The major factors influencing the meandering river pattern in the 20th century (case studies from Sajó River and Sacramento River)

Les facteurs principaux influençant les rivières à méanders au 20e siècle (études de cas de Sajó rivière et rivière Sacramento)

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RÉSUMÉ

L'étude présente l'impact des différents facteurs sur le caractère fluvial des tronçons de la rivière Sajó en Hongrie et de la rivière Sacramento aux États-Unis au cours des périodes plus longues (entre 1952-2011 et 1942-1999). Les facteurs étudiés sont le débit et le régime des précipitations, les interventions anthropiques et l'utilisation des sols. Les indices SPI et RAI ont également été calculés pour les précipitations sur la rivière Sajó. Les caractéristiques étudiées dans les tronçons fluviaux sont les paramètres de l'évolution de la largeur du chenal actif, de la sinuosité, du régime des crues, de l'évolution de l'occupation des sols et du régime d'érosion et d'accumulation. Un changement majeur observé a été le développement de la végétation riveraine le long du cours d'eau, principalement aux dépens des prairies permanentes dans la zone riveraine de Sajó. Le test Mann-Whitney U a confirmé que la végétation riveraine est significativement moins érodée que les terres arables et les prairies permanentes. Le régime et la durée similaire de débits de crue a été atteinte au cours de la période 2005-2011, cependant, le taux d'érosion était considérablement plus faible. La raison semble être l'augmentation continue des ripisylves jusqu'en 2011, qui a stabilisé la rétraction du chenal de la rivière ainsi que sa zone active. Pour résumer les grandes tendances de l'évolution des fleuves, nous discutons nos résultats avec d'autres recherches publiées et avec l´étude de cas de Sacramento.

ABSTRACT

The study presents the impact of factors influencing the river pattern of reaches of the Sajó river in Hungary and Sacramento River in USA during longer time periods (between 1952-2011 and 1942–1999). The studied factors are flow and precipitation regime, anthropogenic interventions and land use. The indexes SPI and RAI were also calculated for precipitation on Sajó River. The observed characteristics in the river reaches are the parameters of the evolution of active channel width, sinuosity, flood regime, the evolution of land use and the erosion and accumulation regime. A major change observed was the development of forest and shrub vegetation along the stream, mainly at the expense of permanent grasslands on Sajó riparian zone. The Mann-Whitney U test confirmed that forest and shrub vegetation are statistically significantly less eroded than arable land and permanent grassland. A similar duration of flood flows was achieved in the period 2005–2011, however, the rate of erosion was significantly lower. The reason seems to be the continuous increase of forest and shrub vegetation until 2011, which stabilized and narrowed the river channel as well as the active zone of the channel (Machová, 2021). To resume the major trends in the evolution of rivers we discuss our results with other published researches and Sacramento case study.

KEYWORDS

channel evolution, lateral erosion, meandering river, Sacramento River, Sajó River

1 INTRODUCTION

1.1 Evolution of river patterns

The rivers are under the anthropic pressure all around the world. Notably on big rivers the simplification of their pattern was recognized. The dominant processes are the river corridor narrowing and straightening. Many studies also try to define the causes of these processes: the response to change of hydrologic regime, the dam construction with the hungry water effect, the levees constructions, the land use changes, the gravel extraction from river bed or recently the climatic change effect. In this contribution the aim is to show how we can verify each of these factors, one by one, and to exclude the less important and to identify the significant one or theirs combinations.

1.2 Meandering rivers

The meandering rivers have typical river patters which develop in relatively flat areas, where the lateral movement is possible. The Sacramento River is the largest river in California and the study reach extends from river miles 143 to 243. About 95% of Sacramento riparian forest has been lost in 19th century. The Shasta Dam has been constructed in 1943.

The Sajó river is a smaller meandering river in Hungary with the mean discharge 24,3 m^3/s, Q_2 is 200 m^3/s, Q_5 has a value 315 m^3/s and the maximal discharge 498 m^3/s. The study reach was 124 km long, starting from Slovak border to confluence to Tisza River. The riparian forest increased continuously.

