Geomorphic adjustment of a gravel bed meandering river as response to contemporary floods and management issues (The Ondava River, Eastern Slovakia)

Ajustement géomorphologique d'une rivière à fond caillouteux en réponse aux crues récentes et questions sur sa gestion (la rivière Ondava, Slovaquie de l'Est)

Miloš Rusnák; Milan Lehotský; Ján Sládek

Institute of Geography, Slovak Academy of Sciences, Department of Physical Geography, Geomorphology and Natural Hazards, Štefániková 49, 814 73 Bratislava, Slovakia (corresponding author: geogmilo@savba.sk)

RÉSUMÉ

Les photographies aériennes (1949, 1961, 1972, 1981, 1987, 2002 et 2009) et le suivi par UAV ont été choisis pour saisir les changements morphologiques du chenal après les inondations sur les 13,2 km de long du tronçon de la rivière Ondava. Deux périodes de crues différentes sont déterminées (1987-1992 et 2002-2009). Le mouvement latéral du chenal été établi pour des unités spatiales d'une longueur de 250m dans les SIG. Un suivi avec UAV a été réalisé pour l'analyse détaillée de la bifurcation du chenal. Deux autres tronçons ont été identifiés en termes du comportement. La catégorie la plus érodée est celle des terres arables. Nous en concluons que les petites crues fréquentes, au lieu de provoquer la destruction du système, ont conduit à la stabilisation du lit, à l'érosion de la berge concave et à la formation des méandres. En revanche, le court intervalle de récurrence des crues exceptionnelles conduit à une augmentation de l'intensité de l'érosion, à un changement de la forme en méandres vers une forme évoquant celle de tresse, et à la formation de bancs de gravier. Le débit de N10 peut être considéré comme le seuil de déclenchement des changements morphologiques. Prenant en considération la zone d'étude, les questions de gestion à l'échelle du bassin, telles que l'équilibre des sédiments, l'extraction du gravier, la politique financière, sont discutées.

ABSTRACT

The aerial photographs (1949, 1961, 1972, 1981, 1987, 2002 and 2009) and UAV scanning were chosen in a way to capture the morphological changes that occurred after floods along the 13.2 km long less regulated meandering reach of the Ondava River. Two different flood periods are determined (1987-1992 and 2002- 2009). The lateral channel shift has been established for spatial units with 250 m separation in GIS. UAV scanning was applied for the detail analysis of the channel bifurcation. Two different river reaches in terms of behaviour were identified. The most eroded category is that of arable land. We conclude that frequent small floods, instead of causing destruction of the system, led to the stabilization of the channel, erosion of the concave bank and to the formation of the meandering planform. In contrast, the short recurrence interval of extreme floods led to an increased intensity of erosion processes, a change of the meandering planform to slightly braided one, straightening of the channel and formation of gravel bars. The discharge of N_{10} can be considered as threshold initiating morphological changes. Taking into consideration the study area setting at the basin scale management issues such as sediment balance, gravel mining, land policy are discussed.

KEYWORDS

Aerial photo; bank erosion; floods; GIS; UAV photogrametry.

1 INTRODUCTION

The recent period is characterized by impacts of climate change and anthropogenetic interventions into river channels and their riparian zones. It is a challenge for the fluvial geomorphology to highlight the morphological response to these events, because the knowledge of the morphological-sedimentological attributes of the river channel is the first step in pursue of a comprehensive knowledge of the riverine landscape and impact on its sustainable management. Research of the spatial variability of landforms and the regime of processes creates an appropriate knowledge base for other sciences interested in the riverine as well as terrestrial systems.

The aim of this research is to analyze the lateral channel shift, changes in river dynamics and the associated changes in in-channel morphological structures and riparian land cover ones by multi-temporal analyzes of aerial photographs in the GIS environment on an example of less regulated and laterally partly-confined meandering channel (13.2 km long meandering reach of the Ondava River (Eastern Slovakia)).

