

Managing your soil to maximise profit and protect the environment

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Intensive dairy farming systems are a balancing act between producing saleable product and protecting the natural farm resources of soil and water – the natural capital. With good management, both objectives can be achieved, although for sensitive soils, or farms in sensitive catchments, special attention is required. This paper covers some of the basic soil management principles that contribute to healthy soil and water and, of course, healthy profits.

How good or bad is our soil health?

Concern has been expressed, both at a public level and within some parts of the scientific community, that intensive dairy farming can have a deleterious effect on soil health. For sensitive soil types, such as those with little organic matter and/or poor structure, these concerns are genuine, and appropriate grazing management systems need to be implemented if soil health is to be maintained. However, the issue needs to be kept in perspective. Past and present monitoring programmes undertaken at a national level generally indicate that soil health under pastures is actually often very good, with high levels of fertility and biological activity typically recorded. This isn't particularly surprising: it is well understood that one of the most effective soil remedial options is to put paddocks back into pasture, thus providing soil stability and much organic matter to help improve soil structure. Of the soil health indicators measured in these monitoring programmes, those that relate to soil physical health tend to be the ones where most concern is expressed. Some soil groups, such as those with little organic matter and/or poor structure, often score poorly for properties such as drainage, aeration and structural integrity. Soil types within the Pallic (meaning "pale") soil order are one group where close attention is needed to ensure drainage and compaction issues are closely monitored.

Within the last 5 years, the Industry has established a Dairy Catchments study programme that includes benchmark sites where soil quality is being monitored and sampled at 2-yearly intervals. Catchments are located in Waikato (Toenepi), Taranaki (Waiokura), Westland (Inchbonnie), Canterbury (Waikakahi) and Southland (Bog Burn). This on-going study provides a picture of the health status of soils that are typically used for dairy farming in these regions, and over the longer term of the project will provide an indication of trends in soil health status. Findings to date (Figure 1) show that:

- overall, levels of soil quality can generally be described as good. Measures of soil biological quality indicate levels of soil organic carbon, mineralizable nitrogen and total nitrogen were considered normal or ample for dairy farms in all the catchments.
- Soil fertility levels were in most cases high. Although this is generally a good thing, higher than optimum levels of soil phosphorus (P) and nitrogen (N) can contribute to water quality problems (discussed in more detail in the following section). A significant proportion of farms within all catchments had higher than optimum levels of soil Olsen P.

- Soil macroporosity, an indicator of soil physical health, was at optimum levels at all dairy farm sites within the Waiokura and Waikakahi catchments. Low macroporosity values recorded in the Bog Burn and Toenepe catchments indicate that soil compaction is likely to be limiting soil aeration, drainage and pasture growth on dairy farms in these locations.

