INTERACTION OF CHANNEL AND FLOODPLAIN PROCESSES AND FORMS

FINAL REPORT

The aim of the research was to study the interaction between channel and floodplain forms, and their development under various human impacts. Actually, the research went further on than the original aims, as we realised that these processes fundamentally influence peak flood levels and flood hazard. Therefore, the flood hazard was also evaluated along the Lower Tisza.

The most detailed studies were made along the Tisza and Maros Rivers, where LiDAR data are available. However, along the Hernád and Dráva Rivers in the lack of high resolution data the study provided less detailed results.

It was an important aim to involve students (BSc, MSc and PhD) in the research to increase their awareness and interest for geomorphology and scientific research. Finally 8 BSc and MSc students wrote their thesis/diploma work in a related topic, and in 2020 3 PhD students completed their research in associated topics supported by the OTKA found.

Finally, 24 articles, one chapter, and 3 PhD dissertations were published based on the results. All together 6 articles were written in Q1 journals, 2 were published in Q2-3 journals, and further 16 scientific papers were published in English and in Hungarian. The cumulative impact factor of the papers is 21.678. One further article is under review (submitted to Geomorphology), and another will be submitted to Remote Sensing.

Results

Based on our results it could be stated that the channel-floodplain connectivity on all studied rivers (Tisza, Maros, Dráva and Hernád) declined, especially during the last decades. The main reason of the disconnectivity is the missing overbank floods on all studied rivers (Kiss et al. 2019b, Balogh 2020), which could be explained by various factors. Besides, the disconnectivity is closely related to different human impacts which have modified the river systems on a century scale. The following altered phenomena were highlighted and studied in detail: (1) hydrology; (2) vertical and horizontal floodplain aggradation, (3) incision and narrowing; and (4) riparian vegetation. The driving factors of the channel-floodplain (dis)connectivity include run-off change, floodplain alteration and channel changes. The results of the research are summarised below, following a system-based approach (Fig. 1).

The altered **run-off** is mainly controlled by climate change (not studied within the frame of the actual project) and ***water retention***, which mainly influences the catchment of the Maros, Dráva and Hernád Rivers, though through the sub-catchments it also alters the flow conditions of the Tisza. Our hydrological analysis show, that low stages became more frequent and long-lasting on all rivers, while floods usually became less frequent though their level increased (Kiss et al. 2019b). These hydrological changes influence the sedimentary processes in the channel (colonisation of the channel slopes by vegetation, lateral aggradation) and on the floodplain (active deposition just during high overbank floods).

The floodplain is altered by **artificial levee constructions** resulting in confined artificial floodplain and land cover changes along all studied rivers. On the narrow, ***confined floodplain*** the rate of vertical sedimentation accelerated, though not in a uniform degree, but it changes from site to site, as it is influenced by floodplain width, downstream changes of the floodplain width, channel sinuosity, riparian vegetation and tributaries (Nagy et al. 2017ab, 2018b, Nagy and Kiss 2020). The overbank floodplain aggradation fundamentally decreases the flood conveyance of the floodplain (Nagy 2020), thus increases flood levels and flood hazard (Kiss et al. under review). On the artificial floodplains the ***land cover*** changed drastically, as the traditional land-uses were given up, and fallows and planted forests became abundant (Fehérváry and Kiss 2020, 2021). These processes increased the vegetation density of the floodplains, which also influences the in-channel processes: the water slope dropped considerably, the contribution of the floodplain to flood conveyance decreased, the flow velocity increased in the channel and decreased on the floodplain, making the actual processes (e.g. vertical floodplain aggradation, channel incision) more emphasized. As the result of land cover changes the peak flood levels increased, further increasing the flood hazard (Delai et al. 2018, Nagy et al. 2018a, Kiss et al. 2019c, Nagy 2020).

