Could humans have triggered avulsion in the Rhine-Meuse delta already 2000 years ago?

Harm Jan Pierik[1)], Esther Stouthamer[1)], Tim Schuring[1], and Kim Cohen[1,2,3)]

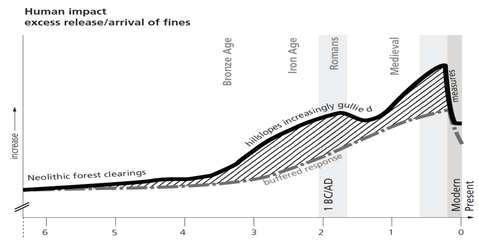
1) Department of Physical Geography, Faculty of Geosciences, Utrecht University, Heidelberglaan 2, 3584 CS, Utrecht. - Corresponding author: h.j.pierik@uu.nl
2) Deltares, Dept. Applied Geology and Deltares, Dept. Applied Geology and Geophysics, Utrecht
3) TNO Geological Survey of the Netherlands, Utrecht

The shifting of river channels (avulsion) has consequences for people living in deltas as it is a key process in the distribution of sediment and water and thus transport and resources. A so far unexplored decisive factor in determining avulsion success is the development of sea ingressions and the role of human activities in forming them. The landward expansions of tidal channels significantly reduce the distance to sea for a potential new river course. In this contribution we infer the role of sea ingressions from a historical case study from the first millennium AD of a multiple-staged avulsion in the Rhine-Meuse delta, the Netherlands. This avulsion resulted in a major reorganisation of the river channel network: it was the first avulsion which successfully crossed an extensive peat area that separated the rivers Rhine and Meuse, thereby distributing a major part of the Rhine discharge towards another tidal inlet. This tidal inlet expanded into the peat area and connected to an active crevasse splay. Archaeological evidence surrounding this ingression strongly suggests that its expansion was accelerated by human-induced soil subsidence related to peat land reclamation. This case study demonstrates that an increase in tidal influence in a low gradient delta plain is an important mechanism determining avulsion success. Considering major subsidence and sediment depletion problems that many deltas are nowadays facing, human-induced sea ingressions will presumably become increasingly important for successful avulsions.

Method

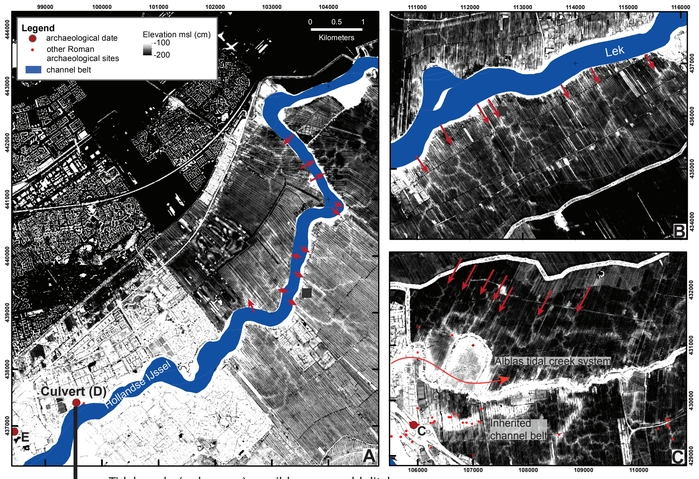
- Date Hollandse IJssel and Lek initiation
- Compare to archaeological evidence of habitation
- Compare to known forcings (e.g. changes in sediment load)

