



Final Report

DAV 12222

***HDLN Soil and Water Dairy
Action Program—
Soil Assessment Component
June 2008***

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HDLN Soil and Water Dairy Action Program— Soil Assessment Component

Final report to Dairy Australia
on DAV 12222

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Executive summary

Introduction

Sustainable use of the soil resource underpins the dairy industry in south-west Victoria. Good physical, chemical and biological health of the soil is essential to reaching and maintaining the productivity required for profitable, pasture-based dairy farming. It is also essential that management of the soil ensures that farms have minimal impact on the environment—both on-farm and in the wider catchment.

In this research project, we aimed to benchmark the soil health on dairy farms in the Curdies River catchment, through measurement of selected soil physical and chemical properties, and visual assessment of soil structure and biota in the field. These measurements and assessments were undertaken at sampling locations across a range of soils between 2005 and 2007. On each of 24 properties, 2–3 sites within each of 3 paddocks were sampled (0–10 cm). In all, soil chemical analyses were undertaken for 157 samples, soil physical analyses on 561 samples and 87 sites were visually assessed by 2 observers using 2 visual assessment tools.

Summary of findings

The main findings from this soil health benchmarking project include:

- The soil physical conditions in the Heytesbury area during the monitoring period (2005–2007) were generally good, with little evidence of pugging.
- Pastures on soils with low pH and high aluminium levels (Figure I) could profitably respond to application of lime.
- Levels of soil phosphorus were high to very high (>25 mg/kg) at most monitoring sites (Figure I). These levels are higher than the economic optimum for pastures and are potentially detrimental to the local environment. Farmers could reduce, or temporarily cease, their phosphorus applications and still maintain high pasture productivity, while saving costs.
- Where soil potassium levels are high (Figure I), potassium inputs can be reduced or deleted from the fertiliser regime. High potassium levels are potentially a concern for farmers, as they are implicated in the occurrence of grass tetany (hypomagnesaemia) in near-calving and lactating cows.
- Soil chemical testing was able to identify potential soil health risks which were not detected by visual assessments. In particular, the production and use of whole farm nutrient maps, as supported by the Heytesbury District Landcare Network, would assist farmers to identify and manage soil health issues on their property.

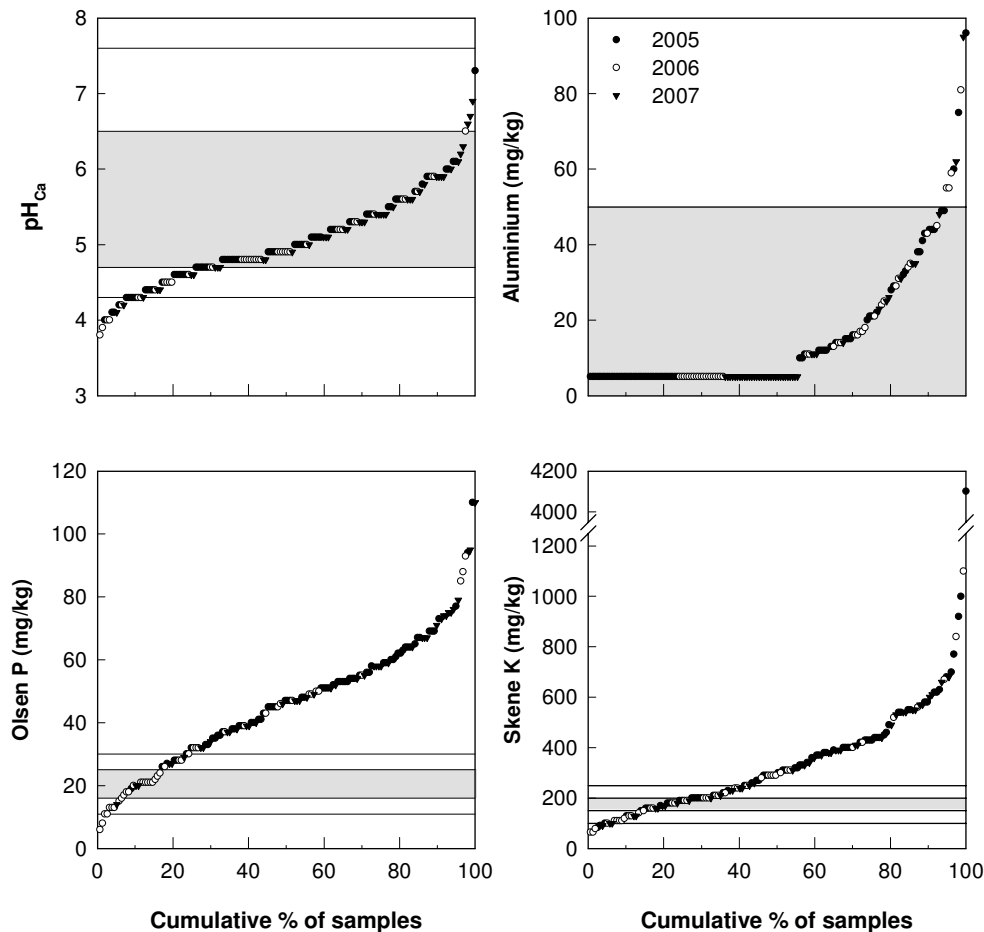


Figure I. Selected soil chemical properties from the monitoring sites in the Heytesbury district. The data are ranked in order from lowest to highest to enable the proportions in each category to be determined. In each graph, the optimum level is shaded and the lines indicate intermediate levels.

Recommendations for commercialization—not applicable

Recommendations for further research

Possible areas for further research include:

- Establishment of research trials, in close consultation with local farmer groups, to demonstrate that high levels of pasture production can be maintained at Olsen P levels of 15–25 mg/kg.
- Highlight the benefits of changed fertiliser management practices through a follow-up benchmarking survey in 5–10 years time, including correlations with improved water quality in the Curdies River.
- Extend the soil benchmarking process to other dairy catchments within Australia, and expand the focus to include life cycle assessments (Haas *et al.* 2001) and estimation of on-farm greenhouse gas emissions (Wheeler *et al.* 2008).

Background

Sustainable use of the soil resource underpins the dairy industry in south-west Victoria. Good physical, chemical and biological health of the soil is essential to reaching and maintaining the productivity required for profitable, pasture-based dairy farming. It is also essential that management of the soil ensures that farms have minimal impact on the environment—both on-farm and in the wider catchment.

While there has been considerable work on pastures and productivity in the past, there has been little research work or extension on the soil health status of soils under dairying in south-west Victoria. Despite the Corangamite Catchment Management Authority soil health strategy (2006) listing excess nutrients, soil structure decline, soil acidification and organic matter content as issues likely to require addressing, they were not given a high ranking because they solely impacted on agricultural productivity. Water quality in the streams of the dairying catchments of the region are generally in poor condition with high nutrient and sediment loadings. Farm soils in poor condition may be a significant non-point source of nutrients and sediment to waterways. Dairy farming is a particular risk factor due to heavy fertiliser applications, high stocking rates and grazing management practices that often lead to soil physical damage.

The Natural Resource Action Plan for the Western Victorian Dairy Industry (Terry Makin and Associates and Mike Weise 2006) lists soil health and protection as a medium to high priority for the region. Furthermore, it lists the development of benchmarks and indicators for key soil chemical, biological and physical properties as a target.

This project (DAV 12222) addresses these issues and is the soil assessment component of the larger Heytesbury District Landcare Network's "Soil and Water Dairy Action Program", funded by the National Landcare Program.

Achievement of project objectives

The project objectives from the original proposal are:

***Objective 1.** Benchmark the current soil health status (physical, chemical and biological) of soils on dairy farms in the Curdies and Gellibrand sub-catchments of south west Victoria.*

Outcome: In Year 1 (2005/06), ten dairy properties were selected and sampled—these properties were in the Scotts Creek/Cooriemungle sub-catchment within the Curdies River

catchment. In Years 2 and 3, a further 12 dairy properties were sampled within the Curdies River Catchment, and 2 properties within the Gellibrand River catchment. On each property, 2–3 sites within each of 3 paddocks were sampled. In all, soil chemical analyses were undertaken for 157 samples, soil physical analyses on 561 samples and 87 sites were visually assessed by 2 observers using 2 visual assessment tools.

Objective 2. *Identify particular soil health risks and issues in these sub-catchments.*

Outcome: Soil phosphorus levels are more than adequate for high pasture yields and phosphorus applications could be substantially reduced, saving costs for the farmer and reducing the risk of phosphorus loss through runoff and deep drainage. Growth of some pasture species may be affected by low pH and high aluminium levels. There is a risk of animal health issues where soil potassium levels are high.

Objective 3. *Improve farmers' understanding of soil health issues in their sub-catchment, the effect that they are likely to have on sustainable production and their impact on the environment and* **Objective 4.** *Encourage the adoption of improved soil management and farming practices to improve soil quality where required.*

Outcome: As part of the Heytesbury Soil and Water Dairy Action Program, the project team have communicated information and results from the project through the following media and forums:

- 3 farmer field days (Mar 06, Feb 07, May 08)
- 24 participant reports
- 1 participant workshop (Mar 07)
- 3 posters at Heytesbury Show and Sungold Field Days
- 5 DPI soil health workshops, including local service providers
- 4 HDLN farmer reference group meetings
- 1 article WestVic Dairy news
- 2 presentations to WestVic Dairy board
- 1 booklet describing local soil types—available from HDLN and Victorian Resources Online website
- 2 conferences (Aug 07, Dec 08)
- Liaison with Accounting for Nutrients, PhD research on nutrient runoff from the local catchments, and DPI soil health projects
- Future preparation of 1–2 papers for publication in international scientific journals

Objective 5. *Adaptation, modification and field testing of farmer self assessment tools to monitor and manage soil quality for use by farmers, groups and advisers.*

Outcome: The two soil health assessment tools compared in this project—the Northern Rivers Soil Health Card and the New Zealand Visual Soil Assessment—have not met the expectations of the project team with regard to consistency between assessors, nor detection of soil health issues. Some of the factors assessed, such as soil strength and earthworm numbers, are sensitive to soil water content and therefore the scores vary with seasonal conditions. Statistical comparison of visual soil assessment data with quantitative soil chemical and physical data showed some interesting trends, but no strong correlations. While these farmer self assessment tools may be beneficially demonstrated in group situations, we recommend that greater priority be given to conducting and interpreting soil nutrient tests to plan fertiliser applications. In particular, whole farm nutrient maps, as promoted by the Heytesbury Soil and Water Dairy Action Program, can be very useful.

Objective 6. *Establish a network of sites that can be monitored in future years to determine if soil quality levels are changing over time, within each sub-catchment and soil group.*

Outcome: Baseline soil chemical and physical data have been collected from a network of 157 sites. At 87 of these sites, the soil profile has been described to a depth of 1 m while topsoil (A horizon) information is available for the remainder. This soil profile information is available from the HDLN. Geographic co-ordinates for these sites, and the baseline data, are listed in a separate confidential document.

Introduction

Soil health can be defined as “the condition of the soil in relation to its inherent, or potential, capability to sustain biological productivity, maintain environmental quality, and promote plant and animal health” (MacEwan 2007). Soil physical health (or structural quality) is important in catchment health and farm productivity for 2 main reasons (Cass *et al.* 1996). The first is the important relationship between soil physical properties and the hydrological processes that occur in catchments such as infiltration, runoff, drainage and erosion. The second is the dominant role of soil physical quality in regulating supply and storage of many of the fundamental requirements for plant growth. These requirements are water, nutrients and oxygen. The healthy functioning of soil, water and plant processes depends on the quality and stability of soil structure.

Similarly, soil chemical health has a large effect on plant growth and catchment health, particularly factors such as soil nutrient status (deficiencies and excesses), process indicators

such as soil pH and capacity factors such as the ability of the soil to retain nutrients (Merry 1996). Finally, soil biological health is responsible for important ecosystem processes in the soil and can be a useful indicator of soil change or degradation in a catchment (King and Pankhurst 1996).

