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COMPARISON OF TWO RIVER SEGMENTATION METHODS IN DETERMINING THEIR RESTORATION POTENTIAL

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Abstract

The aim of the study was to determine the restoration potential of urban river reaches with two different river segmentation methods. The first method was the evaluation of sections with similar characteristics, delineated before assessment. The second method was the assessment of 100 meter [m] long sections. The method of preliminary sections based on the results can be used if it is possible to delimit sections with similar characteristics from most evaluation criteria. While in cases where several different evaluation criteria are applied, the delimitation of shorter sections with the same length can give good results. From the point of view of the plan to be developed, the method of identifying sections with similar characteristics can play a greater role in delineating the most important restoration sub-goals and their target areas. While the method of shorter sections of the same length can be well-used in the development of more detailed concepts or plans. In addition, the territorial scale is also important. In small areas, on shorter river reaches, the method of short, 100 m long sections can also be used. However, it is better to delimit sections with similar characteristics on a large scale or if field surveys cannot be carried out along the entire section length.

Introduction

Watercourses and landscapes along watercourses have been and are currently being shaped by many natural processes and human activities, the adverse effects of which make their protection and restoration one of

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the most important challenges today in Hungary, as well as throughout Europe. A significant part of European watercourses has been changed by human alteration and nearly 95% of the floodplains have been lost (PEDERSEN et al. 2014 and citations therein). The importance of the implementation of watercourse restoration tasks is emphasized by numerous international directives (EU Water Framework Directive – WFD, EU Biodiversity Strategy until 2030, The European Green Deal, Proposal for a Nature Restoration Law), and Hungarian plans and strategies (5th National Nature Conservation Basic Plan – NTA-V, National Landscape Strategy – NLS). The WFD's list of measures includes rehabilitation projects aimed at restoring the beds, banks, and shorelines of watercourses, as well as 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, improvement of hydromorphological conditions, enforcement of ecological aspects (e.g. protection of damaged water and wetland habitats because of the modified water flow, inadequate water supply, improper management, poor water quality or invasive species), and promotion of natural water retention.

Rivers are one of the categories of surface watercourses that can be divided into groups according to size. Rivers have a large catchment area, are considerable in length, and have a significant average water flow (DÉVAI et al. 1998). Small rivers are 50–250 km long, have 500–10,000 km^2 catchment area, and 5–50 m^3/sec annual average water flow based on the categories of DÉVAI et al. (1998). Among the 28 watercourses, which are listed in the Act CXCVI of 2011 on national assets as rivers, and in the second revision of Hungary's river basin management plan, they have a "river" water management classification, 64% belong to the small river category. The subject of this research is the small rivers in Hungary.

Different natural and social features and resulting rehabilitation needs require different solutions when planning the rehabilitation of rivers. These differences must be explored and taken into account. It is important to properly establish the rehabilitation projects and to develop the methods of evaluation of rivers, one of the tools of which can be the determination of their rehabilitation potential.

In addition to the more widespread research on determining the restoration potential of river reaches in rural areas, it is also important to place greater emphasis on the rehabilitation of urban river reaches. Previous research on the topic has mainly focused on river sections in rural areas (ERDEI 2020a). Watercourses are an important pillar of blue infrastructure and are receiving increasing attention in developing green infrastruc-

ture in urban areas (VASZÓCSIK et al. 2014, MTA-OIA 2017). They represent an outstanding value, and their rehabilitation also contributes to the increase of many ecosystem services. Settlements along rivers can also be important destinations from a tourist point of view, for example, STARCZEWSKI et al. (2018) analyzed the tourism development potential of towns along the Krzna river. Due to existing limiting factors, urban river sections are mainly rehabilitated rather than fully restored.

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), and ZUO et al. (2020) are examples of international research that, due to their scale or criteria, used methods applicable in urban areas. In the Hungarian literature, publications on the management principles of the rehabilitation of small watercourses (BÁTHORYNÉ NAGY 2007), the hydromorphological and landscape ecological evaluation of floodplains (LÓCZY 2011), or the improvement of continuity and the prioritization of barrier removal (ERŐS and CZEGLÉDI 2019) can also be mentioned. In these studies, various segmentation methods were used. As a larger-scale study, NORTON et al. (2009) dealt with the assessment of water bodies; ZUO et al. (2020) evaluated the studied river by dividing it into upper, middle, and lower sections. LÓCZY 2011 divided the investigated river into sections with similar morphological characteristics based on preliminary GIS analyses. BÁTHORYNÉ NAGY (2007) evaluated the studied stream by segmenting it based on landscape types and landscape management zones. In contrast to these, HULSE and GREGORY (2004) evaluated sections of the same length while examining a longer river section and divided it into 1 km long sections. BOITSIDIS et al. (2006) examined urban river sections, during which they evaluated river sections with the same length of 500 m.

Taking into account the definitions found in the literature, in this research, we call rehabilitation the improvement of the landscape's physical, chemical, ecological, and aesthetic condition along the river, as well as its integration into the urban environment by increasing its multifunctional role. The present research aims to facilitate the realization of urban river rehabilitations, as its goal is to develop an evaluation methodology suitable for determining the restoration potential of urban river reaches and the restoration sub-goals for a given river reach. The restoration potential was determined by applying two types of watercourse segmentation methods and comparing their results. Our aim is to evaluate the need and possibility of restoration with the established methodology and compare them territorially. In this way, areas that can be included in rehabilitation planning with a better chance can be mapped.

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, which flows into the Tisza, the largest river in 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 a 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 flooding 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 three transversal structures (weirs) in the channel and maintenance practices (afforestation) on the active floodplain.