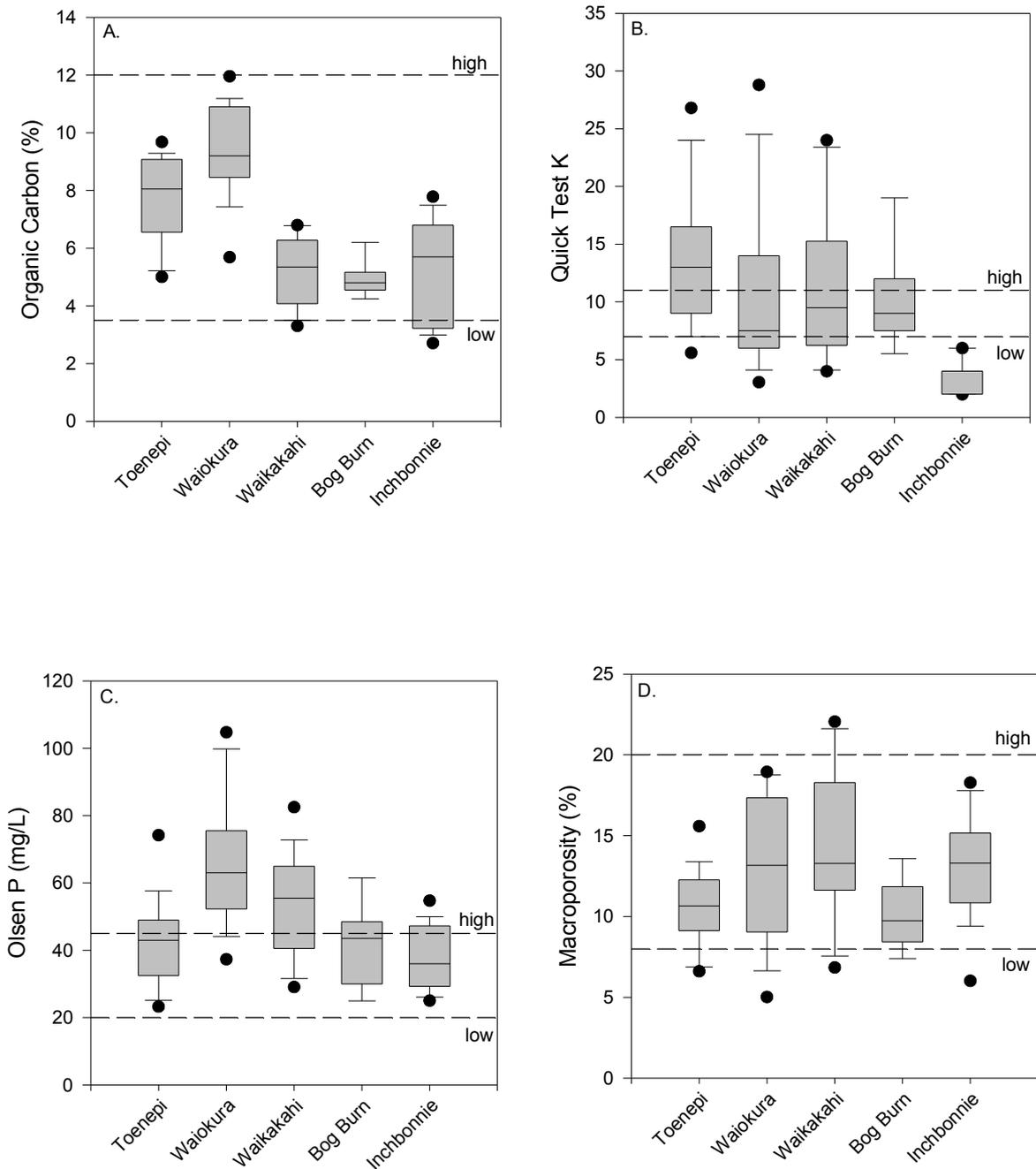
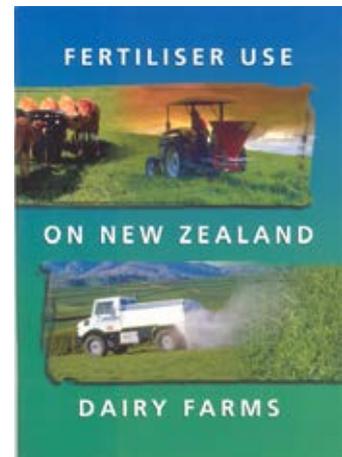


Figure 1. Values of some key soil quality indicators measured on dairy farms within the Dairy Catchments project: (A) Organic C, (B) QuickTest K, (C) Olsen P, and (D) macroporosity. Boxes, whiskers and dots denote 50th percentiles, 80th percentiles and outlier values, respectively.

The importance of optimising soil fertility levels

As mentioned above, higher than optimum levels of soil P and N can contribute to water quality problems. In terms of P management, the simplest and most cost-effective strategy for controlling P losses to water from dairy farms is to ensure that soil Olsen P levels are kept to the economic optimum value for an individual farm. Higher soil Olsen P levels are likely to be uneconomic and pose increased risk of P runoff to waterways. Fertiliser company representatives are best placed to provide guidance on determining the economically optimum soil test target values for an individual farm. A very useful additional resource is the booklet “Fertiliser Use on NZ Dairy Farms” produced by the New Zealand Fertiliser Manufacturers’ Research Association. This publication describes in some detail the relationships between soil test values and pasture growth, and desired target soil test values for different soil groups.



To demonstrate the win-win outcomes that can be obtained by adhering to Best Practice with regard to soil P fertility management, we can look at the monitoring information from the Dairy Catchments study. Nutrient modelling analysis on these farms suggests that reducing soil Olsen P levels to their economic optimum would result in annual savings in fertiliser expenditure of up to \$60 per hectare, whilst reducing P losses to waterways by between 7 and 37%, depending on catchment and soil type. The modelled relationships between soil test P value (i.e. Olsen P) and estimated losses of P to water are shown in Figure 2. These clearly demonstrate how more P is lost from farms that have higher soil Olsen P values; more in = more out.

