Probabilistic Joint Interpretation of Multiple Geophysical Methods for Landfill Characterization

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1) Motivation

RAWFILL project: supporting a new circular economy for RAW materials recovered from landFILLs.

Geophysical characterization (multiple methods)

Optimized sampling survey

Geophysical calibration

Resource distribution model

Resource assessment

2) Case study: geophysical survey + sampling

Context: MSW landfill located in Meerhout (Belgium), active from 1962 to 1998

Multi-geophysical survey: frequency-domain electromagnetic induction (EMI), magnetometry, electrical resistivity tomography (ERT), induced polarization (IP), ground penetrating radar (GPR), multiple analysis of surface waves (MASW) and horizontal to vertical (H/V) spectral ratio measurements.

Guided sampling: 9 boreholes and 7 trial pits.

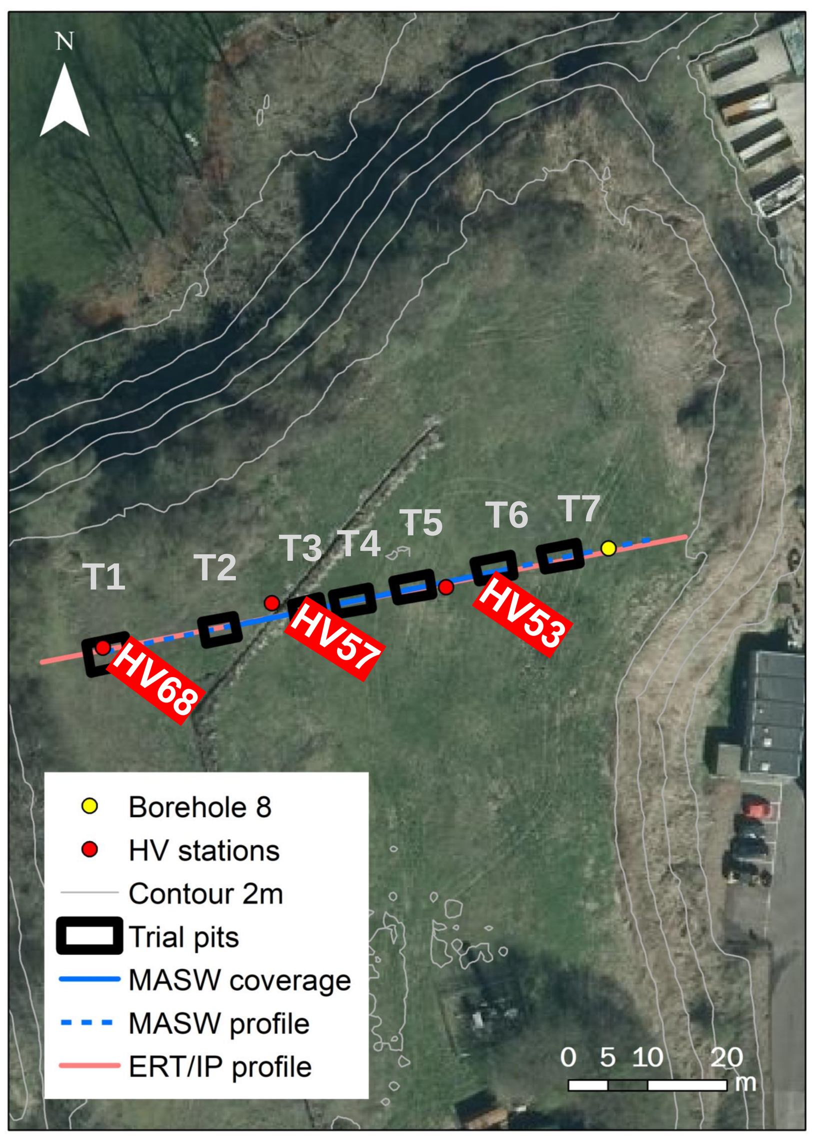

Fig. 1. Multi-geophysical survey using ERT/IP, MASW and H/V co-located with 7 trial pits (black squares) and one borehole (yellow dot). (Aerial image from Geopunt Flanders).

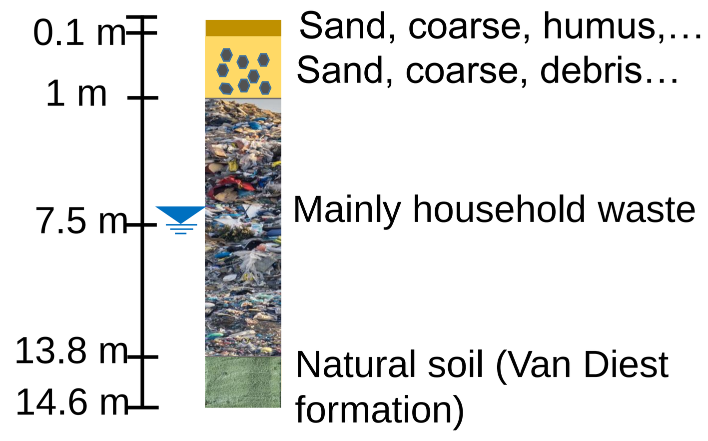

Fig. 2. Description of borehole 8. Water table level was found at 7.5 m and the lower limit at 13.8 m.

