Assessment of vegetation modelling approaches in simulating suspended sediment transport in Delft3D

Liu, Jiaqi; Crosato, Alessandra; Bregolia, Francesco; Calvani, Giulio

Publication date
2023

Document Version
Final published version

Citation (APA)
Liu, J., Crosato, A., Bregolia, F., & Calvani, G. (2023). *Assessment of vegetation modelling approaches in simulating suspended sediment transport in Delft3D*. 56-57. Poster session presented at NCR Days 2023, Nijmegen, Netherlands.

Towards 2048: the next 25 years of river studies

Book of Abstracts
NCR DAYS 2023
12-13 April | Radboud University

Netherlands Centre for River studies NCR

Wilco C.E.P. Verberk
Frank P.L. Collas
Gertjan W. Geerling
Marie-Charlott Petersdorf (eds.)
NCR Publication: 51-2023

NCR DAYS 2023

Towards 2048: The next 25 years of river studies

Wilco Verberk, Frank Collas, Gertjan Geerling & Marie-Charlott Petersdorf (eds.)

Organising partner:

Radboud University

Conference venue

Lindenberg Cultuurhuis
Ridderstraat 23
6511 TM Nijmegen
The Netherlands

telephone: +31 24 327 39 11
e-mail: info@delindenberg.com
www: https://www.delindenberg.com

Contact NCR

dr. ir. K.D. Berends (Programme Secretary)
Netherlands Centre for River Studies
c/o Deltares
Boussinesqweg 1, 2629 HV Delft
P.O. Box 177, 2600 MH Delft
The Netherlands

telephone: +31 6 21 28 74 61
e-mail: secretary@ncr-web.org
www: http://www.ncr-web.org

Cite as: Wilco Verberk, Frank Collas, Gertjan Geerling, & Marie-Charlott Petersdorf (eds.) (2023), *Towards 2048: The next 25 years of river studies: NCR DAYS 2023 Proceedings*. Netherlands Centre for River Studies publication 51-2023

Photo credits cover: F.P.L. Collas

Assessment of vegetation modelling approaches in simulating suspended sediment transport in Delft3D

Jiaqi Liu [a,b],
Alessandra Crosato [a,b]
Francesco Bregoli [a,c]
Giulio Calvani [d]

Highlights

- Experiments are reproduced in Delft 3D to simulate suspended sediment transport in aquatic flow
- The three selected approaches represent the flow field better than suspended sediment transport
- The “3D vegetated” approach is the best one in reproducing fine sediment deposition

Overview

The presence of vegetation increases the water depth, reduces the flow velocity and changes the turbulent structure of the flow influencing the sediment transport capacity (Purich 2006 and Nepf 2012). Because of it, vegetation can be regarded as a geo-enhancing tool that influences the river morphology by preventing erosion, but also as a filtering tool that improves the water quality by removing fine particles from the flow. The physical processes inside the flow-sediment-vegetation interaction have been investigated in the last decades. Theoretical models simulating the effects of vegetation on flow field and morphodynamics have been developed and applied using different software, such as Delft 3D (Crosato and Saleh 2011 and Best et al. 2018). Most studies focused on large-scale issues assuming sediment to be transported as bedload, whereas suspended solids processes have received less attention.

This work aims to compare the performance of 2-dimensional (2D) vegetation modelling approaches implemented in Delft 3D in reproducing the interaction between suspended solids and the flow in vegetated channels. The comparison is based on a set of flume experiments (Sharpe 2003) with emergent plants represented by rigid cylinders. Three approaches are considered in this study: the Baptist approach, based on the assessment of roughness coefficients; the 3D vegetated approach including some effects of turbulence; and a detailed description of the flow with each rigid cylinder being represented by either a dry point or described by thin dams around it. The flow is calculated by shallow water Navier-Stokes equations and the suspended sediment transport is calculated as advection-diffusion equations.

After a proper roughness coefficient calibration, the results shown that all the three approaches perform well in reproducing the flow field. However, only the detailed description (Dry Point and Thin Dam) approach can describe the flow field around the rigid stems. The three approaches can well reproduce the longitudinal distribution of sediment deposition with the calibrated settling velocity. For the deposition in transverse direction, the 3D approach performs the best, the detailed description approach can only partly reproduce the distribution, whereas the Baptist approach, based on the assumption of uniform flow between the plants and high vegetation density, can’t reproduce any differences in sediment deposition in transverse direction. The results of validation emphasize the impact of turbulence on suspended sediment transport through vegetated channels.

