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FORESTATION IN GRAVEL-BED RIVERS AND AN ATTEMPT OF ITS CONTOROLLING

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Recently in Japan, riparian trees in the course of gravel-bed rivers have been very much increasing, while gravel beach without vegetation has been decreasing. Such a situation reduces the capacity for flood discharge. Furthermore, it brings about the degeneration of inherent habitat, causing a loss of original species peculiar to gravel-bed rivers. In order to improve such situation, we need to examine how river vegetation spreads and how to prevent their expansion in gravel-bed rivers. In this paper, we focused on the excessive growth of *Robinia pseudo-acacia*, the dominant species in river forestation. The zone where *Robinia pseudo-acacia* spreads can be divided into two types. One is the stable zone which is rarely submerged even during floods, where the tree can grow under a static environment without flood disturbance. The other is the submerged unstable zone where *Robinia pseudo-acacia* may incline or fall down according to the magnitude of flood disturbances. We focused on the excessive growth of *Robinia pseudo-acacia* in the latter case and proposed an effective method to prevent forestation by leading flood flow over gravel bars.

Key Words **:** *Riparian trees, gravel-bed river, bed-excavation, flood disturbance, Robinia pseudo-acacia*

1. FORESTATION OVER BARS

By means of aerial photos and the records of channel cross-sectional figures, bar morphological change and the extension of the forest area were investigated in the gravel segment (average bed slope=1/150, average size of bed material=10cm) of the Watarase River, a tributary of the Tone River. Figure 1 shows that one of bars in the observation area enlarged and its vegetation-covered zone increased in size from 1966 to 1991. Most of the vegetation consists of one particular species of tree, *Robinia pseudo-acacia*, introduced by the sabou-works for greening hillslopes in the upstream mountain region of the Watarase River. Around densely grown vegetation, the stream velocity is retarded and the fine materials suspended in the water can be deposited, so that the area of the bar increases and vegetation grows widely on the newly deposited zone. The temporal change in the area where vegetation occupied in a sample of bars along the gravel-bed segment of the Watarase River in question is summarized in Figure 2. Thus, in recent years, about 80% of the area in each bar has become covered with forest and the gravel beach decreased markedly. In rivers undergoing bed degradation, such a forest has few chances to be submerged, and even if submerged, cannot be easily washed away during medium-sized floods or floods regulated by dam-controlling, and therefore the wood-landscape still remains and expands widely.

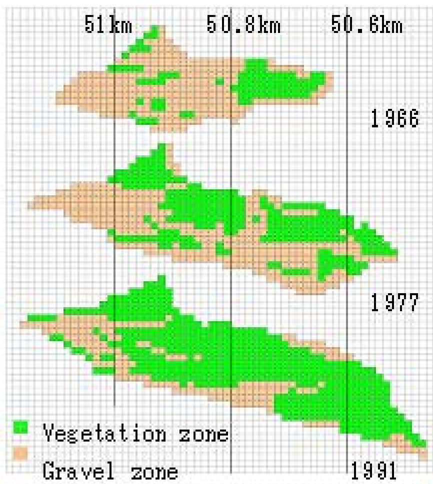

Fig.1 Plane view of the bar morphological changing with forestation in gravel-bed segment of the Watarase River from 50.6km to51.0km

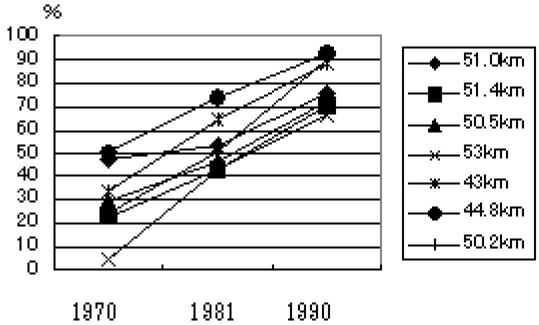

Fig.2 Temporal changing of the forested area in gravel-bars

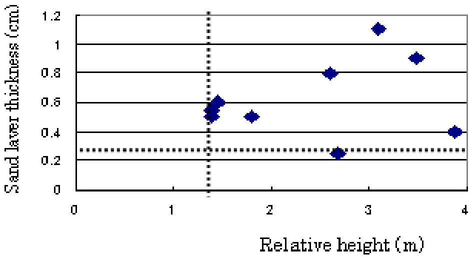

Fig.3 Habitat of *Robinia pseudo-acacia* forest of described by relative height and sand layer thickness

2. RESPOSE OF *"ROBINIA PSEUDO ACACIA"* BY FLOOD DISTERBANCE

Plant communities can be divided roughly into two groups by relative height of the respective habitat: either (a) growing along stream sides; or (b) growing on the higher parts of bars and flood plains. The plant habitat in rivers is described both by this relative height above water level and also by the grain size distribution of sediments (Ishikawa, 1991). Our field study on the forest of *Robinia pseudo-acacia* indicates that the surface layer composed of sand and silt is very important for propagation as it is in this type of ground that its rhizome grows very easily (Shimizu et al (1999)).

