HORIZON 2020

Tidal marshes: bio-geomorphic self-organization and its implications for resilience to sea level rise and changing sediment supply

Reporting

Project Information

TIGER

Grant agreement ID: 798222

Project website

DOI
10.3030/798222

Project closed

EC signature date
19 November 2018

Start date
1 September 2019

End date
31 August 2022

Funded under
EXCELLENT SCIENCE - Marie Skłodowska-Curie Actions

Total cost
€ 258 530,40

EU contribution
€ 258 530,40

Coordinated by
UNIVERSITEIT ANTWERPEN
Belgium

Periodic Reporting for period 2 - TIGER (Tidal marshes: bio-geomorphic self-organization and its implications for resilience to sea level rise and changing sediment supply)

Reporting period: 2021-09-01 to 2022-08-31

Summary of the context and overall objectives of the project

Intertidal landscapes are complex environments located between land and sea, which are regularly flooded by tides. They provide highly valuable ecosystem services that are threatened by increasing sea level rise and decreasing sediment supply.

Previous studies showed that the small-scale (order of square meters) interactions between vegetation dynamics, water flow and sediment transport (so-called biogeomorphic feedbacks) have a great impact on channel network formation and evolution at the landscape-scale (order of square kilometers). This process is called biogeomorphic self-organization.

Our objective is to investigate the impact of plant species traits on biogeomorphic self-organization of intertidal landscapes. More specifically, we hypothesize that (1) different plant species traits lead to the self-organization of different channel network patterns, and (2) the resulting self-organized landscape structures determine the efficiency to distribute and trap sediments on the intertidal floodplains, and hence the resilience of the landscape to increasing sea level rise and decreasing sediment supply.

By using a combination of remote sensing analyses and numerical simulations, we aim at producing new fundamental knowledge on landscape self-organization by biogeomorphic feedbacks, and its implications for the resilience of intertidal landscapes against environmental changes.

Work performed from the beginning of the project to the end of the period covered by the report and main results achieved so far

We developed the biogeomorphic model Demeter to simulate explicitly, in tidal wetlands, the feedbacks between (i) the tidal hydrodynamics, (ii) the sediment erosion, transport, deposition, and resulting bed level changes, and (iii) the vegetation establishment, expansion and die-off, following different colonization strategies (e.g. patchy vs. homogeneous). We adopted a multiscale approach in which the hydro-morphodynamics is simulated at coarser resolution than the vegetation dynamics. As a results, Demeter accounts for relevant fine-scale flow-vegetation interactions (less than a square meter) together with their impact on vegetation and landform developments at the landscape scale (several square kilometers) and on the long term (centuries), which was crucial for the simulations planed in this project.

We also developed the software program TidalGeoPro to extract tidal channel network characteristics from aerial pictures and numerical model results. This allowed us to analyze spatial patterns of tidal channel networks and investigate how they impact the transport of sediments towards the tidal floodplains. Together with Demeter, TidalGeoPro contributed to a better understanding of tidal wetland resilience to accelerating sea level rise.

The multiscale approach of Demeter required the development of novel multiscale coupling techniques. We have developed a convolution method to spatially refine coarse-resolution hydrodynamic simulations of flow velocities around fine-resolution patchy vegetation patterns. and we have provided evidence that it can substantially improve the representation of important biogeomorphic processes.

The first application of Demeter was a tidal marsh restoration project at the Belgian/Dutch border along the Scheldt Estuary, for which we had important datasets for model calibration and validation. It is also an important milestone for this project because it serves as proof of concept that Demeter can be used for assessing tidal marsh resilience to sea level rise.

We also applied Demeter to simulate the biogeomorphic development of a generic tidal marsh landscape, revealing two overlooked mechanisms by which dense vegetation hinders sediment transport from tidal channels towards marsh interiors, hence inhibiting sediment accretion with sea level rise. However, under extreme rates of sea level rise that we may encounter in the next century, these mechanisms weaken, and dense vegetation tends to slow down marsh drowning.

The results of this project lead to four scientific articles (including one in review, and one in preparation) and were presented in six international conferences.

Progress beyond the state of the art and expected potential impact (including the socio-economic impact and the wider societal implications of the project so far)

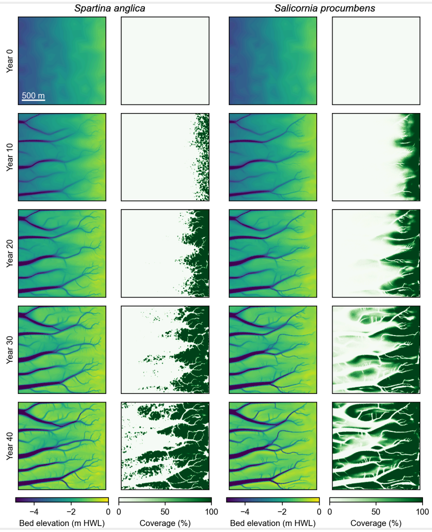
The main objective of this project is to understand the role of vegetation in shaping channel networks in tidal wetlands, and the resulting impact on tidal wetland resilience to increasing sea level rise and decreasing sediment supply. The socio-economic impact of this research is very high, because of the important ecosystem services provided by tidal wetlands (e.g. carbon sequestration and coastal protection).

To reach our objectives, we have developed two software programs at the state of the art in the field of (bio-)geomorphology. TidalGeoPro is the first toolbox able to extract channel network characteristics from aerial pictures and numerical model results that is specifically designed for intertidal systems. Demeter is the first biogeomorphic model able to account for relevant fine-scale flow-vegetation interactions (less than a square meter) together with their impact on vegetation and landform developments at the landscape scale (several square kilometers) and on the long term (centuries). It makes use of state-of-the-art biogeomorphic coupling techniques (Gourgue et al., 2021). TidalGeopro and Demeter are both published with open-source licenses and support state-of-the-art research by other groups internationally.

Our project results demonstrate that the resilience of restored tidal marshes (and the preservation of the ecosystem services they provide) can be steered by restoration design (Gourgue et al., 2022) and that Demeter is a useful resource in that perspective. They also reveal two overlooked mechanisms by which dense vegetation inhibits sediment accretion with sea level rise, hence suggesting that tidal wetlands are more vulnerable than previously thought (Gourgue et al., submitted).

References:

Gourgue, O., van Belzen, J., Schwarz, C., Vandenbruwaene, W., Vanlede, J., Belliard, J.-P. Fagherazzi, S., Bouma, T.J. van de Koppel, J., Temmerman, S. (2022), Biogeomorphic modeling to assess the resilience of tidal-marsh restoration to sea level rise and sediment supply, Earth Surface Dynamics, 10, 531-553, https://doi.org/10.5194/esurf-10-531-2022.
Gourgue, O., Belliard, J.-P. Xu, Y., Kleinhans, M.G. Fagherazzi, S., Temmerman, S., Dense vegetation inhibits saltmarsh accretion with sea level rise, submitted to Nature Geoscience.



Bed level and vegetation cover evolution for two species with contrasting colonization strategies.

Last update: 5 February 2023

Permalink: https://cordis.europa.eu/project/id/798222/reporting