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Performance of natural mangrove structure in downstream velocity reduction as compared to engineered porcupine and geobag structure using OpenFOAM

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Abstract

Bank erosion is a regular occurrence along most rivers. In low-income nations such as India and Bangladesh, economical engineered structures such as porcupines and geobags have been used to counteract such erosions. Nonetheless, at times of extreme flooding, these structures often become unstable and are subsequently washed away, thereby failing to protect the banks. Vetiver grass, which ties the soil with its roots, is a natural method for preventing bank erosion. However, its flexible structure is unable to significantly reduce velocity. In this study, the OpenFOAM open-source hydrodynamic model was used to assess the efficacy of mangrove root structure in reducing flow velocity. It has been compared to single screen porcupine, dual screen porcupine, and geobag structure in terms of performance in downstream flow velocity reduction. It was observed that single screen porcupine was the least effective at reducing velocity (0.32 %), followed by dual screen porcupine (3.63 %) and single geobag (5.66 %). On the other hand, the mangrove structure was able to lower downstream velocity by 14.26%. In terms of its downstream influence, the single screen porcupine had its influence upto 3.63 cm, followed by dual screen porcupine with 5.53 cm, and single geobag with 13.03 cm. The mangrove structure influence zone on the other hand was very close to the geobag structure (11.53 cm). With its greater velocity reduction capabilities and a considerable zone of influence, mangrove plantations on riverbanks may therefore function as a cost-effective and ecologically sustainable soil erosion management strategy.

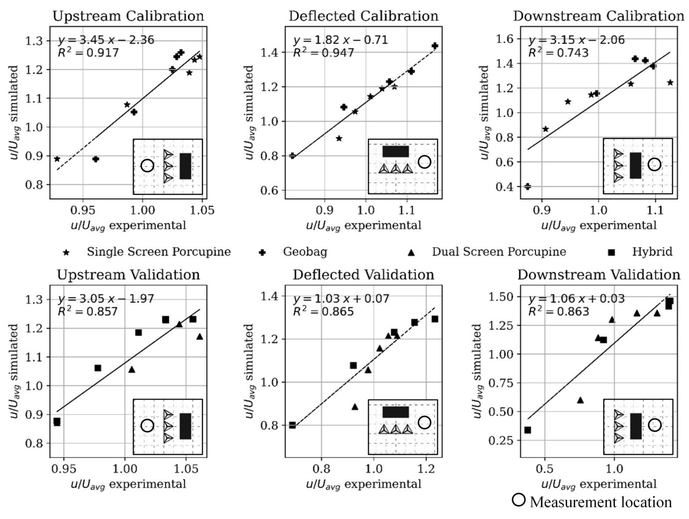
Keywords: *Bank erosion, Geobag, Mangrove, OpenFOAM, Porcupine*

Introduction

The objective is to use open- source hydrodynamic model "*OpenFOAM*" in analyzing performance of engineered river training works as compared to nature based solution.

- The semi- Implicit Method for Pressure- Linked Equations (*SIMPLE*) algorithm (Patankar and Spalding, 1972) used requires less computational time and resources
- Previously it has been used for simulation of jets (Ardalan and Vafaei, 2019) and spillways (Kocaer and Yarar, 2020)
- Due to complexity associated with multiphase models (Gu et al., 2016; Kocaer and Yarar, 2020), incorporating a complex structure such as mangrove root would be difficult
- A single phase model using (*SIMPLE*) algorithm has been simulated to evaluate the performance of natural mangrove root structure as compared to engineered river training works
- A completely open- source approach has been adopted from data collection (*OpenFOAM*) to processing (*ParaView*,*Python 3.8 IDE*) and analysis (*Python 3.8 IDE*)

Validation



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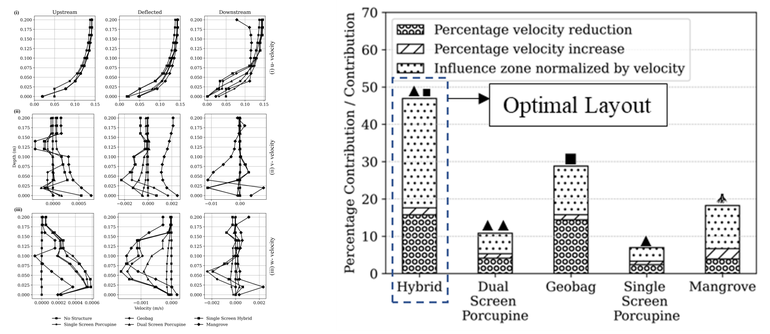
- The model has been calibrated for engineered structures with measured velocity profiles from laboratory experiments at upstream, downstream, and the side of the structure
- The model could replicate the velocity profile of porcupine and geobag structures as compared to laboratory experiments with $R^2 > 0.74$
- The model could also replicate the velocity profile of a hybrid layout comprising of both porcupine and geobag

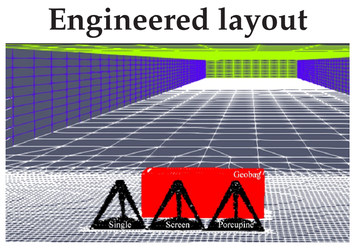
Results



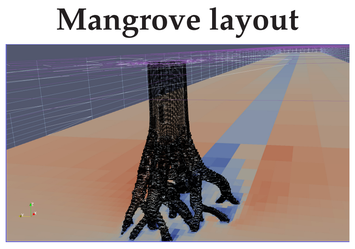
- Single screen porcupine is the least efficient in reducing velocity (2.40%), followed by dual screen porcupine (4.11%) and single geobag (14.40%)
- The mangrove structure reduced downstream velocity by 3.92%, close to the dual screen porcupine
- The mangrove structure influence zone (11.53 cm) was very close to geobag (13.03 cm)
- Secondary currents of the mangrove structure are primarily responsible for the nutrient exchange mechanisms
- Mangrove plantations on riverbanks can be an economically sustainable soil erosion management strategy

Methods

Engineered layout



Mangrove layout



- Generation of mesh using *blockMesh* module
- Incorporation of Stereolithography (*.stl*) model of structure using *snappyHexMesh* module
- Data extraction and processing using *ParaView* and *Python 3.8* IDE

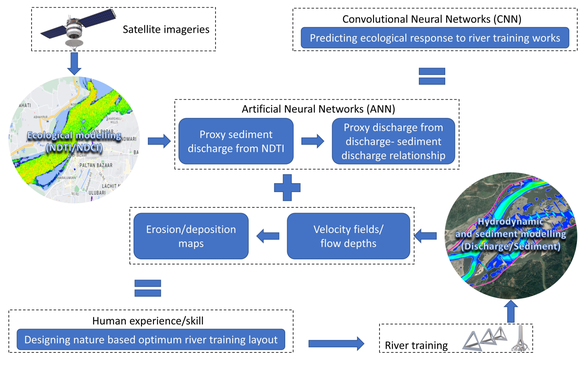
A future direction

More details on this project are available at

https://iitg.ac.in/stud/riddick.kakati/

The big picture

The broad aim of this study is to develop a near real time hydro- ecological monitoring and modelling system. The three- dimensional hydrodynamic modelling of nature based mangrove structure depicted here is a part of the methodological framework developed for this.



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