Materials and Method

In the Szolnok study area, we evaluated the river reach connected to the urban areas to determine the rehabilitation potential (Figure 1). The steps for this are explained in detail in the subsections below. As a first step, we defined the examined river reach units and the possible sub-goals related to their rehabilitation. The determination of the restoration potential was made regarding the sub-goals. A separate evaluation system was compiled from the examination aspects for each sub-goal. This publication presents evaluations related to the sub-goals related to the ecological and hydromorphological state of the riverbed, the bank, and the active floodplain. During the evaluation, the need for restoration (from the condition and characteristics of the river) and the possibilities of restoration (from the presence of factors limiting its implementation) were determined using a scoring method. By comparing the need and possibilities of restoration, we obtained the restoration potential of the given section for the sub-goal. With the help of this, the territorial differences within the examined river reach were revealed, and the areas with good potential in terms of the various restoration sub-goals could be delineated. By com-

paring the results of the restoration potential per sub-goal, it was also possible to base the planning of the restoration.

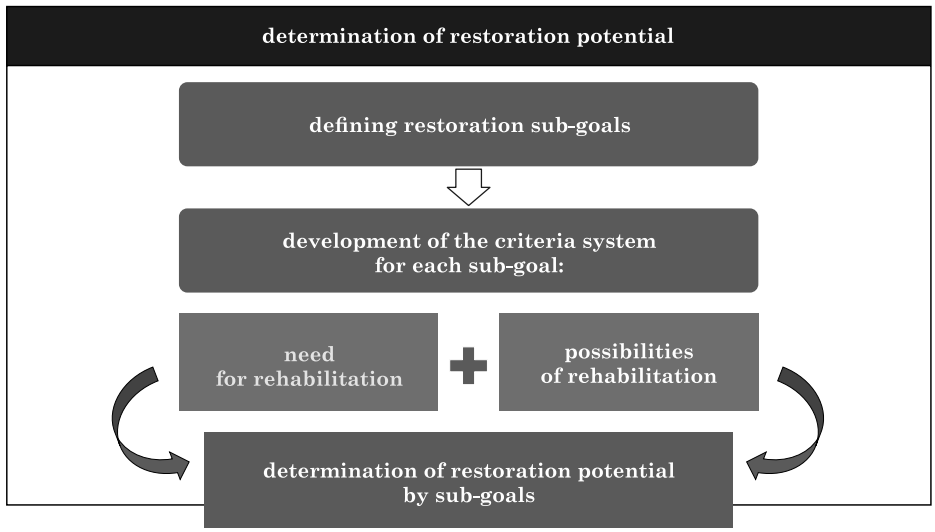

Fig. 1. Method of determining restoration potential

The evaluation was prepared using two types of segmentation methods, which are presented in detail below:

1. Pre-delineated sections with similar characteristics.
2. Sections with the same length of 100 m.

Defining restoration sub-goals

The restoration potential of the examined river reach was determined by establishing restoration sub-goals. The most typical restoration sub-goals related to urban rivers were determined based on the restoration objectives summarized by NAGY and NOVÁK (2004), the guidance standard for assessing the hydromorphological features of rivers (14614:2020) and the analysis of Hungarian projects carried out as a prelude to the present research (ERDEI 2020b). In connection with the most common problems, we determined the restoration sub-goals for which we prepared the evaluation of the restoration potential. The sub-goals of this research are those that primarily affect the area of the riverbed, the bank, and the active floodplain, during which the hydromorphological aspects are an essential part of determining the restoration potential.

The sub-goals evaluated in the current research were the following:

1. Improving the longitudinal connectivity, where artificial structures limit fish migration.

2. Improving the ecological and hydromorphological condition of the active channel.
3. Achieving a more natural channel planform.
4. Improving the naturalness of floodplain vegetation.
5. Improving water quality.

Development of the criteria system for each sub-goal and the source of the data

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). In addition, aspects related to the bed, banks, and floodplain were taken into account in the research and summarized in Table 1.

Table 1

Evaluation criteria related to the need and possibility of restoration

Zone*	Evaluation criteria	Sub-goal
Need of restoration		
1	2	3
Be	water quality based on the informative environmental rating index	5
Be	ecological continuity of artificial structures in the channel	1
Be	ecological and hydromorphological impact of artificial structures in the channel	2
Be	naturalness of the channel form	2
Be	average proportion of aquatic or wetland vegetation cover in open water	2
Be, F	frequency and type of specific morphological features	2
Be	degree of modification of the planform	3
Be	degree of change in the sinuosity index	3
Be	distance of arable land from the bed	5
Be	presence and effect of polluting sources	5
Ba	bank slope degree modifications	2
Ba	bank erosion depending on the influence of the river movement	3
Ba	proportion of river sections affected by bank reinforcement	2, 3
Ba	shading effect of riparian woody vegetation	2
Ba	continuity of buffer vegetation on the river bank	2

cont. Table 1

1	2	3
Ba	width of buffer vegetation on the river bank	2
Be, Ba, F	naturalness of lateral vegetation zonation	4
F	naturalness of floodplain woody vegetation	4
F	proportion of habitat patches infested with invasive species	4
F	proportion of areas affected by human activity	4
F	proportion of areas with nature conservation importance	4
Possibility of restoration		
Be	reduction options for the impacts of artificial structures	1, 2, 3
Be	naturalness of the channel form	4, 5
Be, Ba	degree of influence by sedimentation	2
F	width of the floodplain	4, 5
F	width of the floodplain potentially suitable for the movement of the river	1, 3
F	proportion and naturalness of woody vegetation	1, 3
Ba, F	occurrence of protected species	1, 3
Be, Ba, F	proportion of areas with environmental importance	1, 3, 4, 5
Be, Ba, F	occurrence of areas and values with heritage protection	1, 3, 4, 5

*Be – river bed; Ba – river bank; F – floodplain

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 defence 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 sources of the data.

