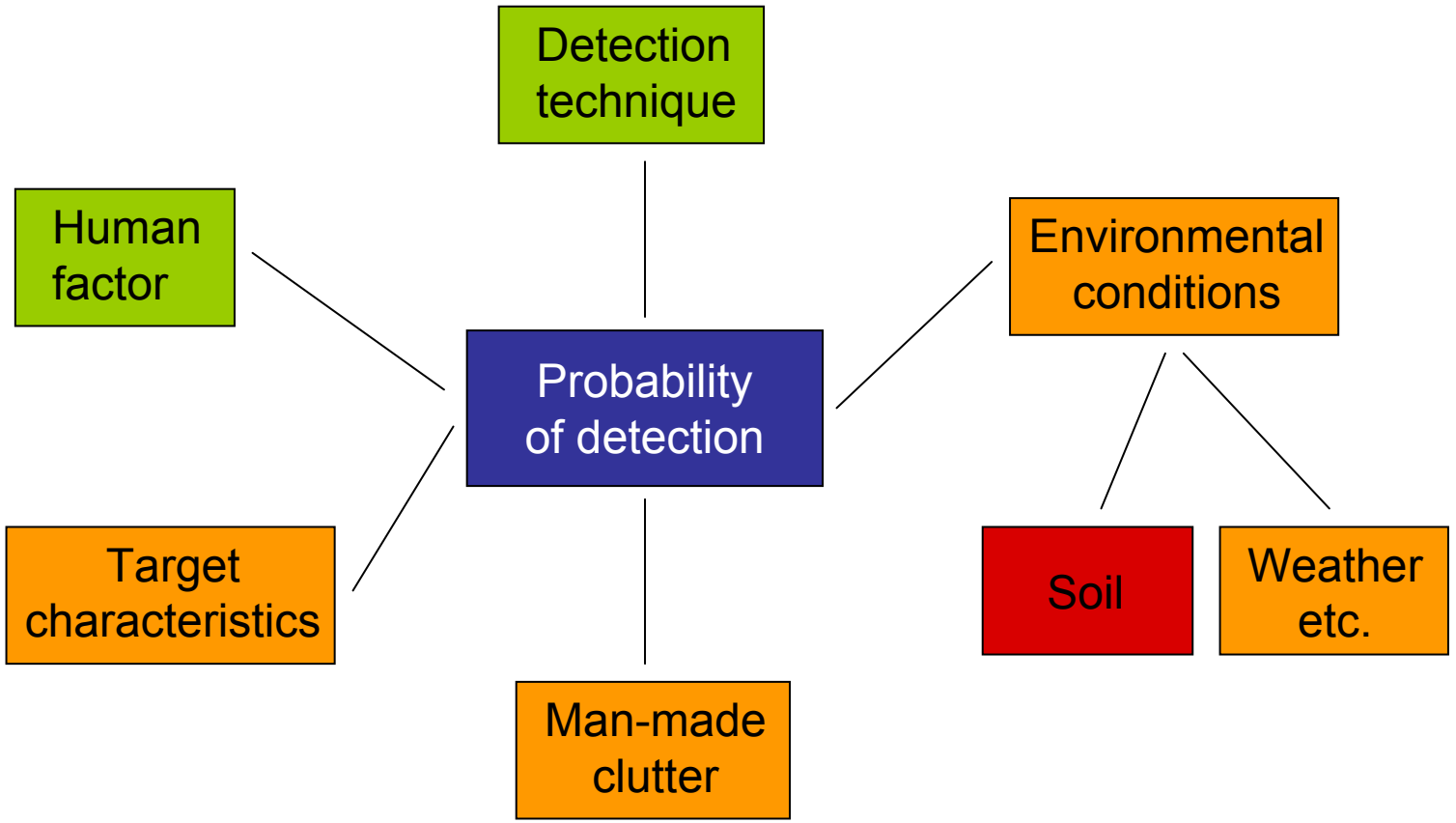
The significance of soil characterisation for metal detector and ground-penetrating radar tests for landmine detection

