Proceedings of the Fábos Conference on Landscape and Greenway Planning

Volume 7
Issue 1 *Moving towards Health and Resilience in the public realm*

Article 47

August 2022

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Recommended Citation

Erdei, Tímea; Boromisza, Zsombor PhD; Domokos, Endre PhD; and Dávid, Szilvia (2022) "Determining the Restoration Potential of an Urban River Reach Along Zagyva River, Hungary," *Proceedings of the Fábos Conference on Landscape and Greenway Planning*: Vol. 7: Iss. 1, Article 47.
DOI: https://doi.org/10.7275/tcsn-pt64
Available at: https://scholarworks.umass.edu/fabos/vol7/iss1/47

etermining the Restoration Potential of an Urban River Reach Along Zagyva River, Hungary

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1. Abstract

When planning the restoration of rivers, different conditions and needs require different solutions, which is highlighted in the Water Framework Directive (2000/60/EC). These differences must be taken into account in the protection and restoration of our rivers.

Research about the determination of the restoration or rehabilitation potential of rivers has been focused mostly on rural river reaches, but it would be important to place greater emphasis on the restoration of urban river reaches. In the case of rivers in urban areas, in addition to supporting, regulating, and provisioning ecosystem services, cultural ecosystem services are also particularly important – such as recreational opportunities, tourist significance, or aesthetic value. Thus, in addition to the environmental benefits, the social benefits also confirm the importance of restoring urban rivers.

The present research aims to develop an evaluation methodology for river reaches related to urban areas, which interprets and determines the restoration potential in relation to restoration goals. The most common goals related to the restoration of urban rivers have been defined, and the criteria for determining the restoration potential have been developed for each goal. To determine the need for restoration, criteria related to condition were used, such as hydromorphological and ecological features in the riverbed, bank and floodplain (e.g., pavements, morphological features, vegetation features), water quality, presence of pollutants, recreational characteristics (e.g., intensity of human use, view of the river, existing recreational infrastructure). To determine the possibilities, criteria about limiting factors were analyzed, including the width of the floodplain, the presence of artificial facilities, current and planned land use. Information from field surveys as well as available databases and GIS data were used for the evaluation.

The need (condition) and possibilities (limiting factors) of the restoration were assessed together for each goal in river sections. As a result of the method, river sections with different restoration potential can be identified, and the territorial priorities of different restoration goals can be assessed. The criteria system of the method can be used on other rivers, even in other countries, but the assessment should take into account the reference characteristics / target condition of the given river reach, which may differ. The results of the research can help in the preliminary planning of the restoration of urban rivers. The method allows for the territorial delimitation of individual restoration goals and the joint assessment of the need and possibilities for restoration.

2. Introduction

Rivers and riparian landscapes have been shaped by a number of natural processes and human activities, making their protection and restoration one of the most important challenges of our time. The importance of the implementation of river restorations tasks is emphasized by several directives, plans, and strategies (e.g., EU Water Framework Directive - hereinafter WFD; EU Biodiversity Strategy for 2030). The list of measures in the WFD includes restoration projects aiming at restoring the bed, bank, and riparian zone of rivers and mitigating the adverse effects of artificial structures. The planned measures of the second revision of Hungary's river basin management Plan (Danube River Basin Management Plan 2021) include the restoration of longitudinal continuity, the improvement of hydromorphological conditions, the enforcement of ecological aspects (e.g., the protection of damaged aquatic and wetland habitats), and the promotion of natural water retention measures. The protection and restoration of rivers must take into account the different natural and social conditions and the restoration needs arising from them. An important task is to properly establish restoration projects and to develop methods for the examination and evaluation of rivers, which can be used to determine their restoration potential.

3. Background and Literature Review

Nowadays, the development of green infrastructure in urban areas is receiving more and more attention (MTA-OIA 2017), of which rivers are also an important pillar, as they represent an outstanding value, and their restoration contributes to the increase of many ecosystem services. Research on the restoration potential of rural river reaches is more widespread (Erdei 2020a), but it is also important to place more emphasis on the restoration of urban river reaches. Research from abroad using methods applicable in urban areas based on their scale or system of criteria can be highlighted: Hulse and Gregory (2004), Boitsidis et al. (2006), Francis et al. (2008), Norton et al. (2009), Gurnell et al. (2014), Guida-Johnson and Zuleta (2019), Zuo et al. (2020). Publications in the Hungarian literature can also be mentioned, such as on the principles of the restoration of small watercourses (Báthoryné Nagy 2007), on the hydromorphological and landscape ecological assessment of floodplains (Lóczy 2011).

