Usability of Ground Penetrating Radar for (Semi-)Automatic Mapping of Subsoil Compaction and soil layers in an Agricultural Field

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Background

Subsoil compaction is known to affect soil functioning as a whole, but conventional sampling methods do not facilitate the acquisition of high-resolution spatial compaction data. Sensing techniques such as ground penetrating radar (GPR) and electromagnetic induction (EMI) have been used regularly to acquire data on soil properties. These techniques are not yet regularly employed in soil compaction studies but can potentially be used to find compaction patterns.

Objective

- To obtain spatial information on the degree of subsoil compaction.
- To (semi-)automatically extract soil layering (e.g. maximum rooting depth, textural information) from GPR profiles.

Methods

GPR signals attenuate exponentially with depth, with the exact rate depending mainly on the material through which the signal passes and the water content (theoretical example in Figure 1). By searching for depths at which the reflected signal strength (amplitude) suddenly changes one can find the boundaries between soil layers (Figure 2).

Conventionally these boundaries are often found using expert judgement and subsequently drawn in using specialised software. We attempted to find changes in soil texture and compaction using statistical changepoint detection.

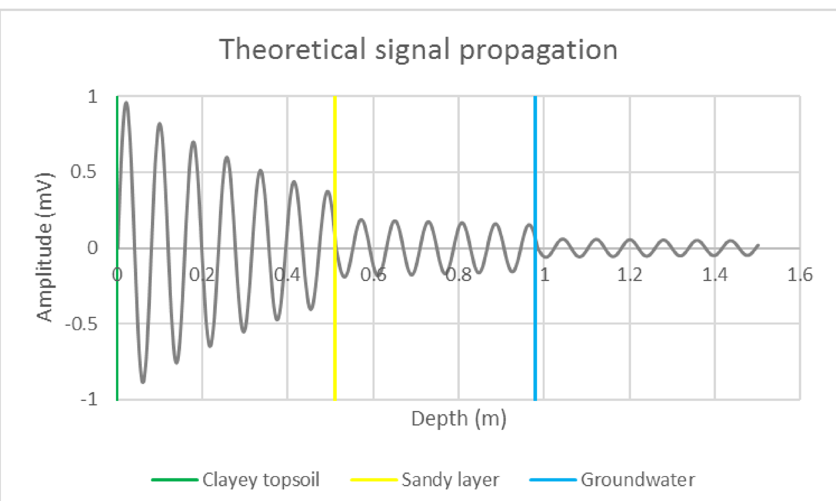

Figure 1. Theoretical example of GPR signal propagation through a multi-layer medium.

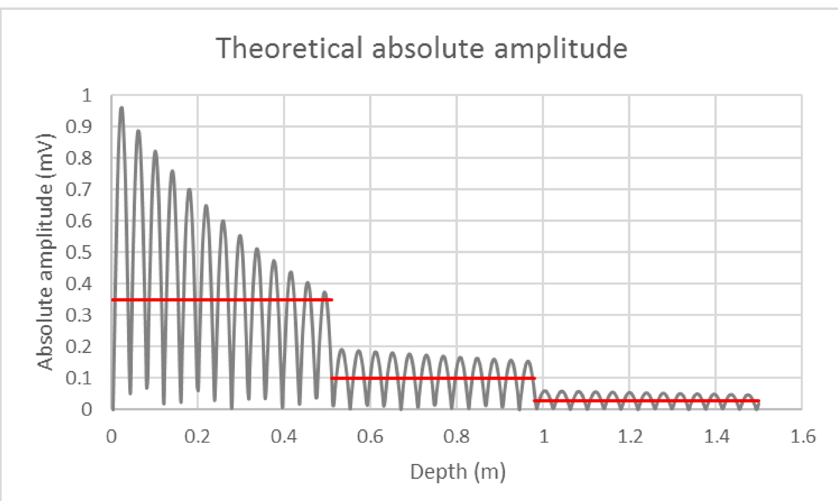

Figure 2. Amplitude corresponding to the theoretical signal from Figure 1. Red lines indicate expected outcome of changepoint detection using the mean absolute amplitude.

