Soil Quality indicators for Australian cropping systems.

Andrew Wherrett[A], Daniel Murphy[A] and Frances Hoyle[B]

[A]The University of Western Australia, 32 Stirling Highway, Crawley, Australia 6009 Email andrew.wherrett@agric.wa.gov.au
[B]Department of Agriculture and Food Western Australia, 3 Baron-Hay Court, South Perth Australia 6151

Abstract
To date, the Western Australian soil quality programme has benchmarked soil status at over 1300 sites across WA's agricultural regions, with a similar campaign currently underway in eastern Australia offering more national coverage. Analyses cover a range of biological, chemical and physical indicators, providing a 'snapshot' of soil quality from which change can be monitored through time. The programme focuses on landholder involvement and extension, with 19 grower groups engaged for soil collection, each receiving two workshops. Development of www.soilquality.org.au continues to provide a unique means of presenting a large soil analysis database in a variety of ways depending on the needs of the user. The use of this website to engage landholders, resource managers and the wider community is a simple and effective link between actual data and information on soil management strategies. The development of a 'traffic light' system is a simple diagrammatic method of sourcing information relevant to critical soil quality indicators, and a range of simple calculators present a means of assessing the economics of changing farm management, comparing lime sources or investigating soil organic matter change.

Key Words
Soil quality, indicator, health, extension, monitor, benchmark

Introduction
The significant interest in soil quality (also termed soil health) is largely related to agricultural production systems and the identification of soil constraints to production so that farming enterprises are sustainable into the future. Compared to other world production systems, Western Australia's grain production sector is relatively young, with the majority of cropped land cleared within the last 100 years. Additionally, the majority of agricultural soil is deeply weathered, infertile and coarsely textured (Moore 1998), presenting a range of difficulties for landholders. The long term impact of agricultural production on these soils is largely unknown, necessitating the need to know current soil status and monitor change through time.
The development of the Western Australian component of the soil quality monitoring programme addressed a number of these issues, through the development of a biological, chemical and physical indicator package. This measure of soil quality had two aims: (1) Provide a benchmark of soil quality for that site allowing for comparison into the future and (2) Determine current possible constraints to production at that site, based on yield potential (French and Schultz 1984).
In addition to actual measurement of soil parameters, the project had a particularly strong focus on community engagement through extension of results and information. All results and soil quality information are housed on the specially developed website www.soilquality.org.au, allowing growers, catchment co-ordinators, and regional development bodies to view individual or aggregated datasets for sites measured in their local area or region. Growers involved with the project are given unique WebID's enabling access to their specific soil analysis results and comparisons with other local producers. Aggregated data in the form of bar-charts identifies critical soil quality issues on a regional and sub-regional basis, and allows for development of strategic management plans for production constraints.

Methods
Grower Engagement
Selection of sites for the project concentrated on engaging active landholder groups focussed on continual improvement of management strategies for long term sustainability of farms. In this way, the soil quality programme conducted initial workshops with each grower group to outline and discuss project aims, but also important soil related issues facing land-holders in that specific area. Identification of key soil types of the area allowed each group to choose initial sample sites based on satellite imagery.

Soil collection
Soil was collected over a four year period from 2005-09 from 1362 sites from a range of cropping and pasture regions across the Western Australian agricultural zone. All sites where used predominantly for grain

production, however some sites included mixed cropping and beef/dairy enterprises. At each site a composite of between ten and fifteen separate sample points where collected at three depths; 0–10 cm, 10–20 cm and 20–30 cm. Further sampling at 30-60 cm and 60-90cm was carried out with two groups to investigate deeper soil constraints in the form of boron toxicity and salinity. Sample collection occurred during summer months to avoid within-crop fluctuations in soil biology related to crop stage and rainfall events. This also enabled chemical data from soils to be used as part of fertiliser decision support systems.

Soil Analysis and Measurement

The 0-10 cm layer from each site was subject to a range of biological, chemical and physical analyses (Table 1) with some chemical analyses also conducted in sub-soil layers. A major focus of the project was to introduce agricultural communities to biological functioning of the soil, and how various management practices impact upon these processes. For ease of understanding, labile carbon, microbial biomass carbon, microbial respiration and potentially mineralisable nitrogen was measured on each sample. Further biological measurements involved “Predicta-B®” DNA analysis for range of pests and diseases of crops. Standard chemical analysis by a commercial laboratory matched typical soil testing carried out by growers on an annual basis. Particle size analysis, gravel content and water holding capacity represented the physical status at each site. Samples taken below 10 cm were analysed for pH ($CaCl_2$) and electrical conductivity only, except where further boron analysis was required.