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. To determine the restoration potential, we evaluated each aspect on a 5-point scale. In the case of aspects relating to the river bank, the characteristics of the right and left banks were also taken into account, however, the characteristics of the two sides were summed up, and the river section was evaluated together based on them. In that way we could describe the given section with one evaluation result

according to the characteristics of the bank. In the case of the floodplain, this is less possible, there can appear much different characteristics, and they are geographically far from each other, so we found it more worthwhile to evaluate them separately, which resulted in two separate evaluations result. Aspects were weighted in terms of importance. The scores for each section were summed and averaged using weighting. We separately aggregated the evaluation results of the aspects related to the need for restoration (current condition of the river: higher score = greater need) and separately the evaluation results of the aspects related to the possibilities of restoration (limiting factors: higher score = better implementation possibilities) per subgoal.

To determine the restoration potential of the given section, the need and the possibilities of restoration were compared (Table 2). Based on the results of the separate evaluation of the necessity and the possibility,it can be seen which makes the restoration potential of the given section worse, so the two partial results and the final result can be interpreted together.

Table 2

Determining restoration potential based on the need and possibility of restoration

Specification		Possibility of restoration		
		high	medium	small
Need of restoration	high	5	4	3
	medium	4	3	2
	small	3	2	1

During the evaluation, we considered the need for restoration to be greater, the more the given section is in a modified/unfavourable condition. On the other hand, we considered restoration possibilities to be better, the fewer the limiting factors. During the restoration potential determination, the sections with the most modification or worse condition and the fewest limiting factors became those with the best restoration potential. On the other hand, the less modified sections with many limiting factors were the ones with the worst restoration potential.

Segmentation methods

Sections with similar characteristics. During the evaluation, pre-delineated sections (including the river bed, river bank, and floodplain) were evaluated in accordance with the recommendation of the CEN 14614:2020 standard. The floodplain sections were delineated in connection with the river sections, which in some cases were further divided due to the different land uses along the floodplain. In the case of the method,

the purpose of segmentation is to determine river and floodplain sections with similar properties, even before more detailed investigations, based mainly on aspects that can be clearly delineated from maps and databases. In the present research, sections were delineated, taking into account the following aspects:

– location (urban/rural),

– main land use next to the active floodplain (forest/grassland/agricultural area/horticultural area/*residential area*/*holiday-weekend house area*/*industrial area*/*mixed area* – last four together built-up areas),

– width of the active floodplain (narrow/medium or variable/wide),

– presence of significant cut-off meander and

– presence of artificial structures.

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 main land use was determined based on settlement plans and satellite images. The width of the floodplain has a fundamental effect on restoration options, and major cut-off meanders indicate sections affected by previous significant river regulations. Based on these, seven river sections in the Szolnok study area were delineated. During the evaluation, the floodplains on the right and left banks were treated separately.

By delineating the sections with similar characteristics, seven sections were defined in the examined river reach (Figure 2). The first three sections are all rural areas outside the city and have a wide active floodplain. Along Sections 1 and 2, there are forest and agricultural areas. Meander cutting took place in the case of Section 2, where a cut-off meander called 'Holt-Zagyva' is located. On the eastern side of Section 3, there are areas with holiday houses. On the western side of Section 4 lie built-up areas, where mainly residential and industrial areas are located. This section typically has a wide (>300 m) active floodplain. Sections 5 and 6 cross the built-up areas of the city and have a medium-width (100–300 m) active floodplain. Along Section 5, mainly residential areas are typical, and along Section 6, there are both residential and mixed areas adjacent to the floodplain. Section 7 is located at the mouth of the Zagyva, which crosses the city centre. The floodplain is narrow here (<100 m width), and mixed land use is typical along the floodplain.

Sections with the same length of 100 m. According to the second method, the examined river reach was divided into equal sections of 100 m in length. The method's purpose is to reveal the differences in the area of the river and floodplain during the evaluation with sections of the same length instead of preliminary delimitation based on characteristics. For

this purpose, the centerline of the river was uniformly divided into sections of 100 m in length. We defined the floodplain sections in connection with river sections of the same length. Due to the meandering nature of the river, the resulting floodplain sections cannot form completely uniform, parallel boundaries. Because of this and due to changes in the width of the floodplain, their territorial extent is not the same. In the Szolnok study area, 75 sections of 100 m were demarcated (Figure 2).

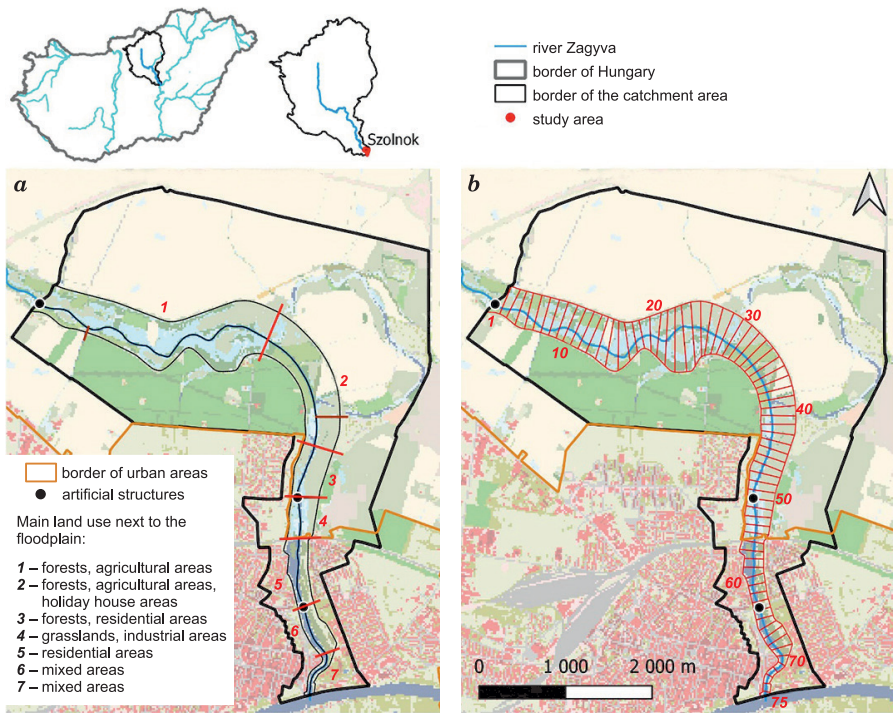

Fig. 2. River sections with similar characteristics, delineated before assessment (*a*) and 100 m long river sections (*b*) in the Szolnok study area

