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INVESTIGATIONS OF CHANNEL DYNAMICS ON THE GREAT HUNGARIAN PLAIN SECTION OF RIVER MAROS

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Abstract

The present paper is concerned with the study of a 20 km segment of river Maros near the Hungarian border. The major goal of this study was to shed light on the geomorphological changes occurring in the section under investigation, created by close-to-natural and semi-anthropogenic processes since the implementation of the river control works with a special attention to the period of the past 50 years, focusing mainly on a single distinguished morphological unit: the point-bar and island system of Apátfalva within the extent of this reach. With the help of the revealed dynamic morphological changes of the channel, an assumption was made to evaluate the stability and state of equilibrium of the composing units of the section at different scales.

Introduction

Though river Maros is the largest tributary of the river Tisza, it has received far less attention from geomorphological research dealing with its channel dynamics and the variety of geomorphological forms present within the riverbed. Nevertheless, the analyzed section of river Maros offers ideal conditions to investigate and evaluate the influences of close-to-natural processes in an area, which was exposed to intensive human activities and anthropogenic influences in the past.

The major goal of the present investigations was to shed light on how this river section, as a complex system, being relatively undisturbed since the 19th century river control, responded to various human influences and intervention. In order to achieve this, several methods and approaches have been utilized for the evaluation, beginning from revealing the dynamic processes present in the island and point-bar channel system of river below Apátfalva, and reaching to the evaluation of stability and equilibrium of this 20-km-long river section.

Preliminaries in the literature

Though the questions of morphological stability, equilibrium and sensitivity within fluvial systems are widely discussed in the literature, only a few studies are concerned with the analysis of the relationship between the various natural forms of the riverbed and changes in its state of equilibrium.

The first statements related to the state of equilibrium in these systems are found in the works of LEOPOLD and WOLMAN (1957). According to their interpretation, the state of equilibrium within the fluvial systems is equal to a long-term stable phase or, in other words, during this phase the nature of the course remains unaltered for a longer time, considering meandering as the ideal morphological type.

However, they also showed that the braided or anastomising morphologies, which had been considered to represent a disturbed state earlier, represent a state of equilibrium after all as well, it also represents a stable phase maintainable for a longer period of time, only assuming a different energy level; i. e. different hydrological and load characteristics.

According to GREGORY and WALLLING (1973) and later HOWARD (1982), the state of equilibrium can be represented by a "function of the inputs and outputs of a geomorphological system with relatively unchanged values for a certain period of time". In other words, we can speak about disturbance when the output variables, in this case the bed forms, undergo significant change. Naturally we must account for some buffering effect in the system as well, only responding with a change of the forms after an action of certain strength. Furthermore, the time as a separate factor should also be taken into account during the course of equilibrium evaluation; i.e. the time needed to balance the influences affecting the system (RICHARDS, 1982).

The states of equilibrium are not to be schematized allowing for different responses from the side of the system following the loss of stability (WERRITTY – LEYS, 2001). Consequently, two major types are known for the state of equilibrium in fluvial systems in the literature: (1) there is a lower energy level, a so-called robust state when the system is capable to adapt to the influences affecting it via only minor modifications, preserving its original morphology; (2) and there is a so-called sensitive state, characterized by increased energy levels and a significant response to external influences represented by permanent or long-lasting alteration of the morphology, like that of the channel pattern.

The introduction of the notion of geomorphological threshold into the literature is linked to SCHUMM (1973). According to him, the majority of morphological changes are related to sudden events, when the energies affecting the system exceed a certain value; the so-called threshold value, above which the system becomes unstable. Consequently, the sensitivity of a geomorphological system equals to its resistive competency providing for the preservation and maintenance of its balance (BRUNDSEN, 2001).

Changes in intrinsic or extrinsic parameters of the system may lead to surpass of the threshold (LEWIN – BREWER, 2001). After this, the system reaches a newer state of equilibrium providing lower or higher stability compared to the previous state depending on the circumstances. The time needed for the emergence of this new state of equilibrium equals to the response time of the system.

The high complexity of the fluvial systems; i.e. a river is made up of several reaches with several bends within the reaches and different bed forms within the individual bends, further complicates the problematics of threshold value determination in fluvial environments. The stability of the different composing elements is both spatially and temporally variant, thus this factor must be accounted for when setting the values of threshold (KERN, 1998; CARSON, 1984a,b). In certain cases it is only the subsystems that are displaced from their state of equilibrium. However, in other cases when more subsystems collectively become unstable, e.g. as a result of a catastrophic event, it may result in the unstability of a structure at a higher level of hierarchy as well.

