Combining an integrated geophysical survey into a landfill model: A case study from Emersons Green, UK

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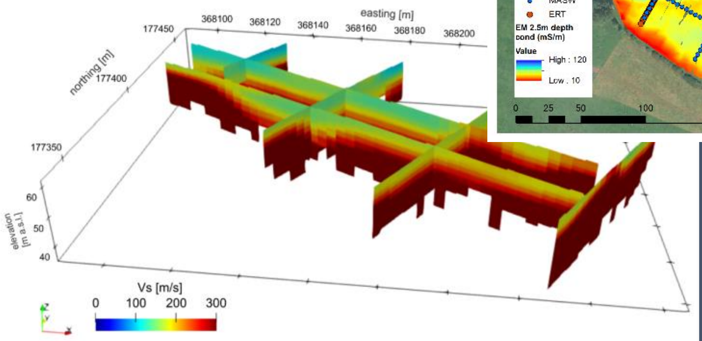
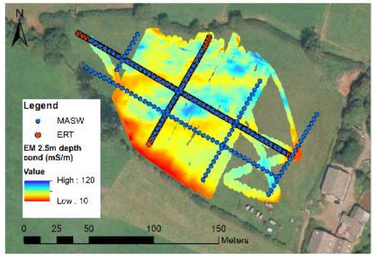
Context and objectives

- Characterizing landfills remains a challenge due to their high heterogeneity and complexity.
- As part of the **RAWFILL project**, we investigate best practices to obtain an improved landfill model by applying complementary geophysical techniques in combination with targeted sampling.
- Building a landfill model from data measured at different resolution, coverage and with different uncertainties is a challenge. This presentation presents a possible workflow applied to the former solid waste landfill in Emersons Green.
- The Emersons Green landfill has been fully excavated providing nearly continuous information on the waste and cover layer thickness. This enables us to validate our workflow.

Workflow overview

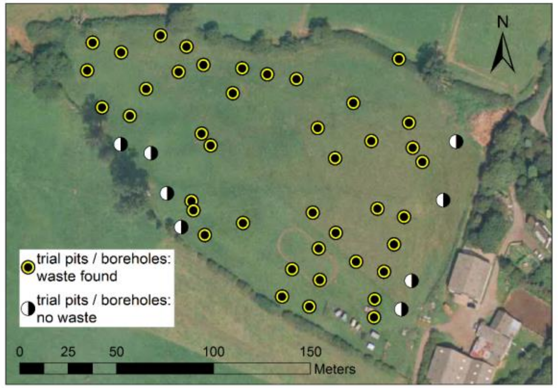
Geophysical data





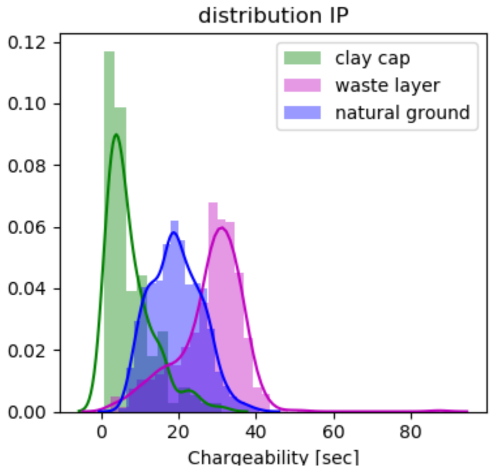
extract geophysical data in vicinity of samples

Trial pits & boreholes



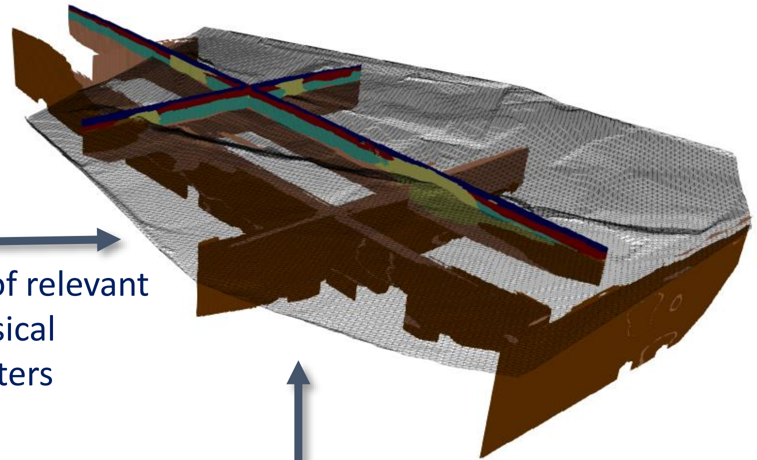
discretize sampling logs into relevant categories (e.g. clay cap, saturated waste…)

