The effect of mud and vegetation on shaping infilling estuaries in laboratory scale experiments

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Objective

Building and raising land is urgently needed to keep up with future sea level rise. Palaeogeographical reconstructions show that such land formation had occurred in Holocene estuaries that were infilled over time (e.g. de Haas et al., 2019), and this is still ongoing in some natural systems, such as the Dovey Estuary in Wales, England. While this infill process is still unclear, current understanding and analogies with rivers suggest that mud and vegetation play a key role by elevating bars and confining flow.

Aim: to unravel experimentally how mud and vegetation shape and affect the infill of entire estuaries and what the resulting stratigraphy becomes.

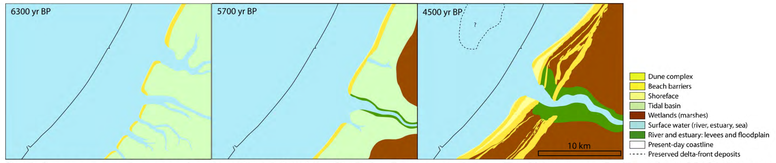


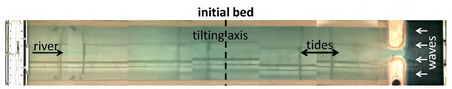
Fig. 1: Palaeogeographical reconstruction of the infill of the Old Rhine Estuary near Leiden, The Netherlands (De Haas et al., 2019). Ages are in cal yr BP.

Methods

Previous experiments simulated **exporting** estuaries in a tilting flume (the Metronome) with sand (Leuven et al., 2018), with mud simulated as crushed nutshell (Braat et al., 2018), and with mud and vegetation (Lokhorst et al., 2017).

Novel: The simulation of **importing** estuaries using flood asymmetry, and study the effect of mud and vegetation on the infill process in three experiments.

- Initial sand bed, rectangular basin with barrier islands
- Flood asymmetric tilting (M2+M4)
- 10,000 tidal cycles
- Tilting period = 40 s
- Maximum slope = 6 mm/m
- River discharge = 0.25 L/s during ebb
- Waves during flood
- Crushed nutshell as mud simulant
- Nutshell feed to river & tidal inlet = 7 ml/cycle
- Seeds every 500 cycles via river & tidal inlet
  - Alfalfa, *Lotus pedunculatus*, *Veronica beccabunga*



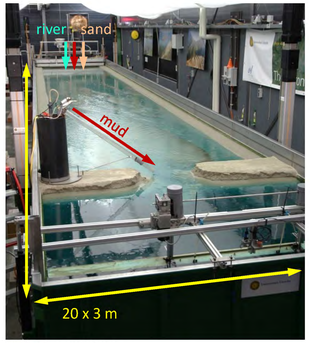


Fig. 2: Overview of the tilting flume "the Metronome" along with a top view of the initial bed morphology.

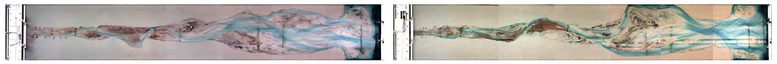


Fig. 3: Top view of previous experiments of exporting estuaries in the tilting flume "the Metronome". Left: first estuary on a laboratory scale with mud by Braat et al. (2018). Right: first with mud and vegetation (Alfalfa, *Lotus*, *Veronica* and *Sorghum bicolor*) by Lokhorst et al. (2017).

Results

Morphological development

- Net import of sediment, which results in high bars, some of which are risen above the high water level.
- Dynamic large shoal in the middle of the estuary.
- More stable and slightly higher bars when mud and especially vegetation are included.
- Bayhead delta formation.

