Application Note AN-NIR-133

Soil analysis with NIR spectroscopy

Multiparameter determination of soil in a few seconds

Soil is a complex matrix made of organic and inorganic mineral matter, water, and air. The organic material ranges from decomposed and stable humus to fresh particulate residues from different sources [1]. Texture affects soil behavior (e.g., water holding capacity, nutrient retention and supply, drainage, and nutrient leaching [2]) and depends on the proportion by weight of the sand, silt, and clay it contains. Cation-exchange capacity (CEC), a measure of the ability to hold positively charged ions, influences soil structure stability, nutrient availability, pH, and its reaction to fertilizers and other ameliorants. The main ions associated with CEC in soils are Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+} [3]. Soil pH directly influences the availability of nutrients to plants, microbial activity, and overall soil health, affecting plant growth, crop yields, and the sustainability of agricultural practices. This study describes how organic matter content, pH value, silt, clay and sand content, exchangeable calcium and magnesium, and limestone content were measured in soil in seconds by using near-infrared spectroscopy (NIRS).

EXPERIMENTAL EQUIPMENT

Air-dried samples of soil [4] were measured on a Metrohm NIR Analyzer. All measurements were performed in reflection mode (1000–2250 nm) using the large cup accessory. The samples were measured in rotation to collect spectral data from several areas. Spectral averaging of signals from several spots helped to reduce sample inhomogeneity. Metrohm software was used for all data acquisition and prediction model development.

RESULT

The obtained NIR spectra of soil samples (Figure 1) were used to create prediction models for the quantification of organic matter, pH, silt, sand, limestone, clay, and exchangeable calcium and magnesium. The quality of the prediction models was evaluated using correlation diagrams (Figures 2–9) which display a high correlation between the NIR prediction and the reference values measured with standard methods described in Table 1. The respective figures of merit (FOM) display the expected precision of a prediction during routine analysis.

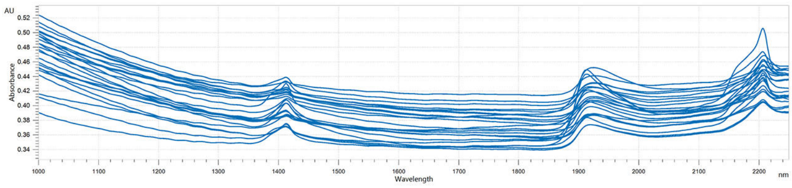

Figure 1. NIR spectra of soil samples analyzed on a Metrohm NIR Analyzer.

Result organic content in soil

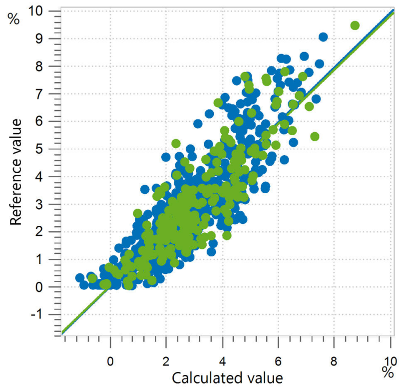

Figure 2. Correlation diagram and the respective figures of merit for the prediction of organic matter in soil.

R^2	SEC (%)	SECV (%)	SEP (%)

0.994	0.14	0.21	0.87

Result pH in soil

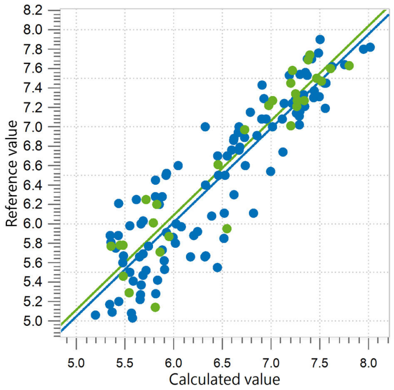

Figure 3. Correlation diagram and the respective figures of merit for the prediction of pH in soil.

R^2	SEC	SECV	SEP
0.887	0.30	0.34	0.29

Result limestone content in soil

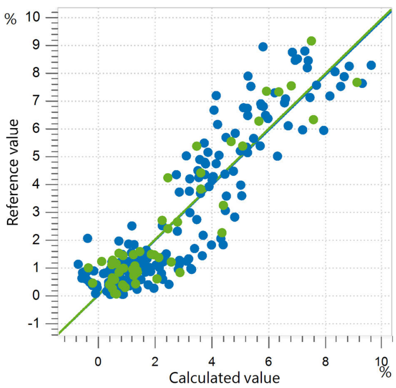

Figure 4. Correlation diagram and the respective figures of merit for the prediction of limestone content in soil.

