Historical agricultural land use leads to reduced groundwater dynamics in a restored freshwater tidal marsh

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In the past centuries, many tidal marshes along estuaries and coasts have been embanked to gain land for industry and agriculture, leading to severe problems such as an increased flooding risk, loss of biodiversity and a deteriorating water quality. Nowadays, numerous of these former marshes are being restored to recover their ecosystem functions. There are, however, more and more indications that restored tidal marshes do not deliver these ecosystem services to the same extent as natural tidal marshes. In particular, we hypothesize that a reduced groundwater flow, caused by historical agricultural soil compaction, implies a reduced biogeochemical nutrient cycling and decreased contribution of restored marshes to water quality improvement.

Conducted research

We measured groundwater flow and soil properties in both a natural freshwater tidal marsh (De Plaat) and a restored freshwater tidal marsh (Lippenbroek) along the Scheldt estuary in Hamme, Belgium. The soil in the restored marsh consists of a layer of freshly accreted sediment, underlain by compact relict agricultural soil. Our results indicate that groundwater level fluctuations are occurring over a deeper soil profile in the natural marsh (median groundwater level 34 cm below the surface) compared to the restored marsh, where groundwater level fluctuations are restricted to the layer of freshly accreted sediment (median groundwater level 8 cm below the surface). Using X-ray CT-scans of soil cores, we found that the soil in the natural marsh and the upper layer of the restored marsh is intersected by macropores that increase the hydraulic conductivity of the sediment, whereas these macropores are absent in the compacted agricultural soil. As a result, the compact agricultural soil forms a barrier for groundwater flow and puts constraints on the amount of pore water that is exported to the creeks in between tidal events. By consequence, nutrient cycling in restored tidal marshes is expected to be negatively affected.

The next step

We now aim to link the groundwater dynamics to the biogeochemical functioning of freshwater tidal marshes. Furthermore, we will determine the optimal soil structure and creek density a restored tidal marsh should have to maximize its nutrient cycling function. To accomplish this goal, we will set up a mesocosm experiment in which different soil treatments (e.g. adding organic matter or creating artificial macropores) will be applied to the compact agricultural soil. Additional field measurements will be performed to set up a numerical groundwater and solute transport model. Based on this model and in consultation with the hydraulic engineering sector, the ultimate goal of the research is to formulate viable design criteria for future tidal marsh restoration projects.

Keywords: tidal marsh restoration; Scheldt estuary; groundwater dynamics; soil structure; nutrient cycling