In the case of N, soil testing is not normally used to assess whether more or less fertiliser N should be added to pastures. This is because current soil test information cannot accurately predict the short term N supply from soil under a range of climatic conditions. Instead, soil N levels are usually controlled by ensuring that N inputs to the dairy system (i) are applied at rates and times that match short-term plant demand and (ii) do not exceed certain thresholds that have been determined based on leaching studies throughout the main dairy regions of the country (including Southland). These studies generally show that annual fertiliser N inputs greater than 150 – 200 kg N/ha/year should be avoided if drainage water nitrate concentrations are to remain below current guidelines for safe drinking water. Some specific N management guidelines are:

- Avoid applying N fertiliser when soil temperatures are less than 5°C (spring) or 7°C (late autumn)
- Keep individual applications of N fertiliser to less than 50 kg N/ha.
- Adjust N fertiliser inputs to account for other farm N inputs such as those imported to the farm via supplemental feed, or onto farm blocks via farm dairy effluent (FDE).
- Avoid late summer or autumn cultivation of pastures. Cultivated soils can leak a lot of N to drainage water as soil organic matter breaks down, particularly if soils are left fallow over winter.

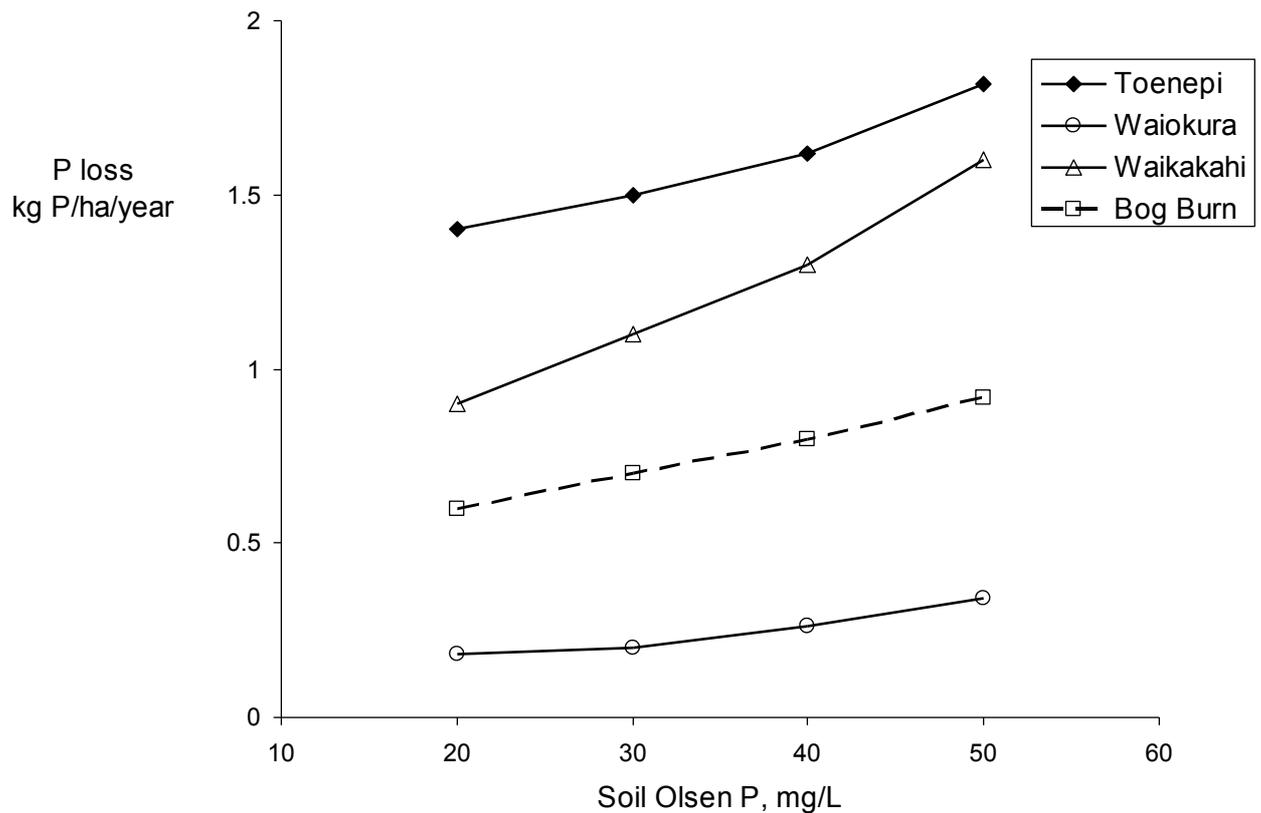


Figure 2. Modelled relationships between soil Olsen P values and P loss to water for “typical” farms within the Best Practice Dairy Catchments. Relationships derived using the OVERSEER[®] nutrient budget model, which in turn was run using information obtained from 21, 17, 12 and 6 surveys of dairy farms within the Toenepi, Waiokura, Waikakahi and Bog Burn catchments, respectively.

With the on-going intensification of landuse in the South Island, including dry-stock farming, some groundwater resources are coming under increased pressure with respect to N enrichment. For these sensitive aquifers, reductions in N losses from farming activities may be more urgently sought in the future. Government- and Industry-funded research programmes have identified a range of improved N management options available to farm businesses that can reduce N leaching. Although still in the early stages of field research, some of these, such as nitrification inhibitors and restricted grazing systems (i.e. restricted autumn and winter grazing management) appear to be cost effective options for reducing N leaching losses from dairy farms.

The role of nutrient budgeting as a tool for fine-tuning soil fertility management

Nutrient budgets are useful tools for assessing the sustainability of nutrient flows within a farm and for highlighting some potential negative environmental impacts of nutrient use. Some of the reasons for doing a nutrient budget include:

- assessing the inputs and fate of nutrients on farms.
- accounting for nutrients in supplements and effluent.
