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Soil indicators and their use by farmers in the Billabong Catchment

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Soil indicators and their use by farmers in the Billabong Catchment

Abstract

"Soil health" programs and projects in Australia's agricultural districts are designed to influence farmers' management behaviours, usually to produce better outcomes for production, conservation and sustainability. These programs usually examine soil management practices from a soil science perspective but how soils are understood by farmers, and how that understanding informs their farm management decisions, is poorly documented. The research presented in this paper sought to better understand how dryland farmers in the Billabong catchment of southern NSW use soil indicators to inform their management decisions. Thematic content analysis of transcripts of semi-structured, face to face interviews with farmers suggest a number of themes that have implications for soil scientists and other professionals wishing to promote soil health in the dryland farming regions of south eastern Australia. In particular, all soil indicators, including those related to soil 'health', need to relate to some clear, practical use to farmers if they are to be used in farm decision making. This research highlights a reliance of the participants of this research on agronomists. Reliance on agronomists for soil management decisions may result in increasing loss of connectivity between farmers and their land. If this reflects a wider trend, soil 'health' projects may need to consider where best to direct their capacity building activities, and/or how to re-empower individual farmers.

Introduction

Earth's ecosystems depend on functional soil. Soil is critical for decomposition and nutrient cycling, which in turn sustains plant and animal productivity, support biodiversity, enhance air quality and maintain water quality (Torsvik *et al.* 1990; Doran 2002; Sojka *et al.* 2003). Humans exert a major influence on the world's soil, in particular through agricultural land use. To meet the increasing demands of the growing human population, contemporary agricultural methods in developed countries have created an 'industrial' system of high inputs and outputs. However, increased agricultural production has come at a high cost to soil resilience, and aspects of the industrial approach threaten the vital ecosystem services soil provides (Doran 2002). This threat to ecosystem function is recognised in current public discourse on soil management, which is framed in terms of 'soil health', as exemplified by the 2006 State of the Environment report (Australian Government Department of Environment and Water Resources 2007). State and Federal governments currently fund various 'soil health' projects, including the Australian Government's 'Healthy Soils for Sustainable Farms Programme' (DAFFA 2007). Because governments have limited powers to influence management on privately owned farms directly, these soil health projects follow traditional agricultural extension practice by providing a mix of information and incentives to encourage farmers to undertake recommended best practice. What constitutes 'best' practice in this context is predominantly determined by soil scientists.The perspectives of soil specialists is reasonably well documented as it is they who publish most papers on soil and its management. However, how soils are understood by farmers, and how that understanding informs their farm management decisions, is less well documented. The research presented in this paper sought to better understand how dryland farmers in the Billabong catchment of southern NSW use soil indicators to inform their management decisions.

Soil indicators

The use of soil indicators can be traced back to Roman philosophers who suggested sight, taste, touch, and smell as qualitative criteria for evaluating soil and its suitability to grow particular crops (Doran *et al.* 1996). Experiential, anecdotal soil indicators of this type supported traditional agriculture until relatively recent times, when a more explanatory, quantitative approach developed in parallel with industrial farming. Previous research projects have identified the variety of soil health/soil quality indicators available for farmers in different situations, and their results are summarised in Table 1.

Insert Table 1 about here

Much of the published research has sought to assess the ‘value’ or ‘accuracy’ of traditional soil indicators in comparison with modern scientific technology (Agbenin and Andeniyi 2005; Desbiez *et al.* 2004; Mowo *et al.* 2006). Many visual indicators are dismissed in the scientific literature as unreliable (Schwenke *et al.* 2003). There is also some literature available on the use of laboratory based soil tests. Lobry de Bruyn and Abbey (2003) found that many farmers regard soil testing as a way of eliminating poor crop performance from causes they cannot see. However, some farmers regard soil testing as unreliable (Hayman and Alston 1999). This scepticism is possibly attributable to the farmers’ perception of soil testers, rather than the tests *per se*, as the people doing the testing are employed by agricultural companies to sell fertiliser and to give advice (Lobry de Bruyn and Abbey 2003). Wilkinson and Parminter (1997) suggested that soil tests were used mainly to help solve a particular problem, and complemented rather than replaced informal monitoring. Indeed, Australian farmers appear to use multiple soil indicators. For example, as well as using scientific testing for nutrition, organic carbon, and soil pH, some farmers in the central NSW area also used more traditional methods such as visual observation and the feel of 'the dirt between their hands' (Lobry de Bruyn and Abbey 2003).