H. Preetz, K. Takahashi & J. Igel

Leibniz Institute for Applied Geophysics , Hannover

Influences on the detectability of targets



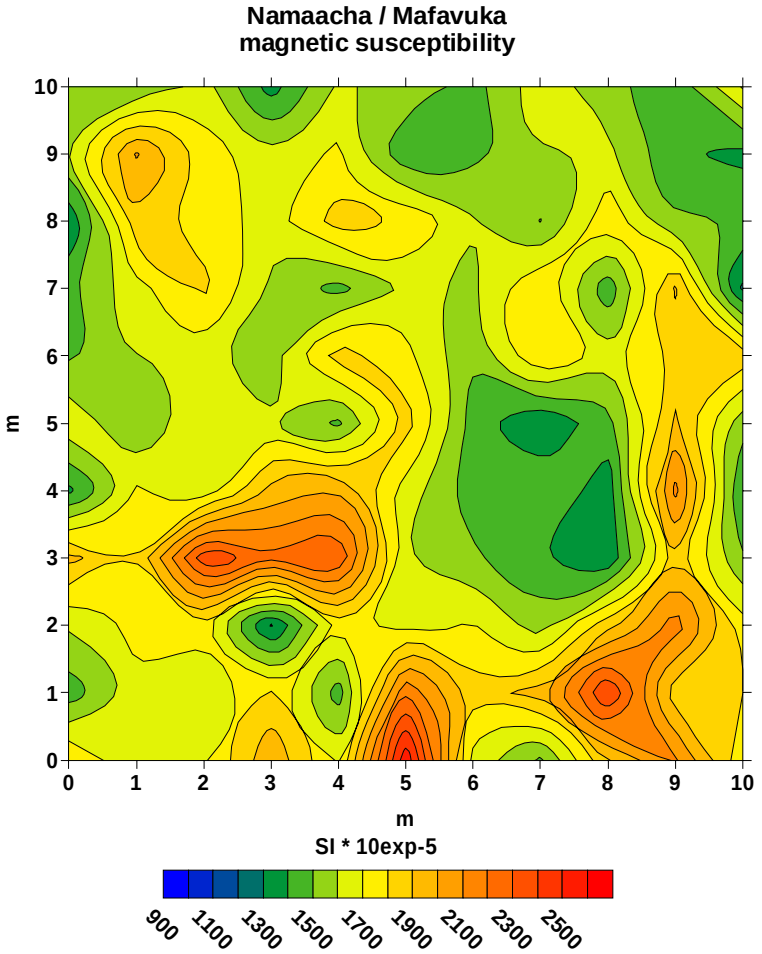
Soil influence on sensors for landmine detection

Metal Detector	Ground-Penetrating Radar
Physical parameters	
- magnetic susceptibility κ - frequency dependence of magnetic susceptibility - electric conductivity σ	- dielectric constant (permittivity) ε - electric conductivity σ
Soil parameters	
- mineral compound - soil moisture - soil texture etc.	- soil moisture - soil texture etc.

