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Roles of Aquatic Plants on Erosion Relief of Stream Bed

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Abstract**—**Roles of the vegetation to mitigate the erosion of the stream bed or to facilitate the deposition of the fine sediments by the species of the aquatic plants were presented. Field investigation on the estimation of the change of the bed level and the estimation of the flow characteristics were performed. The results showed that *Phragmites japonica* has the mitigation function of 0.3m-0.4m of the erosion in the range of higher than 1.0m/s of flow velocity at the vegetated region. *Phragmites communis* has the mitigation function of 0.2m-0.3m of the erosion in the range of higher than 0.7m/s of flow velocity at the vegetated region. *Salix gracilistyla* has greater role than *Phragmites japonica* and *Phragmites communis* to sustain the stable channel. It has the mitigation function of 0.4m-0.5m of the erosion in the range of higher than 1.4m/s of flow velocity. *Miscanthus sacchariflorus* has a weak role compared with that of *Phragmites japonica* and *Salix gracilistyla,* but it has still function for sustaining the stable bed. From these results, the vegetation has effective roles to mitigate the erosion or to facilitate the deposition of the stream bed.

Keywords**—**Aquatic plants, *Phragmites japonica, Phragmites communis, Miscanthus sacchariflorus, Salix gracilistyla.*

I. Introduction

VEGETATION in the river is affected by the flow structure, but inversely affects the flow structure. Vegetation may be destroyed and damaged by the high tractive force of the flood flow.

Vegetation impact by the flow was studied by several scientists. Kim [1] showed that most of the aquatic plants except for *Salix gracilistyla* were bent and destroyed by the flood flow, and moreover *Salix gracilistyla* was even destroyed when the scrubs and the floating trashes were caught in it since they enabled to make higher the dynamic pressure of the flow. He suggested that vegetation behavior was classified into 4 stages of stable, recovered, damaged and swept away. Criteria between recovered and damaged stage was determined by the bending angle of the aquatic plants. Miyazaki et al. [2] studied about the river hydraulic examination which considers the dynamic characteristics of reed community at the time of the flood. Vegetation impacts in a degraded gravel-bed river were studied by Shimizu et al. [3]. They evaluated the maximum size of the movable gravels and the local bed degradation based on the field study and the numerical calculations with 2D-flow model.

Transport of the bed sediments during the flood seasons resulted in the deposition of the vegetated area and the vegetation may be buried and damaged. Thus, the flow characteristics and the riverbed sediments affect the vegetation impacts.

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On the other hand, vegetation inversely affects the flow structure. It reduces the flow velocity, increases the flow resistances and raises the water level [4]. It was found that the vegetation reduces the flow velocity and facilitates the mitigation of the erosion of the stream bed or deposition of the fine sediments [5]. Thus, the vegetation and flow structure has mutually reciprocal relationships [6].

As mentioned, vegetation impacts by the flow structure are studied well, but alleviations of the flow structure by the vegetation itself are not studied well. The purpose of this study is focused on the latter. This paper presents the roles of the vegetation to mitigate the erosion of the stream bed or to facilitate the deposition of the fine sediments by the species of the aquatic plants.

Field investigation on the estimation of erosion/deposition of the bed level using the reinforced bar staff and the estimation of the flow characteristics were performed to determine the functions of the vegetations by the species of the aquatic plants.

II. Variation of Stream Bed by Aquatic Plants

Stream bed before and after the flood flow is shown in Fig. 1. Variation of the stream bed after the flood at the vegetated area may be two cases. One will be the scoured (or eroded) case and the other will be the deposited case. The scoured case will of course correspond to the mitigated one of the erosion by the function of the aquatic plants. The scoured case will only occur outside the vegetated area, that is, at the right side of the vegetated area shown in Fig 1.

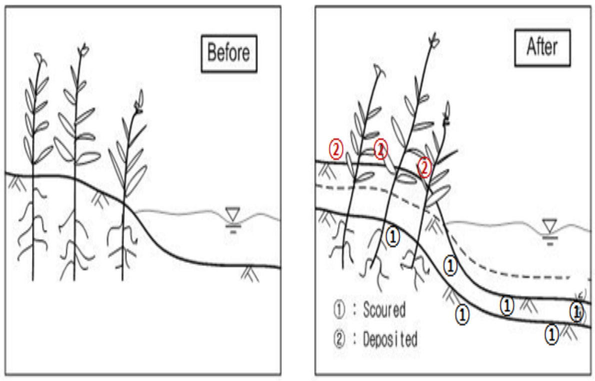

Fig. 1 Stream bed before and after the flood flow

The scoured case occurs at the fast and deep part of the channel, which corresponds to the upstream part of the channel, and at the areas of *Phragmites japonica* or *Salix gracilistyla*. On the other hand, the deposited case occurs at the slow part of the channel, which corresponds to the downstream of the channel, and at the areas of *Phragmites communis, Miscanthus sacchariflorus* or *Persicaria blumei*. [7]