Correlation analysis



choice of relevant geophysical parameters

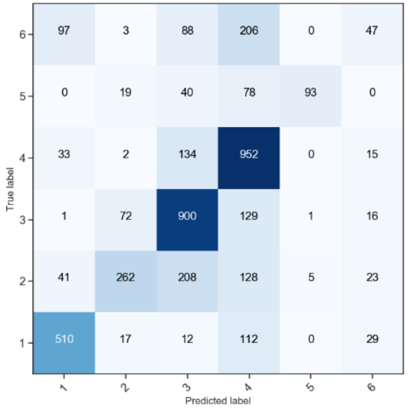
Model building through supervised machine learning (classification)



choice of optimal classification algorithm

1. Train the model based on co-located geophysical data and categorized sampling records
2. Predict the most probable category for the whole dataset

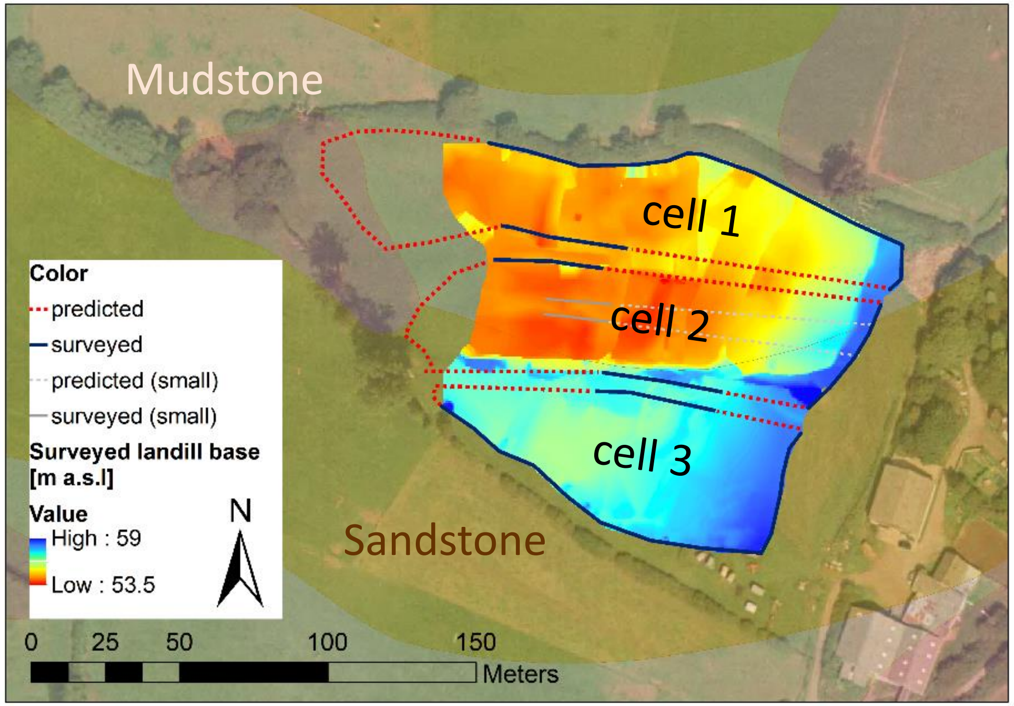
Model validation and comparison with observations from excavation



The Emersons Green landfill

The landfill was operational from 1984 to 1991 during which it mainly accepted inert, industrial/commercial, construction and office wastes. It was designed on a dilute and disperse basis on top of sandstone and mudstone host rock. After completion, the landfill was capped with inert soil and topsoil.

clay stank dividing the waste cells



Findings during the excavation in 2019

The landfill was separated into three cells. These cells were excavated into the natural clayey ground and filled with waste.

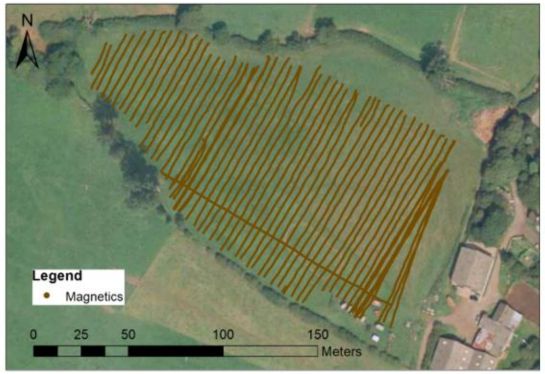
- A thicker clay cap and a thinner waste layer was found in cell 3.
- A step in the landfilll base between cells 2 and 3 might be associated with the underlying sandstone.
- The waste composition was a mix of plastic, metal, wood, paper, fabric, inert etc. with no strong compositional changes across the site.