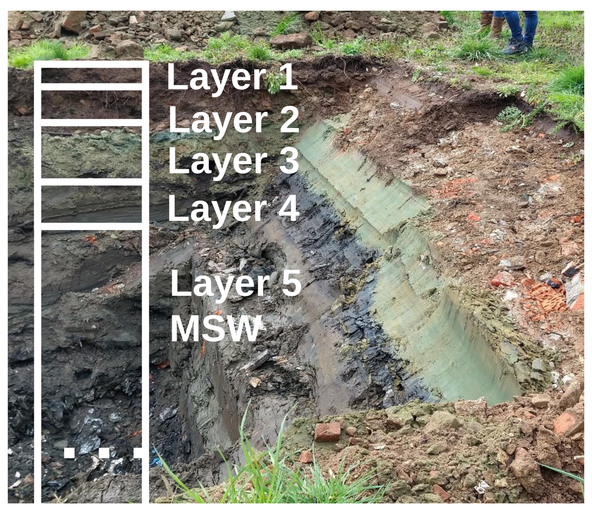

Fig. 3. Illustration of the 5 layers identified after trial pitting

Fig. 4. Magnetometry (top), EMI (middle) and ERT/IP (bottom) acquisition.

3) Methods

Geoelectrical methods: ERT/IP

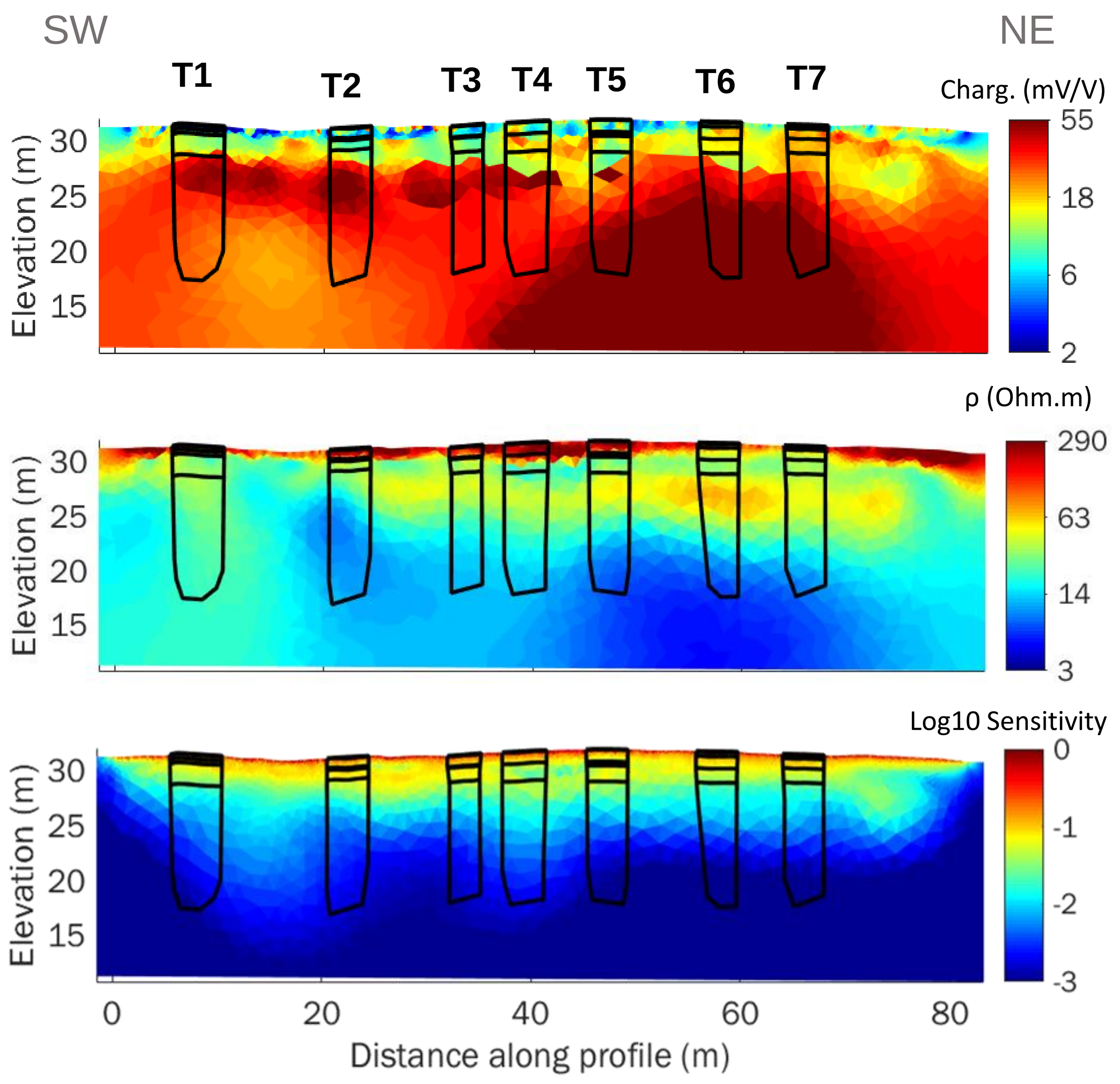

Fig. 5. From top to bottom: chargeability, resistivity and the sensitivity models. The trial pits and identified layers are shown in black polygons (the deeper limit is extrapolated from B8).

Active source: MASW

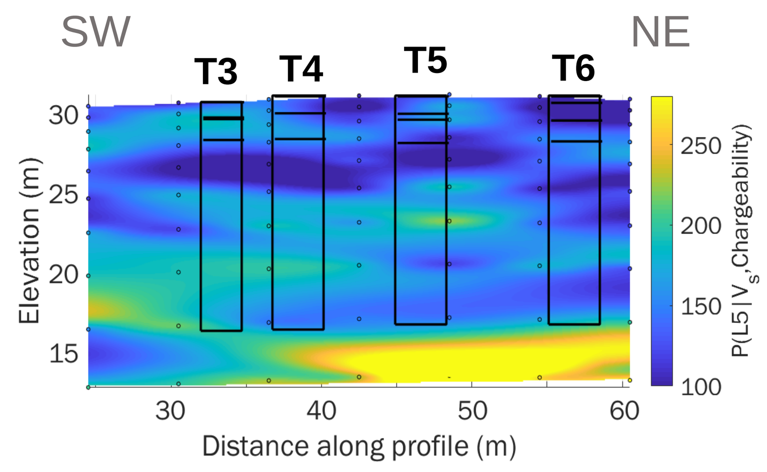

Fig. 6. S-wave velocity model from MASW using Rayleigh wave dispersion data.

4) Probabilistic approach

1. Compute histograms by comparing the inverted models with the co-located data from trial pits.
2. Derive conditional probabilities of each of the N layers given the inverted models. Sensitivity correction using Bayes' rule.
3. Select model(s) than can better resolve structure of the landfill.