Field survey of the variations of the stream bed inside and outside of the vegetated area was performed, respectively. Fig. 2 shows the variations of the stream bed. Erosion was not occurred seriously inside the vegetated area compared with that outside the vegetated area, which implies that vegetation has functions to mitigate the erosion of the stream bed.

Fig. 2 Variations of the stream in and outside the vegetated area

If the vegetations will be planted at the toe side of the embankment slope, they will have effective functions to mitigate the erosion of the toe side shown in Fig. 3.

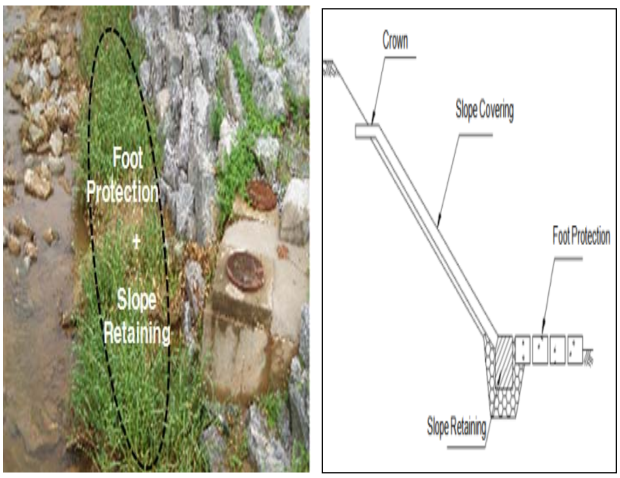

Fig. 3 Function of the vegetation to mitigate the erosion of the side slope

III. Field Measurements

Variation of the stream bed was measured by using the reinforced bar staff marked with scales. It was installed inside and outside the vegetated area, respectively and the erosion/deposition could be estimated by measuring the exposed length. Fig. 4 shows the process of marking the scales to the reinforced bar staff.

Fig. 4 Process of marking the scales to the reinforced bar staff

Flow velocity and depth were also measured and these values were compared with variation of the stream bed by the species of the aquatic plants.

Phragmites japonica, Phragmites communis, Salix gracilistyla and *Miscanthus sacchariflorus* were chosen as for the aquatic plants. Height and density of the plants were measured, but their values were not analyzed because of the limited data.

These values are shown in Table I. Here, “height” means the growth of the plant, “variation” means the erosion or deposition of the stream bed, “-“ means erosion, “+” means deposition, “①” means the inside of the vegetated area, “②” means the outside of the vegetated area, and ”mitigation” means the mitigation of erosion of the stream bed.

