PATCH SIZE EFFECT ON SEDIMENTATION BY SUBMERGED AQUATIC VEGETATION

Keisuke Nakayama, Kobe University, nakayama@phoenix.kobe-u.ac.jp
Keita Matsumura, Kobe University, 226t137t@stu.kobe-u.ac.jp
Tetsuya Shintani, Tokyo Metropolitan University, shintani@tmu.ac.jp

INTRODUCTION

Seagrass meadows provide critical ecosystem services in the coastal ocean, regions of extremely high biodiversity and productivity, providing a nursery and habitat for various organisms. They can sequester carbon, accumulate particulate organic matter, produce oxygen and remove nutrients essential to ecosystem services in the coastal ocean. Seagrass meadows generally exist entirely in shallow water areas and grow in patches, meaning their interactions with coastal flows may induce complexity for mass transport (Adams et al., 2016). Adams et al. (2016) showed the importance of the blade bending angle on current and turbulence inside a seagrass meadow, resulting in the fact that the more the blade bends, the more significantly the sediment accumulates. Previous studies have investigated the interactions between flow and submerged aquatic vegetation (SAV) using laboratory experiments. Luhar and Nepf (2011) proposed the Cauchy number and the buoyancy parameter to capture the characteristics of SAV, such as blade bending angle. In contrast, several numerical methods have been applied to reconfigure the leaf blade model. For example, Dijkstra and Uittenbogaard (2010) proposed a method by including all necessary forces; that method well predicted the results of their laboratory experiments. Nakayama et al. (2020) recently proposed an SAV model by considering all necessary forces and the interaction between flows and SAV by dividing each blade into segments in good agreement with the results of laboratory experiments. Since the SAV model is based on object-oriented programming that can be used on an ordinary PC, it is easy to analyze many different lengths and characteristics of SAV, including the complicated patch-like SAV meadows that interact with flows. Thus, this study uses the SAV model to investigate the patch size effect on sedimentation by SAV meadows. Additionally, we conducted laboratory experiments to verify the accuracy of the SAV model.

METHODS

To investigate the fidelity of the SAV model around the patch-like meadows under a uniform flow, we conducted laboratory experiments using an SAV replica in an open channel, whose channel length and width were 25 m and 0.9 m (Figure 1). Low-foam polyethylene was applied to design SAV replicas with an elasticity of 0.2 GPa and a density of 600 kg m^{-3}. The leaf of the SAV replica was 0.3 m long, 0.0024 m wide, and 0.001 m thick. The SAV patch was set at 0.2 m wide and 2.0 m long in an open channel. Particle image velocity (PIV) was used to measure velocities inside the SAV meadow in the laboratory. We used the SAV model Nakayama et al. (2020) developed to investigate the interactions between the flows and the flexible ecosystem. In the numerical simulations, the computational domain was set at 250 m to remove the reflection effect of waves from the downstream end to the SAV meadow.

RESULTS AND CONCLUSION

The SAV numerical model was successfully applied to analyze flows around a patch-like SAV meadow, and the results agreed with those of the laboratory experiments. Numerical simulations revealed that larger velocities occurred above the SAV meadow when the elasticity was smaller, and the SAV bent considerably, with the lowest velocity near the SAV bottom. The patch occupancy of the channel width was revealed to be the most substantial factor in controlling hydrological conditions and sedimentation due to SAV, and deflection was found to be the second critical factor.

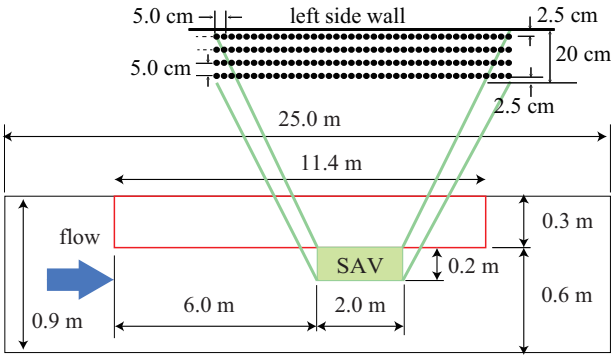

Figure 1 Open channel in the laboratory experiment. The SAV replica was installed in the green-highlighted area.

REFERENCES

Adams, P.A., Hovey, R.K, Hipsey, M.R., Bruce, L.C., Ghisalberti, M., Lowe, R.J., Gruber, R.K., Ruiz-Montoya, L., Maxwell, P.S., Callaghan, D.P., Kendrick, G.A., and O'Brie, and K.R. (2016): Feedback between sediment and light for seagrass: Where is it important? Limnology and Oceanography, 61, 1937-1955.

Dijkstra, J. T., and Uittenbogaard, R. E. (2010): Modeling the interaction between flow and highly flexible aquatic vegetation. Water Resources Research, 46(12), W12547.

Luhar, M., and Nepf, H. (2011): Flow-induced reconfiguration of buoyant and flexible aquatic vegetation. Limnology and Oceanography, 56(6), 2003-2017.

Nakayama, K., Shintani, T., Komai, K., Nakagawa, Y., Tsai, J.W., Sasaki, D., Tada, K., Moki, H., Kuwae, T., Watanabe, K., and Hipsey, M. R. (2020): Integration of submerged aquatic vegetation motion within hydrodynamic models. Water Resources Research, 56(8), e2020WR027369.