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Coastal marsh degradation: modeling the influence of vegetation die-off patterns on flow and sedimentation

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Coastal marshes are vulnerable ecosystems that provide ecosystem functions such as storm protection and carbon sequestration. However, degradation of vegetated marshes into bare tidal flats or open water has been reported as a worldwide phenomenon, threatening their valuable wetland functions. Moreover, tidal marshes and bare flats are considered as alternative stable ecosystem states, which implies that, once vegetated marshes have degraded to bare flats, the (re)conversion from bare flats to marsh vegetation may be very difficult. Recent aerial photo analysis has demonstrated that the degradation or die-off of a marsh area is a spatial process, whereby vegetation is typically replaced by non-vegetated areas in the form of interior marsh pools, also known as ponds or marsh basins. On a small scale, these pools have similar characteristics among different marshes worldwide: pools that are located further away from tidal channels and with broad channel connections to the tidal channel system appear to have low surface elevations and a low probability for marsh recovery (this is re-establishment of vegetation on the surface). Interior pools located closer to, but that are not connected to channels on the other hand, are positioned on higher elevations and are more likely to recover. These findings may have important implications for the restoration potential of degraded marshes and their functions.

We hypothesize that bio-geomorphologic interactions are the main mechanisms causing these differences in elevation and recovery potential of interior marsh pools: pools that are not connected to the channel system, are separated from the channel by vegetation, which reduces the flow velocity, increases sedimentation and may explain our observation of higher surface elevation of this type of pools. In contrast, pools that are connected with the channel system are not protected by vegetation and will experience higher flow velocities and lower sedimentation rates or even erosion, which may explain their lower surface elevation. Therefore the establishment of marsh plants will be unfavorable. So far, however, this hypothesis has not been verified.

In order to investigate the influence of these different types of pool patterns on spatial flow and sedimentation patterns, we used an existing hydrodynamic and sediment transport model (Delft3D) that has been calibrated and validated against field data on tidal marsh flow and sedimentation. The model reproduces the bio-geomorphologic effects of complete vegetation removal, but different pool patterns have not been studied until now. By simulating different pool patterns, we are able to verify our hypothesis regarding elevation changes and marsh recovery potential in degraded marsh pools. This highlights the importance of bio-geomorphologic feedbacks for marsh degradation and recovery.