Results

During the research, we determined the restoration potential for the following restoration sub-goals: (1) improving the longitudinal connectivity where artificial structures limit fish migration, (2) improving the ecological and hydromorphological condition of the active channel, (3) achieving a more natural channel planform, (4) improving the naturalness of floodplain vegetation, and (5) improving water quality. Figure 3 shows the results of the two types of segmentation methods for sub-goals 1 and 2; Figure 4 shows the results for sub-goals 3 and 4; and figure 5 shows the results for sub-objective 5.

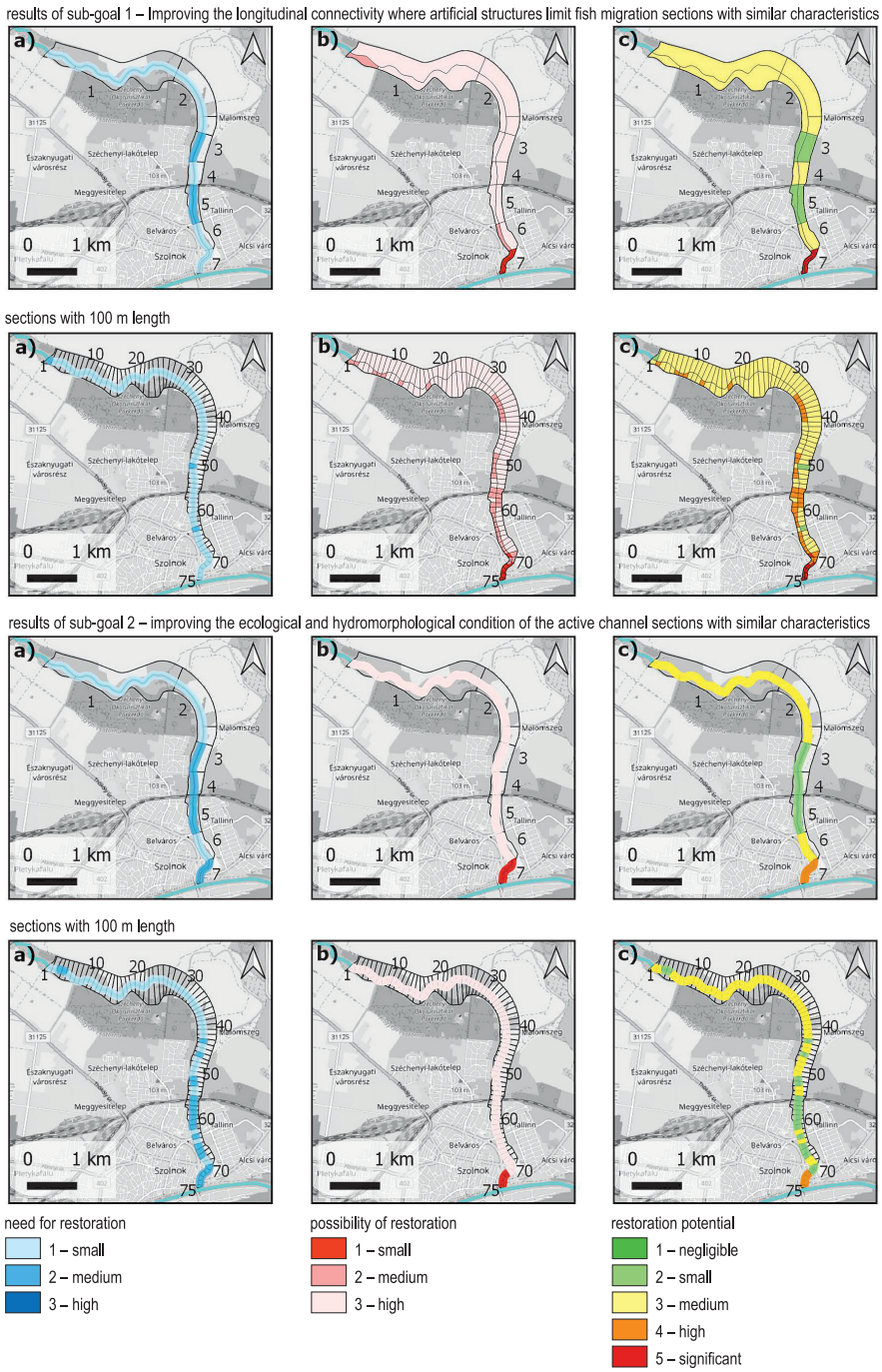

Fig. 3. Evaluation results for sub-goal 1 and 2: *a* – need of restoration; *b* – possibility of restoration; *c* – restoration potential

