Assessment of pore-size distribution using a flatbed scanner based image analysis method.

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Introduction

Soil physical conditions have the potential to affect the crop yield. The availability of the correct size pore space can have an affect on the way roots elongate and thus access water and nutrients (Valentine et al., 2012). Tillage is used to prepare the soil for sowing and changes soil structure. Traditional ways to assess the physical conditions of the soil involve the use of tension tables, CT scanning and visual soil assessment (Rabot et al., 2018). Some of these assessments can be time consuming, involve processing of large individual datasets and/or be reliant on expert opinion. Within the scope of this study an alternative and complementary process for quantifying soil structure will be investigated, utilising affordable high resolution scanners.

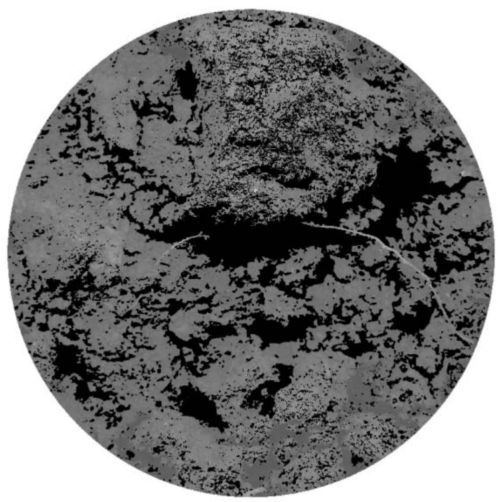
Material and Methods

Soil samples were collected after a barley crop had been harvested during September 2016 at the Mid-Pilmore site, the James Hutton Institute, Dundee. The tillage (Tillage - TILL) treatments sampled were conventional, mouldboard ploughing to 20 cm and disking (P) and minimum tillage, shallow non-inversion tillage to a depth of 7 cm (M). Twenty four intact soil cores, 50mm diameter by 100mm height, were taken from 2-12cm below the soil surface. The soil water content was adjusted to a matric potential of -1kPa, -5kPa, -20kPa and -50kPa (matric potential – MP) six cores each. Once soil cores had equilibrated they were broken in half either (Break Method - BM) by hand or with the use of a bread knife. The exposed surfaces of both sections were scanned using a cheap, but high resolution flatbed scanner at 1200dpi. Images obtained from the scanner were analysed using an Rscript developed to analyse the surface features of the samples and produce a pore size distribution plot. Comparisons of the pore size distribution obtained using the image analysis method was made with pore size distributions obtained from water retention curve assessments of cores taken from the same plots but at different sampling time (McKenzie et al., 2017). Cores used for image analysis are currently being processed through water release curves. The effects of TILL, MP and BM on the pore size distribution was analysed using mixed models in R.

Results and Discussion

Pores size diameter, recorded by the image analysis method, is limited by the resolution of the scanner and the image quality. The data are not suitable to measure the very fine pores obtained at the dry end of a water retention curve. However soil pores were measured in the range which covered the range of pores sizes found to be important for root elongation of barley roots in (Valentine et al., 2012) and the range of pores usually considered important for plant available water. An example of structural information captured is illustrated in Figure 1. Breaking Method ($P=0.045$) and the Matrix Potential ($P= 0003$) significantly affected the number of pores captured by the image analysis methods. The Break Method also interacted with the pore distribution profile ($P<0.001$). The knife splitting method produced a smoother surface for imaging the split soil cores, but also resulted in soil drag across the surface. While this may enable more accurate water release curves, the hand break method produced a more complicated and structurally relevant surface for imaging as the cores broke along natural weak surface cracks. Analysis of the hand split cores, found no significant contribution of MP to the final model but significant differences between the different Tillage treatments (P=0.04), with Shallow non inversion cores having a higher number of pores that those from Plough plots. There was no significant interaction with pore sizes. These specific cores are currently being processed through a series of matric potentials to produce water retention curves, however, the image analysed cores results were compared with pore space information gained from analysis of water retention curves from the same site but using a different set of cores taken at 2-5cm and 7-12 cm (McKenzie et al., 2017). For these cores no differences were found between the two tillage treatments as main effects (P=0.582) but difference were found for the interaction between tillage and pore size groups (P=0.003). Consistent with the image analysis methods apart from the largest category of pores, a higher number of large pores were found in the Shallow non-inversion cores than in the cores from the plough system.

Figure 1 Structural information extracted marked in black. Areas with large structural cracks can be separated from areas with small structural features. Method does not capture cracks that continue to edge of assessment area. The smallest category of pores is estimated at 0.02 mm diameter



Conclusion

This method enabled a fast assessment of the larger pore size ranges present in two sets of cores obtained from two different tillage treatments, showing differences in the counts of different cores categories between two tillage systems. Utilising high resolution flatbed scanners makes it a cost effective and high through put method.

References

McKenzie B.M., Stobart R., Brown J.L., George T.S., Morris N., Newton A.C., Valentine T.A., Hallett P.D., 2017. Platforms to test and demonstrate sustainable soil management: integration of major UK field experiments. *AHDB Final Report* RD-2012-3786, 178pp.

Rabot E., Weismeier M., Schluter S., Vogel H.-J., 2018. Soil structure as an indicator of soil functions: A review. *Geoderma*, 314, 122-137.

Valentine T.A., Hallett P.D., Binnie K., Young M.W., Squire G.R., Hawes C., Bengough A.G., 2012. Soil strength and macropore volume limit root elongation rates in many UK agricultural soils. *Ann.Bot.*, 110(2), 259-270.