2 METHODS

Spatial data about the channel, the in-channel landforms and the riparian zone land cover were generated from remote sensing images (aerial photographs and orthophotographs). They were analysed in seven time horizons (1949, 1961, 1972, 1981, 1987, 2002 and 2009) applying the ArcGIS in SJTSK (Krovak East North) coordinate system. Changes of channel planform were assessed by overlapping bank positions according to the methodology of Lehotský et al. (2013), Rusnák and Lehotský (2014). The spatial aspect of the individual parameters of the lateral shift, gravel bars and bank erosion was expressed for 250 m segments.

During the field research campaigns in 2011, 2012, 2013 and 2014 individual morphological forms and processes were specified. In the study area several methods of data analysis e.g. remote sensing, geodetic and geophysical measurements, close range photogrammetry by use of micro UAV (Unmanned Aerial Vehicle) were applied.

3 RESULT AND DISCUSSION

In study period of 60 years is visible long-term degradation of the river system (Fig. 1) as reflected in inner-channel changes such as the straightening and narrowing of the channel and markedly decreasing of area of bars (Fig. 2). This trend is also confirmed by comparison of changes in riparian zone and incision of channel bed to bedrock. Cross section profile points to several benches created during study periods that are from 1 to 3 meters above recent water table level. They were dating by aerial photos. Regarding this elevated vertical position in relation to the new incised channel, the bars are attached into the lowest floodplain level invaded by herb associations. In last time period (after 2002) in study reach is evident local rejuvenation of the stream accompanied by channel and gravel bars expansion. The recurrent large floods after 2002 led to an increased intensity of erosion processes, change of the planform and formation of gravel bars. The discharge of approximate size of N10 (appearing after 2002) can be then considered a threshold, which initiates morphological changes of the channel and local rejuvenation in its meandering reaches in the study area. The succession process simultaneously takes place in study area that leads to gradually increase of a proportion of riparian forest in riparian zone in last 3 decades. Bars are stabilized by the pioneer wood species almost exclusively represented by *Salix sp*. After floods in 2010 new channel pattern (new chute cutoff, dimension: 450 m length and 150 m wide) was developed during three flood events in 2010 (3 floods with discharge Qculm 150 m3.s-1 /17.05./, 220 m3.s-1 /04.06./ and 150 m3.s-1 /29.07./ with recurrence interval 1 – 5 years). Since 2012, the river bed evolution and bank erosion is captured by series of ortophotos and 3D models constructed by close range photogrammetry method by using mikro UAV (Hexacopter XL). The construction of the series of 3D models allowed the calculation of volume changes in banks and channel. Since 2010, when the chute cutoff was developed, its bank line retreated in avulsion channel up to 3 – 4 meters. Exposed gravels (after chute cutoff) were dated by C14 methods base on the buried tree (2590 ± 35 cal. BP). We identified several old channels in floodplain based on ERT profile and aerial photography analysis.

For the overall management of streams it is important to be aware of instable reaches. It is also necessary to bear in mind that bank erosion is a natural process in stream channels. “Green” approach is now preferred worldwide which avoids technical interventions into the channels and the rivers are left to meander in the certain area or in certain reaches freely. Piegay et al. (1997) also point out that active restrictive interventions in channels are expensive and result in a spiral effect leading to

degradation of streams and increased flood risk. But the effects of bank erosion, bank destruction and changes of river systems are not given much attention in Slovakia.

