Airborne Geophysical Peat Volume Mapping: Advantages and Limitations Compared to Traditional Methods

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Introduction

Peatlands release greenhouse gases to the atmosphere, e. g. via anthropogenic drainage and land use for agricultural, silvicultural or horticultural purposes. In Germany, 2.8% (7.8 Mio. T CO_2-C-equiv.) of the total national greenhouse budget of 2006 came from peatlands[1]. Thus, the knowledge on peat occurences is essential to accurately estimate carbon stocks and to facilitate appropriate peatland management.

Ground-based methods are both labour intensive and not able to capture spatial information on regional scales. As airborne geophysics has not been investigated sufficiently for peat mapping so far, we examine here a combination of airborne geophysical methods and discuss the feasibility at a peatland in north-western Germany[2].

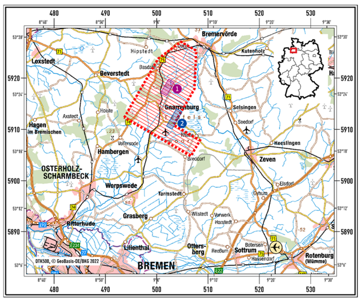

Fig. 1: Airborne survey area "Gnarrenburg" and location of detail study areas (1 and 2)

Airborne Survey

BGR conducted an airborne geophysical survey (173 km², 887 line-km, Figure 1) in May 2022 within 4 days, which covered the northern half of the "Teufelsmoor", one of the largest contiguous areas of bog in north-western Germany. The helicopter-borne system recorded electromagnetic (HEM), magnetic, and radiometric (HRD) data. In addition, ground-based (e.g. GPR) measurements as well as in-situ data were sampled within a small area located in study area 2. Peat thicknesses derived from GPR[3] and LBEG borehole data[4] served as reference for the airborne results.

Peatland Mapping

A peat index PI derived from a combination of HEM (apparent depth d_{a6} @ f_6 = 133 kHz) and radiometric (natural logarithm of the exposure rate E) data: $PI = -(d_{a6} + \ln(E)) / 2$, for $d_{a6} < 0.4$ m, $E < 1.5$ µR/h and $PI > 0$ m, else PI = 0 m, helps to map peatlands. Figure 2 shows the area estimated by PI = 0.2 m compared to mires mapped on soil maps. About 90 % of the boreholes with peat are within this area.

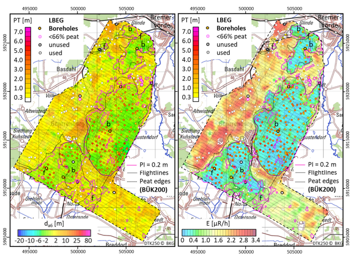

Fig. 2: Low apparent depths d_{a6} (left) and low exposure rates E (right) vs. mapped (BÜK200) bogs (b) or fens (f) as well as peat thicknesses PT (dots) derived from LBEG boreholes.

Peat Depth Estimation

In order to estimate peat thickness PT from HEM (ρ_{a6}, d_{a6}) and HRD (E) parameters, scaling factors have to be applied:

$PT_{ta6} = -d_{a6} \cdot 180/\max(\rho_{a6},\rho_m)$, $\rho_m = 130\,\Omega$m,
$PT_{Ex} = 4{,}0 - 3{,}0 \cdot E$.

Results of 6– and 20–layer HEM-1D-inversion require normalization to mean values:

$PT_{P1m} = d_1 \cdot \rho_{1m}/\rho_1$, $\rho_{1m} = 50\,\Omega$m,
$PT_{SGm} = d_{SG} \cdot \rho_{SGm}/\rho_{SG}$, $\rho_{SGm} = 55\,\Omega$m.

Figure 3 shows the corresponding peat depth estimates z = Topo (surface) – d and their differences $\Delta z = z - z_{GPR}$ to ground-based GPR data in detail area 2.

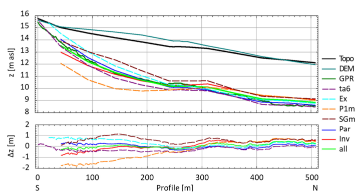

Fig. 3: Comparison of peat depth estimated from airborne data (HEM or/and HRD) vs. ground-based GPR results.

Combined HEM + HRD Results

HEM and HRD results (Figure 3, dashed lines) differ in places due to their individual sensitivities. Combined results:

$PT_{Par} = (PT_{ta6} + PT_E)/2$,
$PT_{Inv} = (PT_{P1m} + PT_{SGm})/2$,
$PT_{all} = (PT_{Par} + PT_{Inv})/2$,

help to balance these deviations (Figure 3, solid lines). Figure 4 shows the final airborne result (PT_{all}) compared to a peat thickness map based on boreholes.

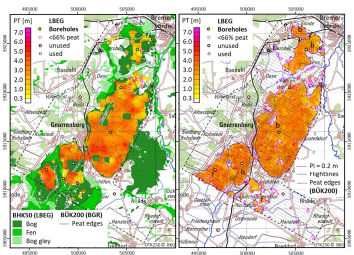

Fig. 4: Peat thickness derived from boreholes (left) and estimated from HEM and HRD data (right) vs. peat maps (BHK50 and BÜK200) and peat thicknesses PT (dots) from boreholes.

Conclusions

Airborne surveys are extremely fast enabling the estimation of lateral and vertical extents of peatlands. The differences of airborne mapping and borehole results are small on average, but standard deviations are high (≳ 1 m) and correlations are weak ($R^2 < 0.2$). Referred to ground-based GPR data, deviations are smaller (< 0.3 m) and correlations are better ($R^2 > 0.7$). This discrepancy may result from the comparison of point values (old borehole data) with grid values (airborne data being always smoother). Airborne geophysical peat mapping is useful on a regional scale (e.g. to estimate total peat volumes), but not on a local scale with fading peat layers.

References

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