Thet pilot area

The river Maros is the largest tributary stream of the river Tisza with a length of 749 km, and an estimated area of discharge of 30.000 km^2 comprising about 20% of the total discharge area of the river Tisza. It's a rather flashy stream with a discharge of 1600 m^3/s at high water, that of 161 m^3/s at mean water and that of only 21 m^3/s at low water; i.e. there is an almost 80-fold difference between the rate of high and low waters. The slope of the river in the area of the reach under investigation was 14 cm/km before the implementation of the river controlling works increasing to 28 cm/km afterwards. The rate of sediment transport is quite significant. Consequently, in case of the river Maros one must account for intensive channel forming processes, both as a result of the suddenly changing discharges, as well as the amount of sediment transported, and the stream power.

Our investigations concentrated on the near-border section of the river Maros between Apátfalva and Nagylak (**Fig.1.**). This unit, located between the fluvial kms of 31 and 50 is made up of four major bends, with an individual length of 2-3 kms, in the upper part (40.5-50 fluvial kms). In the lower part (between 40-31 fkm), the river occupies an almost straight and highly widened channel with a width of 200-300 m and forms near-bank and mid-channel point bars and islands.

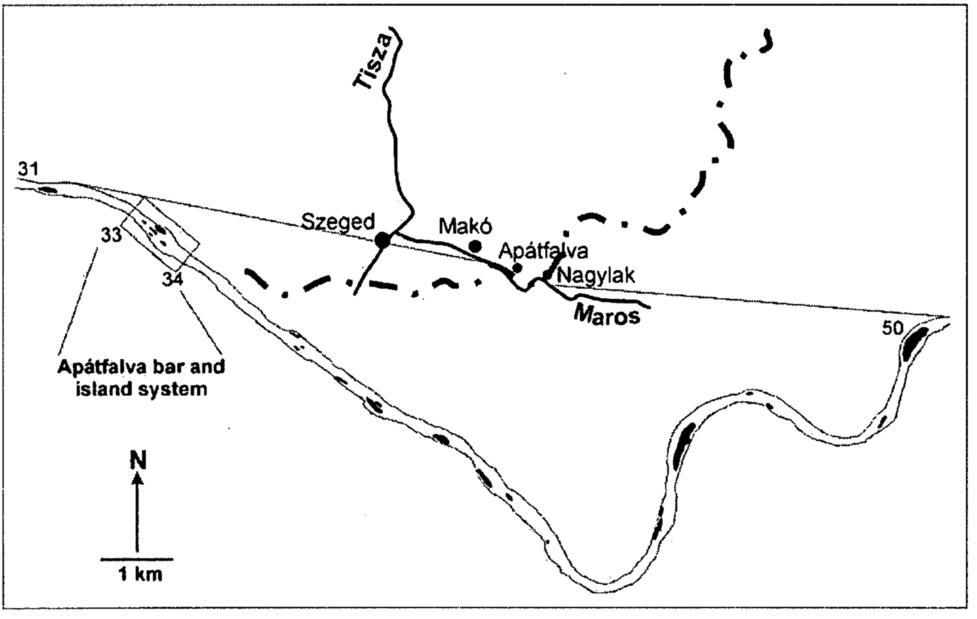

Figure 1. The location of the studied area

The river is dominantly aggrading in the section under investigation with a meandering and braided morphology. As the reach of the river between Nagylak and Makó is practically abandoned since the implementation of the Trianon treaty, the semi-anthropogenic processes deriving from the preceding river controlling works are highly accentuated.

Within the above mentioned 20 km section, a single node located downstream of Apátfalva (33-34 fkm) was analyzed in details (**Fig.1.**). The chosen morphological unit is an 800 m-long system of islands and point-bars, covering an area of 9 ha at low water. Data collected here and the deductions made from the analysis of these give the basis of the majority of statements related to the conditions of the wider section.

Materials and methods

The geoinformatical analysis was carried out in two stages at different scales. As a first step, spatial alterations occurring during the past 50 years were determined with the help of three aerial photographs (1950, 1964, 1991), a topographic map of 1:25.000 (1981) and GPS data collection (2001). Spatial data deriving from five different time periods enabled a comprehensive analysis of the area and the determination of the directions and tendencies of the major changes.