The present research aims to help achieve the goals of urban river restoration and to develop an evaluation methodology that is suitable for determining the restoration potential of urban river reaches. The goal is to evaluate the need and possibility of restoration and compare them spatially. In this way, areas with a better chance of being involved in restoration planning can be mapped.

4. Method and Data

Study area

The study area of the research was the urban river reach of Zagyva, in Szolnok. Szolnok is a Hungarian city in the Northern Great Plain region, in the county of Jász-Nagykun-Szolnok, with a population of nearly 70,000. The city is located at the mouth of the Zagyva and the river is flowing into the river Tisza, the most significant river of the Great Hungarian Plain. The Zagyva River reach included in the evaluation was delineated with the help of the 300 m buffer area of the land use units of Szolnok with residential, holiday, and recreational functions. The study area contained the active floodplain of the river reach (bed, banks, and floodplain). According to the type of water

body, the Zagyva is a lowland river with a small slope and large catchment. The examined Zagyva reach was affected by river regulation works, the cut-off meander called 'Holt-Zagyva' is located north of the settlement. The floodplain accessible for flood has been significantly reduced to secure more space for the city and eliminate flood risk on agricultural land. There are significant elements of the green infrastructure north of the city, on the former floodplain (mainly due to public welfare forests). The main human interventions affecting the river reach in Szolnok are 3 transversal structures (weirs) in the channel and maintenance practice (afforestation) on the active floodplain.

Evaluation method

The restoration potential of the Zagyva reach connected to the urban area in the Szolnok study area was determined by the following steps:

1. Defining restoration sub-goals
2. Delineation of river sections treated separately during the assessment
3. Development of the criteria system for each sub-goal, and carrying out the evaluation
4. Determining restoration potential: comparing the need and possibilities of restoration

Defining restoration sub-goals

As a first step, the most important sub-goals related to the restoration of the examined river reach were formulated, as the restoration potential was determined in relation to the sub-goals, compiling separate evaluation criteria for each sub-goal. The possible sub-goals were determined based on the analysis of the restoration goals summarized by Nagy and Novák (2004), the analysis of Hungarian projects carried out as a prelude to the present research (Erdei 2020b), and the guidance standard for assessing the hydromorphological features of rivers (14614:2020). The sub-goals evaluated in the current research were the followings:

Sub-goal 1: Improving the longitudinal continuity where artificial structures limit fish migration
Sub-goal 2: Improving the ecological and hydromorphological condition of the active channel
Sub-goal 3: Achieving a more natural channel planform
Sub-goal 4: Improving the naturalness of floodplain vegetation
Sub-goal 5: Improving recreational opportunities
Sub-goal 6: Improving urban landscape aesthetic value

Delineation of river sections treated separately during the assessment

During the assessment, pre-delineated sections of active floodplain with similar characteristics (including bed, banks, and floodplain) were assessed. In the present research, sections were delineated taking into account the following aspects: location, main land use next to the active floodplain, width of the active floodplain and presence of significant cut-off meander. The location (rural/urban area) and the land use characteristics of the areas adjacent to the floodplain have an impact on, among other things, the loads on the river section, the natural condition, and the use of the section. The width of the floodplain has a fundamental effect on restoration options, and major cut-off meanders indicate sections affected by previous significant river regulation. Based on these, eight active floodplain sections in the Szolnok study area were delineated. During the evaluation, the floodplain at the right and left banks were treated separately.

Development of the criteria system for each sub-goal, and carrying out the evaluation

During the evaluation, the need for restoration (which follows from the condition of the river) and the possibilities of restoration (which follows from the presence of factors limiting the implementation) were determined using a scoring system. The collection of assessment criteria was based on a review of the literature on restoration potential (Erdei 2020a), the literature related to small watercourses (Báthoryné Nagy 2007), the guidance standard CEN 14614:2020, and the methodological manual on the generation and evaluation of hydromorphological data (VIZITERV 2019). Aspects related to the bed, banks, and floodplain were taken into account in the research and summarized in Table 1.

The sources of the data included the data provided by the General Directorate of Water Management (artificial structures - characteristics, continuity, possible measures; bank protection, map of the related flood defense system; water bases); data provided by the Middle Tisza District Water Directorate (map of the channel at low flow; bank reinforcement), data provided by the Hortobágy National Park Directorate (occurrence of invasive species and protected species; nature conservation areas). For the remaining aspects of the study, analysis of field surveys, satellite imagery, settlement plans, and historical maps were the source of the data.

