Roles of Fine Sediment in Woodland Expansion on a Gravel Riverbed

○Samhee LEE[1], Koh-ichi FUJITA[2], Koichi YAMAMOTO[3], Jinhong KIM[4]

1. INTRODUCTION

One of the major elements that characterizes a gravel riverbed is the existence of gravel bars without vegetation (also called white bars) exposed above the surface of the water. It has been reported that in recent years the spread of luxuriant vegetation and woodland expansion occurring on gravel riverbeds of this kind have sharply reduced the number of white bars. Such changes in the state of river beds are important phenomena that should be accounted for when evaluating the natural environment and flood safety of a river. Moreover, there is a strong demand for the clarification of this mechanism and the establishment of methods for forecasting changes in river course vegetation.

This research project, which was undertaken to clarify the basic mechanisms of the spread of luxuriant vegetation and woodland expansion, focussed a 400 m section of the Tamagawa River in Japan. The study includes a detailed investigation of various phenomena that could influence these processes and the analysis of their interrelationships from a biological and river hydraulics perspectives. This report describes the mechanisms of the spread of luxuriant vegetation and woodland expansion in the study area and presents information important for the prediction of the dynamics of in-stream vegetation.

2. Phenomena in the River Section Studied

2.1 Study Site

The study section lies between Nagatabashi Bridge (51.8 km from the river mouth) and Hamurabashi Bridge (53.2 km from the river mouth) on the Tamagawa River in the Tokyo cities. A particularly detailed study was carried out on the section between 52.2 km and 52.6 km. In this section, the average riverbed gradient (Ib) is 1/250, the average grain diameter of the river bed surface close to the low stream on the left bank side is about 6 cm, and the average distance between the levees is 275 m. The section is categorized as segment-1 (fan-shaped river course). The average annual maximum flow volume is about 600 m^3/s.

2.2 Overviews of River Course Characteristics and Woodland Expansion

(1) Changes in the Form of the River Bed and Spread of Luxuriant Vegetation

Figure 1 shows change over the years in the transverse shape of the riverbed and the distribution of vegetation at the 52.4 km location. The riverbed was largely flat in 1968, but by 1975, the riverbed had risen on the right bank side while the left bank had fallen forming a compound cross section. By 1993, the width of the low flow channel was between 40 and

1) Senior Researcher, Korea Institute of Construction Technology, Korea, samhee.lee@kict.re.kr
2) Director, Mie Work Office, Ministry of Land, Infrastructure and Transport, Japan
3) Director, Foundation of River & Watershed Environment Management, Japan
4) Professor, Chung-Ang Ubiversity, Korea

50 m and it was about 4 m in depth, while the high water channel on the right bank side was about 200 m in width. A comparison of changes in the transverse shape and changes in the vegetation distribution show that luxuriant vegetation spread in the river bed area formed by the high water channel on the right bank.

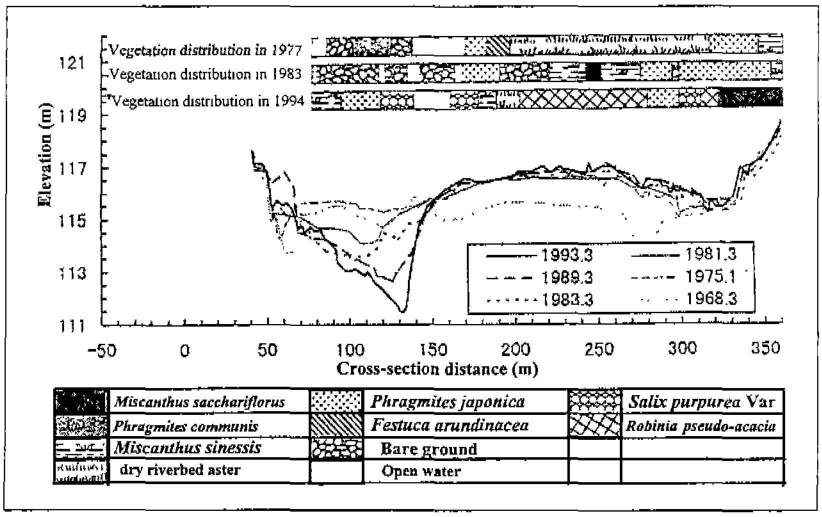

Figure 1. Riverbed Shape Fluctuation and the Spread of Luxuriant Vegetation

Figure 2 shows the changes over the years of the average heights of the low flow channel and the high water channel. This figure reveals that overall, the compound cross section characteristic resulting in a difference of more than 2m between the heights of the low and high flow channels appeared in 1975. Also, the decline of the river bed elevation on the low flow channel became marked between 1987 and 1989, and this was accompanied by the clearer manifestation of the compound section.

