From natural to human-dominated floodplains – A Holocene perspective for river catchments in Flanders, Belgium

Evolution de la plaine d'inondation à l'Holocène en Flandre, Belgique

Nils Broothaerts, Gert Verstraeten

KU Leuven, Department of Earth and Environmental Sciences, Celestijnenlaan 200E, 3000 Leuven, Belgium

RÉSUMÉ

Les rivières et les plaines inondables représentent une importante ressource en termes de services écosystémiques, tels que la conservation de la biodiversité, ou le stockage du carbone. Ces services écosystémiques peuvent être influencés par plusieurs facteurs comme les changements climatiques, d'utilisation du sol ou de gestion des cours d'eau. Afin de modéliser les réponses des plaines inondables aux futurs changements socio-écologiques, il est crucial de comprendre l'interrelation entre les changements physiques des plaines inondables à long terme et les perturbations humaines sur le bassin-versant. Au sein de cette étude, nous discutons de manière holistique une combinaison de données détaillées, récoltées en Flandres (Belgique), sur l'évolution des plaines inondables et sur l'impact anthropogénique ayant eu lieu durant l'Holocène. Les résultats tendent à démontrer que pendant la période néolithique, l'impact anthropogénique était négligeable et les plaines inondables consistaient majoritairement en un environnement marécageux fortement végétalisé où la matière organique s'accumulait. Cet état est considéré comme l'état naturel des plaines inondables. À partir de l'Âge de bronze, l'impact humain s'est accentué, provoquant une augmentation de l'érosion. Par conséquent, l'apport de sédiments dans le système de plaine inondable augmenta et la géo-écohydrologie de la plaine inondable a évolué vers une plaine inondable ouverte, dominée par des dépôts clastiques résultant principalement, de manière indirecte, d'une intensification des activités agricoles. En résumé, les résultats de notre étude permettent de mieux comprendre la vulnérabilité potentielle des systèmes fluviaux aux changements futurs envisagés dans un bassin versant.

ABSTRACT

Rivers and alluvial floodplains represent many ecosystem services such as biodiversity, carbon storage and recreation. These ecosystem services may alter due to climate change, land use change, or a change in river management. In order to model floodplain responses to future socio-ecological changes it is crucial to understand the relation between long-term floodplain changes and human disturbances in a catchment. In this study, we present a holistic discussion in which we combine detailed data on floodplain changes with detailed data on human impact through the Holocene for some river catchments in Flanders, Belgium. The results show that during the Neolithic Period, human impact was nearly absent and floodplains consisted of a strongly vegetated marshy environment where organic material accumulated, which is considered as the natural state of the floodplains. From the Bronze Age onwards, human impact increased and caused an increase in soil erosion and hillslope-floodplain connectivity. Consequently, sediment input in the floodplain system increased and floodplain geo-ecohydrology changed towards an open floodplain dominated by clastic overbank deposits, mainly as the indirect result of an intensification of agricultural activities. Overall, the results of our study provide more insight in the potential vulnerability of fluvial systems to future changes in a catchment.

KEYWORDS

Biophysical history, floodplain, human impact, sedimentary archive, sustainable management

1 INTRODUCTION

Rivers and alluvial floodplains represent many ecosystem services such as biodiversity, carbon storage, groundwater storage, agriculture, water buffering and recreation. Many of these ecosystem services are, however, conflicting for involved social users and policy makers. Furthermore, these ecosystem services may alter due to climate change, land use change, urbanization, or a change in river management. The various stakeholders involved with rivers and floodplains currently lack the necessary tools to compare the value of the various, often conflicting, ecosystem services attributed to floodplains in order to make more balanced policy and management decisions. A sustainable management of future floodplains requires in the first place a fundamental insight into the various geomorphological, hydrological and ecological processes and their interactions. In order to get a detailed understanding of the sensitivity of floodplain geo-ecohydrology to changing driving forces and controlling factors, and in order to study the dynamics of floodplains under changing socio-ecological conditions, an interdisciplinary approach is needed, in which this interplay of processes is studied in a holistic way. The Future Floodplains project (www.futurefloodplains.be) is focussing on this interaction between geomorphological, ecological and hydrological processes in Flanders' floodplains. In the present study, as part of the Future Floodplains project, the geo-ecohydrology evolution of the floodplain through time is reconstructed using an interdisciplinary approach. Understanding the relation between long-term floodplain changes and human disturbances in a catchment is crucial to model floodplain response to future socio-ecological changes. Such long-term perspective can provide a framework showing the possible magnitude and rate of floodplain changes that can be expected as a response to changes in land use, climate or floodplain management. Moreover, long-term data can be used as a baseline to understand long-term variability and interaction between ecological, hydrological and geomorphological processes. It can also provide insights in the nature of floodplains before significant human impact. Many studies in NW and Central European catchments have shown that floodplains underwent important changes through the late Holocene under influence of human activities. However, a detailed model of the impact-response relationship is lacking. Therefore, this study aims to provide insights in the spatial and temporal relation between human impact and changing floodplain geo-ecohydrology, for river catchments in Flanders, Belgium. As such, the study wants to provide more insight in the potential vulnerability of fluvial systems to future changes in a catchment.