Lee et al (1998) proposed that the growth condition of the plant can be represented in a coordinate system of relative height above a water surface at the annual mean of daily discharge versus sand layer thickness. Using this method, Figure 3 shows the habitat of *Robinia pseudo-acacia* by using data from our investigation. This suggests that it is necessary for both layer thickness and relative height to be above critical values to enable propagation, but the data points are widely distributed. In particular, the stands of *Robinia pseudo-acacia* at low height are sometimes submerged and are subject to medium-size floods. The characteristics of the growth and propagation of *Robinia pseudo-acacia* must therefore be different in the positions at low and high levels.

In 1998, the Watarase River has experienced a flood and the forested bar at 43.6km was disturbed. Figure 4 shows the transverse distribution of water surface elevation and the maximum size of movable

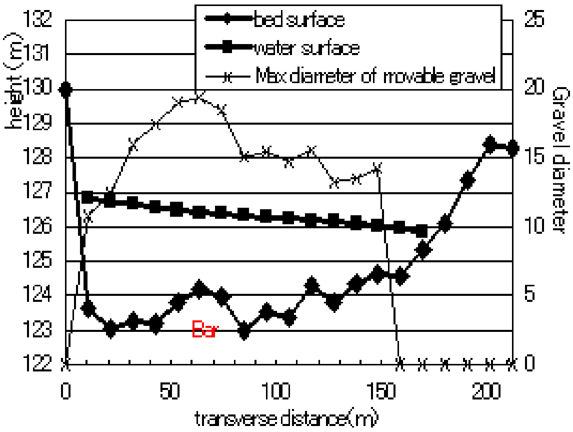

Fig.4 Transverse distribution of calculated water surface and maximum diameter of movable gravel at the 43.6km cross-section in the peak discharge of the 1998 flood

Photo 1 Destruction of woodland at just after the 1998 flood in the 43.6km bar

Photo 2 Germination from a fallen trunk and around the ground

Photo 3 Germination from a fallen trunk (one year after the 1998 flood)

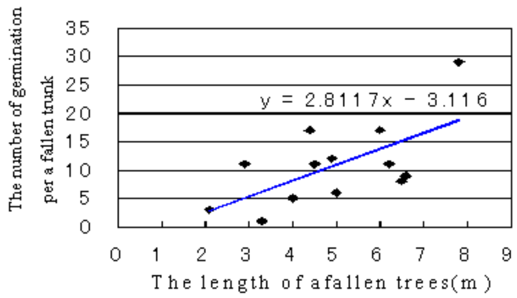

Fig.5 Number of germination per a fallen trunk (one year after the 1998 flood)

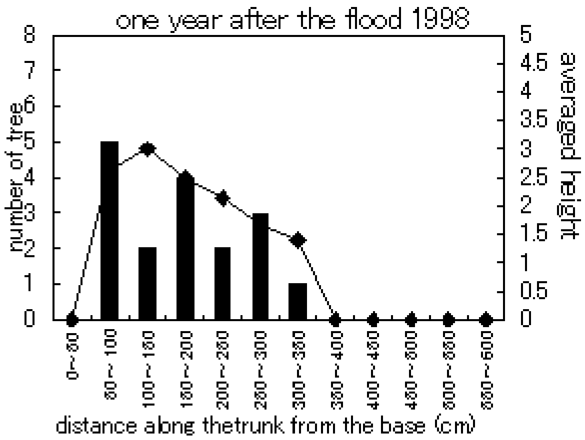

Fig. 6(a) Number of new tree and its average height at an interval of 50cm from the base along the a fallen trunk (one year after the 1998 flood)

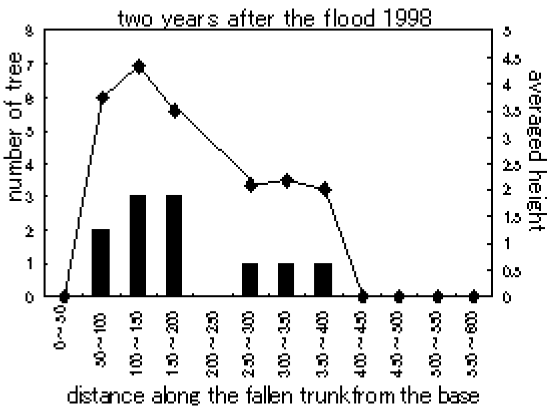

Fig. 6(b) Number of new tree and its average height at an interval of 50cm from the base along the a fallen trunk (two years after the 1998 flood)

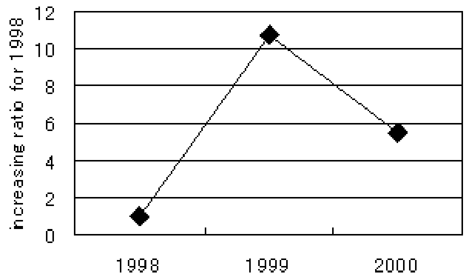

Fig.7 Change of the total number of Robinia pseudo-acacia in the bar at 43.6km

gravel materials reproduced by 2D-flow numerical calculation at the peak discharge of the flood, and shows that the range of movable maximum gravel size in the bar area is about 10-20cm. Here our main interest is in what degree of damage the *Robinia pseudo-acacia* forest receives. Photo 1 depicts the appearance of this bar just after the flood and shows that most trees(*Robinia pseudo-acacia)* had fallen. The forest was destroyed, but its roots remained inside the bed surface layer. After several weeks, new germination both from the trunks of fallen trees and from rhizome inside the bed layer was widely observed (Photo 2).