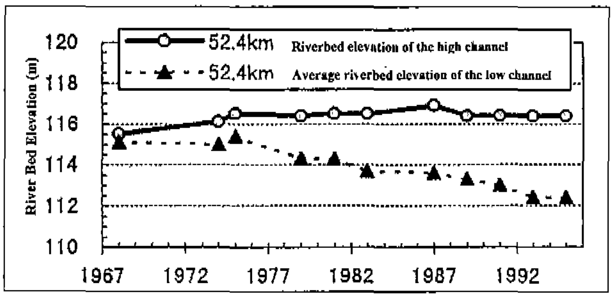

Figure 2. Change over Years in the Riverbed Elevations of the Low Flow at 52.4 km

(2) Change over Years in the Annual Maximum Flood Flow Volume and the Annual Maximum Depth on the High Water Channel

Figure 3 reveals that large-scale flooding occurred in 1974 and from 1981 to 1983. Also, the depth of the water on the high water channel was significant only during these four flood periods.

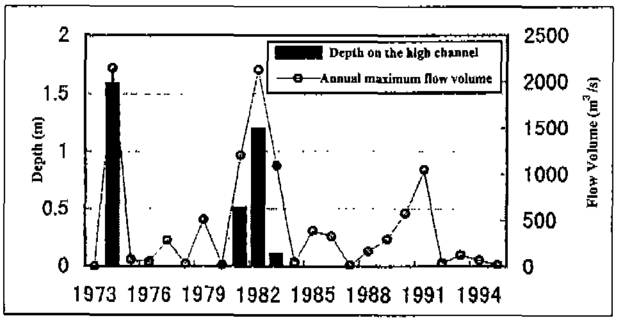

Figure 3. Maximum Annual Flow Volume and Maximum Annual High Water Channel Water Depth

(3) Characteristics of Change Over Time of the Luxuriant Growth Area of Each Vegetation Cluster

The change in the surface area of each type of cluster can be classified into four patterns(Figure 4).

① Those that declined very rapidly (bare ground)

② Those that increased rapidly after 1983 (*Robinia pseudo-acacia*)

③ Those that were extremely large in 1983 (*Phragmites japonica*)

④ Those that changed very little (*Salix integra, Miscanthus sinensis*)

Overall, during the 17 years since 1977, bare ground sharply declined. The arboreous *Robinia pseudo-acacia* and the herbaceous common reed (*Miscanthus sacchariflorus*) have expanded resulting in the spread of luxuriant vegetation and woodland.

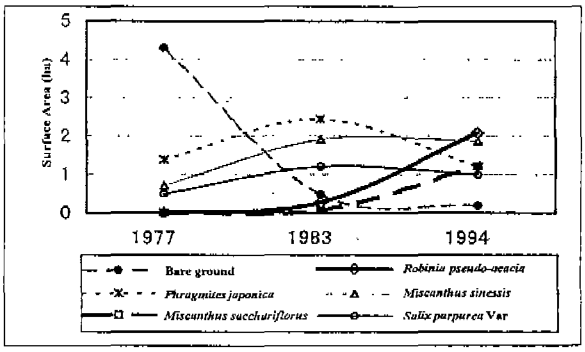

Figure 4. Change over Time of the Growth Area by Type of Vegetation Cluster

The factors contributing to the expansion of the woodlands on the gravel riverbed are generally assumed to be the reduction in the frequency of the submersion of the high water channel and the fall in the ground water level accompanying the formation of the compound cross section. The woodland area expanded slowly from a period beginning immediately after the flooding of 1974 until 1979 when the compound cross section had formed and the high water channel was almost never submerged. The growth of the luxuriant vegetation advanced between 1984 and 1989: a period when conditions were almost identical to those in the earlier period (1974-1979).

