Long-term Analysis of Peatland Subsidence in two intensive agricultural used lowlands in Northern Germany

A. Herrmann[1], T. Martens[2], J. Schrautzer[2], M. Trepel[2], J. Zeitz[1]

1 Humboldt-Universität zu Berlin, Faculty of Life Sciences, Albrecht Daniel Thaer-Institute of Agricutural and Horticultural Sciences, Department of Soil Science
2 Christian-Albrechts-Universität zu Kiel, Faculty of Mathematics and Natural Sciences, Institute for Ecosystem Research, Department of Applied Ecology and Paleoecology

andreas.herrmann.1@agrar.hu-berlin.de

Introduction

Intensive drainage measures for agricultural use led to a progressive peatland subsidence in addition to the release of greenhouse gas (GHG) emissions. For example, in the Netherlands, approximately 2 to 4 m of peatland soil has disappeared since the Middle Ages (Van Asselen, 2018). In contrast to the growth rate of peat, the loss rate is relative quick. Studies have shown that the subsidence rate of peatlands is approximately between 0,7 and 1,5 cm per year (Nieuwenhus & Schokking, 1997; Van den Akker, 2008; Van den Akker, 2017). The loss corresponds to high GHG emissions, high costs for water management and major damage to infrastructure (Van Hardeveld, 2018).

Peatland subsidence and high GHG emissions in degraded peatlands is also an ongoing problem in Germany, because of an intensive agricultural tradition for decades and centuries. In the context of global climate change the federal states, e.g. Schleswig-Holstein and Brandenburg face different challenges in the near future. On the one hand the local farmers and authorities have to deal with a higher sea level related with investments for higher pump capacity and on the other hand they have to deal with a loss of productive land due to a continued progressive drainage infrastructure, leading to further peatland degradation. For future water management strategies valid information on these processes are needed, but reliable statements are not yet or only partially available.

In the presented study we estimated the loss of organic soils in two project regions in northern Germany and assess the small-scale heterogeneity of this process for the future. We also assumed, that there are some factors, which affect the peatland subsidence, e.g. the drainage depth, but also the peat thickness, the presence or absence of a mineral top layer as well as the underlying substrates.

Study area

Eider-Treene-Sorge (ETS) Lowland (Schleswig-Holstein)

The Eider-Treene-Sorge Lowland is located about 50 km western of Kiel and covers an area of about 45.000 ha. The Lowland was formed after the last glaciation due to the runoff of meltwater. Peat growth was initiated during the Holocene by predominantly paludification processes. The geologic bedrock is characterized by mainly holocenic sands and scattered occurrence of basin clay and organic or mineral gyttja. Due to high precipitation rates (800-900 mm) fens and raised bogs occur naturally peat thickness ≤ 50 dm are widespread. The ETS is dominated by intensively agricultural dairy farming with up to 5 cuts per year. These intensively used peatlands show strongly degradation in the uppermost layers. Large parts of the lowland are below the sea level and are actively drained by pumping stations; in higher areas, ditches and other pumping systems ensure drainage and thus the agricultural usability of the peat soils.

Upper Rhinluch (UR) (Brandenburg)

The Upper Rhinluch is situated ca. 60 km northwest of Berlin and covers an area of 14.000 ha. The landscape was formed in the late glacial period as a result of paludification processes. The geologic bedrock is composed of holocenic sands and calcareous gyttja. The organic soils are characterized by shallow peat layers, in general the thickness is no more than 5 to 7 dm. The annual precipitation amounts to ca. 500 mm and the mean annual air temperature is 9,6 °C.

Due to intensive drainage the peatland soils are very degraded and show strongly earthified peat in the topsoil related with an aggregated subsoil with shrinking cracks. Land use is dominated by large dairy farms and in some extensive suckler cow husbandry. Due to the drier climate the mowing intensity does not exceed 3 cuts per year.

Methodical approach

In this study, we investigated the long-term change of agriculturally used peatlands with special focus on soil stratigraphic data like peat thickness, underlying bedrock and peat substrates. First, we analysed historical soil recordings contained in a database provided by the regional State Offices and selected all profiles older than 30 years, with a full description up to the underlying substrate and a constant grassland use. In total we extract 24.000 soil profiles in the ETS and ca. 10.000 profiles in the Upper Rhinluch. Then, we calculated probability distribution focused on soil types (according to German Soil Classification), peat thickness as well as the presence and thickness of mineral top layers. Finally, we derived typical model soil profile classes, which are characteristic for the different regions and area-representative.

After that we selected randomly historical profile sets, which are evenly distributed across all model soil profile classes for some reference drilling campaigns, which was carried out in 2020 and 2021 very close to the historical points (accuracy amounted about 3 meter). In total we resume 111 soil profiles in the ETS and 164 profiles in the UR. During these surveys we recorded different soil parameter such as peat thickness, horizon and substrate sequences, decomposition status. Additionally, we took soil samples to determine physical and chemical parameters, like bulk density, pH-values and carbon content, among others.

The difference of the historical and the current peat thickness gives an indication of the specific subsidence rates of the previously model soil classes. The data will apply into a thickness alteration model, integrating two components: 1.) the alteration due to compression of organic substrates within the aeration zone and 2.) a constant loss due to postglacial isostatic compensation movement or due to higher loads of upper layers because of former drainage. A similar approach could be found by Hoogland et al., 2012.

