Monitoring shallow subsidence in cultivated peatlands: an update

S. van Asselen[1], G. Erkens[1,2], F. de Graaf[3]

1 Deltares Research Institute, Daltonlaan 600, 3584 BK, Utrecht, The Netherlands
2 Utrecht University, Princetonlaan 8a, 3584 CB, Utrecht, The Netherlands
3 Waterschap (Waterboard) Drents Overijsselse Delta, Dokter van Deenweg 186, 8025 BM, Zwolle, The Netherlands

sanneke.vanasselen@deltares.nl

Introduction

This is an update of the Van Asselen et al. (2020) TiSOLS paper, in which we presented methods used for, and preliminary results of, elevation measurements in a cultivated peatland area in the north-eastern part of the Netherlands. The main objective of this ongoing study is to test and compare different techniques to monitor land subsidence in peatlands, and to eventually design a monitoring system that is able to (1) measure vertical soil movement at mm-scale accuracy, (2) capture the spatial and temporal variability of soil movement at farm to regional scale, and (3) does not severely impact (dairy) farming activities. Results of this study also increase our understanding of soil movement dynamics and processes in peatlands. The methods used include conventional (spirit) levelling, extensometer measurements, LiDAR and InSAR. In this update, we present an updated, now about 4-year long, levelling and extensometer time series from two reference peat meadow parcels without submerged water infiltration drains, and briefly mention most important derived insights so far. Research background, study site description, and methodology are described in Van Asselen et al. (2020).

Preliminary results

Levelling results

At both monitoring fields 05-REF and 09-REF (of site details see Van Asselen et al., 2020), levelling results show a cm-scale seasonal trend. In the wet season the surface rises and in the dry season it subsides (Figure 1; Table 1). The annual vertical range is about 3 cm for location 05-REF (3 m peat), and about 2 cm for location 09-REF (1.25 m peat). No long-term subsiding trend is observed so far.

	Average vertical movement relative to the first measurement in October/November 2018 (mm)																		
Parcel	**Feb 2019**	**Apr 2019**	**Jul 2019**	**Vertical range**	**Oct 2019**	**Jan 2020**	**May 2020**	**Aug 2020**	**Vertical range**	**Oct 2020**	**Jan 2021**	**Apr 2021**	**Jul 2021**	**Vertical range**	**Oct 2021**	**Jan/Feb 2022**	**Apr 2022**	**July 2022**	**Vertical range**
05-LEV	8 *(13)*	-20 *(13)*	-26 *(12)*	**34**	28 *(12)*	36 *(14)*	15 *(14)*	6 *(13)*	**31**	29 *(13)*	40 *(15)*	30 *(16)*	14 *(14)*	**27**	15 *(15)*	27 *(16)*	42 *(16)*	4 *(16)*	**38**
05-EXT				**37**					**37**					**26**					**34**
09-LEV	9 *(8)*	4 *(11)*	-10 *(10)*	**20**	10 *(10)*	8 *(10)*	-3 *(11)*	-14 *(11)*	**24**	8 *(11)*	12 *(11)*	7 *(11)*	-5 *(12)*	**17**	-5 *(12)*	3 *(12)*	6 *(13)*	-20 *(12)*	**26**
09-EXT				**19**					**21**					**17**					**26**

Table 1 Average elevation changes relative to the start of measuring, for parcels 05 and 09, based on levelling (LEV) and extensometer (EXT) measurements. Standard deviation of levelling measurements in italics between brackets. Vertical range is the difference between the maximum and minimum height defined for the period October to October next year.

Extensometer results

The extensometer measurements show a similar seasonal trend, with annual vertical ranges in the same order of magnitude as observed for the levelling measurements (Figure 1; Table 1). Although not quantified, the extensometer graphics also show a clear visual correlation between the vertical soil movement and phreatic groundwater dynamics (Figure 1). At both locations, every succeeding monitoring year the maximum surface level height in winter is lower than that of the previous winter. A weak long-term (linear) surface level subsiding trend may be fitted for both locations (location 05: R^2=0.44, slope=-6.1 mm/yr; location 09: R^2=0.48, slope=-3.4 mm/yr; not presented in Figure 1). Another important observation is the significant contribution of the saturated peat layer to total vertical movement of the surface level: the anchor level at 1.15 m below surface, i.e. the saturated peat layer below this level, may explain >~50% of the surface level dynamics (Figure 1).