3. Relationship of the Spread of Luxuriant Vegetation with the Location Conditions

3.1 Field Survey Methods

Approximately 2m belt transects were installed along the 52.2km, 52.4 km, and 52.6 km traverse lines to investigate the relationship of each vegetation cluster with its location conditions. The types of clusters studied were the six types shown in Figure 4 that include almost all the ground cover in the study section. Field surveys were performed three times in 1997: in April, May, and August. The three location conditions considered were the grain diameter of the surface material, the thickness of the surface fine sediment layer, and the relative elevation above the ground water level. On the high water channel of the study section, fine sediment with a grain diameter equal to or smaller than the grain size of medium sand is deposited at various depths on top of the gravel river bed in a number of patterns that are described later. This layer was defined as the surface fine sediment layer. The thickness of this sediment layer was investigated with a core sampler. The relative elevation above the ground water level was obtained by hypothesizing the cross-section line of the ground water level based on the layer structure of the right bank of the low flow channel, observations of the state of seepage at the ground water level, and previous studies. The identification of the vegetation clusters and the survey of the location conditions were performed at a pitch of 10 m.

3.2 Results and Discussion

Summarizing the above results permits the following conclusions regarding the relationship between the spread of luxuriant vegetation and location conditions in the study area.

1) There is a clear correlation between location conditions and the distribution of various kinds of vegetation clusters, and these can be described quantitatively as shown in Figure 8.

2) If location conditions where various kinds of clusters exist are broadly categorized, they are bare ground type, *Salix integra* and *Phragmites japonica* type, and *Robinia pseudo-acacia* type (see Figure 8). And within the Robinia pseudo-acacia type locations, there are separate

location conditions for common reed (*Miscanthus sacchariflorus*) and eulalia.

3) Location conditions for *Robinia pseudo-acacia* that encouraged woodland expansion in the study area are extremely widespread.

As explained in 2(3), the primary cause of the spread of luxuriant vegetation and woodland expansion in the study area has been the growth of *Robinia pseudo-acacia* and common reed (*Miscanthus sacchariflorus*). As Figure 8 reveals, these do not grow where the thickness of the surface deposition of fine sediment is zero. And considering the characteristics of the river channel in the study area, it is assumed that the river bed surface was originally gravel (surface soil layer thickness of zero). The above conclusions strongly suggest that the most important factor behind the spread of luxuriant vegetation and woodland expansion studied by this project was the deposition on the surface of a layer of fine sediment. The next step was an investigation of the way the surface layer of fine sediment formed.

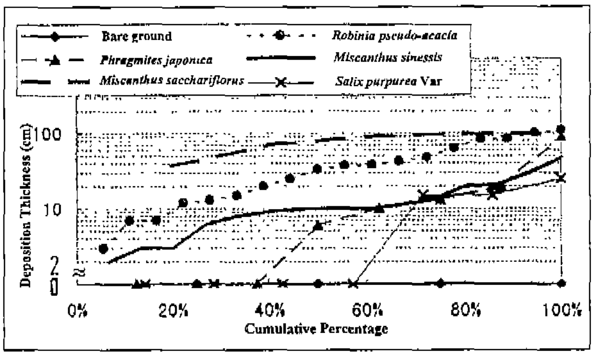

Figure 5. Thickness of the Fine sediment Layer and Vegetation Clusters

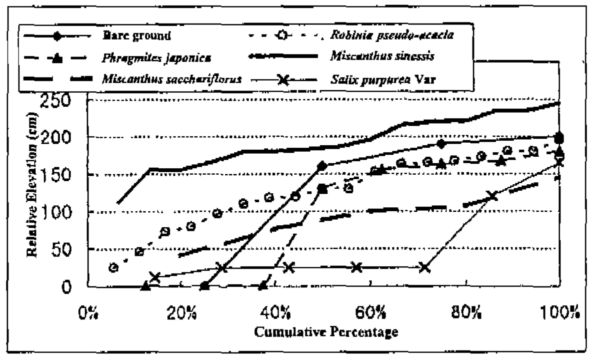

Figure 6. Relative Elevation Above the Ground Water Level and Vegetation Clusters

4. Formation of the Surface Layer of Fine Sediment

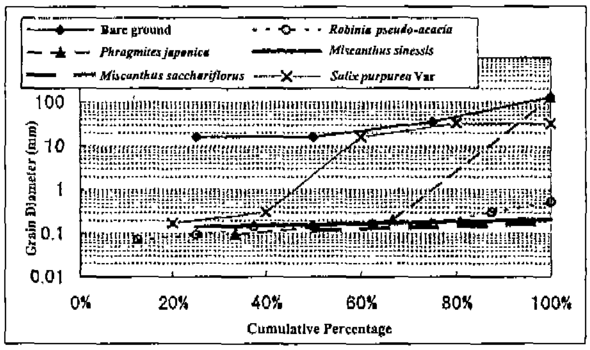

Figure 7. Surface Layer Riverbed Material and Vegetation Clusters

Figure 9 shows the transverse shape of the riverbed on the high water channel at the 52.4 traverse line. The figure shows the elevation where the gravel surface was first touched when the surface was probed with a core sampler. The figure is accompanied by the thickness of the surface layer of fine sediment on top of this gravel.