Results

Soil compaction from GPR 'depth-slice'

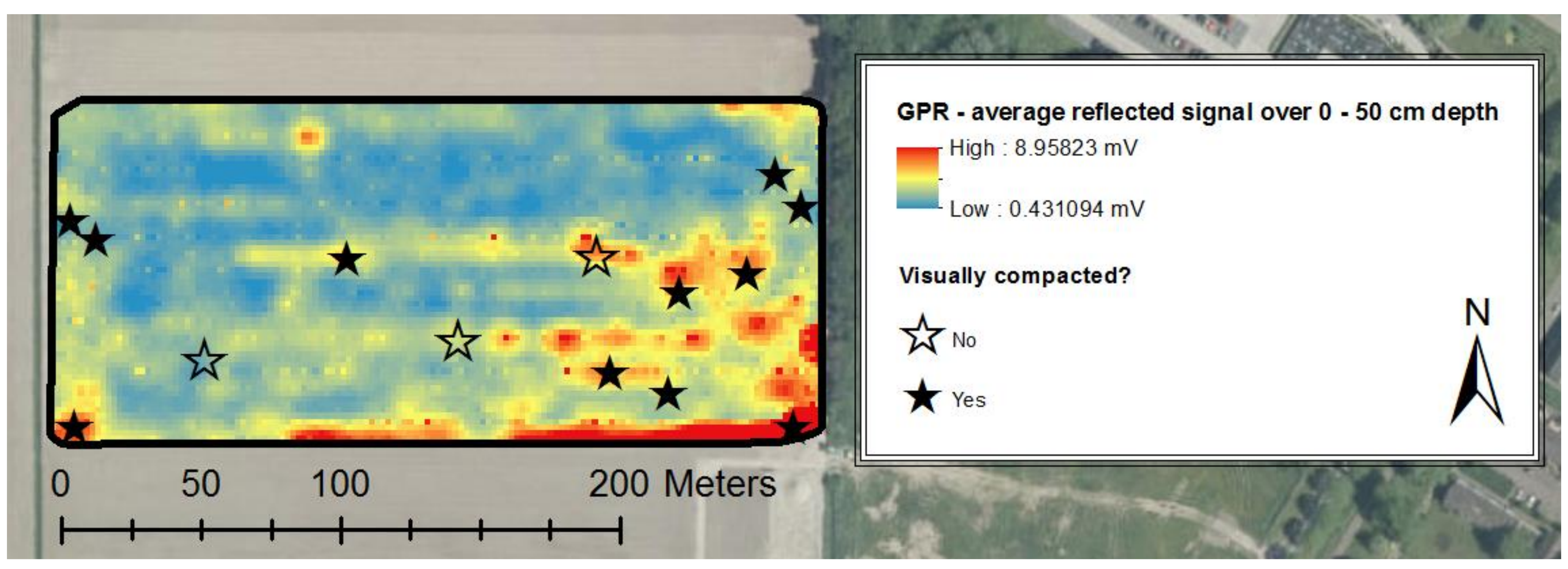

Figure 3. Depth slice of GPR average absolute reflected amplitude and visual observations made regarding the presence of subsoil compaction.

The scan in Figure 3 show resemblance to the expected pattern of subsoil compaction, based on field observations and dry bulk density measurements. Up to this point were unfortunately unable to directly link quantitative soil properties to these scans. This is most likely due to the low number of measurement locations and the strong influence of soil moisture on the GPR signal reflection.