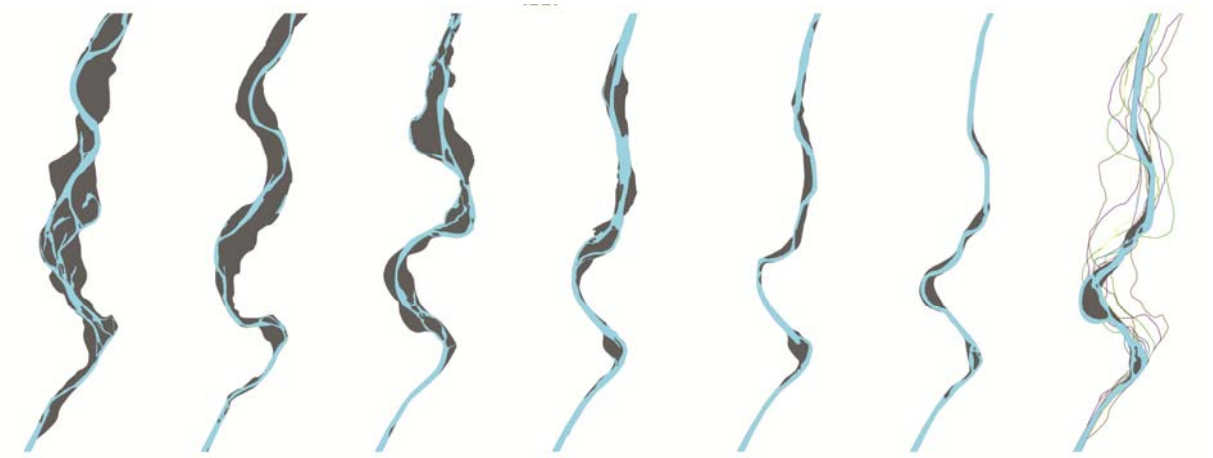

Fig. 1 Changes of channel planform of the Ondava River from year 1949 to 2009 (from left to right channel in year 1949, 1961, 1972, 1981, 1987, 2002 and 2009)

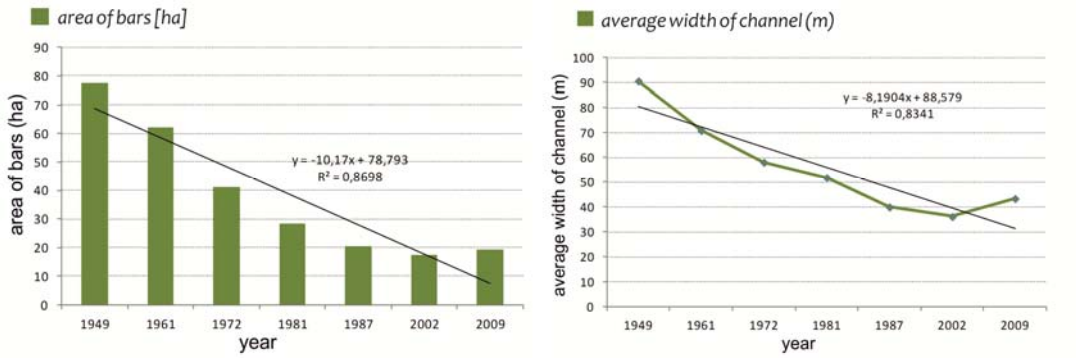

Fig. 2 Changes of average channel width and area of bars in selected river reach in study period

4 CONCLUSION

The Ondava River directly affects human activity on the floodplain and degraded several hectares of arable land, which occupy a given area before chute cutoff. Monitoring of the area is important for next evolution of channel and riparian zone as well as of changes in channel planform, destruction of floodplain agriculture land cover and assessment of river response in relation to environmental changes.

LIST OF REFERENCES

Lehotský, M., Frandofer, M., Novotný, J., Rusnák, M., Szmańda, J. B. (2013). Geomorphic/Sedimentary responses of rivers to floods: Case studies from Slovakia. In: *Geomorphological impacts of extreme weather: Case studies from central and eastern Europe*, D. Lóczy (Ed.). Springer, 37–52.

Piégay, H., Cuaz, M., Javelle, E., Mandier, P. (1997). Bank erosion management based on geomorphological, ecological and economic criteria on the Galaure River, France. *Regulated Rivers: Research & Management*, 13, 433–448.

Rusnák, M., Lehotský, M. (2014): Time-focused investigation of river channel morphological changes due to extreme floods. *Zeitschrift für Geomorphologie*, 58, 2.