Geophysical measurements and sampling

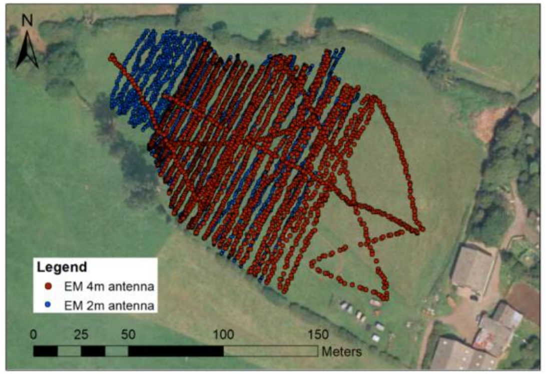
Geophysical methods applied:

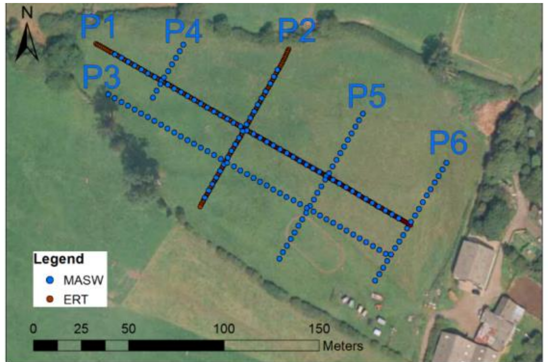
- Electromagnetic mapping (EM)
- Magnetic mapping (Mag)
- Multichannel Analysis of Surface Waves (MASW)
- Electrical Resistivity Tomography (ERT)
- Induced Polarization (IP)

EM grid at four depths



Mag grid

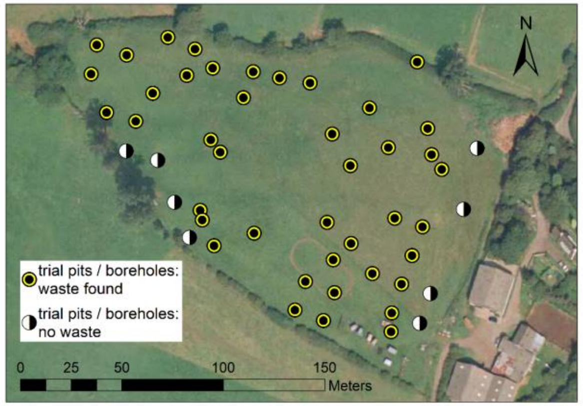




2 ERT profiles
6 MASW profiles

Ground truth data available across site:

- 35 Trial pits
- 4 Boreholes
- Elevation of waste and cover layer base (surveyed during excavation)



Main layers found:

- Clay cap
- unsaturated / saturated solid waste incl. plastic, metal, wood, paper, fabric, inert (no strong compositional changes across the site)
- Clay stank separating waste cells
- Mudstone
- Sandstone