High levels of both phosphorus and nitrogen occur in the surface waterways of the dairying areas of the Corangamite region (Corangamite Catchment Management Authority Nutrient Management Plan). In particular, high phosphorus levels pose a major risk in the Curdies River Estuary, leading to periodic blue-green algae outbreaks (Court pers comm). As dairying is the major landuse in the catchment, there is increasing pressure on the dairy industry to reduce the loss of P and N to waterways.

Soil chemical health, especially excessive levels of soil P, has a significant effect on the loss of dissolved P in the surface runoff to waterways (Sharpley *et al.* 2001). Other factors which influence P release from soil, and hence risk of dissolved P loss in runoff, include the dominant forms of P in soil, texture, aggregate diffusion, degree of interaction between soil and water, organic matter content, vegetative soil cover and sorption capacities (Sharpley 1983; Sharpley *et al.* 1999). Experimental evidence shows that the concentration of dissolved P in surface runoff increases exponentially with increasing surface soil P content (Sharpley *et al.* 2001), with soils of lower P buffering capacity showing the greatest increase in loss (McDowell pers comm). An important component of any strategy to reduce P losses to waterways is to minimise or reduce the build-up of P in the soil above levels sufficient for optimum plant growth (Sharpley *et al.* 2001). In the New Zealand dairy industry, a major P loss reduction strategy is to encourage dairy farmers to adjust their soil Olsen P levels to the pasture agronomic optimum for that soil type, and then through nutrient budgeting, only apply a maintenance application of P fertiliser (Monaghan pers. comm).

The New Zealand dairy industry has funded a range of soil health research and survey programs in recent years. An example is the “Best Practice Dairying Catchments for Sustainable Growth” study of four dairy catchments across the country. The project, funded by Fonterra and MAF, had primary objectives of encouraging the adoption of improved practices and to demonstrate industry commitment to change and sustainable management of the soil resource that underpins the New Zealand industry. It also included soil quality assessments on the major soil types within each of the four catchments during spring 2001. A range of soil chemical, physical and biological quality indicators was assessed for each sampling site. Some of the key findings were that some soil types were in physically poor

condition due to treading and pugging damage and in some catchments, a high proportion of sites had high Olsen P levels and represented a high risk of excessive P loss.

The New Zealand industry also has several soil health self-assessment tools that are designed to enable farmers to assess their own soils. The Dairy Soil Management System (DSMS) is a set of practical tools to monitor changes in soil quality, which can help farmers meet their production targets with minimal impact on the environment. DSMS is being developed by AgResearch and Crop and Food and has been trialled with farmer groups. Some of the tools such as Olsen P levels and macro-porosity require samples to be sent for laboratory analysis, while others, such as nutrient budgeting and earthworm counts, can be done by the farmer. Included in the system are recommendations on the interpretation of results and best management practices. A second system is the Visual Soil Assessment (VSA) developed by Landcare Research. It is based on the fact that many physical, biological and, to a lesser degree, chemical soil properties show up as visual characteristics. VSA involves a visual examination of soil samples in the field and comparison with a series of condition score photos and descriptions from the field guide booklet. Results are recorded on a score card and allow soil condition and problems to be determined. Soil management guidelines and recommendations to improve soil health are also included in the package. A number of Australian-developed soil health assessment tools, such as the “Northern Rivers Soil Health Card” are also being investigated.

In this research project, we aimed to benchmark the soil health on dairy farms in the Curdies River catchment, through measurement of selected soil physical and chemical properties, and visual assessment of soil structure and biota in the field. These measurements and assessments were undertaken at sampling locations across a range of soils to determine relationships between the techniques.

Methodology

Site location

This project was focused on the Curdies River catchment, with particular emphasis on the Scotts Creek/Cooriemungle sub-catchment. Ten dairy farms were sampled in 2005 and 7 farms in each of 2006 and 2007 (Figure 1). These farms represented the major landscape components in the catchment, and were selected in conjunction with DPI extension staff. On each of these farms, three paddocks in different landscape positions were chosen for monitoring, giving 72 monitor paddocks.



Figure 1. Location of the farms selected for soil health monitoring.

The soil types represented included:

- grey, yellow and black gradational (earth) soils
- grey, yellow and black texture contrast soils
- sands and sands with pans, and
- yellow, brown and red strongly acidic mottled texture contrast soils.

At each monitoring site, the soil profile was described in as much detail as possible, according to McDonald *et al.* (1990). In 2005, the topsoil only of the 30 paddocks was described while in 2006 and 2007, the 87 sites were described from samples hand-augered to about 1 m depth. Photographs were taken at each site for reference.

Weather data

Daily minimum and maximum air temperature, rainfall and potential evapotranspiration were sourced for Timboon (lat 38°29', long. 143°00') from the SILO data drill database (<http://www.bom.gov.au/silo/>). Monthly averages and totals for the period from July 2005 to December 2007 are presented in Figure 2. Rainfall in 2006 totalled 611 mm compared with 902 mm in 2007. Long-term average annual rainfall is about 900–950 mm (G. Ward, pers. comm.).

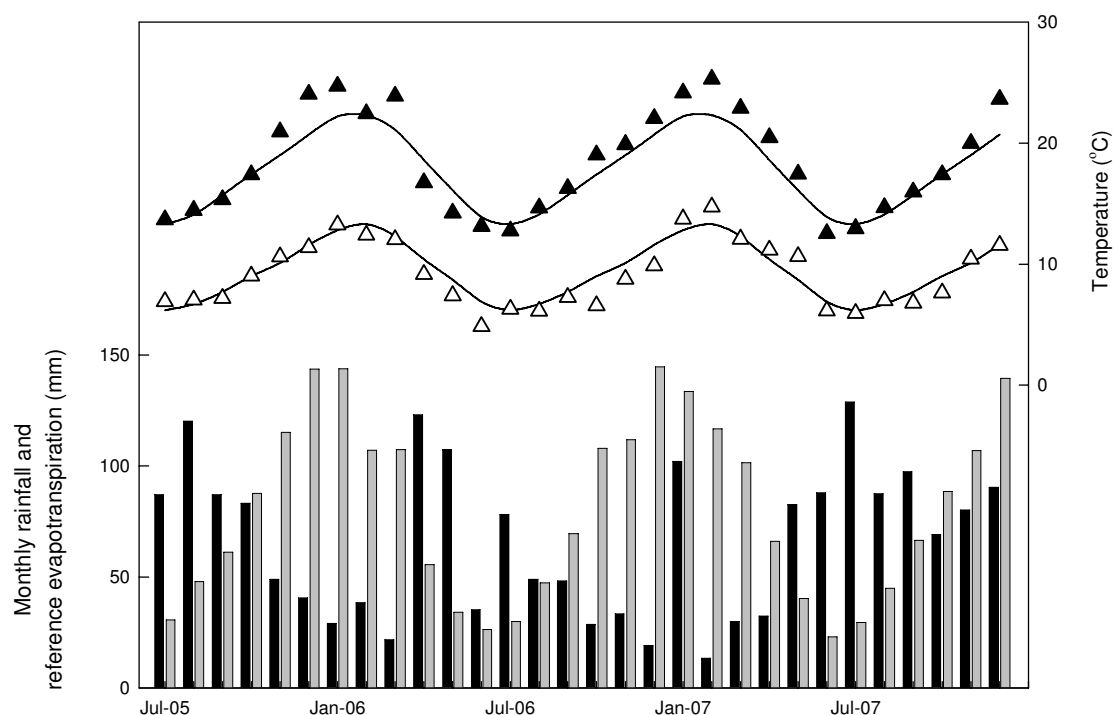


Figure 2. Monthly total rainfall (black), reference evapotranspiration (grey), average daily minimum (hollow) and maximum (solid) temperatures for Timboon, spanning the survey period. The long-term average temperatures for Warrnambool (1897–1983) are indicated by the lines.

Soil physical analyses

Sampling

During late October and early November 2005, intact soil cores were taken from each of the 30 monitor paddocks. Ten cores were taken along a transect at 10 m intervals, resulting in a

total of 300 intact cores. The cores were taken in the field by first removing the pasture mat and then driving a PVC pipe (5 cm high and 7 cm diameter) into the ground.

In October 2006 and 2007, 2–3 monitoring sites (10 m by 10 m) per paddock were selected to cover the range of expected soil physical conditions incorporating both landscape and management issues e.g low-lying vs well-drained areas, high stock density vs low stock density. For the intact cores, three 30 cm square quadrats were randomly located within the monitoring site. Within each quadrat, the herbage was cut short (and discarded) and a template with five holes, which matched the diameter of the corer was placed on the ground and the hole with the median basal cover of herbage was selected by eye. On pastures, the median plant cover has been shown to provide an unbiased estimate of the mean plant mass for the sample site (Hutchinson 1967; Nastis 1990), and we expected that this relationship would be reflected in the near-surface soil physical properties, reducing the within-site sample variability. The intact soil core was collected using a single brass cylinder (73 mm diameter and 47 mm high), hammered into the soil to a lower depth of about 60 mm. The soil and pasture thatch above the rim of the core (about 10 mm) was trimmed, as was the soil at the base of the core. Values for the 3 cores were averaged.

All undisturbed soil cores were placed into a sealed plastic bag and transported back to the laboratory, within 4 days, where they were stored in a cool room at 4 °C until analysis.

Analyses

Analyses undertaken were: volumetric soil water content as received, volumetric soil water content at 0 kPa, 1 kPa and 10 kPa tensions, measured at the base of the core, and bulk density. Air-filled porosity was calculated from the volumetric soil water content at 10 kPa tension and assuming a particle density of 2.65 g/cm³.

In the laboratory, the soil cores were trimmed flush with the rims, then weighed to determine the soil water content as received. The cores were then placed in tubs, which were filled with water to the level of the tops of the cores. The cores were allowed to wet up until free water showed at the soil surface. The cores were then placed on suction plates at 0 kPa, for at least 1 week then weighed again. The tension on the suction plate was then increased to 1 kPa for 7 days to allow equilibration, and the cores weighed again. The process was repeated for 10 kPa tension, with an equilibration time of 2 weeks. Finally, the cores were oven-dried at 105 °C, until constant weight, to determine the bulk density.

Additionally, in 2006 and 2007, the soil water content at 1500 kPa tension was determined from a bulked 0–10 cm sample from each monitoring site, which was dried at 40 °C and ground to pass a 2 mm sieve. The sample was placed into a 10 mm high by 50 mm diameter retaining ring on a ceramic pressure plate, wetted up overnight, then a pressure of 1500 kPa was applied for at least 72 hours until the soil water content reached equilibrium. The gravimetric water content was determined by oven-drying, and the volumetric water content calculated by multiplying by the average bulk density for the site.

Soil strength was also measured in 2005 and 2006 in the field with a Rimik CP20 cone penetrometer to 30 cm depth. Five insertions were made at random locations within each monitoring site, and the data averaged in 5 cm depth intervals.

The clay content of the topsoil at each site was estimated from field textures after reference to Northcote (1979).

We did not undertake the planned assessment of pugging (Nie *et al.* 2001) at each site as conditions were very dry in October 2006 (only 2 sites showed evidence of prior pugging) and severe pugging was only evident at 3 sites in 2007.

Soil chemical analyses

Sampling

During mid-December 2005 to early January 2006, the 30 monitor paddocks were sampled for nutrient status of the surface soil (i.e. 0–10 cm). Paddocks were sampled in 2–3 strata in order to gain an understanding of where high and low nutrient values occur within a paddock. When dividing a paddock for sampling, factors such as animal movement within the paddock, variation in topography, vegetation and obvious drainage lines were taken into consideration. Samples from each strata of the paddock consisted of 30–40 sub-samples taken with a foot sampler. The soil samples were then placed into plastic bags and sealed.

In October 2006 and 2007, 30 sub-samples were taken with a foot sampler, from the same 10 m by 10 m monitoring sites used for the soil physical analyses.

