How vegetation affects fluvial pattern and estuarine sedimentation

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Problem definition

Floodplain formation by vegetation settlement and mud capture is thought to cause meandering because the resulting cohesive floodplain increases bank stability, which reduces channel width-to-depth ratio and leads to alternate bars and bank erosion. However, Palaeozoic vegetation had much shallower rooting than river banks were high, meaning that early vegetation could not have led to meandering by enhancing bank stability.

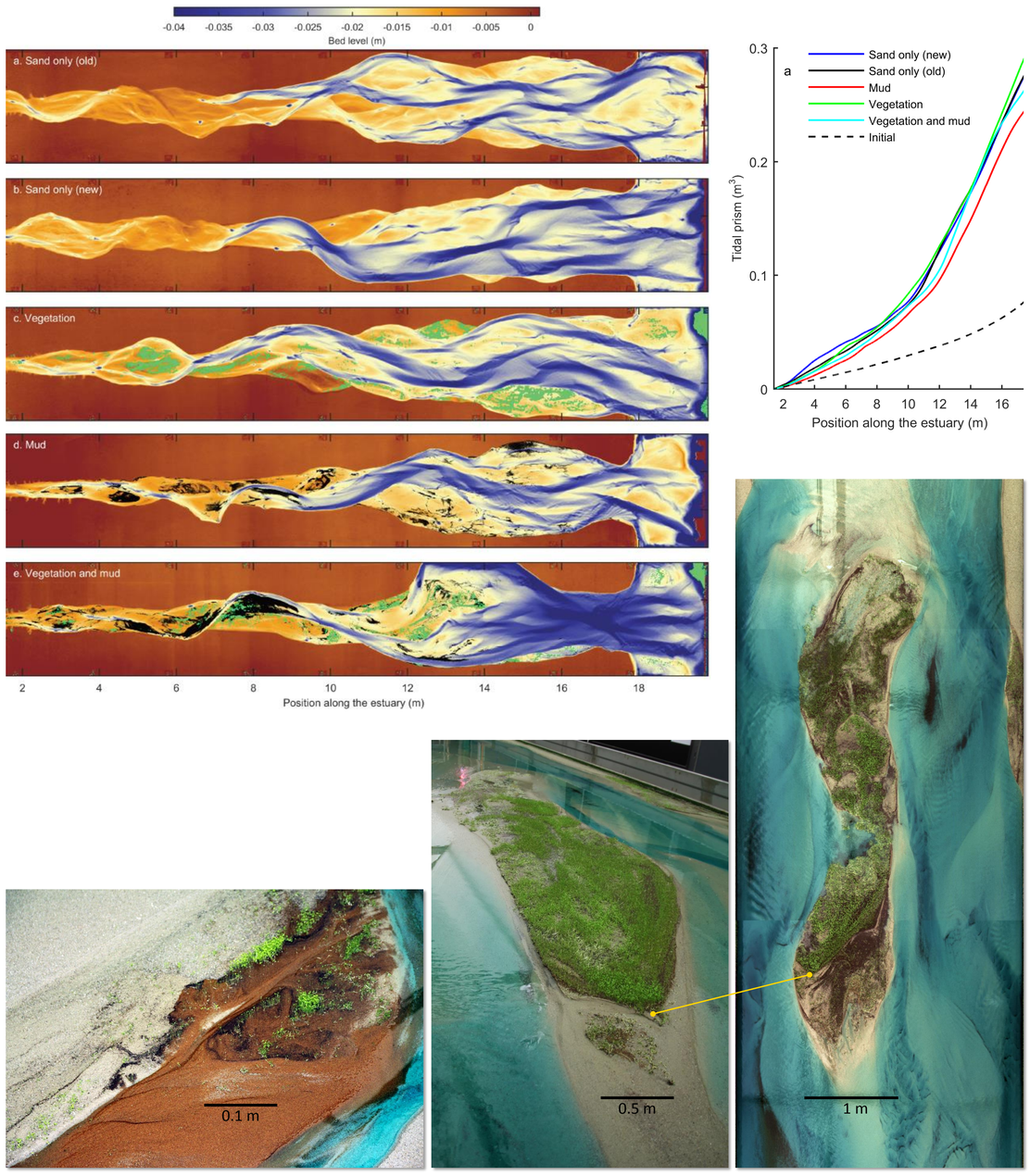
Likewise, present and past estuaries and tidal basins flanked by mud flats and salt marsh have much larger channel depths than rooting depths.