Heterogeneity of the parameters

Heterogeneity of a natural soil

Spatial variability of magnetic susceptibility on a site in Mozambique



<u>magnetic susceptibility</u>

mean	1648 SI*10^{-5}
coefficient of variation	14.4 %
correlation length	1.2 m

6 Test lanes and 4 different soil types with different textures

Lane 1.1: Laterite

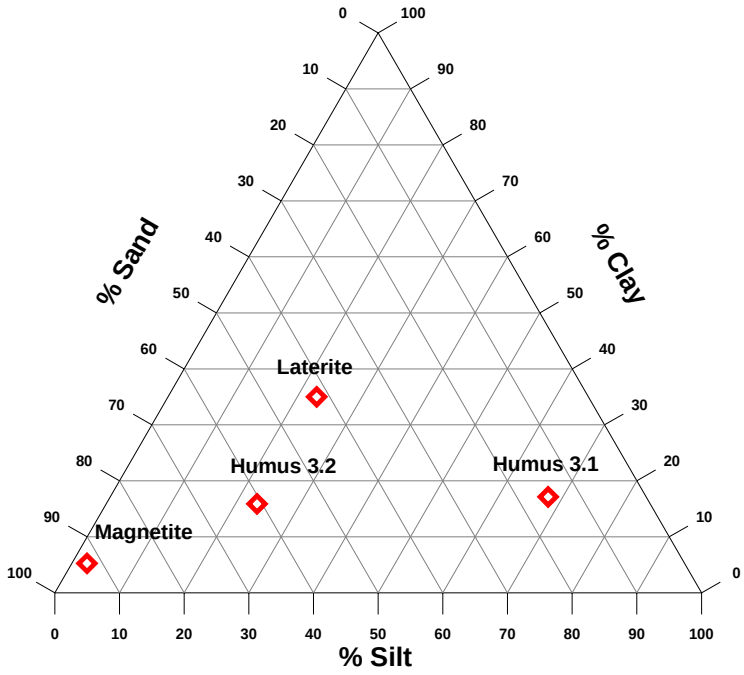
Lane 1.2: Laterite

Lane 2.1: „Magnetite“/Sand

Lane 2.2: „Magnetite“/Sand

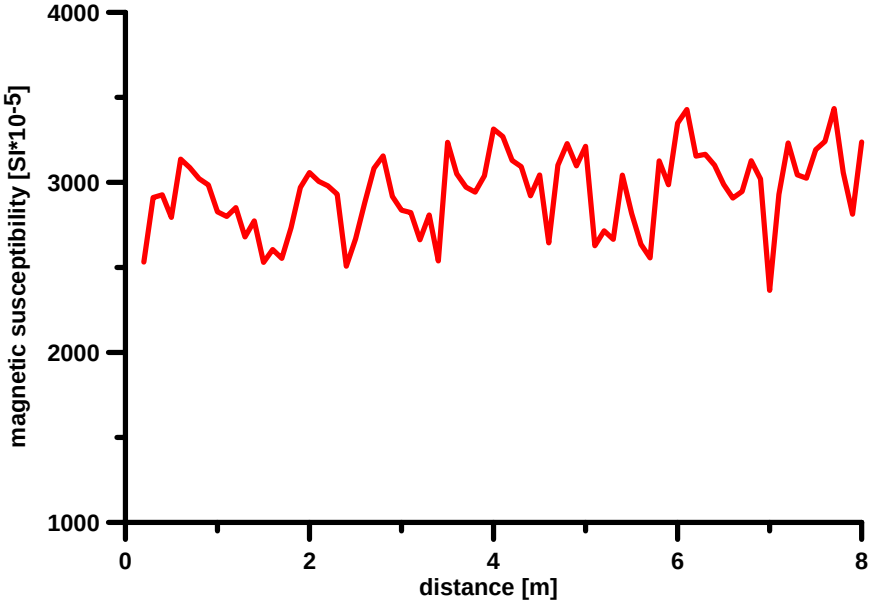
Lane 3.1: „Humus“ - low gravel content

Lane 3.2: „Humus“ - high stone content



Soil magnetic properties – Field measurements

1.3 Laterite



1.3 Laterite

magnetic susceptibility	
mean	2977 SI*10^{-5}
coefficient of variation	8.4 %
correlation length	0.35 m

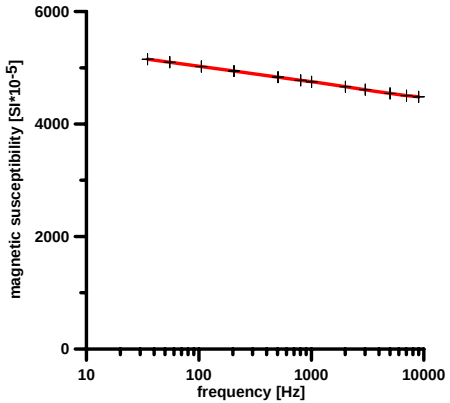
2.3 Magnetite

magnetic susceptibility	
mean	3324 SI*10^{-5}
coefficient of variation	7.4 %
correlation length	-

