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

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Problem

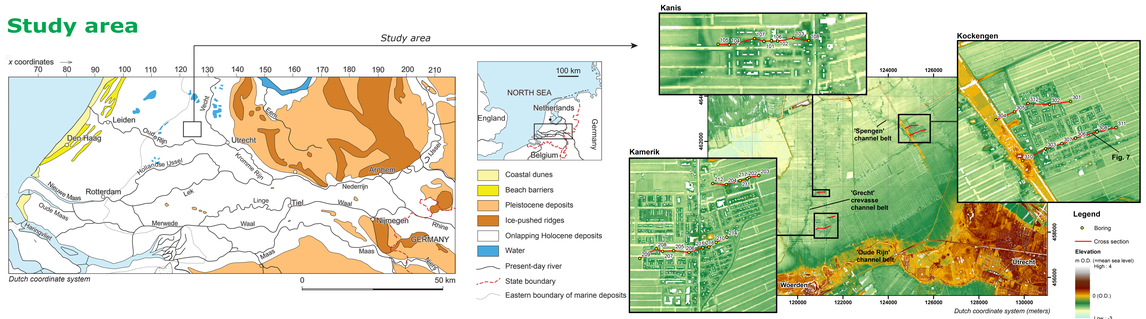
An increasing number of people live on soft-soil coastal sequences that often contain substantial amounts of peat. Loading and draining these soils for cultivation causes land subsidence due to peat compaction and oxidation. This increases flood risk and causes damage to buildings, infrastructure and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

Approach

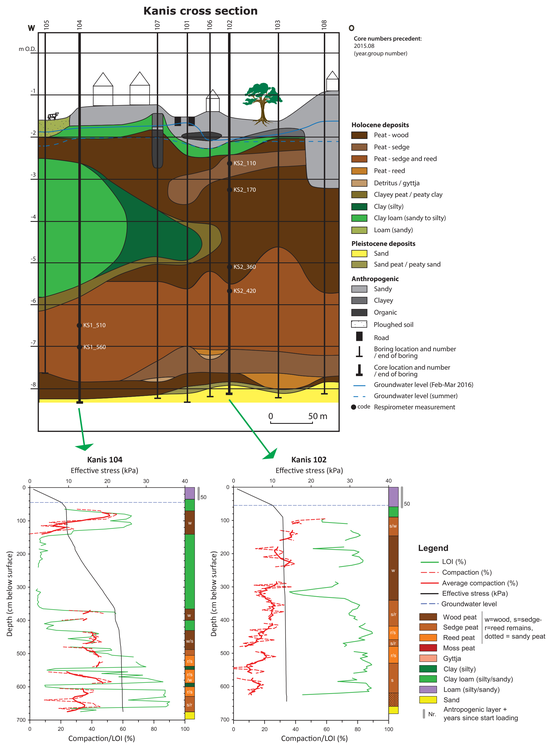
We studied subsidence due to peat compaction and oxidation in three built-up areas in the Rhine-Meuse delta (NL).

1. We made cross sections based on borehole data to reveal the litho-logical composition of the Holcoene sequence below built-up areas.
2. At selected sites, we extracted cores for which we determined variations in (a) effective stress, and (b) the amount of peat compaction, calculated based on the organic-matter content (LOI) and dry bulk density of compacted and uncompacted peat (Van Asselen (2011); this study*).
3. We calculated the relative contribution of peat compaction and oxidation to total subsidence over the last 1000 year, using a DEM representing peatland topography at 1000 AD (Erkens *et al*, 2017).

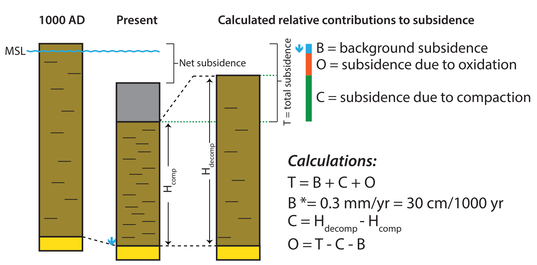
Study area



Typical subsurface composition



Relative contributions compaction & oxidation



Calculations:

$T = B + C + O$

B *= 0.3 mm/yr = 30 cm/1000 yr

$C = H_{decomp} - H_{comp}$

$O = T - C - B$

Legend

- Anthropogenic layer
- Holocene sequence
- Weichselien substrate
- Background subsidence of Weichselien substrate (*Van de Passche, 1982)
- H_{comp} = compacted Holocene thickness
- H_{decomp} = decompacted Holocene thickness (based on dry bulk density and organic matter measurements of compacted and uncompacted peat, cf. Van Asselen (2011).

Site	T (m)	B (m)	C (m)	O* (m)	B (%)	C (%)	O (%)
Ka-202	5.8**	0.3	1.7±0.4	2.2±0.4	5	29±7	38±7
Ka-203	2.4	0.3	1.2±0.3	1.0±0.3	12	48±11	39±11
Ks-102	2.9	0.3	1.4±0.3	1.2±0.3	10	49±11	41±11
Ks-104	2.5	0.3	0.4±0.1	1.8±0.1	12	17±4	71±4
Ko-310	3.1	0.3	2.0±0.4	0.8±0.4	10	65±15	25±15

*Calculations are validated using CO_2 respiration measurements.
**1.6 m is due to peat excavation.

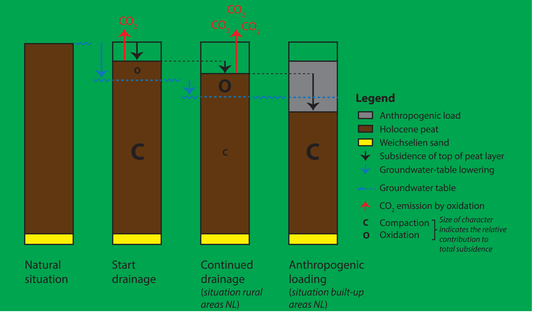
Conclusions

Temporal and spatial variability

The relative contribution of peat compaction and oxidation varies in time and space, due to the heterogeneity of Holocene coastal sequences and spatial and temporal variations in groundwater table depth. We measured total subsidence over the last 1000 years due to peat compaction and oxidation of up to ~4 meters, and subsidence rates, averaged over an 11-year time span, of up to ~14 cm yr^{-1}. At peatland sites that have experienced mainly drainage and no or minimum loading, oxidation is the main contributor to total subsidence (in this study up to ~70%). Total subsidence at sites that have been heavily loaded for centuries is predominantly caused by compaction (in this study up to ~65%).

Subsurface-based planning

We expect a subtantial subsidence potential in many soft-soil coastal areas. To sustain projected population growth and urbanization in these zones we call for (1) subsurface-based spatial planning, (2) collection of targeted subsurface information before new developments start (e.g. current compaction grade, peat depth and organic-matter content), and (3) subsidence-resilient building (e.g. use of lighter construction materials and adapting groundwater tables).



References

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*Full details of this study are submitted to *Science of the Total Environment*.