Table 1. Evaluation criteria related to the need and possibility of restoration

	Zone*	Evaluation criteria	Sub-goal
Need of restoration			
1	Be	ecological continuity of artificial structures in the channel	1
2	Be	ecological and hydromorphological impact of artificial structures in the channel	2
3	Be	proportion of river sections affected by bed reinforcement	2
4	Be	naturalness of the channel form	2
5	Be, F	relative frequency of the type specific morphological features	2, 6
6	Be	average proportion of aquatic or wetland vegetation cover in open water	2, 6
7	Be	the degree of modification of the planform	3
8	Be	the degree of change in the sinuosity index	3
9	Ba	proportion of river sections affected by bank reinforcement	2, 3
10	Ba	bank slope degree modifications	2, 5, 6
11	Ba	proportion of river sections affected by bank erosion	3
12	Ba	frequency of river sections with potential bank erosion	3
13	Ba	shading effect of riparian woody vegetation	2
14	Ba	continuity of riparian woody vegetation	2
15	Ba	accessibility of riverbanks	5
16	Be, Ba, F	naturalness of lateral vegetation zonation	4
17	F	naturalness of floodplain woody vegetation	4, 6
18	F	proportion of habitat patches infested with invasive species	4
19	F	proportion of areas affected by human activity	4, 6
20	F	proportion of areas with nature conservation importance	4
21	F	accessibility of the floodplain	5
22	F	proportion of woody vegetation on the floodplain	5
23	F	proximity and quality existing linear recreational	5

DOI: https://doi.org/10.7275/tcsn-pt64

		infrastructure	
24	Ba, F	proximity and quality of existing non-linear recreational infrastructure	5
25	F	proximity and density of cultural and historical attractions	5
26	F	intensity of use	5
27	F	distance from existing green areas	5
28	F	distance from residential and holiday areas	5, 6
29	F	view on the river	6
30	Be, Ba, F	proportion of areas with landscape aesthetic protection	6
Possibility of restoration			
31	Be	reduction options of the impacts of artificial structures	1, 2, 3
32	F	width of the floodplain	4
33	F	width of the floodplain potentially suitable for the movement of the river	1, 3
34	F	proportion of woody vegetation	1, 3
35	F	naturalness of woody vegetation on the floodplain	1, 3
36	Ba, F	occurrence of protected species	1, 3, 5, 6
37	Be, Ba, F	proportion of areas with environmental importance	1, 3, 4, 5, 6
38	Be, Ba, F	occurrence of areas and values with heritage protection	1, 3, 4, 5, 6
39	Be, Ba, F	proportion of areas with nature conservation importance	5, 6

**Be = river bed, Ba = river bank, F = floodplain*

Determining restoration potential

To determine the restoration potential, the presented evaluation criteria were assigned to the restoration sub-goals, so the restoration potential was determined for each sub-goal. Aspects were weighted in terms of importance. The scores for each section were summed and averaged using weighting. The scores were aggregated separately for the need for restoration and the possibility of restoration. To determine the restoration potential of the given section, the need and the possibilities of restoration were compared (Table 2). During the evaluation, we considered the need for restoration to be greater, the more the given section is in a modified/unfavorable condition. We considered the possibilities of restoration to be better, the fewer the limiting factors.

Table 2. Determining restoration potential based on the need and possibility of restoration

Determining restoration potential		**Possibility of restoration**		
		High	**Medium**	**Small**
Need of restoration	**High**	5	4	3
	Medium	4	3	2
	Small	3	2	1

5. Results

By evaluating the Zagyva river reach in Szolnok, we obtained the restoration potential of the sections for each sub-goal. The results of the evaluation by sub-goals are shown in Figure 1. There is high restoration potential **to improve the longitudinal continuity** of artificial structures on all affected sections, as all of them are only periodical obstacles and could be handled with a more natural solution. To **improve the condition of the active channel**, the restoration potential is high on section 1 by the river mouth. Although it would be necessary to improve the condition of the other urban sections, as they are affected by the presence of an artificial structure, they may require additional interventions. The restoration potential to **achieve a more natural planform** is high on section 6 affected by the cut-off meander, as this is where the biggest changes during the river regulation took place. In addition, the restoration potential is high in section 4 adjacent to the urban areas (Figure 2), as point erosion processes can be seen on the bank, suggesting the potential in the channel dynamics. In terms of **improving the naturalness of the floodplain vegetation**, there is significant restoration potential in the floodplain at the left bank of section 4 adjacent to the urban areas, mainly due to the high coverage of invasive species, no limiting factors in the area and it is also affected by areas of nature conservation importance, which makes the implementation of the sub-goal even more important. The restoration potential of the sub-goal is high in several other sections, except the urban sections, where the restoration potential is small or medium, mainly due to the limiting factors present (e.g., floodplain width, presence of environmental or heritage sites). The restoration potential of the **improvement of recreational opportunities** in the urban section 2 and 3 is high. On the left bankside floodplain of section 3 the restoration potential is significant, as there are fewer recreational opportunities in the vicinity of high-density residential areas, and there are few limiting factors. In terms of **improving urban landscape aesthetic value**, the restoration potential is significant or high in section 3 and on the left bankside floodplain of section 5. In the urban areas, there is a lack of woody vegetation from the bank and the active floodplain, or most of them is plantation forest, which is unfavorable from a landscape point of view.