3.3 Humus

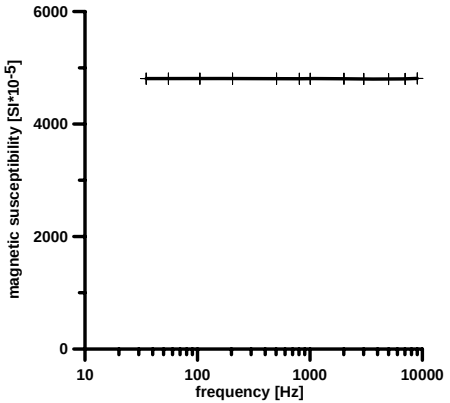
magnetic susceptibility	
mean	18 SI*10^{-5}
coefficient of variation	38.9 %
correlation length	0.26 m

Soil magnetic properties – Frequency dependent susceptibility



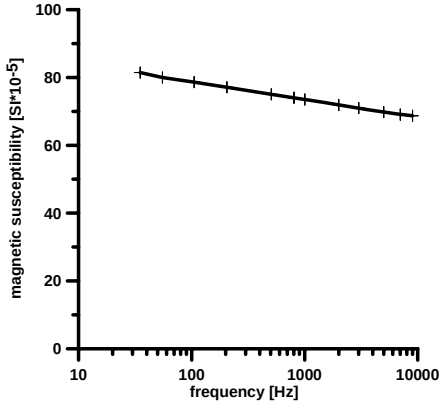
1.3 Laterite

frequency dependence = 290 SI*10^{-5} (6 %)



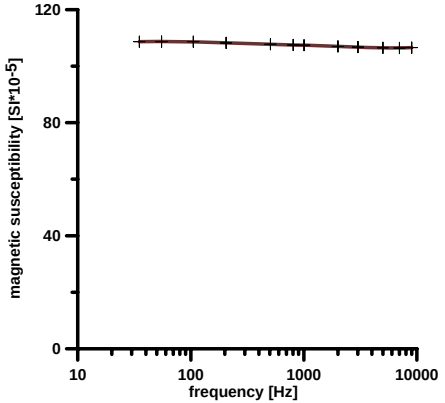
2.3 Magnetite

frequency dependence = 7 SI*10^{-5} (0.1 %)



3.1 Humus

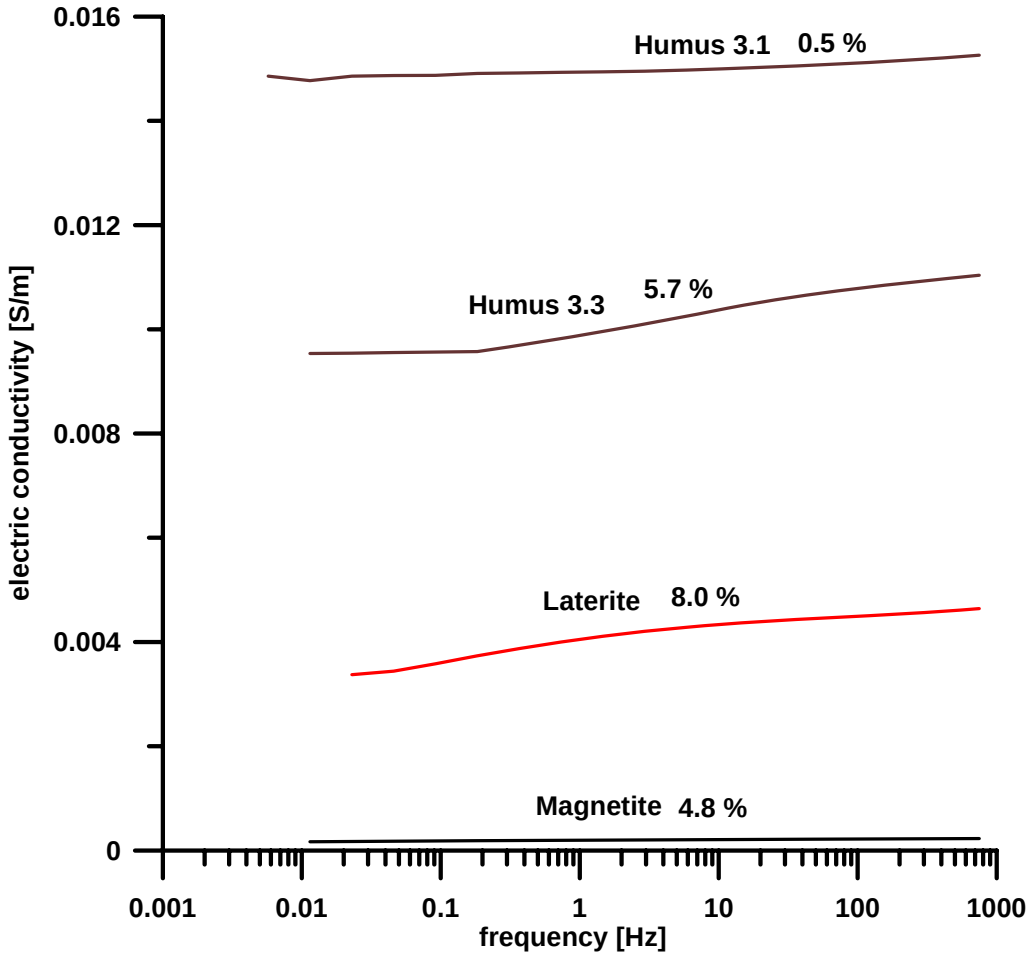
frequency dependence 5.3 SI*10^{-5} (7 %)



