Changes of a braided-wandering river as a response to flood fluctuations during last 60 years inferred from aerial photographs (the Belá River - Slovakia)

Changements d'une rivière anastomosée en réponse aux fluctuations des crues pendant les 60 dernières années, sur la base des images aériennes (la rivière Belá - Slovaquie)

Anna Kidová; Milan Lehotský

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 changements dans la structure morphologique de la rivière Belá (Carpates slovaques) ont été étudiés pour montrer l'impact des inondations et des changements environnementaux sur la tendance évolutive de la rivière depuis le milieu du 20e siècle. Plusieurs séries de photos aériennes (1949, 1961, 1973, 1986, 2003, 2009) prises après les périodes d'occurrence ou d'absence de crues extrêmes ont fourni des données sur l'évolution morphologique de 227 segments de rivière de 100 m de longueur et 13 profils en transversaux, qui ont été analysés avec l'utilisation de logiciels ArcGIS. L'étude a porté sur l'évaluation de la manière dont les cinq périodes possédant des caractéristiques de crue différentes ont influencé le développement de la diversité géomorphologique de la rivière. Les questions suivantes ont été examinées : (i) les variations spatiales et temporelles du tressage, la région, le nombre et la longueur des formes fluviales (les bras pérennes, le lit à faible débit, les bancs de galets, les îles) et dans le domaine de trois catégories de surfaces émergées en lit de rivière : sans végétation, avec une végétation clairsemée et avec une couverture de végétation dense ; (ii) les variations spatiales et temporelles dans le nombre et la densité de paires confluent-diffluence (nœuds) ; (iii) les changements dans le modèle du lit interprétés avec utilisation de paramètres de base fluviaux (noyaux et bords fréquence, l'indice de diversité de Shannon) ; et (iv) l'identification et l'interprétation des causes des changements du lit.

ABSTRACT

Changes in the morphological pattern of the Belá River, Slovak Carpathians, were investigated to infer about the impact of flood events and environmental changes on the evolutionary trend of the river since the mid-20th century. Several sets of aerial photographs (1949, 1961, 1973, 1986, 2003, 2009) taken after the periods with the occurrence or, on the other hand, lack of extreme floods provided data about channel landform changes in 227 river segments (each 100 meters in length) and 13 cross-sections, that were analysed in ArcGIS software. The study focused on assessing how the five periods, with differing flood characteristics, have influenced the development of geomorphic diversity of the river. The following issues were considered: (i) spatial and temporal analyses of the mid-channel landform parameters, planimetric parameters and the three types of vegetation cover on bars (no vegetation, sparse vegetation, dense vegetation); (ii) spatial and temporal variations in the number and density of flow confluence–diffluence pairs (nodes); (iii) changes in the channel pattern interpreted using the basic landscape metrics (cores and edges frequency, Shannon's diversity index); and (iv) identification and interpretation of the causes of the channel changes.

KEYWORDS

Aerial photo; braided river; flood; GIS

1 INTRODUCTION

Intellectual constructs are required to interpret changes in morphological pattern of braided rivers and its contemporary evolutionary trends. The river geomorphic response to flood events depends on the frequency and magnitude of flood intensity, which is usually impacted by climate change and human activities. Channel adjustment after extreme floods depends also on a stabilisation function of the in-channel vegetation (Bertoldi et al. 2009) and riparian zone (Rusnák and Lehotský, 2014).
This research presents such framework and it's aimed to understand the behaviour of a braided-wandering river as a response to modern flood events and environmental changes, while focusing on spatial and temporal variations of the landform parameters that influenced the development of the morphological complexity and geomorphic diversity. Assessment of the channel planform evolution during last 60 years was performed in GIS environment, using the method for understanding to multi-channel river dynamics of the longest braided-wandering river of Slovakia, the Belá River (Kidová and Lehotský, 2012).

2 METHODS

Comprehensive morphological study of the braided and wandering Belá River in ArcGIS environment was based on analysis of remote sensing data (aerial photographs and orthoimages from seven time horizons: 1949, 1961, 1973, 1986, 1992, 2003 and 2009). Time horizons of the aerial images were selected on a premise that they always follow an extreme water level (flood event). A database of parameters corresponding to fluvial forms and classification of terestrical channel landforms (stream river valley, river terrace, floodplain, island/ bar area) and aquatic channel landforms (water surface area) was created. For the channel pattern assessment, selected in-channel landforms and its time-spatial distribution were analysed within 227 regular 100 m long river reaches (RR_{100m}), based on the unique combination of the following parameters: channel number, island number and mid-channel-bar number. According to listed rules we distinguish three types of channel patterns: 1) single-thread channel planform (one to two perennial channels, island and mid-channel bar appearance is neglectable); 2) wandering channel planform as a bar-island channel type with avulsion appearance (more than two perennial channels, at least one island, mid-channel appearance was neglectable); 3) braided channel planform as a mid-channel bar channel type (more than two perennial channels, at least one mid-channel bar, no island). Synchronic and diachronic scheme of the channel pattern evolution was made for 7 time spans (1949-2009) within all 227 RR_{100m}. Based on occurrence of confluence-diffluence pairs (nodes), as a time-spatial indicators of mid-channel bar/ island evolution, the cores of channel dynamics were identified for study period (1949-2009).

