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RECENT RIVER CHANNEL CHANGE DETECTIONS IN THE SECTION OF THE RIVER TISZA ABOVE TISZAÚJLAK (ВИЛОК)

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Abstract
In the section above Tiszaújlak, despite the presence of embankments, the River Tisza shows active meandering tendency and it splits into branches resulting in side channels, dead channels and backwaters that follow the main channel. In our work we examined the right- and the left-side riverbank sections of the River Tisza, between Tiszaújlak (Вилок) and Tiszasásvár (Тросник), as well as between Tiszaújlak and Tiszapéterfalva (Пийтерфолво), to reveal the extent of bar depositions between 2006 and 2015, and to what extent the intensity and direction of the riverbank formation processes were influenced by the material of the bank and the plant coverage, its rate and characteristics. We tried to reveal which sections were eroded by the river and what security risks they have for the safety of the settlements along the Tisza River. On the right side of the Tisza River riverbank 51, and on the left side 62 main measuring points were recorded by GPS positioning satellite in 2009, 2010 and 2015. Our results were compared to the satellite images of Google Earth taken in 2006, too. According to our experience, in several bends of the examined sections of the river, active bar deposition can be observed; in some cases more than 100 m of bar depositions were detected.

Keywords: Ukraine, Upper-Tisza, anastomosing channel type, lateral erosion, cut bank, plant coverage, riverbank material

1. Introduction

River channels are almost never at rest. In the background of river channel development there are quite difficult natural and often anthropogenic factors (Németh 1954; Church 1992; Tímár 2005). It is very important to investigate rivers which often change their riverbends for several reasons, e.g. to provide the safety of people living there, because of the social exploitation of the riverbank or to preserve their natural characteristics (Nagy et al. 2002; Somlyódy 2002; Szikura – Kolozsvári 2012). Regular field researches are indispensable to reveal the direction of riverbend depositions, its dynamics, or to realize the risk of possible floods.

The River Tisza has always been famous for its fast and capricious river channel change tendency. In Transcarpathia, leaving the Huszt-gate and the area of the Fekete-mountain, the river's descent decreases approximately to 1‰, its speed moderates and it builds an ever widening floodplain (Mike 1991; Афанасьєв 2006). The section between Huszt and Tiszaújlak often splits into branches and from place to place it shows an anastomosing pattern (Коноваленко 2007). The stream's energy expends on lateral erosion in a large measure and it results in the continuous rearrangement of the riverbank. Point bars and cut banks are frequent as well as extended mid-channel inlands and islands (Alföldi – Schweitzer 2003; Коноваленко 2007).

In the water regime of the River Tisza there is a yearly, regularly occurring flood period that is also important in the rearrangement of the channel and riverbank structures caused by the spring snow melting. Besides, floods occur any time of the year because of the abundant and regionally extensive rains (Заставецька et al. 1996; Поп 2003; Somogyi 2003; Molnár 2009; Левчак et al. 2013). In case of floods, sediment transportation increases, from the cut banks more alluvium is being transported away and in other places there is more sedimentation (Németh 1954). Riverbanks have been reinforced to protect the Tisza-valley's settlements, most often with built-in stone blocks, wire nettings, wattles and spur dykes in many places. However, the River Tisza regularly disrupts these protected riverbanks too. The continually reconstructing and transforming feature of the river channel is rather unique and it creates dynamically changing relations that are rich in different forms. Therefore, it is important to have up-to-date and precise information about the river channel formation activity of the rivers.

We aimed to detect the river channel change of the River Tisza in the sections between Tiszaújlak and Tiszasásvár (Тросник), Tiszaújlak and Tiszapéterfalva (Пийтерфолво) with the help of recording coordinates of the examined cut banks between 2006 and 2015. Our further aim was to evaluate the extent of characteristics, material and plant coverage influence on the intensity and direction of the river channel change. Our long-term aim is to create a database that can be used as a reference point in similar researches.

2. Materials and Methods

Our field work was carried out on 24 July 2009, 9 April 2010, and 13 April 2015 on the right bank of the River Tisza (in the section between the road bridge at Tiszaújlak and the natural gas line crossing the River Tisza near Tiszasásvár). The exploration of the left-bank section (between the road bridge at Tiszaújlak and Tiszapéterfalva) was carried out on 2 November 2009, 26 April 2010 and 23 April 2015. On the right side of the riverbank the coordinates of 51, while on the left side the coordinates of 62 main measuring points were recorded with the help of GPS positioning satellite based on UTM projection.