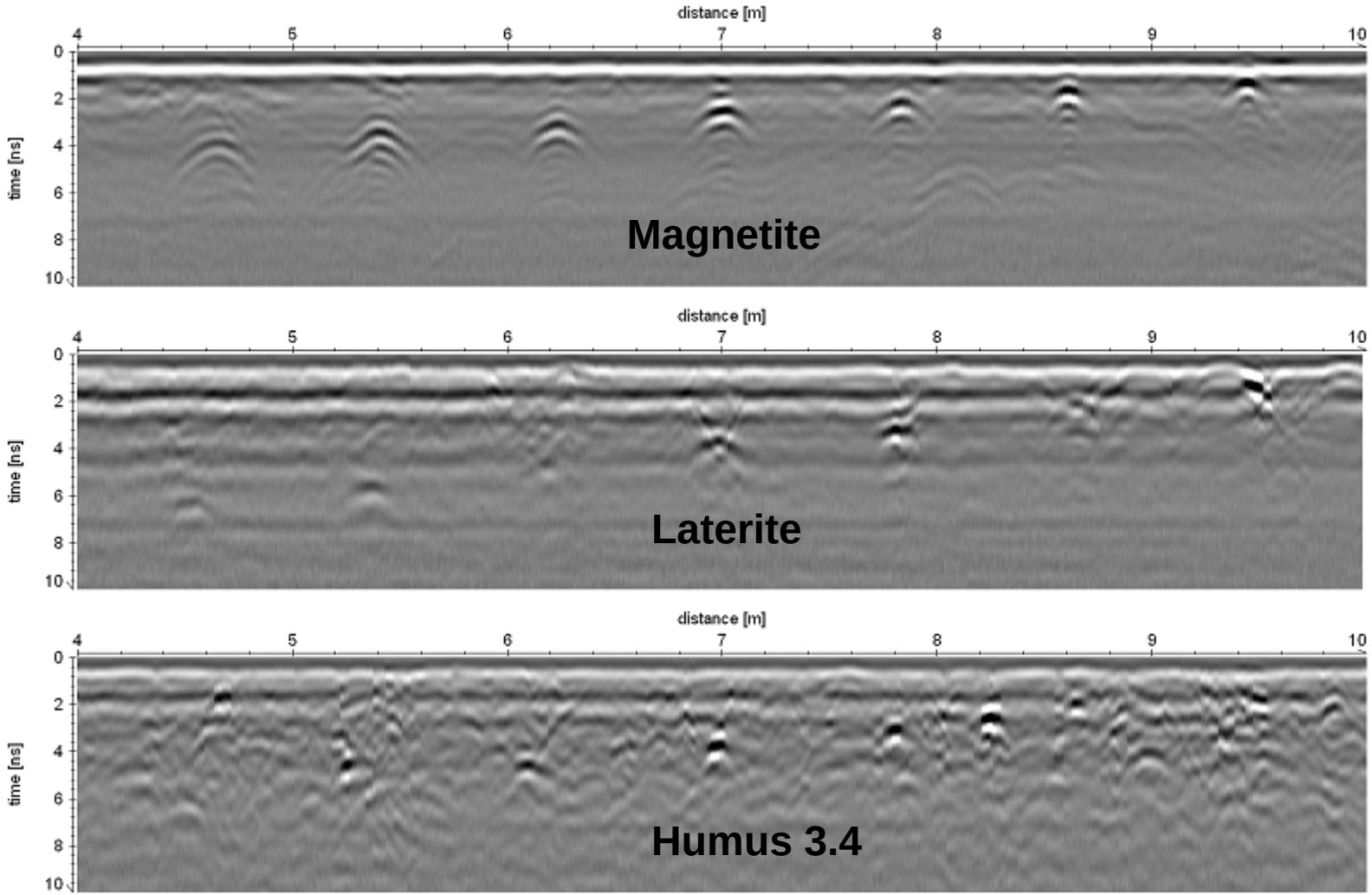
3.3 Humus

frequency dependence 1.3 SI*10^{-5} (1 %)

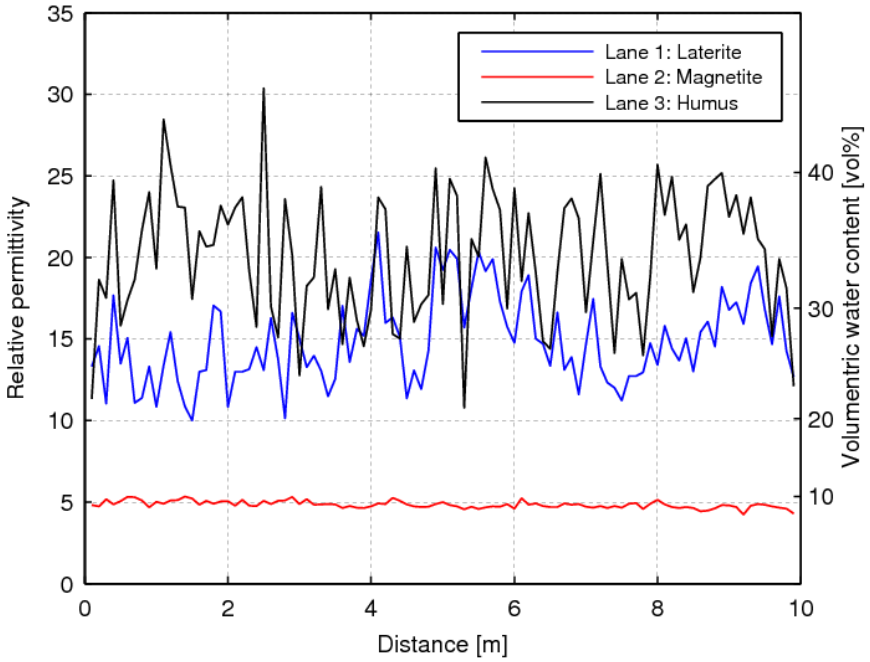
Frequency dependence of the electric conductivity



GPR performance – measurement with GSSI equipment (1.5 GHz)



Soil moisture distribution – Field measurements



1.3 Laterite

soil moisture	
mean	25.6 %
coefficient of variation	12.8 %
correlation length	1.35 m

