EVALUATION OF EXPANSION THRESHOLD FOR *TYPHA ANGUSTIFOLIA* IN RIVER

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Improving the flow capacity and protecting the banks of a small river in a city sometimes requires a concrete-lined channel, which decreases the biodiversity in the channel. However, *Typha angustifolia*, an emergent macrophyte, can sometimes survive in such conditions and enlarge in the cross-stream direction. Excessive enlargement of *T. angustifolia* reduces the flow capacity, sometimes necessitating the cutting of stems for their management. Considering their role in biodiversity and their negative effects on water depth in flood events, the enlargement threshold to flood disturbance should be clarified. The roughness characteristics, momentum loss and shear stress of emergent vegetation were investigated using circular cylinders arranged in a grid and staggered in a water flume. However, much previous research suggested that the roughness characteristics of a real plant change with water depth, species composition and other factors (Järvelä, 2002). The drag force on the plants inclined them in the downstream direction. The inclination was also varied by whether they were located at the center or at the edge of a *Typha* stand. Thus, the water-depth effects on the drag force of *T. angustifolia* are quite large and cannot be considered as comparable to a solid cylinder.

Therefore, the purpose of this study was to elucidate the enlargement threshold for *T. angustifolia* considering its horizontal expansion characteristics. For this purpose, the actual roughness characteristics of real *T. angustifolia* were investigated with water flume experiments, its stem-breaking characteristics were measured and the river flow velocities and the drag moment acting on the plant body were analyzed by a two-dimensional depth-averaged Reynolds equation.

The drag coefficient, C_d, for each model (shoot-base, dense-leaf and sparse-leaf) was measured with changing roughness inclination toward flow direction. The drag coefficient varied from 0.2 to 1.6 with the change of parts and inclination (Fig.1). The drag coefficient varied greatly with differences in plant parts and the inclination of *T. angustifolia*. The drag coefficient of the shoot base was around 1, but it increased with changing water depth and had a peak at the height of the dense leaves because of the complexity of the leaves just above the shoot base. However, it decreased from the peak due to the large inclination of the leaves.

By using the characteristics of C_d as a function of water depth and velocity, the threshold line of breaking moment for *T. angustifolia* was calculated (Fig. 2). In the case of the Touemon River, the drag force in Area A (narrow vegetation area) does not exceed the threshold, but it does in Area B (sparsely vegetated area) for the possible secondary shoot density. On the other hand, the plot does not go over the threshold in Area A or Area

B for the Denu River. By evaluating the real C_d of *T. angustifolia*, the breaking moment of the shoot base and the velocity in the primary shoot and secondary shoot zones, the threshold line can clearly express well the different habitats in the two rivers. The width of vegetation at Touemon River is narrow and changes seasonally, and the Denu River is completely covered with vegetation across its width. The threshold line can indicate whether artificial management is required.

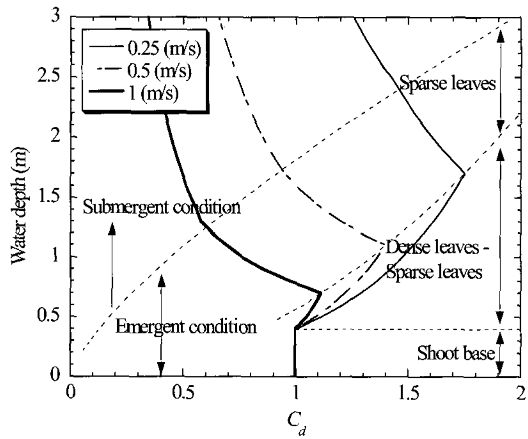

Fig. 1 Variation of C_d with different velocities and water depths.

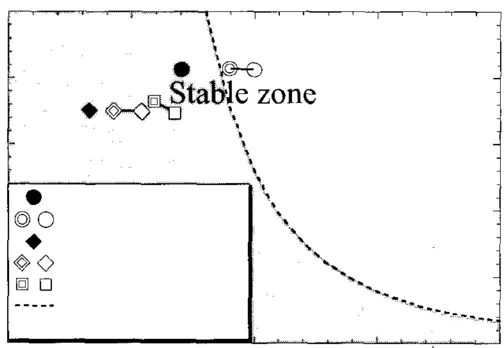

Fig. 2 Relationship between water velocity and water depth for the different area in the Touemon and Denu rivers. The gray area is the stable zone for *Typha angustifolia*. ◎, ◈ and ▣ are for dense condition (density: $12/m^2$ in Area B, $24/m^2$ in Area C). And ○, ◇ and □ are for sparse condition (density: $4/m^2$).

REFERENCES

Järvelä, J., 2002. Flow resistance of flexible and stiff vegetation: a flume study with natural plants, J. Hydrology, 269, pp. 44-54.