First the geocorrection of the aerial photos and the maps was carried out transforming them into the EOV map system with the help of the software ERDAS Imagine 8.4. Then the surficial forms (islands and the banks) were digitized as vectors with the help of Arcview GIS 3.2 software and the raster and vector data were overlapped. The gained composite was utilized for measuring the changes in the position of the bank and the migration of the islands and bars. The influence of the different water levels was negligible on the pictural sizes of the islands, despite the fact that the photos were taken at low-and medium water, as the sides of the islands are generally highly steep, thus the deducted movements are much greater than the possible size differences resulting from the nature of the photography.

The second stage of the analysis involved the discovery of greater interrelations in this 20 km reach. Maps and aerial photographs, or better to say a sequence of these, deriving from 6 different times were used as a starting point in the work. The oldest map was a 1914 reworked edition of an earlier map of 1: 75.000 prepared during the 3rd military survey. This has been adjusted to two mosaicized topographic map series of 1:10.000 (1969, 1982). The aerial photos were taken in 1951, 1981 and 1991, respectively. GPS data collected in 2002 provided information on the most recent changes.

Results

The island and bar system of Apátfalva

The island and bar system of Apátfalva occupies a node[1] within the riverbed of the Maros. This form can be linked to the channel patterns of the braided rivers (LEOPOLD – WOLMAN, 1957). The highly varying bar forms, as well as the five largest islands, make this node the most developed and most complex out of the ones observable within the section analyzed.

The location of the islands and the course of the banks could have been analyzed at five different times within this island system.

[1] Node is a widening section of rivers with more or less straight channels, where usually bars and islands are formed within the active channel resulting in the development of a braided pattern (Leopold et al. 1957).

According to the comparison of the results gained, the most intensive changes occurred before the 1960s in the area, resulting in highly significant displacement of the islands as well as the the banks.

From the 1960s onwards, only minor changes could have been inferred, however, they still indicate significant annual displacement at the scale of several meters (**Table 1.**). The following intensive island formation processes could have been reconstructed for the pilot area: At the first time of the analysis, in 1950, the Maros formed a slight left bend with the largest width of the riverbed located in this section (275 m) and being significantly narrower upstream and downstream (140-148 m). In order to counterbalance this increased width of the riverbed, a dozen of minor islands were formed by the river resulting in a decrease of size of the active channel (to a degree of 80% of the original width but a still impressive 220 m).

Table 1. The rate of erosion and accumulation in terms of the Apátfalva node islands

	Island 1.	Island 2.	Island 3.	Island 4.	Island 5.	days above 200 cm	days above 350 cm
	The rate of retreat at the upstream end of islands (m/y)						
1950-64	1	*	0,4	*	7,8	457	73
1964-81	2,1	2,7	1,2	3,7	3,5	978	156
1981-91	0,3	0,3	1,1	1,6	0,6	235	8
1991-01	0	0	0	6,5	1	161	43
	The rate of growth at the downstream end of islands (m/y)						
1950-64	*	*	2,2	*	2,2		
1964-81	1,9	1,5	0,5	2,2	0,7		
1981-91	5,3	1,7	2,1	1,6	0,9		
1991-01	0	0,5	1,8	11,3	4,7		

* the island did nort exist in 1953

This stage represents an aging node, where the islands are so much crushed up together close to the left banks (**Fig. 2/A-B**), which allows for the pass of a very low velocity course only in between. This foreshadowed the future plugging of the anabranches just as it had happened in case of the right bank areas among similar conditions. In case of this latter part, a wide sandy area, attached much more to the floodplain than the active riverbed, emerged in the 1950s where waters could pass over during the event of high waters only.

On the next aerial photograph (1964) a rejuvenated node (**Fig. 2/A-B**) can be seen with increased channel widths, the largest one being around 300 m. The hydraulic conditions have also changed within the active channel allowing for the formation of mid-channel bars and new island cores, islands within the channel. This was the time when the five islands observable even today, though in a somewhat altered form, were born. If we compare the fluvial morphological changes of this time period with the length of the floods between 1950-1964, we can clearly see that the number of days with water levels higher than the mean 200 cm (on the basis of the fluviometer at Makó, where the LWL: -107cm and the HWL: 625 cm) was relatively low

(9% of the total period) with even fewer floods resulting in an overbank flow (1.3%). Consequently, the mean water conditions play a crucial role in the formation of islands, starting off from point-bars, partly as a result of the prevailing accumulation processes and the stabilizing effect of the vegetation settling onto the surfaces of the bars.