This figure reveals that the surface layer of fine sediment is thin at less than a few tens of centimeters a little towards the left bank from the 250 m cross-section distance (zero in some parts), but that it thickens abruptly from there to the right bank. In the former range, the gravel surface elevation determined using a core sampler conforms closely to the river bed elevation in 1983. The riverbed elevation measurements shown in this paper were all performed at the beginning of the year, and as Figure 3 shows, it is possible to conclude that this gravel surface was formed immediately after flooding in 1982.

Because gravel was not sampled in this section after 1968, the change in the cross-section in Figure 9 can be linked to the action of flooding through a comparison with Figure 3. It is assumed that the rise in the riverbed between 1968 and 1975 was caused by flooding in 1972 and 1974 (the effects of the latter were particularly strong). Judging from an aerial photograph taken in 1975, it is possible to conclude that the range from at least the cross-section distance of at least 240 m towards the left bank was a gravel surface immediately after the flooding of 1974. There are places where the riverbed fell a little from 1975 and 1979, and the causes are not clear, but judging from local information that no significant flooding occurred during that period, it is possible that some kind of riverbed adjustment occurred immediately after the 1974 flooding. The rise in the riverbed between 1979 and 1983 was deposition caused by the flooding in 1981 and 1982. As stated above, from the cross-section distance of 240 m towards the left bank, there was a gravel surface immediately after the 1982 flooding. The rise in the riverbed from 1983 to 1993 is assumed to be the result of deposition caused by the flooding of 1983 because there was no significant flooding in any year other than 1983. In brief, the relatively thin surface layer of fine sediment from the cross-section distance of 250 m towards the left bank is assumed to have been formed by deposition during the flooding of 1983.

5. Conclusions : The Spread of Luxuriant Vegetation and Woodland Expansion Mechanism and Forecasting these Processes

It is hypothesized that the riverbed fluctuations shown in Figure 10 occurred from the cross section distance of 240 m towards the right bank: a range that includes the principal range of the high water channel at the 52.4 km location. However, Chapter 2 and Chapter 3 have shown that the major vegetation accounting for the spread of luxuriant vegetation and woodland expansion were the herbaceous plant, the common reed (*Miscanthus sacchariflorus*) and the arboreous *Robinia pseudo-acacia*. Both of these species grow with extreme difficulty where there is no surface layer of fine sediment. Judging from Figure 10, it can be concluded that within the principal range of

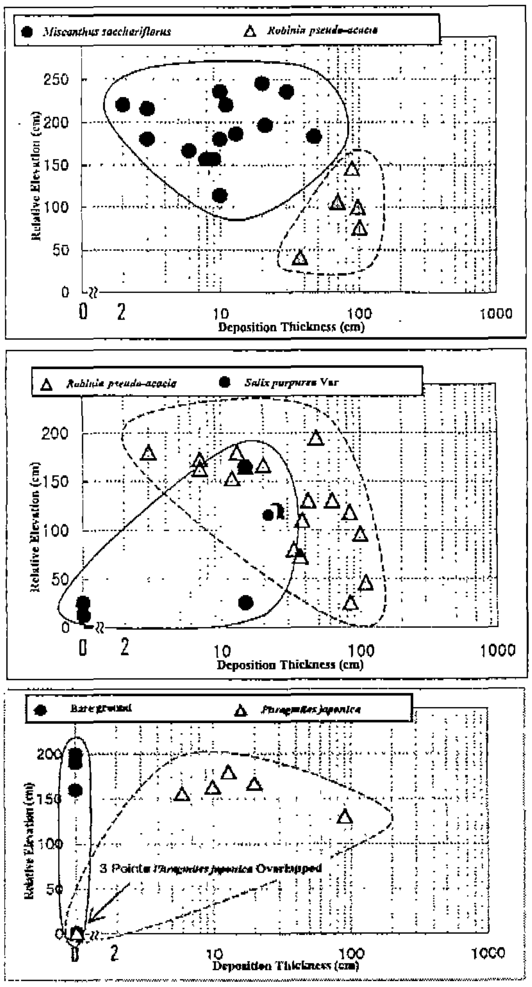

Figure 8. Thickness of the Surface layer of Fine sediment/Relative Elevation from the Ground Water Level - Vegetation Cluster Relationship