Although it is clear that both technical and non technical soil indicators are accessed by farmers there is little information about how the farmers use these different sources of information in their farm management decision making. In particular, there is no indication of why one soil indicator may influence decision making more than another. This is significant, as research has shown that changes to one indicator may create significant changes to several others, making the choice of indicator more complex (Andrews *et al.* 2002). Nor is there much published information about how farmers make sense of possibly conflicting information.

Methods

To begin to better understand how soil indicators are used by Australian farmers a qualitative research project was undertaken within the Upper Billabong Creek Catchment (see the small map in Figure 1), an area that has been dominated by agriculture since European settlement in 1836 (Greater Hume Shire Council 2007). The study area consists of alluvial landscapes with Chromosols and Kurosols on the higher terraces and Grey and Brown Dermosols on the lower terraces, and colluvial and erosional landscapes with Rudosols on ridges and crests, Kurosols and

Chromosols on mid-lower slopes and Yellow and Grey Sodolsols on lower slopes (Doughty 2003).

The objective of the research was to better understand some of the complexities of decision making by dryland farmers in south eastern Australia, rather than to make statistical generalisations about their practice. Because depth rather than breadth of understanding was the aim qualitative data were sought and analysed. The principal source of data was 15 face to face semi-structured interviews with farmers, with additional information gained by observation of two 'soil health' management workshops in the same district. The authors do not claim that the results are representative of the Billabong district, nor farmers in general. However, the results draw attention to ideas that may provide ways of understanding similar situations, and which may usefully inform broader based research.

Insert Figure 1 about here

Because qualitative research is valuable for rich understanding and generalisation through analogy, population sampling is focused on finding people with particular attributes (ie purposeful sampling), rather than on attaining a sample for quantitative statisical analysis (Rossman and Rallis 2003). A government-employed district agronomist supplied two initial contacts, who then suggested other possible research participants. Additional potential participants were recruited at a district drought relief meeting, and, to incorporate diversity, a farmer using 'alternative' farming approaches was found via the internet. The majority of participants were recruited by recommendations made from those just interviewed, and this created local pockets of respondents, as shown in Figure 1. Due to changes in terrain and rainfall there is a gradual topographical shift in the type of farming practiced with pastoral livestock farming primarily in the east, and cropping becoming increasingly dominant west of the Hume Highway (National Land and Water Resources Audit (NLWRA) 2001), so the sample included farmers with a variety of dryland enterprises.

Semi-structured, one to one interviews use a conversational process to enable the researcher to gain an understanding of the informants' perspective of their lives, experiences, and social reality (Furze *et al.* 1996). Semi-structured interviews are open-ended, with the intent of gaining an understanding of the views of the participant, rather than the concerns of the researcher (Henn *et al.* 2006). To achieve this, the interviews began with the question; "Could you tell me about your farming operation?" The participants were encouraged to discuss any influences or management actions associated with their farm's soil, aided by prompts and further questions as required covering farmers' choice of soil indicators, and their sources of information about soils. Prior to discussing soil indicators, the researcher read the following definition to each participant to improve understanding between the researcher and the participant, and to provide consistency to the survey. '*Indicators are measurable attributes of the environment; they can be monitored via field observation, field sampling, remote sensing, or compilation from existing data*' (Meyer *et al.* 1992 cited in Walker and Reuter 1996, p.7). The interviews varied between 40 minutes to almost three hours.

All interviews were audio taped and transcribed to provide written data for analysis. Thematic content analysis was used to interpret the wealth of qualitative data collected. This involves systematic reading and interpretation of the data to identify and label predetermined and emerging categories of information and ideas into themes. Themes thus represent patterns in the data (Shank 2006).The process of identifying and categorising themes was aided by the use of the computer-assisted qualitative analysis software NVivo2.

Results

The major themes from the 15 participants identified through the analysis are presented as headings below, supported by direct quotes from the research participants, whose identities are kept anonymous by using a code, eg F7, instead of their name.