2.3 Magnetite

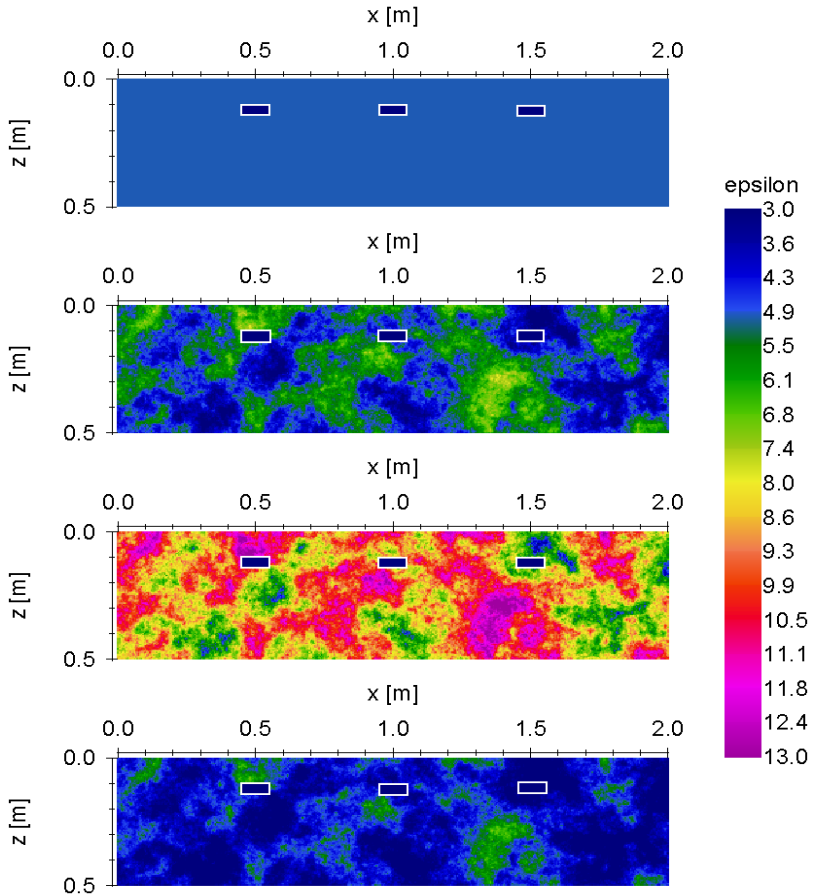
soil moisture	
mean	7.5 %
coefficient of variation	6.9 %
correlation length	-

3.3 Humus

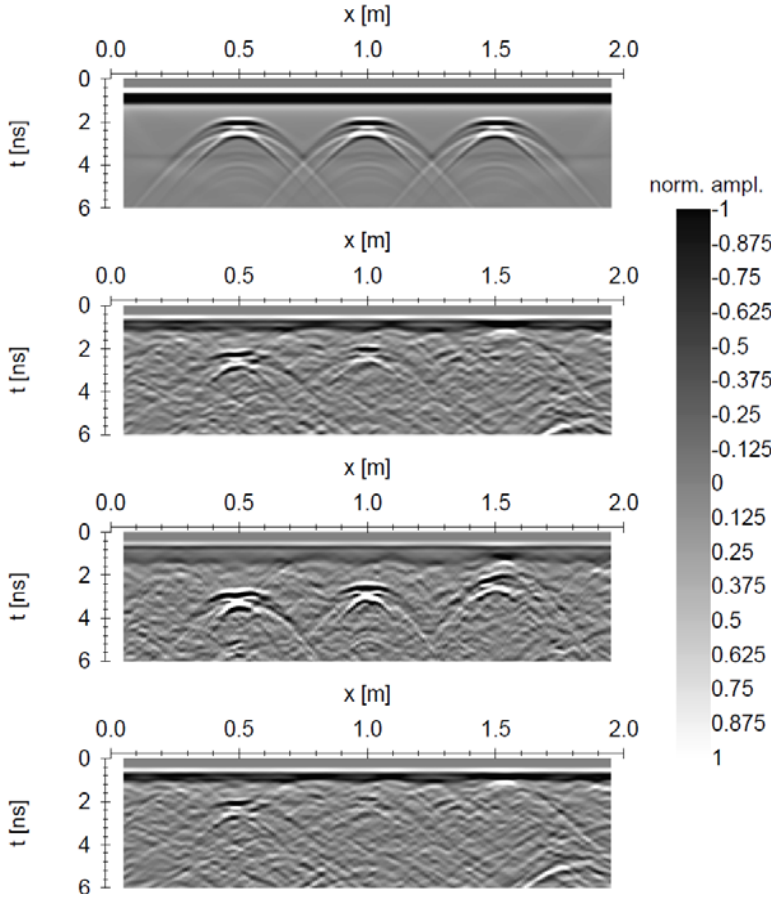
soil moisture	
mean	30.3 %
coefficient of variation	10.0 %
correlation length	-