Affiliations

[a] *IHE Delft Institute for Water Education, Delft, the Netherlands*
[b] *Delft University of Technology, Delft, the Netherlands*
[c] *Radboud University, Nijmegen, the Netherlands*
[d] *École Polytechnique Fédérale de Lausanne, Lausanne, Swiss*

References

Best, Ü. S. N., M. Van Der Wegen, J. Dijkstra, P. W. J. M. Willemsen, and B. W. Borsje. 2018. “Environmental Modelling & Software Do Salt Marshes Survive Sea Level Rise ? Modelling Wave Action , Morphodynamics and Vegetation Dynamics.” *Environmental Modelling and Software* 109(September 2017):152–66.

Crosato, Alessandra and May Samir Saleh. 2011. “Numerical Study on the Effects of Floodplain Vegetation on River Planform Style.” *Earth Surface Processes and Landforms* 36(6):711–20.

Nepf, Heidi M. 2012. “Hydrodynamics of Vegetated Channels.” *Journal of Hydraulic Research* 50(3):262–79.

Purich, Ariaan. 2006. “The Capture of Suspended Particles by Aquatic Vegetation.” *University of Western Australia* (October):1–97.

Sharpe, Richard. 2003. “Suspended Sediment Transport through Non-Submerged Reeds.” University of the Witwatersrand.

Stoesser, Thorsten, Guillermo Palau Salvador, Wolfgang Rodi, and Panayiotis Diplas. 2009. “Large Eddy Simulation of Turbulent Flow through Submerged Vegetation.” *Transport in Porous Media* 78(3 SPEC. ISS.):347–65.

Results

Each approach needs a specific calibration of Manning coefficient, drag coefficient and horizontal eddy viscosity. The calibrated values are determined by minimizing the relative root mean square error (RRMSE) between measured and modelled water depths (Table 1). All the three approaches show high accuracy in water depth prediction. About the detailed description, the results are the same for the Dry Point and Thin Dam approaches.

Table 1. Calibrated parameters for three vegetation modelling approaches

Calibrated parameter	Vegetated modelling approach					
	Baptist		3D vegetation		Dry Point and Thin Dam	
	Value	RRMSE	Value	RRMSE	Value	RRMSE
Bottom Manning coefficient (s/m$^{1/3}$)	0.021	0.087%	0.021	0.087%	0.021	0.087%
Drag coefficient	1.15	0.257%	1.35	0.440%	-	
Horizontal viscosity (m^2/s)	10		10		0.00008	0.290%

The velocity and water depth distributions obtained with the Baptist and the 3D vegetated approach are uniform, because these approaches do not consider the single cylinders. However, the detailed description allows obtaining that the water flow passes around each stem leading to local differences in water depth and velocity (Fig. 1).

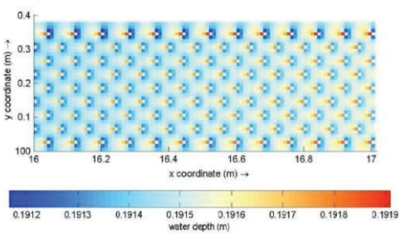
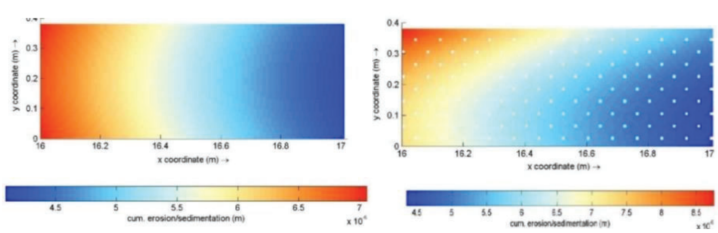


Figure 1. the section of water depth distribution in a Dry Point model

As in Sharpe's experiments, sediment is added to the flume after getting uniform flow conditions. Morphodynamic calibration is obtained by adjusting the value of the settling velocity based on the comparison between the computed longitudinal sediment deposition to the experimental data.
The different approaches result in different distributions of sediment deposition. It is uniform when using the Baptist approach. However, for the 3D vegetated and detailed description approaches deposition is higher near the walls than in the central area. More specifically, the distribution obtained with the 3D vegetated approach is symmetric (Fig. 2a), which is in accordance with the experimental observations. Instead, the sediment deposition is asymmetric for the detailed description approach (Fig. 2b).



(a) *(b)*

Figure 2. Sediment deposition distribution obtained with (a) the 3D vegetated approach and (b) the detailed description approach

Conclusions

The 3D vegetated model approach can be regarded as the best one in reproducing suspended solids transport in aquatic systems at the flume scale. However, the sub-grid turbulence may impact the accuracy of the results with respect to sediment deposition.

Acknowledgments

The authors would like to thank Dr Richard Sharpe from Griffith University, Australia, for providing the experimental data.