The importance of soils

Despite the centrality of soil in dryland farming operations, and the small sample size, the comments from farmers who participated in this study suggest that soil may be understood and valued differently by different land managers. For example:

"So how important is soil?"(Researcher)

"Well I say its 1/25th of all the things I have to think about."(F 12)

"My tree plots and fencing off the creeks and planting trees…Stabilisation, and shade, native wildlife, they're my priorities for doing that…I don't do it to improve the soil."(F 4)

“It’s been in the background, as it was just taken for granted, and in fact I think the soil has just been seen as a medium to grow things… I think that’s the way people have viewed the soil up until recent years…I think there has been a bit of a shift in thought that it is actually a little more than that, it’s a living organism that you have to look after.”(F 15)

“I’m a conservative operator, concerned with long term sustainability so I probably, well to some degree it’s economic but it’s not the be all and end all. I’m more interested in the long term health of the soil.” (F 4)

“Without soils you haven’t got anything you can’t do anything, if you have rat shit soils you can’t grow anything can you?... No I think it starts with the soil …Soils are the most important.”(F 9)

Indicators

The participants identified a range of soil indicators that they used (Table 2). The most frequently mentioned indicators were from laboratory soil testing.

Insert table 2 about here

Soil tests

Most of the farmers interviewed relied strongly on proprietary laboratory soil tests to inform their decision making in some way. For example

"We'd soil test and start from there, and then the soil test tells us what we have to do."(F 9)

"I suppose it just confirms for the sake of a $100 to test a paddock …it's just the amount of lime you put on I think is the main thing whether you put on the equivalent to 2 tonnes/ha or 3 tonnes/ha."(F 10)

While soil tests provide a large amount of data, many of the participants who used tests focused their discussions on three properties of their soils; phosphorus, aluminium, and pH. Despite the use of soil testing by most of the participants, confidence in the soil tests varied. While the above quotes reflect positive views about the reliability of the results, others participants were sceptical.

"We did it through landcare and had 4 different soil tests done on the same paddock and the results were somewhat different."(F 11)

"But it didn't seem to give you the results that we needed so we… we still do it but have become less reliant upon it."(F 7)

Management decisions were clearly influenced by a number of indicators, and the role of laboratory soil testing in those decisions was not as straightforward as might be anticipated. Many of the participants explained that initially they used indicators such as pasture composition and weed species to identify what they perceived as a problem, and then confirmed their initial observation with a soil test. Despite most participants' emphasis on the need for soil testing before they undertook any significant management actions, when it came to fertiliser applications, standard 'recipes' for specific activities such as pasture renovation were also important. For example

"Try and get a young pasture up and established in the first 3 years …once the pasture gets to about 6.5 you can drop back to more of a maintenance application which might be minimum of 100 kg/ha of super, single super …whereas the new pastures get more like 150-200kg…maybe 200 in the first year then back to 150 for a couple of years, then 130, then back to 100." (F 10)

As noted, 'indicators' were defined at the beginning of the each interview, and the participating farmers were asked to articulate what soil indicators they used. The list of indicators elicited from direct questioning about a predominantly subconscious process was understandably brief. Over the course of each interview, however, it became apparent that farmers use more indicators of the state of their soil than they readily label as such. This was particularly noticeable when discussing animal health and trace elements. Some farmers who had not earlier mentioned ill thrift in lambs, animals' coat colour, or tensile strength in wool, did connect these characteristics to deficiencies in the soil of trace elements such as selenium and copper. For example

"Probably the health of our cattle has been a huge indicator; our health is much, much better now… I suppose that's one of the ultimate…and it all goes back to soil."(F 8)

Most of the participants thought that it would be unlikely that visual indicators would conflict with the results from soil tests. If they did, most stated a preference for scientific confirmation of what they saw through the use of laboratory soil tests, and often sought backing of their decisions from agronomists.

"We'd consult an agronomist…you just wouldn't go out and spend money and think you can fix a problem when you've done everything the soil test told you …right amount of supers.. and everything's gone yellow."(F 9)

Participants who believed they had trace element deficiency problems tested their animals by blood tests; none of the farmers used tissue testing of their pastures to measure trace element levels. It was a different story on crops, however, as most participants, under the guidance of their agronomist, used tissue testing of their crops when they believed crop performance was not what it should be.