Table 1. List of all soil quality indicators measured during the soil quality project.

Biological	Chemical	Physical
Microbial biomass	pH ($CaCl_2$, H_20)	Particle Size Analysis
Labile carbon	Electrical conductivity	Gravel Content
Microbial respiration	Water repellency (MED)	Water holding capacity
Potential mineralisable N	Total organic carbon	
Take-All disease	Nutrients (N, P, K, S, B)	
Rhizoctonia		
Root lesion nematode		
Cereal cyst nematode		

Figure 1. Home page of www.soilquality.org.au.

Presentation and Extension

A significant portion of the project was devoted making soil quality data accessible and useful for members of the agricultural community. Key to this aim was using indicators that are easily interpretable to landholders and the wider community, with direct connections to management strategies. The soil quality indicator package was developed to educate growers of potential constraints to grain production and methods of management improvement. In some cases issues outside the standard analyses where identified by the individual grower group as significant soil constraints in their area. In particular, two grower groups funded further sampling to 90 cm to investigate boron toxicity common to local soils. All data developed through the project was delivered back to individual growers in the form of a group workshop, results booklet and through WebID access to www.soilquality.org.au. This website (Figure 1), was developed to provide public access to otherwise unseen scientific data presented diagrammatically and linked to information about soil quality and the economics of associated management practices.

Expert Panels

Three self-auditing sessions were held during the project that encouraged criticism of the choice of soil quality indicators and importantly, the functionality of the website. Two separate sessions invited experts in their respective topics to discuss (a) soil biological indicators, and (b) soil physical and chemical indicators. A third session invited key extension officers to scrutinize www.soilquality.org.au. The outcome of these sessions was a list of critical values for a range of relevant indicators, and ultimately, an improved website.

Results

Data Presentation

The data housed on www.soilquality.org.au is presented in a number of different ways. At the simplest the data from a grower group or region is presented in the form of a bar chart indicating the relative range of values for each indicator, giving a general overview that is useful for catchment co-ordinators, agronomists and natural resource management officers. As a grower, it is possible to compare individual soil test data against other local farms. This is presented in the form of basic box plots split into upper and lower 25% of sites, and middle 50% of sites (Figure 2). While not necessarily providing an indication on absolute status it provides the user with an indication of where they are operating in local community. Finally, a relationship graphing function provides an extension tool used to improve understanding of inherent soil properties and how they impact upon soil biological functioning. Using actual data it is possible to follow each biological indicator and how each one influences others.

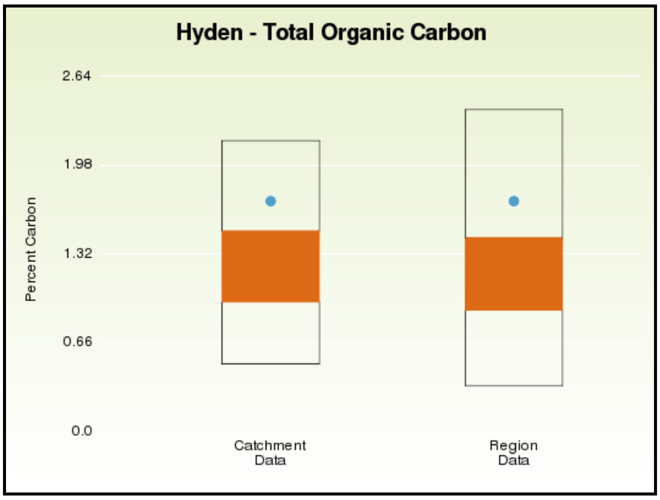

Figure 2. Simple box plots represent the spread of total organic carbon values locally at a catchment level and for the larger regional dataset. The blue dots indicate the individual landholders' value.

Traffic Lights

The traffic light system is a simple and easy interpretive tool that provides a visual 'snap shot' of the status of a group data set. It quickly and easily presents an idea of the potential soil constraints facing a particular group. Development of these diagrams on www.soilquality.org.au provides "point and click" access to management implications and strategies for specific indicators when the user hovers over the diagram. For example, pH throughout the soil profile is an obvious issue in the Hyden area (Figure 3). Hovering over the red portion of the diagram informs the user there is an acidity issue in the area. Clicking this leads to fact sheets on soil acidity and information regarding amelioration strategies.