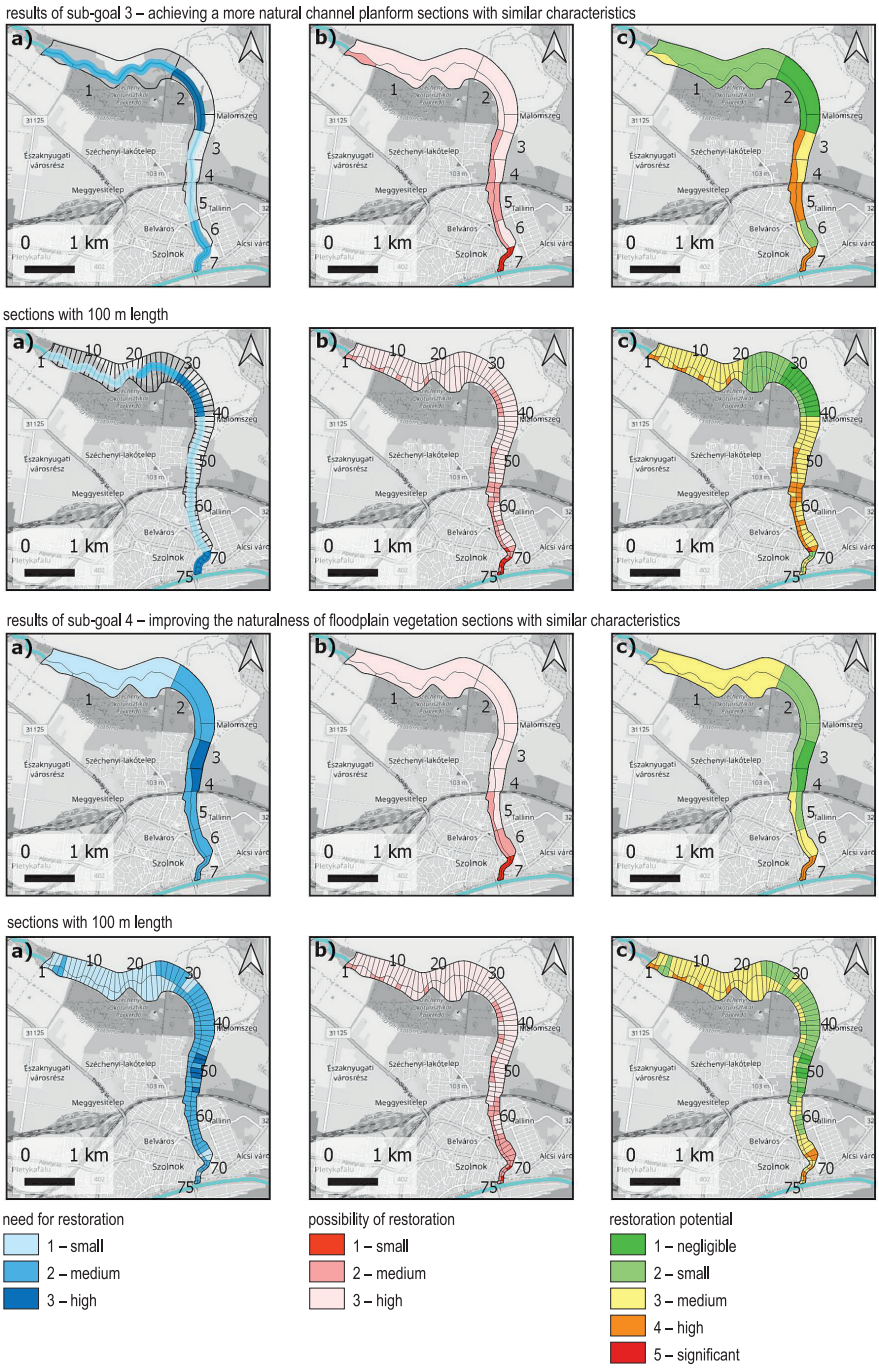

Fig. 4. Evaluation results for sub-goal 3 and 4: *a* – need of restoration; *b* – possibility of restoration; *c* – restoration potentia

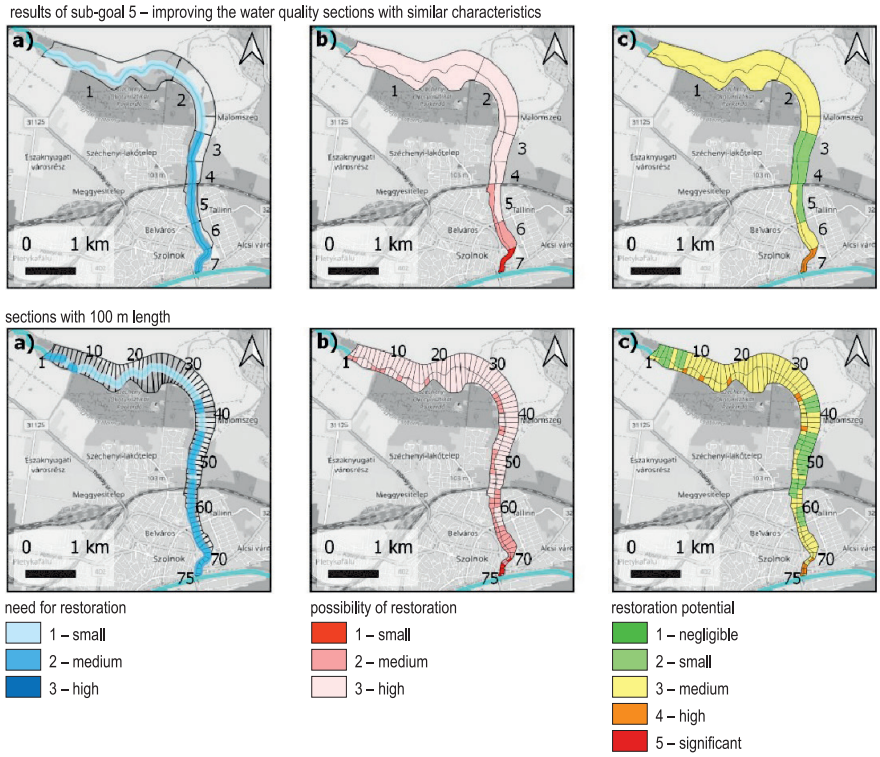

Fig. 5. Evaluation results for sub-goal 5: *a* – need of restoration; *b* – possibility of restoration; *c* – restoration potential

In the case of **sub-goal 1 – improving the longitudinal connectivity where artificial structures limit fish migration** – based on the evaluation results of sections with similar properties, it can be seen that Sections 3 and 5 have good restoration potential. These sections are affected by the presence of artificial structures at their downstream boundaries. Based on the results, achieving the sub-goal is a realistic goal for all artificial structures located on the river reach. The reason for this is that each of the artificial structures present only provides connectivity periodically, and they could all be rebuilt with a more natural solution. In addition, it is possible in the case of artificial structures created to reduce channel slope, e.g. to make the river bed pattern more meandering, as a significant limiting factor does not affect the given floodplain sections. A limiting factor is mainly the width of the floodplain potentially suitable for the movement of the river in section 7, but this is not affected by the presence of an artificial structure.

