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Low-cost NIR spectroscopy for rapid assessment of soil organic matter and total carbon

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Abstract

Near-Infrared Spectroscopy (NIRS) offers a rapid, non-destructive, and environmentally friendly approach to analyse soil properties and the quality of agricultural products. While commercial NIR spectrometers are often costly, hindering widespread adoption, researchers have developed more affordable portable and handheld alternatives. A portable NIR device capable of assessing soil health and crop quality could significantly streamline field management from cultivation to harvest. This study aims to evaluate the efficacy of a homemade NIR spectrophotometer, first developed for assessing the quality of agricultural products, in estimating organic matter and total carbon in agricultural soils. A total of 400 soil samples were collected from diverse agricultural regions in northern Thailand. These samples were analysed for OM using the Walkley-Black method and for TC via dry combustion, serving as reference data. Soil samples (particle size < 0.5 mm) were then scanned using the homemade NIR spectrometer (900–1,700 nm range) and a commercial NIR spectrometer (800–2,500 nm range) for comparison. To optimise the predictive power of the NIR data, five data preprocessing techniques were evaluated, including smoothing, Savitzky-Golay derivatives (SGD), multiplicative scatter correction (MSC), mean centering (MC), and standard normal variate (SNV). These preprocessed data were then analysed using partial least squares regression (PLSR) to build predictive models. The performance of the prediction was evaluated by the coefficient of determination (R^2) and the root mean square error (RMSE). The results indicated that the combination of smoothing preprocessing and PLSR yielded the best prediction from the homemade NIR spectrophotometer. The R^2P values for organic matter (OM) and total carbon (TC) were 0.70 and 0.69, with RMSEp values of 1.20 and 0.73, while the most accurate model came from the commercial NIR spectrometer, which had R^2P values of 0.88 for OM and 0.86 for TC, and RMSEp values of 1.17 and 0.70 when using SGD and PLSR. This study demonstrates the potential of a low-cost, homemade NIR spectrophotometer as a viable alternative for determining both agricultural products and soil properties. Future research focusing on larger sample sizes and the refinement of predictive algorithms could further enhance the accuracy and reliability of homemade NIR spectrometers for these applications.

Keywords: Chemometric, prediction, soil property, spectrometer

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