Soil 'health' indicators

Some of the indicators discussed by the participants and listed in table 2 can be classified as relating to soil 'health', including *humus* and *microbial activity*, *an ability to grow grass without fertiliser application*, *worms*, *bird population*, *dung beetles* and *the organic content in the top levels of the soil*. While recognising the value of organic matter, and expressing a desire to have significant levels of it in their soils, some of the participants were unsure about how to monitor it and what the current measures provided by soil testing actually reflected. Despite this, at least one participant felt that laboratory soil testing was one way of learning about organic matter in soil:

"With these soil tests it said that the organic matter varied a lot from a pasture paddock to a cropped paddock … like I'd have no idea what the level of organic matter was in soil if you held it up in front of me, so that's one where the soil test is helpful."(F 10)

However other, more traditional indicators were also used to assess soil carbon, even if a soil test was also used;

"Well this paddock I'm talking about we'll have only raised the organic matter by about 1%, there doesn't seem to be anymore earthworms there than anywhere else, but that paddock is now our most friable soil type so I don't know what that means, it doesn't go hard in the summer, and it doesn't go hard in the winter, so you could go up there now and get a shovel in the ground."(F 1)

As with fertiliser and lime application, recipes for action were used in attempts to build soil organic matter.

"That is why we are not really looking at cropping one paddock for 30 years …its going to go back into perennial pasture and probably be spelled for 10 years, and that will hopefully build up the organic matter side when it is in the pasture phase."(F 14)

Interpretation of soil indicators

Agronomists

When it came to interpreting the information farmers attained from their soil tests, farmers for the most part relied upon the services of their agronomists. In many instances multiple agronomists were employed by participants in order to obtain advice in specific areas such as soil, crop management or pastures.

"I would get professional advice and ask why is this happening? Rather than relying on my soil knowledge, I'd be saying why? And I may go to 2 different agronomists."(F 12)

"My time is so limited in finding out information, I would much rather pay a person to come and tell me what I should be thinking about and whatever…an independent person at that, someone who I trust rather than pushing out products, rather than trying to divulge a whole lot of stuff." (F 12)

Despite the increased use of agronomists at least one participant was sceptical about how much of what experts say can be applied to their own farming operation, and how much influence outsiders should be having over the management of the farm.
"I think agronomists have to make work for themselves so they're always suggesting new beaut pasture mixes from the rest to keep you involved."(F 9)…."There are some farmers in this area that wouldn't know what boot to put on unless the agronomist told them."(F 9)

The participants who engaged the services of industry based agronomists appeared, from the interview discussions, to have a long term goal of highly productive, sustainable soils. The one participant who chose to receive advice from a soil scientist rather than an agronomist had a more holistic outlook to soil management, and not only wished for productive sustainable soils, but also improved ecosystem function.

"*Well our long term plan is to keep a 100% ground cover, so we want vigour over every acre of the place and in doing that it is not over grazed and in that there are a lot of spin offs from that in animal health, better water infiltration, better water holding, better water cycling, better nutrient cycling, perennial grasses, there are a whole lot of spin offs just from that one action. More microbes in the soil, more pH dissipates which we have evidence of all ready, salinity dissipates because it promotes perennial grasses and that sort of thing, and the water cycle's improving so that's where we are coming from."(F 8)*

Local knowledge and trials

Local and experiential knowledge were also discussed in some of the interviews. While most participants denied being directly influenced in their soil management by reference to their neighbours' activities, some recognition of shared local understanding was suggested, with local agronomists acting as the gatherers and sharers of local knowledge:

"Have none of your neighbours influenced you since you've been here?"(R)
"No, we look over the fence certainly, but that sort of thing, like if we are influenced by a neighbour it might be more like what type of stock are you running or a crop variety that performed really well, or a pasture looks really terrific and what variety is it along those lines, but nothing to do with soil management."(F 7)

"Well to my way of thinking agronomists re- tells what they've learnt from good operators anyway so if you can seek out good operators and learn from them you're just cutting out the middle man."(F 4)

The Internet

Included in the sources of information for farmers is the use of the internet. The internet does not appear to be replacing more traditional sources of information, but it is used to locate other sources for discussion of specific topics where that information is not easily accessed for farmers in the Upper Billabong Catchment.

"Oh well, I read it and then if I think its relative to here then I start to look for contacts like the author of the article or people's names who are mentioned in the article. Because I like to get the information from the horse's mouth."(F 1)

"So are you using the internet because the agronomists aren't supplying you with the answers?"(R)

"No, I think you want to take in as much information as I can on everything, no one's got the right answer, so I'll bring in all the information and I'll make my own decision."(F 14)

Discussion

The design of this study does not enable the cause and effect to be stated, but the themes that emerged from the interviews suggest a number of issues that can be discussed within the context of exisiting literature, and which may warrant further exploration in this and different localities.

