Understanding the resilience of salt marshes to changes in external forcings

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Abstract

Salt marshes are ecosystems with significant economic and environmental value. They provide numerous ecosystem services and act as natural coastal defences by buffering storm waves and stabilising sediments (Leonardi et al., 2016). However, with accelerating rate in sea-level rise, possible increases in storm intensity and increasing land reclamation, it is not clear whether salt marshes will be able to retain their resilience. The current paradigm is that a positive sediment budget supports the survival and accretion of salt marshes while a negative sediment budget causes marsh degradation (Ganju et al. 2015). Here we present the results of a series of studies that used a sediment budget approach and an integration of modelling and paleoenvironmental analysis to investigate the resilience of estuaries and salt marshes to rise in sea-level, change in storm activity and anthropogenic interventions. The Ribble Estuary, North-West England, was used as a test case, as it is one of the largest salt marsh systems in Europe, it was subject to several anthropogenic interventions (e. g. embankment construction) and it was anthropogenically restored through managed realignment to provide coastal protection against flooding (Pontee et al., 2014). The various processes were investigated using the hydrodynamic model Delft3D to simulate the estuary morpho-dynamics under selected scenarios, and optically stimulated luminescence (OSL), geochemistry and particle size analysis to reconstruct the past evolution and adaptation of the estuary morphology. Results showed that sea-level rise threatens estuary and marsh stability by promoting ebb dominance and triggering a net export of sediment. Conversely, storm surges promote flood dominance and trigger a net import of sediment, therefore aiding the resilience of the system. Storms with the highest intensities also have the potential to counteract the negative impact of sea-level rise by masking its effects on the sediment budget. The addition of embankments, on the other hand, can further promote ebb dominance in the system and intensify sediment export, further threatening marsh stability. Leonardi, N. et al. (2016). PNAS, 113(1), 64-68. Ganju, N.K. et al. (2015). Geoph. Res. Lett., 42(19), 7992-8000. Pontee, N.I. et al. (2009). Eng. Sust., 162(4), 223-228.

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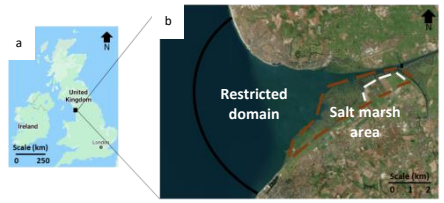
1) Aim and objectives

Investigate marsh resilience under various scenarios of climate and environmental change using a sediment budget approach:

- ❑ Study n. 1 investigates changes in sediment budget in relation to storm surges and sea-level rise using Delft 3D.
- ❑ Study n. 2 investigates changes in sediment budget in relation to sediment supply and embankment construction using a combination of paleoenvironmental analysis and Delft 3D.

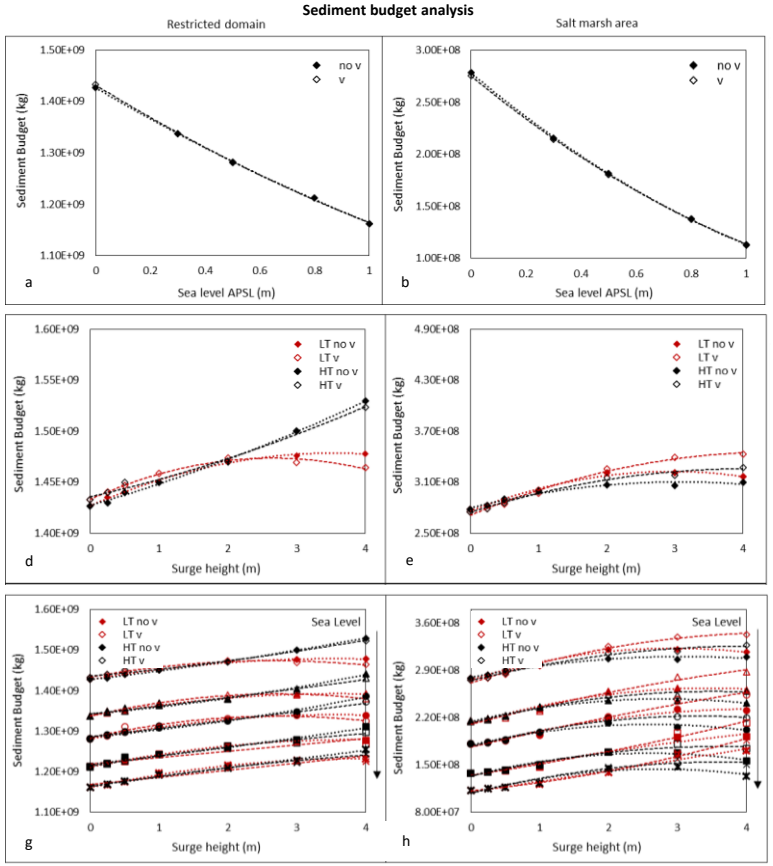


2) Study site

Ribble estuary, North West England:

- ❑ Funnel shaped, hypertidal.
- ❑ Widespread anthropogenic interventions including embankment contruction since 1810.
- ❑ One of the largest tidal flat - salt marsh complexes in Europe, part of which recently restored through managed realignment.
- ❑ Marsh accreting at a fast rate, previously thought to be linked to embankment presence.

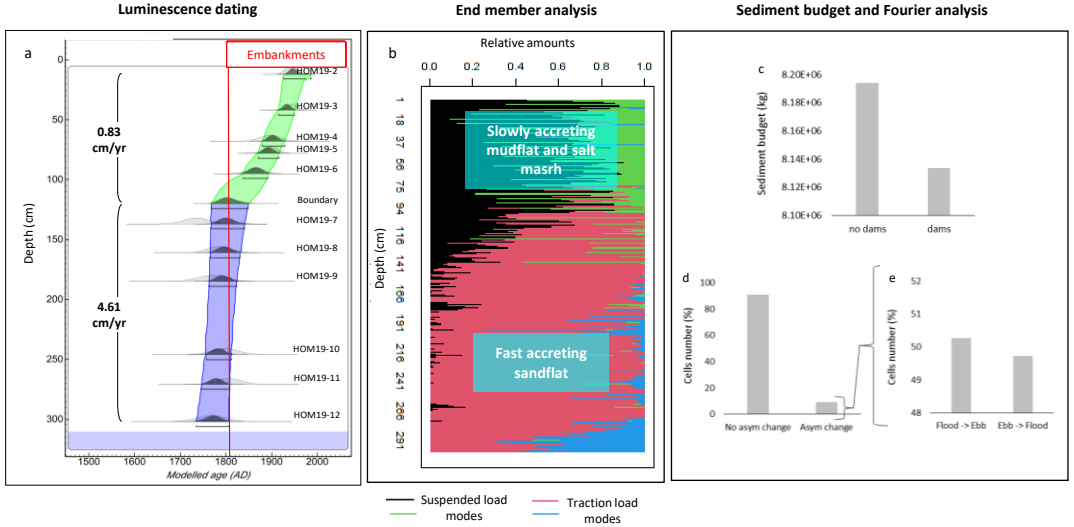
3) Study n. 1 - Sea-level rise threatens marsh resilience but intense storm surges counteract sea-level rise impact



Key findings

- ❑ Sea-level rise enhances ebb tides and triggers a net export of sediment (a,b).
- ❑ Increase in storm intensity (i.e. surge height) enhances flood tides and triggers a net import of sediment (d,e).
- ❑ Changes in deposition are caused by changes in tidal distortion and asymmetry (c,f).
- ❑ Intense storm surges counteract sea-level rise impact (g,h).
- ❑ For other factors causing further changes to the trends - [1,2].

4) Study n. 2 – Embankments threaten marsh resilience but high sediment supply helps marsh survival



Key findings

- ❑ The rapid accretion precedes embankment construction (a).
- ❑ Correlation between accretion rates (a) and natural evolution of the system from rapid accreting sandflat to slower accreting mudflat and salt marsh (b).
- ❑ Geochemistry correlated sediment supply to the marsh platform with sediments from the bed of the Irish Sea, characterised by high quantity of mobile sediment, legacy of Irish Sea Glacier [3].
- ❑ Embankments enhanced ebb tides and increased sediment export (c,d,e).

5) Conclusions

- ❑ Sea-level rise and embankment construction threaten marsh resilience.
- ❑ Intense storm surges and high natural sediment supply help marsh survival.

6) Future research

Using a combination of Delft3D, field monitoring and machine learning to characterise spatial variability of storm deposits on salt marsh platforms.

References

[1] Pannozzo et al. (2021). Geomorphology, 389 (4): 107825. [2] Pannozzo et al. (2021). Data in Brief, 38: 107336. [3] Pannozzo et al. (2021). JGR: Earth Surface, In Review.