Semi-automatic soil layer extraction

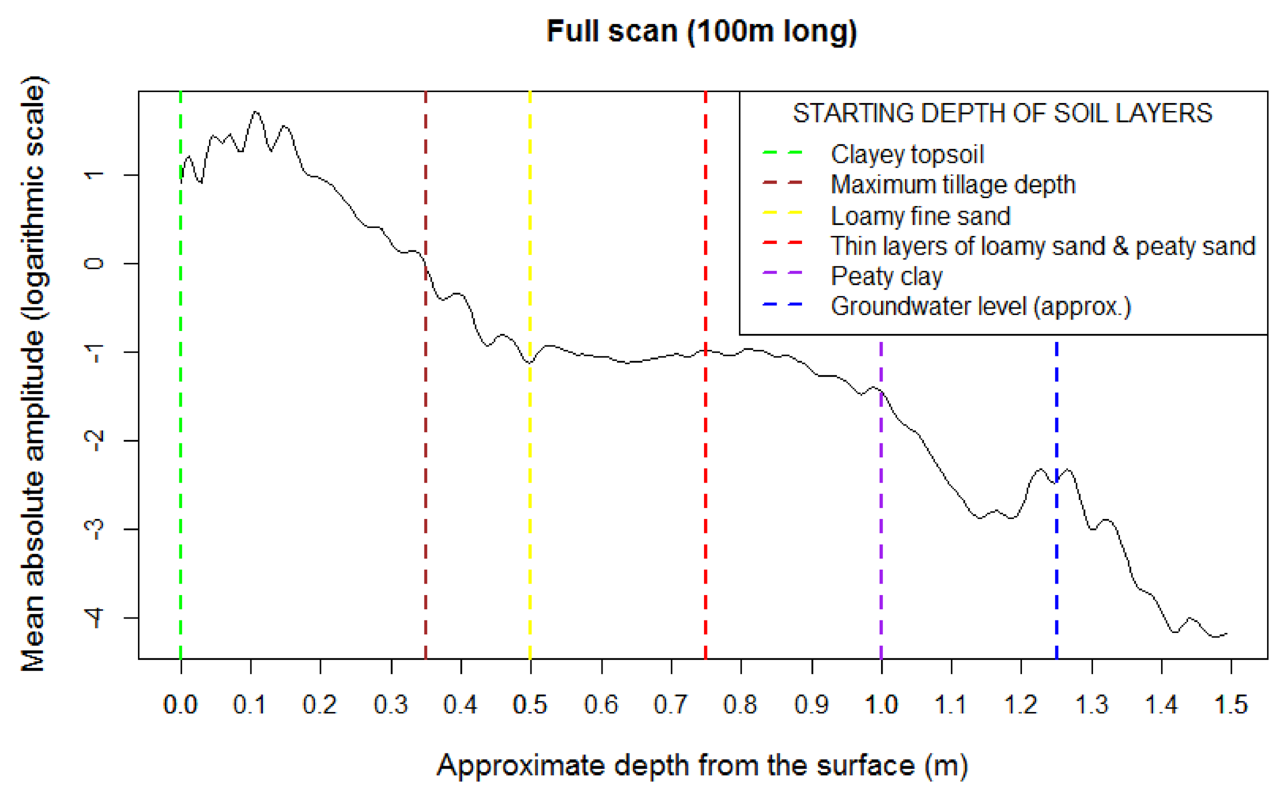

Figure 4. Mean absolute amplitude of a filtered GPR signal over a full scan (100m), depths of soil layers were determined from pit excavations.