TABLE I
VARIATIONS OF STREAM BED BY SPECIES OF AQUATIC PLANTS

Species	Height	Density	Before flood		After flood		Variation		Vegetation function
			①	②	①	②	①	②	
	1.5	80	0.45	0.55	0.25	0.75	+0.20	-0.20	deposition
	1.4	70	0.50	0.55	0.40	0.85	+0.10	-0.30	deposition
	1.5	75	0.60	0.45	0.42	0.85	+0.18	-0.40	deposition
Phragmites japonica	1.0	80	0.45	0.55	0.35	0.75	+0.10	-0.40	deposition
	1.2	70	0.50	0.30	0.70	0.55	-0.20	-0.50	mitigation
	1.5	75	0.40	0.45	0.75	0.62	-0.35	-0.60	mitigation
	1.5	80	0.40	0.52	0.80	0.55	-0.40	-0.70	mitigation
	1.8	85	0.50	0.55	0.10	0.75	+0.40	-0.20	deposition
	2.4	75	0.60	0.52	0.40	0.72	+0.20	-0.20	deposition
	2.2	80	0.50	0.48	0.40	0.78	+0.10	-0.30	deposition
Phragmites communis	2.0	70	0.55	0.55	0.65	0.85	-0.10	-0.30	mitigation
	2.2	80	0.50	0.50	0.70	0.85	-0.20	-0.35	mitigation
	1.8	85	0.60	0.45	0.70	0.75	-0.10	-0.30	mitigation
	1.8	70	0.60	0.52	0.80	0.87	-0.20	-0.35	mitigation
	1.6	70	0.40	0.56	0.20	0.64	+0.20	-0.08	deposition
	1.8	70	0.55	0.50	0.45	0.90	+0.10	-0.40	deposition
	1.5	80	0.60	0.45	0.40	0.92	+0.20	-0.30	deposition
Salix gracilistyla	1.6	75	0.55	0.40	0.45	0.80	+0.10	-0.40	deposition
	1.5	70	0.55	0.42	0.47	0.82	+0.08	-0.40	deposition
	1.7	75	0.60	0.27	0.70	0.87	-0.10	-0.60	mitigation
	1.5	80	0.50	0.20	0.70	0.80	-0.20	-0.60	mitigation
	0.6	75	0.50	0.55	0.20	0.65	+0.30	-0.10	deposition
	0.4	70	0.55	0.56	0.35	0.66	+0.20	-0.10	deposition
	0.5	65	0.60	0.52	0.50	0.72	+0.10	-0.20	deposition
Miscanthus sacchari-florus	0.6	70	0.65	0.55	0.75	0.85	-0.10	-0.30	mitigation
	0.8	80	0.60	0.52	0.68	0.87	-0.08	-0.35	mitigation
	0.5	75	0.60	0.45	0.70	0.75	-0.10	-0.30	mitigation
	0.5	80	0.50	0.56	0.70	0.89	-0.20	-0.33	mitigation

IV. RESULTS AND DISCUSSIONS

Variation of the stream bed compared with flow velocity inside and outside the area of *Phragmites japonica* is shown in Fig. 5. Here, H means the variation of the stream bed, V means the flow velocity. “Planted” and “Not Planted” mean the area inside and outside the vegetation, respectively.

It can be seen that *Phragmites japonica* inhabits in the range of fast flow and low depth, thus high values of the Froude number, which means the typical case that *Phragmites japonica* inhabits the upstream part of the river.

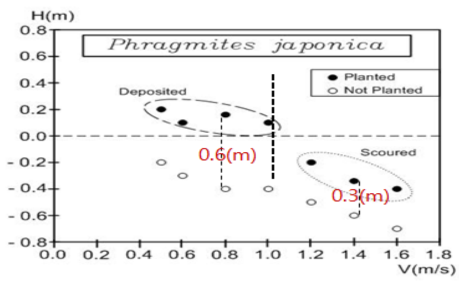

Fig. 5 Variation of the stream bed at the area of *Phragmites Japonica*

Field survey showed that *Phragmites japonica* inhabited in the range of more than 1.0m/s of flow velocity except for flow area. Deposition occurred in the range of lower than 1.0m/s of flow velocity, while erosion occurred in the range of higher than 1.0m/s at the vegetated region. But only the erosion occurred outside the vegetated area.

Compared with data of the inside and outside of the vegetated area, it can be seen that *Phragmites japonica* has the mitigation function of 0.3m-0.4m of the erosion in the range of higher than 1.0m/s of flow velocity at the vegetated region. This means that *Phragmites japonica* has effective role for depending the stable channel.

Fig. 6 shows the variation of the stream bed inside and outside the area of *Phragmites communis.* Parameters in Fig. 6 are same as those in Fig. 5.

Compared with *Phragmites japonica, Phragmites communis* inhabits in the range of slow and deep part of the flow area, thus low values of the Froude number, which means the typical case that *Phragmites communis* inhabits the downstream part of the river.

Field survey showed that deposition occurred in the range of lower than 0.6m/s of flow velocity, while erosion occurred in the range of higher than 0.7m/s at the vegetated region. But only the erosion occurred outside the vegetated area.

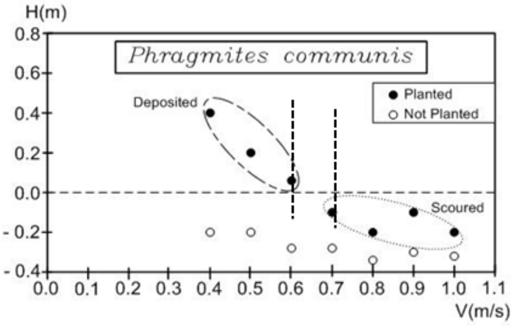

Fig. 6 Variation of the stream bed at the area of *Phragmites communis*

Compared with data of the inside and outside of the vegetated area, it can be seen that *Phragmites communis* has the mitigation function of 0.2m-0.3m of the erosion in the range of higher than 0.7m/s of flow velocity at the vegetated region. This means that *Phragmites communis* has also effective role for sustaining the stable channel.