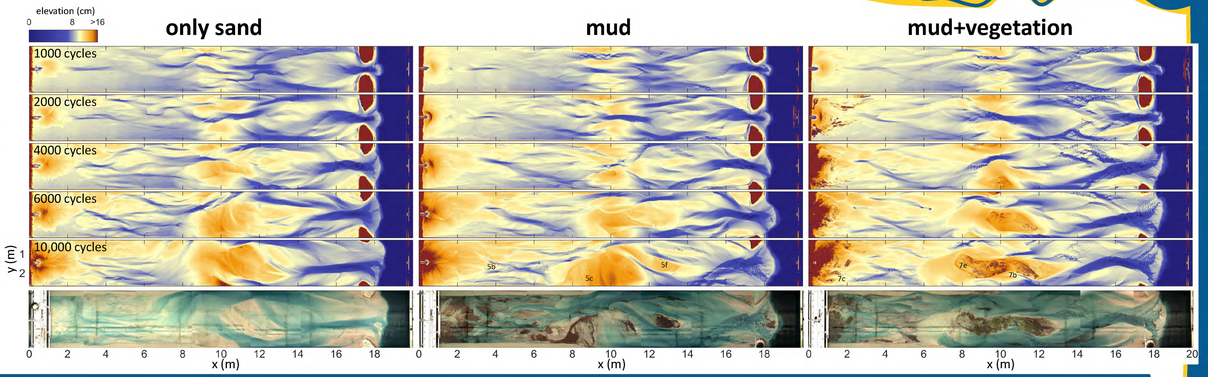


Fig. 4: Morphological development of the three flume experiments. Overhead imagery is taken at the end of flood.

Mud distribution and effects

- Mud mainly ends up on top of bars and in abandoned channels, especially in the upstream part.
- Cohesive mud decreases channel and shoal dynamics (in line with Braat et al., 2018).
- Mud layers are better preserved and more abundant in the upstream half of the estuary.

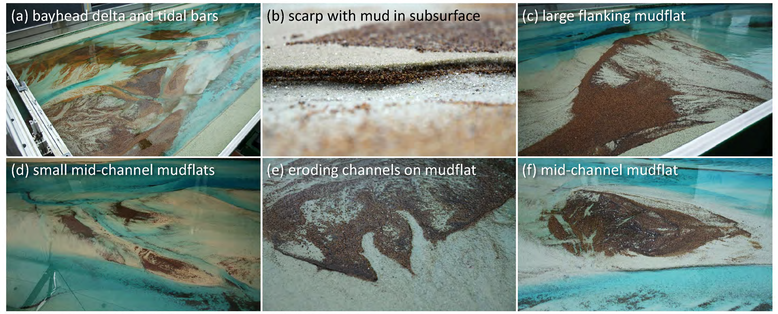


Fig. 5: Examples of mud deposits on tidal flats and in the subsurface.

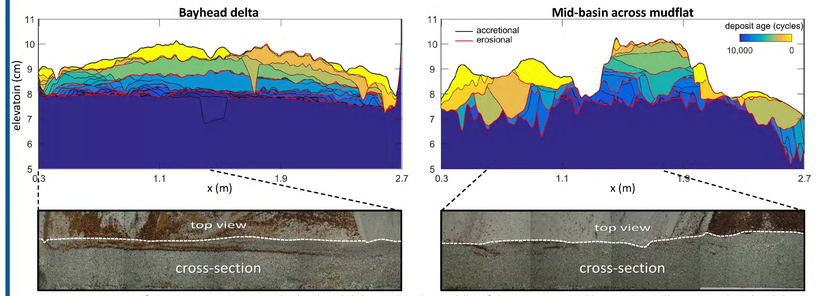


Fig. 6: Deposit age for a cross-section over the bayhead delta and in the middle of the estuary. Mud layers are well-preserved in the delta, but not in the mid-basin due to fewer mud deposits and higher dynamics. Images are taken obliquely, so both top view and cross-section.

Vegetation distribution and effects

- Vegetation ends up on high bars, with *Veronica* commonly acting as the pioneering species.
- It effectively traps fluvial sediments and channelises flow → high bayhead delta.
- Bars and new land are more fixed than in the experiment with only mud → lower dynamics.

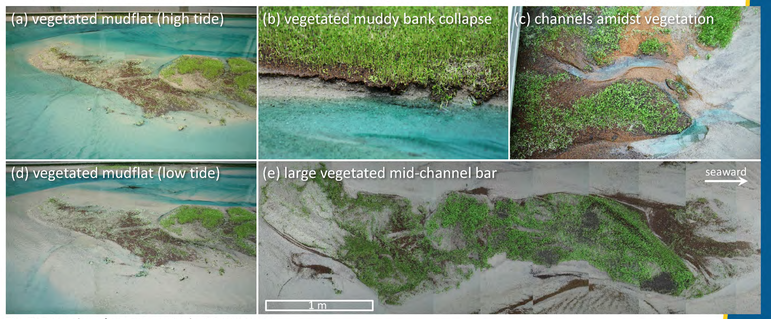


Fig. 7: Examples of vegetation in the Metronome.

Conclusions

- For the first time: simulation of a net infilling estuary on a laboratory scale.
- Mud and especially vegetation fixate bars and decrease dynamics in infilling estuaries, especially in the upstream part.
- Building and raising land is most pronounced when vegetation is included.
- Preservation potential increases in the landward direction.

References & acknowledgements

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Photography encouraged

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