Do algae boost landscape formation?

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Introduction

The development from intertidal mudflat towards salt marsh is characterised by strong positive feedbacks in which drainage, mud consolidation and benthic algae mat growth might play a central role. We suggest that bistability can arise between a fluidic mud state and a vegetated state. Once drainage channels have been formed, lateral drainage further enhances mud consolidation, promoting benthic algae growth, which again reinforces drainage structures. On the other hand, when mud is poorly consolidated ("fluid mud") any topography, essential for good drainage, is rapidly flattened out again. The resulting lack of drainage topography impedes algae growth, such that the system remains in a fluidic mud state. This raises the question how (drainage) bedforms can arise from initially very poorly consolidated, fluidic mud. We hypothesise that benthic algae can actively decrease the mud fluidity locally; this enables the formation of self-organised bedforms (Figure 1), facilitating the transition from poorly consolidated to well-drained mudflat state and setting the stage for further development towards a salt marsh.

Methods

We motivate our hypotheses with a simple numerical biogeomorphological model (Figure 2), coupling depth-averaged hydrodynamics to algae mat growth and a simplified bed evolution equation. Algae mats limit sediment erosion, whereas inundation reduces algal growth. A crucial, new assumption herein is that algae locally decrease the fluidity of deposited sediment. Model assumptions and results are compared to field measurements on an intertidal mudflat in the Schelde estuary on the Dutch-Belgian border. Field data comprises aerial photos (drone) to detect algae presence, bathymetric measurements (terrestrial laser scanner) to determine bedforms and sediment samples to quantify mud consolidation.

Conclusions

We show that benthic algae mats can, by locally reducing mud fluidity, trigger the formation of mudflat drainage structures and further development to a vegetated state. This mechanism might be especially relevant for initially poorly consolidated mudflats, e.g. after managed coastal realignments. Without the influence of benthic algae, development from such a fluidic mud state towards a well-drained vegetated state might be strongly impeded. This emphasises the importance of biotic processes for intertidal morphodynamics.

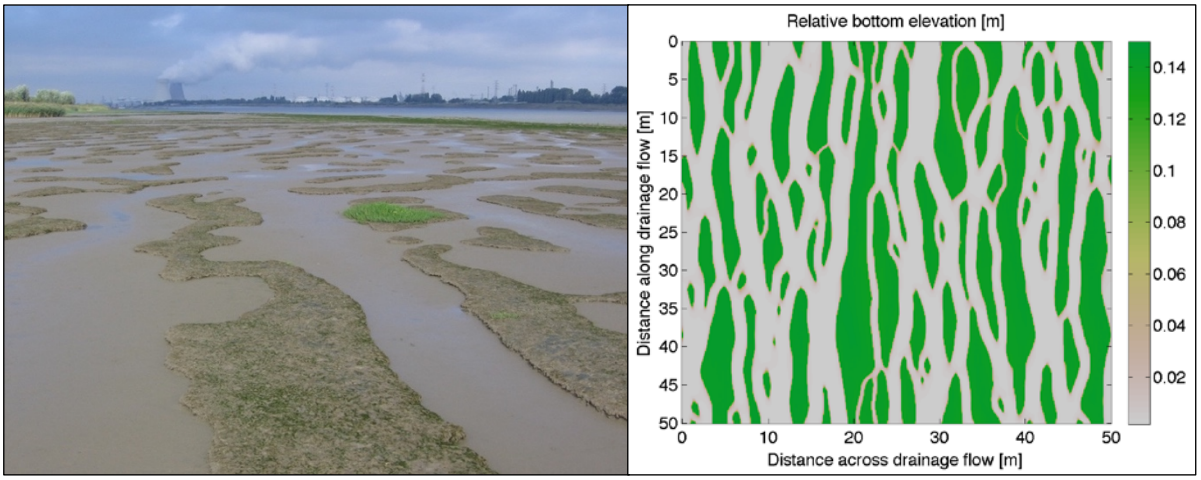

Figure 1 (left). Regular bedforms induced by benthic algae mats (Vaucheria) on an intertidal mudflat in the Schelde estuary, Dutch-Belgian border. Figure 2 (right). Numerically simulated bedforms (top view) formed by biogeomorphological interactions; drainage flow is oriented from top to bottom of the picture.