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# The potential of visible-near infrared hyperspectral imaging for determining soil organic matter and carbon fractions in forest top soils

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Soils are the largest terrestrial pool of organic carbon (OC) but being labile in the short-term act as both a carbon sink, converting net primary production into stable soil OC as humic substances, and as a carbon source, where soil OC is decomposed as a result of changes to land-use management or the effects of climate change. Supplementary soil C sequestered (or lost) in agricultural soil, within the context of the United Nations Framework Convention on Climate Change (U.N. 1992) and the Kyoto Protocol (1998), will be accountable post 2012 in carbon budgeting for national greenhouse gas inventory. Simulated soil carbon sequestration must be verifiable by direct measurement of soil OC at benchmarked sites. Since current methods of determining soil C are prohibitively expensive, infrared techniques particularly laboratory based hyperspectral imaging (HSI) have the potential to provide a rapid cost-effective substitute method. This study examines the potential of HSI and partial least square regression (PLSR) to predict soil organic matter (OM), total carbon (TC), inorganic carbon (IC) and OC in forest top soils (0-10cm) from Avondale Forest park, Co. Wicklow, Ireland. The most suitable spectral region (visible (VIS); 400 – 1000 nm, near infrared (NIR); 880 – 1720 nm; VIS-NIR; 400 – 1720 nm) was determined for each soil property and the robustness of the best performing models were tested using alternative sample partitioning methods.

Nineteen soil profiles were samples to generate a dataset (N = 152). Approximately 30g of soil sample (dried and sieved to < 2 mm) was scanned using two individual pushbroom line-scanning hyperspectral imaging systems operating in the VIS and NIR regions. Each hyperspectral image was treated as 2 dimensional spectral data by selecting one large region of interest at the centre of the soil sample image (VIS: 180 x 180 pixels; NIR: 72 x 72 pixels) in the Spectral Scannar software (DV Optics, Padua, Italy) to represent the mean spectra of each soil sample. The dataset was partitioned by random selection into calibration (75%) and validation (25%) datasets, whereby samples selected were maintained for each spectral range. Reflectance values were converted to apparent absorbance (log [1/reflectance]). Partial least square regression (PLSR) models were built in the Unscrambler v.10X (CAMO, Oslo, Norway) for OM, TC, IC and OC in each spectral range using the full leave-one-out cross validation method run with 15 factors on the calibration dataset. Independent validations showed that the best soil TC and OC predictions were achieved in the VIS region in the order of VIS > VIS-NIR > NIR regions and the ratio of predicted deviation (RPD) indicated excellent predictions for both TC and OC (3.39). The best OM and IC predictions were achieved in the VIS-NIR region, ranked as having excellent (3.06) and poor predictive ability (1.75), respectively. Alternative partitioning methods showed that ranking soil TC and OC by concentration produced the most accurate models (RPD improved by 1.4 fold) and model accuracy was improved most for soil OM when a uniform soil profile representation was considered (RPD improved by 1.9 fold). In addition, soil OC could be accurately predicted for most soil profiles ($\geq$ 13 out of 19 soil profiles) when 'new' samples from this profile were validated against a model built with all the remaining soil profile samples. A higher OC range in soil OC concentration was the factor that prohibited accurate prediction for the soil profiles predicted with poorer accuracy. Overall, poor predictions were observed for soil IC, however considering very low concentrations, this may not have been a fair assessment of the ability of HSI and PLSR to predict IC.