R^2	SEC (%)	SECV (%)	SEP (%)
0.843	1.08	1.14	1.11

Result clay content in soil

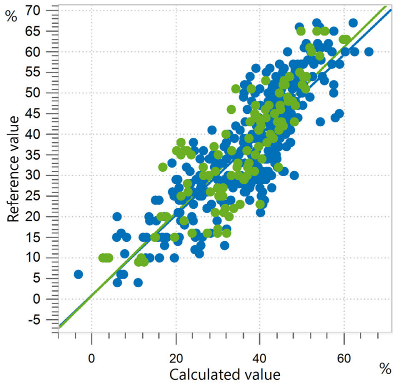

Figure 5. Correlation diagram and the respective figures of merit for the prediction of clay content in soil.

R^2	SEC (%)	SECV (%)	SEP (%)
0.724	6.97	7.45	7.58

Result silt content in soil

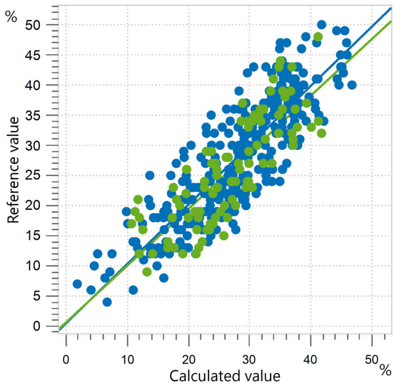

Figure 6. Correlation diagram and the respective figures of merit for the prediction of silt content in soil.

R^2	SEC (%)	SECV (%)	SEP (%)
0.663	5.01	5.13	5.20

Result sand content in soil

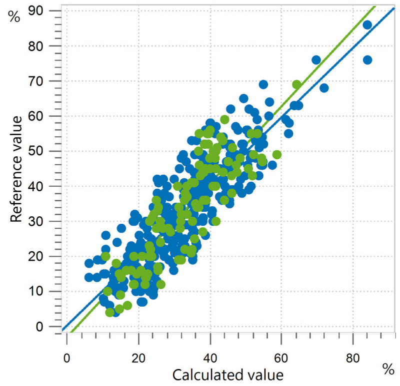

Figure 7. Correlation diagram and the respective figures of merit for the prediction of sand content in soil.

R^2	SEC (%)	SECV (%)	SEP (%)
0.732	7.44	7.57	7.64

Result exchangeable calcium in soil

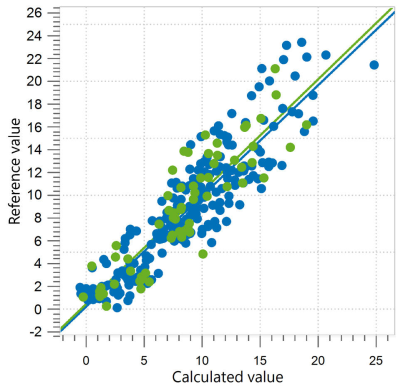

Figure 8. Correlation diagram and the respective figures of merit for the prediction of exchangeable calcium in soil.

R^2	SEC (‰)	SECV (‰)	SEP (‰)
0.783	2.09	2.24	2.36

Result exchangeable magnesium in soil

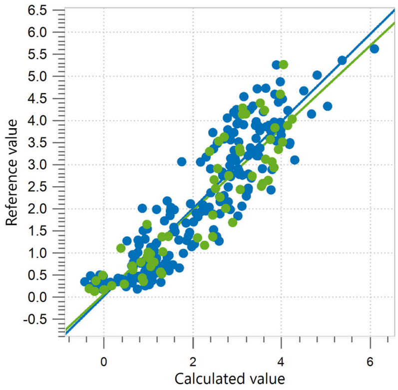

Figure 9. Correlation diagram and the respective figures of merit for the prediction of exchangeable magnesium in soil.

R^2	SEC (‰)	SECV (‰)	SEP (‰)
0.804	0.57	0.60	0.63

CONCLUSION

This Application Note displays the benefits of using NIR spectroscopy for soil analysis. All the presented soil quality parameters can be measured simultaneously in only a few seconds. Compared to other conventional methods (Table 1), near-infrared spectroscopy soil analysis requires no sample preparation nor solvents. This ultimately leads to a reduction in workload and related costs, as well as keeping lab personnel safer.

Table 1. Overview of different standard methods used for the determination of reference values for various soil quality parameters.

Parameter	Norm	Method
pH value	ISO 10390:2021 Soil, treated biowaste and sludge – Determination of pH	pH measurement
Organic matter	ISO 23400:2021 Guidelines for the determination of organic carbon and nitrogen stocks and their variations in mineral soils at field scale	Titration
Clay, silt, sand	ISO 11277:2020 Soil quality — Determination of particle size distribution in mineral soil material — Method by sieving and sedimentation	Sieving and sedimentation
Exchangeable sodium and magnesium	ISO 11260:2018 Soil quality — Determination of effective cation exchange capacity and base saturation level using barium chloride solution	ICP-AES
Limestone	ISO 10693:1995 Soil quality — Determination of carbonate content — Volumetric method	Titration

REFERENCES

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