Analyses

All samples were dried at 40 °C and ground to pass through a 2 mm sieve. The soil samples were analysed at 1:5 soil:solution for pH in water, pH in 0.01 M CaCl₂ and electrical

conductivity (EC), Leco furnace for total nitrogen (N) and total carbon (C), Olsen extract for available phosphorus (P), CPC (calcium phosphate plus charcoal) extract for available sulfur (S), 1 M KCl for exchangeable aluminium (Al), 1M ammonium acetate extract for exchangeable calcium (Ca), magnesium (Mg), potassium (K) and sodium (Na) (Rayment and Higginson 1992). Potassium (K) was analysed according to the method of Skene (1956). The electrical conductivity of a saturation extract (EC_e) was estimated by multiplying the EC by a factor dependent on the soil texture (Peverill 1990). Exchangeable acidity, using the triethanolamine method, was also measured in 2005 only. Laboratory analyses also included physical tests such as slaking, dispersion and field texture.

The same analyses were conducted 2006 and 2007, with the exception that exchangeable acidity was not measured while phosphorus buffering index (Burkitt *et al.* 2002) was included.

Soil health self-assessment

Two soil health self-assessment tools were evaluated at each monitoring site in 2006 and 2007. The selected tools were: “Visual Soil Assessment” from New Zealand (Shepherd 2000) and the “Northern Rivers Soil Health Card” from New South Wales (Tuckombil Landcare Inc 2002). These tools were selected after a review of 8 publicly available assessment tools (Appendix A).

To test the hypothesis that visual assessment scores were similar, regardless of operator, 2 assessors independently undertook the soil health assessments at each monitoring site. The main assessor undertook these assessments at all sites, and the second assessor was rotated between 5 people. All assessors had undertaken some tertiary-level training in soil science. For some parameters, multiple measurements were made within the monitoring site, and the data were averaged.

NZ visual soil assessment

The first part of the visual soil assessment (Shepherd 2000) is for soil indicators. This involves site characterisation (texture of surface soil, moisture condition at time of sampling and seasonal weather conditions), followed by scoring of soil structure and consistence; soil porosity; soil colour (relative to a fenceline sample); number and colour of mottles and earthworm counts based on a 20 cm cube of topsoil removed from the pasture with a spade. The final soil assessment is the scoring of surface relief, which gives an indication of pugging damage.

The second part of the assessment is the scoring of plant indicators. These indicators include pasture composition, pasture growth and regrowth rates, pasture utilisation, areas of bare ground, drought stress of pastures during dry periods, degree of surface ponding, stock carrying capacity and fertiliser use.

The ranking scores of both the soil and plant indicators can then be calculated, using the weighting factors listed in the manual (Shepherd 2000). Ranking scores potentially range from 0 to 28 for soil indicators and 0 to 30 for plant indicators.

Northern Rivers soil health card

Measurements for the soil health card include: ground cover % in a random quadrat, penetrometer (home made from heavy gauge fencing wire), infiltrometer (home made from PVC tube > 50 mm diameter) and diversity of soil life in a random quadrat. From a 20 cm cube of topsoil removed from the pasture with a spade, the soil is assessed for root development, soil structure, aggregate stability, earthworm number, and soil pH (field test at 5 and 20 cm soil depth). Finally, leaf colour is assessed.

Each test is scored on a scale of 1–9, with 9 being best.

Soil health benchmarks

Benchmarks for the main soil health parameters tested are suggested in Table 1, to assist farmers and service providers relate technical data to soil health. These benchmarks are already provided for the soil health self-assessment tools. Soil health criteria for soil strength are listed in Table 2.

Data analyses

Linear regression was used to compare the visual soil assessment scores by the two assessors, and between the visual soil assessment scores and the quantitative soil chemical and physical data.

Landscape assessment for offsite impact risk

The Farm Nutrient Loss Index (FNLI) (Melland and Smith 2006) was used to identify the risk of nitrogen and phosphorus loss from each of the monitor paddocks. The FNLI indicates which of the 4 major pathways for nutrient loss—surface runoff, deep drainage, subsurface flow or gaseous emissions—are potentially contributing the most nutrients to the

environment. This knowledge can then be used by farmers and advisers to improve the efficiency of nutrient use on farms.

Table 1. Soil health benchmarks.

Soil health parameter	Optimum	Moderate	Too high or too low	Source
Bulk density (Mg/m ³)	1.1–1.3	1.3–1.4	> 1.4 or < 1.1	
Air-filled porosity (%) (at 10 kPa)	> 15	10–15	< 10	Grable (1971); Greenwood (1975); Hodgson and MacLeod (1989)
Olsen P (mg/kg)	16–25	11–15 or 26–30	<11 or >30	Melland and Smith (2006)
Total carbon (%)	>3.1	2–3.1	<2	Target 10 (2005)
pH _{Ca}	4.7–6.5	4.3–4.7 or 6.5–7.6	<4.3 or >7.6	Target 10 (2005); Merry (1996)
ECe (dS/m)	<1.8	1.8–3.8	>3.8	Target 10 (2005); Shaw (1999)
ESP (%)	<6	6–15	>15	Northcote and Skene (1972)
Skene K (mg/kg)	150–200	100–150 or 200–250	<100 or >250	Gourley (1989; 1996)
CPC S (mg/kg)	9–12	4–8 or 13–20	<4 or >20	Target 10 (2005); Lewis (1996)
Al (KCl method)(mg/kg)	0–50	>50		Target 10 (2005)

Some of the data required to determine the FNLI were included in the soil chemical analyses. Additional observations such as soil profile type, slope and land shape, % water-logged area, runoff modifying features, proximity to waterways, groundcover (%), pasture type, depth to groundwater, and extent of nutrient hotspots were recorded at the time of soil health self-assessment. The farmer's input was required to determine the timing and rate of nitrogen and phosphorus applications, timing, rate and method of effluent application and stocking rate.

Table 2. Descriptive labels relating the effect of soil strength to root growth (Mullins *et al.* 1992).

Soil strength (MPa)	Effect on root growth
<0.75	Easily rootable
0.75–1.5	Significant impedance
1.5–3	Poorly rootable
3–6	Little or no growth
>6	Impenetrable

Results and discussion

Soil health benchmarks

Soil chemical properties

The main soil chemical properties for all 157 sites are shown in Figure 3. Soil pH_{Ca} was within the optimum range for about two thirds of the samples. However, for about one third of the sites, the soil pH_{Ca} was 4.7 or lower, indicating that these pastures could profitably respond to lime application. Potential problems that can occur in acid (low pH) soils include aluminium and manganese toxicity; decreased availability of major nutrients to plants; decreased soil biological activity and hence reduced nutrient cycling; reduced nodulation of legumes by rhizobia and reduced root growth leading to greater frequency of water stress and reduced nutrient uptake (Target 10 2005).

Further evidence of potential problems with low pH is the strong relationship between pH_{Ca} and available aluminium (Figure 4). For soils with a pH_{Ca} greater than 5, exchangeable aluminium levels were at or below the detection limit of 5 mg/kg. However, for pH_{Ca} less than 4.7, there were some very high exchangeable aluminium values, and about 50% of the sites sampled had high aluminium levels. While ryegrass and tall fescue are moderately tolerant of high aluminium levels, there may be some reduction of their root growth with consequences for water and nutrient uptake on these low pH, high aluminium soils (Slattery *et al.* 1999).

Soil pH can be increased, and hence aluminium levels reduced, by applying agricultural lime. The Target 10 Soils and Fertilisers program (Target 10 2005) includes a large section on correcting soil acidity by application of lime.

Soil salinity was high ($\text{ECe} > 3.8 \text{ dS/cm}$) on about 10% of the sites sampled. One of these sites was a sacrificial feed area while another was close to the Curdies River estuary. Most of the other saline samples were from the 2005 sampling which was undertaken in late December, compared with October sampling in 2006 and 2007. Possibly this later sampling in 2005 resulted in temporarily high salinities at local discharge areas (often where there is a break of slope) where, at wetter times of the year, the salts would have been flushed down the profile by rain. The general consensus of DPI staff with considerable local knowledge was that soil salinity was not a major issue in the Heytesbury region (Jo Crosby and Graeme Ward, pers. comm., January 2008).

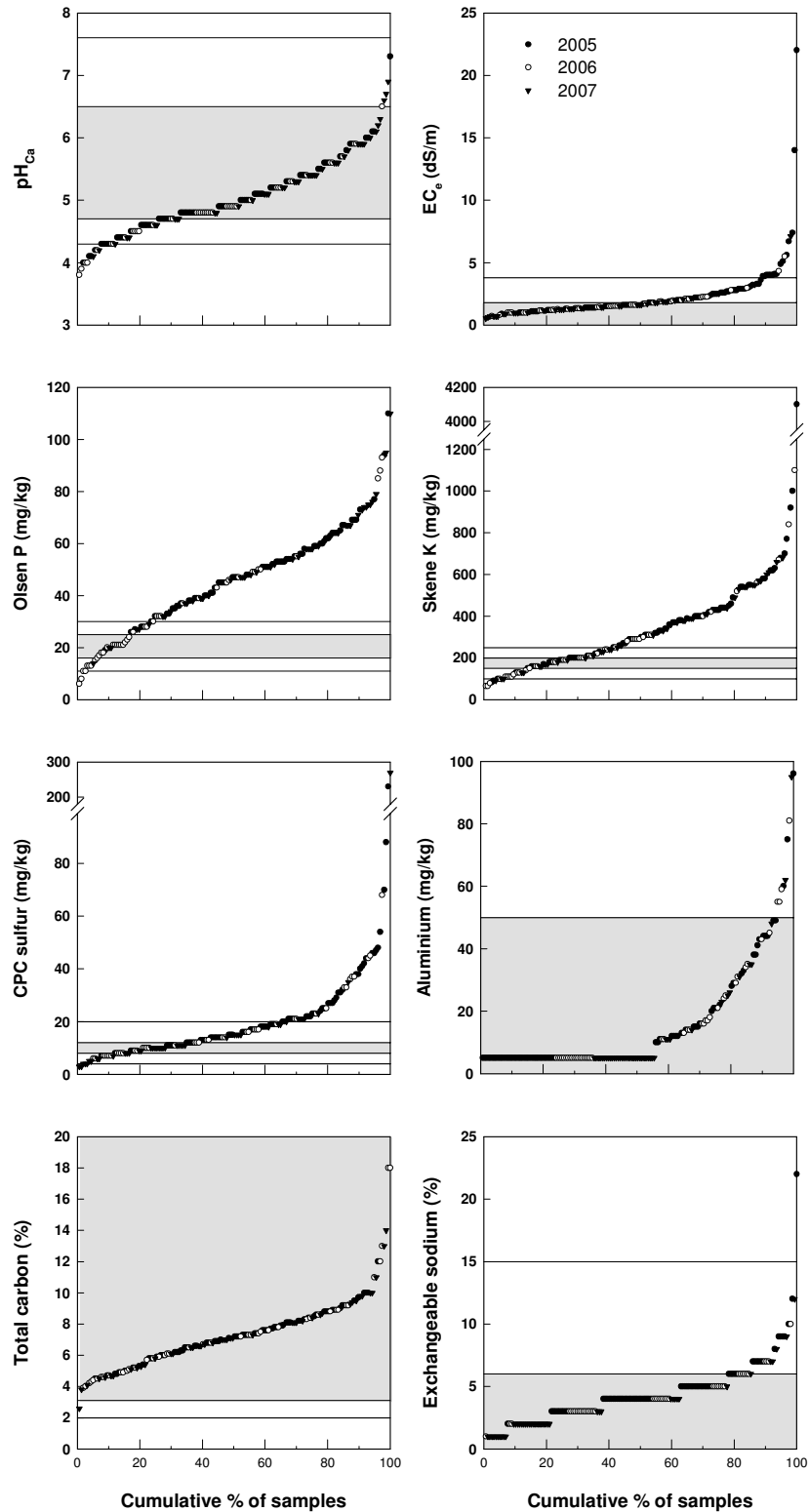


Figure 3. The main soil chemical properties from the monitoring sites in the Heytesbury district. The data are ranked in order from lowest to highest to enable the proportions in each category to be determined. In each graph, the optimum level from Table 1 is shaded and the lines indicate intermediate levels.

