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Quantification of the impact of pre-historic land use on suspended sediment accumulation in the Rhine delta

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Deltaic sedimentation is facilitated by sea-level rise and tectonics, but most importantly is the result of the sediment input by the rivers. The architecture of the Holocene Rhine delta in the Netherlands ($\sim$ 3000 km2) is well documented and the provision of accommodation space by sea level rise and tectonics well quantified. Using budget analysis, we have now also independently quantified the amounts of sediment input and storage in the delta. This provides much wanted quantitative understanding of the sediment delivery history from the Rhine catchment ($\sim$ 185,000 km2), which has a relative long history of human deforestation, from the Neolithic ($\sim$ 6 ka BP) onwards. We developed a method that utilizes the extensive geological datasets available for the Rhine delta (boreholes, dates, stratigraphical cross-sections, palaeogeographic maps). In the sediment storage budgeting for successive 500-yr time slices spanning the last 9000 years, we included quantification of internal reworking. We split the analysis over 11 subsegments of the delta and 6 facies-associations.

The results of our quantifications show that sediment delivery increased during the late Holocene by an impressive 60 %, compared to the pre-human impact time interval. Changes in sediment-trapping efficiency and climate are unable to explain the encountered sedimentation trends, and the bulk of this increase seems to be the result of land use changes. Similar increased sediment delivery to the fluvial system as a result of prehistoric human activities had been documented in smaller tributaries of the Rhine, undisputedly since the Bronze Age ($\sim$ 4 ka BP), but amounts and timing of sediment pulse arrival had so-far not been quantified for the delta at the downstream end of the catchment. This is important, because once the delta shows significance increase one can safely state that human impact has become of catchment scale. For the Rhine, this is the case around Roman times ($\sim$ 2 ka BP), and the increased sediment represents the accumulated response of pre-historic deforestation (i.e. Bronze and Iron Age land use) up to that time. The Rhine catchment is a prominent example how prehistoric humans were capable of invoking a shift from a natural controlled to a human modified fluvial system on a sub-continental scale.

The human-induced suspended sediment delivery caused distinct back-filling in the delta apex zone and a downstream extension of the clastic floodplain deposition area over peat areas, effectively diminishing peat growth in the delta. These were dramatic geomorphic responses for the upper and central delta causing major reorganisation of channel patterns, including a mega-avulsion that resulted in the formation of the large Gelderse IJssel-branch outside the main delta. It is hypothesised that the downstream clastic wedge covering peat marshes provided easier access to this previously inaccessible area, in that way enabling cultivation of these peat marshes in Medieval times. The reconstruction of past sediment delivery highlights the importance of (pre-historic) land use for delta development. It also provides an impression of the magnitude of fluvial system response to future changes in climate and land use.