Guest Editors' Introduction

Throughout the globe, there is an urgent need to determine where soil quality and functionality are threatened by processes such as loss of organic matter, contamination, compaction, salinization, loss of biodiversity, soil sealing, landslides and desertification. Conclusive evidence of the impact of these processes can only be acquired by making repeated measurements of the soil and many countries have established soil monitoring networks for this purpose.

However, there are a number of challenges and difficult choices associated with the implementation of a soil monitoring network. For instance, the operators of the network must decide exactly which soil indicators should be measured and the analytical methods that should be used. It is imperative that these indicators relate directly to the functionality of the soil and that measurements made many years apart are comparable. The designers need to also decide where they should measure and how frequently they should make measurements. Should they select sites at random or sample on a purposive design such as a regular grid? Should they revisit the same sites? Should they sample evenly or favour areas where threats are prevalent of where the soil has an important function? Other key questions relate to the statistical methods that will be used to analyse the data. The choice of the most appropriate methods is intrinsically linked to how the measurement sites were selected but statisticians must also decide what assumptions they will be willing to accept about the variation of the soil indicators and they must devise methods that can separate local changes caused by management and land use changes from more broad-scale change. The answers to these questions will critically influence the effectiveness of the network at identifying and quantifying change but it is only possible to know the implications of a particular choice if we know what soil threats are going to be important in the future and how the soil is going to change.

In 2010 the International Union of Soil Scientists formed a working group on Soil Monitoring to provide a forum where these issues could be discussed. The primary aims of this group were to identify the problems which were hindering effective soil monitoring, to suggest state-of-the-art solutions to these problems and then to communicate these outcomes to the operators of soil monitoring networks. The group has published a paper describing the challenges of soil monitoring (Arrouays *et al.*, 2012) and organised symposia at international conferences. The papers in the special section of this issue result from presentations made in the "Current issues and applications of soil monitoring" colloquia at the 2012 Fourth International Congress of the European Confederation of Soil Science Societies or Eurosoil 2012 meeting in Bari. The colloquia consisted of six oral presentations and 29 poster presentations which covered the monitoring of a vast range of soil properties that were subject to varied threats across the globe. Many specific issues were highlighted, such as the challenges of monitoring soil properties when material can move up or down the soil profile or the integration of legacy soils information into soil monitoring efforts.

The three manuscripts in this issue all highlight issues regarding the selection of sites at which measurements are made and the statistical analyses of the data that result. Brus (2014) reviews the relative merits of monitoring networks that select sites at random and those which use a purposive design. A fully random monitoring network randomly selects both the times and locations at which the soil is sampled. Brus (2014) suggests a hybrid approach where the samples are randomly located in space but regularly sampled in time and demonstrates and compares all three approaches in a case study where soil eutrophication and acidification are monitored.

Hassler *et al*. (2014) go beyond the broad choice between random and purposive monitoring networks and consider the exact details of a random design. They apply a stratified random design when monitoring the soil hydraulic conductivity at three sites in central Panama. They use the measurements to test whether the stratification has led to more accurate estimates of the changes in hydraulic conductivity and also consider the merits of re-visiting previously sampled locations in each phase of the survey.

Finally, Lark *et al.* (2014) look in detail at the sampling protocol that is required at each site of the network. They particularly consider soil bulk density which in addition to being an important soil indicator in its own right must be measured to determine volumetric stocks of other indicators and to apply many pedotransfer functions. Bulk density is a laborious quantity to measure and therefore there is a desire to be as efficient as possible in the number of measurements that are made at a site. Lark et al. (2014) conduct experiments on two fields with differing soils to suggest an optimally efficient approach to measure bulk density at each site.

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References

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