Figure 1. Extensive salt marshes along the Wadden Sea dikes (Image courtesy Jantsje van Loon-Steensma).

Jantsje van Loon-Steensma

INTEGRATING SALT MARSH FORELAND INTO THE DIKE DESIGN

A WINDOW OF OPPORTUNITY FOR A SELF-MAINTAINING LEVEE

Dr. ir. Jantsje van Loon-Steensma is a researcher and lecturer of Climate Change and Flood Protection in the department of Enviromental Sciences at Wageningen University & Research. In the MFFD Program she works as a Postdoc in the project 'Contribution of Multifunctional Flood Defenses to landscape values and spatial quality'. Her research focuses on climate adaptation by integrating functions in flood defenses. She combines hydraulic, ecological, geographical and economical aspects in the search for climate proof, robust flood defenses that in addition to flood protection, also favor nature, landscape, heritage, recreation or economic values.

Integrating natural salt marsh foreland with a structural flood defense is increasingly seen as a promising approach to flood protection under changing climatic conditions and as a way to combine multiple functions and values in the coastal zone (see Van Loon-Steensma page 148 this volume). The potential of this multifunctional flood defense concept has been explored in the Dutch Wadden Sea region.

Extensive salt marshes are present along the dikes of both the Wadden Sea mainland and the barrier islands (see figure 1). These marshes form a shallow transition zone that attenuates incoming waves before they reach the dike. When water depths in this zone diminish to less than the wave base, the wave's shape is modified and it starts shoaling. Wave length and wave velocity both decrease, and wave height increases before breaking. After breaking, wave energy is further dissipated by drag induced by marsh vegetation and by bottom friction. Wave damping depends strongly on the profile of the coast, the water depth above the salt marsh, the width of the salt marsh zone, surface topography, and vegetation characteristics (Le Hir et al. 2000; see also studies cited in Anderson et al. 2011 and in Gedan et al. 2011).

Salt marshes are areas vegetated by salt-tolerant plants and subject to periodic flooding due to the fluctuating water levels of the adjoining saline water body (Adam 1990). They generally develop high in the intertidal zone in sheltered conditions where wave action is limited, allowing fine sediment to settle and accumulate (Allen and Pye 1992; Allen 2000). Once the upper part of the intertidal zone is no longer submerged with each tide, salt marsh plants can become established. By trapping sediment, pioneer vegetation contributes to accretion and development of creeks, rendering the environment suitable for species (forbs, grasses and low shrubs) that need more stable sediment and are less tolerant to flooding (in duration as well as frequency) (Adam 1990; Allen 2000). This results in zones, with pioneer species seaward and more mature vegetation in the higher landward zone. Because of the positive feedback effects of salt marsh vegetation and sedimentation, vegetation plays an important role in salt marsh formation (Allen 2000). Salt marsh plants can thus be understood as eco-engineers, as organisms that physically change the abiotic environment (Jones et al. 1994; Hastings et al. 2007).

However, like most coastal systems, salt marsh ecosystems are extremely sensitive to changing environmental conditions. Strong currents or wave attack may lead to lateral erosion. Generally, a moderate sea level rise creates conditions where marshes build up by accretion (Allen 2000) or shift landward. To keep pace with a rising sea level, however, a permanent supply of sediment needs to enter the tidal system. If sediment import is insufficient, flats and marshes will drown (Van Goor et al. 2003).

Various exploratory and field studies have been conducted in the Wadden Sea region (which is characterized by shallow water depths and moderate storm wave heights). These studies have shown that the salt marsh areas adjacent to the dikes significantly affect wave impact on the dike (see e.g. Smaale, 2014; Vuik et al. 2016). Including salt marsh foreland into the dike design would affect both the height and revetment requirements needed to meet the required safety level. Analysis of the effect of realistic vegetation characteristics on modeled wave heights also showed that wave damping is strongly related to the variety of vegetation

Figure 2.
Salt marshes along Galveston Island at the bay shore, Texas, USA (Image courtesy Baukje Kothuis).

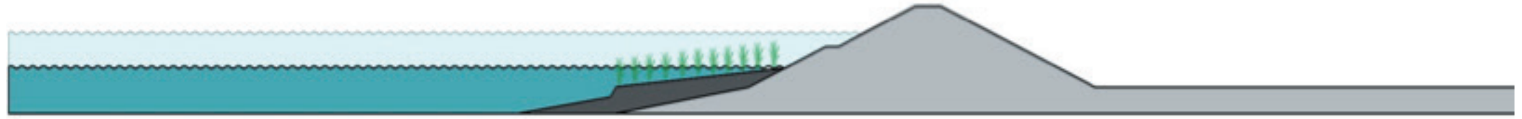

Figure 3. (above). Coastal defense system combining hard engineered infrastructure (a dike) with an adjacent dynamic ecological zone (a salt marsh) (Source: Van Loon-Steensma et al. 2014).

and the specific zone of the salt marsh (Van Loon-Steensma et al. 2016). At the study site, a densely vegetated foreland 90 m wide would dampen the wave height more than 80% under average storm conditions (with a frequency of 5–10 times/y), whereas under extreme conditions (1/2000 y) the same foreland would dampen the wave height up to 50% (Van Loon-Steensma et al. 2016). These results emphasize the potential of a multifunctional flood defence using salt marsh forelands, which integrates safety with nature and landscape values.

However, flood protection imposes different requirements on the extent and features of salt marshes than nature conservation and development (Van Loon-Steensma & Vellinga, 2013). Wave damping is most effective with a high, stable, and densely vegetated salt marsh, while nature thrives with dynamic processes and differences in elevation (Allen, 2000). In practice, this means that the design of the flood defense must offer space for natural salt marsh processes, which require variations in height and depth developing over time in the foreshore zone. The design needs to combine hard coastal defense infrastructure with a dynamic ecological zone adjacent to it: The overall design will thus be characterized by a broad zone that includes a hard engineered solution, rather than by a merely metered cross section commonly used in engineering solutions (Figure 3). If this ecological zone is able to adapt to changing conditions, for example keeping pace with sea level rise, then such a broad flood protection zone can be seen as a self-maintaining levee. Of course, the vegetated foreland and adjacent mudflats must be managed and maintained in such a way that they can meet as far as possible both the ambitions of flood protection and those of nature conservation.

Extensive research on this subject can be found in the PhD thesis of Jantsje van Loon-Steensma: 'Salt marshes for flood protection. Long-term adaptation by combining functions in flood defenses' (2014).

The thesis investigates if and how the same or an even higher level of safety can be achieved in the Wadden region by means of creating a flood defence zone that favours, besides flood protection, nature and landscape values or heritage, recreational, and even economic values. While all available innovative flood defenses are considered, special attention is given to the role of salt marshes in this context.

The thesis shows that integration of salt marshes into long-term adaptation strategies is very promising for the Wadden region, especially for dike sections where salt marshes are already present or developing. Vegetation is a major factor in the wave damping capacity of salt marsh forelands, therefore it is important to take into account the zonation of different plant. Furthermore, the thesis reveals that in salt marsh restoration, the goals of flood protection and nature and habitat conservation and enhancement can be mutually reinforcing.