Calculators

In addition to providing data and information relating to range of soil quality indicators, www.soilquality.org.au houses a number of calculators aimed at providing basic agronomic/economic data for a range of management options. A most useful example relating to management of soil acidity is the

“lime comparison calculator”, allowing users to compare the relative neutralising value of different lime sources as well as accounting for the cost of transport and spreading the product.
With the current interest in the ability of soils to store increasing amounts of organic matter, a calculator was developed to indicate the relative amounts of organic matter required for a targeted change in soil organic carbon (%). Other calculators cover issues surrounding stubble retention, green manuring and controlled traffic farming.

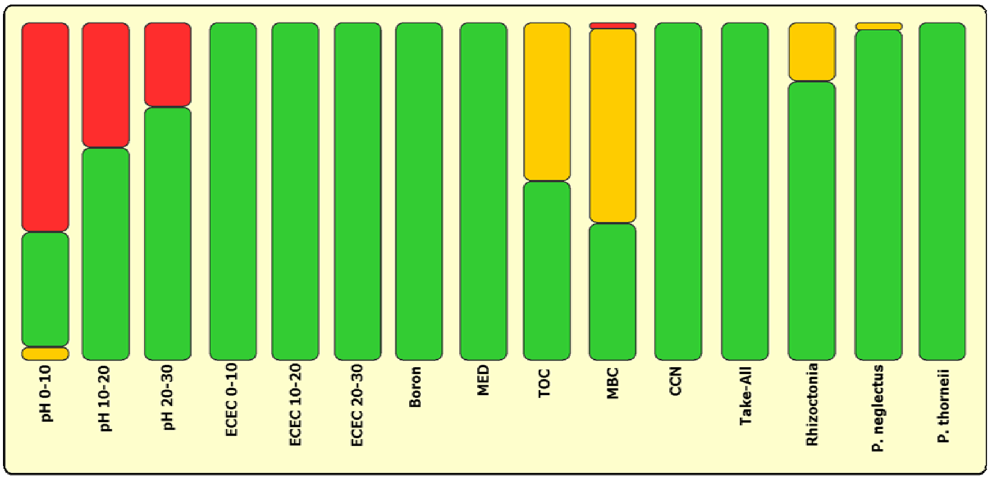

Figure 3. An example of a traffic light diagram from growers sampled in the Hyden area of Western Australia. Red indicates negative production impacts and the need for immediate action, amber indicates probable production penalties and the need to consider management change, while green represents no impact on production but ongoing monitoring is suggested.

Conclusion

The soil quality monitoring programme has produced www.soilquality.org.au as an easily accessible tool for the introduction of soil related issues to the wider community. It is a useful resource of general information on a wide range of soil related topics, while also providing specific data and management tools for growers, agronomists, natural resource management officers and regional development personnel. Experience with landholders suggests a preference for diagrammatic representation of analytical data that must be easy to interpret and linked to management strategies. Current pressures of profit driven primary production limit landholders’ ability to research and obtain reliable information on soil related issues.
The soilquality website allows every interested research and/or grower group to take ownership of their own datasets and soil issues pertinent to local production systems. As such, it is currently undergoing national expansion to include monitoring and education from other Australian states.
The 1362 sample sites throughout Western Australia provide a benchmark for soil quality, from which future sampling and analysis can provide indications of change in WA’s agricultural soil resource. This is recommended to occur on a 5-year time frame so repeat analysis of sites can occur prior to assessment of 2020 targets for soil properties such as pH. It also introduces a range of soil biological properties relating to crop production and provides a range of tools and information to understand the relevance of each one. While biological indicators of soil quality are not necessarily linked directly to crop production, the agricultural community recognises the important roles organic matter plays in production systems and a greater awareness of soil biology is actively sought by the agricultural sector.
The ongoing development of www.soilquality.org.au provides the wider community with a significant database of soil analytical data with which to investigate and interpret. It allows landholder groups to identify local soil related production issues, access relevant information, and formulate strategies to manage or overcome these constraints. Improved knowledge of a wide range of soil quality issues limits degradation of productive soils, has positive impacts on food and fibre production and ultimately provides for sustainable soil systems.

References

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