Farmers' choice of soil indicator

This research suggests that the use of soil indicators by individual farmers is complex and varied. The findings of this research dominated by data gathered from pastoral farmers when compared to other work in areas of cropping dominace (Romig *et al.* (1995; Lobry de Bruyn and Abbey 2003) highlights the different management practices relating to types of farming. Romig *et al.* (1995) ranked the properties they believed surveyed farmers of Wisconsin regarded as most important for soil health. Of the fifty properties identified; first was organic matter, second was crop appearance, and third was erosion. Lobry de Bruyn and Abbey (2003) ranked the way surveyed farmers of NSW defined soil health; first was the feel of soil, second plant growth, third plant yield and colour, and fourth organic matter. In contrast, the participants from the Upper Billabong Creek Catchment painted a complex picture that almost always privileged laboratory soil testing to measure nutrients, along with the presence of pasture species and weeds, and soil colour, as indicators for their soil management.

The farmers of the Upper Billabong Creek Catchment who took part in this study do not appear to be making management decisions with the aim of creating a healthy soil as an end in itself. Rather they considered that soils capable of producing what they wanted (often high and/or sustained yields) are healthy

Farmers' use of Soil Indicators

In contrast to farmers of less industriously developed countries who are still using many traditional methods (Agbenin and Andeniyi 2005; Desbiez *et al.* 2004; Mowo *et al.* 2006), the participant farmers of the Upper Billabong Creek Catchment used far fewer soil indicators to inform their farm management. Comparison of the cited soil indicators that farmers' may use (Table 1) and soil indicators identified by the participants (Table 2) highlights the limited range of soil indicators used by these participants. However, simply knowing that soil tests were used tells only part of the story. All participants had at one time sent samples of their soil for laboratory tests, although the frequency of repeat testing varied among the participants. Some of the participants were sceptical about the reliability of soil testing, which echoes the findings of other research (Hayman and Alston 1999; Lobry de Bruyn and Abbey 2003). For many of the participants, the results of the soil tests confirmed what they already knew, but they appeared to be reluctant to trust their own observations. For example, although many of the participating farmers recognised the plants silver grass and sorrel to be indicators of high soil acidity, most said that they would confirm such an observation with a soil test before they applied lime. The unwillingness of the participants to act upon their own observations may be due, at least in part, to the industrialisation of farming. A conventional industrial farming approach that requires increased levels of inputs, larger farm size, and fewer labour units to be financially viable, is closer to the 'domination of nature' than the 'harmony with nature' model (Beus and Dunlap 1990). A reliance on explanatory soil tests at the expense of hands-on, experiential indicators is in keeping with a loss of connectivity with the land as farming becomes more industrialised.

Another possible reason for these farmers wanting to confirm their observations with quantitative indicators is to reduce the level of risk in the decision process. Most farm management activities involving soil management, such as applying fertiliser or mechanical cultivation, are very expensive. The findings of this research suggest that the degree of perceived risk may vary depending upon the value of the product the farmer is attempting to produce. As the economic value of a product increases, there appeared to be a greater awareness of soil indicators and a change in the type of soil indicator used not only to rectify a problem, but also in the endeavour to maximise production. This was highlighted by the use and non-use of 'tissue testing'either in response to observing something wrong with the crops through visual observation, or as a monitoring action to ascertain whether their crop's production may be limited by a nutrient deficiency in the soil, and in particular a deficiency of a trace element. Most of the participants had used tissue testing on crops of potentially high economic value. In contrast most of the participants had not contemplated doing a 'tissue test' on their pastures, as pastures don't have the same financial potential to generate income as crops.

Soil testing may adhere to the principles and methods recommended through conventional agricultural extension activities and agricultural colleges, but this study suggests that the ability of the farmers to use these results to the extent that the promoters of industrial farming intend is variable. Most of the participating farmers relied upon other sources to decipher the results of their soil tests to the level of knowing what nutrients and what quantity of nutrients are needed for maximum yield. Most of the participating farmers within the Upper Billabong Creek Catchment only referred to the most dominant components of the soil that they believe effects their farm production; notably phosphorous, pH, and aluminium. Most had soil nutrient levels significantly below the optimum levels required for maximum production, and the quantities of fertiliser that they applied could not reach these optimum levels because of budget restrictions. Management actions were not often based upon soil tests, but rather on a proven recipe for establishing new pasture, or the required amount to provide maximum yield dependent upon sufficient annual rainfall.