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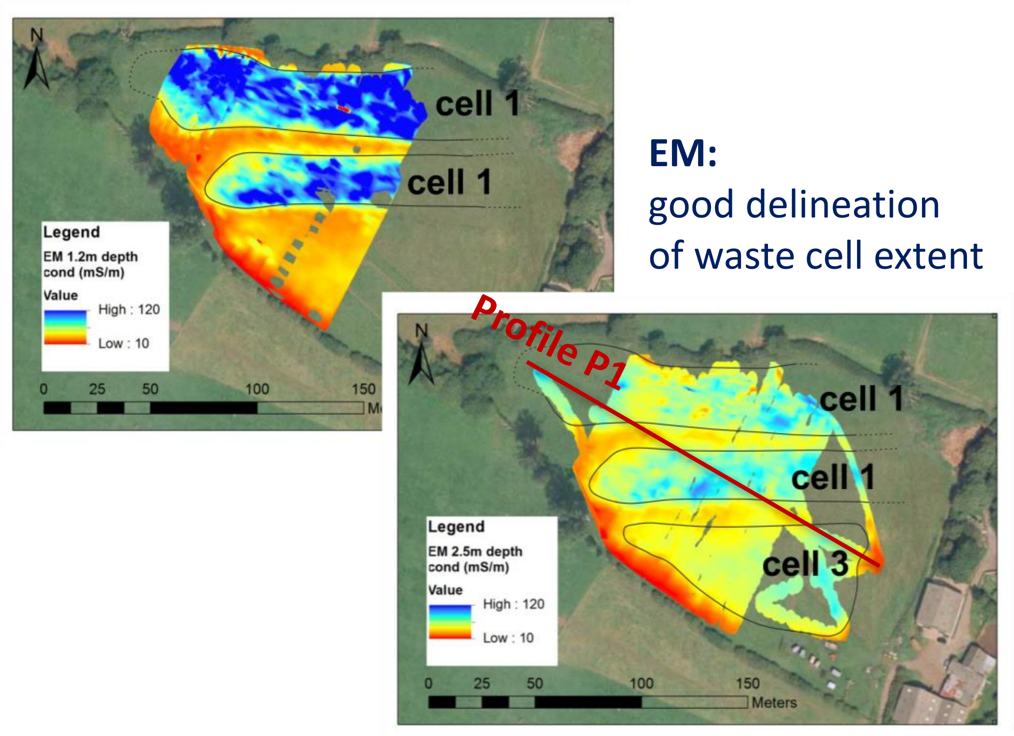
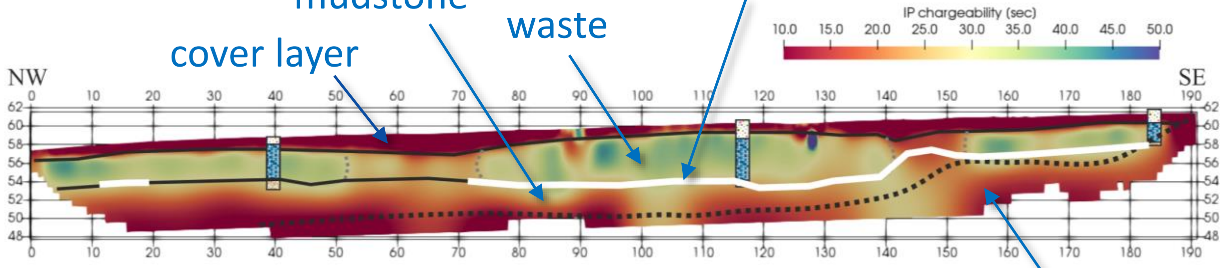
Geophysical measurement results



