# THE RESPONSE OF RIPARIAN VEGETATION TO SEDIMENT DEPOSITION IN MIDSTREAM RIVER CHANNEL

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Gravelly channels are typical landscapes of the midstream of rivers providing a unique habitat for pioneering species. These species are recently being replaced by intensive vegetation colonization. A better understanding of the cause of this situation and restoration strategies are requested in many Japanese rivers. We hypothesized that the increase of vegetation cover is caused by the reduction of gravelly sediment which is trapped by dams. Aerial photos of several rivers were analyzed to identify the period required for the re-colonization of vegetation after a flood, in relation to the condition of overlying sediments. Longer periods were required for re-colonization at sediment deposition sites, compared to sites without deposition or eroded sites. Deposition of cleansed sediments, which are low in moisture, nutrients and seeds content, over the original substrate, delayed the germination and the growth of vegetation. The Dynamic Riparian Vegetation Model (DRIPVEM) was developed to describe this process. Simulated results reflected observations of vegetation distribution and delay for re-colonization. Results suggest that vegetation coverage increases as the size of sediment deposition area, the magnitude and the frequency of floods decreases. We concluded that the reduction of unstable sediments in the river channel was the main cause of the recent increase of vegetation colonization in riparian areas.

## 1 INTRODUCTION

Gravelly areas are typical landscapes of midstream riparian zones providing a unique habitat for diverse pioneering species. In many countries, coverage of gravelly substrates is decreasing as vegetation cover increases in riparian areas. The cause of this situation remains unclear. The increase of tree coverage is also a serious problem for flood protection as washed trees can cause damage to infrastructures [1].

Frequent flooding is a crucial process for preserving the gravelly surface of riverbanks by washing off trees and other vegetation. The construction of flood control dams reduces the peak flow of rivers and stabilizes the channels, which reduces the potential for flushing riparian vegetation downstream. This potential is gradually recovered with additional inflows downstream. Thus, highly vegetated riparian habitat may be found over 20 to 30 km downstream of dams [2].

In rivers with a gentle slope, fine nutrient-rich sediments accumulate during floods. In steep rivers however, coarse gravelly sediments are moved and then deposited on the riparian areas during floods. The deposition of cleansed coarse sediments produces a layer containing few nutrients and little moisture in the riparian zone, which suppresses the recovery of vegetation [3].

Here, we assumed that sediment transportation reduces the vegetation in riparian areas of river channels, and that the reduction of sediments deposition was one of the main reasons vegetation coverage has been increasing. The Dynamic Riparian Vegetation Model, DRIPVEM [4, 5], which previously has been mainly focused on nutrient dynamics in riparian areas, was used to test this hypothesis.

## 2 METHOD

### 2.1 Aerial images and field observations of riparian areas

Aerial photos with resolution between 1-1.5m and scale between 1:20000 to 1:10000 and satellite images of 109 major Japanese rivers covering the last 60 years, along with the present condition of neighboring country rivers were analyzed with Arc GIS 9.3 software to obtain the general trend of vegetation coverage. Recent photos and field observations were used to evaluate the distribution of trees and herbaceous vegetation, as well as the timing of their recruitment or disappearance.

The geomorphology of river sections in five selected rivers was surveyed in 200 m sections every 5 years. Water levels were measured automatically every hour by several stations. The monthly maximum peak flood levels at the targeted sites were calculated from hourly flood level data. The areas where surface sediments were eroded or sediments were deposited, were obtained with aerial photos. The vegetation re-colonization process was then assessed by series of aerial photo and field observations.

Samples of herbaceous vegetation were collected at target sites during summer covering the eroded and deposited locations. Fifteen random sampling points were selected for each location for herbaceous plant sampling. These samples were then dried in an oven to obtain dry biomass of each species at the laboratory.

### 2.2 Model Analyses

The Dynamic Riparian Vegetation Model (DRIPVEM) [4, 5] was used to understand the effects of sediment condition on the vegetation coverage of the riparian zone and sandbars. The model consists of modules for the recruitment and later growth of trees, herb biomass based on the edaphic condition, and the nutrient budget of the riparian soil based on the flood records, and geomorphology. The structure of the model flow is shown in Figure 1. The model consists of four modules: Hydro, Herb, Tree, and Soil. The Hydro module provides the peak flood level and change of channel morphology caused by each flood. The Herb module simulates the herb biomass as a function of soil nitrogen concentration, substrate sediment size and shading of neighboring trees. The Tree module provides the density and morphology of tree species. This is given by the recruitment density associated with the occurrence of suitable floods, and density reduction in the growth process due to self-thinning, and flushing by succeeding floods, depending on flood level (erosion depth) and tree age [5]. Tree morphology is given by species and organ-specific allometric functions based upon tree age. Soil nitrogen concentration is given by the Soil module, which calculates the nitrogen uptake and the release in the growth and decomposition processes of herb and trees. Other than that, the effects of nitrogen fixation, atmospheric fallout and denitrification are provided empirically. In the simulation, the targeted riparian zone is divided into10m by 10m meshes, then under the given flood condition, the above processes were calculated for a monthly time step.

