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Predicting soil cation exchange capacity for variable soil types with visible near infrared spectra

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Cation exchange capacity (CEC) represents soil's ability to hold positively charged ions and is crucial for several applications in agronomy and civil engineering. Conventional methods for determining CEC are slow and laborious and existing proxy methods (e.g., pedotransfer functions and proximal sensing techniques) can accurately predict CEC only when the soil is from the same geographical area or has similar properties (e.g. clay mineralogy). We evaluated the potential of visible near infrared spectroscopy (vis-NIRS, 350 to 2500 nm) to predict CEC for soils from different geographical regions. Prior to development of the prediction model, the relationship between CEC and the soil clay and organic carbon contents were evaluated with the whole dataset (235 soil samples from 21 countries). Based on the significance of the relationship, the dataset was divided into calibration (188 samples) and validation (47 samples) subsets. Thereafter, a NIRS-based partial least squares regression model was developed from the calibration set and evaluated with the validation set. The independent validation of the NIRS model compared with ammonium acetate-measured CEC showed very good prediction accuracy (root mean squared error of prediction (RMSEP) = 4.96 $cmol_{(+)}$/kg, ratio of performance of interquartile range (RPIQ) = 4.6 and mean error (ME) = 0.078 $cmol_{(+)}$/kg). The CEC prediction performance of the NIRS model was superior to the prediction accuracy of existing and the calibration dataset-based pedotransfer functions (PTF) based on clay and organic carbon content (existing PTFs:- PTF-1:- RMSE = 10.2 $cmol_{(+)}$/kg, ME = -3.2 $cmol_{(+)}$/kg; PTF-2:- RMSE = 13.1 $cmol_{(+)}$/kg, ME = 2.8 $cmol_{(+)}$/kg and calibration based PTF:- RMSE = 11.5 $cmol_{(+)}$/kg and mean error (ME) = -2.2 $cmol_{(+)}$/kg). This study is a first step towards providing large-scale spectroscopic estimation of CEC, demonstrating the potential for meeting an increasing demand for information on the state of the soil that can be used in many agriculture, civil and environmental applications.