The question is therefore how vegetation stabilises banks in fluvial and estuarine environments.

Analogue landscape experiments of an estuary

Experimental conditions

- **Periodically tilting flume: the Metronome (Kleinhans et al. 2017 ESurf)**
- **Coarse sand at high mobility, crushed nut shell for mud mobility (Kleinhans et al. 2017 Sedimentology, Braat et al. 2018 ESPL)**
- **Tiny flow-distributed sprouts of three plant species (Lokhorst et al. 2019 ESPL)**

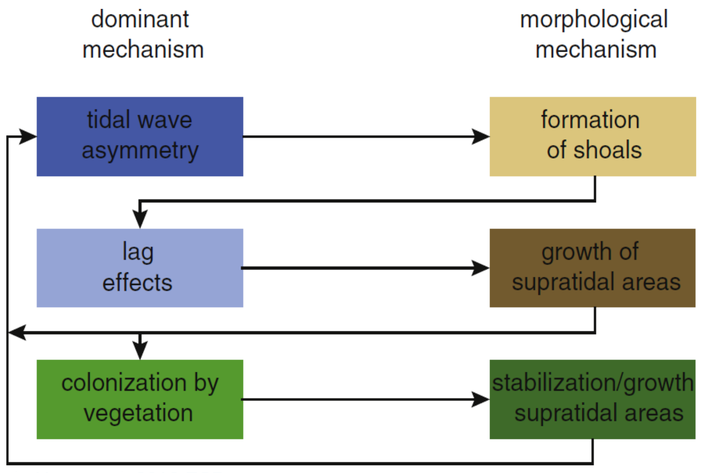


Experimental results (Weisscher et al. in prep and others)

- **Stable estuaries fill by mud and/or vegetation from land- to seaward direction**
- **Flood-dominant filling estuaries fill faster when vegetation stabilises mud**
- **Vegetation settles on shore-connected tidal flats and highest bars**
- **Vegetation and mud reduce tendency to cut bars**
- **Filling reduces tidal prism as positive feedback**

Synthesis: filling estuaries enhanced by plants

Net vegetation colonization: balance of settling, growth and mortality with environmental forcings, which reduce with tidal prism as estuary fills



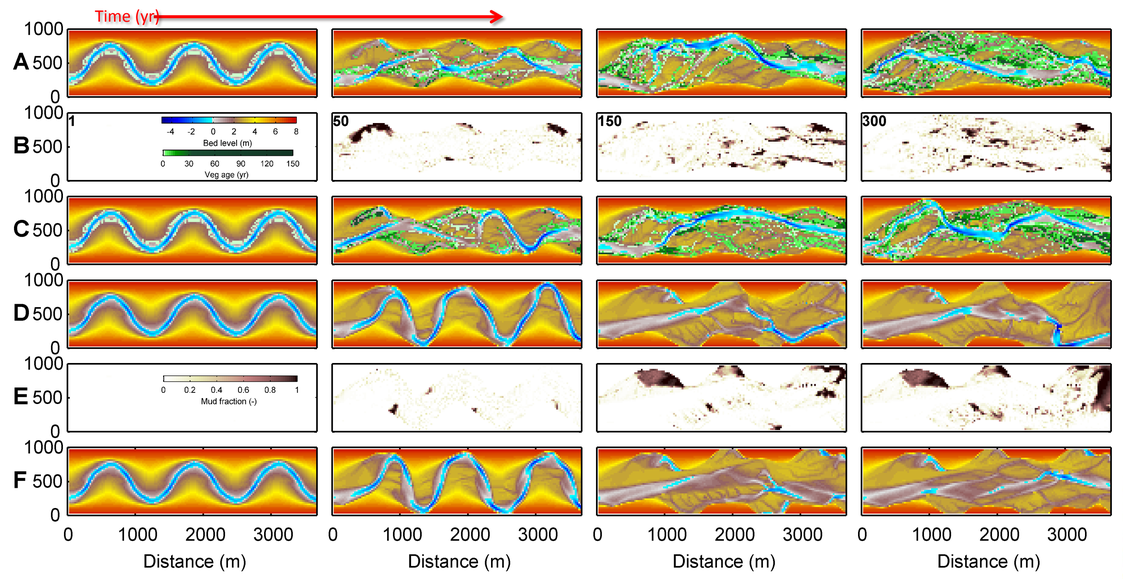
de Haas et al. 2018 ESR

Numerical modelling of 1. river and 2. estuary

Delft3D+vegetation numerical model setup

- **Freely movable sand, also in outer banks; sand and cohesive mud from inflow**
- **Vegetation: settle, grow and die**
- **Eco-engineering effect: no rooting strength! combined flow resistance as function of age and density of population in each grid cell**
- ***River*: seasonal flood peaks, 300 years development, Poplar and willow**
- ***Estuary*: neap-spring tides, 30 years development, Spartina**