EM:
good delineation
of waste cell extent

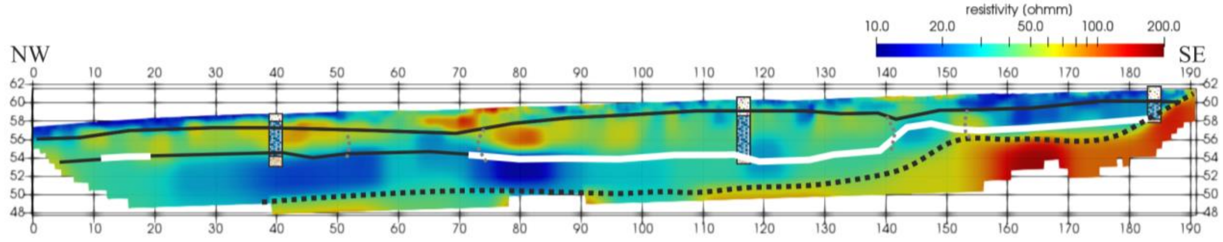
Profile P1

excavated landfill base (white)
mudstone
waste
cover layer

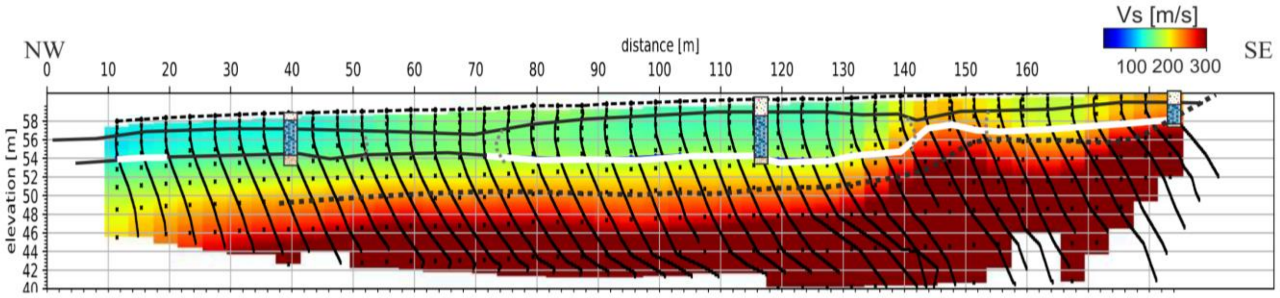


sandstone

IP: resolves clay cap and waste cells



ERT: resolves sandstone interface



MASW: resolves sandstone interface, mudstone interface less clear

Correlation analysis

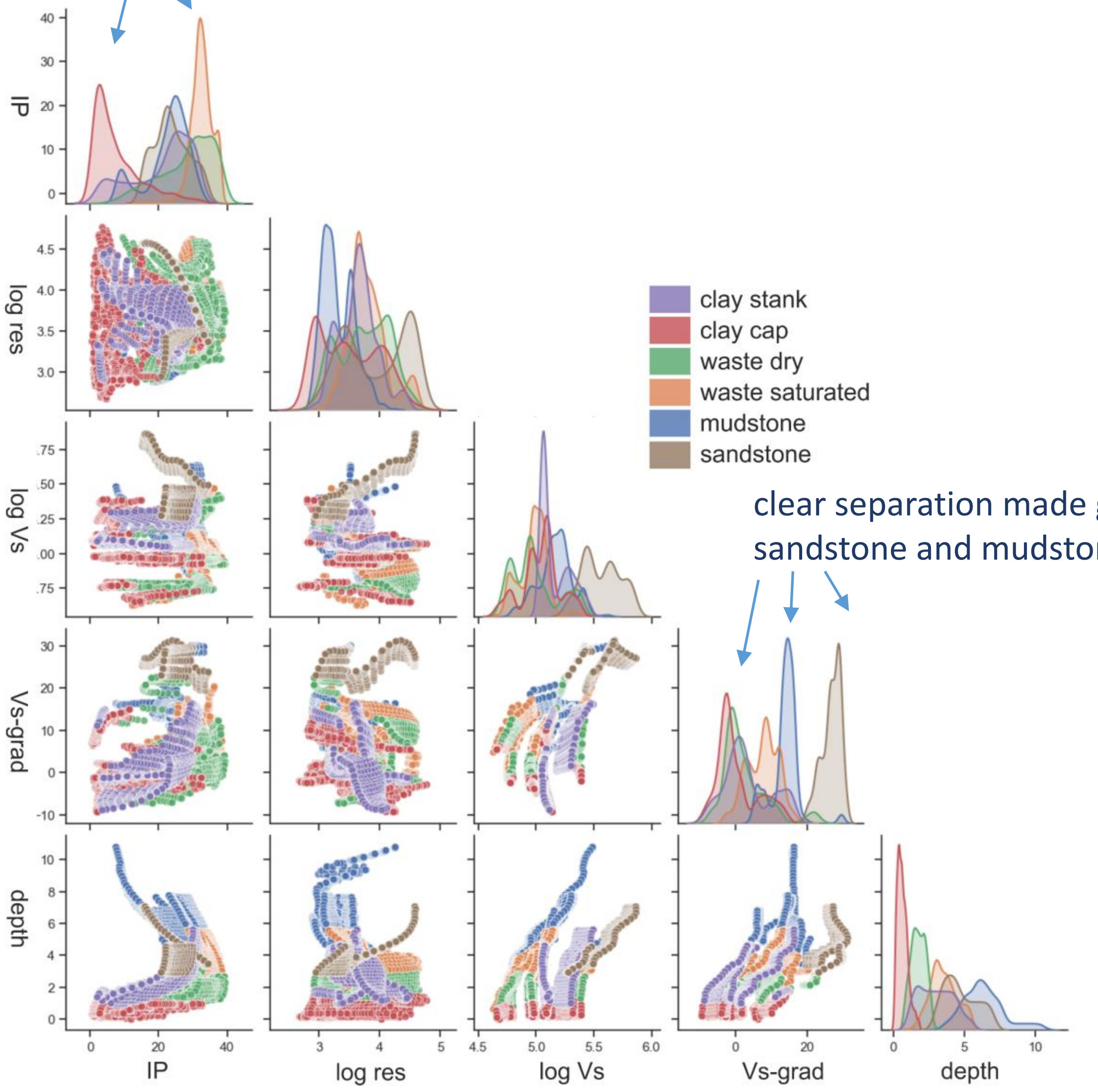
Input for the correlation analysis:

