Groundwater and vegetation succession: controls on river morphodynamics and morphology

Nappe phréatique et succession végétale : contrôles sur la morphodynamique et la morphologie des cours d'eau

Nico Bätz[1,2], Colombini Pauline[1], Cherubini Paolo[3], Lane Stuart N.[1]

1) Institute of Earth Surface Dynamics, University of Lausanne, Switzerland
2) Eawag - Swiss Federal Institute of Aquatic Science and Technology, Department of Surface Waters - Research and Management
3) WSL - Swiss Federal Institute for Forest, Snow and Landscape Research, Dendroecology Research Group. (nico.baetz@eawag.ch)

RÉSUMÉ

L'effet stabilisant de la végétation sur la morphologie des rivières a été largement démontré par des expériences sur les canaux et des analyses d'images aériennes (historiques). Ainsi, l'évolution géomorphologique et biogéomorphique à long terme des rivières peut être conceptualisée résultant de l'équilibre entre les processus perturbateurs et stabilisateurs liés à la végétation. Les recherches récentes ont porté sur la façon dont les changements dans la fréquence des perturbations (p.ex. les changements climatiques) influent la morphologie fluviale, mais beaucoup moins a été fait pour comprendre ce qui influence la succession végétale. Ici, nous quantifions l'importance de l'interaction entre l'accès à la nappe phréatique, la fréquence des perturbations et la succession végétale pour les morphodynamique fluviales. Nous avons étudié cette interaction sur une rivière graveleuse près de Genève (Suisse). Les résultats montrent que dans le tronçon avec des eaux souterraines peu profondes, la végétation se développe à des taux élevés, augmentent la stabilité morphologiquement du tronçon contre les perturbations. Par contre le tronçon distal de la nappe montre un taux de succession faible garantissant une dynamique géomorphologique plus importante. Il apparaît donc, que l'accès à la nappe peut contrôler les morphodynamiques fluviales grâce à son impact sur "l'effet d'ingénierie" de la végétation, soulignant ainsi son importance pour la gestion future des cours d'eau.

ABSTRACT

The stabilizing effect of developing vegetation on river morphology has been widely shown by flume experiments and (historic) aerial image analysis. As such, the long-term geomorphic and biogeomorphic evolution of a river can be conceptualized as resulting from the balance between disturbing and stabilizing processes, with the latter potentially mediated by vegetation. Research has addressed how changes in disturbance frequency (i.e. climate change) affect river channel pattern, but much less has been done to understand what impacts vegetation succession. Here, we quantify how the interplay between groundwater access, disturbance frequency and vegetation succession, drive changes in channel pattern. We studied this interplay on a gravel-bed river system close to Geneva (Switzerland). Results show that in reaches with shallow groundwater, vegetation encroachment rates were high and, as flood-related disturbance decreased, the river has shifted towards a meandering state. Inversely, in reaches with deeper groundwater levels, vegetation growth was limited by water-access and vegetation encroachment rates were low. Even though there was a reduction in flood disturbance, it was still sufficient to maintain a morphologically dynamic state. Thus, it appears that access to groundwater can control river channel pattern through its impact upon the "ecosystem engineering" effects of vegetation, thus stressing the importance of this feedback for process oriented river management.

KEYWORDS

Channel pattern, channel stability, dendroecology, groundwater access, vegetation succession

1 INTRODUCTION

Dynamic braided rivers are characterized by high rates of morphological change. However, despite the potential for frequent disturbance, the “ecosystem engineering” effects of vegetation may lead to the creation of well-developed vegetated zones (concept of biogeomorphic succession sensu Corenblit, et al., 2007). On the long term, the effects of the stabilizing effects of vegetation on river morphology have been widely shown by flume experiments and analysis of (historical) aerial imagery (e.g. Tal and Paola, 2007). Thus, it appears that there is a balance between disturbance and stabilization, mediated through vegetation, that may determine the long-term geomorphic and biogeomorphic evolution of the river. It follows that with a change in disturbance frequency relative to the rate of vegetation establishment, a systematic geomorphological shift could occur. However, research has addressed how changes in disturbance frequency affect river channel pattern, but has rarely addressed the way in which the stabilizing effects of biogeomorphic succession interact with the disturbance frequency to maintain a river in a more dynamic or a less dynamic state. Especially, a better understanding of factors influencing the rate of biogeomorphic succession is crucial to improve process-oriented understanding for river management.

Based on Bätz, et al. (2016), we quantify here how the interplay between groundwater access, vegetation succession and disturbance frequency, drive changes in channel pattern.

2 METHODS

We studied the complex interplay between groundwater access, vegetation succession and disturbance frequency, on a transitional 2 km gravel-bed river reach (braided, wandering, meandering) close to Geneva (Switzerland) - the Allondon River.

Plant growth was reconstructed via dendrochronological methods for 150 samples distributed across the floodplain. These data were then related to the available water resources, notably the flowing water in the main channel and the groundwater. The latter changes gradually from downwelling to upwelling along the reach.

Further geomorphological interpretation was then aided by historical imagery classification. Via a supervised classification, succession rates and changes in channel pattern could be reconstructed for recent decades.

3 RESULTS AND DISCUSSION

Dendroecological analysis demonstrate that vegetation growth is driven by groundwater access along the reach. High and significant correlations between yearly vegetation growth rates and the groundwater table fluctuations were found in the downwelling sub-reach, indicating that vegetation growth is limited by the access to this deep and fluctuating water resource. However, in the upwelling reach, vegetation growth rates showed no significant correlations with groundwater, as the shallow groundwater table seams providing a year-round water supply. Growth was more correlated with non-hydrological variables such as temperature.

On the other hand, decadal scale aerial image classification showed that where groundwater is shallower, vegetation succession rates were higher and, as flood-related disturbance decreased, the river shifted towards a meandering state. Where groundwater was deeper, vegetation succession rates were low. Even though there was a reduction in flood disturbance, it was still sufficient to maintain a wandering/braided state.

As such, groundwater access appears to condition the rate of vegetation stabilization (via succession) at the sub-reach scale and, due to a reduction in flood-related disturbance frequency over the last 50 years, drive a change in channel pattern.

4 CONCLUSION

Groundwater availability was shown to facilitate biogeomorphic succession, due to its effect on moisture availability. As such, the access to groundwater appears to control the “ecosystem engineering” effects of vegetation and to influence the riverbank and fluvial landform resistance to disturbance. Over the long-term, this feedback influences floodplain turnover rates, which may lead to changes in river channel pattern.

Considering the recent tendency towards a more process oriented river management (i.e. aiming at reintroducing more dynamic river morphologies), consideration will have to be given to the extent to which groundwater is likely to affect project success.

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