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論文の要約

Forestation in a river creates a valuable natural environment, which is mainly important in terms of bank stabilization and ecological restoration, but sometimes it can become a problem because it enhances flow resistance, reduces river flow downstream and accumulated debris of vegetation can increase the drag force around bridge piers while causing large scour holes around them. Furthermore, excessive forestation by a single species can sometimes affect the biodiversity of the river ecosystem.

Therefore, for proper rehabilitation and management of river environment, it is important to determine what kind of flood disturbance can increase the diversity of vegetation but control the rate of forestation in a river habitat. When the vegetation condition on the gravel bars of the river is considered, with the increase of flood disturbance, the possibility of washout of vegetation on gravel bars increases, but on the other hand, i.e., when the flood disturbance decreases, the possibility of vegetation existence on gravel bars will be increased. Moreover, it has been found that vegetation existence on gravel bars is affected mainly by flood intensity and frequency. Since flood disturbance is the combined effect of flood intensity and frequency, some indices are required to define middle-class flood disturbance for the above purpose.

The middle-class flood disturbance proposed in early studies have focused on tropical forests but did not define it for river habitat, and it was not included in previously defined biodiversity indices. In previous studies such indices have been derived to define middle-class flood disturbance based on investigations on Arakawa and Tamagawa Rivers, Japan, but the trend of diversity of vegetation with those indices was found to be different for the two rivers. Therefore the applicability of the flood indices needs to be verified with other rivers, while determining the reasons for the differences. In predicting the possibility of forestation in rivers, previous studies discussed mainly the washout condition of trees. However, the degree of damage on trees is also considered in this study because trees that were broken or bent down by a flood might regenerate after the flood, and the washout condition of grasses is also considered.

Therefore in this study the relationship between the diversity index of vegetated area calculated by the vegetation species map and flood disturbance index, a kind of expectation value of flood disturbance, was investigated for four

gravel bars in the Karasu River and compared with the results of previous studies of the Arakawa and Tamagawa Rivers. The relationship between the diversity of vegetated area on gravel bars in the middle stream of a river and flood disturbance characteristics was investigated. Six Regions (A-E) were defined to classify the possibility of forestation in a river based on two indices: BOI, to evaluate trunk breakage, and WOI, for washout condition of trees and grasses. According to definition, in Region A there is a high possibility to be a forest and in Region E forestation is not easy to be occurred. The diversity of vegetated area was found to be correlated with the flood disturbance index in Regions A and E for the investigated rivers. In addition, the diversity of vegetated area in Regions A and E showed the same trend for the Karasu and Arakawa Rivers and a different trend for the Tamagawa River, where the trend was affected by previous floods of the investigated gravel bars. However, this indicates the possibility of expressing middle-class flood disturbance of gravel bars in the middle stream of rivers and confirms the applicability of studies of other rivers investigated.

But Regions B, C, and D did not show any noticeable trend. In case of Region D, there can be several reasons for that. Firstly, tree-type vegetation was found less frequently on the investigated gravel bars, and at the same time, the existing trees were almost grown ones that were rarely subjected to breaking. Secondly, most of the gravel bars were occupied by perennial grasses rather than annual grasses, because by definition, Region D is related to breaking or bending of trees and washout of annual grasses.

In Regions B and C, flood disturbance values were found to be small and no trend could be identified. According to definition, the tree diameter in Region B is small (related to initial development of vegetation) with a large gravel size, and Region C has a larger tree diameter with a smaller gravel size. However, the trees on the investigated gravel bars were not very young, having a larger tree diameter and large gravel size diameter, so that the flood disturbance in Regions B and C was small.

Furthermore, middle-class flood disturbance was not clearly defined in terms of flood return period (frequency) in previous research, so this study was focused on defining a specific range of flood return periods for middle-class flood disturbance in rivers. Based on the analysis it was found out middle class flood disturbance for the investigated rivers can be defined for return periods of flood between 3 – 12.5 years. Also based on the above results a methodology was proposed for river cross-section design towards increased diversity of vegetation in river habitat.

The second stage of this study was based on the sedimentation and flow structure in compound water channels. Compound water channels are one of the most important flood control methods used in river engineering since in many areas where flooding cannot be allowed because of infrastructure around the rivers. For the purpose of increasing flow capacity, extension of only low channel width would not be enough in some cases because with time, sand bars can be formed in the low channel due to reduction of flow velocity and cause the reduction of flow capacity. Therefore construction of middle water channel by excavating floodplain would be a better solution in this matter.

However, it also creates opportunity for frequent inundation on middle water channel bed due to lowered floodplain. Then due to the velocity difference between low channel flow and middle channel flow, complicated flow patterns are generated and the shear layer that develops at the interface between main channel and middle water channel (floodplain) affects the turbulent flow structure. This complex turbulent flow structure leads to generation of two types of vortices. One is horizontal vortices that are generated due to shear layer of the streamwise flow and other type is vortices with longitudinal axis called secondary currents due to anisotropy of turbulence. Since these vortices enhance lateral mass and momentum exchange, it causes a net transfer of sediment from the low channel to the floodplain. Moreover, sediment will tend to settle out once transferred to the floodplain region because of the reduced transport capacity of the flow. Therefore with time there is a possibility of increasing sedimentation on floodplain, which can promote the growth of vegetation and decrease of depth. This study hypothesized that the slope of the middle water channel in transverse direction could be an important factor to control the sedimentation on middle water channel bed so that vegetation growth also can be controlled on it. Although many studies have been conducted related to compound channel flow, the studies related to the effect of inclined floodplain on sedimentation and flow structure with physical simulation of sedimentation are still rare. Therefore this study was focused on turbulent flow structure and sedimentation on flat and inclined as well as smooth and vegetated floodplain. Two types of experiments (PIV-Particle Image Velocimetry to evaluate the change of the secondary flow, and the Reynolds stresses related to sediment transportation and sediment experiment to observe sediment deposition) were conducted for flat/inclined floodplain, plain/vegetated floodplain, and low/high water depths.

From the results it can be seen that possibility of sedimentation on floodplain is increased with vegetation due to the momentum transport towards floodplain from the interface of low channel. Also it can be concluded that construction of middle water channel with inclined floodplain can be effective in minimizing sediment deposition on middle water channel bed in short term, but in long term when vegetation starts growing on it, it would become less effective towards that purpose. (Still it performs better than flat floodplain). Furthermore sediment deposition on inclined floodplain would be less for low water depths in comparison to high water depths with or without vegetation on floodplain. This situation in high water depth is similar also in case of flat floodplain. In addition, it can be concluded that on vegetated floodplain, for low water depths sediment deposition would be distributed over the floodplain while for higher water depths sediment deposition would be prominent in the middle of floodplain.

Finally, this information on river cross-section shape can be used to discuss the relationships between flood indices of middle class flood disturbance and diversity of vegetation of first part of this study, based on the proposed method for design of river-cross section shape. In future studies, it needs to be checked with different river channel morphologies, with different flood disturbance effects and vegetation conditions. It will lead for more effective and economical river bed design with increased diversity of vegetation and proper management of river habitat.