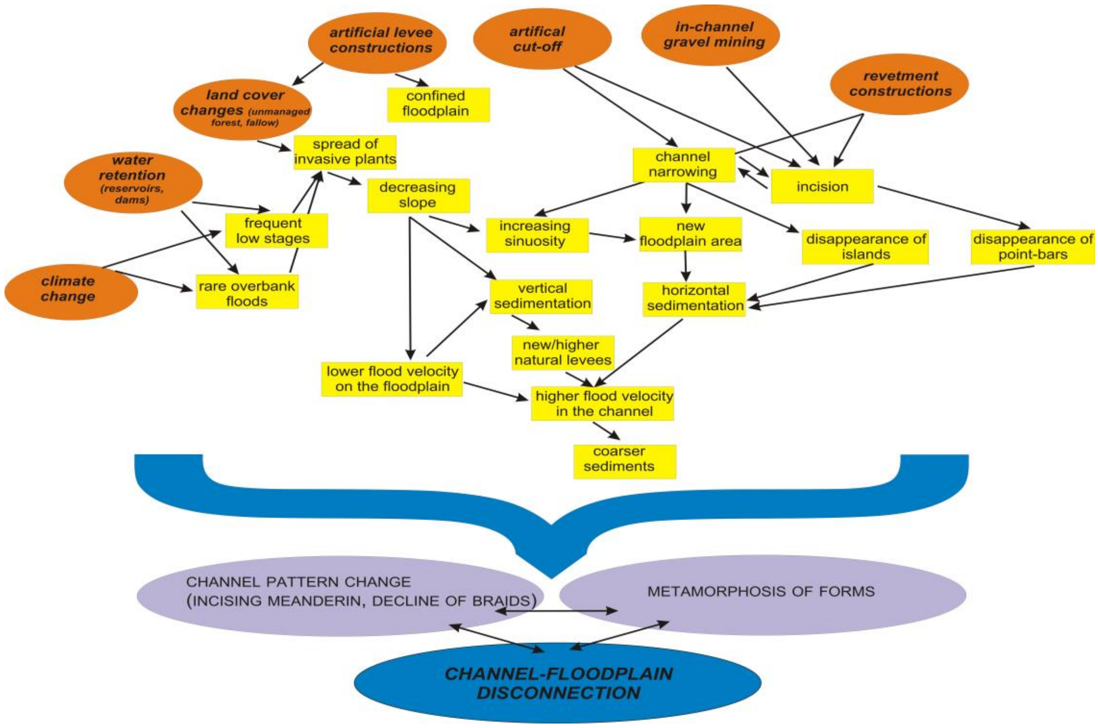

Fig. 1. Influencing factors and processes of the channel-floodplain disconnectivity

Artificial cut-offs are very important in the evolution of the Tisza and Maros River, while they have less importance on the Dráva, and natural cut-offs appear on the Hernád. **Revetment constructions** play the most important role in the development of the Tisza, though they were constructed in the other rivers too. These in-channel engineering works accelerated the incision and the interrelated narrowing (horizontal floodplain aggradation) of the channel (Amissah 2020). However, these processes are related to decreased discharge caused by water retention and reservoir construction, increased floodplain vegetation roughness and in-channel sediment mining too (Balogh et al. 2017). Channel narrowing is common on all studied rivers, resulting in horizontal floodplain accumulation, thus it increases the floodplain area (Kiss and Andrási 2017, Balogh 2020). The newly developed floodplain patches are usually narrow and low-lying, often natural levees develop on them (Kiss et al. 2017). The channel incision and narrowing combined with groynes construction resulted in the disappearance of islands (e.g. Tisza), or their decline (e.g. Dráva, Maros), as the island development slowed down and they often merged to each other or to the banks (Kiss and Andrási 2017, Balogh 2020). In the narrower ad deeper, often revetted channel sections the stream power increased, predicting further incision, thus drop of low stages and the erosion of old revetments (Kiss et al. 2019a). These processes combined with the flood level and flood return period changes, and with the continuous elevation increase of the floodplain influence the overbank sedimentation processes too. Nowadays the last, active point-bars and natural levees are considerably high and their coarsening sediment profiles refer to greater stream power during their development (Balogh 2020, Nagy 2020). (The coarser sediment is also connected to "clear water erosion" downstream of reservoirs and in-channel mining). However, the dense riparian vegetation impedes the sediment transport towards the distal parts of the floodplain, thus the elevation of the near-bank zone increases, obstructing the channel-floodplain connectivity (Balogh et al. 2020).

