Soil science on the ground

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Abstract

Management of soil health for sustainable agricultural productivity can be achieved if appropriate knowledge and tools are in the hands of land managers. A review of available tools for soil assessment, development of training modules in aspects of soil health, and a pilot for a soil health management planning process, formed the principal elements in a four year "Healthy Soils" project in Victoria, Australia. The tools review provided a summary of tools covering physical, chemical and biological properties that could be applied to managing and monitoring soil health and could therefore be incorporated into a soil health management plan. Tools were rated with respect to their technical complexity, cost and usefulness for decision making. Three examples of tools are given in this paper. 96 training sessions were delivered for six healthy soils training modules (understanding soil biology; understanding your soils and soil structure; managing soil organic matter; understanding subsoil constraints; understanding soil acidity; and understanding soil tests – chemical) during the project; the cumulative total of attendees (farmers or their advisers) at these sessions was 1996. A pilot soil health management planning process was carried out for two farms and focussed on getting the farmers to apply the principles and tools demonstrated in the 'Healthy Soils' modules. Evaluation of participants has demonstrated that the approaches used have been effective in delivering new information and encouraging changes in farming practice.

Key Words

Soil health, soil condition, soil quality, tools, training, planning

Introduction

Farmers need good information and tools to assist them in managing soils. The Victorian Department of Primary Industries (DPI) four year (2007-2010) 'Healthy Soils' project had four objectives to ensure better soil health outcomes for agriculture in Victoria:

1. Improve access to available soil health information – via DPI's Victorian Resources Online (VRO) website and Victorian Soil Information System (VSIS).

2. Develop improved and new soil health assessment tools – to be used by trainers and advisers to assess soil management impacts on the farming system.

3. Deliver enhanced soil health extension programs – (i.e. more finely targeted to industry and region; training modules and courses developed and delivered within agricultural extension programs; on-farm demonstrations and discussions).

4. Promote a coordinated Victorian program for soil health – to improve future institutional capacity.

This paper summarises work carried out towards achieving objectives (2) and (3).

Soil health and measurement of soil properties

Soil health has been defined by many authors (Doran et al. 1994; Carter et al. 1997). There is general agreement that soil health refers to functional capacities of soil (water storage, nutrient cycling, supporting plant growth, suppressing disease) and that dynamic soil properties (pH, structural integrity, soil biotic populations) affect changes in soil health by their controls on these functional properties or soil processes. Since the early 1990's there has been consideration of 'minimum data sets' and appropriate tests for monitoring soil quality or soil health (Doran and Jones 1996; Gregorich and Carter 1997). For the purposes of the Victorian DPI (2009) review, definition of a soil assessment 'tool' was broad ranging and encompassed methods for measuring individual soil properties, soil assessment kits, manuals, decision support systems, rating systems such as soil health score cards, management and planning systems. 75 tools, tests, kits and models are summarised in the Victorian DPI 'Tools and systems for assessing soil health' report (DPI 2009). The report is an information resource, rather than advisory document, envisioned as a single source summary for biological, physical and chemical tests, or tools, that would have most relevance to farm scale soil health management planning.

Delivery of soil health training modules

Training workshops of 3-6 hours were used to deliver training modules. Each workshop was regionally specific with the goal to provide land managers with an understanding of local soils, and skills to assess and adapt land management practices. Workshop topics included 'Understanding soil structure and soil types', 'Understanding soil biology', 'Managing soil organic matter', 'Managing subsoil constraints' and 'Understanding soil tests – chemical'. Over the four year project 96 separate events were held with a cumulative total of 1996 attendees comprising farmers or advisers. Sessions combined PowerPoint assisted talks with hands on bench top activities and soil pit assessments. A selection of assessment tools were demonstrated to and used by the participants.

Examples from the 'Tools and systems for assessing soil health' (DPI 2009) report

Tables 1-3 illustrate 3 examples of tools described in DPI (2009).

Table 1. Summary of soil penetrometer test (from DPI 2009).