3 RESULT AND DISCUSSION

A decreasing trend of the area of river active zone (from 2.5 km^2 in 1949 to 1.4 km^2 in 2009) was identified. Channel pattern simplification was influenced by external conditions (hydrological and climatic conditions, tectonic forces, human impact) and response in internal dynamics in-channel landforms organization between bars and islands. The largest rate of the braided pattern was recorded in 1949 with little developed wandering pattern. The period 1949-1961, with a very high-magnitude flood in 1958, was characterised by increasing total length of low-flow channels, island number/area and the number/density of confluence–diffluence pairs (nodes), and by decreasing bar area. The frequency of cores and edges of channel dynamics as well as the Shannon's index of landform diversity reached the highest values. The following period 1962-1973 exhibited a decreasing trend in a several mid-channel landforms parameters: island number/ area, channel length, node density, although the frequency of cores and edges of channel dynamics and Shannon's diversity index were still high. Synergism of the flood protection works (building-up a flood protection dikes, check-dams or bank stabilization) and downward trend of geomorphological flood effect caused in-channel landform stabilization. No major floods occurred between 1974 and 1986 and the river system seems to have been relatively stable, with some decrease in the area of mid-channel landforms and in landscape metrics values. During the following period 1987-1992 decreasing trend in some mid-channel landforms have been deepen. During the years 1993-2002 two large floods occurred. Their consequences in landform changes were expressed by an increase of all channel parameters analysed, especially the area of mid-channel bars and landscape metrics values. The lowest values of mid-channel bar area and landscape metrics were recorded during years 2002-2008, whereas island area increased at the same time period. Mid-channel bar stabilization and its transformation into islands due to developing of the transitional wandering channel pattern. Identification of the cores of channel dynamics present specific hierarchy in its time-spatial organisation. The core size is

equivalent to volume of (in)stability related to potential in-channel landforms changes (bar, island) during flood events. The most dynamic river reaches (Fig. 1.) reflect to distribution of the average bar number and generally relate to the high-energy type of the channel pattern.
The study shows that a renewed occurrence of high-magnitude floods in recent years has not returned the Belá River to its former state probably because of the changes in catchment sediment supply induced by the increasing forest cover in the catchment area (from 22.7% in 1957 to 34.8% in 2008) as well as due to the changes in channel boundary conditions (channelization, small hydropower plant constructions).

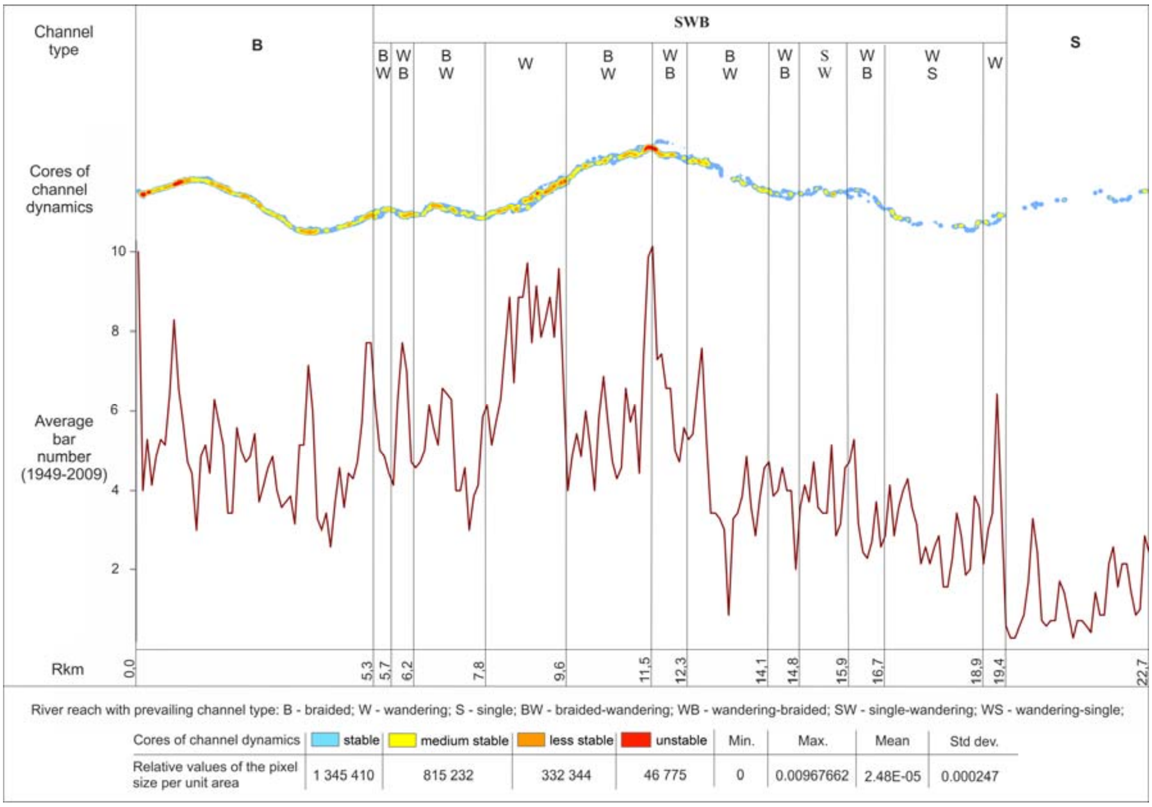

Fig. 1 Diagram of the prevailing channel pattern related to cores of channel dynamics within average annual water level and average bar number and of the Belá River (1949-2009)

4 CONCLUSION

Presented study of the Belá River provides some insights into the long-term morphological dynamics of typical gravel-bed river subjected to hydrological conditions and local climatic influence in flood frequency within the catchment. By performing specific GIS analyses we obtained complex informations about the Belá River focused on parallel recent channel morphological changes. Results have definitely showed that the studied Belá River is subject to morphological changes such as lateral channel shift, incision, origins, duration and disappearance of gravel bars and their transformation into islands. The possible hypothesis is that its behaviour represents a situation close to a threshold, degrading behaviour of a multi-channel river system.

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