EVALUATION OF SATELLITE-BASED OPTICAL AND THERMAL TRAPEZOID METHODS FOR GROUNDWATER TABLE DEPTH MONITORING IN ESTONIAN BOGS

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INTRODUCTION
The position of the water table in the peat layer relative to the ground surface, i.e., the water table depth (WTD), is an important feature of peatlands. We explored the feasibility of applying the satellite-based soil moisture indices for the WTD monitoring in two peatlands in Estonia. The specific objectives were to:
- calculate two thermal-based and one shortwave-infrared-based soil moisture indices using Landsat 5, 7 and 8 observations (2009 – 2019),
- evaluate the temporal and spatial correlation of the indices with in-situ measured WTD.

MATERIALS AND METHODS
One of the most well-known approaches for soil moisture estimation is the “trapezoid” model concept (Sadeghi et al., 2017). Two different types of the trapezoid concept exist:

Thermal-Optical TRAPEzoid Model (TOTRAM)

\[ W_{TOTRAM} = \frac{LST_{MAX} - LST_{MIN}}{LST_{MAX} - LST_{MIN}} \]

Optical TRAPEzoid Model (OPTRAM)

\[ W_{OPTRAM} = \frac{STR_{MAX} - STR_{MIN}}{STR_{MAX} - STR_{MIN}} \]

In TOTRAM scenario 1, the estimation was solely based on observed pixel values. The remotely sensed LST and FVC data were used to construct the trapezoid with its dry and wet edges. In TOTRAM scenario 2, additional to LST and FVC, supplementary data were used to model the theoretical dry edge, among which are friction velocity and total column water vapour data from ERA5, land surface albedo and in-situ meteorological data. The OPTRAM soil moisture index was calculated based on remotely sensed STR and NDVI data.

RESULTS

TEMPORAL CORRELATION OF SOIL MOISTURE INDICES WITH WTD
Figure 4 shows for each pixel the temporal correlation coefficient R between the mean WTD of the 8 monitoring wells and soil moisture indices. For the two TOTRAM scenarios the R values are close to zero. R values of OPTRAM are positive throughout the whole bog area. The highest R values are observed for treeless areas.

SPATIAL VARIABILITY OF SOIL MOISTURE INDICES AND WTD
Figure 5a-b indicate that the soil moisture indices from both TOTRAM scenarios do not positively correlate with WTD. Only the OPTRAM indices show a positive correlation over the whole WTD range (Figure 5c). Figure 5c shows that OPTRAM indices over treed parts of the bog are systematically higher than over the treeless parts of the bog.

CONCLUSIONS
We evaluated the temporal and spatial relationships between in-situ measured WTD and soil moisture indices from three different trapezoid models over two northern bogs in Estonia. We compared the performance of two trapezoid models based on optical and thermal imagery (TOTRAM scenario 1 and 2) and one solely based on optical imagery (OPTRAM). Our results demonstrated:
- a general inapplicability of the TOTRAM index for WTD monitoring in our study area,
- a high potential of OPTRAM index for monitoring temporal changes in WTD,
- the highest temporal correlation coefficients (0.8) for the OPTRAM index over treeless bog areas with little or no surface water (no bog pools), and
- a high sensitivity of OPTRAM index to the vegetation type which strongly limits the spatial interpretability and probably also the temporal interpretability under progressive vegetation changes.