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A novel method for soil aggregate stability measurement by laser granulometry with sonication

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Regulatory authorities need to establish rapid, cost-effective methods to measure soil physical indicators – such as aggregate stability – which can be applied to large numbers of soil samples to detect changes of soil quality through monitoring. Limitations of sieve-based methods to measure the stability of soil macro-aggregates include: i) the mass of stable aggregates is measured, only for a few, discrete sieve/size fractions, ii) no account is taken of the fundamental particle size distribution of the sub-sampled material, and iii) they are labour intensive. These limitations could be overcome by measurements with a Laser Granulometer (LG) instrument, but this technology has not been widely applied to the quantification of aggregate stability of soils. We present a novel method to quantify macro-aggregate (1–2 mm) stability. We measure the difference between the mean weight diameter (MWD; μm) of aggregates that are stable in circulating water of low ionic strength, and the MWD of the fundamental particles of the soil to which these aggregates are reduced by sonication. The suspension is circulated rapidly through a LG analytical cell from a connected vessel for ten seconds; during this period hydrodynamic forces associated with the circulating water lead to the destruction of unstable aggregates. The MWD of stable aggregates is then measured by LG. In the next step, the aggregates – which are kept in the vessel at a minimal water circulation speed – are subject to sonication (18W for ten minutes) so the vast majority of the sample is broken down into its fundamental particles. The suspension is then recirculated rapidly through the LG and the MWD measured again. We refer to the difference between these two measurements as disaggregation reduction (DR) – the reduction in MWD on disaggregation by sonication. Soil types with more stable aggregates have larger values of DR. The stable aggregates – which are resistant to both slaking and mechanical breakdown by the hydrodynamic forces during circulation – are disrupted only by sonication.

We used this method to compare macro-aggregate (1–2 mm) stability of air-dried agricultural topsoils under conventional tillage developed from two contrasting parent material types and compared the results with an alternative sieve-based technique. The first soil from the Midlands of England (developed from sedimentary mudstone; mean soil organic carbon (SOC) 2.5%) contained a substantially larger amount of illite/smectite (I/S) minerals compared to the second from the Wensum catchment in eastern England (developed from sands and glacial deposits; mean SOC=1.7%). The latter soils are prone to large erosive losses of fine sediment. Both sets of samples had been stored air-dried for 6 months prior to aggregate analyses. The mean values of DR (n=10 repeated subsample analyses) for the Midlands soil was 178μm; mean DR (n=10 repeat subsample analyses) for the Wensum soil was 30μm. The large difference in DR is most likely due to differences in soil mineralogy. The coefficient of variation of mean DR for duplicate analyses of sub-samples from the two topsoil types is around 10%. The majority of this variation is likely to be related to the difference in composition of the sub-samples. A standard, aggregated material could be included in further analyses to determine the relative magnitude of sub-sampling and analytical variance for this measurement technique.

We then used the technique to investigate whether – as previously observed – variations (range 1000 – 4000 mg kg^{-1}) in the quantity of amorphous (oxalate extractable) iron oxyhydroxides in a variety of soil samples (n=30) from the Wensum area (range SOC 1 – 2%) could account for differences in aggregate stability of these samples.