The river's erosional efficiency on its bed and banks greatly depends on the terrain of the area, the stream relations and the peculiarities of the river bed material resistance. Moreover, the characteristics of the riverbank vegetation play an important role in the stabilization of the river bed, too (Lászlóffy 1949; Ackers 1982; Church 1992; Brookes 1994; Wade 1994; Robert 2003; Richard et al. 2005; Lóki – Szabó 2006). When marking out the measuring points we took into consideration the flowing characteristics of the given Tisza-section, we observed the structural peculiarities of the given riverbank section, we surveyed the characteristics of the river bank material, as well as the sediment grain size and plant coverage.

During the analysis, first of all we concentrated on the changes of the concave, high, cut bank sections because these are the main scenes of the lateral erosion. Furthermore, according to our experience, the current territorial extension of the convex, being built-up point bar sections, greatly depends on the river's water level when measured. On the right side of the riverbank we added prefix A, on the left side we added prefix B to the labels of the numbered and examined river bends (Fig. 1 and Table 1). To help the identification of the river bends we measured the UTM geocoordinates of the middle points of the river bend curvatures. Since the given section of the River Tisza is fast-changing and it splits into branches, the retrieval of the river bends is more precise and easier this way than with the determination of the river kilometres.

We used the ArcGIS 10.0 (ESRI) and the Google Earth to represent the examined area. We vectorized the study area's river bend curvatures in 2006 then compared them to the bend shapes of 2009, 2010 and 2015. We corrected the joining imprecisions of the Google Earth satellite images with correctional measuring. We defined the coordinates of some distinct terrain objects that can be identified both in the field and on satellite images easily. We appointed linear correctional values regarding to the X and Y coordinates read from the satellite images with the help of the following formulae

$$\Delta X = \frac{\sum_{i=1}^{n}(X_{GPSi}-X_{GEi})}{n}, \text{ and } \Delta Y = \frac{\sum_{i=1}^{n}(Y_{GPSi}-Y_{GEi})}{n}$$

where ΔX – is the correctional value of X coordiante; XGPSi – is the value of the i nth point's X coordinate read from Google Earth satellite image (the second formula contains analogue notations referring to the Y coordinate's correctional values). So we got the real coordinates of the riverside points with adding the correctional values to the coordinates read from the Google Earth satellite images. The application of the method was confirmed with that the correctional values referring to different parts of the riverside of the River Tisza did not differ considerably.

The extension of the riverbank erosion (the extension of the wash away area) was defined with the help of polygons determined by the measuring points' coordinates. The River Tisza has several branches in the examined section. Considering that the speed of erosion greatly depends on the water discharge, we had to estimate the relative water discharge of the certain river branches. We made an estimation with the assumption that the relative water discharge of the river branch can be calculated as its squared width ratio to the squared sum of the width of all branches (to confirm further research should be done in the given river section that would exceed the frames of the present research); i.e. in the cross-sections of the river branches the width-average depth ratio, as well as the average speed do not diverge considerably. where BRD1 – is the relative water discharge

$$BRD_1 = \frac{W_1^2}{W_1^2+W_2^2},$$

on the scale 0–1, W1 – is the width of the 1st river branch in meters; W2 – is the width of the 2nd river branch in meters. We performed statistical analysis to determine what factors influenced the bank erosion speed. First we revealed the connection between the water discharge flowing through the given section and the bank erosion speed because this part of the River Tisza is anastomosing and it created a braided, branched river bed system. We applied the non-parametric Spearman's correlation according to the lack of normal distribution of the involved variables (relative water discharge, speed of lateral erosion). We analysed the differences of the erosion index of the gritty and the sandy-aleurit riverbank material referring to the research period as well as to the role of the river bank vegetation affecting bank erosion with t-tests.