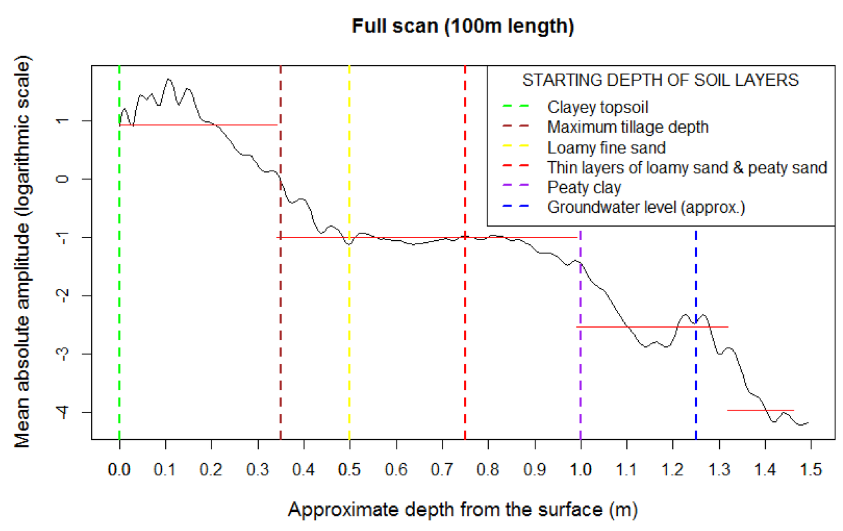

Figure 5. Mean absolute amplitude for a full scan with automatic changepoint extraction (horizontal red lines).

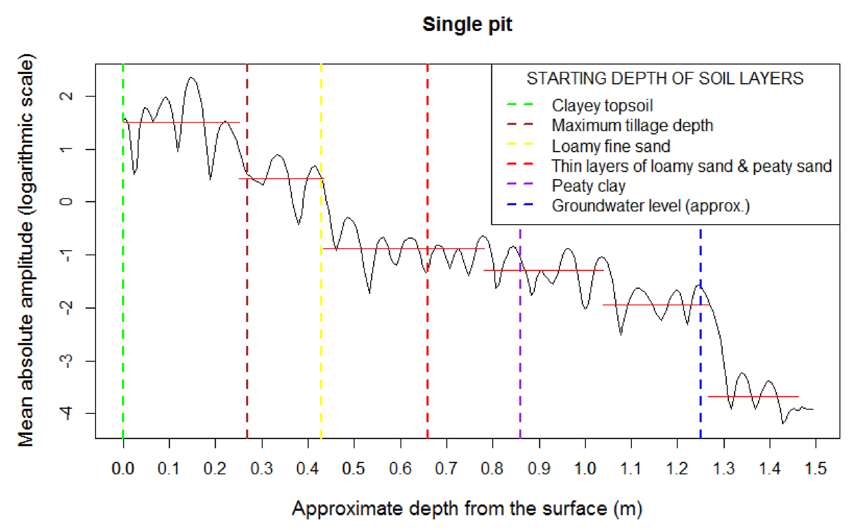

Figure 6. Mean absolute amplitude for a single pit (1x1m) with automatic changepoint extraction (horizontal red lines).

The amplitude profile in Figure 4 corresponds well with theory. In the clayey topsoil the signal attenuates quickly, while the profile straightens out in the sandy subsoil. Amplitudes quickly drop in the peaty clay and below the groundwater level due to the presence of more water.

Figures 5 and 6 show changepoint detection finds many of these layers, but some of the steeper slopes are poorly handled. Some features are less clearly visible at pit level (~1 m).

Conclusions

- A GPR depth-slice does indeed show areas which may be compacted (field observations), but mainly because it includes a strong soil moisture effect. A direct quantitative link to measured soil bulk density was not statistically significant.
- Manual examination of the mean absolute amplitude profile shows a clear link to soil layering. This link is more clearly visible on trace-level (~100 m) than on pit-level (~1 m).
- Changepoint detection shows potential but both pre-processing and the detection itself require further refinement.

Acknowledgements

The authors are grateful for the contributions of K. Pepers, L. Bos, M. de Ruiter, F. Tigchelhoff, and R. Schierholz during field-work. Furthermore we would like to thank Medusa Explorations, especially R. Koomans and S. Ceulemans, for geophyiscal data acquisition and technical support.

The work presented in this poster received funding from NWO-SIA under a RAAK-PRO grant.

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