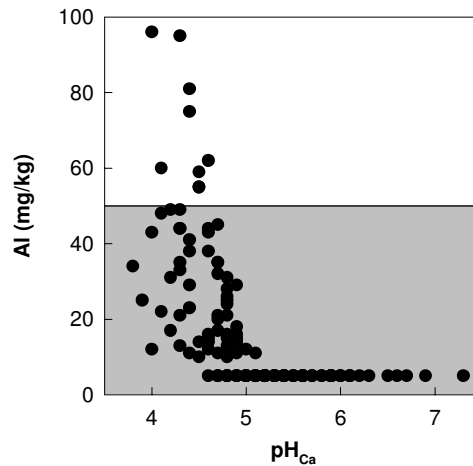


Figure 4. Relationship between soil pH and exchangeable aluminium levels. The optimum levels for Al are shaded.

Soil Olsen P levels were high (> 25 mg/kg) in 75% of the samples tested. The median value of the 157 samples was 47 mg/kg. These levels are much higher than the critical Olsen P soil test value of 15 mg/kg, which is required to achieve 95% of maximum pasture production (Gourley *et al.* 2007) and higher than the range of 18–22 mg/kg formerly recommended by DPI (Target 10 2005). At these high Olsen P levels, there is little if any pasture growth response to applied P fertiliser, and more fertiliser is required to maintain these high levels (Saul *et al.* 1999). With current high fertiliser prices, farmers with these high soil P levels have the opportunity to save a considerable amount of money (potentially tens of thousands of dollars) by reducing or stopping their fertiliser P application. Annual monitoring of soil P levels will assist farmers to determine when to recommence maintenance applications.

A minority of sites tested (about 5%) had Olsen P levels less than 15 mg/kg, and most of these occurred on one farm. This farmer, who had recently purchased the farm, was aware that these low Olsen P levels may be limiting pasture production and was applying capital applications of fertiliser to increase the P status of his soils.

As Olsen P measures available P, it is independent of soil type (Gourley *et al.* 2007). Figure 5 shows that there was no relationship between Olsen P and the estimated clay content of the monitoring sites, and also no relationship between Olsen P and the phosphorus buffering index (PBI). The two sites with very high PBI's were both low-lying and had total carbon contents of at least 10% and clay contents of 27–32%. A few sites had PBI's less than 50 indicating that the phosphorus would be prone to leaching. On these soils, smaller quantities of P, if required, should be applied throughout the year.

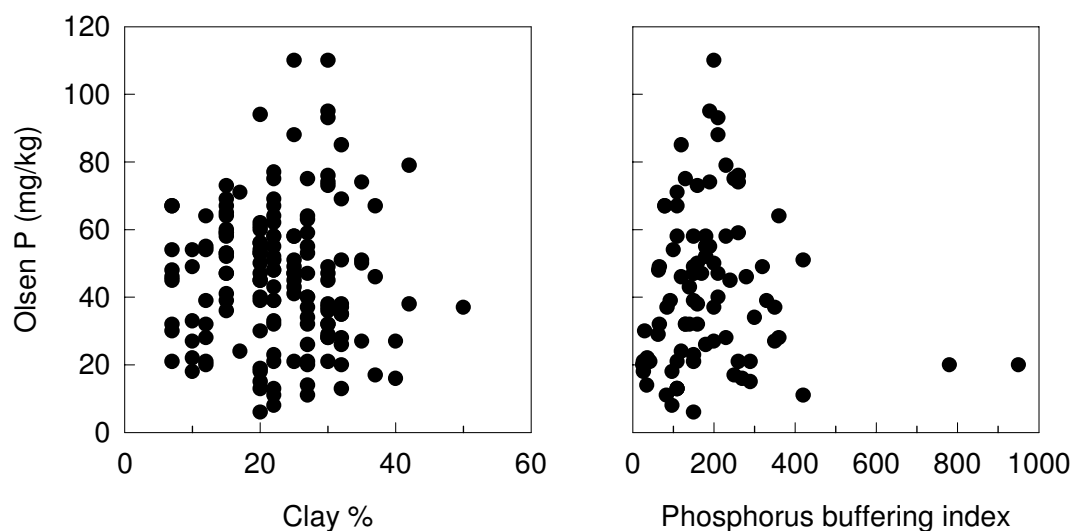


Figure 5. Olsen P levels were not related to either the clay content of the soil or the phosphorus buffering index.

High soil phosphorus levels increase the risk of loss of P to local waterways (Dougherty *et al.* 2004; Melland *et al.* 2007; Melland *et al.* 2008). Phosphorus concentrations in runoff from dairy pastures are usually in the range 1–10 mg/L (Nexhip *et al.* 1997; Nash and Murdoch 1997; Mundy *et al.* 2003) while the water quality targets for Victorian coastal rivers, such as the Curdies River, are 75% of samples less than 0.045 mg/L (State of Victoria 2003). High levels of P in runoff are exacerbated by recent applications of fertiliser or dung (Dougherty *et al.* 2004), higher annual rates of fertiliser application (Robertson and Nash 2008), proximity to the waterway, and factors which lead to greater surface runoff such as steep slopes and water-logged areas (Melland *et al.* 2007). Farmers can reduce the risk of P loss by not exceeding the soil Olsen P levels required for high pasture production, avoiding fertiliser application when rainfall is imminent and avoiding high fertiliser applications in seasonally waterlogged areas.

The Skene potassium levels, shown in Figure 3, are generally very high. The average value is 358 mg/kg, while the median is 300 mg/kg. Critical values to achieve 95% of potential pasture production vary with soil texture, but range between 126 and 161 mg/kg (Gourley *et al.* 2007). The highest potassium level was 4100 mg/kg on a sacrificial feed area. Where soil potassium levels are high, potassium inputs can be reduced or deleted from the fertiliser regime. Farmers with low potassium levels would need to check their individual soil test results with the critical value appropriate for their soil type (Gourley *et al.* 2007). Guidelines for capital and maintenance applications of potassium fertilisers are provided in the Target 10 Soils and Fertilisers program (Target 10 2005).

High potassium levels are potentially a concern for farmers, as they are implicated in the occurrence of grass tetany (hypomagnesaemia) in near-calving and lactating cows. The causes of grass tetany are complex, and the incidence varies between seasons but may affect up to 30% of cows in a particular herd (Harris 1997). Most cows clinically affected by grass tetany will die. Some management options to reduce the risks of grass tetany include determining fertiliser applications of potassium from soil test results (soil potassium levels should not exceed the critical values required for pasture growth), avoid grazing pastures soon after they are fertilised with potassium and, when using potassium fertilisers, ensure that pasture growth is not limited by other nutrient deficiencies (Harris 1997).

Soil sulfur (CPC test) levels were also generally high within the monitoring area. The average value is 22 mg/kg, while the median is 15 mg/kg and the maximum 270 mg/kg. The critical value for CPC sulfur has recently been revised down to 3 mg/kg (Gourley *et al.* 2007), compared with 9–12 mg/kg formerly considered adequate (Target 10 2005). While high soil sulfur levels are not associated with any adverse pasture production, animal health or off-site environmental effects, further sulfur applications could be minimised for one or more years, until adequate levels are indicated by soil testing.

Total carbon levels were generally high in the monitoring sites, ranging between 2.6 and 18%, with an average and median of 7.2%. Pastures in a high rainfall zone would typically have total carbon levels in the range 3.1 to 6.2% (Target 10 2005). The high total carbon levels in the Heytesbury area reflect the high rainfall conditions and the perennial nature of the pastures on most of the monitoring sites. High carbon levels are good for improving soil structure and holding nutrients.

Soil sodium levels were generally less than 6% exchangeable sodium percentage (ESP). At ESP's greater than 6%, many Australian soils are susceptible to structural problems such as dispersion and slaking (Northcote and Skene 1972). However, even the samples with higher ESP's in our survey showed little, if any, evidence of dispersion or slaking in laboratory tests, probably due to the high carbon contents.

The sum of cations ranged between 4 and 46 meq/100 g, with an average of 14 meq/100 g and a median of 12 meq/100 g. The higher the sum of cations, the greater the ability of the soil to hold nutrients, and a sum of cations greater than 15 meq/100 g is considered good (Target 10 2005). Sum of cations, however, is dependent on soil type and organic matter content (Figure 6). The outlying points on the bottom right of each graph in Figure 6 had either a high clay content (estimated at 50%) and low total carbon (2.6%) or low clay content

(about 10%) and high total carbon (18%). Split applications of K and S fertilisers may be more appropriate on soils with a low sum of cations (Target 10 2005).

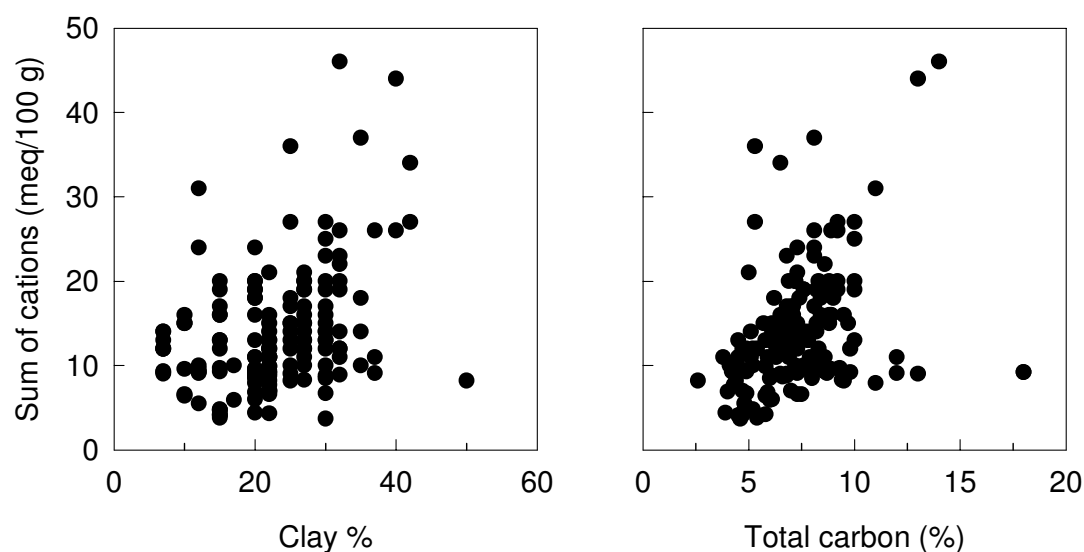


Figure 6. The sum of cations was positively correlated with both clay content and carbon content.

While these soil chemical results are from bulked sub-samples from either substrata within the paddock (2005) or 10 m by 10 m monitoring sites (2006 and 2007), rather than whole of paddock samples, they are still representative of soils on dairy farms within the region. Soil testing by an independent laboratory in 2007 of whole of paddock samples collected at the same time and from the same paddocks as the monitoring sites showed good agreement between the data for all analyses (Appendix B).

Soil physical properties

Soil bulk densities in the Heytesbury district were generally within or below the optimum range (Figure 7). We speculate that at these bulk densities, root growth would be possible at most water contents greater than permanent wilting point. While not directly influencing plant growth (Letey 1985; Williams *et al.* 1987), bulk density has been found to be a useful indicator of soil changes due to grazing and has the advantage of being relatively easy to measure (Greenwood and McKenzie 2001).

