

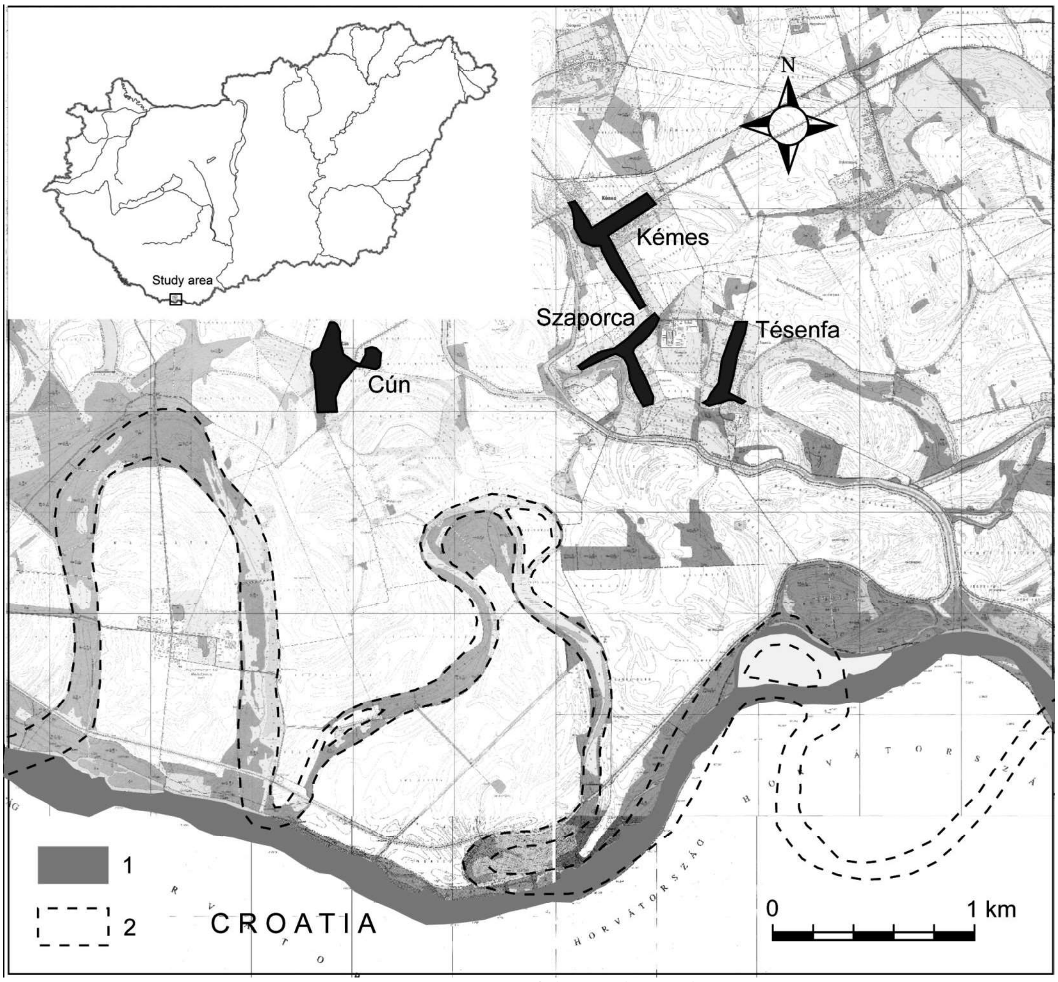

Fig. 1. Location of the study reach

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 Cún-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 (Piégay 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	small amounts of large wood	0–3	2
F12	width of functional vegetation (Gurnell et al. 2015)	wide strip of functional vegetation	0–3	1
F13	length of functional 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	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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