3. Results

In the examined 20.3 km long section of the River Tisza we could detect considerable dislocations on 16 concave cut banks (Fig. 1). The radius of the examined river banks in 2006 varied between 141 m and 736 m, on average it reached 375 m. On the outward side of the curvatures, in the period between 2006 and 2015 we detected 1.9 and 33.9 m/year dislocations on average, and considering the average of the whole section the results show 9.7 m yearly erosion speed. On the examined river section the lateral erosion washed away 6.68 ha of floodplain area on average every year. Results showed significant coherence between water discharge and the lateral erosion speed, as the result of the Spearman-correlation is $r= 0.542$ ($p<0.05$).

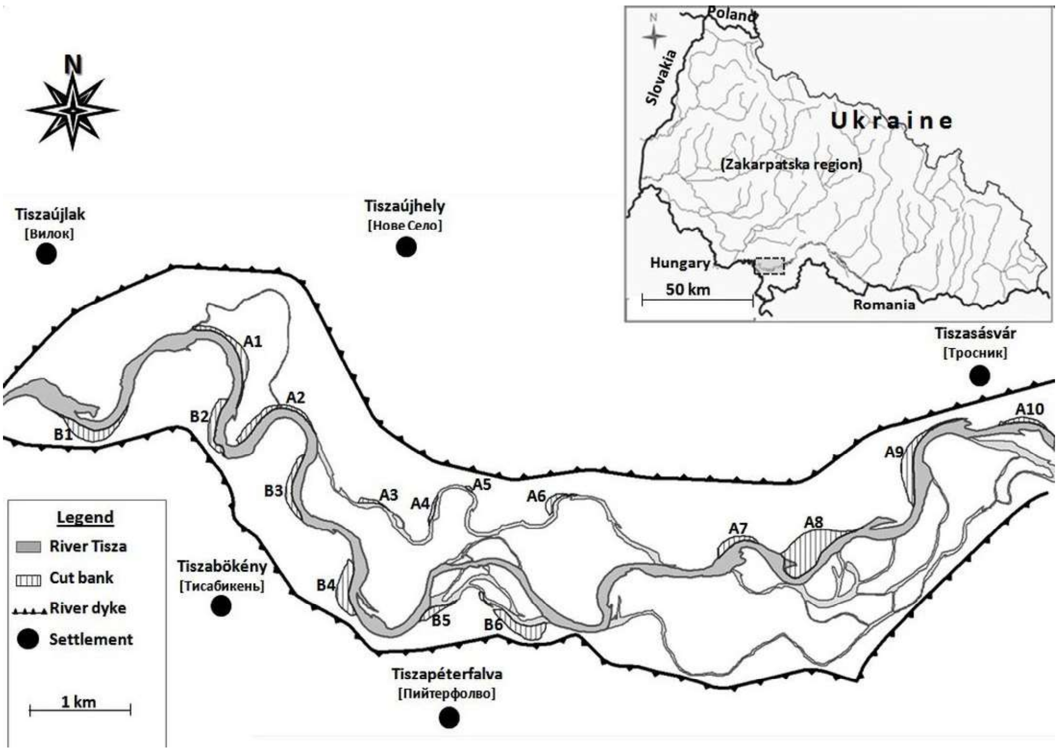

Fig. 1. The examined cut bank sections of the River Tisza between Tiszaújlak and Tiszasásvár

Furthermore, we also revealed the relationship between the radius of the curvature and the speed of the lateral erosion. The Spearman's correlation coefficient, between the radius of the curvatures and the speed of the lateral erosion, was very weak ($r = 0.022$; $p>0.05$). Our prior expectation, according to which in the bends with smaller radius and, thus, with bigger curve the riverbank wash away was more intense, was not confirmed. This can be also explained by the active components eliminated the effect of the bend's curvature.

Throughout our work we were also interested in that how the examined Tisza-section's cut bank grain composition peculiarities influence the degree of bank material wash away. The examined river bends were gathered into two groups based on their material. The sections with crucially gravelly bank material (10 pcs) and the sections with sandy-aleurit (6 pcs) material were separated. The gravelly cut banks yearly average deposition was 6.6 m while the sandy-aleurit was 14.8 m between 2006 and 2015. According to the t-test this difference was significant to 95% probability. Accordingly, the gravelled river bank sections seem to be more resistant to lateral erosion.