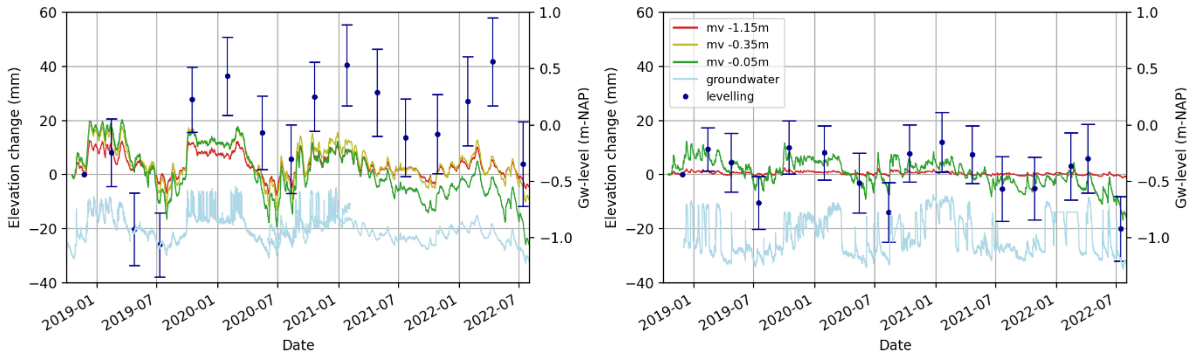

Figure 2 Extensometer (three measurement levels), levelling (average with standard deviation indicated by vertical bars) and phreatic groundwater monitoring results for locations 05-REF (left) and 09-REF (right). Elevation changes measured by the extensometers are relative to October '18, for levelling relative to November '18.

LiDAR and InSAR

Here we only briefly report on the airborne LiDAR and InSAR monitoring results. The main conclusion on applying airborne laser altimetry in peat meadows it that it is unsuitable for monitoring land subsidence in peatlands at mm-scale, mainly because of limitations regarding accurate assessment of the surface elevation height in areas where the grass cover is dense and high, which occurs regularly in peat meadows (Van Asselen et al., 2022). Using radar interferometry for assessing changes in surface elevation at mm-scale in peat meadows is promising but still subject of ongoing research (e.g., Conroy et al., 2022). Potentially, this technique results in accurate time-series of maps of elevation change, allowing to determine spatial and temporal variations of vertical land movement in peat meadows, and assess effects of land management measures and other environmental conditions on these variations. Extensometer data and other contextual data are used to optimize this technique and specifically the data processing procedures.

Preliminary findings

The levelling and extensometer data both show a cm-scale seasonal trend, moving upward in the wet season and downward in the dry season. Although not yet quantitative established, the extensometer measurements also show a clear correlation with phreatic groundwater dynamics. Based on the current extensometer monitoring series, a weak long-term subsiding trend may be fitted. This may indicate long-term subsidence but may also be caused by seasonal meteorological, and hence hydrological, variations. The maximum winter surface level does get lower every succeeding year. However, the levelling results do not (yet) show a clear long-term subsidence trend. We will continue monitoring in order to filter out seasonal cm-scale dynamics and make a reliable and accurate estimate of the long-term mm-scale subsidence trend. The extensometer results may also be used to assess the contribution of different soil layers (i.e., processes) to vertical surface movement. For example, our results demonstrate a significant contribution of the saturated peat layer to surface movement, which is attributed to variations in hydrostatic pore pressures and the poro-elastic response of this layer.

References

Van Asselen S, Erkens G, De Graaf F (2020) Monitoring shallow subsidence in cultivated peatlands. *Proc. IAHS*, 382, 189–194, 2020, https://doi.org/10.5194/piahs-382-189-2020.

Van Asselen S, Erkens G, Zandbergen S, De Zeeuw R, De Graaf F (2022) In Dutch. Bodemdaling meten met LiDAR*, Land+Water*, nr. 7/8, p. 32-33, July 2022.

Conroy P, Van Diepen SAN, Van Asselen S, Erkens G, Van Leijen FJ, Hanssen RF (2022) Probabilistic Estimation of InSAR Displacement Phase Guided by Contextual Information and Artificial Intelligence. *IEEE Transactions on Geoscience and Remote Sensing* 60, 1-11, doi: 10.1109/TGRS.2022.3203872.