- defining any potential environmental impacts due to nutrient use.
- examining nutrient use efficiency (e.g. kg nutrient use per kg milksolids produced).
- proof of clean & green farm systems (quality assurance programmes).
- may in future be part of a statutory or supply requirement.

A nutrient budget program can also be used to evaluate the potential effects of changes in farm management practices on nutrient efficiency and environmental implications. The OVERSEER® nutrient budget model was developed as a farm-specific decision support tool to generate nutrient budgets and for examining nutrient flows and losses, and greenhouse gas emissions and energy inventories of individual farms. It also enables the user to examine the impact of a range of specific on-farm management scenarios to increase the efficiency of resource use and decrease environmental impacts. It links to maintenance nutrient requirement models to indicate maintenance fertiliser and lime needs. The model was developed with funding from MAF and is available free from MAF or can be downloaded from <http://www.agresearch.co.nz/overseerweb/>.

On dairy farms, effluent blocks can receive substantial inputs of nutrients, particularly N and K, depending on their size relative to farm productivity. In general, the recommended nutrient requirements in fertiliser are lower on effluent blocks than non-effluent blocks. A 'typical' Central Southland dairy farm is used below to illustrate the effect of effluent applications on nutrient blocks (Table 1). On this typical dairy farm, 12% of the farm received farm dairy effluent, with effluent applied at the calculated rates shown in Table 1. The amounts of nutrient applied in effluent are calculated within the model based on estimates of the total nutrient load in excreta and relative deposition in the yard/shed associated with milkings. Also shown in Table 1 are the calculated maintenance fertiliser requirements for the effluent block and the non-effluent blocks. These indicate that on the effluent block, N and K fertiliser can be omitted as the N application rate is already near the recommended maximum range of 150-200 kg N/ha/yr, and more than sufficient K was applied to meet pasture K requirements. Phosphorus maintenance fertiliser applications for the effluent block were about half that of the rest of the farm. Effluent supplied 45% and 100% of the pasture requirements for Ca and Mg, respectively, and reduced lime requirements. Maintenance lime rates are generally lower on effluent blocks due to the alkalinity brought in from the effluent. The rates shown in Table 1 will vary from farm to farm but the general trends still apply if the effluent block receives the equivalent of 150-180 kg N/ha/yr as effluent.

Table 1. Rates of nutrients applied in effluent to a ‘typical’ Southland dairy farm effluent block, and the maintenance fertiliser requirements for this effluent area and rest of farm. Effluent block assumed to represent 12% of farm area.

