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High-resolution spatial patterns of Soil Organic Carbon content derived from low-altitude aerial multi-band imagery on the Broadbalk Wheat Experiment at Rothamsted,UK

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Soil organic C (SOC) contents in arable landscapes change as a function of management, climate and topography (Johnston et al, 2009). Traditional methods to measure soil C stocks are labour intensive, time consuming and expensive. Consequently, there is a need for developing low-cost methods for monitoring SOC contents in agricultural soils. Remote sensing methods based on multi-spectral images may help map SOC variation in surface soils. Recently, the costs of both Unmanned Aerial Vehicles (UAVs) and multi-spectral cameras have dropped dramatically, opening up the possibility for more widespread use of these tools for SOC mapping. Long-term field experiments with distinct SOC contents in adjacent plots, provide a very useful resource for systematically testing remote sensing approaches for measuring SOC. This study focusses on the Broadbalk Wheat Experiment at Rothamsted (UK). The Broadbalk experiment started in 1843. It is widely acknowledged to be the oldest continuing agronomic field experiment in the world. The initial aim of the experiment was to test the effects of different organic manures and inorganic fertilizers on the yield of winter wheat. The experiment initially contained 18 strips, each about 320m long and 6m wide, separated by paths of 1.5-2.5m wide. The strips were subsequently divided into ten sections (>180 plots) to test the effects of other factors (crop rotation, herbicides, pesticides etc.). The different amounts and combinations of mineral fertilisers (N,P,K,Na & Mg) and Farmyard Manure (FYM) applied to these plots for over 160 years has resulted in very different SOC contents in adjacent plots, ranging between 0.8% and 3.5%. In addition to large inter-plot variability in SOC there is evidence of within-plot trends related to the use of discard areas between plots and movement of soil as a result of ploughing.
The objectives of this study are (i) to test whether low-altitude multi-band imagery can be used to accurately predict spatial patterns of SOC at a very high spatial resolution (< 10cm) (ii) to quantify the uncertainties on the predictions and potential of the method for monitoring SOC changes in experimental plots. This study used multi-band images with wavelengths between 450-1000nm taken at low altitude and at the landscape scale with a Tetracam Mini-MCA6. Images were taken of plots on section 9 on Broadbalk (continuous wheat) in November 2013 using a UAV-platform (Octocopter) at an altitude of 120m. The different images obtained were corrected for vignetting, noise and geometric deformation then stitched and georeferenced; the radiance was converted for reflectance with white calibration panels. Also, the vegetation effect (a cover mean of 10%) was removed by linear spectral unmixing. Finally, the spectra was calibrated and validated with SOC (0-5cm) measurements from 57 soil samples (37 calibration samples and 20 for the validation) taken along transect. The resulting map of SOC contents has a resolution of 10cm and an associated error of about the same magnitude as that for routine laboratory analyses (i.e. 0.2%). The map shows clear differences between plots relating to the different long-term fertilizer and organic manure inputs.