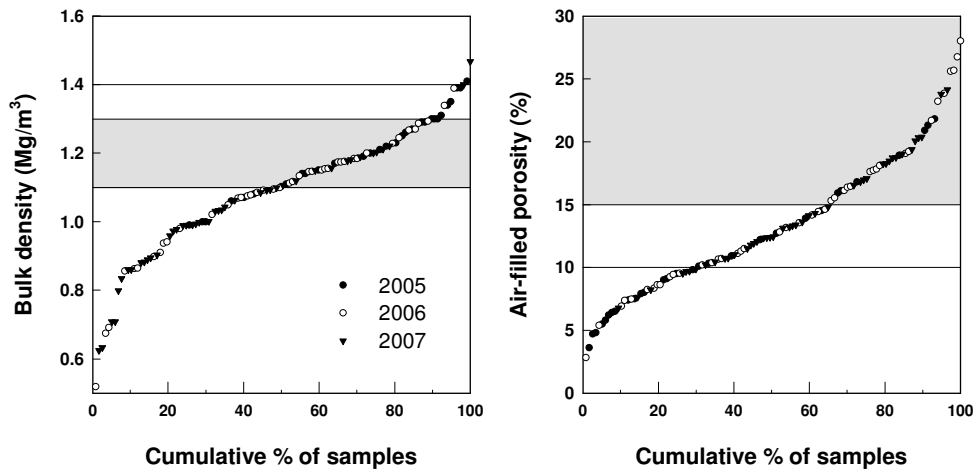


Figure 7. Two soil physical properties—bulk density and air-filled porosity—from the monitoring sites in the Heytesbury district. The data are ranked in order from lowest to highest to enable the proportions in each category to be determined. In each graph, the optimum zone from Table 1 is shaded.

The lower optimum bulk density of 1.1 Mg/m^3 is a speculative value included because of the greater risk of pugging at low soil densities (Scholefield and Hall 1985). However, as shown in Figure 8, there is a strong correlation in this data set between bulk density and total carbon content, with the high carbon contents presumably assisting these low bulk density soils to resist deformation (Guérif 1979; Ohu *et al.* 1985; Gupta *et al.* 1987).

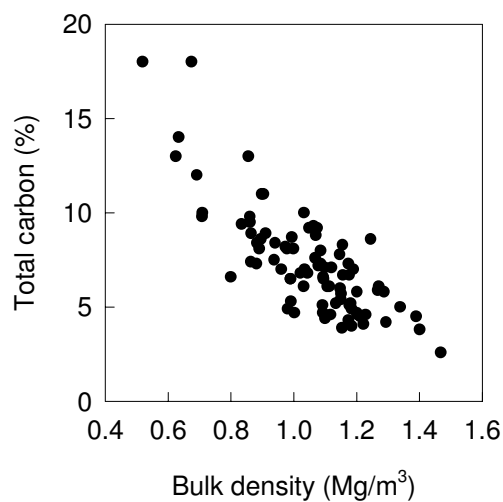


Figure 8. There was a strong negative correlation between bulk density and total carbon.

The air-filled porosity of samples from the monitoring sites, when assessed at field capacity (10 kPa soil water tension), was generally moderate to high (Figure 7), indicating that oxygen and carbon dioxide diffusion rates would only be limiting plant growth when the soil is poorly drained. Poor drainage reduces the air-filled porosity of the soil and gas diffusion through the water-filled pores in negligible. The consequences of poor aeration for pasture

production may include wilting, chlorosis, decreased dry matter production and death. Other potential problems of water logging and poor aeration include reduction of nitrate to gaseous nitrogen, possible interactions with pathogens and disease, and reduced nutrient absorption. Waterlogging in spring can be more detrimental to pasture growth than waterlogging in the winter, due to higher temperatures promoting greater respiration, and hence, depleting oxygen more rapidly. In areas which are poorly drained, farmers may consider installing some form of surface or subsurface drainage to improve pasture production.

The soil strength measured at each monitoring site at the time of sampling is shown in Figure 9. The figure clearly shows the typical exponential relationship between soil strength and soil water content (Greenwood *et al.* 1997), despite these measurements being from different soil types and across a range of management conditions. In 2006, the average soil water content was 0.25 kg/kg and the average soil strength was 2.9 MPa while, in 2007, the average soil water content was 0.49 kg/kg and the average soil strength was 1.3 MPa. Obviously in the wetter soils, there was potential for greater root growth due to lower mechanical impedance. Note, however, that while high soil strengths may severely limit root growth, the roots may still be functioning and absorbing water and nutrients.

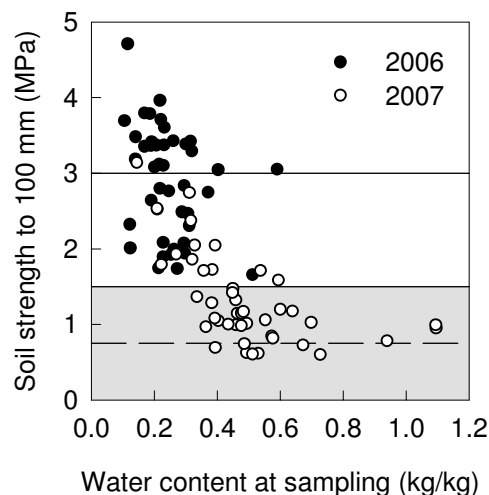


Figure 9. The average soil strength in the top 100 mm at each monitoring site was correlated with the soil water content at the time of sampling. The optimum range from Table 2 is shaded.

The available water content is the amount of water between field capacity and permanent wilting point, and this water is available for plant growth. The available water content of the soils at the monitoring sites in 2006 and 2007 is shown in Figure 10, and agrees with the general principle that available water content is higher for loamy soils than either sandy or clayey soils (Brady 1974). The high carbon contents of these soils in the Heytesbury district has also increased the available water content relative to typical values for these clay contents

(Allen *et al.* 1998). With an available water content of $0.2 \text{ m}^3/\text{m}^3$ over a rooting depth of 0.6 m, a pasture plant would have access to about 120 mm water, which is high for an Australian soil.

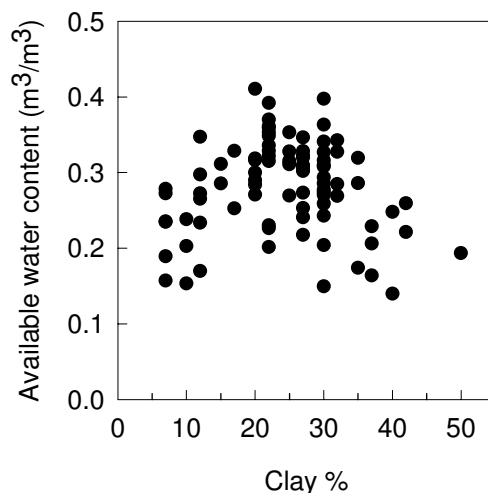


Figure 10. The available soil water content is highest at intermediate clay contents, and lowest in both sandy and clayey soils.

Soil biological properties

Soil biota are important for the decomposition of organic matter and mineralisation of nutrients, as well as assisting in the maintenance of good soil structure. However, assessment of soil biota as indicators of soil health requires specialist expertise which is not generally available in commercial laboratories (King and Hutchinson 2007). Often chemical surrogates for soil biota, such as organic matter contents, active or labile carbon, and potentially mineralisable nitrogen are used in soil health assessments (Gugino *et al.* 2007). In a review of invertebrate bioindicators, King and Hutchinson (2007) questioned whether soil invertebrates are sensitive to subtle changes in pasture systems, and therefore also recommended the use of surrogates such as soil carbon, soil nutrient levels and the botanical composition of pasture.

In this report, soil carbon and other nutrient levels have been discussed in the soil chemical properties section and earthworm numbers are discussed in the following section on soil health self-assessment tools.

Soil health self assessment tools

Using the NZ visual soil assessment (VSA) (Shepherd 2000), most monitoring sites scored well for plant indicators of soil quality and moderate to good for soil indicators (Figure 11).

Many sites, especially in 2006, had a visual score of 0 for less than 10 earthworms per shovelful of soil, which reduced the ranking by 6 points. Most other indicators had a moderate to good visual score.

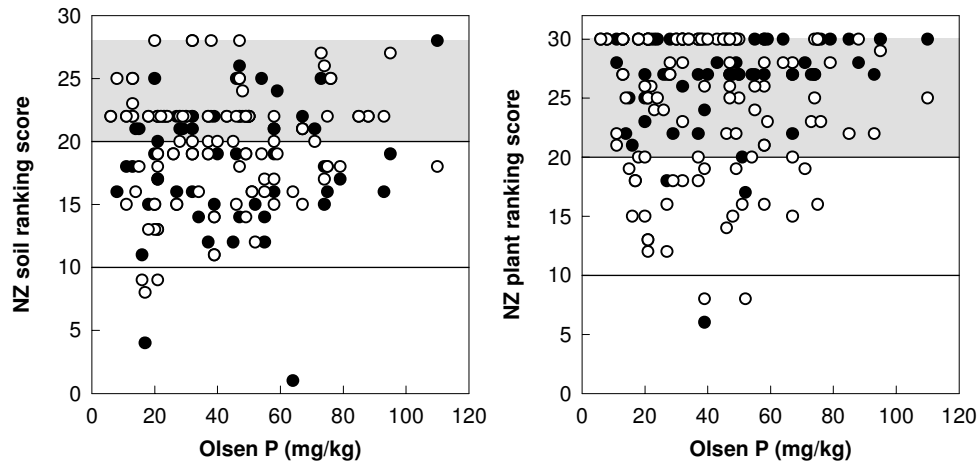


Figure 11. Comparison of the NZ soil ranking and plant ranking scores with soil Olsen P levels. The optimum zones for ranking scores are shaded (Shepherd 2000).

The NZ VSA ranking scores showed interesting relationships with soil Olsen P levels (Figure 11). In both cases, the data are clustered within the upper and/or left-hand side of the graph, indicating that high ranking scores are possible regardless of the soil Olsen P level, but with one exception, all soils with high Olsen P levels also had high ranking scores.

Agreement between independent observers was not as high as expected as shown in Figure 12. While there was a statistically significant relationship between observers, the slopes were not close to 1, the intercept for the soil ranking score was not close to 0, and the r^2 values were low (Table 3). In addition, the root mean square error (RMSE—a weighted average

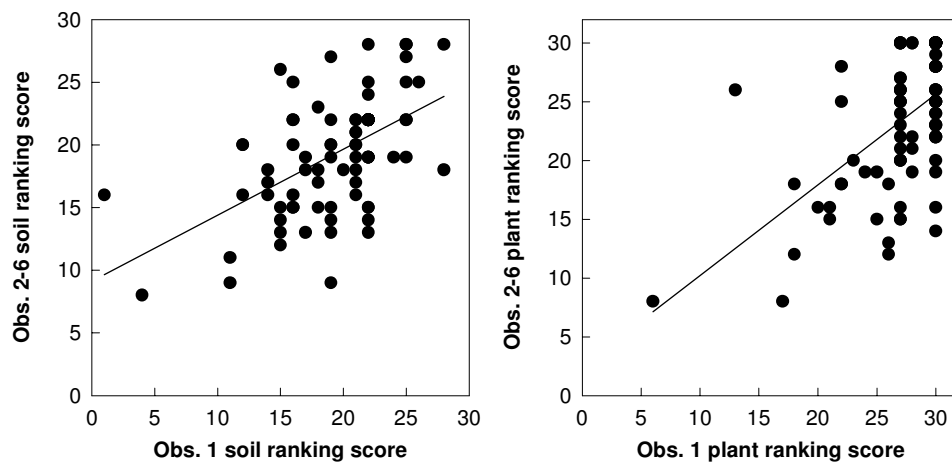


Figure 12. Comparison between the ranking scores of different observers at the same monitoring site.

difference between observers) was 4.3 for soil indicators and 6.1 for plant indicators, which is much higher than the difference of 2 units which we would consider acceptable.

Table 3. Regression coefficients, residual degrees of freedom (df), root mean square error (RMSE), and coefficients of determination (r^2) for the regression equation of the form: Obs. 2-6 = m x Obs. 1 + c

Parameter	NZ soil ranking score	NZ plant ranking score
m (slope)	0.53	0.77
c (constant)	9.1	2.5
df	86	84
r^2	0.29	0.32
RMSE		

For the Northern Rivers soil health card (Tuckombil Landcare Inc 2002), the majority of farms scored well in the ground cover, root development, soil structure, soil slaking and leaf colour categories (Table 4). Scores were moderate to good for soil pH, poor for macrolife diversity and infiltration, and variable for earthworm numbers and soil strength. Soil conditions were much wetter in 2007 than when sampled in 2006 and would have contributed to the better soil strength scores and high earthworm numbers that year. However, macrolife diversity remained low, even in 2007.