- Geophysical data in vicinity of trial pits and boreholes
- Geophysical data at additional "virtual" sampling locations derived from the information gained during the excavation and the landfill extent extracted from the EM maps (for testing)

The correlation analysis indicated different sensitivities of geophysical properties (see graph on the right). The following standardised datasets are therefore included in as training sets for the classification:

- along profiles where ERT, IP and MASW data are available: chargeability, log(resistivity), log(Vs), $\partial Vs/\partial z$ and depth
- along profiles where only MASW data is available: log(Vs), grad(Vs) and depth

clear separation of clay cap, natural ground and waste

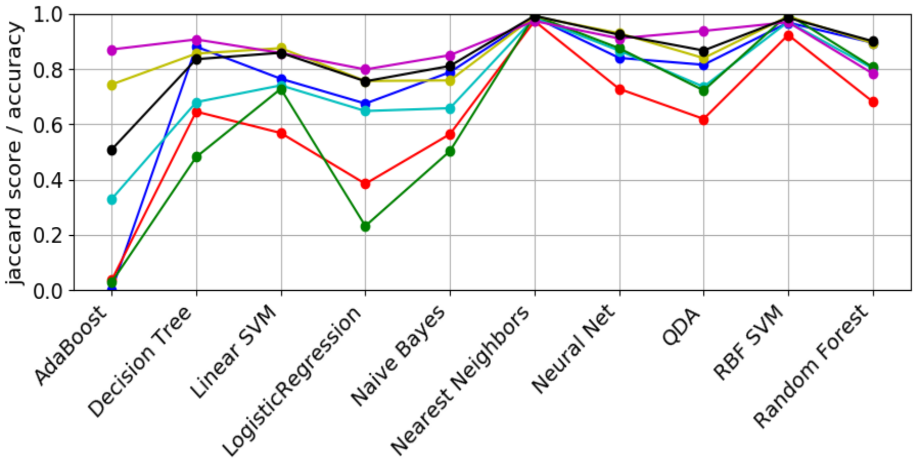


clear separation made ground, sandstone and mudstone

Classification

Comparison of performance of different algorithm within training set:

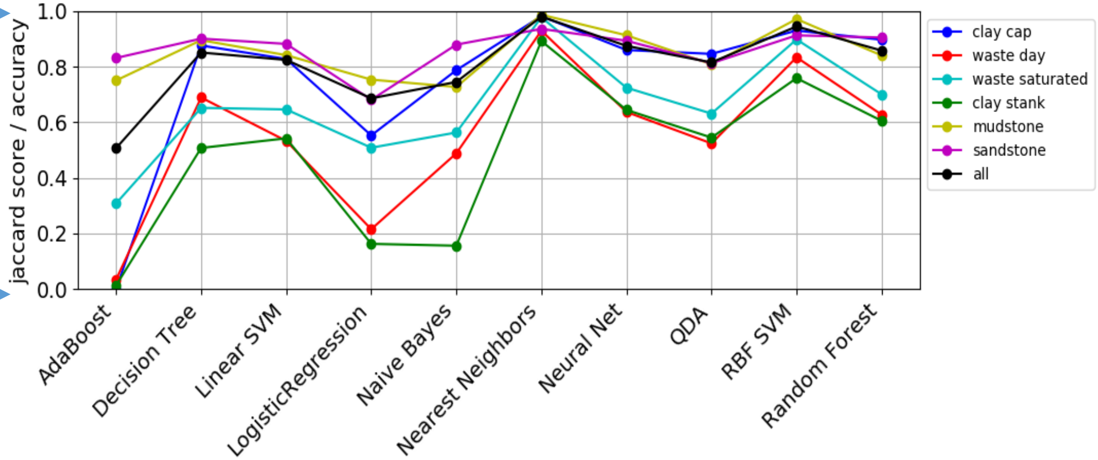
Including: IP, log(res), log(Vs), $\partial Vs/\partial z$ and depth