Modelling of GPR performance

Model



FD-Simulation

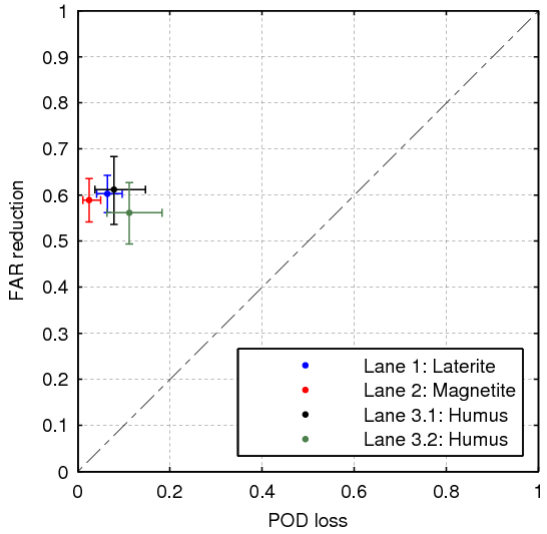


Classification of soil properties

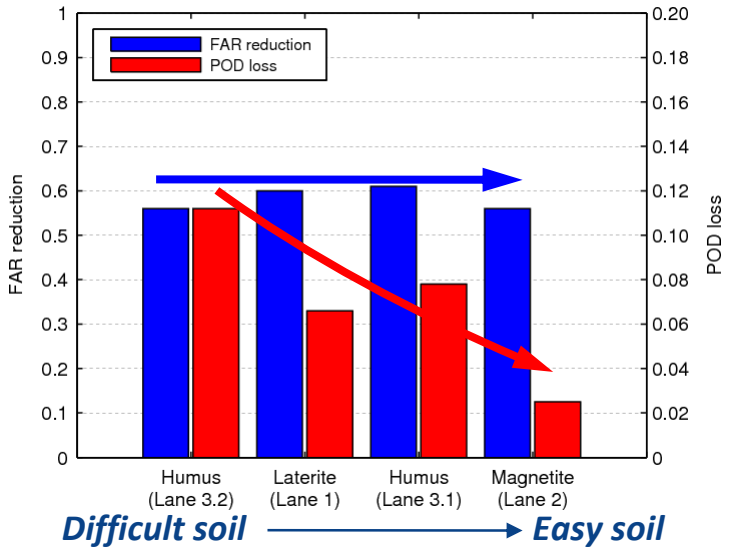
	Laterite (Lane 1.1-1.4)	Magnetite (Lane 2.1-2.4)	Humus (Lane 3.1)	Humus with high stone content (Lane 3.2-3.4)
κ κ(ω) ε, θ ε(r)	very high very high high large	very high very low low very small	very low large high large	very low very small high very large
MD	***very severe***	***moderate***	***neutral*** ***moderate***	***neutral***
GPR	***moderate*** ***severe***	***neutral***	***moderate***	***very severe***

κ : Magnetic susceptibility
κ(ω) : Frequency dependence of magnetic susceptibility
ε, θ : Permittivity (dielectric constant), water content
ε(r) : spatial variation of permittivity

Relation of soil classification and discrimination performance (GPR)



	Laterite	Magnetite	Humus Lane 3.1	Humus Lane 3.3
FAR reduction	60 %	56 %	61 %	56 %
POD loss	6.6 %	2.5 %	7.8 %	11.2 %



Difficult soil:

Higher POD loss

Easy soil:

Lower POD loss

Conclusions

- Soil properties can have a considerable influence on detection performance
- Different soils with different textures and electromagnetic properties determine different detection results
- Main soil parameters are easy to measure
- Soil characterisation is useful for comparison of test results from various regions
- Knowledge on soil characteristics can be used for the choice of proper detection technique for demining activities
- Conclusions hold for metal detectors and GPR technique as well