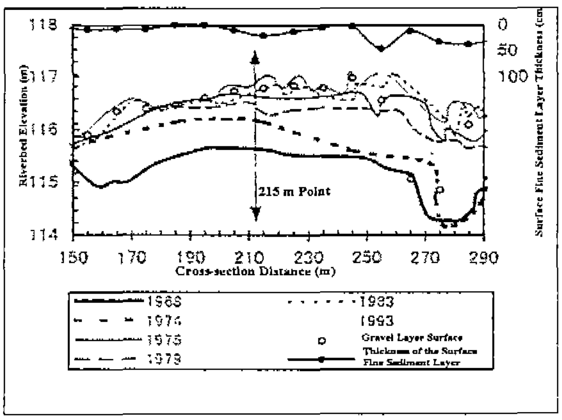

Figure 9. Cross-section Shape of the High Water Channel at 52.4 km

the high water channel, the riverbed surface was gravel from after the 1974 flooding until just before the 1981 flooding and that it was covered with a surface layer of fine sediment after the 1983 flooding. The growth of the common reed (*Miscanthus sacchariflorus*) and *Robinia pseudo-acacia* progressed rapidly from 1984 to 1989. From the above facts, it can be concluded that the direct cause of the growth of luxuriant new vegetation in the study section, mainly common reed (*Miscanthus sacchariflorus*) and *Robinia pseudo-acacia*, was the formation of a surface layer of fine sediment by the flooding of 1983. Turning to indirect causes, the compound cross section not clearly present during the 1974 flooding was clear when the flooding of 1981 to 1983 occurred. The presence of a compound cross section along with the hydraulic conditions provided by these three floods provided all the conditions necessary for the deposition of fine sediment on the high water channel. Another contributing factor is the fact that after the flooding of 1983, there was no flooding that would have disrupted the high water channel where the surface layer of fine sediment had formed.

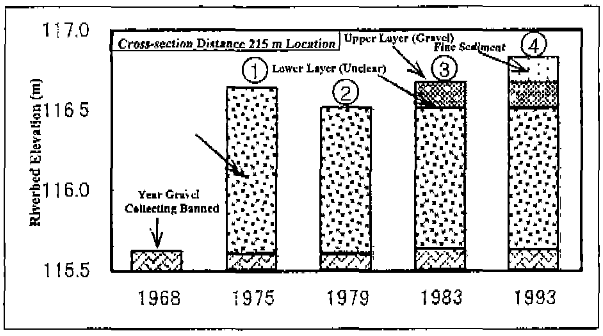

Figure 10. Hypothetical Deposition History Near the Left Bank of the High Water Channel at 52.4 km

Judging from these findings, floods and the transport of fine sediment during floods played an essential role in the spread of luxuriant vegetation and woodland expansion on the gravel riverbed, at least in the section studied.

This research project has shown, in order to predict the dynamics of vegetation in a river, it is extremely important to consider changes in location conditions caused by the action of flooding, soil transport (particularly fine sediment), growth of new vegetation and changes in the cluster types accompanying these changes. The study of the quantitative relationship between the luxuriant growth of vegetation and location conditions allows for quantitative clarification of the changes in location conditions caused by flooding and sediment deposition. In order to link the two processes organically as was done during this study, it is, to some degree, possible to predict the dynamic change of vegetation that displays characteristic behavior because it exists on a river.

5. Refernces

(1) Lee, S., K. Yamamoto, Y. Shimatani, and K. Kayaba, The relevance of the main factor causing change in in-stream vegetation distribution in the Tama alluvial fan river, Environment System Research Thesis, JSCE (Japanese Society of Civil Engineers), vol.24, pp.26-33, 1996.

(2) Lee, S, K. Fujita, T. Tsukahara, S. Watanabe, and K. Yamamoto, The effect of flood and fine sediment flow on stable vegetation in a gravel bed river. Annual Journal of Hydraulics Engineering, JSCE, vol.42, pp433-438, 1998.

(3) Fujita, K. S. Watanabe and S. Lee, The importance of sedimentation on vegetation change in a gravel bed stream, Proceedings from the 4th seminar on river water use and environment, River Division of Hydraulics Engineering Committee, JSCE, pp117-122, 1998.

(4) Okuda, S., et. al., Existing vegetation map of the Tama river, Tokyo Purification Environment foundation, 1979.

(5) Sone, N., Existing vegetation map of the Tama river, Tokyo Purification Environment foundation, 1984.

(6) Okuda, S., et. al., Existing vegetation map of the Tama river. Keihin Work Office, MOC, Japan, 1995.