Name of test:	Penetrometers – measuring soil strength
Description	A penetrometer, preferably with a gauge (hydraulic penetrometer) (Figure 1), is pushed into the soil at a constant rate and readings observed as it moves down the soil profile. Penetrometers are one of the most widely used methods of estimating resistance to root growth in soil, and may also be used for detecting layers of different soil strength. Useful to demonstrate impact of management practices on soil compaction e.g. hard pans, high traffic areas etc.

Method reference	Operating instruction sheet supplied with hydraulic penetrometer.
Complexity	A simple on-site test that can be carried out by anyone. However, need to understand the importance of exerting a constant pressure on the penetrometer when pushing it down the profile and impact of soil moisture on penetration resistance.
Technology	Need specialist equipment, preferably a penetrometer with a gauge, though a simple ‘T’ penetrometer provides an experience of soil strength without quantification of force required.
Cost and time	AU$348 from www.themeterman.com.au A large number of readings can be collected across a paddock in a short period of time (20 mins).
Interpretation	Colour coding on the gauge (green, yellow and red) provides a broad indication of restrictions to root growth. Particularly effective for locating areas of compact or strong subsoil.
Decision	General decisions on managing compaction can be made but need to understand the soil type.
Value	Penetrometers are widely used to measure soil resistance to penetration. A useful tool to start discussion and to get a visual or quantifiable assessment of soil strength.

(a)

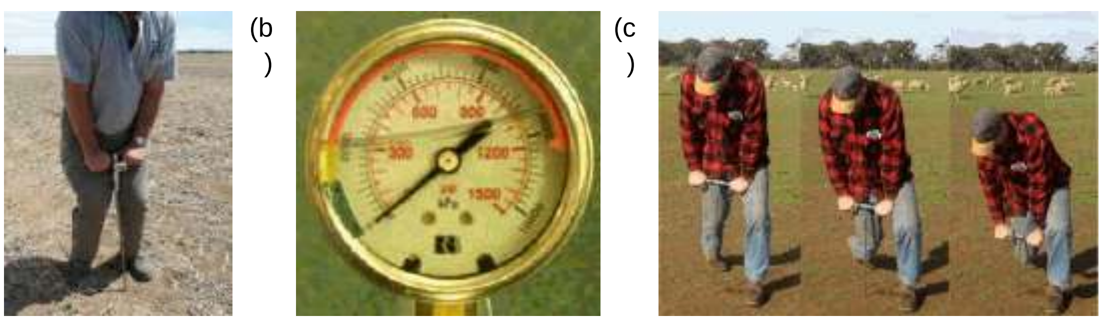


Figure 1. Soil strength assessment (a) hydraulic penetrometer (b) gauge (c) simple ‘T’ penetrometer.

Table 2. Summary of paint percolation test (from DPI 2009).

Name of test:	Paint Percolation Test
Description	The paint percolation test provides a visual assessment of soil structure, particularly on cracking clay soils. An open-ended steel frame or 30 cm steel ring is inserted 5 cm into the soil and diluted white acrylic paint (approx 1:7 paint:water by volume) is poured

	carefully into frame or ring, using an object under the flowing paint to prevent direct disturbance of the soil surface. The paint is then left overnight or for 24 to 48 hours to infiltrate into the soil. Once the paint has infiltrated, the frames are lifted and the soil is excavated with a spade or mattock to expose the depth of paint percolation.
Method reference	McKenzie (1998). The SOILpak for Cotton Growers procedure was based on methods developed by The University of Sydney and CSIRO Land and Water, Canberra.
Complexity	An easy test for field staff to demonstrate.
Technology	Steel frames or rings need to be manufactured. Alternatively large diameter PVC rings (>200 mm) could be used if easily sourced.
Cost and time	Cost of manufacture of steel frames or rings ($50/each) plus 2 litres of acrylic paint per frame. Time consuming as need to wait 12-48 hours for the paint to infiltrate into the soil.
Interpretation	The greater the amount of paint infiltrated down the soil profile, the better the interconnection of soil pores indicative of better soil structure (Figure 2).
Decision	Can be used to help make in-paddock decisions regarding management practices (traffic, ripping).
Value	A very useful method to demonstrate the impact of management practices on soil structure (e.g. comparison of random traffic vs. controlled traffic).