In the evaluation results of the 100 m sections, the location of the sections affected by the artificial structures (sections 50 and 63) is shown more precisely due to the shortness of the evaluated sections. Based on the results, it can be seen that in the neighbourhood of the sections affected by the artificial structures, there are always sections on at least one side of the river that have a floodplain of adequate width so that they can be included in the restoration.

In the case of **sub-goal 2 – improving the ecological and hydromorphological condition of the active channel** – based on the evaluation results of the sections with similar properties, the urban and adjacent sections 3, 4 and 5 have a high restoration potential. The need to achieve the sub-goal in these sections arises mainly due to the lack of woody vegetation along the bank, the unfavourable ratio of the bed being covered with aquatic vegetation, and the lack of special morphological elements in the riverbed. In the 7th section, it would be necessary to improve the condition of the small water bed (a trapezoidal bed and an unfavourable bank slope are typical), but the condition of the estuary section is strongly influenced by the Tisza floods. The section is characterized by sedimentation. The main possible interventions on the sections with high restoration potential affect the riverbed and the river bank, so they do not involve areas of the floodplain. Such e.g. increasing the variety of bed depth and width; placement of the bank reinforcement "backwards", thereby providing more space for the river; increasing the variety of flow dynamics, and placing elements in the river bed that match the type of river (e.g. dead wood); restoring the near-natural shape of the riverbed and bank or planting woody vegetation along the river.

During the evaluation of the 100 m long sections, sections 51–63, which have high rehabilitation potential based on the results, are similarly visible. In addition, among sections 65–71, it can also be a realistic goal to improve the ecological and hydromorphological condition of the small water bed and bank, as they have a high restoration potential.

In the case of **sub-goal 3 – achieving a more natural channel planform** – based on the evaluation results of the sections with similar properties, based on the results of section 2, which is affected by the presence of the cut-off meander called 'Holt-Zagyva', has significant restoration potential, as this is where the biggest changes took place during the regulation, in addition, the potential for restoration is high thanks to a wide floodplain. Section 1 also has great potential for restoration since the alignment of the bed has been changed here as well (although only within

the area of the floodplain), and it also has a few limiting factors. The position of the river bed was also changed in section 7, where the mouth was once located on the eastern side of the Szolnok castle. However, the possibility of restoration in this section is small, mainly due to the narrow floodplain, so the restoration potential is small.

Based on the evaluation results of the 100 m long sections, the 30–40 sections affected by the 'Holt-Zagyva' cut-off also have significant restoration potential. In the case of the preceding sections, there is a visible difference in the results. Here, sections 21–29, in which the alignment of the bed changed within the area of the floodplain, can be seen more precisely. The possibility of restoration is typically high in these sections as well, so their restoration potential is also high.

In the case of the **sub-goal 4 – improving the naturalness of floodplain vegetation** – based on the results of the sections with similar characteristics, the restoration potential is significant in the left floodplain of sections 3 and 4. The main reasons are that there is a high level of invasive species coverage, there are typically no limiting factors in the area, and there are areas of nature conservation importance, which makes implementing the sub-goal even more important. In addition, the restoration potential for the realization of the sub-goal is also high on the 2nd section and the left floodplain of the 5th section. In the 1st section, the vegetation is semi-natural, which means that the need for restoration and the restoration potential is only moderate. In the urban sections, the restoration potential is low or moderate due to limiting factors (e.g. narrow floodplain, the presence of areas of environmental or heritage protection importance). From the point of view of recreation and aesthetic value, the improvement of vegetation on the floodplain may also be important in these urban sections, but these will be evaluated as a separate restoration sub-goal in the later phase of the research.

This result can also be seen by evaluating the 100 m sections. Sections 47–54 have significant restoration potential due to the reasons described above. The restoration potential is typically high in the 25–63. Sections, at least on one side of the floodplain, since the need for restoration on these sections is moderate (e.g. lack of woody vegetation on the river bank, lateral vegetation zonation is not close to nature, presence of plantation forests), and the possibility of rehabilitation is high (floodplain width is adequate).

From the point of view of **sub-goal 5 – improving the water quality** – the restoration potential is high in sections 3, 4 and 5. In the case of section 5, there is a better opportunity for the application of resto-

ration solutions on the left side of the floodplain. The need for restoration in these sections is moderate due to the water quality characteristics and lack of woody vegetation/wetlands near the river that would have a buffer capacity. The water quality in the entire river reach is unfavourable. The other urban sections are also characterized by the lack of buffer vegetation on the riverbank. However, due to the limiting factors (e.g. narrow floodplain, the presence of areas of environmental or heritage protection importance) in these sections, it may be more difficult to create vegetation of significant impact.

Based on the evaluation results of the 100 m sections, there are also some sections (1–7 and 37–39) in the rural areas that are in great need of restoration, mainly due to the lack of woody vegetation or wetlands capable of buffering on the river bank. In accordance with the evaluation of sections with similar characteristics, on sections 71–75, the possibility of restoration is small (narrow floodplain, the naturalness of the channel form is not suitable). Therefore, the restoration potential is also small.

Discussion

Based on the results of the study area evaluations, the method of sections with similar characteristics can be used well in case of aspects that characterize the occurrence frequency of point-like elements (such as the occurrence of special morphological elements in the riverbed or protected species). By evaluating longer sections, sections with a different frequency of occurrence are more clearly defined. When applying the method, it is particularly important to properly define the section boundaries because if the properties of some aspects do not change at the boundary of the pre-delineated sections, then certain information loss must be expected. Therefore, it is important that the criteria selected for preliminary delimitation enable the appropriate delimitation of the sections, i.e. the most significant properties are taken into account (or it is also possible to delimit the section boundaries after the examination has been carried out, but this may cause difficulties during the examination and evaluation of a large number of criteria).

