The Rhine-Meuse delta: a record of intra-Holocene variable sediment delivery

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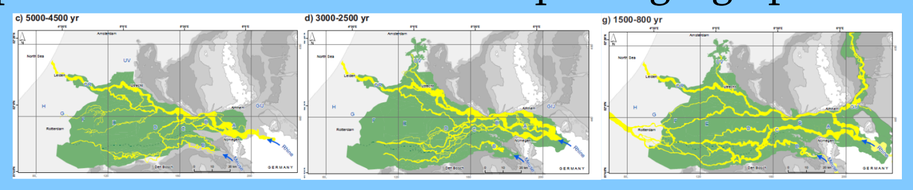
VARIATION IN SEDIMENT DELIVERY

- **Deltaic sediment** is **trapped** in **accommodation space** that is created under **control of sea level rise and subsidence**, and in **excess space created by delta apex sedimentation** itself.
- Whereas trapping space had been quantified in earlier studies for successive time steps in the Holocene, we present a **time-sliced quantification of the trapped sediments.**
- **Sediment delivery was not constant during the Holocene!**
- Recovering **vegetation** in the drainage basin under influence of **climate change** at the beginning of the Holocene, and further variation due to the **agro-pastoral transition (deforestation)** are the principal controls on **sediment delivery variability**.

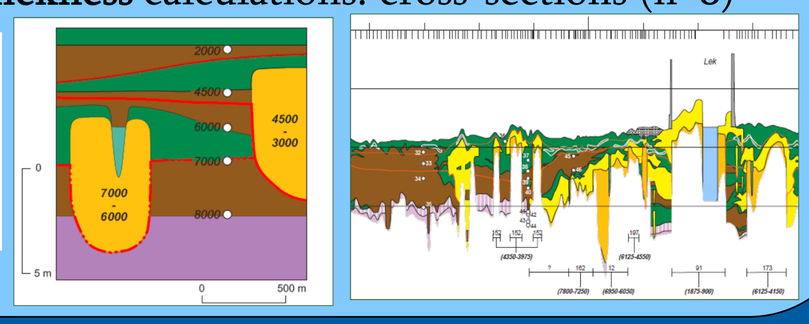
INPUT DATA:

Input data for **area** calculations: palaeogeographic maps



Input data for **thickness** calculations: cross-sections (n=8)

- Coring data: ~270.000 boreholes
- Time control: ~ 1400 ^{14}C/OSL dates, archaeology
- Time lines bound sediment bodies



DATA AND APPROACH

i) Sediment Delivery (SD) is quantified starting from the amount of Stored Sediment (SS) and Trapping Efficiency (TE), solving **SD * TE = SS**

ii) SS per time slice follows from sediment budgeting equations.

Total mass = bulk density (ρ) * summed volume (quantified per facies, segment and subarea of the delta from the Input Data).

SS (mass) = ∑ ρ * [THICKNESS * AREA]

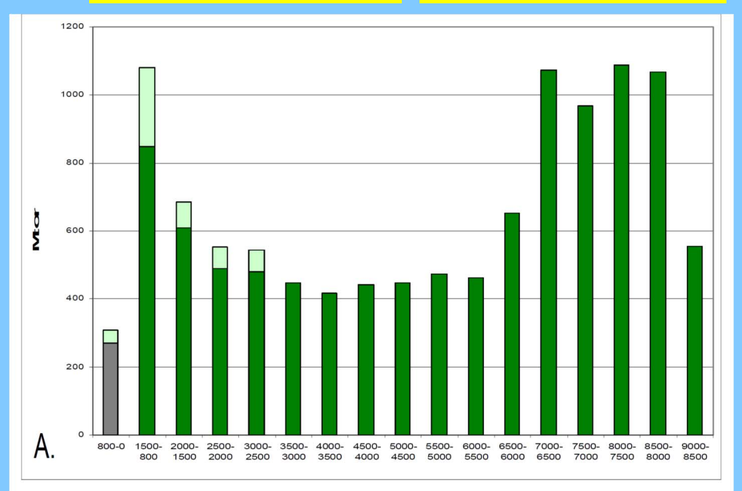
iii) TE of the delta is estimated to be 70% in the middle and late Holocene, and 90% in the early-middle Holocene (8.5-6.5 ka)