good fit

bad fit

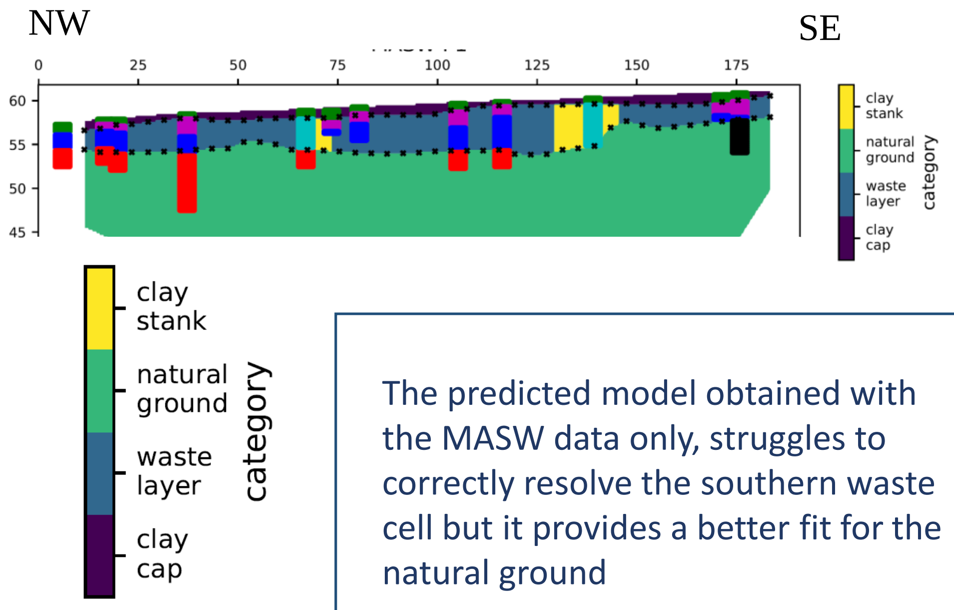
Including: Vs, $\partial Vs/\partial z$ and depth



Training sets which include IP and resistivity perform better in predicting made ground

Classification (comparison and validation of profile 1)

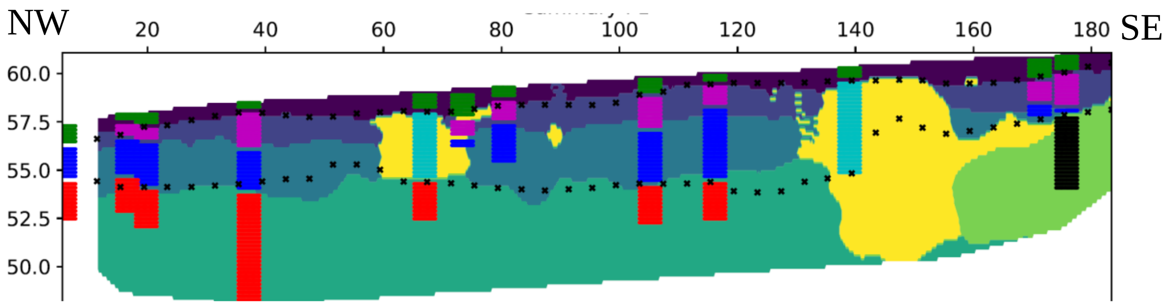
Conceptual model obtained from excavation data and landfill extent derived from EM data



Predicted model

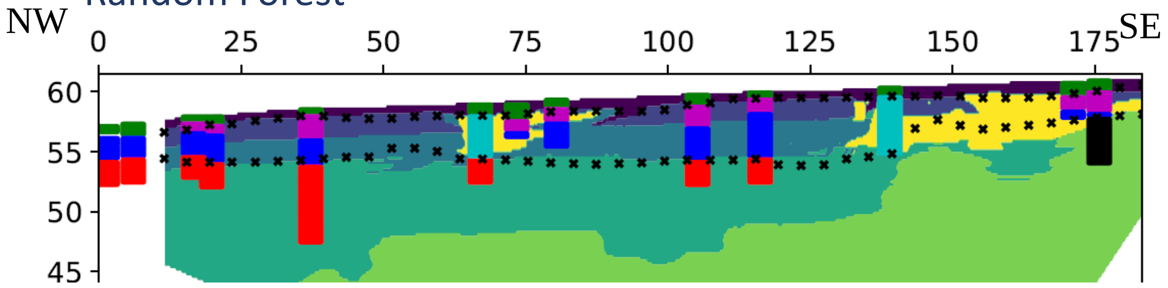
Including: IP, log(res), log(Vs), $\partial Vs/\partial z$ and depth

