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Subsidence due to peat compaction and oxidation in built-up coastal areas

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Problem

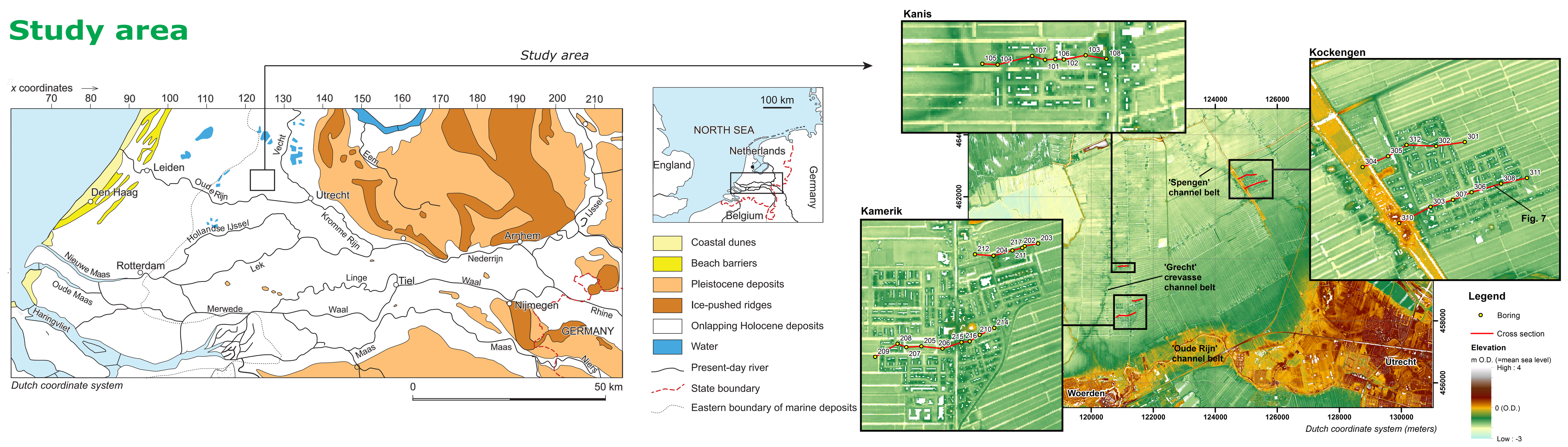
An increasing number of people live on soft-soil coastal sequences that often contain substantial amounts of peat. Loading and draining these soils for cultivation causes land subsidence due to peat compaction and oxidation. This leads to increased flood risk and damage to buildings, infrastructure and agriculture. Especially built-up areas, having densely-spaced assets, are heavily impacted by subsidence, in terms of damage-related costs and impact on livelihood. However, these areas have not yet received the full attention of land subsidence research.

Approach

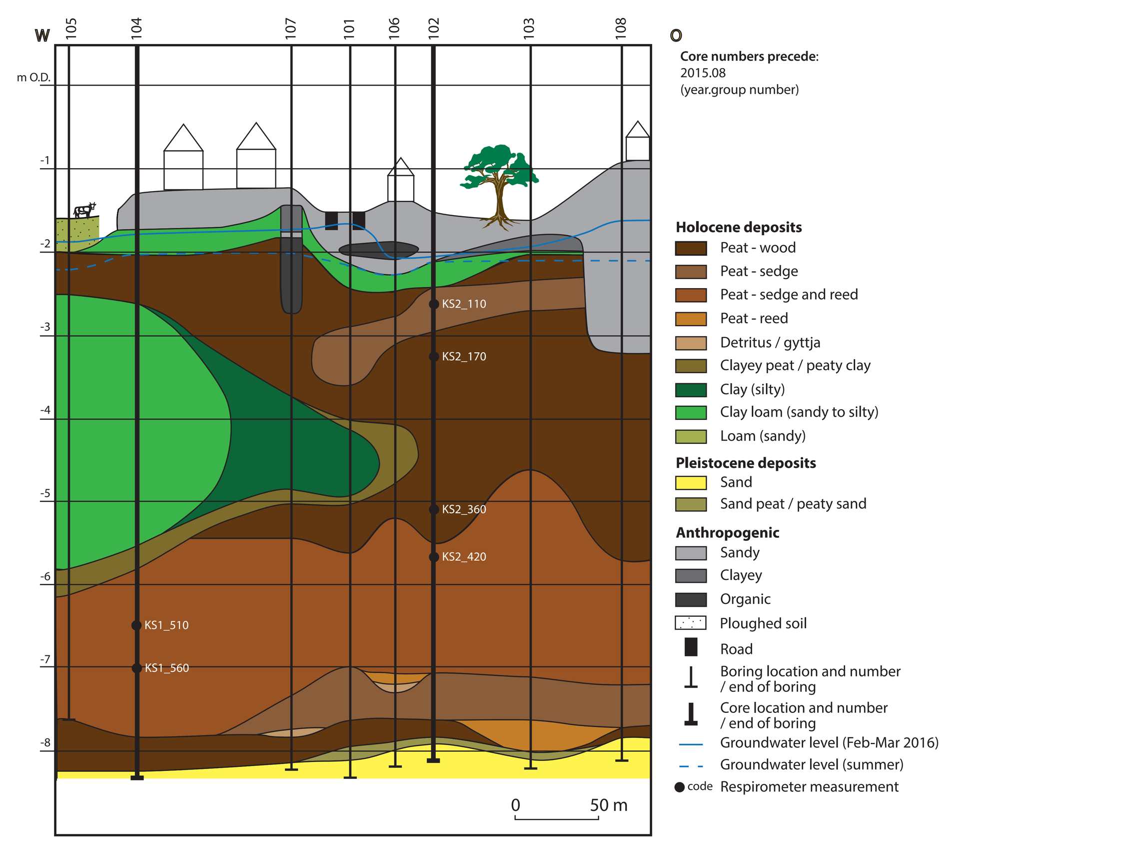
We studied subsidence due to peat compaction and oxidation in three built-up areas in the Rhine-Meuse delta (NL). Here, we present peat compaction results*.