Both the type of the riverside macro vegetation and its coverage ratio has a great effect on the river bank's degree of erodibility by the river (Hey 1994; Kiss et al. 2008). The riverbank vegetation increases the stability of the bank material, thus, the riverside becomes more protected compared to bare, vegetation-free riversides (Hickin 1984; Davis – Gregory 1994). Examining the effect of vegetation to the riverside stability we hypothesized that the arborescent vegetation, due to its more developed root system, has the largest potential to slow down the erosion. Out of the 16 riverbends 7 were covered with arborescent vegetation, while another 7 were covered with herbaceous vegetation; in 2 cases different composition of mixed phytocoenosis were found, so they were left out from the given analysis.

According to our preconception, bends covered with arborescent vegetation showed smaller erosion (8.4 m) on the outward curvature while in the case of bends covered with herbaceous vegetation it was bigger (12 m) although the difference was not found significant by the t-test (probably because of the relatively small number of cases).

4. Discussion

The River Tisza plays an important role in the formation of its surrounding area, thus, it became the part of people's life living here with all of its advantageous and devastating characteristics. Besides, on both riversides embankment systems were built, we cannot leave out of consideration the quite significant riverbank rearrangements from place to place. The resistance of the riverbanks may show great differences in the sections. Rivers attack the river banks consisting of loose-bind rock the fastest and with the most intensity (Balogh 1991; Bulla – Mendöl 1999). In case of some protected riverbends we also experienced that protective rip-rap, built-in spurs etc. mean only temporary solution because the River Tisza continuously tears them up.

We detected the greatest riverside erosion in the sections between Tiszasásvár and Tiszabökény. Regarding our study area, the biggest riverside curvature regression (305 m) and the previous channel structure's basic rearrangement was detected at Tiszasásvár in a right-side section, labelled as A8 (Fig. 1). Because of the distance between the embankment and the riverside none of the right-side flood control dyke sections are endangered by the River Tisza. In the left-side section, out of the 6 examined cut banks, in the environment of the B6 section at Tiszabökény the most active rearrangement events were detected (136 m maximal deposition). Here, the River Tisza comes near to the embankment, only a few meters far, therefore, such riverside erosion in this rate in the future may threat the settlement's safety. Although section B1 (105 m max. deposition) showed a bit smaller erosion than the river bend labelled as B6, it can have risk if the erosion goes on like this, because the dyke is quite near (Table 1 and Fig. 2).

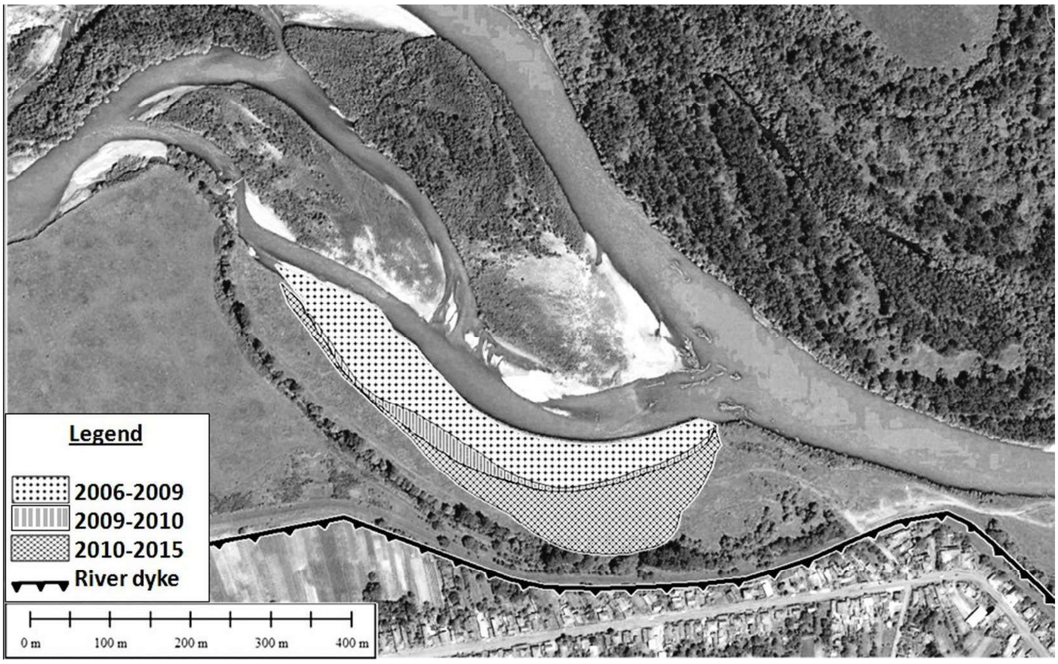

Fig. 2. Side erosion of the riverbend labelled as B6 at Tiszabökény in different time periods between 2006 and 2015