Table 4. Summary of visual assessment scores for the Northern Rivers soil health card. Ratings are on a scale of 1-9, with 9 being the best. The root mean square error (RMSE) is a weighted estimate of the variability between observers.

Category	Average	75 th percentile	Median	25 th percentile	RMSE
Ground cover	8.0	8.8	8.3	7.6	1.0
Penetration	5.8	7.8	6.1	4.0	1.8
Infiltration	2.2	2.7	2.0	1.0	1.4
Macrolife diversity	2.4	3.4	2.2	1.4	1.2
Roots	6.9	8.0	7.0	6.0	1.2
Structure	7.1	8.0	7.0	6.0	1.6
Slaking (5 cm)	6.8	8.0	7.0	6.0	2.2
Slaking (20 cm)	6.5	8.0	7.0	6.0	2.3
Worms	3.8	7.0	2.0	1.0	2.9
Acidity (5 cm)	5.1	7.0	5.0	3.0	2.3
Acidity (20 cm)	4.8	7.0	5.0	3.0	2.6
Leaf colour	7.4	8.0	8.0	7.0	1.4

Agreement between independent observers was also poor for the Northern Rivers soil health card. The best agreement between observers was for the ground cover score (RMSE = 1.0), at least partly due to the narrow range of scores. The categories with the greatest difference between observers (RMSE > 2) were slaking, worms and pH. Despite revising our definition of slaking after the sampling in 2006, the differences between observers were as large in 2007. The variability between observers for worm scores were not surprising, given that worms can be spatially variable and the size of the sample sorted varied between individuals. In 2007, we also recorded the actual field pH, and there was better agreement between observers, with RMSE's of 0.6 pH units at 5 cm depth and 0.9 pH units at 20 cm depth. We recommend that actual field pH values be recorded, rather than the assessment score.

There was good agreement between the field pH and the analytical results for pH (Figure 13). Farmers concerned about low pH levels could quickly and cheaply check a large number of soils within their paddocks to assess whether lime is required or, if in doubt, whether further tests should be undertaken. For example, if the field pH is 6 or less, a laboratory test would be warranted.

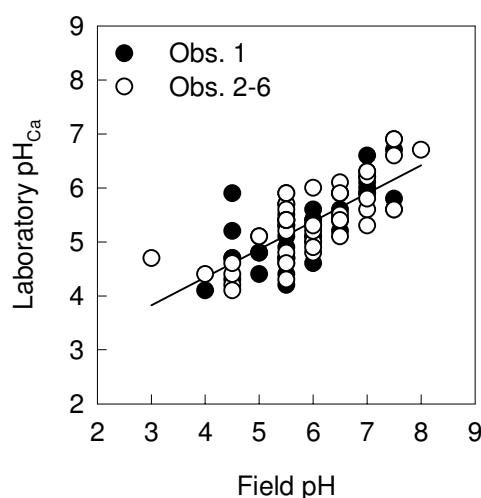


Figure 13. Correlation between the field pH and the laboratory test of pH_{Ca} from the bulked sample for the 2007 monitoring sites.

There was a significant correlation between the soil strength scores for all observers and the quantitative measures from the cone penetrometer (Figure 14), although individual observer biases are apparent. As a rapid, low-cost indicator of soil strength, this test was particularly useful. However, soil strength is not a good indicator of soil health as it varies with soil water content (Figure 9). Usually, differences in soil strength between soil management treatments are more pronounced when the soil is dry (Greenwood *et al.* 1997), however it is more easy to standardise the soil water content when the soil is wet i.e. near field capacity.

Also, while soil strength (mechanical impedance) has a direct impact on root growth, it probably has minimal effects on root functioning (uptake of water and nutrients). Therefore,

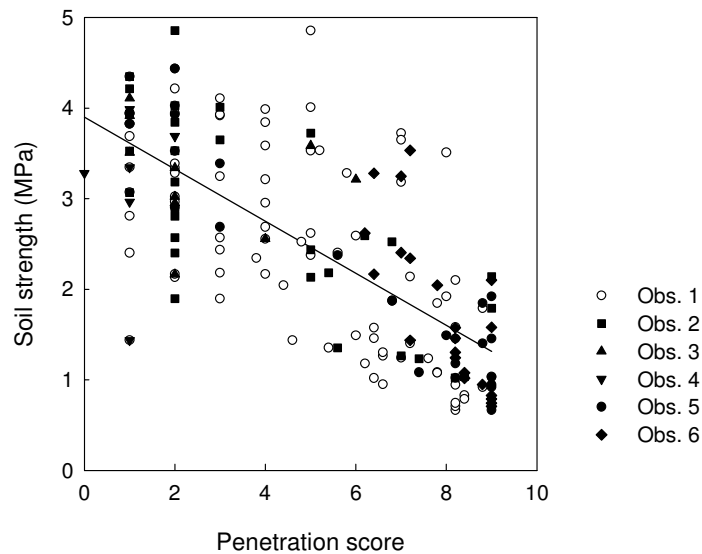


Figure 14. Penetration score was a reasonable predictor of soil strength measured with a cone penetrometer (data averaged to 200 mm depth).

in permanent pastures, soil strength is unlikely to be limiting pasture production if water and nutrients are readily available.

There were statistically significant linear correlations between the visual soil assessments, for both observers, and the quantitative measures listed in Table 5. However, the strength of these correlations for most of these regressions was small, with only the relationships between NZ soil ranking score and total carbon, NZ soil ranking score and exchangeable Ca, NZ soil ranking score and saturation water content, Northern Rivers penetration and pHCa, and Northern Rivers roots and field capacity having r^2 values of 0.1 or greater. Note that there was a negative correlation between NZ soil ranking score and total carbon, whereas a positive correlation would have been expected.

There were no correlations between any visual assessment scores and soil Olsen P or Skene K levels—parameters identified earlier as being important in the Heytesbury region. Only 2 visual assessment scores were correlated with soil pH: penetration and leaf colour, and neither could be relied upon to detect low soil pH due to high variability (Figure 15).

Table 5. Pairs of visual assessments and quantitative parameters which had a statistically significant linear regression. The r^2 is the proportion of variation in the quantitative parameter accounted for by the visual assessment.

Visual assessment	Quantitative measure	Slope	r^2
<i>New Zealand Visual Soil Assessment</i>			
Soil ranking score	Total carbon (%)	-0.203	0.11
	Electrical conductivity (dS/m)	-0.005	0.05
	CPC sulfur	-1.23	0.04
	Ca:Mg	0.128	0.05
	Exchangeable Ca (%)	0.861	0.16
	Exchangeable Na (meq/100 g)	-0.0364	0.06
	Sum of cations (meq/100 g)	-0.329	0.03
	Saturation water content (vol. %)	-0.441	0.10
	Field capacity (vol %)	-0.391	0.08
	Permanent wilting point (vol. %)	-0.370	0.08
Plant ranking score	Exchangeable Na (%)	-0.119	0.09
<i>Northern Rivers Soil Health Card</i>			
Penetration	pH _{Ca}	0.106	0.13
Ground cover	Bulk density (Mg/m ³)	-0.0437	0.06
Macrolife diversity	CPC sulfur	0.357	0.00
Roots	Phosphorus buffering index	33.4	0.07
	Field capacity (vol %)	2.23	0.15
	Air-filled porosity (%)	-1.24	0.06
	Available water capacity (vol %)	1.49	0.07
	Clay (%)	2.49	0.08
Leaf colour	pH _{Ca}	0.129	0.09
	Exchangeable Mg (meq/100 g)	0.175	0.01
	Clay (%)	1.39	0.05

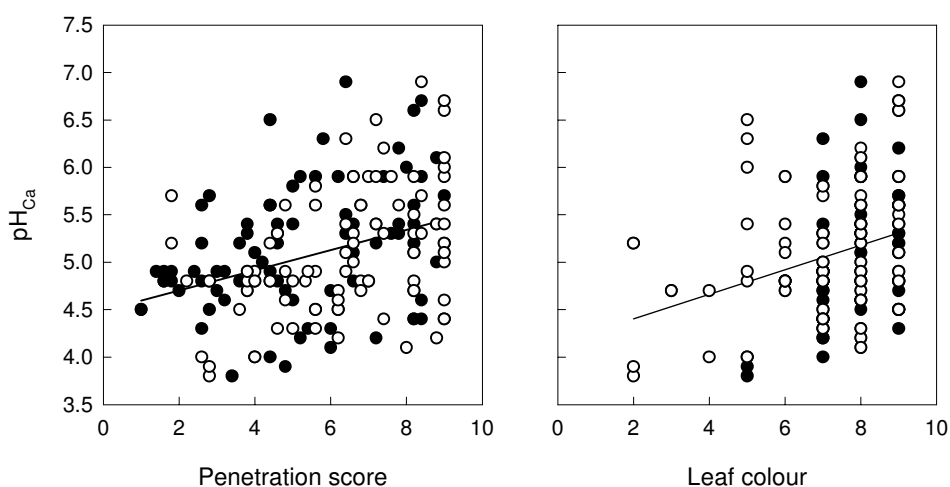


Figure 15. The relationship between soil pH and the Northern Rivers soil health card scores for penetration and leaf colour.

The two soil health self-assessment tools compared in this project—Northern Rivers SHC and the New Zealand VSA—have not met the expectations of the project team with regard to consistency between assessors, or to detecting potential soil health risks. However, the tools may be useful for service providers and others involved with farmer groups to generate interest and understanding of soil types and soil health issues. Field measurement of soil pH has the potential to alert farmers to low soil pH levels, but low field pH tests should be followed up by a quantitative soil test from a bulked sample. Soil health self-assessment tools are not recommended as a surrogate for soil testing.

Landscape assessment for offsite impact risk

The Farm Nutrient Loss Index (FNLI) (Melland *et al.* 2007) was used to assess the risk of nutrient loss at each monitoring site in 2006 and 2007 (Table 6), with the exception of one farm where fertiliser information was not available. With the exception of nitrogen in deep drainage, most sites were in the low or medium risk categories. The factors which contributed to the high risk of phosphorus in runoff and subsurface lateral flow were the Olsen P levels, phosphorus application rates and soil types. The factors which contributed most to the high risk of nitrogen in deep drainage were either a sandy soil type or high fertiliser rates associated with high stocking rates.

Table 6. Number of sites (of a total of 81) in each FNLI risk category.

Risk category	Phosphorus			Nitrogen			Greenhouse N gas emission
	Runoff	Subsurface lateral flow	Deep drainage	Runoff	Subsurface lateral flow	Deep drainage	
Low	69	62	34	75	79	28	55
Medium	9	15	45	6	–	2	24
High	3	4	–	–	2	51	2
Very high	–	–	2	–	–	–	–

Intuitively, the risks of phosphorus losses in runoff and subsurface lateral flow would be higher than categories indicated in Table 6, given that the median Olsen P level was 47 mg/kg. One possible reason for these seemingly low risks is that the FNLI gives the same high risk factor to any Olsen P level over 30 mg/kg (Melland *et al.* 2007). Hence, all other things being equal, a site with an Olsen P of 100 mg/kg, or 47 mg/kg, will be in the same risk category as a site with an Olsen P of 31 mg/kg. Hence, the risks of off-site phosphorus impacts, given in Table 6, seem to be conservatively low.

