Assessing safety of nature-based flood defenses: Dealing with extremes and uncertainties

Authors: Vincent Vuik[a,b], Saskia van Vuren[a,c], Bas W. Borsje[d,e], Bregje K. van Wesenbeeck[a, f], Sebastiaan N. Jonkman[a]

[a] Delft University of Technology, Faculty of Civil Engineering and Geosciences, Delft, the Netherlands
[b] HKV Consultants, Lelystad, the Netherlands
[c] Rijkswaterstaat, Utrecht, the Netherlands
[d] University of Twente, Water Engineering & Management, Enschede, the Netherlands
[e] Board Young Waddenacademie, Leeuwarden, the Netherlands
[f] Deltares, Delft, the Netherlands

Abstract

Vegetated foreshores adjacent to engineered structures (so-called hybrid flood defenses), are considered to have high potential in reducing flood risk, even in the face of sea level rise and increasing storminess. However, foreshores such as salt marshes and mangrove forests are generally characterized by relatively strong temporal and spatial variations in geometry and vegetation characteristics (e.g., stem height and density), which causes uncertainties with regards to their protective value under extreme storm conditions. Currently, no method is available to assess the failure probability of a hybrid flood defense, taking into account the aforementioned uncertainties. This paper presents a method to determine the failure probability of a hybrid flood defense, integrating models and stochastic parameters that describe dike failure and wave propagation over a vegetated foreshore. Two dike failure mechanisms are considered: failure due to (i) wave overtopping and (ii) wave impact on revetments. Results show that vegetated foreshores cause a reduction in failure probability for both mechanisms.
This effect is more pronounced for wave impact on revetments than for wave overtopping, since revetment failure occurs at relatively low water levels. The relevance of different uncertainties depends on the protection level and associated dike height and strength. For relatively low dikes (i.e., low protection levels), vegetation remains stable in design conditions, and plays an important role in reducing wave loads. In case of higher protection levels, hence for more robust dikes, vegetation is less important than foreshore geometry, because of expected stem breakage of the vegetation under these more extreme conditions. The integrated analysis of uncertainties in hydraulic loads, dike geometry and foreshore characteristics in this paper enables the comparison between nature-based flood defenses and traditionally engineered solutions, and allows coastal engineers to design hybrid flood defenses worldwide.

Keywords:

Salt marsh, Vegetation, Foreshore, Wave attenuation, Uncertainties, Wave overtopping