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Directional reflectance factors for monitoring spatial changes in soil surface structure and soil organic matter erosion in agricultural systems

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Soils can experience rapid structural degradation in response to land cover changes, resulting in reduced soil productivity, increased erodibility and a loss of soil organic matter (SOM). The breakdown of soil aggregates through slaking and raindrop impact is linked to organic matter turnover, with subsequently eroded material often displaying proportionally more SOM. A reduction in aggregate stability is reflected in a decline in soil surface roughness (SSR), indicating that a soil structural change can be used to highlight soil vulnerability to SOM loss through mineralisation or erosion. Accurate, spatially-continuous measurements of SSR are therefore needed at a variety of spatial and temporal scales to understand the spatial nature of SOM erosion and deposition. Remotely-sensed data can provide a cost-effective means of monitoring changes in soil surface condition over broad spatial extents. Previous work has demonstrated the ability of directional reflectance factors to monitor soil crusting within a controlled laboratory experiment, due to changes in the levels of self-shadowing effects by soil aggregates. However, further research is needed to test this approach in situ, where other soil variables may affect measured reflectance factors and to investigate the use of directional reflectance factors for monitoring soil erosion processes.

This experiment assesses the potential of using directional reflectance factors to monitor changes in SSR, aggregate stability and soil organic carbon (SOC) content for two agricultural conditions. Five soil plots representing tilled and seedbed soils were subjected to different durations of natural rainfall, producing a range of different levels of SSR. Directional reflectance factors were measured concomitantly with sampling for soil structural and biochemical tests at each soil plot. Soil samples were taken to measure aggregate stability (wet sieving), SOC (loss on ignition) and soil moisture (gravimetric method). SSM values varied from 8.70 to 20.05% and SOC from 1.33 to 1.05%, across all soil plots. Each plot was characterised using a close-range laser scanning device with a 2 mm sampling interval. The point laser data were geostatistically analysed to provide a spatially-distributed measure of SSR, giving sill variance values from 3.15 to 22.99. Reflectance factors from the soil states were measured using a ground-based hyperspectral spectroradiometer (400-2500 nm) attached to an A-frame device. This method allowed measurement at a range of viewing zenith angles from extreme forwardscatter (-60°) to extreme backscatter (+60°) at a 10° sampling resolution in the solar principal plane.

Reflectance measurements were compared to geostatistically-derived indicators of SSR from the laser profile data. Forward-scattered reflectance factors exhibited a very strong relationship to SSR ($R2 = 0.84$ at -60°; $p< 0.05$), demonstrating the operational potential of directional reflectance for providing SSR measurements, despite conflicting variation in SSM. SSM also presented an interesting directional signal ($R2 = 0.99$ at +20°; $p< 0.01$). Furthermore, the results showed an important link between SRR decline as measured using directional reflectance, with a decline in aggregate stability and SOC content. These findings provide an empirical and theoretical basis for the future retrieval of spatially-continuous assessments of soil surface structure and carbon turnover within a landscape context.