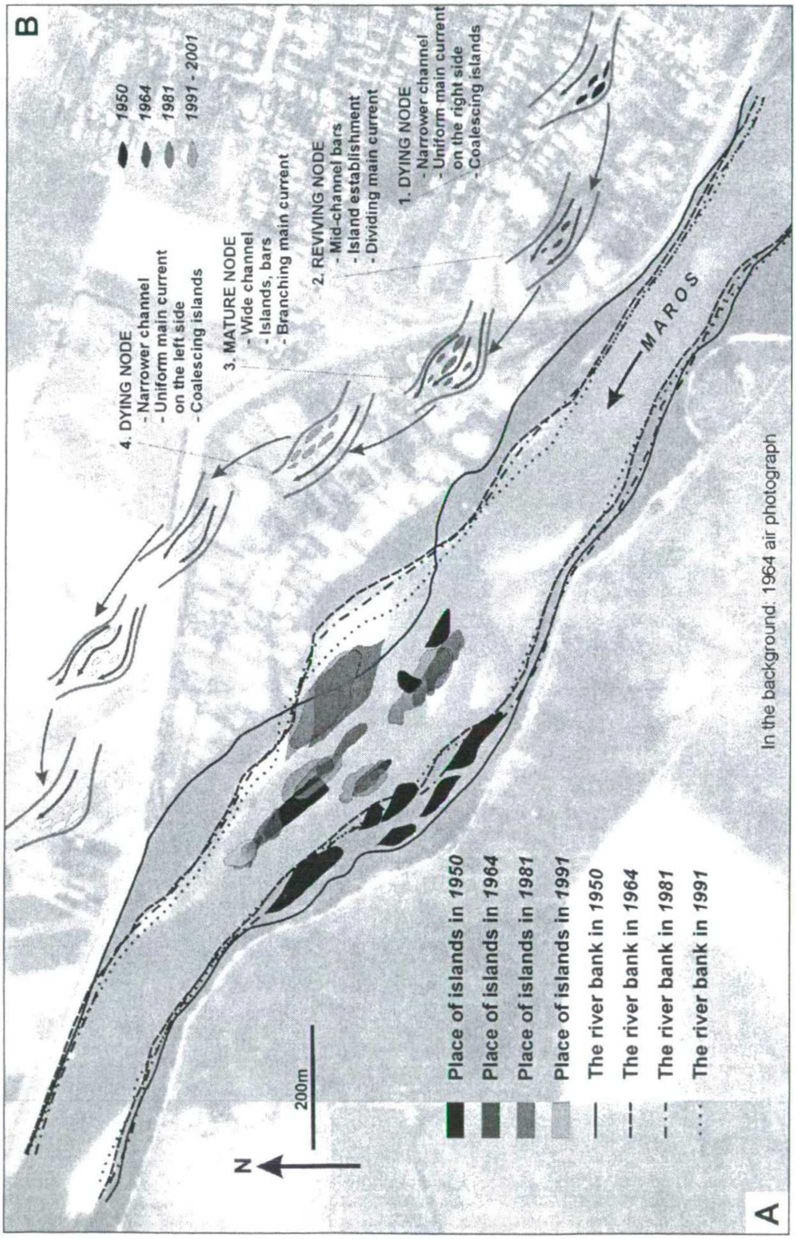

Figure 2. (A) The process of island building in the Apátfalva node
(B) The life cycle of a node, based on the example of the Apátfalva node

Only minor changes could have been observed up till 1981 showing that the node reached a mature state, consuming most of the river's energy. There is hardly any change in the course and location of the banks with an initiating downstream migration of the former islands (**Fig. 2/A**). During the 17 years between 1964 and 1981, the upper end of the islands recessed 50-60 m with a downstream growth of only 30-40 m. This corresponds to an average annual change of 3-3.5 and 1.8-2.3 m, respectively.

All these changes were by no means gradual, but rather can be linked to one or two significant events, thus we can speak about highly considerable individual displacements. This time period must have brought about the destruction of the islands with the prevalence of frequent high waters (15% of the total period) and floods (2.5 % of the total period). This was also the time when the highest record-breaking water levels were recorded on the Maros in 1970 and 1975, repectively (with values of 624 and 625 cm at Makó).