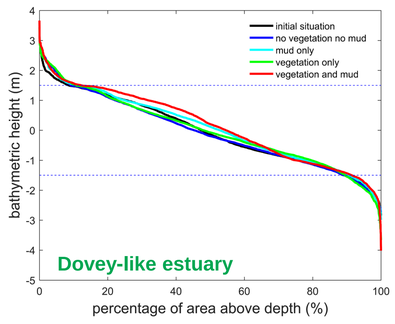
1. Numerical river model results (Kleinhans et al. 2018 ESPL)



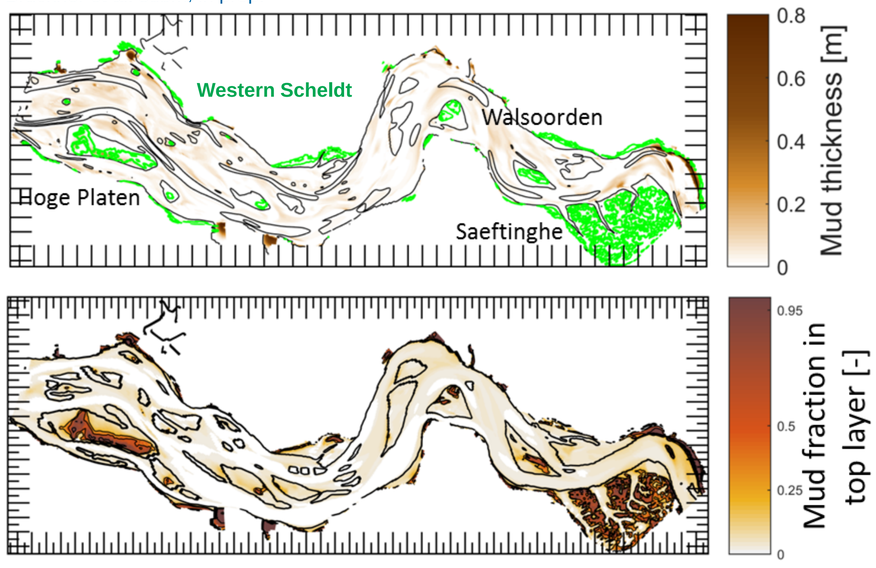
- **A,B: veg+mud, C: veg, D,E: mud, F: control with sand only**
- **Vegetation captures mud closer to channel than mud alone**
- **Valley confinement and denser vegetation enhances braiding**
- **Mechanism: floodplain of vegetation+mud reduces chute cutoff formation in *inner* bend that would otherwise lead to braiding**
- **This may be more representative of ancient preserved meander deposits than 'typical' large low-land meandering rivers dominated by scroll bars**

2. Numerical estuary model results (Brückner et al. in prep, Lokhorst et al. 2018 ESurf)

Lokhorst et al. 2018 Esurf, simplistic vegetation and mud



Brückner et al. subm, in prep.



- **Vegetation settles on shore-connected tidal flats and highest bars**
- **Vegetation and mud reduce tendency to cut bars**
- **Mud fills flood storage space and reduces tidal prism**

Conclusions

***Effects of vegetation in rivers*:**

- **captures mud closer to river, enhances floodplain formation**
- **reduces cutoff incision on the *inner* banks which enhances meandering tencency**
- **but valley-flooding water levels *increase*, which may enhance braiding**

***Added effect of vegetation in estuaries*:**

- **fills flood storage space (by friction and mud capture), which reduces *tidal prism***

***Ramifications for the interpretation of Palaeozoic fluvial and tidal facies*:**

- **even vegetation with limited rooting enhances meandering**

more publications

doi tidal experiments

www.uu.nl/Metronome

numerical model doi

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