The difficulty of applying the method of the same 100 m long sections based on the results of the study area evaluations is that the frequency of occurrence of point-like elements can be evaluated less well with it. The more precise location of their occurrence can be clearly detected by evaluating short sections, but the sections with a similar frequency of occurrence can be defined only by analyzing the pattern of the sections. Suppose

we apply many evaluation aspects during the evaluation (and during the preliminary delimitation we would not be able to take them all into account - with the same weight), then by evaluating sections of appropriate length, even in the case of less significant aspects. In that case, local differences can be better distinguished since within longer sections, there is a greater chance that several characteristics are typical for some aspects in the same section (e.g. how the vegetation cover of the riverbed changes), so some local differences can be less distinct.

In order to choose the segmentation method used in evaluating a river reach, it is necessary to define the purpose of the given assessment and at what scale we want to explore the characteristics of the given river section. By evaluating longer sections with similar characteristics, the results may become homogenized if inappropriate section boundaries are chosen; or in the case of using a large number of evaluation criteria, when not all of them can be taken into account for the preliminary delimitation so that some local characteristics may disappear in the evaluation.

The application of pre-delineated sections works well when preparing for homogeneous sections, or the effect of point-like elements can also be properly evaluated on the entire section (e.g. by introducing an index). However, if the evaluated sections are too short, it can be difficult to interpret the results and their applicability in certain cases (e.g. in the case of the frequency of appearance of point-like elements). In addition, section boundaries that do not adapt to local conditions, but are delineated mechanically, do not adapt to changes in the properties of the aspects. Therefore it is important to create indexes during the evaluation in order to more accurately show the appearance rate of each characteristic.

If, among the aspects to be evaluated, it can be well determined in advance which ones influence the main properties of the river, and thus homogeneous sections can be delineated for the majority of the aspects to be evaluated, then clearer results can be obtained by applying this method. Suppose we have a large number of aspects to be evaluated during the evaluation, and due to their differences, it is impossible to create homogeneous sections by prior delimitation. In that case, the evaluation of shorter, same-length sections can also be used, but it is important to choose the appropriate length of the sections.

During the research, field surveys played an important role in most of the evaluated aspects. Pre-delineated sections with similar characteristics can also be used with less precise surveys. In contrast, in the case of evaluating shorter sections of the same length, it is important to assess the exact territorial location of the given properties. Also, based on the guidance standard CEN 14614:2020, the level of detail depends on the purpose

but emphasizes the importance of consistent internal properties for pre-delineated sections. The pre-delineated sections with similar characteristics can therefore be well used for the conceptual delineation of the most important restoration sub-goals and their main target areas in the river reach. Shorter sections with the same length can play a role in establishing a more detailed concept.

In small areas, on shorter river reaches, such as in urban areas, the method of short sections with the same length can also be used, as long as the river reach is easily accessible. On a large scale of investigation or if the river reach cannot be easily accessed, which means that surveys cannot be carried out along the entire length of the river reach, it is better to delimit sections with similar characteristics. In this case, it is possible to select smaller, representative locations where the characteristics of the given aspect can be assessed, and the result can be extrapolated to longer sections.

Conclusions

During the research, we evaluated the restoration potential of an urban river reach of Zagyva in the city of Szolnok by comparing two types of river segmentation methods. We obtained this by evaluating the need and possibility of restoration for the following restoration sub-goals : (1) improving the longitudinal connectivity where artificial structures limit fish migration, (2) improving the ecological and hydromorphological condition of the active channel, (3) achieving a more natural channel planform, (4) improving the naturalness of floodplain vegetation, and (5) improving water quality. One of the segmentation methods was done by delimiting sections with similar characteristics, and the other by evaluating river sections with the same length of 100 m. Based on the results, the main differences in the river reach in the case of the evaluated sub-goals emerged with both segmentation methods. In the case of a section with similar characteristics, it is very important to choose the appropriate section boundaries. In the case of shorter, 100 m long sections, the territorial extent of the effects of point-like elements (for example occurrence of special morphological elements in the riverbed or protected species, which were located at a given point of the area) should be taken into account. Regarding the examined sub-goals, we determined which river sections have a high restoration potential within the Zagyva river reach of Szolnok, thereby defining which river sections and which restoration sub-goals are more important to achieve.

The method is suitable for evaluating and spatially comparing the need and possibilities of restoration before planning the restoration of urban river reaches. The method helps in the territorial delineation of restoration sub-goals, but further, more detailed analyses are necessary to plan precise interventions. The criteria system of the method can be used on other rivers, even in other countries. Still, the assessment should take into account the reference characteristics/target condition of the given river reach, which may differ. As a continuation of the research, the restoration sub-goals included in the assessment can be expanded, such as improving recreational opportunities or improving urban landscape aesthetic value. As a further continuation, it is possible to experiment with a method where the entire study area is divided by raster, thus resulting in a mosaic area unit assessment. After the evaluations in the study areas, country-scale analyzes are planned as a continuation of the research, with the aim of exploring the possibilities of a national analysis of the restoration potential based on the country-scale available databases.

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References

BARDÓCZY L., BARDÓCZYNÉ SZÉKELY E., HORVÁTH J. 2004. *Kis vízfolyások revitalizációs tervezésének kezdeti lépései Kismaros településen, a Morgó patak belterületi szakaszán*. Hidrológiai Közlöny, 84(4): 27–32.

BÁTHORYNÉ NAGY I.R. 2007. *Kisvízfolyások tájrehabilitációjának rendezési elvei és módszere*. (Ph.D. thesis). Budapesti Corvinus Egyetem, Tájépítészet és Döntéstámogató rendszerek Doktori Iskola, Budapest.