While there was no significant alteration in the course of the left banks, by 1991 the channel has become 50 m narrower on the right side compared to the previous conditions. The area of the islands also increased considerably (**Fig. 2/A**), as their lower ends underwent a 20-50 m growth compared to the 5-10 m destruction of their upper ends. The islands occupied 21% of the largest width of the node. However, the width of the active channel on the lower part was only 59% of the original. Besides the downstream movement and growth, a lot more sediment accumulated on the downstream right side of the islands during this time as a result of the left-hand displacement of the channel line. The above mentioned pace of island building during this time can be explained by the lower frequency of mean and high waters compared to the previous periods (this was also the time when the lowest water levels in 50 years were recorded).

The results of GPS measurements carried out in the pilot area indicate the continuation of the above mentioned tendencies and processes, the underlying result of which might be the further increase in the frequency of mean and high waters (only 5.5%). The extension of the No. I-II-III. islands hardly changed. On the other hand, the No. IV. and V. islands have become largely elongated while performing a retreat. The islands become gradually longer and narrower downsteam, and most likely will be completely consumed in the end. The underlying factor of this might be that as the islands are restricted to a more and more confined area at the lower ending of the node (occupying only 41% of the total cross section in 1991), this results in an increase of the velocity, and a destruction of not only their upper ends but the sides as well.

As it can be clearly seen from the above-mentioned statements, highly dynamic morphological changes occurred in out pilot area within a relatively short period of time (**Fig. 2/A**). The location of the islands gradually changed during the 50 years of time analyzed, with such changes as clustering, migration towards the left and the right banks as well while moving downstream parallely. During one or two extreme periods, their upstream edges might have eroded as much as 6 m annually with a parallel even 11 m annual increase of their downstream ones.

Meanwhile, during these 50 years, the node once earlier had reached a state, when the majority of the islands melted into the banks, resulting in a temporary cessation of the node within the channel.

However, two remaining island cores in the middle of the channel enabled the redivision of the channel line and the rejuvenation, and widening of the braided unit enabling the formation of newer islands as well. As there was no human intervention in the area during this time; i.e. no control works influenced the processes in the channel, the direction and tendency of morphological change seems to follow a cyclic trend within the present node with the easily identifiable recurrent stages.

As such, three major node developmental stages can be distinguished within a single cycle: reviving, mature and aging (**Fig. 2/B**). The continuous recurrence of these represent a dynamic state of equilibrium, making the unit seemingly uniform from the outside; changes in the picture from the outside do not even reach the rate of intrinsic changes. However, one can not exclude the possibility on the basis of the left or right disposition of the main channel line, that this disposition within an aging node can lead to the ultimate distruction of the island system within the channel, which on the other hand would respresent a change in the morphological state of equilibrium.

The reach between Apátfalva and Nagylak

Islands

The next stage of our analysis involved the investigation of the processes of the whole reach embedding the node analyzed earlier at length, thus the scale of our investigations has changed significantly granting a different character and degree of the observed phenomena as well (**Fig. 3.**).

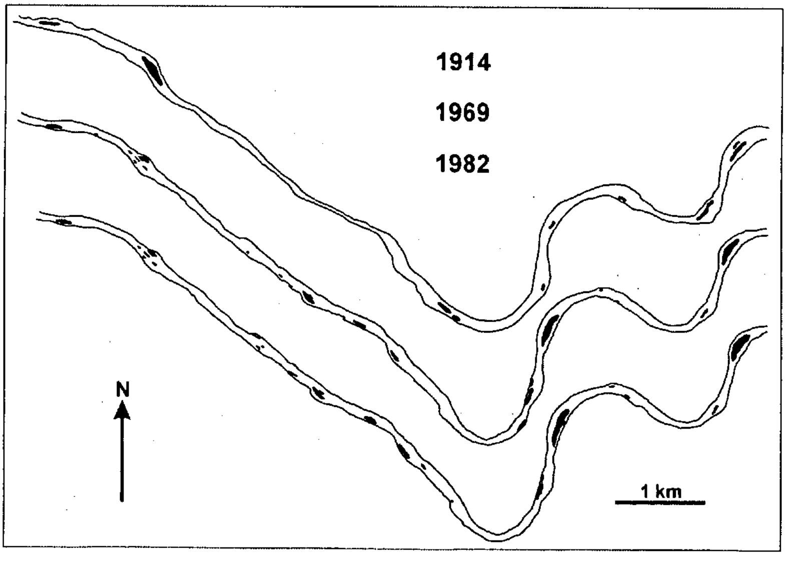

Figure 3. The islands of the studied reach in 1914, 1969 and 1982

Changes between 1914 and 2002 for the reach between Apátfalva and Nagylak were quatified at this stage complemented with the results of observations made in the bar and island system of Apátfalva.