1. We made cross sections based on borehole data to reveal the lithological composition of the Holcoene sequence below built-up areas.
2. At selected sites, representing different loading histories, we extracted cores and determined variations with depth of the (1) amount of peat compaction, calculated based on organic-matter content and dry bulk density measurements of compacted and uncompacted peat (Van Asselen (2011); this study*), and (2) effective stress.

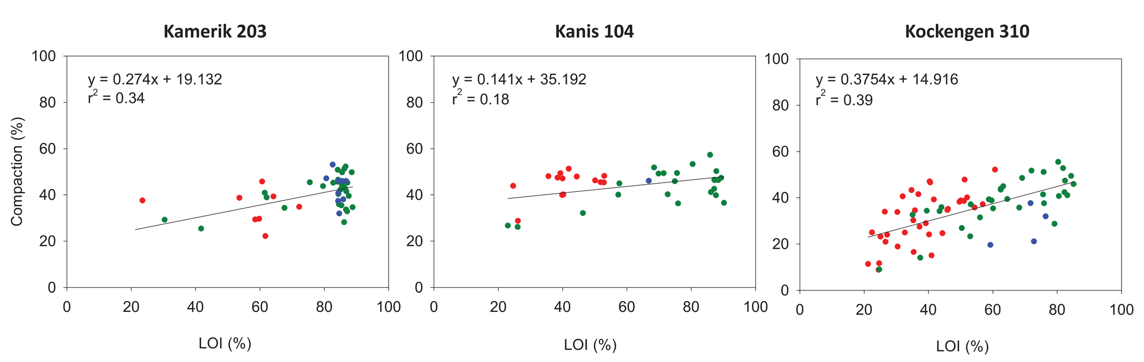
Study area



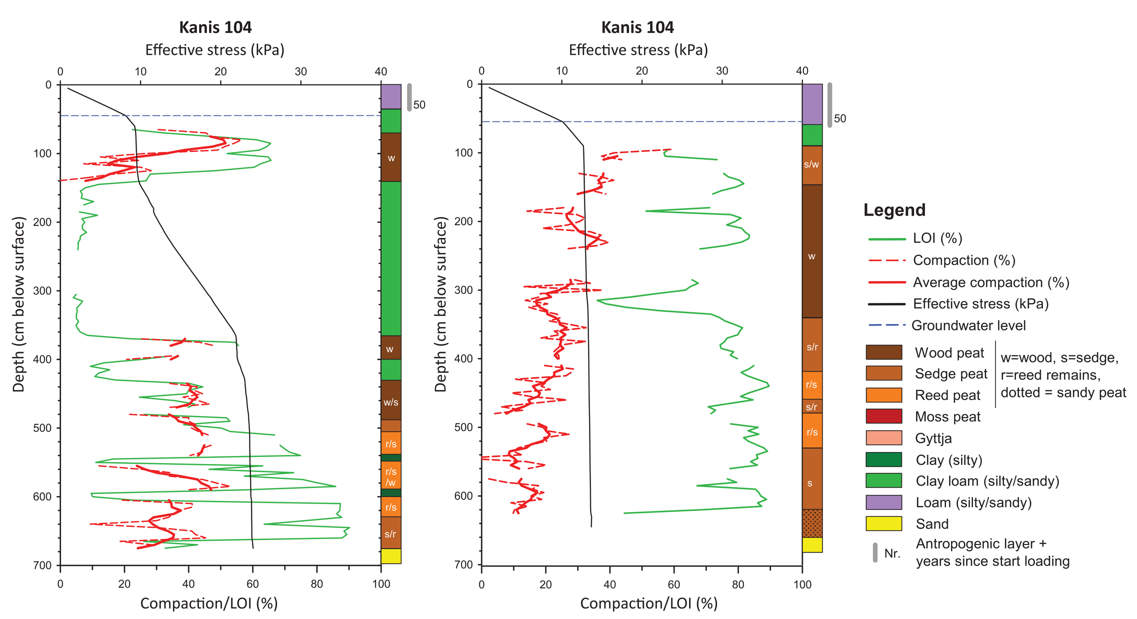
Results (selected)