Role of Science

Traditional visual soil indicators observed by farmers are regarded as being unreliable by scientists (Schwenke *et al.* 2003), and most of the farmers participating in this study emphasised the need for scientific backing for the decisions they make. Indeed, the benefits of quantitative soil monitoring are highlighted by the inconsistencies and bias between the participating farmers' observations, especially in relation to animal health issues. Participants who primarily earned their income from livestock as opposed to those who emphasised cropping, made more comprehensive observations of their stock. These observations included observations of the tensile strength in the wool and the colour of the stock in winter, which they attributed to trace element deficiencies in the soil. However, the participants who focused on cropping did not readily associate aspects of their livestock's health with the composition of the soil, apart from the threat of parasitic worm infestations.

Also, participants displayed varying reliance on soil testing and a 'need for scientific proof'. While most noted they had consciously chosen not to adopt an alternative farming approach, most conceded that they had little knowledge of the subject. The conventional farming approach used by most of the participants is a continuation of a farming regime that had been inherited, and then reinforced at 'Agricultural College'. Bias may occur within the decision making process as a consequence of restricted alternatives (Das and Teng 1999).

Role of information sources

The sources of information most valued by the participants were comparable to those in the research of Lobry de Bruyn and Abbey (2003). These included the people and representatives that the farmers had direct contact with, including the district agronomist, family members, neighbours, farmer as expert, agricultural consultant, and NSW Agriculture. However, it is apparent that many of the participants farming within the Upper Billabong Creek Catchment rely upon private agronomists as a source of scientific knowledge and as a source of local knowledge. In particular it is notable that as the value of a product increases, the choice of soil indicator is made by the consultant(s) they employ. Many participants noted that if they detected a problem with their crop, their first response is to get their agronomist to look at it, and it had then been the agronomist's suggestion to do, for instance, a 'tissue test'.

Some of the participants noted that their agronomist learned from other clients and passed information on. It is possible that some farmers may be selecting their agronomist on the basis of an agronomist's other clients, so that they might learn from them. Also through such associations, farmers may be regarded within the community as being a good farmer. This is a dominant value for some farmers (Frost 2000).

Most of the participants felt that the best scientific information is delivered by their agronomists, although the one 'holisitc' farmer in the sample preferred to go straight to the research scientists for information.

In Australia there has been a decline in the availability of one to one advisory services from public sector extension agencies, resulting in an increase in the number of private farm consultants (Black 2000). The participants surveyed stated that they have less time for farming because they are being required to conduct wages audits, and OHS requirements, and as a consequence are using the services of agronomists more. Although private agronomists may not necessarily be promoting products, they have a greater need in the private sector to provide a service to individual farmers that will ensure a continuance of their employment. Most monitoring by farmers relates closely to farm performance (Ridley *et al.* 2007). Therefore agronomists need to address the direct interests of farmers. For most of the participants this was management that produced sustainable high yields. There would appear to be a degree of irony associated with the decline in government advisory services (Black 2000) and the present government emphasis on soil health (Australian Government Department of Environment and Water Resources 2007). Not only have governments reduced their ability to communicate new information to farmers, but the former government employees that are now private agronomists may also be limiting the uptake of governmental soil information by farmers. A preference to the information supplied by the private agronomist may be due to; trust of information source, lack of time to attend meetings and field days, information overload, and burn out from attending meetings and field days.

Conclusion

The participants in this study used a limited range of soil indicators that were mostly associated with production of a saleable product, rather than the ‘health’ or function of the soil base. While some of the indicators were noted through visual observation, most of the participants stated that they would not make management decisions on the information from such indicators but would need to confirm their suspicions through a ‘scientific’ approach. For most this meant soil samples being laboratory tested for a number of measurable, mostly chemical, attributes. However, despite the participants undertaking soil testing, the range of soil information supplied by the laboratory testing was not used, with production recipes relied on once a farmer’s suspicions had been confirmed by the test. All of the farmers in the study sought assistance with understanding the various soil indicators they used, with the use of industry employed agronomists a notable feature of on farm decision making. Although this study involved a small number of participants, these findings suggest two areas of interest for current soil scientists, especially those involved with promoting a more holistic or ecologically sustainable approach to soil management than has been the case hitherto.