	N	P	K	S	Ca	Mg	Na	Lime
	kg /ha/yr							
Applied in effluent	129	15	132	12	24	12	4	
Maintenance: effluent block		22	0	16	0	0	0	30
Maintenance: rest of farm		40	97	31	53	10	0	210

The value of nutrient budgeting is maximised when outputs are related to an on-going soil monitoring programme. Regular soil testing on well-defined and representative transects will help to confirm if situations of nutrient depletion or accumulation are occurring as a nutrient budget may indicate. Ideally, this type of monitoring programme would include herbage analysis to fine-tune farm nutrient management decisions, and confirm that soil fertility levels are optimised with respect to pasture production and environmental protection.

Key management issues for looking after wet and/or mole-pipe drained soils

Local research has found that the management of wet and/or mole-pipe drained soils has an important impact on the transfers of pollutants from farms to waterways. This is because these soils (i) can generate a lot of overland flow, which is enriched with sediment, faecal bacteria, phosphorus and ammonium-N, and (ii) the mole-tile drainage network is a very efficient conduit for the transfer of irrigated effluent from soil to surface waters. It is important to emphasize here that drainage of wet soils is a very good thing for pasture productivity and environmental health, given our current systems of farm management; our point is that soils with artificial drainage need special consideration when effluent is applied to them. Their importance for P and faecal bacteria is demonstrated in Figure 3, which shows the inventories of P and faecal bacteria losses from a typical Southland dairy farm located on mole-tile drained land.

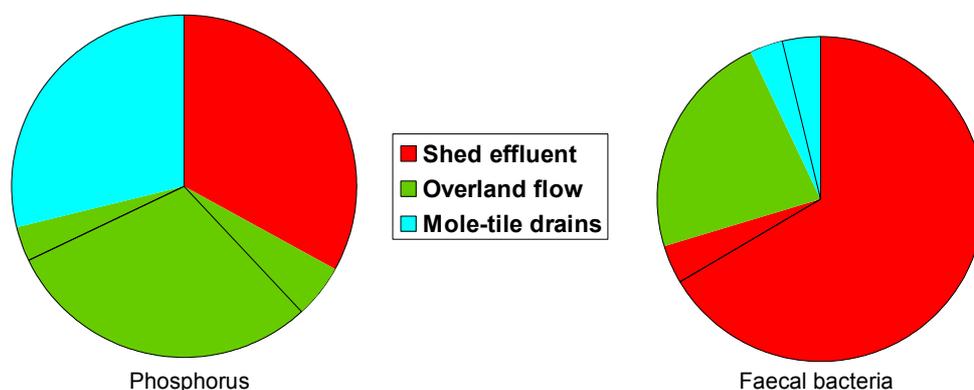


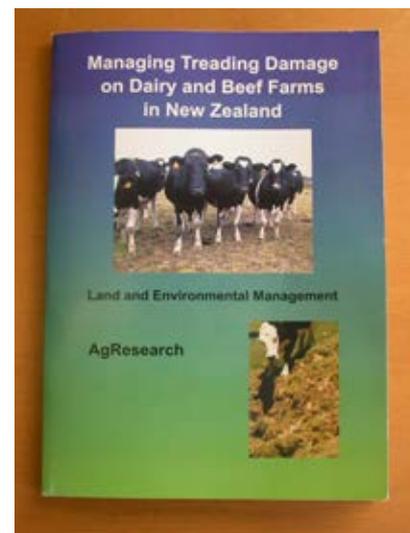
Figure 3. Inventories of P and faecal bacteria sources lost from a typical Southland dairy farm located on mole-tile drained land. Shed effluent discharges refer to the direct drainage of irrigated FDE through the mole-tile drainage network.

Local research has also shown that there are a number of strategies that can be followed to avoid the direct drainage of effluent through the mole-tile network. These include:

- The provision of pond storage and deferred irrigation of effluent when soil conditions are drier.
- Applying as small a depth of effluent as possible by adjusting the irrigator to its fastest groundspeed setting.
- Applying effluent via a low rate sprinkler irrigation system such as K-Line.

Unfortunately, each of the above BMPs incur some additional, albeit small, cost. Expressed on an annualized basis, the deferred irrigation strategy incurs a cost of approx. \$7 per cow, whilst speeding up the irrigator is estimated to cost an additional \$1.5 per cow due to an increased labour requirement. Low rate effluent irrigation technology, particularly if combined with pond storage, is estimated to incur a net cost of \$3 per cow per year. On-going field work with K-line effluent irrigation systems indicates that this method of application can significantly reduce direct transfers of effluent P and bacteria through the mole-tile drainage system compared to that achieved using a traveling irrigator. In addition to applying the effluent more evenly, this low-rate application method appears to achieve a considerable degree of filtration of effluent P, ammonium-N and *E. coli* bacteria by the soil, particularly under an intermittent pumping regime that avoids excessive ponding of applied effluent on the soil surface.