Results

We confirm that all investigated peatland profile pairs under agricultural use are subject to subsidence and the process does not end by a certain peat thickness. The mean calculated subsidence rate amounts to 0,7 cm per year with some difference between the project regions. In the ETS the rates vary between 0,37 and 1,44 cm per year, while in the Upper Rhinluch the rates are some lower with 0,33 and 0,86 cm per year. Further it becomes clear, that these subsidence rates differ within the peat thickness (Fig. 1). Peatland soils with a lower former total thickness class (< 30 or 30-70 cm) show subsidence rates of 0,30 to 0,48 cm per year, respective. In contrast, peatland soils with a higher former thickness class (120-200 or >200 cm) exhibit higher subsidence rates of 1,02 to 1,25 cm per year. Similar results could be found if we consider only the first meter of the aerated zone. Figure 2 shows the alteration of peat thickness as a function of the different proportion of peat in the first profile meter. Light different rates appear with 0,20 cm per year in peaty soils with an amount of 20 percent and 0,85 cm per year in soils with 100 percent peat in the first meter. However significant differences are found only between the lower former peat thickness (<120 cm) and the higher ones (>120 cm).

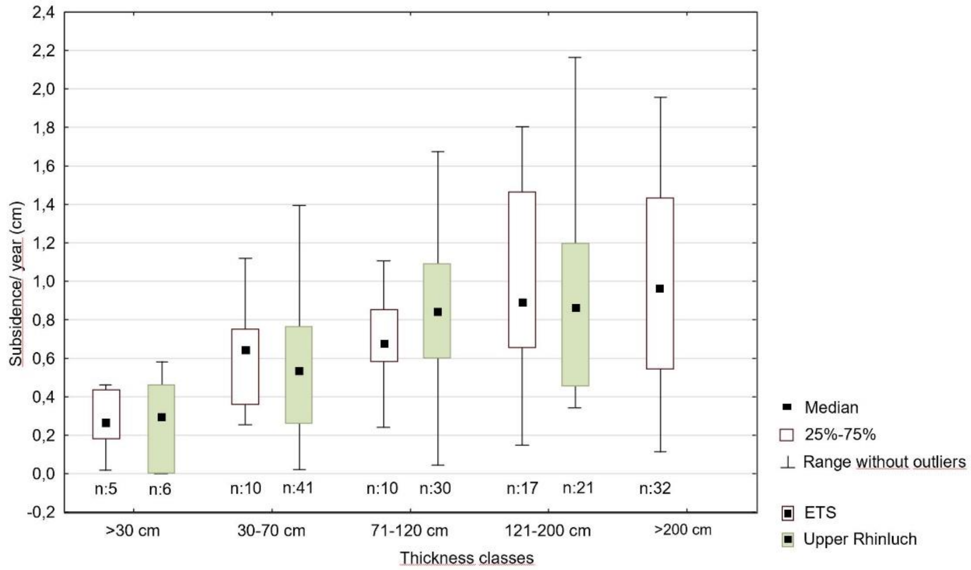

Figure 1 Subsidence rates differentiated by former peat thickness classes and project regions

We could not find a significant dependence between the subsidence rates and the underlying substrate. We also find a slight trend between the presence/absence of a mineral top layer and the subsidence. The mean rate with a mineral top layer amounts to 0,76 cm per year, in contrast 0,68 cm without a mineral cover.

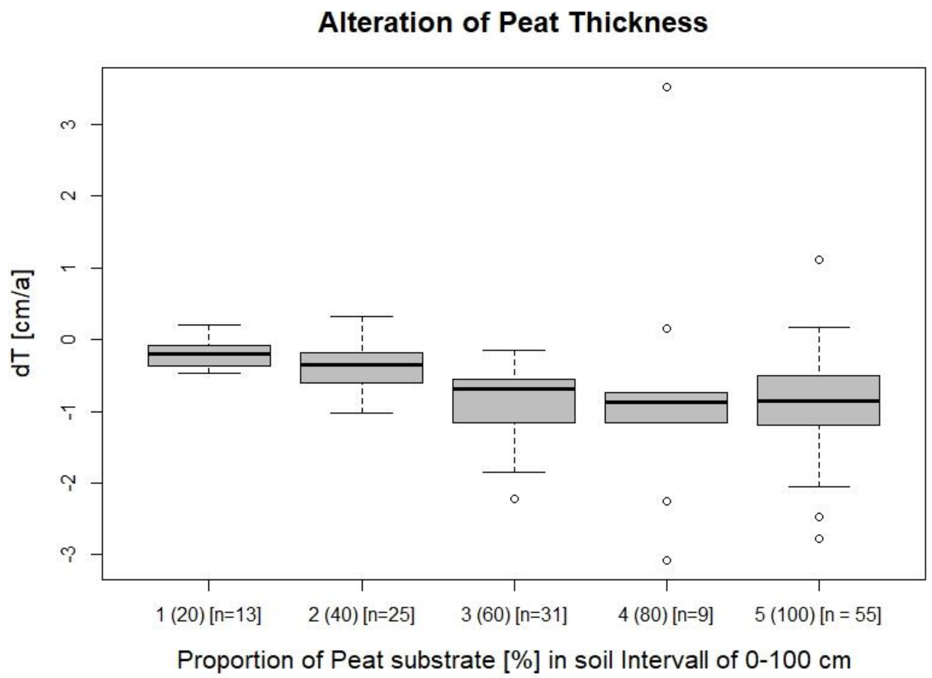

Figure 2 Alteration of peat thickness for different portion of peat substrate; comparison between historical pedological data and soil-geological reference surveys; sample size in brackets

Conclusions

By comparing the pedologic profile records with the historical profile records, there are rather low rates of subsidence over time at the sites with particularly shallow peat layers. When comparing the current profile information with the historical data, it also becomes clear that the composition of the peat at these sites has changed. Significantly, higher proportions of mineral components (sand, silt) are present in these profiles today. These higher proportions of mineral components could also be a reason for the lower subsidence rates in these profiles.

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