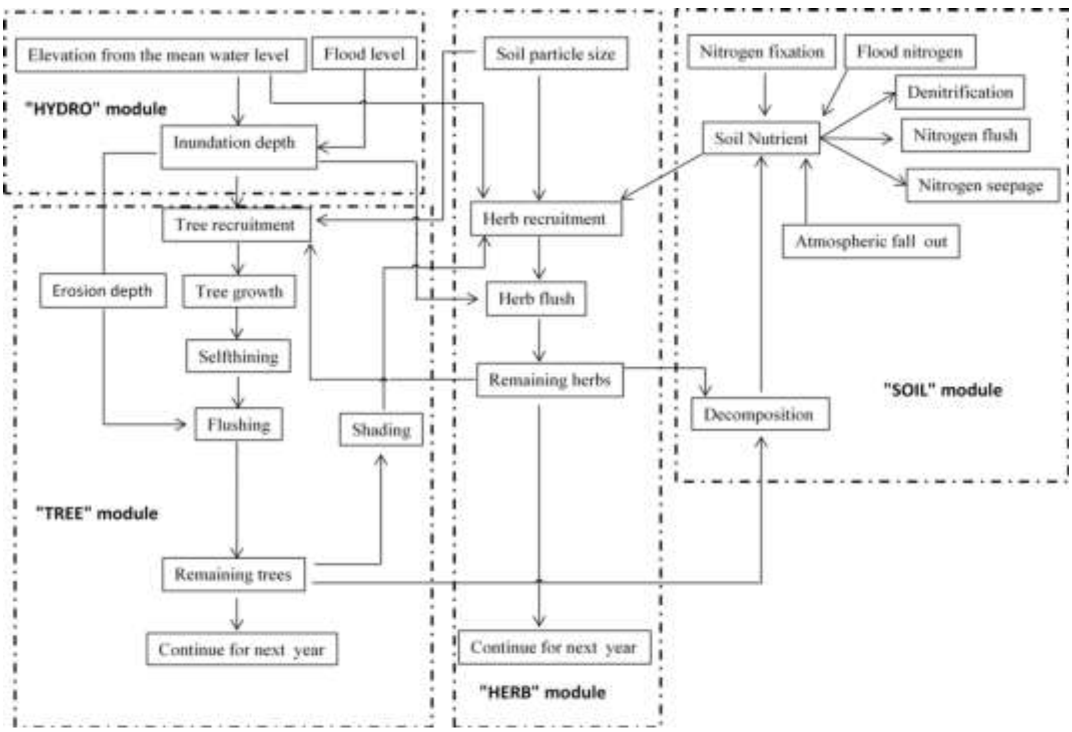


Figure 1. The schematic representation of the model flow

## 3 RESULTS

### 3.1 General trend of vegetation coverage of Japanese Rivers

Analyses of 60 years of aerial photos indicated that the vegetation coverage of river channel area (between levees) was nearly zero in 1940s. Sixty years later, the vegetation coverage had increased up to 40%. Tree coverage was relatively higher in the northern area and on the Coast of Japanese Sea, while, it was lower in the metropolitan area. The coverage by herbs was much higher than that of trees in the metropolitan area. In fact, in Korean rivers, the fraction of tree coverage was relatively high. On the other hand, the fraction of non-vegetated area in the upstream basin has a negative correlation with vegetation coverage on the riparian zone (Figure 2). Afforestation of the upstream areas and increasing farming and urbanization in the catchment reduce gravelly sediment production. Therefore, the reduction of barren area in the upstream increases the riparian vegetation cover on the riparian zone.

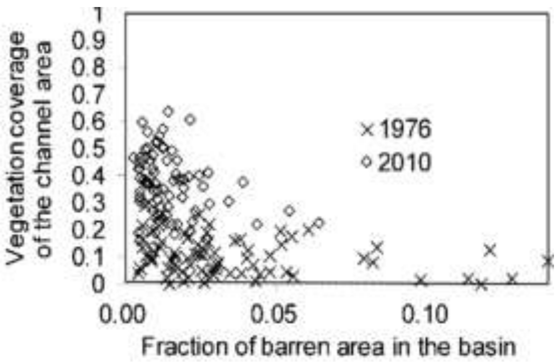


Figure 2. The proportion of vegetation coverage in the channel according to the fraction of barren land in the basin

### 3.2 Validation of the model with respect to vegetation distribution

The model was applied to several rivers to simulate the distribution of dominant tree species and herb biomass. The simulated vegetation distribution was compared with observed vegetation distribution on the study reaches. The positive and correctly simulated percentage of meshes for bare area was 50 to 70%. It was about 70% for trees while herbs showing about 80% compatibility.