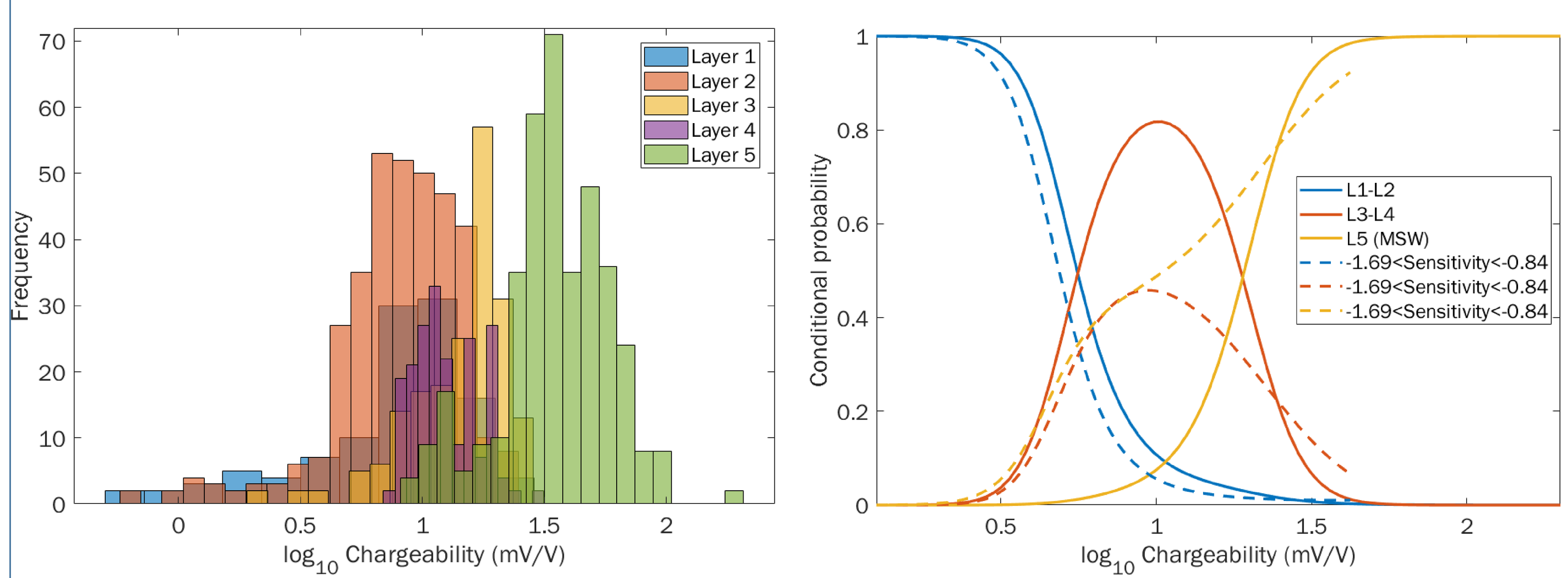

Fig. 7. Histogram of the chargeability model and conditional probabilities of the 5 identified layers.

5) τ-model: combining multiple data

- This is an alternative to assess an unknown event A through its conditional probability $P(A|B,C)$ given 2 (or more) data events B, C of different sources (Journel, 2002).

$$\frac{x}{b} = \left(\frac{c}{a}\right)^{\tau(B,C)} \quad \tau(B,C) \geq 0 \quad \text{where} \quad x = \frac{1-P(A|B,C)}{P(A|B,C)} \quad a = \frac{1-P(A)}{P(A)} \quad b = \frac{1-P(A|B)}{P(A|B)} \quad c = \frac{1-P(A|C)}{P(A|C)}$$

If the unknown event A = waste body (Layer 5) and events B and C = S-wave velocity and chargeability models, we can estimate $P(L5|V_s, chargeability)$ using co-located data.

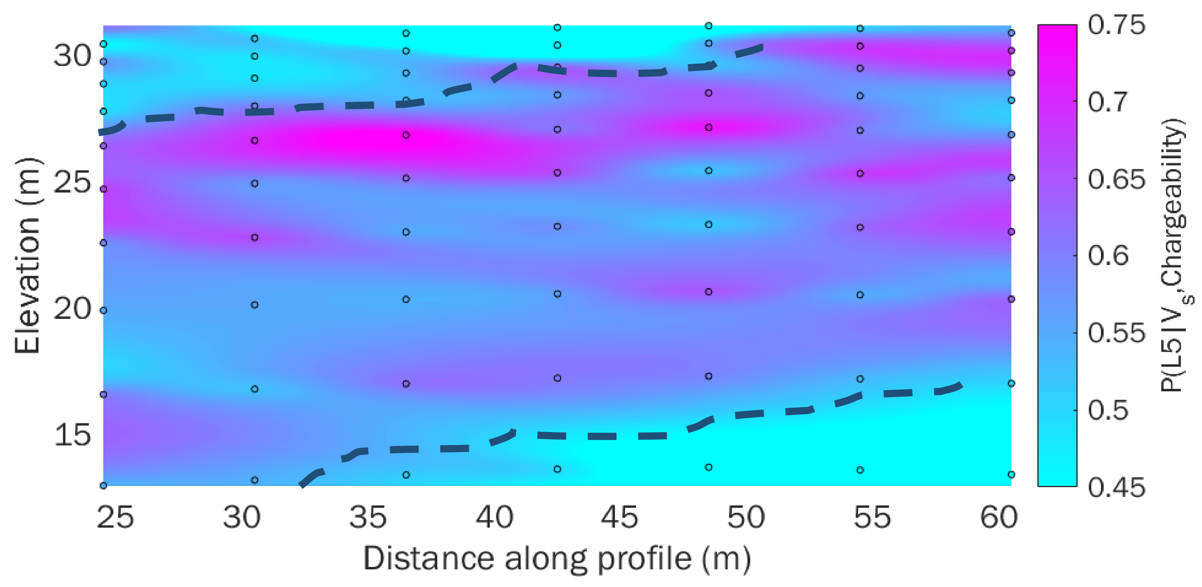

Fig. 8. Conditional probability of layer 5, given the chargeability and the S-wave model, using a τ(B,C)=0.2.

6) Conclusions and perspectives

- IP method is useful to delineate MSW (plastics, paper, organics, wood, textile, metals, glass, etc.) overall. ERT is more sensitive to saturated zones within the waste.
- H/V results show a low amplitude peak around 2Hz (thus it might not be reliable), however a parametric analysis at this frequency is still in agreement with the estimated thickness of the waste.
- For this case there is no clear improvement of using the τ-model for combining the chargeability and S-wave velocity models mostly due to the heterogeneity of the latter.

7) Key references

- Hermans T. and Irving J., Facies discrimination with ERT using a probabilistic methodology: effect of sensitivity and regularization, NSG, 2017.
- Journel A. G., 2002, combining knowledge from diverse sources: An alternative to traditional data independence hypotheses, Mathematic Geology.