
# Towards universal applicability of on-the-go gamma-spectrometry for soil texture estimation in precision farming by using machine learning applications

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## Summary

High resolution soil data are an essential prerequisite for the application of precision farming techniques. Sensor-based evaluation of soil properties may replace or at least reduce laborious, time-consuming and expensive soil sampling with subsequent measurements in the lab.

Gamma spectrometric field measurements may provide high resolution information on topsoil texture. Yet, calibrations for the estimation of texture data usually have to be done site-specifically (Priori et al., 2014). The lack of site-independent calibrations thus limits the easy and

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universal use of proximal gamma-ray sensing in soil mapping and precision agriculture. Our objective was to develop a study site-independent prediction model for topsoil texture from gamma-ray spectra. We surveyed ten study sites across Germany with 417 reference samples (291 for calibration, 126 for test set-validation), providing soils from a broad range of parent materials and with widely varying soil texture. First, study site-specific models were calibrated by a linear regression approach. These models provided reliable estimations of sand, silt, and clay for most of the study sites. Second, study site-independent models were calibrated via i) linear regression and ii) support vector machines (SVM), the latter being mathematical methods of data pattern recognition. Based on the non-linear relationship between gamma spectrum and soil texture, which varied widely between the different parent materials the linear models were not appropriate for satisfactory soil texture prediction (averaged R2 of 0.73 for sand, 0.61 for silt, and 0.18 for clay and averaged absolute prediction errors of 9 to 5%, respectively; data not shown). In contrast, the SVM calibrated prediction models revealed reliable performance also for site-independent calibrations (Fig.1). With the non-linear SVM approach we were able to include all sites in one single prediction model for each texture fraction although the different mineralogical composition of their parent materials led to complex and partly opposing relationships between gamma features and soil texture. Site-independent predictions via SVM were often even better than site-specific linear regression models. The site-independent SVM calibrated predictions yielded an averaged R2 of 0.96 (sand), 0.93 (silt), and 0.78 (clay), and corresponding averaged absolute prediction errors of 2 to 4%, respectively (Heggemann et al., 2017).

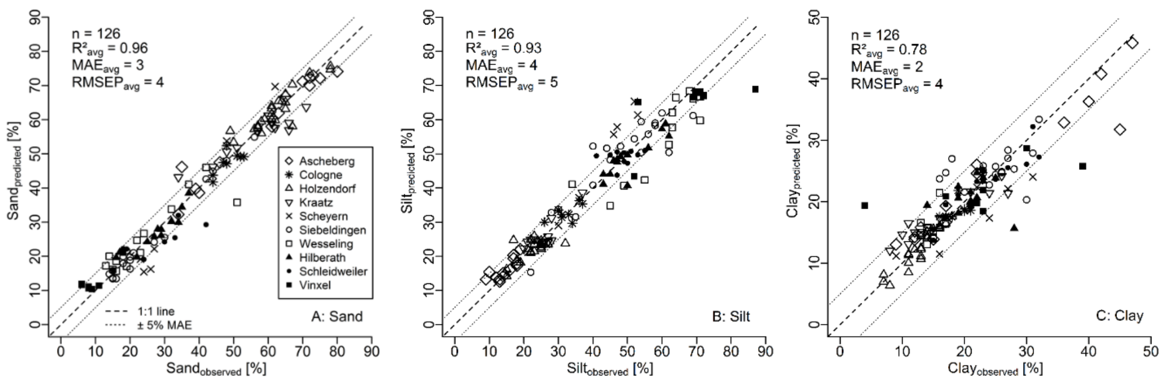


**Fig. 1: Independent test-set validation for prediction of a) sand, b) silt, and c) clay using universal prediction models calibrated via support vector machine. 1:1 line and range of plusminus 5% MAE indicate prediction quality ($R^2$avg = averaged $R^2$ over all sites, MAEavg = averaged mean absolute error over all sites, RMSEPavg = averaged rootmean squared error over all sites, n = 126).**

In the ongoing project "I4S - Intelligence for Soil" in the frame of the German Federal BonaRes program we are broadening the database. Thereby, we focus on crucial parent materials and environmental settings that are not yet represented in the dataset.

Further, we discuss challenges in spectra analyses and prediction routines that have to be overcome for future on-the-go texture prediction from a driving tractor. Promising results were achieved inter alia on the central I4S-test site Görzig. In many cases, predictions of sand, silt, and clay were as precise as conventional lab analyses. This approach enables us to directly adapt texture-related agronomic measures such as lime and fertilizer application on-the-go.

References

Heggemann, T., Welp, G., Amelung, W., Angst, G., Franz, S.O., Koszinski, S., Schmidt, K., Pätzold, S. (2017). Proximal gamma-ray spectrometry for site-independent in situ prediction of soil texture on ten heterogeneous fields in Germany using support vector machines. *Soil Till. Res.* 168, 99-109.

Priori, S., Bianconi, N., Costantini, E.A.C. (2014). Can gamma-radiometrics predict soil textural data and stoniness in different parent materials? A comparison of two machine-learning methods. *Geoderma* 226, 354–364.