Fig. 7 shows the variation of the stream bed inside and outside the area of *Salix gracilistyla*.

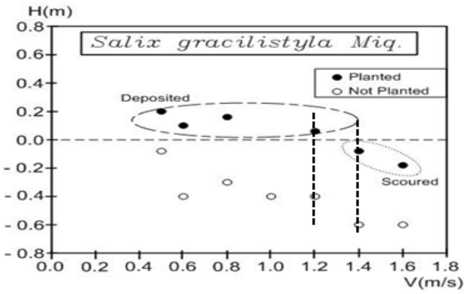

Fig. 7 Variation of the stream bed at the area of *Salix gracilistyla*

Compared with *Phragmites japonica* and *Phragmites communis, Salix gracilistyla* inhabits in the wide range of flow velocity, which means that it inhabits in the part of the water front as well as of the flow area of the river.

Deposition occurred in the range of lower than 1.2m/s of flow velocity, while erosion occurred in the range of higher than 1.4m/s at the vegetated region. But only the erosion occurred outside the vegetated area.

Compared with data of the inside and outside of the vegetated area, it can be seen that *Salix gracilistyla* has the mitigation function of 0.4m-0.5m of the erosion in the range of higher than 1.4m/s of flow velocity at the vegetated region. This means that *Salix gracilistyla* has greater role to sustain the stable channel than *Phragmites japonica* and *Phragmites communis.*

Variation of the stream bed inside and outside the area of *Miscanthus sacchariflorus* is shown in Fig. 8.

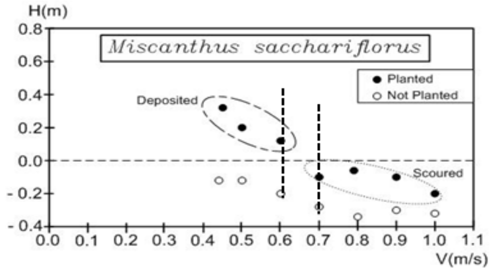

Fig. 8 Variation of the stream bed around the area of *Miscanthus sacchariflorus*

Miscanthus sacchariflorus inhabits in range of low and shallow flow area, which means that it inhabits the water front or the wetland. [7] Deposition occurred in the range of lower than 0.6m/s of flow velocity, while erosion occurred in the range of higher than 0.7m/s at the vegetated region. But only the erosion occurred outside the vegetated area.

Compared with data of the inside and outside of the vegetated area, it can be seen that *Miscanthus sacchariflorus* has the mitigation function of 0.2m-0.3m of the erosion in the range of higher than 0.7m/s of flow velocity at the vegetated region. This means that *Miscanthus sacchariflorus* has a weak role compared with that of *Phragmites japonica* and *Salix gracilistyla,* but it has still function for sustaining the stable bed.

From these results, the vegetation has effective roles to mitigate the erosion or to facilitate the deposition of the stream bed.

V. Conclusions

Roles of the vegetation to mitigate the erosion of the stream bed or to facilitate the deposition of the fine sediments by the species of the aquatic plants were presented. Field investigation on the estimation of the change of the bed level using the reinforced bar staff and the estimation of the flow characteristics were performed to determine the functions of the vegetations by the species of the aquatic plants.

The results showed that *Phragmites japonica* inhabits in the range of fast flow and low depth, thus high values of the Froude number. It has the mitigation function of 0.3m-0.4m of the erosion in the range of higher than 1.0m/s of flow velocity at the vegetated region. *Phragmites communis* inhabits in the range of slow and deep part of the flow area, thus low values of the Froude number. It has the mitigation function of 0.2m-0.3m of the erosion in the range of higher than 0.7m/s of flow velocity at the vegetated region. *Salix gracilistyla* inhabits in the wide range of flow velocity, which means that it inhabits in the part of the water front as well as of the flow area of the river. It has the mitigation function of 0.4m-0.5m of the erosion in the range of higher than 1.4m/s of flow velocity. Thus, it has effective role greater than *Phragmites japonica* and *Phragmites communis* to sustain the stable channel. *Miscanthus sacchariflorus* has a weak role compared with that of *Phragmites japonica* and *Salix gracilistyla,* but it has still function for sustaining the stable bed. The vegetation has effective roles to mitigate the erosion or to facilitate the deposition of the stream bed.

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