2 DATASETS AND METHODS

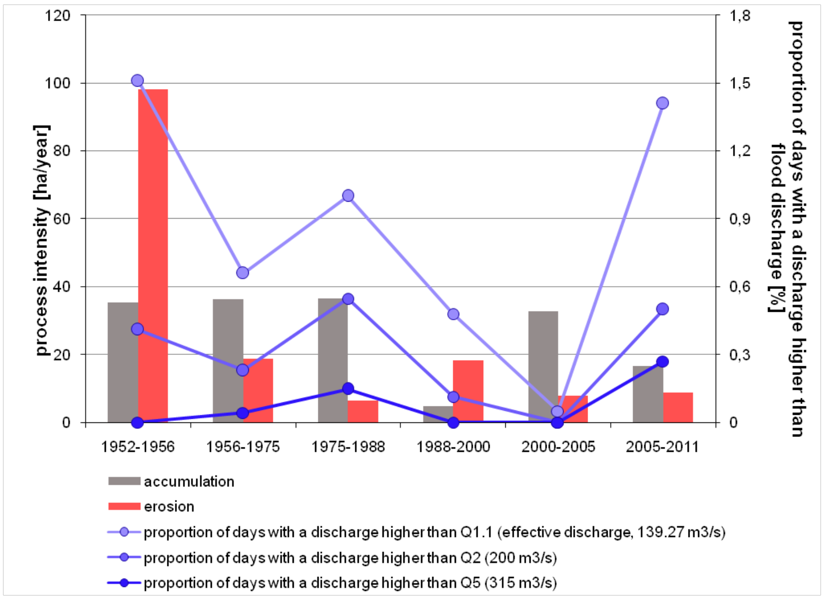
This contribution is based on synchronic and diachronic analysis of the active channel, flood analysis and land use mapping for both rivers. Historical photographs were selected and the digitalization provided at scale 1:2000. Cumulative curves of active channel width were plotted and studied in term of identification the thresholds in trends. The statistical methods (Kruskal-Walis, ANOVA, Mann-Whitney test) were used.

3 RESULTS

3.1 Erosion rates versus discharge regime and flood frequency

The analysis of flood discharge pointed out that in the first monitored period the reaction to the high proportion of flood flows was a significantly elevated erosion rate (98.1 ha / year) in the entire river reach compared to other periods. In the last studied period, a similar floods sequence rate was achieved, but the erosion rate was very low (8.9 ha / year). The highest erosion rates in the initial periods were found in all monitored sections, either between 1952 and 1956 or in the period 1956–1975.

- Evolution of erosion and acumulation processes of Sajó River shown in context with discharges



3.2 Climatic indexes

The anthropogenic influence was evaluated also by use of a double sum line. It was found out in which sections of the Sajó there is a levees near the riverbed and what interventions are taking place. The double total line showed that the investigated series of discharges is homogeneous. The reason for this should be to influence the flows before 1951, from which the line was constructed. A large part of the Sajó river basin has been an important industrial and mining area in Hungary since the middle of the 20th century and to this day there is significant water pumping of both groundwater and surface water, directly from the riverbed. The effect of precipitation was investigated using the RAI and SPI indices. The RAI index indicated a much more frequent occurrence of very dry months compared to the occurrence of very humid months. The SPI, built for a 12-month horizon, shows a continuous humid period from 1951 to 1956 and a long drier period between 1982 and 1995, during which there were only a few humid years. Hooke (1979) points out that long-term precipitation leads to wetting of the banks and thus to their lower stability and increased susceptibility to erosion. The erosion in the initial period of 1952–1956 could therefore be exacerbated by the wetting of the banks.

3.3 Land use changes

Land use was mapped in all seven years covering the study period on Sajó River. It turned out that in the first two monitored years, 1952 and 1956, arable land and permanent grassland formed the dominant category of land. These areas are characterized by higher rates of sediment and a higher degree of erodibility. The higher susceptibility to erosion of these land use categories to shrub and forest areas in the studied sections was verified by the Mann-Whitney U test. At the same time, an increase in forest areas was found from 1952 to 2011 in each section.

4 CONCLUSIONS

The main factor at the beginning of the study period (1952–1975) was probably flood flows. They caused the highest erosion rates in all studied sections and in the entire Sajó stream. Gradually, forest areas increased, and a shrub in some reaches. The increase in riparian forest and shrub land could have helped the period of higher drought frequencies from 1982 to 1995, as pointed out by the SPI. During this period, the banks were drier and more stable. The long dry period probably meant lower runoff and flows, which enabled or helped the succession and development of coastal vegetation. Forest and shrubs probably gradually stabilized the riverbed with their root system. In the period 2005–2011, the course of the floods did not have such a significant effect on shore erosion as between 1952 and 1956, because the riverbed was already stabilized. The riverbed stabilized, i.e. a continuous increase in the width of the core without sudden fluctuations, took place between 1988 and 2000. The reason should be the observed continuous growth of the forest and the decrease of the areas of permanent grassland and arable land. The development of the widths of the active zone of the riverbed was quite variable in all sections. A common feature of half of the sections was the decrease in average widths from 2000 to 2011. The relationship between sinuosity and forests was observed in the six studied sections. It is evident that with the increase of riparian forests the sinuosity increases in these sections. Lateral shifts were plotted using erosion and accumulation graphs. As mentioned, the highest erosion rates were observed in all sections in the period 1952–1975. This is attributed to: (i) a higher proportion of easily erodible areas, making up the most represented land use during this period in all sections outside section 8, increasing sediment inflow and outflow into the riverbed, and (ii) a significant amount of alluvium carried and deposited in the riverbed in many sections they formed a significant part of the core of the riverbed. The riverbed was wider and probably shallower due to alluvium, so its capacity was reduced. The lower erosion rate in subsequent periods should be due to the stabilizing effect of forest and shrub vegetation.

From Sacramento study case we concluded that the channel narrowing promotes the longitudinal simplification inside the active channel and the large oxbows have not been created since the early 20th century (Michalková et al., 2011). Also, the Shasta dam caused the decrease in active channel width due to peak flow decrease.

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