Comparing the sections with high or significant restoration potential for the sub-goals, it is conspicuous in which sections of the examined Zagyva reach which restoration sub-goals are more necessary and possible (Figure 2). Thus, the territorial differences of the reach were explored. By comparing the results of the restoration potential by sub-goals, the planning of restoration measures can be established.

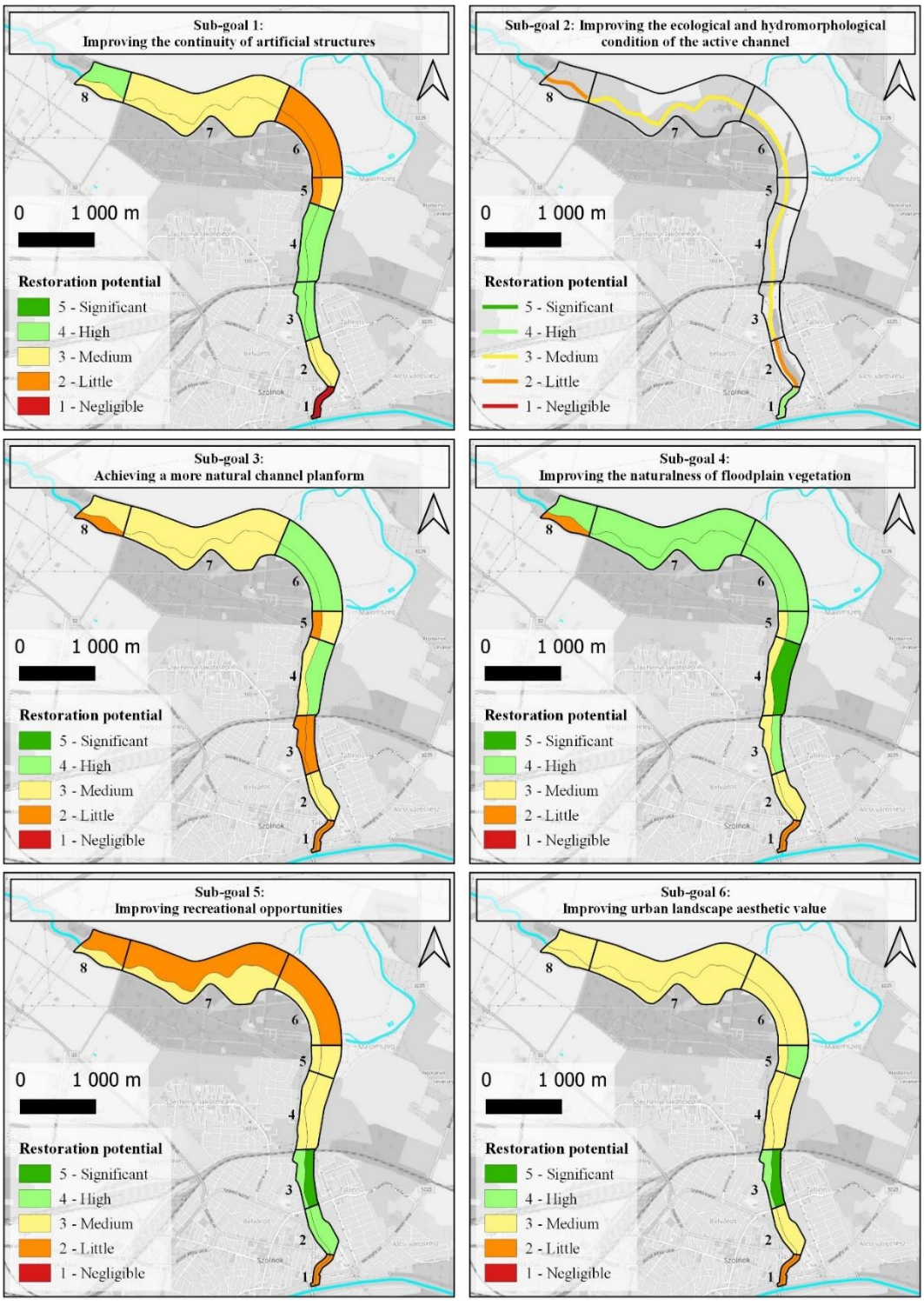

Figure 1. Results of determining the restoration potential of sub-goals

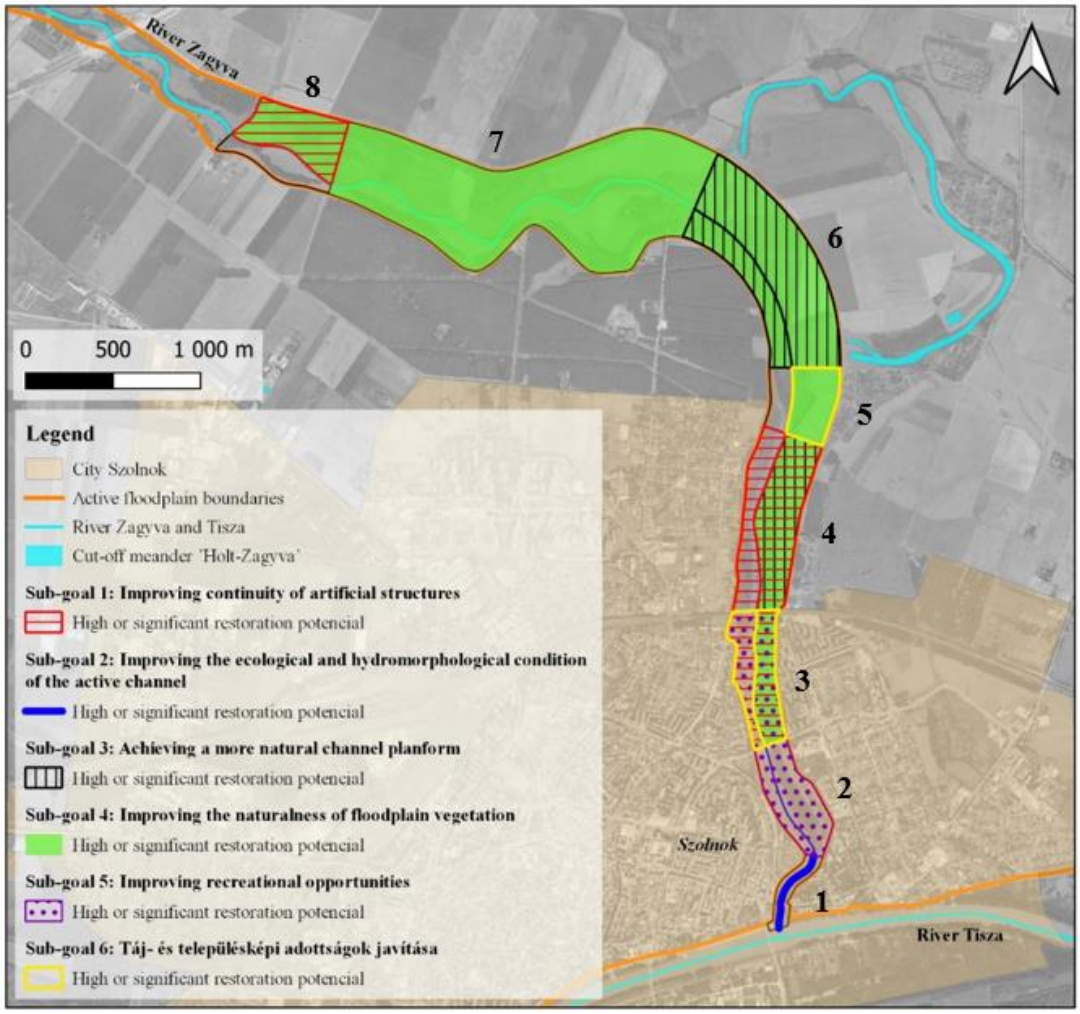

Figure 2. Comparison of the high and significant restoration potential of sub-goals

6. Discussion and Conclusion

As a result of the research, an evaluation methodology for the determination of the restoration potential of urban river reaches was prepared with regard to restoration sub-goals. The method is suitable to evaluate and spatially compare the need and possibilities of restoration before planning the restoration of urban river reaches. Compared to the methods reviewed during the literature research, the difference is that the restoration potential has been determined in relation to sub-goals, with the help of which the evaluation of restoration priorities can be further differentiated. As a continuation of the research, the restoration sub-goals included in the assessment can be expanded, such as improving water quality or improving water storage opportunities. In addition, it is planned to test the method in several study areas along the Zagyva River. The criteria system of the method can be used on other rivers, even in other countries, but the assessment should take into account the reference characteristics/target condition of the given river reach, which may differ.

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