2 METHODS

This study focusses on three river catchments in Flanders, Belgium; i.e. Dijle River, Nete River and Demer River. Special focus is on the Dijle catchment south of Leuven (758 km²), situated in the central Belgian loess belt. In this study, a holistic interdisciplinary approach is used, combining geomorphological and ecohydrological data, to provide a catchment scale understanding of human influence on floodplain geo-ecohydrology. Reconstruction of the floodplain morphology is retrieved from coring data, grouped in transects across the floodplain, at several study sites. Textural data, organic matter and carbonate content and other sedimentological properties were used to identify different lithostratigraphical units. A detailed chronology of the floodplain changes is provided by more than 50 AMS radiocarbon ages. Floodplain ecohydrology was reconstructed based on palynological analysis and testate amoebae analysis. In addition, palynological analysis was used to reconstruct regional vegetation changes throughout the Holocene. Data on human impact was extracted from the palynological data based on statistical analysis (cluster analysis and nonmetric multidimensional scaling (NMDS)).

3 RESULTS AND DISCUSSION

The results show that during the Neolithic Period, human impact was nearly absent and floodplains consisted of strongly vegetated marshy environments where organic material accumulated, which is considered as the natural state of most of the floodplains in Flanders. It was an environment with limited sediment discharge and sediment deposition. Water transport occurred through a multi-channel or diffuse water-network, without a clear river channel. Such a floodplain environment resulted in peat and gyttja accumulation. From the Bronze Age onwards, human impact increased and caused an increase in soil erosion and hillslope-floodplain connectivity. Time-differentiated sediment budgets indicated an increase in anthropogenic soil erosion and colluviation from this period onwards.

Consequently, sediment input in the floodplain system increased. Simultaneously, floodplain geoecology changed from a marshy, forested environment towards an open floodplain dominated by clastic overbank deposits. This transition in floodplain geo-ecohydrology can be seen as the indirect result of an intensification of agricultural activities in the entire catchment. Based on these data, a generalized model of floodplain development in one of the catchments, the Dijle catchment, is presented: At the scale of the entire Dijle catchment, the gradual changes in floodplain morphology coincided with the gradually increasing human impact in the catchment, which suggests a linearity between the external forcing (human impact) and geomorphic response (floodplain change). However, at the narrow floodplains in the headwaters, the gradual increase in human impact contrasts with the abrupt change in floodplain geoecology, only triggered when human impact reached a threshold. Observed differences at catchment scale in time-lags and in the process-response model are attributed to differences in hillslope-floodplain connectivity, the location within the catchment and to differences in the timing and intensity of human activities between subcatchments.

4 CONCLUSION

This study demonstrates that floodplain geo-ecohydrology changed during the Middle and Late Holocene under influence of increased human impact in the catchment. During the Neolithic Period, human impact was nearly absent and floodplains consisted of a strongly vegetated marshy environment where organic material accumulated, which is considered as the natural state of the floodplain. From the Bronze Age onwards, human impact increased and caused an increase in soil erosion and hillslope-floodplain connectivity. Consequently, sediment input in the floodplain system increased and floodplain geoecology changed towards an open floodplain dominated by clastic overbank deposits, mainly as the indirect result of an intensification of agricultural activities. The study shows that a holistic approach, integrating data from different study sites on a catchment scale, is needed to get more insights in the driving forces of environmental changes. Moreover, the study provides a framework showing the possible magnitude and rate of floodplain changes that can be expected as a response to changes in land use, climate or floodplain management.

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