The Soil and its Chemistry- Critical Futures

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Abstract. Unlike changes over time to the earth’s atmosphere or oceans, changes to soils occur at a very local scale, with much less interconnectedness between the points of change. A further difference between soils and other media is the much greater buffer capacity of the system to change, which means that changes are more gradual and difficult to measure. Further difficulties of assessing changes in soil “condition” are due to the natural heterogeneity of soils across landscapes, which poses sampling, analysis and statistical interpretation challenges of a much greater magnitude than those for the atmosphere or for surface or ground waters. Superimpose localised anthropogenic disturbances and enhancements to soil on this (at a farm or paddock level) and it is evident that knowledge and assessment of soil “condition” is needed at a relatively small scale compared to assessments of atmospheric or aquatic system “condition”. At the same time, soils contribute significantly at larger scales in modifying (in both good and bad ways) to the quality of water systems, to emissions of gases (greenhouse and others) to the atmosphere, and to feeding a steadily growing human population around the globe – so changes to soil really do matter. This juxtaposition of scale issues means that to understand the global impact of changes to soil “condition”, we need to measure changes at small scales and integrate the mosaic of effects up to larger scales i.e. think globally, measure locally.

1. Rates of soil change
Changes to the chemistry of our soils have accelerated rapidly in the last 250 years due to the “industrialisation” of agriculture where inputs of chemicals and fossil fuel energy (in the form of mechanised equipment) has allowed deforestation, cultivation, fertilisation and farm chemical inputs on a much larger scale than observed in previous millennia – a good example for changes in soil organic carbon content over time was provided recently by Richter and Yaalon [1] (Figure 1).

Similarly here in Australia, we have seen dramatic changes over time in the chemistry of our soils due to the introduction of phosphatic fertilisers and legume-based pastures [2] (Figure 2) – and note these changes in soil properties have been predominantly positive in contrast to some negative yet beliefs about fertiliser use and soil health not backed up by good scientific data. Nonetheless, changes to soil chemical properties are generally slow gradual changes, due to the inherent inertia of the soil to additions or removal of elements, or to changes in composition in terms of minerals and organic matter – what soil scientists usually term the “buffer capacity”.

Because of the slow nature of change, it is imperative that measurement technologies are both accurate and precise (discussed further in the presentation), and that we have “sentinel” sites that alert us to adverse changes – in soil science the sentinels are often long-term field experiments (e.g. Rothamsted, Morrow plots, Waite Long Term Rotation Experiment) that provide invaluable information on how management practices affect crop production, soil properties, water quality and emissions of gases to the atmosphere [3].
Figure 1. Rates of change in soil organic carbon in response to cultivation, manure amendments, reforestation, and other practices contrast with rates of change in soils that are products of natural soil formation. Plotted are average rates of change over the indicated age of soil or soil-management regime (from [1]).

Figure 2. Relationship between amounts of single superphosphate applied to six properties and soil concentrations of nitrogen (from [2]).

2. Scale of changes in soil properties
As noted in Figure 1, use of soils in agricultural systems has in many cases increased the heterogeneity of soil properties across the landscape, and inference of soil condition from the pedogenic background
state is becoming less relevant with time. In addition, pollution of soils from industrial or urban activities is also extremely localised, so that assessment of soil contamination (and remediation) is often confounded by variability of properties and analytes across quite small scales.

Traditional assessments of soil chemical “condition” have usually been by field sampling (at various intensities dependent more often on factors such as time, cost and enthusiasm rather than actual heterogeneity) and laboratory analysis (with the suite of analytes again more often dependent on time, cost and enthusiasm than anything else). Cost is usually the critical factor which drives the adoption and use of soil analysis, so that multi-analyte tests are now much preferred in many countries e.g. the Mehlich soil test widely used in USA [4]. Unfortunately the dominance of the cost driver in soil analysis means that the adoption of multi-analyte tests is often driven more by laboratory expediency than by predictive power.

New technologies have emerged in the last 20 years which have revolutionised assessment of soil condition, which allow much faster analysis of soils at much lower cost, and which can be placed in the hands of land managers – direct spectroscopic methods which are field portable. Good current examples of these are near- and mid-infrared soil spectrometers, as well as laser induced breakdown spectrometers, portable x-ray fluorescence spectrometers and laser-induced fluorescence instrumentation. It is important these powerful multi-analyte techniques are well calibrated and validated before adoption but I believe rapid, direct and inexpensive spectroscopic analysis of soils is key to assessing and managing soils at the local scale, where all the “action” is.

3. Conclusions
Changes in soil chemical properties will increasingly need to be measured at high spatial resolution by simple, low cost field-based techniques so that landscape-scale changes over time can be determined by an aggregation of data, or a using a spatial covariate, rather than compositing of soil samples over an area (to reduce analytical costs) and measuring by laboratory techniques.

References
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