Industry implications

The main industry implications of this project are:

- Soil Olsen P levels were very high at most of the monitoring sites within the Heytesbury district. Farmers could reduce, or temporarily cease, their phosphorus applications and still maintain high pasture productivity while saving costs. If soil Olsen P levels were reduced on dairy farms within the Curdies River catchment, it is likely that the water quality within the Curdies River and its tributaries would improve and the incidence of algal blooms would decline.
- Pastures on soils with low pH and high aluminium levels could profitably respond to application of lime. Many of the pastures on the most severely affected soils would probably need to be resown with more desirable species once the soil pH, particularly in the subsoil, had increased. In the Heytesbury region, it appears that 5.0 is the critical pH_{Ca} , below which high aluminium levels are potentially a problem.
- Where soil potassium levels are high, potassium inputs can be reduced or deleted from the fertiliser regime. High potassium levels are potentially a concern for farmers, as they are implicated in the occurrence of grass tetany (hypomagnesemia) in near-calving and lactating cows.
- The high total carbon levels in the Heytesbury area reflect the high rainfall conditions and perennial nature of most of the pastures. High carbon levels are good for improving soil structure and holding nutrients.
- The soil physical conditions in the Heytesbury area during the monitoring period (2005–2007) were generally good, with little evidence of pugging due to the relatively dry conditions. The Department of Primary Industries has Agriculture Notes available on their web site (www.dpi.vic.gov.au and select Information Notes Series) for the management of wet soils including use of subsurface drainage, stand-off areas, feed pads, on-off grazing and renovation of damaged pastures and soils.
- Soil chemical testing was able to identify potential soil health risks which were not detected by soil visual assessments. In particular, the production and use of whole farm nutrient maps, as supported by the Heytesbury District Landcare Network, would assist farmers to identify and manage soil health issues on their property.

Benefit/cost implications

The industry issues identified by this research have potentially very high benefit/cost implications. The main implications are:

- Reduction in the need for phosphorus, sulfur and potassium fertilisers on most farms within the Heytesbury region.
- Profitable increases in pasture productivity through the application of lime, and possible re-sowing of pastures, on soils with low pH and high aluminium levels.

Anecdotal evidence indicates that many farm businesses could save tens of thousands of dollars through managing their fertiliser applications in accordance with soil test results.

Communication

As part of the Heytesbury Soil and Water Dairy Action Program, the project team have communicated information and results from the project through the following media and forums:

- 3 farmer field days (Mar 06, Feb 07, May 08)
- 24 participant reports
- 1 participant workshop (Mar 07)
- 3 posters at Heytesbury Show and Sungold Field Days
- 5 DPI soil health workshops, including local service providers
- 4 HDLN farmer reference group meetings
- 1 article WestVic Dairy news
- 2 presentations to WestVic Dairy board
- 1 booklet describing local soil types—available from HDLN and Victorian Resources Online website
- 2 conferences (Aug 07, Dec 08) where project results were presented
- Liaison with Accounting for Nutrients, PhD research on nutrient runoff from the local catchments, and DPI soil health projects
- Future preparation of 1–2 papers for publication in international scientific journals

Future research

Feedback from farmer groups during the communication of these project results indicated that many farmers were reluctant to accept the veracity of research supporting optimum Olsen P levels of the order of 15–25 mg/kg. Given that individual farmers could potentially save large amounts of money by reducing their phosphorus fertiliser use, and the local environment would consequently benefit through better water quality in the local rivers and

streams, it seems necessary that research trials are undertaken locally to demonstrate that high levels of pasture production can be maintained at Olsen P levels of 15–25 mg/kg. To have the greatest impact, these trials would need to be conducted with farmer groups involved throughout the research process, including site selection, experimental design, management procedures, data collection, analysis and interpretation.

This research has highlighted soil health issues with offsite environmental implications. It would be useful to demonstrate the benefits of any changed fertiliser management practices through a repeat of this soil health benchmarking in 5–10 years time, and possible correlation with water quality conditions in the Curdies River.

This soil health benchmarking process could be usefully extended to other dairy catchments within Australia. The data complements other industry survey data such as the Australian Dairy Industry in Focus.

New research areas associated with climate change, such as life-cycle assessments and carbon foot-prints, could be proactively fostered and developed by the Australian dairy industry. International examples include life cycle assessments (Haas *et al.* 2001) and estimating on-farm greenhouse gas emissions (Wheeler *et al.* 2008).

Intellectual property

There is no intellectual property arising from this project.

Technical summary

Not applicable.

Acknowledgments

We are grateful to Andrew Standish of DPI Colac, the project manager for the Heytesbury Soil and Water Dairy Action Program, for his enthusiasm and professionalism. Without Andrew's continued support and initiative, this sub-project would not have been a success. Nerissa Lovric and Graeme Ward initiated the project, and Becky McCann and the members of the farmer reference group of the Heytesbury District Landcare Network are thanked for their input and encouragement. Graeme Ward and Jo Crosby also provided valuable local knowledge.

Our field work was greatly assisted by the cheering and thoughtful inputs of Tim Johnston, Andrew McLennan, Shari McConachy and Doug Crawford. Sorn Norng undertook the statistical analyses. And last, but not least, we are grateful to the farmers who participated in this survey for allowing us access to their farms and for their helpful cooperation.

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Appendix A—Comparison of Soil Health Self Assessment Tools

by Kerry Greenwood, DPI Kyabram.

SOILpak for cotton growers (Third edition) 1998

By D.C. McKenzie (Ed.)

NSW Agriculture

SUMMARY: SOILpak is a manual for assessing the condition of the soil, with the emphasis on structure. It also considers management options for maintaining or improving soil condition.

HISTORY: SOILpak was developed to improve the soil management skills of cotton growers and consultants. It combines the results of soil management research in the Macquarie and, later, Namoi Valleys with hands-on expertise of local growers. Appropriate soil management techniques were originally summarised by McKenzie and Hulme at the 1986 Australian Cotton Conference and the first SOILpak manual was produced in 1991 by Daniells and Larsen (Daniells *et al.* 1996).

FORMAT: At least 200 loose-leaf pages in a ring binder, including 6 sections. The accompanying Pocket Notes are 33 pages, with spiral binding. Three recording sheets are provided, for different assessment situations. Each set of recording sheets is 4 A4 pages.

INTENDED USERS: Irrigated cotton growers. Almost half of the users are consultants and a large proportion of the remainder would be corporate agronomists (Daniells *et al.* 1996). Most would have tertiary qualifications in agriculture or similar.

TRAINING: Most users have attended a 2-day field workshop covering assessment of soil structure and soil management.

SCORING: Visual assessment of the soil profile is undertaken from a backhoe pit with recommended dimensions of 1 m wide by 4 m long by up to 1.5 m deep. Scoring is on a scale from 0 to 2 in 0.5 units for beginners, but as small as 0.1 units for experienced users. The SOILpak score is then averaged, with weighting factors as originally suggested by McKenzie. The average score can be adjusted, if warranted by over-riding factors.

SUITABILITY FOR SOIL HEALTH ASSESSMENT IN THE HEYTESBURY REGION: While some of the principles of SOILpak would be useful and applicable for this project, there are too many differences (e.g. soil type, cropping vs pasture, skills of intended users) to make SOILpak a useful basis for adaptation to local Heytesbury needs.

REFERENCE:

Daniells I, Larsen DL, McKenzie DC, Anthony DTW (1996) SOILpak: a successful decision support system for managing the structure of Vertisols under irrigated cotton. *Australian Journal of Soil Research* **36**, 879-889.

SOILpak for Southern Irrigators 1999

By J.D. Hughes

NSW Agriculture

SUMMARY: SOILpak for Southern Irrigators is a manual for recognising local soil types, diagnosing soil problems and providing management options.

HISTORY: SOILpak for Southern Irrigators follows on from the successful SOILpak for Cotton Growers. It was developed in consultation with government departments and local irrigators. The aim of SOILpak is to provide best management practices for a range of irrigated crops in grown in southern NSW.

FORMAT: At least 120 loose-leaf pages in a ring binder, including 6 sections. A 2-page soil assessment form is included on page C5.13.

INTENDED USERS: Irrigators, consultants and extension officers.

TRAINING: Not essential, but some soil science background would be an advantage.

SCORING: Visual assessment of the soil profile is undertaken from a backhoe pit with recommended dimensions of 1 m wide by 4 m long by up to 1.5 m deep. Each soil parameter is assessed separately. There is a section for the observer's conclusions regarding the main structural features which may be reducing plant growth.

USEFUL FEATURES: Chapter A4 describes soil formation and soil types of the riverine landscape, including annotated, colour photographs of representative soil profiles.

SUITABILITY FOR SOIL HEALTH ASSESSMENT IN THE HEYTESBURY REGION:

While some of the principles of SOILpak for Southern Irrigators would be useful and applicable for this project, there are too many differences (e.g. soil type, requirement for a soil pit, skills of intended users) to make SOILpak a useful basis for adaptation to local Heytesbury needs.

Indicators of Catchment Health: a technical perspective

Eds. J. Walker and D.J. Reuter

CSIRO

SUMMARY: A technical book of “scientifically valid and pragmatic” indicators to assess land and water degradation, particularly on a catchment scale, in dryland areas.

HISTORY: Developed by CSIRO in the early 1990’s to support the Landcare movement.

FORMAT: A 174-page book with 3 overview chapters and 9 technical chapters describing 29 soil- and water-based indicators of paddock, farm and catchment health. There are 4 sections relating to soil health.

INTENDED USERS: Landcare and community groups, although most of the indicators would apply at the paddock and farm scale.

TRAINING: Although detailed instructions are provided, or referred to, in the book, training in the use of the various techniques would be helpful.

SCORING: Indicators were selected by the authors after consideration of criteria such as cost, availability of standard methods, availability of interpretation criteria and significance to catchment health. The book suggests that users choose the indicators relevant to their needs, then score these indicators with ratings of good, fair or poor. An overall value judgement of good, fair or poor (on a continuous scale) can also be assigned. An exemplar “trend report card” is also provided which can illustrate changes in catchment condition over time.

USEFUL FEATURES: The book contains a lot of technical information and many of the indicators can be measured quantitatively rather than qualitatively. The threshold guidelines for condition indicators is a useful reference.

ADAPTATION REQUIRED FOR HEYTESBURY USE: About 25 of the 29 indicators would be suitable for use in the Heytesbury region. A condition (and trend) scoring card could be easily developed. Access to specialised equipment (eg tensometer for measuring strength of cotton strips, cone penetrometer for soil strength, rings for measuring water intake) would need to be arranged. The time required to undertake each condition assessment would need to be considered when selecting indicators to include.

SUITABILITY FOR SOIL HEALTH ASSESSMENT IN THE HEYTESBURY REGION:

While “Indicators of Catchment Health” would be suitable for Heytesbury region, the strong technical perspective means that it would require a larger amount of training, time and resources than available.

Soil morphological indicators and their importance to soil fertility

By R.W. Fitzpatrick, N. McKenzie and D.J. Maschmedt

Interpretation of some soil physical indicators for assessing soil physical fertility

By A. Cass

In “Soil Analysis: an Interpretation Manual”

Eds K.I. Peverill, L.A. Sparrow and D.J. Reuter (Eds)

SUMMARY: These book chapters describe 6 soil morphological descriptors and 6 soil physical indicators of soil quality. They are part of a much larger book focussed on soil chemical analyses.

HISTORY: The manual was prepared to provide a standard for the conduct and interpretation of soil tests relevant to Australian conditions.

FORMAT: As well as the two chapters considered here, this 369 page book has general chapters on the conduct of soil testing, soil test interpretation, major soils used for agriculture and 18 chapters on specific soil analytes

INTENDED USERS: The manual is intended for users of soil tests, particularly professional agronomists and soil scientists.

TRAINING: The user would require some training in agriculture, soil science or natural resource management.

SCORING: An example of a soil description field sheet is provided, and there is some interpretation of different indicators.

USEFUL FEATURES: This book’s strength is its comprehensive reviews of soil chemical parameters and their interpretation. The soil morphological and soil physical chapters are included for completeness and are covered in more depth in other books.

SUITABILITY FOR SOIL HEALTH ASSESSMENT IN THE HEYTESBURY REGION:

The book is a useful reference for consultants and service providers in the interpretation of soil chemical tests, which may be undertaken as part of soil health assessment. However, it is not suitable as a practical, on-farm visual assessment tool.