### 3.3 Effects of sediment load on vegetation colonization

Figure 3 presents the comparison of observed and simulated time (years) required for colonization of herbs after a flood. The simulation provides a nearly perfect agreement with the observed results. Although vegetation recolonizes relatively quickly at eroded sites, it takes three to four years at deposited sites. Simulated vegetation coverage with different flood level and different fraction of deposition is shown in Figure 4. It can be clearly seen that the fraction of the deposited area has a strong impact to reduce the vegetation coverage in a long run.

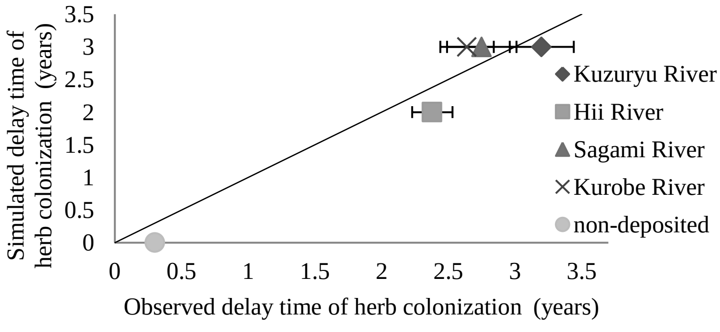


Figure 3. The comparison of observed and simulated herb colonization delay time

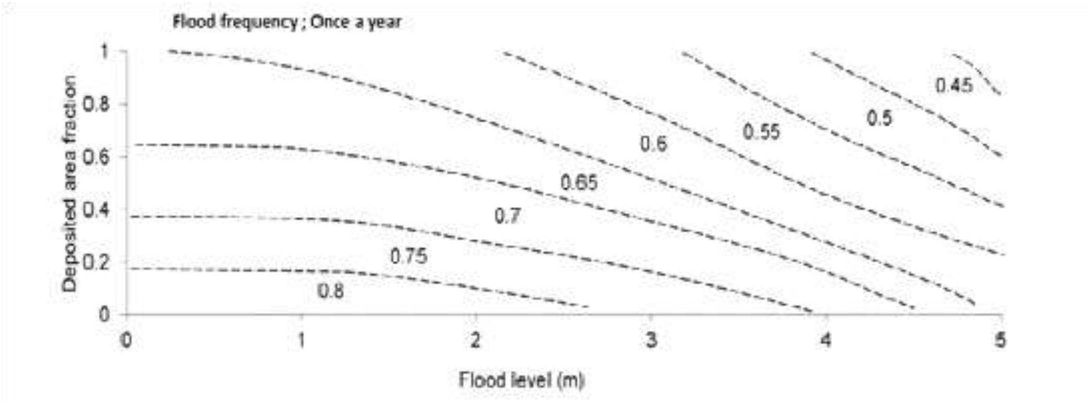


Figure 4. Vegetation coverage with respect to flood level and the proportion of the area covered by deposited sediments. Vegetation cover is indicated by the inset numbers, with dashed lines separating 5th percentiles

## 4 DISCUSSION

Gravelly sediment loads are transported by flood flows and re-distributed in the channel, through the concurrent processes of erosion and deposition. At eroded sites, the underlying sediments are exposed after removal of the surface sediment. They maintain the original seed bank; contain organic matters and nutrients, and fine sediments in the matrix of gravelly sediments, though partially removed by interstitial currents. Thus, re-colonization of vegetation is relatively fast after the flood compared to the deposited sites.

Deposited sites, on the other hand, are covered with gravelly sediments, which are cleansed off organic matters and fine soils while transported and contain little nutrients and moisture. Thus, it takes a particularly long period for the re-colonization of vegetation and the growth of large herb biomass.

Gravelly sediments are normally transported along the bed surface, while most seeds are floating when transported. Thus, seeds are segregated from the sediment load during transport, and re-colonization of vegetation takes a long period after floods at the deposited sites of gravelly sediments. Therefore, more frequently occurring and wider gravelly sediment deposition areas rather than erosion at flood time delays the development of vegetation in the riparian zone.

Moreover, the construction of dams and weirs, afforestation in the catchment reduce sediment inflow into the river channel. In particular, gravel mining has an extreme impact on gravels in the river channel. All these factors decrease the gravel sediment transport and the deposition at flood time, and are likely causes of the increasing vegetation coverage of the riparian zone seen in recent years.

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