Salt marshes for flood risk reduction: Quantifying long-term effectiveness and life-cycle costs

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Abstract

Flood risks are increasing worldwide due to climate change and ongoing economic and demographic development in coastal areas. Salt marshes can function as vegetated foreshores that reduce wave loads on coastal structures such as dikes and dams, thereby mitigating current and future flood risk. This paper aims to quantify long-term (100 years) flood risk reduction by salt marshes. Dike-foreshore configurations are assessed by coupled calculations of wave energy dissipation over the foreshore, sediment accretion under sea level rise, the probability of dike failure, and life-cycle costs. Rising sea levels lead to higher storm waves, and increasing probabilities of dike failure by wave overtopping. This study shows that marsh elevation change due to sediment accretion mitigates the increase in wave height, thereby elongating the lifetime of a dike-foreshore system.
Further, different human interventions on foreshores are assessed in this paper: realization of a vegetated foreshore via nourishment, addition of a detached earthen breakwater, addition of an unnaturally high zone, or foreshore build-up by application of brushwood dams that enhance sediment accretion. The performance of these strategies is compared to dike heightening for the physical boundary conditions at an exposed dike along the Dutch Wadden Sea. Cost-effectiveness depends on three main factors. First, wave energy dissipation, which is lower for salt marshes with a natural elevation in the intertidal zone, when compared to foreshores with a high zone or detached breakwater. Second, required costs for construction and maintenance. Continuous maintenance costs and delayed effects on flood risk make sheltering structures less attractive from a flood risk perspective.
Third, economic value of the protected area, where foreshores are particularly cost-effective for low economic value. Concluding, life-cycle cost analysis demonstrates that, within certain limits, foreshore construction can be more cost-effective than dike heightening.

Keywords:

Salt marsh, Flood risk, Sea level rise, Nature-based solutions, Life-cycle costs