The natural levees, point-bars, crevasses and crevasse splays could be considered as linking elements between the floodplain and the channel. However, their morphology changed during the last century, referring to their slow decline: the active point-bars are vanishing from the incising channels (Kiss et al. 2018b, Amissah et al. 2019, Nagy and Kiss 2020), the development of natural levees and crevasses terminates due to the lack of overbank floods (Kiss et al. 2018a).

As the result of these processes it could be declared that **the channel-floodplain connectivity** is getting looser by time on all studied rivers:

The greatest disconnectivity was found on ***Dráva River***, where the connectivity became practically extinct due to the operation of reservoirs and hydroelectric power stations. As a result, the typical overbank floodplain processes terminated, and they are almost totally replaced by horizontal accretion related to channel narrowing (Kiss and Andrási 2019). During the last almost 150 years the floodplain area increased by several thousand hectares simultaneously with the loss of channel territory. The side channels gradually lose their water conductivity; therefore, the islands are merging into the floodplain. The meander development speeded up, as the instability of the eroding banks increases due to the drop of stages. Therefore, the rate of bank erosion increases and simultaneously the point-bar development became more intensive, thus the lateral aggradation accelerates (Kiss and Andrási 2017, 2019).

The decreasing floodplain-channel connectivity of the ***Maros River*** is indicated by channel incision up to 6 m, related to in-channel gravel mining (Kiss et al. 2017). Therefore, floods are not common any more, the crevasses and the ox-bows became dry, and especially on the Romanian section artificial flood control measures became useless. Channel narrowing is typical along the entire lowland section of the Maros, providing space for the development of low-lying new floodplain surfaces (Kiss et al. 2017, 2020). The connectivity of the channel remained just along the eroding banks and with the new floodplain patches, where the processes are very rapid due to their small area and low elevation. The closest floodplain-channel connection was found between Angyalkút/Fântânele –Temeshidegkút/Zăbrani and Sajtény/Șeitin –Munár/Munar, where channel changes are active on the highly sinuous section with loose gravely bed-material. On the Maros unique for assemblage (natural levee series) was identified in relation to human impact (Balogh et al 2016, 2017, Balogh 2020).

The floodplain-channel connectivity is better on the ***Lower Tisza River***, where floods still occur, though the hydrology of the Tisza altered too (Kiss et al. 2019b). The connectivity is realised by vertical and horizontal floodplain aggradation and lateral bank erosion. The point-bar series refer to locally changing channel processes in the past (Nagy 2020), however, recently the point-bars are vanishing (Amissah et al. 2017, 2018). The increasing height of the banks and the dense vegetation (even in the channel) block the material flow towards the distal parts of the floodplain, referring to declining connectivity. The studied processes increased flood hazard since the late 19th century river regulation works by 272 cm in average, though at some points it is over 400 cm (Kiss et al. under review).

The connectivity between the channel and the floodplain is the best along the ***Hernád River***. The floodplain is confined only at some locations, so overbank floods can reach even the distal parts of the floodplain. though due to the incision and water retention water levels dropped and floods became rare. The vertical aggradation is quite limited, though channel narrowing related lateral accumulation is common (Blanka and Kiss 2018). Bank erosion is intensive, and in the near future a natural neck-cut-off is predictable at Aszaló, while slightly upstream a chute-cut-off is developing.

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