# 1 ABSTRACT

The interaction between vegetation, water flow and geomorphology has created diverse fluvial landforms on the Earth. Investigating the interaction between these elements also has significant engineering value. The interaction has been studied extensively in last decades. By using numerical model that developed rapidly in the last decade, vegetation effects, i.e., vegetation distribution and flexibility, on the transitional and equilibrium river morphology are discussed in this study. The effects of vegetation transect distribution on braided river morphology, and effect of flexibility on reach-scale river morphology has been firstly demonstrated. The problems are investigated through simplified scenarios aiming to understand the fundamental interaction between vegetation and river morphology. The results have compensated the bio-hydro-geomorphology interaction triangle and deepened the understanding of the interaction.

Firstly, a numerical experiment is performed to investigate the effects of floodplain vegetation combined with various initial low water channel planforms on the meandering development in a gravel-bedded river. Three different low water channels, whose wavelengths are determined by an empirical criterion of the mobility of alternate bars through river bends, are studied. Two different floodplain covers are considered: a bare floodplain and a vegetated floodplain. The simulation configurations are based on the Otofuke River at Hokkaido. Results show that with suitable initial low water channel planform and floodplain vegetation, meandering develops in a gravel-bed river without periodic vegetation establishment on bare bars. The sinuosity in the simulation is close to the river in the field. Meandering develops from two processes in gravel-bed rivers, (1) alternate bar growth with an erodible bank and (2) growth from the initial low water channel bend. The wavelength and amplitude of developed meandering are similar. The results suggest that appropriate initial low water channel and floodplain vegetation is sufficient condition for meandering initiation in a gravel-bed river. Furthermore, vegetation establishment

on the floodplain is not a necessary condition for meandering development in short-term river morphology development. This chapter demonstrated vegetation on the floodplain can bring serious damage to river embankment in a vegetated river, and implies the important role of water edge vegetation in the formation of channel meandering.

Since the combination effect of floodplain vegetation and channel planform may induce serious embankment failure, countermeasures are necessary for the management of a vegetated river. In the Satsunai River in Hokkaido, reopening of a closed channel on floodplain is used as a measure to reduce embankment failure risks and remove vegetation coverage. To evaluate the performance of the reopened side channel, the morphological change of river reach (between 31.0 km and 28.8 km from the downstream confluence) during the 2019 flushing flood is simulated by the hydro-morphological model, iRIC Nays2DH. Results show that numerical simulation can capture the trend of river morphological change around the bifurcation introduced by the reopening, but the erosion in the reopened side channel is overestimated compared to field-measured data. The morphology of the side channel is quite stable to the flushing flood based on the field measurement after both 2019 and 2020 flushing floods. The inactive morphological response of the reopened side channel to the flushing flood is inefficient in reactivating the river bed. By narrowing the inlet of another side channel near the bifurcation, more discharge has entered the bifurcation and increased the efficiency of the reopened side channel according to the simulation. The results suggest that by artificially changing the low water channel planform and redirecting the flow, short-term morphological responses can be modified to meet river management requirements. Combined with previous chapter, appropriately modifying the floodplain, e.g., artificially creating a new watercourse on the floodplain, can reduce the risks brought by vegetation expansion.

Second, the effect of vegetation distribution on river morphology in a braided river is studied. Vegetation distribution along river transects is controlled by hydrological conditions and flow disturbance. It can also be influenced by human activities. As one of the most dynamic river patterns, braided river can be significantly influenced by vegetation encroachment, while the effect of vegetation distribution along river transects on braided river characteristics is still unknown. A depth-averaged hydro-morphodynamic model is employed to study the influence of vegetation transect distribution as the development of numerical model in the last decade has proved its efficiency in studying the interaction between vegetation and river morphology. Rather than discussing specific reason that induces different vegetation distribution and their effects on river morphology, the problem is generalized and studied by varying the vegetation habitat extension. Two patterns of transect distribution of vegetation have been investigated: (1) Vegetation establishment near the low water channel; and (2) Vegetation establishment on bar tops and keeps distance from the low water channel. The model has successfully reproduced the reduction in braiding index of a vegetated braided river. The results show that transect distribution of vegetation has a significant influence on the statistical properties of braiding river bed elevation. Bed variance increases with the increase of vegetation habitat area in both distribution patterns. Skewness and kurtosis decrease and increase with the increase of vegetation habitat area in case of type (1) distribution, respectively. With a distribution type (2), the relationships between skewness, kurtosis, and vegetation habitat area are opposite. These results have provided an extra explanation for the discrepancy in the skewness between field observation and laboratory experiment and show implications for managing vegetated braided rivers with a gravel bed. For restoration project in a vegetated braided river, vegetation near water edge should be removed rather than vegetation on bar top. This chapter shows that only with a vegetation belt that is close to the water edge, the river morphology can be significantly influenced. The results further prove the importance of water edge vegetation in the fluvial system.

Finally, the effect of vegetation flexibility on river morphology is investigated. The flexibility of riparian vegetation affects the flow around vegetation patches and alters bed shear stress below and surrounding the patches. To investigate the effects of vegetation flexibility in a fluvial bio-hydro-morphodynamic simulation, a model to predict flexible vegetation reconfiguration is incorporated to a bio-hydro-morphodynamic model based on Delft3D. The effects of vegetation flexibility in a gravel bed river with alternate bars have been studied. *Phragmites japonica*, which is an extensively existing reedy grass in riparian environment is the target vegetation. Results show that vegetation flexibility impacts river hydrodynamics and morphology development processes. With flexibility accounted for, the water depth decreases, averaged Shields stress in vegetation patch increases, and active channel width widens. Erosion and deposition in the channel are reduced. The significance of flexibility depends on multiple factors, i.e., stem density growth rate, rigidity, and sediment size. With a fast stem density growth rate or large gravel size, the difference between flexible and rigid cases can be neglected. Compared to previous chapters, the effect of flexible water edge vegetation is demonstrated in this chapter. With flexibility considered, the floodplain formation rate can be better estimated.

In this thesis, the effects of riparian vegetation on transitional and equilibrium river morphology have been studied. The results demonstrate the significant influence of vegetation, i.e., its distribution and flexibility, on river morphology. The results emphasize the necessity to understand the geomorphological influence of water edge vegetation, including its spatial distribution and mechanical properties.