Firstly, this research suggests that soil indicators need to be of some clear, practical use to farmers if they are to be used in farm decision making. This may mean finding and communicating the links between measurable indicators and farm productivity and plant growth, an approach modelled on the current adopted practice.

Secondly, this research suggests further research may be warranted to determine if farmers have an increasing reliance on agronomists, and that this may result in a delegation of decision making, and a possible loss of connection between farmers and their land. Soil 'health' projects may need to consider where best to direct their capacity building activities, and/or how to re-empower individual farmers. Future research on the impact of agronomist use would provide an indication of whether the agronomists' influence is resulting in either an increase or decrease of farmers' knowledge of soil, and a potential loss of connectivity to the land. Also, increasing use of private agronomists may reduce the effectiveness of traditional agricultural extension. The development of small learning groups appears to attract farmers who would have traditionally been deemed 'progressive' farmers by government agencies. Agencies would have encouraged these farmers to adopt new technology, anticipating that they would then introduce it to the community through 'top-down' linear adoption. The established barriers to information, such as a lack of time, burn out, and information overload, may result in these farmers now confining their activities to their organised groups. This has the potential to create a divide in the farming community between those generating, and those not using new knowledge.

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Figure caption

Figure 1. Location of study site.

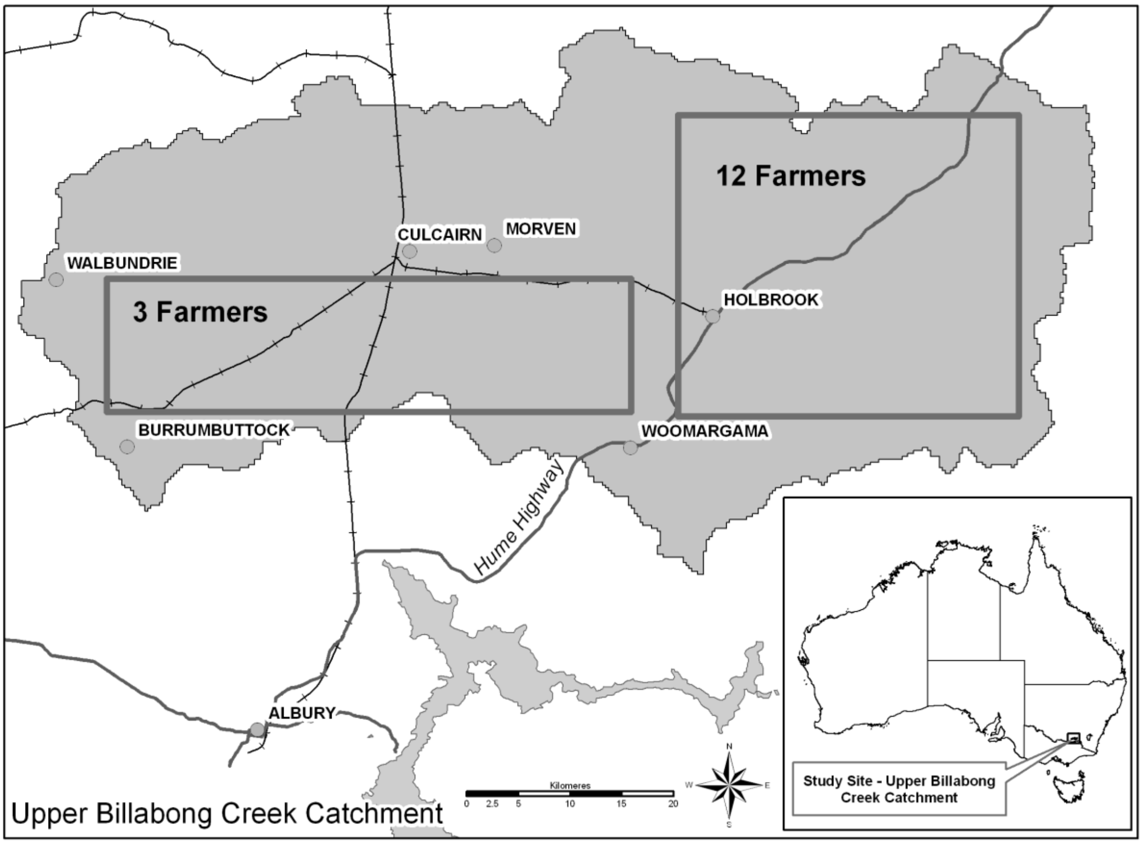
Table 1. Cited features, indicators, or techniques used by farmers to identify the status of their soils' health, quality, or fertility. Cited authors; A. (Carberry *et al.* 2002); B. (Desbiez *et al.* 2004); C. (Hayman and Alston 1999); D. (Lobry de Bruyn and Abbey 2003); E. (Mowo *et al.* 2006); F. (Romig *et al.* 1995)