Upstream human drivers

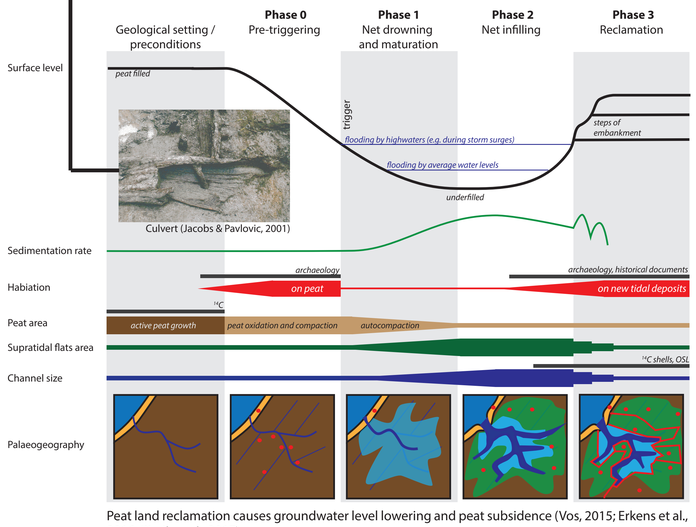


Upland deforestation caused increased suspended sediment load since ca. 500 BCE (Erkens, 2009) -> faster crevasse progradation, more sediment to cover the peat

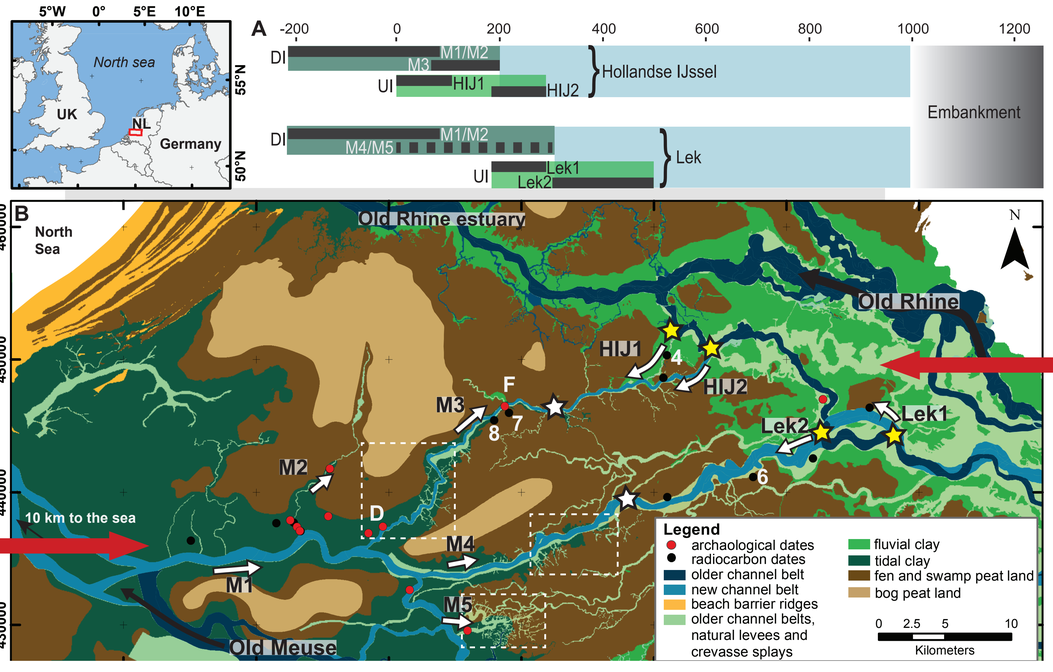
Downstream human drivers



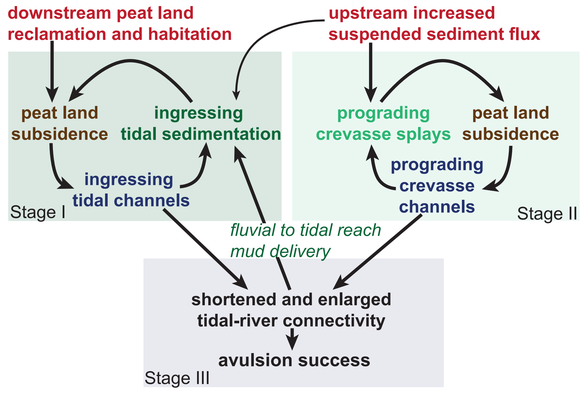
- Tidal creeks (red arrows) possibly occupy old ditches
- Archaeological evidence of habitation on peat and reclamation works (culverts)