(a)

(b)

Figure 2: Paint infiltration test for visual assessment of infiltration (a) under wheel tracks and (b) under crop.

The examples above contrast the highly technical microarray test, essentially a research tool, with the more simple and visual paint percolation test, whilst the hydraulic penetrometer (with gauge) offers a semi-quantitative assessment as well as tactile experience of soil strength. In spite of the soil biology topic being highly technical there was strong interest from the farmers in the potential of soil biology in their farming systems. This presents a challenge to us as scientists, both to find answers to their questions, but also to develop tools that can be applied to assessment and management of soil biology.

Table 3. Summary of microarray technology for soil (from DPI 2009).

Name of test	Microarrays
Description	Using microarrays the entire suite of taxonomic and/or functional variation within microorganism communities from soil can be targeted. Useful for determining differential gene expression and as such can be used to determine if particular taxonomic groups or functional processes are up or down as regulated by management practices, soil types, climatic regions etc.
Method reference	Sessitsch *et al*. (2006) Diagnostic microbial microarrays in soil ecology. New Phytologist 171, 719-736.
Complexity	Very complex techniques - specialist knowledge required.
Technology	Requires specialist equipment/facilities and computer software for data analysis.
Cost and time	Expensive but reasonably quick. Data analysis is time consuming.
Interpretation	No benchmarks in place to relate differential gene expression to soil health – however very good for paddock to paddock or within paddock comparisons and can be used to give a regional perspective.
Decision	Offers great potential to be useful for in paddock decision making but a research tool at this stage. At this point too expensive for use as soil health indicator. Will become cheaper with time.

Soil Health Management Plan

The development of a soil health management plan pilot provided a single focus for the outputs of the 'Healthy Soils' project. While there is wide experience in 'whole farm planning', there are only limited examples to show how whole farm planning can enhance the year to year management of soil; the New South Wales SoilPak for cotton growers (McKenzie 1998) is one of the exceptions. The pivotal philosophy of the soil health management plan (SHMP) is represented by the oft-quoted Chinese proverb 'teach a man to fish and you feed him for a lifetime'. The SHMP is a paddock by paddock, farm scale plan. It should be created by farmers for farmers. The SHMP is not an end in itself — it needs to make sense as part of business plans for the farm enterprise. Kitchen table conversations and farm walks were used to gain the perspective of the participating farmers and to gain their confidence. In house (DPI) interactive sessions were used to map the properties within a GIS and provide training in a farm planning tool, 'Agrigater' (DPI 2008) (Figure 3).

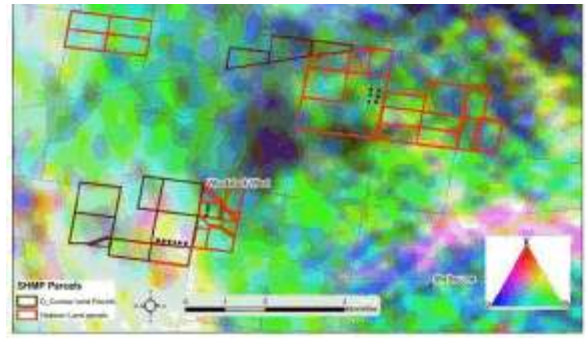
(a)  (b) 

Figure 3. (a) In house training session, and (b) Land parcel boundaries overlain on gamma radiometrics.

Conclusion

The Soil Health Management Plan (SHMP) was conceived as an effective endpoint in which the information and tools, reviewed in the ‘Healthy Soils’ project, could be applied on farm (MacEwan 2009). The SHMP process is being piloted on two properties in central Victoria and at this stage it is too early to be able to measure any soil health or production improvements. The concept of a SHMP became the litmus test for relevance of information incorporated in the training modules - 'if it cannot be applied to management, it may be interesting but is useless'. Similarly, in the review of tools for soil assessment these were rated for their ease of use and their value to decision making. Evaluation of the project (Heemskerk et al. 2010) showed that participants (farmers and advisers) had a high level of satisfaction with the delivery of training modules. Future efforts will be made to integrate the learnings and outputs of the Healthy Soils project into DPI programs such as ‘FarmPlan21’, an initiative described as ‘whole farm planning for the 21st Century’.

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