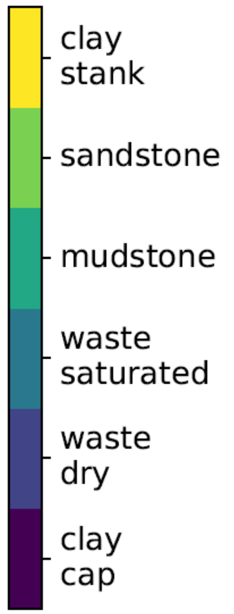
Neural Net



Including: Vs, $\partial Vs/\partial z$ and depth

Random Forest





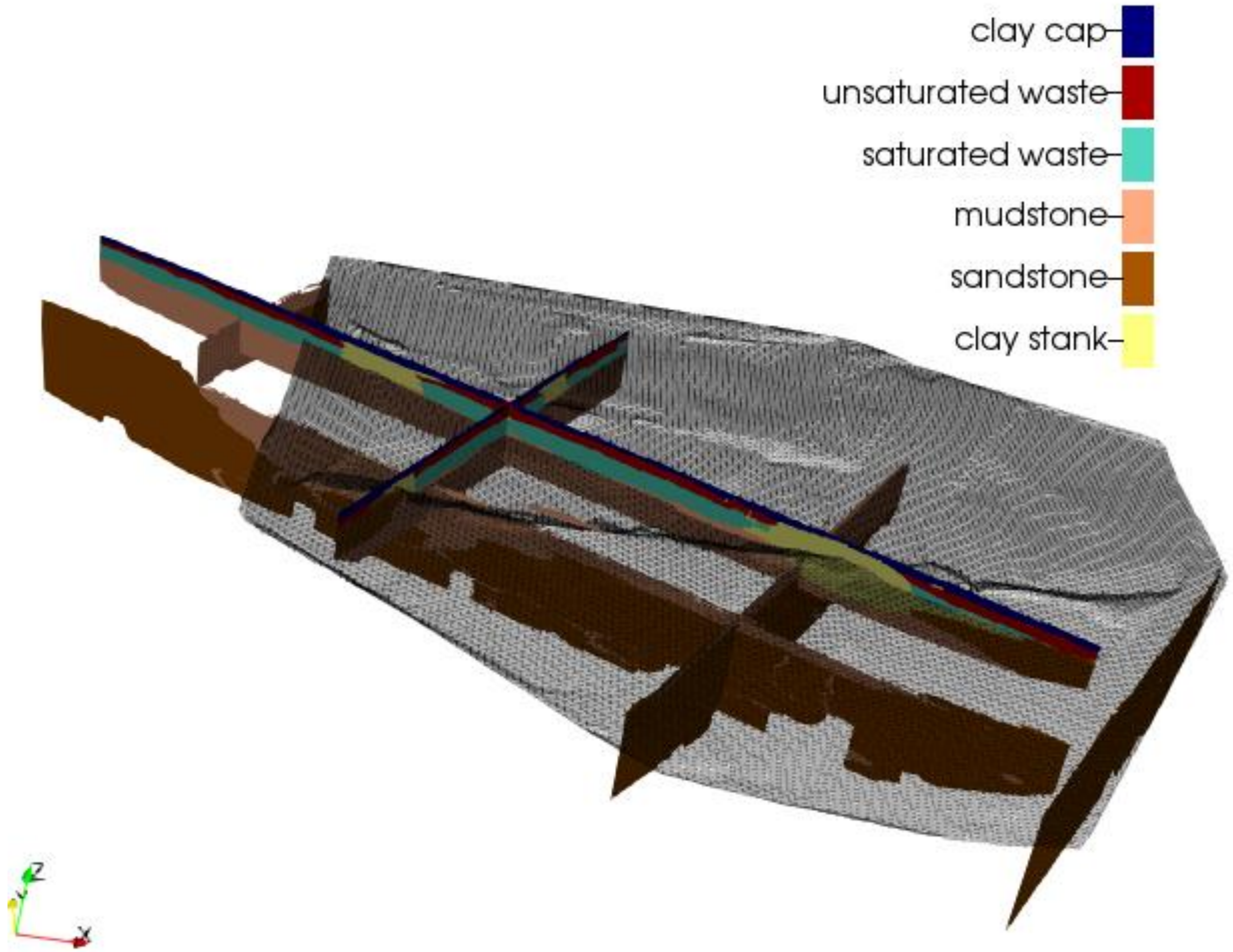
The predicted model obtained with the MASW data only, struggles to correctly resolve the southern waste cell but it provides a better fit for the natural ground

The Nearest Neighbors algorithm tends to “over fit” the data.

Next steps

- Further testing of different algorithms and influence of using different amount of samples

- Estimate a 3D model to calculate volumes



Conclusions

- Classification is a good approach to combine geophysical methods and ground truth data providing an uncertainty estimation in terms of probabilities.
- Complementary geophysical methods are required for a successful categorization of landfills.
- Non co-located measurements make model building and classification more difficult

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Thank you!