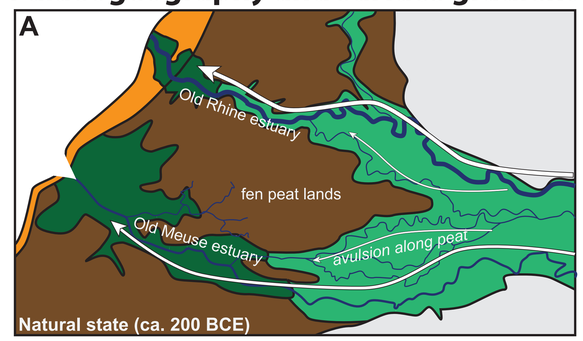
Peat land reclamation causes groundwater level lowering and peat subsidence (Vos, 2015; Erkens et al., 2016; Pierik et al., 2017)

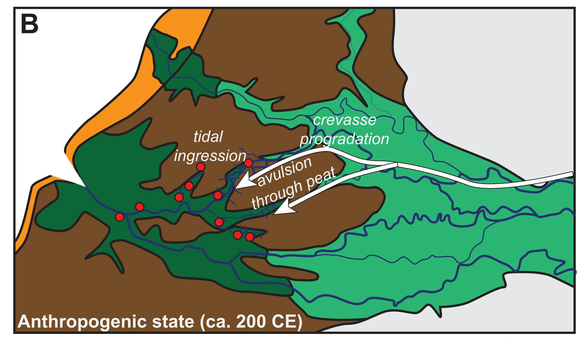


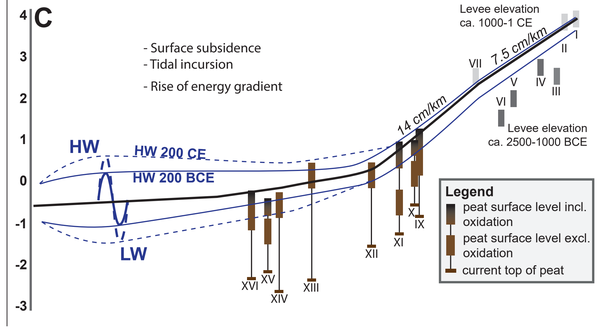
Reconstructed process loops



Palaeogeography and surface gradient







Conclusions

Hollandse IJssel and Lek rivers were the first rivers to cross the peat land in 3000 years this was possible when:

- Human-induced peat-land subsidence caused the tides to invade the peat land
- Deforestation in the upstream catchment caused more suspended sediment load to be fed to the expanding sea ingression and crevasse splays accelerating the avulsion process.

Both forcings triggered a process loop that led to avulsion success

Erkens, G., 2009. Sediment dynamics in the Rhine catchment: Quantification of fluvial response to climate change and human impact. Utrecht: Utrecht University.
Erkens, G., M.J. van der Meulen & H. Middelkoop, 2016. Double trouble: subsidence and CO_2 respiration due to 1,000 years of Dutch coastal peatlands cultivation. Hydrogeology Journal, 24(3), pp.551–568.
Jacobs, E., A. Pavlovic, O. Brinkkemper & P. Van Rijn, 2001. Een archeologisch onderzoek van een dam met duikers uit de Romeinse Tijd
Pierik, H.J., K.M. Cohen, P.C. Vos, A.J.F. van der Spek & E. Stouthamer, 2017. Late Holocene coastal-plain evolution of the Netherlands: the role of natural preconditions in human-induced sea ingressions. Proceedings of the Geologists' Association, 128(2), pp.180–197.
Vos, P., 2015. Compilation of the Holocene palaeogeographical maps of the Netherlands. In P. C. Vos, ed. Origin of the Dutch coastal landscape. pp. 50–81.

Utrecht University

NWO
Netherlands Organisation for Scientific Research