This growth characteristic is due to vegetative propagation, a property which the artificially introduced *Robinia pseudo-acacia* shares with the native *Salix* often seen along riversides. The observation demonstrates rapid reforestation of *Robinia pseudo-acacia*, and the same situtations must have occurred after the experienced floods. One year after the 1998 flood, the growth rate of *Robinia pseudo-acacia* was investigated by a field survey at the same bar (43.6km). Photo 3 shows trees which have germinated from a fallen tree, and their averaged height is already over 3m. Figure 5 shows the number of germinations per trunk length of a random sample of fallen trees. The germination rate from fallen trunks was traced for 2 years. Measurements were taken of the number of new trees and their average height per 50cm section of each fallen trunk. A typical example of results for one trunk is shown in Figure 6(a), (b). Due to competition for survival, the number of germinated trees decreased over time, but the height of surviving trees increased. Figure 7 shows the change in the number of *Robinia pseudo-acacia* trees in the bar at 43.6km. One year after the flood, the number of *Robinia pseudo-acacia* had increased 10-fold compared with before the flood but by two years after the flood it had dropped to six times lower than before the flood. However, these data still clearly demonstrate the occurrence of post-flood reforestation (Shimizu et al (2001)).

Photo 4 The area of bed excavation (a pilot channel) over the forested bar

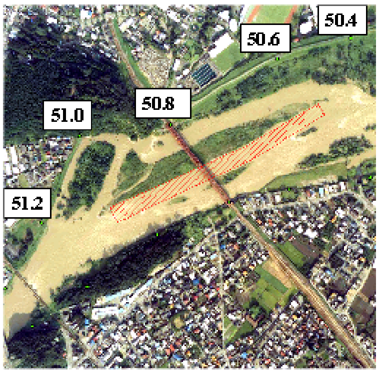

Photo 5 Flooding bar induced by a pilot channel

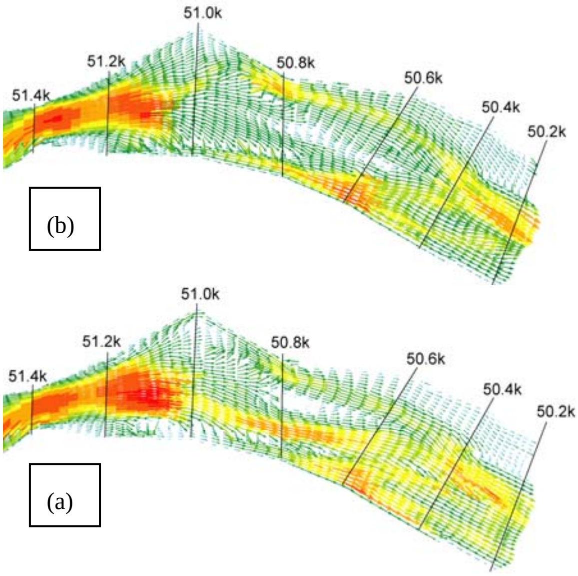

Fig.8 Calculated velocity field (a)with and (b)without a pilot channel (Iwami et al (2009))

3. AN ATTEMPT FOR CONTROLLING OF RIVER FORESTATION

In order to prevent river forestation, removal of shoots of *Robinia pseudo-acacia* in the surface layer must be required. However, the amount of external force due to the recent experienced floods is insufficient for washing them away in bars. For production of effective flood disturbances which causes bed materials to be in motion and especially brings about bed erosion events, a pilot channel was designed as the flood way leading flood flows into the forested bar by using 2D flow and bed changing simulation. The bed excavation in the forested bar (50.6km-51.0km) for making the flood way was carried out in the Watarase River, as shown in Photo 4. A flood on September 2007 brought about the active sediment transport and the marked bed degradation, according to characteristic of bed materials distribution, induced by the pilot channel (Photo 5, Fig.8). The gravel bar has recovered and reforestation cannot be seen from present situation.

4. CONCLUSION

Robinia pseudo-acacia communities are sometimes locally fallen down by flood flows, but the rhizomes send up new shoots very immediately so that the communities are formed again in two or three years, that is one of the reasons why the forestation occurs in gravel-bed rivers. This paper focused on such a dynamic process of river forestation and showed an attempt of its controlling, which can be regarded as an effective idea for the management of gravel bed rivers with forestation.

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