Table 1. The most important characteristics of the examined river bank sections (A – right-side curvature; B – left-side curvature; M – main channel; S – side channel)

Curvature sign	River branch type	Geocoordinates of the middle point of the curvature (UTM)	Radius of curvature (m)	River bank type based on the mechanic composition of the rock material	Main phytocoenosis of the bank	Relative water discharge of the river branch (absolute=1)	Maximum deposition of the bank between 2006 and 2015 (m)	Yearly average deposition of the bank(m/year)	Area of the eroded foreshore between 2006 and 2015 (ha)	Average yearly erosion of the foreshore (ha/year)
A1	M	34U 639221 5329073	458	stratified gravel and aleurit	forest	1.00	91	10.1	5.030	0.559
A2	M	34U 639459 5328641	299	stratified gravel and aleurit	forest	1.00	70	7.8	4.563	0.507
A3	S	34U 640458 5327712	397	stratified gravel and aleurit	grass/pasture ground	0.13	57	6.3	0.941	0.105
A4	S	34U 640982 5327689	320	stratified gravel and aleurit	bushy, grassy grove	0.13	17	1.9	0.432	0.048
A5	S	34U 641346 5327854	141	stratified gravel and aleurit	wood belt, behind pasture ground	0.13	37	4.1	0.262	0.029
A6	S	34U 642144 5327772	316	stratified sand and aleurit	grass/pasture ground	0.13	32	3.6	0.678	0.075
A7	M	34U 643819 5327357	292	stratified gravel and aleurit	forest	0.95	73	8.1	2.503	0.278
A8	M	34U 644648 5327445	736	stratified sand and aleurit	grass/pasture ground	0.99	305	33.9	14.581	1.620
A9	M	34U 645502 5328158	428	stratified sand and aleurit	forest	0.99	117	13.0	6.354	0.706
A10	M	34U 646669 5328525	651	stratified gravel and aleurit	grass/pasture ground	0.87	53	5.9	1.720	0.191
B1	M	34U 637756 5328301	288	stratified sand and aleurit	forest	1.00	105	11.7	5.396	0.600
B2	M	34U 638878 5328236	376	stratified gravel and aleurit	grove	1.00	66	7.7	3.434	0.382
B3	M	34U 639582 5327803	432	gravel	forest	0.84	57	6.3	2.778	0.309
B4	M	34U 640081 5326930	316	stratified sand and aleurit	grass/pasture ground	0.84	106	11.8	4.721	0.525
B5	S	34U 641064 5326682	307	stratified gravel and aleurit	grass/pasture ground	0.32	69	7.7	1.500	0.167
B6	S	34U 641983 5326398	243	stratified sand and aleurit	grass/pasture ground	0.30	136	15.1	5.193	0.577

Our results showed that the sections with sandy-aleurit riverbank material are less protected; they are more liable to the effects of lateral erosion than the gravelly structured sections. Although our researches did not clarify with full certainty the riverbank erosion differences coming from the characteristics of the riverside covered with arborescent vegetation and herbaceous vegetation as well as their incidence rate; thus, it is certain that riverbank vegetation plays an important role in the fixation of the bank material.

5. Conclusions

Regarding the extensive river regulations we have less and less opportunity in the Carpathian Basin to study the riverbank formation processes of such fast changing, mostly naturally preserved rivers with braided branch system. With the help of the river bend change analysis, with respect to the Tisza section between Tiszaújlak and Tiszasásvár between 2006 and 2015, we established a digital database that can be used as a reference point to similar researches and justified that river bank erosion is influenced by the vegetation and there is moderate correlation between water discharge and the speed of lateral erosion. Contrary, there was no statistical relationship between the radius of the curvatures and the speed of the lateral erosion.

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