BOITSIDIS A.J., GURNELL A.M., SCOTT M., PETTS G.E., ARMITAGE P.D. 2006. *A decision support system for identifying the habitat quality and rehabilitation potential of urban rivers*. Water and Environment Journal, 20: 130–140.

CEN Guidance standard for assessing the hydromorphological features of rivers (CEN 14614:2020).

Danube River Basin Management Plan Update 2021. II. Draft. OVF, 2021, https://www.icpdr.org/main/wfd-fd-plans-published-2021, access: 1.03.2022.

DÉVAI GY., NAGY S., WITTNER I., ARADI CS., CSABAI Z., TÓTH A. 1998. *A vízi és a vizes élőhelyek sajátosságai és tipológiája*. Oktatási segédanyag. KLTE Ökológiai Tanszéke, Hidrobiológiai Részleg, Debrecen.

Directive 2000/60/EC of the European Parliament and of the Council (23 October 2000) establishing a framework for Community action in the field of water policy. 2000.

ERDEI T.K. 2020a. *A folyók helyreállítási potenciáljának fogalma, és a meghatározás módszereinek szakirodalmi áttekintése*. Tájökológiai Lapok, 18(2): 113–125.

ERDEI T.K. 2020b. *Hazai vízfolyáshelyreállítási projektek tájépítészeti szempontú vizsgálata*. In: Dr. Szabó Csaba (szerk.): XXIII. Tavaszi Szél Konferencia, Tanulmánykötet. Tavaszi Szél – Spring Wind 2020. Doktoranduszok Országos Szövetsége, Budapest, pp. 164–176.

ERŐS T., CZEGLÉDI I. 2019. *Barrierek elbontásának priorizálása és halátjárók építésének szükségessége Magyarországon*. Szakmai jelentés. MTA, Ökológiai Kutatóközpont.

European Commission, Directorate-General for Environment, EU Biodiversity Strategy for 2030: bringing nature back into our lives, Publications Office, 2021.

FRANCIS R.A., HOGGART S.P.G., GURNELL A.M., COODE C. 2008. *Meeting the challenges of urban river habitat restoration: developing a methodology for the River Thames through central London*. Area, 40(4): 435–445.

GUIDA-JOHNSON B., ZULETA G.A. 2019. *Environmental degradation and opportunities for riparian rehabilitation in a highly urbanized watershed: the Matanza-Riachueloin Buenos Aires, Argentina*. Wetlands Ecology and Management, 27: 243–256.

GURNELL A., SHUKER L., WHARTON G. 2014. *Urban river survey manual*. Queen Mary University of London.

HULSE D., GREGORY S. 2004. *Integrating resilience into floodplain restoration*. Urban Ecosystems, 7: 295–314.

LÓCZY D. 2011. *A Kapos árterének hidromorfológiai és tájökológiai értékelése*. MTA doktori értekezés, Pécs.

MSZ 12333 szabvány. Vízgazdálkodás. Kisvízfolyások természetes állapotának kialakítása és megőrzése.

MTA Ökológiai Kutatóközpont and Ormos Imre Alapítvány 2017. *Zöldinfrastruktúra-hálózat fejlesztése*. Budapest.

NAGY I.R., NOVÁK T.J. 2004. *A folyóvíz rehabilitáció nemzetközi gyakorlata és a hazai megjelenése*. II. Magyar Földrajzi Konferencia absztraktkötet, Szeged. p. 11.

NAGY I.R., NOVÁK T.J. 2007. *A hazai vízfolyás-helyreállítás fogalomhasználatáról*. Hidrológiai Közlöny 87(1): 40–44.

NORTON D.J., WICKHAM J.D., WADE T.G., KUNERT K., THOMAS J.V., ZEPH P. 2009. *A method for comparative analysis of recovery potential in impaired waters restoration planning*. Environmental Management, 44: 356–368.

NTA-V: V. Nemzeti Természetvédelmi Alapterv – 2021–2026. Tervezet.

National Landscape Strategy 2017–2026 (NLS), Hungary; Department of National Parks and Landscape Protection, Ministry of Agriculture: Budapest, Hungary, 2017, https://kormany.hu/dokumentumtar/national-landscape-strategy-2017-2026, access: 1.03.2022.

PEDERSEN M.L., KRISTENSEN K.K., FRIBERG N. 2014. *Re-meandering of lowland streams: Will disobeying the laws of geomorphology have ecological consequences?* PLoS ONE 9(9): e108558. doi: 10.1371/journal.pone.0108558.

Proposal for a nature restoration law: Proposal for a regulation of the european parliament and of the council on nature restoration. European Commission, Brussels, 22.6.2022 COM(2022) 304 final. 2022/0195 (COD).

STARCZEWSKI K., AFFEK-STARCZEWSKA A., RYMUZA K., BOMBIK A. 2018. *Analysis of tourist attractiveness of communes situated on the Krzna river*. Polish Journal of Natural Sciences, 33(1): 171–182.

VASZÓCSIK V., GÖNCZ A., SCHNELLER K., TÓTH P., PROKAI R. 2014. *Magyarországi területi tervezést támogató térképes indikátor rendszer kialakításának lehetséges lépései a zöld infrastruktúra koncepció megvalósításáért*. Tájökológiai Lapok, 12(2): 411–428.

The European Green Deal. European Commission, Brussels, 11.12.2019. COM(2019) 640 final

VIZITERV ENVIRON KFT. 2019. *Módszertani kézikönyv – hidromorfológiai monitoring*. KEHOP-1.1.0-15-2016-00002 projekt.

ZUO Q., HAO M., ZHANG Z., JIANG L. 2020. *Assessment of the happy river index as an integrated index of river health and human well-being: A case study of the Yellow River, China*. Water, 12(11): 3064.