Rapid acquisition of site specific lime requirement with mid-infrared spectroscopy

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Summary

In Germany, the lime requirement (LR) of arable topsoils is derived from the contents of soil organic matter (SOM) and clay, and pH($CaCl_2$). For this purpose, it is common practice to determine LR of a field size up to three hectares from only one composite soil sample, whereby site heterogeneity is regularly not taken into account.

To consider site heterogeneity, a measurement technique is required which allows a rapid and high resolution data acquisition. Mid-infrared spectroscopy (MIRS) is a cost-effective, high throughput technique and in combination with partial least squares regression (PLSR) an accurate method for prediction of a large number of soil properties.

The objectives of our study were (i) to test separately the performance of SOM, clay, and pH($CaCl_2$) prediction for LR derivation, and (ii) to calibrate prediction models for direct lime requirement recommendations. However, on many fields with partially calcareous parent material, topsoils reveal a small scale pattern of non-calcareous areas and calcareous zones; the latter should not be limed. Consequently, these zones have to be identified. Thus, another objective of the study was, (iii), to find a spectral index to distinguish between non-calcareous and calcareous soil samples.

We surveyed seven study sites across Germany and a total of 458 soil samples in the frame of our Bonares-I4S project funded by the German Federal Ministry of Education and Research. The topsoil of four study sites (*Ascheberg West, Ascheberg Ost, Görzig, and Wilmersdorf*) was partially calcareous. The prediction models were calibrated by PLSR. To identify calcareous soil samples, we used the spectral bands for $CaCO_3$ at 2646 - 2423 cm^{-1}, 1833-1782 cm^{-1}, and 930-730 cm^{-1}.

In Table 1 the accuracy of SOM, clay, and pH($CaCl_2$) predictions are highlighted for the seven study sites. All input variables for LR estimation can be predicted by MIRS with accuracy comparable to conventional soil analyses.

Table 1 Leave-one-out cross validation by PLSR of soil organic matter (SOM), clay, and pH($CaCl_2$)

Location	n	SOM [%]			Clay [%]			pH($CaCl_2$)		
		R^2	RMSECV	RPD	R^2	RMSECV	RPD	R^2	RMSECV	RPD
Ascheberg West	69	0.91	0.19	3.36	0.97	1.6	6.31	0.89	0.26	3.02
Ascheberg Ost	46	0.88	0.32	2.88	0.99	1.5	8.36	0.92	0.23	3.52
Bölingen	71	0.95	0.10	4.35	0.98	1.3	6.55	0.70	0.17	1.83
Görzig	112	0.83	0.20	2.44	.072	1.0	1.99	0.87	0.15	2.72
Hergarten	62	0.82	0.07	2.37	0.72	1.1	1.89	0.92	0.17	3.53
Hilberath	39	0.73	0.27	1.93	0.71	1.4	1.84	0.75	0.23	2.01
Wilmersdorf	59	0.92	0.14	3.63	0.91	1.0	3.26	0.90	0.30	3.22

Compared with the conventional method (CM), separate parameter prediction (SPP) and subsequent derivation of LR yields satisfactory results. Best results are achieved for *Ascheberg Ost* with R^2 = 0.93 and RMSEP = 0.68 t CaO ha^{-1} (Fig. 2a). Local PLSR models for direct LR prediction (DP) (R^2 up to 0.78, RMSECV = 0.66 - 1.42 t CaO/ha) can also be successfully calibrated (Fig 2b). However, calcareous samples, which in reality have no lime requirement, are in many cases inaccurately predicted. This is also reflected in the calcareous samples of *Ascheberg Ost* (Fig. 2 b, samples $LR_{GT} = 0$).

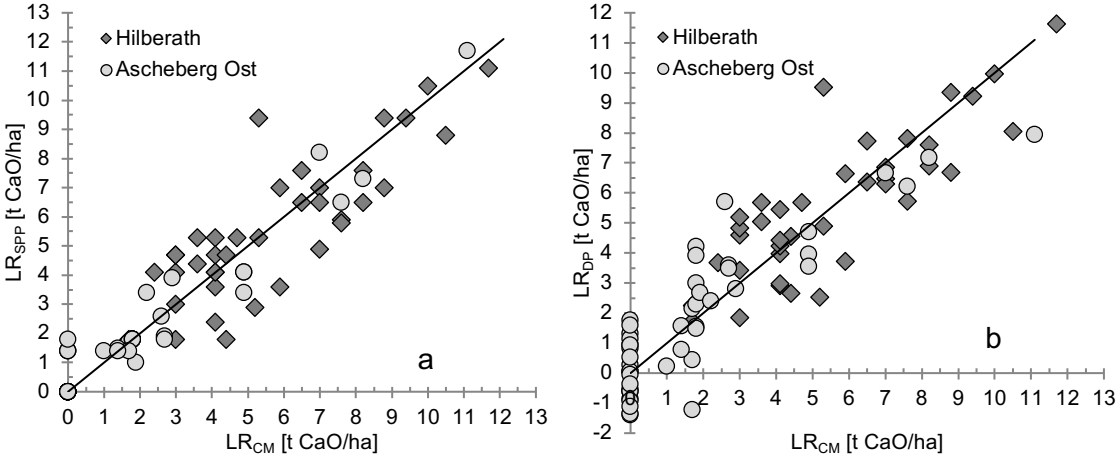

Fig. 2 Relationship between LR determined by the conventionally method (LR_{CM}) and the LR a) derived from separate parameter predictions (LR_{SPP}) and b) direct LR predictions (LR_{DP}) for the partially calcareous study site *Ascheberg Ost* and the non-calcareous study site *Hilberath*

The difference between the absorption at the wavelengths 2513 and 2439 cm^{-1} is highly correlated with the $CaCO_3$ content (R^2 = 0.94, all sites, results not shown). Due to this, calcareous samples without LR can be identified already before LR prediction.

We conclude that MIRS is a promising tool for the determination of site specific lime requirement as basic information for variable rate lime application.