In this 20 km section, both the number and the area of the islands underwent a gradual increase: with a rate of 19% between 1914 and 1969, and a further 16% by 2002 (**Table 2.**). Similar conclusions could have been made for the island system of Apátfalva on the basis of the analysis of aerial photos (1953, 1964 és 1991). The underlying factors might be on one hand the sediment stabilization effect of the vegetation, as well as the alterations in the certain hydraulic parameters of the river (discharge, quality and quatitiy of transported load, cross section of the riverbed), resulting in periodic relatively large-scale sediment accumulations. When the percentages of the total areas of the islands are taken collectively in comparison to the open-water areas, this provides further evidences of intensive island formation in the section under investigation (**Table 2.**) This also implies a gradual aggradation of the channel within this reach of the Maros.

Table 2. The growth of the number and area of islands located in the Apátfalva node

date	number of islands	total area of islands	growth of total area compared to the previous date	total area compared to the open water surface of the channel
On the studied 20 km reach				
1914	10	185 000 m²	-	5,65 %
1969	22	220 000 m²	19 %	6,73%
1982	27	255 000 m²	16 %	7,74%
In the Apátfalva node				
1953	5	15 900 m²	-	10,07 %
1964	5	17 500 m²	10 %	11,74 %
1991	5	20 200 m²	15 %	15,85%

Nodes

Twelve significant nodes could have been identified in the 20 km section analyzed considering the 2002 conditions (**Fig. 4**).

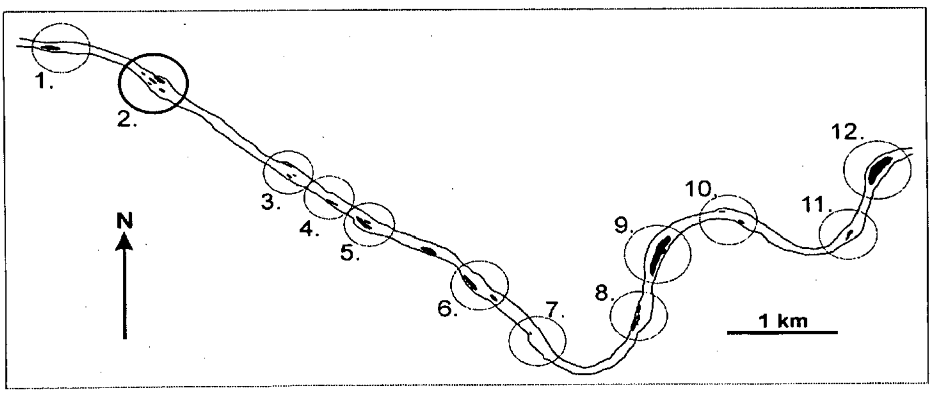

Figure 4. The nodes identified on the studied reach

Their lengths are between 300-800 m with widths varying between 230-300 m. The most mature and complex of these was the No. II node located downstream of Apátfalva. The evaluation of the prevailing processes in this node allowed for the classification of the other nodes of the reach as well on the basis of their developmental stages within the certain time periods; i.e. we can speak about nodes in their reviving, mature and aging phases. The certain characteristics of the different nodes for the periods examined are given in **Table 3**. From the lowest part of the pilot area, the No. III, IV., and V. nodes must by all means be mentioned, as these are not depicted on the 1914 military survey maps (**Fig.4.**).

The channel is relatively narrow with a width of 70-100 m, representing a stage developed right after the river control works. On the 1969 map well-developed nodes can be identified in this section with mature and aging nodes present on the 2002 maps. The most dynamic changes could have been observed in the No. III. node. Here, while we can find only an island core on the 1969 photo, 30 years later three mature islands could be spotted. Besides, the latest GPS measurements indicate surprisingly great displacements as well (85 m accumulational growth in case of the central islands). On the whole, the lower, straight part of the reach under investigation, articulated with pseudo-bends, gave birth to several new nodes experiencing dynamic changes afterwards, which implies a certain degree of instability within the system.