Main features of the Sediment Budgeting Analysis

- Calculations are over 500 year intervals
- Results are corrected for reworking-lost amount
- Budgets are for a moving area of deltaic deposition.
- Trapping efficiency (TE) for early time-slices (pre 6.5 ka; freshwater fluvial-tidal estuary fill included) is higher than post-6.5 ka (brackish lagoon excluded)
- The youngest 0.8 ka has much lower TE as river embankment strongly increased sediment throughput

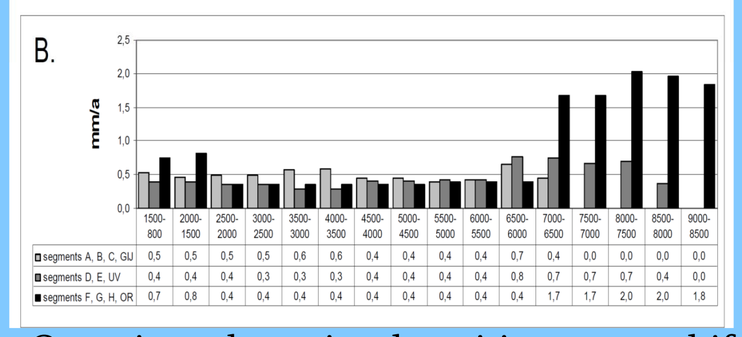
SEDIMENT STORAGE AND DEPO-CENTRES

Late Holocene	*High stand*	*Transgressive phase*
3-0.8 ka BP	6.5-3 ka BP	9-6.5 ka BP
TE= 70%, SD=high	TE= 70 %, SD = low	TE=90%, SD = high



Holocene storage Rhine-Meuse delta:

- 32.1 Gton clastics
  - 13.0 Gton sand
  - 19.1 Gton fines
- 2.1 Gton organics



	1500-800	2000-1500	2500-2000	3000-2500	3500-3000	4000-3500	4500-4000	5000-4500	5500-5000	6000-5500	6500-6000	7000-6500	7500-7000	8000-7500	8500-8000	9000-8500
segments A, B, C, GIJ	0,5	0,5	0,5	0,5	0,6	0,6	0,4	0,4	0,4	0,4	0,7	0,4	0,0	0,0	0,0	0,0
segments D, E, UV	0,4	0,4	0,4	0,3	0,3	0,3	0,4	0,4	0,4	0,4	0,8	0,7	0,7	0,7	0,4	0,0
segments F, G, H, OR	0,7	0,8	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4	1,7	1,7	2,0	2,0	1,8

Rates of clastic accumulation per subarea, in mm/a.

A-GIJ upper delta, D-UV central delta, F-OR lower delta.

Over time, the active deposition centre shifts upstream. It makes the apex region gradually gain importance over downstream reaches in terms of sediment trapping and avulsion dynamics.

BED vs. SUSPENDED LOAD TRAPPING

- Channel (bed load) trapping efficiency varies more than Floodbasin trapping efficiency (fines).
- This is a geometric-architectural effect of avulsion and operates through the reworking/replacement of earlier trapped floodbasin fines by new-formed channel belts.
- The internal (re-)uptake of fines along the pathways of new avulsed channels amounts for up to 20% of coeval floodbasin deposition, in successive time slices

UPSTREAM SUSPENDED SEDIMENT INPUT

- During the early Holocene, deposition of fines is high because of i) better trapping conditions, ii) a delayed arrival of sediment produced during glacial times, slowly released from upstream storages.

- During the Late Holocene, deposition of fines is high because of increased sediment input, released from the hinterland due to prehistoric agricultural revolutions, increasing erosion catchment-wide.

MAIN FINDINGS / CONLUSION

ONE: Pre-Historic deforestation of the Rhine catchment caused steadily increased sediment delivery to the delta 3,000 to 500 yr ago. Increased sediment input caused significant deltaic reconfiguration (size, type and rates of sedimentation). This was the (pre-)historic background setting for human delta reclamation, and a success factor for Late Medieval embankment and polder management.

TWO: Fluvial sediment input to the delta was significantly variable and overprints the delta architecture. A quantitative volumetric approach in documenting Holocene deltaic sedimentary history is needed for meaningful comparison of regions within deltas and intercomparisson of deltas, for their relevance for ancient systems and for assessment of their 'antropocene' vulnerability alike.

Deltares
Enabling Delta Life

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Reference:
Erkens, G. , 2009. Sediment dynamics in the Rhine catchment - quantification of fluvial response to climate change and human impact. Published PhD-thesis Utrecht University. Netherlands Geographical Studies 388, 278 pp.