Visual Soil Assessment Vol. 1 Field guide for cropping and pastoral grazing on flat to rolling country 2000

By G. Shepherd

Visual Soil Assessment Vol. 2 Soil management guidelines for cropping and pastoral grazing on flat to rolling country 2000

By G. Shepherd, C. Ross, L. Basher and S. Saggar

Horizons.mw and Landcare Research

SUMMARY: The pastoral components of these booklets are aimed at providing farmers with assessment tools and guidelines to minimise the effects of poor drainage and pugging.

HISTORY: The booklets were developed in response to the need to improve or maintain soil quality for environmental and economic sustainability.

FORMAT: “Visual Soil Assessment” is a set of 2 booklets: volume 1 is the field guide and has 83 pages; and volume 2 is the soil management guidelines and has 41 pages. The first part of each booklet is aimed at cropping land, with grazing land covered in the latter part.

INTENDED USERS: These booklets are aimed directly at farmers, particularly dairy farmers.

TRAINING: Little or no training would be required to undertake the visual assessment described in the field guide as the pictures are self-explanatory.

SCORING: The field guide contains pictures of each indicator and its scores [2 (good)–0 (poor)]. A 2-page score card is provided with one side of the card focussed on soil indicators and the other side on plant indicators. Each visual score is multiplied by a weighting of 1, 2 or 3 to give the VS ranking. The sum of the rankings, with a potential maximum of 28 for soil indicators or 30 for plant indicators, is used to assess the soil quality as poor, moderate or good.

USEFUL FEATURES: The pictures in the booklets are good quality and very helpful. The inclusion of plant indicators is important as maintenance of a vigorous pasture should be a major aim of grazing management and would contribute to maintaining and improving soil health. The soil management guidelines are an important component of the soil quality assessment and most of the management recommendations would be applicable in the Heytesbury region.

ADAPTATION REQUIRED FOR HEYTESBURY USE: Little or no adaptation would be required for use of these visual soil assessment guidelines in the Heytesbury region, as they were developed specifically for areas of poor drainage and pugging.

The main difficulty in using these booklets would be in obtaining copies as they are out-of-print, pending revision by the author.

SUITABILITY FOR SOIL HEALTH ASSESSMENT IN THE HEYTESBURY REGION:

These booklets are highly recommended for soil health assessment in the Heytesbury region, pending field validation.

Northern Rivers Soil Health Card: A soil management tool developed by farmers for farmers

Part of the Good Soil Project and the Good Worm Project, an initiative of the Tuckombil Landcare Inc. in partnership with NSW Agriculture and the Natural Heritage Trust

SUMMARY: The Soil Health Card was developed as a practical tool for farmers in the northern rivers region of NSW to monitor the health of their soils.

HISTORY: The card was developed through a series of workshops involving Landcare members, other farmers and staff of NSW Agriculture and Wollongbar TAFE.

FORMAT: A loose-leaf document of 12 black-and-white A4 pages.

INTENDED USERS: The Soil Health Card is intended for farmers across a range of industries.

TRAINING: Little or no training would be required to undertake the simple tests described in the Soil Health Card.

SCORING: A scoring and interpretation sheet is provided for the 10 tests described by the Soil Health Card. There is space to record scores from 5 sites. Each test can be scored on a scale of 1–9 in categories of poor (1–3), fair (4–6) and good (7–9). There is no overall value of soil health calculated.

USEFUL FEATURES: The Soil Health Card is very simple in presentation, clear, concise and appears easy to use. The document follows a logical order describing test preparations, home-made equipment, the soil tests, test results, some possible causes of low test scores and sources of additional information. The page of the site plan is helpful.

The 9 soil tests (and 1 leaf colour observation) are all easy to apply and require minimal equipment.

ADAPTATION REQUIRED FOR HEYTESBURY USE: The Soil Health Card could be easily adapted for use in the Heytesbury region. It would be useful to include an indicator of pugging damage or susceptibility to pugging.

SUITABILITY FOR SOIL HEALTH ASSESSMENT IN THE HEYTESBURY REGION: The Soil Health Card is highly recommended for soil health assessment in the Heytesbury region, pending field validation.

Monitoring Tools supporting Environmental Best Management Practice on Farms

including

Soil Structure Monitoring Tools

Water Monitoring Tools

Nitrogen (N) Monitoring Tools

Phosphorus (P) Loss Monitoring Tools

Groundcover Monitoring Tools

Anonymous

Department of Primary Industries Victoria

SUMMARY: Monitoring Tools are a suite of documents covering assessment techniques for a range of environmental factors. These monitoring tools are referred to by the Environmental Best Management Practice on Farms (2003) workbooks.

HISTORY: These monitoring tools, available from the DPI external web site, support the Environmental Best Management Practice on Farms project.

FORMAT: The monitoring tools are relatively short (7–14 pages) loose-leaf colour documents. Workbook 1 contains the farm self assessment sheets (96 pp) and Workbook 2 contains the action planning and monitoring sheets (48 pp plus loose-leaf sheets).

INTENDED USERS: The monitoring tools provide additional background information to Victorian farmers undertaking self-assessments of their environmental management.

TRAINING: The workbooks include instructions and aim to be self-explanatory.

SCORING: Farmers assess their management using a scale of A–E (where A is best achievable and E is very poor) for a range of 118 issues, across 11 themes.

I have concerns that without comparison with an external reference or assessor, some farmers may be incorrectly assessing their environmental management. Also, the large number of issues to be assessed would be daunting.

ADAPTATION REQUIRED FOR HEYTESBURY USE: The soil structure monitoring tool discusses only soil drainage (referring to Baxter and Williams book) and soil texture in any detail. However, Workbook 1 covers other issues such as mapping of areas of waterlogging, high salinity and sodicity, etc. The water monitoring tool focuses on factors that are associated with surface and subsurface drainage. The phosphorus and nitrogen monitoring tools are better, and more simply, covered by the Farm Nutrient Loss Index (Melland and Smith 2006).

SUITABILITY FOR SOIL HEALTH ASSESSMENT IN THE HEYTESBURY REGION:

Not suitable for soil health assessment in the Heytesbury region as the scope of the documents is too broad. However, any soil health assessment implemented in the Heytesbury region would complement the EMBP on Farms project.

DairySAT 2005

By Cindy Nielson and Olivia Newton

Department of Primary Industries Victoria

SUMMARY: DairySAT (self assessment tool) is designed to assist dairy farmers understand the environmental issues on their farms and compare their environmental practices with industry practice.

HISTORY: DairySAT was developed in response to concerns by Gippsland dairy farmers that they needed to be pro-active in addressing environmental issues. Preparation of the Checklist and Guide involved 2 years' consultation nationally with farmers and others in the dairy industry.

FORMAT: DairySAT consists of a loose-leaf 3 page Checklist, a bound 67 page Guide, loose-leaf action plans for each of the 9 modules and an optional Environmental Management System declaration.

INTENDED USERS: DairySAT is aimed at Victorian dairy farmers.

TRAINING: Training is probably not required, although the Guide includes contact details for a range of relevant organisations if further assistance is required.

SCORING: Within each of the 9 modules, there are a number of questions. Each question is answered using the scoring system of unacceptable, acceptable and above acceptable industry practice. The questions focus on the farmer's knowledge and understanding of the different topics and whether appropriate management plans are in place. Users are asked to prepare an action plan for any unacceptable practices.

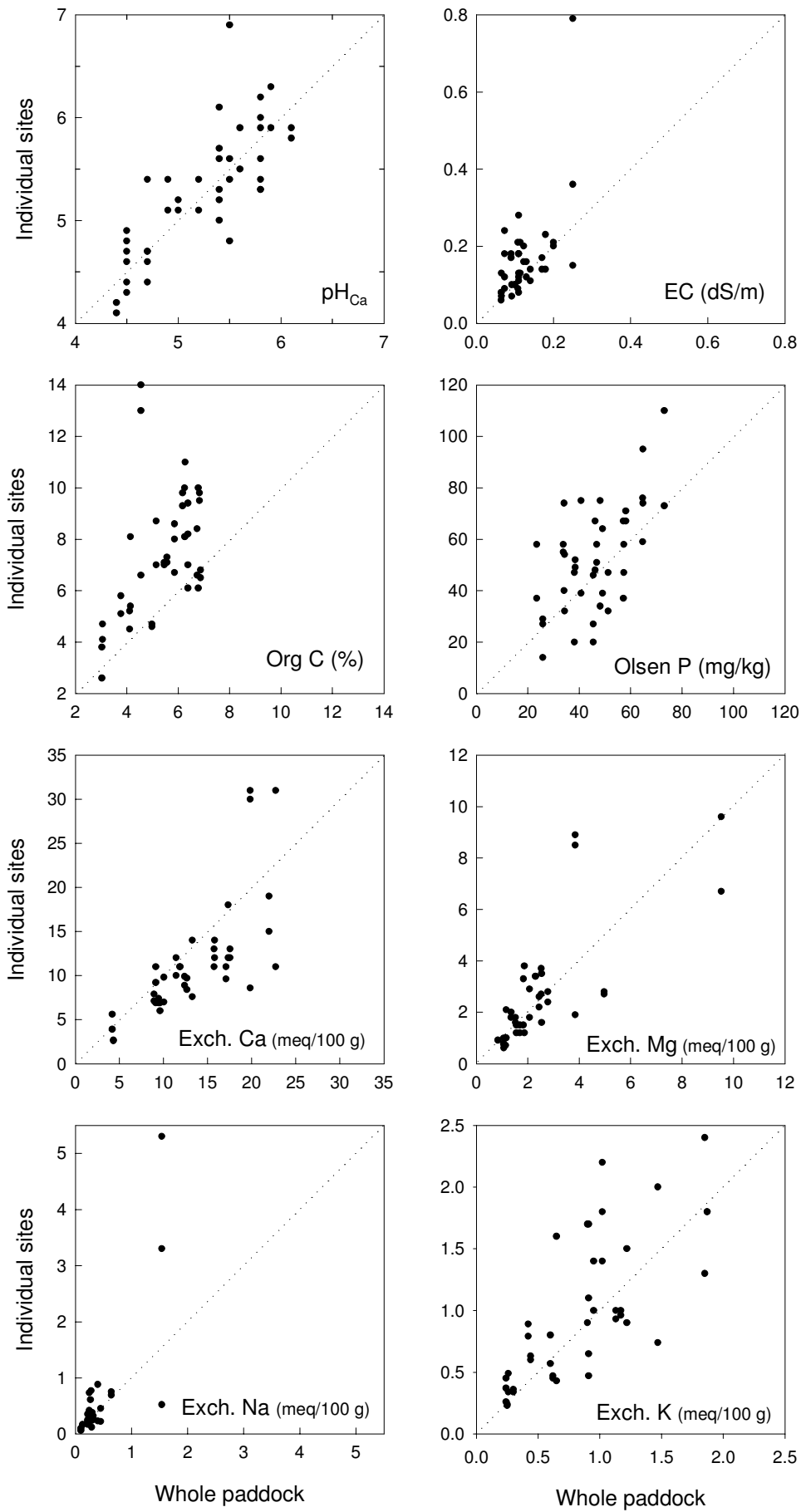
I have concerns that without comparison with an external reference or assessor, some farmers may be incorrectly assessing their environmental management.

USEFUL FEATURES: The contact lists for additional information are comprehensive, and include information on how to access information from the internet, particularly DPI's external website.

ADAPTATION REQUIRED FOR HEYTESBURY USE: DairySAT is aimed at a higher, less hands-on, level than is probably required in the Heytesbury area for this project. For example, acceptable practice for the soil structure section of the soils module includes:

- Understand the different soil structural problems than can occur and the causes
- Plan in place to address pugging or compaction on the farm
- Management practices have been implemented to address existing pugging and compaction problems.

SUITABILITY FOR SOIL HEALTH ASSESSMENT IN THE HEYTESBURY REGION: DairySAT would not be suitable to benchmark the soil health in this project, however, any soil health assessment implemented in the Heytesbury region would complement DairySAT.



Appendix B. Selected soil chemical properties of individual monitoring sites in 2007 compared with a whole of paddock sample analyzed at a different laboratory.