SOIL	**PLANTS**	**LOCATION**
Soil feel (B,D,F)	Crop yield (B,F)	Quality of water source (B)
Organic matter (D,F)	Colour of crop (B)	Shade from trees (B)
Soil erosion (B,D,F)	Crop size (B,E)	Distance from water source (B)
Soil life (D)	Growth rate (B,D,E,F)	Distance from house (B)
Soil type (F)	Crop suitability (B)	Landslide potential (B)
Texture (B,D,F)	Crop height (B)	Size of plot (B)
Hardpans (D)	Disease (B,F)	Terrace heights (B)
Water absorption (B,D)	Density of plants (B,E,F)	Native animals' destruction (B)
Soil colour (B,D,E)	Size of fruit seed (B)	Slope (B,F)
pH (D,F)	Crop appearance (B,F)	Southern exposition (B)
Organic Carbon (D)	Germination (B,F)	Water temperature (B)
Nitrogen level (A,F)	Crops wilting early (B)	Altitude (B)
Phosphorous (F)	Leaves (F)	Position within fields (B)
Potassium (F)	Stems (F)	Water availability (B)
Protein level (D)	Feed value (F)	Drought resistant (F)
Compacted soils (E,F)	Native vegetation (D)	Chemicals in ground water (F)
Ca:Mg ratio (F)	Presence of weeds (B)	**TECHNIQUES**
Infiltration (F)	Weed species (B,E,F)	Soil testing (C,D,F)
Micronutrients (F)	Weed cover (B)	Difficulty to plough (B,F)
Nutrient deficiency (F)	Weed height (B)	Quality of ploughing (B)
Biological activity (B,E,F)	Tree roots in field (B)	Number of ploughings (B)
Smell (F)	Plant roots (B,D,F)	Deep soil coring (A)
Salinity (D,E)	Response to manure (B)	Surface water appearance (F)

Scalding (D)	No. of crop rotations (B)	Costs of production
Stoniness (B,E)	Decomposition (F)	and profit (C,F)
Surface crust (F)	Weed colour (B)	Quantity of inorganic
Moisture (A,B,C,D)	Paddock history (C,D)	fertiliser applied (B)
Water holding capacity (B)		Quantity of
Soil temperature (B)		chemicals needed (B)
Top soil depth (B,F)		**OTHER**
Chemicals response (B)		Rats (B)
Cracks forming (B,E)		Pests (B,F)
Drainage (F)		Human health (F)
Structure (F)		Animal health (F)
Fertility (F)		Wildlife (F)
Hardness (F)		
Aeration (F)		

Table 2. Soil indicators identified by interviewed farmers

Soil testing	Pasture quality
Tissue testing	Greenness of grass
Brix readings	Ground cover and perennial grasses
Soil pits	A golden colour in dry feed
Deep N test	
Weeds	Saline soak
▪ Silver grass	Gully erosion,
▪ Sorrel	Rill erosion
▪ Capeweed	
▪ Annual grasses	Health of cattle
▪ Onion grass	Tensile strength in the wool
▪ Patterson’s curse	Stock go a bit light coloured in winter
	Ill thrift in lambs
Stocking rate	
Growth rates in pasture	Flocks of ibis
	Dung beetles
Change of slope and texture	Microbes
Bit rocky	Earthworms
Getting bogged	“Lerps in trees indicate your out of balance a bit”
Like bull dust	“Different trees grow in different soil types”
Blowing away	“Lucerne won’t tolerate acid soils”
Colour, and aspect	
Organic content in the top levels of the soil	


12 Farmers
3 Farmers
CULCAIRN
MORVEN
WALBUNDRIE
HOLBROOK
BURRUMBUTTOCK
WOOMARGAMA
Hume Highway
ALBURY
Kilomeres
0 2.5 5 10 15 20
N
W
E
S
Study Site - Upper Billabong Creek Catchment
Upper Billabong Creek Catchment