The second major group of nodes (VII. – XII.) is linked to the meanders of Nagylak (**Fig.4.**). They tend to be generally more stable and static; i.e. the island systems embedded have hardly changed at all lately, and all of them are depicted on the 1914 map as well. This sort of stability is also relative, as in the majority of the cases there is a significant growth in the area of the islands and a disposition of the islands from one side to the other at certain nodes (VIII, XI) (**Fig.3.**). The nodes located in the bends tended to move downstream as well with the pass of time at a collective rate of approximately 250-300 m.

The whole reach

As the two groups of nodes are linked to well-distinguishable sections of the channel, the general analysis of these two sections was also desirable in order to see how much change happened in the morphological pattern of the river Maros during the analyzed period of 90 years. A slight downstream movement of the meanders is observable in the upper part of the reach. The meandering pattern can be considered as a stable and permanent one for the period analyzed. On the other hand, the presence of well-developed nodes and islands in the bends refer to higher energy conditions in this case as well, as it was shown in other fluvial systems earlier (LEOPOLD – WOLMAN, 1957; RICHARDS, 1982; GREGORY – WALLING, 1973; WEST, 1978).

However, significant changes happened in the morphological type of the lower part of the reach. Here, the average width of the channel experienced a significant increase, in case of the newly born nodes with a value of even 100 m while on other parts with a value of 50-60 m from 1914, and the former straight channel pattern was replaced by a braided one.

Table 3. States of development in terms of the identified nodes

Section	Node		1914	1953	1969	1982	1991	2002
lower, straightened section	1.	islands	1 large rb*	1 large lb*	1 large, lb	getting closer to lb.	merging into lb.	merging into lb.
		state	*mature*	*mature*	*mature*	*dying*	*dying*	*dying*
	2.	islands	1 large	3 large, 4 small, lb.	5 mature islands	5 islands moving right	5 islands	reviving branch
		state	*mature*	*dying*	*mature*	*dying*	*mature*	*mature*
	3.	islands	no island	1 huge bar	1 island core lb.	3 islands	3 islands	significant migration
		state	-	*reviving*	*reviving*	*mature*	*mature*	*mature*
	4.	islands	no island	1 small lb.	1 small, 1 large merging into lb.	1 growing	1 merging into lb.	1 merging into lb.
		state	-	*reviving*	*reviving*	*mature*	*dying*	*dying*
	5.	islands	no island	2 large, 2 small, lb.	1 lage, 1 small, toward lb.	1 large, 1 small, toward lb.	2 coalescing islands	1 island, merging into lb.
		state	-	*reviving*	*mature*	*mature*	*mature*	*dying*
	6.	islands	no island	2 islands lb.	1 island lb.	1 large island merging into lb., 1 small	1 large island merging into lb., 1 small	slight change
		state	*widened channel*	*mature*	*dying*	*reviving*	*reviving*	*reviving*
upper, meandering section	7.	islands	2 islands	2 small lb.	no island	1 small mid-channel	1 small mid-channel	the island elongated
		state	*mature*	*reviving*	*widened channel*	*reviving*	*reviving*	*reviving*
	8.	islands	1 island mid-channel	no island	1 large, 3 small, rb.	3 islands merging into rb.	1 large, 1 small merging into rb.	no island
		state	*reviving - mature*	*reviving*	*dying*	*dying*	*dying*	*widened channel*
	9.	islands	1 small mid-channel	1 growing island	1 large lb.	1 large, 1 small blocking branch	1 large merging into lb.	slight change
		state	*reviving - mature*	*mature*	*dying*	*dying*	*dying*	*dying*
	10.	islands	1 small lb.	1 island lb., huge bars	2 island cores	2 growing islands	1 active rb., 1 merging into lb.	1 island rb.
		state	*mature*	*reviving*	*reviving*	*reviving*	*mature*	*mature*
	11.	islands	1 large lb.	2 small lb.	1 large mid channel	1 large moving left	1 island lb.	1 island lb.
		state	*dying*	*reviving*	*mature*	*mature*	*mature*	*mature*
	12.	islands	2 islands mid-channel	1 growing island mid channel	1 large mid-channel	1 large mid-channel	1 large mid-channel	1 large moving right
		state	*mature*	*mature*	*mature*	*mature*	*mature*	-

* rb.: right bank, lb.: left bank

This gradual widening is quite evident for the period between 1969 and 2002, thus might be accounted for in the future as well. The widening and the development of nodes must be the result of not the alterations of the hydrological conditions of the river, but can be explained as a return from the pattern forced onto this fluvial system by the river control works into the original morphological type. Thus, it might be a sort of forerunner of the development of new nodes, and the rejuvenation of the former meanders in case of the bar and island system of Apátfalva.