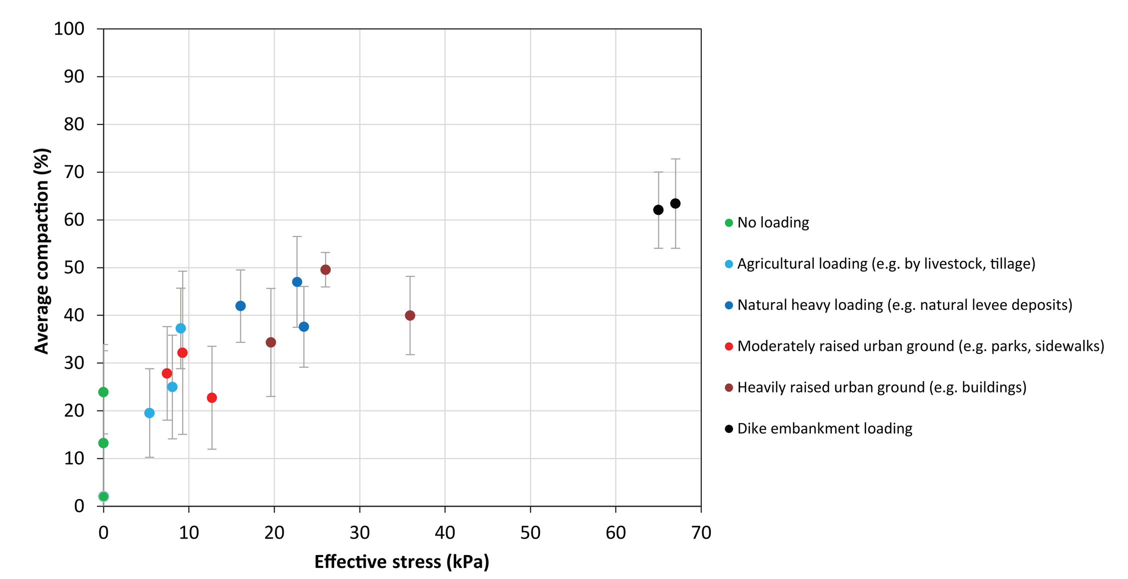
Cross section of the Holocene sequence of the Kanis site. Broadly, an anthropogenic layer of varying thickness overlies an up to 6-m-thick peat layer that is partly dissected by natural clayey overbank deposits.



For compacted peat, the amount of **peat compaction** is positively related to **LOI** (Loss On Ignition; indicator for organic-matter content).



Variations in the **amount of peat compaction**, **LOI** and **effective stress** with depth for 2 cores (Kanis site). The amount of compaction is highest below the thick clayey layer at site Kanis 104. Relatively high compaction grades also occur at the top of the sequences, caused by oxidation and compaction in the zone above the groundwater table.



The **amount of peat compaction** is positively related to the **effective stress** (= total stress - pore water pressure).

Conclusions

Quantifying subsidence due to peat compaction

Due to the heterogeinity of Holocene coastal sequences the amount and rate of subsidence due to peat compaction varies in time and space in coastal zones. The amount of compaction is positively related to the (1) overburden weight, (2) time since loading, and (3) organic-matter content of peat. Groundwater table lowering also induces compaction. Peat below urban ground was compacted up to ~50%. We measured subsidence due to peat compaction in built-up area of up to ~2 meters, and subsidence rates, averaged over an 11-year time span, of up to ~14 cm yr^{-1}.

Subsidence potential

In the built-up areas we studied, peat compaction grades varied from ~20-30% in moderately raised urban areas (e.g. parks, sidewalks) to ~30-50% in heavily raised urban areas (e.g. for buildings). The potential for future subsidence due to peat compaction at these sites is considerable. This is evident from measured compaction of up to ~75% at a nearby site where a similar peat layer as occurs in the study area has been heavily loaded since ca 700 years by a dike embankment (6-7 m thick).

Subsurface-based spatial planning

To sustain projected population growth and urbanization in coastal zones we call for (1) geology-based spatial planning, (2) collection of targeted subsurface information before new developments start (e.g. current compaction grade and organic-matter content), and (3) subsidence-resilient building (e.g. use of lighter construction materials and adapting groundwater tables).

References

Van Asselen, S. (2011). The contribution of peat compaction to total basin subsidence: implications for the provision of accommodation space in organic-rich deltas. *Basin Research* 23, 239-255.

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*Full details of this study, including subsidence due to oxidation estimates, are submitted to *Earth's Future*.