

VEGETATED HYDRODYNAMIC SYSTEM: PARAMETERIZATION AND STOCHASTIC DEPENDENCE MODELLING

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INTRODUCTION

Coastal flood risk is an alarming threat due to increasing hazard and vulnerability owing to climate and anthropogenic changes. Concurrently, vegetation as a nature-based solution, along with conventional solutions like dikes, has convincingly shown potential for flood hazard (wave load) reduction. However, be it numerical or experimental, only a few isolated case evidences have been presented. Therefore, there is a need for generalized wave load reduction results. To do so, beside costly and labor-intensive physical modeling, numerical modeling is also demanding.

Modeling complex systems necessitates elaborating dependence among constituting system components. As a possibility, Bayesian networks (BN) are being used in different studies in coastal engineering. Until now, mostly discrete BNs with conditional probability tables have been used which are mostly quantified with synthetic datasets requiring an impractical number of numerical simulations. The combination of conditions required to get meaningful generalized results for a vegetated hydrodynamic system, for example 10 parameters with 4 variations each, is in the order of a million simulations as one parameter is varied at a time. This study introduces stochastic dependence modelling using non-parametric Bayesian networks (NPBN) for vegetated coastal systems. The system has been parametrized using continuous distributions, and likely (conditional) correlations among variables. NPBNs can cater continuous marginal distributions and use Gaussian copulas. The model represents a consistent joint probability distribution and hence can be used to generate conditions in physically realistic windows. It adds value to numerical modelling by reducing the number of simulations required to get meaningful generalized results.

METHOD

Vegetated coastal foreshores have been parametrized for benthic, submerged, and emergent vegetation through three types of variables: i) hydraulic, ii) vegetation, and iii) hybrid (dike) variables. Each variable has been described with a continuous marginal distribution along with (conditional) rank correlations among variables. These were determined from literature, data, or "in house" expert judgement. Gaussian-copula based non-parametric Bayesian networks have been created for submerged (saltmarshes) and emergent (mangroves) vegetation, both combined with a seagrass meadow in the lower intertidal. Monte Carlo sampling was carried out from the NPBNs which resulted in realistic physical conditions sampled from a stochastic model which takes multivariate dependence into account.

RESULTS

The major result is the probabilistic parametrization of the vegetated hydrodynamic system in terms of ranges, distributions, and correlations. Another major result is the stochastic model using NPBN which captures dependence among variables of interest using Gaussian copulas. The NPBN also samples varied vegetated hydrodynamic conditions in physically realistic windows. The correlation matrix of the NPBN helps to identify and quantify the sensitivity of the system to the different variables considered. The system response, in relevance to flood hazard reduction, could be observed using variables related to wave attenuation, set-up, or run-up.

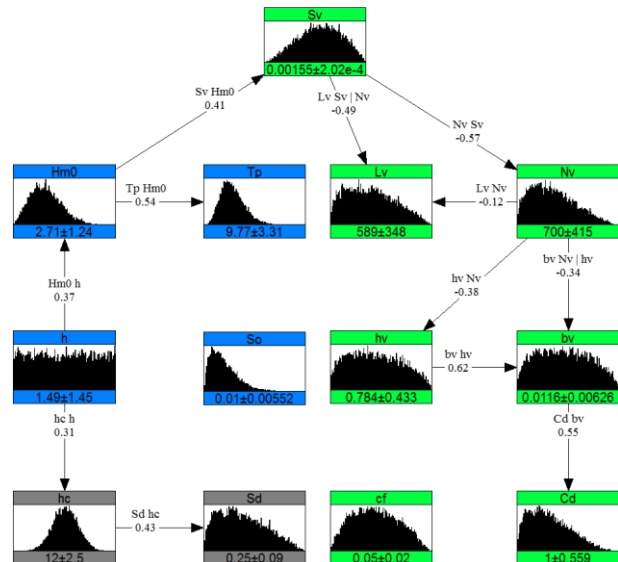


Figure 1 - Stochastic model, an NPBN, for a seagrass-saltmarsh coupled vegetated hydrodynamic system.

DISCUSSION

The value of the stochastic dependence modelling of vegetated coastal systems is that physically realistic conditions are simulated which reduces bulk simulation time and increases authenticity. Also, more variations per parameter are possible as in each run all parameters are varied at once which helps in obtaining generic results in much lesser, e.g. just a hundred, simulations. Hence, by using the dependence modeling, numerical simulations could be improved and reduced by orders of magnitude.

CONCLUSION

Main findings, that were derived by using a NPBN, help to pave way for implementation of nature-based solutions for a range of realistic conditions that can be found across global coastal foreshores.