Changes confined to the lower part of the section analyzed refer to an unstable phase of an artificially created system, though the rate of change here is not as rapid as the processes prevailing in the individual subunits of the system.

Evaluation of the stability of the present channel

According to the above mentioned results, the nodes located in the lower part of the reach analyzed emerged after the river control works as an unwanted morphological side-effect of these artificial interventions. In contrast to the general expectations in connection with the prevailing relationship between the process and forms, changes of the morphological forms resulted in a modification of sediment accumulation and the processes responsible for the shaping of the channel in our case in this reach not vice versa. The changes in the location of the channel line, its divisions, displacements and periodical unifications tends to indicate a border-line case between the braided and the meandering pattern for the lower parts of the system. However, one can expect a further development and migration of the meanders in the upper parts of the system. The geomorphological forms experience highly considerable alterations in certain parts of the reach analyzed, which do not result in a disruption of the equilibrium but imply a certain degree of instability within the system.

The state of equilibrium is characterized by a periodic consistence of the characteristics of the forms. Thus, the island and bar system of Apátfalva has been in a state of equilibrium lately as no significant changes resulting in the disintegration of the unity of the system occurred here during the 52 years period of the analysis. However, the emergence of the bar system surmise the disintegration of balance, created by the river control works in the 19th century, when the formerly meandering channel was straightened, and this morphological change favored the development of a braided pattern. This is also true for the whole of the lower parts, where the nodes proved to be highly active in creating a braided pattern in this area of the reach analyzed. Thus the forms of this system, which emerged right after the river control works, refer to a disintegration of the state of equilibrium. At this scale however, changes in the whole reach were not as significant as the ones observed within the individual nodes. In case of the upper parts, when the course of the channel and the changes in the pattern are considered alone, we may discover the presence of a state of equilibrium during the period analyzed.

Thus, most likely this upper part was capable to buffer the effects of a much smaller intervention, thus preserving the original energy level with a robust response. Conversely, the lower part was unable to outrule the effects of much more drastic transformations getting into a higher energy level with a sensitive response.

Consequently, one can expect another sensitive response to newer minor changes as well in this case in the future. The major displacements of the islands can be linked to catastrophic events; i.e. floods, in case of the islands system of Apátfalva and the analogous nodes as well. Such events may result in the obstruction of certain anabranches within the nodes or the expansion or widening of the nodes.

As even the minor floods can result in considerable changes in the nodes analyzed, e.g the displacement of the channel line, the more extreme floods may result in the total loss of the state of equilibrium of the generalized system. This can initiate further changes in the sections downstream the nodes.

Summary

According to the results of geoinformatical analysis, considerable dynamic morphological alterations took place in the island system of Apátfalva in case of the islands located in the nodes within a relatively short period of time, with an annual displacement rate of even 5-10 m. Furthermore, the direction and the mode of morphological change in the above mentioned node, analyzed in details, seem to have been following a cyclic pattern lately (reviving, mature and aging stage), thus reflecting the presence of a dynamic balance, where the intrinsic processes do not exceed the threshold value, which would otherwise result in the expansion of the node or the initiation of significant channel transformations.

The gradual development of newer islands for the whole of the section analyzed may refer to the aggradation of the channel as well. The identified nodes can be classified into two major groups within the 20 km section analyzed: dynamically transforming ones characteristic of the lower parts and more permanent, static ones characteristic for the upper parts.

According to the results of the analysis of the subunits (islands, nodes), the reach under investigation can be divided into two major units different in their characteristics, with a stable meandering upper part, and a straight lower part, where changes refer to unstable conditions. The nodes analyzed became dominant after the river control works, in some cases their emergence is directly linked to the effects of these.

On the whole within this dual reach a robust state of equilibrium emerged in the upper part and a sensitive state of equilibrium developed in the lower part within the channel. Thus several minor or one extreme event may lead to the loss of equilibrium in case of the lower parts in the future.

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