For many wet and/or mole-tile drained soils, soil pugging damage can result in the generation of relatively large amounts of overland flow, and thus transfers of sediment, P and faecal bacteria to waterways. Thus, a desirable grazing management goal is to ensure that soil pugging damage is kept to a minimum, soil infiltration rates are therefore maximized and overland flow volumes are reduced. Strategies that help to achieve these outcomes include using stand-off or feed pads to protect soil structure when soil conditions are particularly wet. Dexcel have recently published an excellent manual detailing design and management guidelines for these structures. Spreading cows out (ie lowering stocking density) during wet periods, or, if you have the luxury, grazing the more robust and well-drained soils are some additional options to help minimize pollutant losses in overland flow. For more detailed discussion on managing soil treading damage, the reader is directed to the booklet entitled “Managing Treading Damage on Dairy and Beef Farms in New Zealand” which has been published by AgResearch .



Soil Health diagnostic tools and extension services available to Southland farmers

The physical condition of a soil has an important influence on farm economics and the health of the environment. It is vital to have knowledge on the important diagnostic tools to measure soil structure or soil physical condition, which is commonly referred to as soil health.

A. Soil Information

Environment Southland and Crops for Southland have produced a Soil Technical Data Sheet for each of the 175 soil types that were mapped by Topoclimate South in the 1:50,000 soil survey of Southland's soil resources. The Soil Technical Data Sheet series is intended for users with some knowledge and understanding of soil science. The Technical Data Sheets provide detailed descriptions of the soil profiles, along with typical values for the physical and chemical properties of every horizon.

A companion series, Southland Soil Information Sheets, summarise the soil survey's technical data and present it in a more user-friendly form for the non-scientifically inclined reader. They are designed to inform Southland people about the properties and sustainable diversification potential of the soils in their region.

It is important to understand that the soil sheets in both series describe the typical average properties of a soil type. These average values are essentially a summary of a number of separate soil profiles that were described for each soil type during the Topoclimate soil survey. Environment Southland or Crops for Southland can provide the detailed data from a specific soil profile if you need it.

The soil sheets also provide sustainability and land use versatility interpretations for each soil type. Again, it is important to recognise that these are typical average ratings of an un-disturbed soil and it is assumed there has been minimal management intervention to overcome the major soil limitations. A land user can assume a higher versatility rating where significant efforts have been made to overcoming a limitation to the versatility of the soil. A common example of this is where land users have significantly improved soil aeration and reduced water logging by installing mole and tile drainage networks.

B. Soil Health Diagnostic Tools

1. Visual Soil Assessment (VSA)

The visual soil assessment procedure is a diagnostic tool of the physical health of the soil. Physical properties control the movement of water and air through the soil, and the ease with which roots penetrate the soil. Damage to the soil can change these properties and reduce plant growth, regardless of nutrient status. Decline in soil physical properties takes considerable expense and many years to correct, and can increase the risk of soil erosion by water or wind. Safeguarding the soil resource for present and future generations is a key task of land managers.

Many physical and, to a lesser degree, chemical soil properties show up as visual characteristics. Changes in land use or land management can markedly alter these. The VSA Field Guide has been developed to help land managers assess soil quality easily, quickly, reliably and cheaply on a paddock scale. It requires little equipment, training or technical skill. Assessing and monitoring soil quality on your farm with VSA, and following guidelines for prevention or recovery of soil degradation, will help you develop and implement sustainable land management practices.

The VSA method:

VSA is based on the visual assessment of key soil 'state' and plant 'performance' indicators of soil quality, presented on a scorecard. Soil quality is ranked by assessment of the soil indicators alone. It does not require knowledge of paddock history. Plant indicators, however, require knowledge of immediate crop and paddock history. Because of this, only those who have this information will be able to complete the plant indicator scorecard satisfactorily.

If you are thinking of buying or leasing some additional land, VSA can provide important information about the soil quality of the land under consideration, which can help you decide whether to lease, buy, or look for an alternative block of land.

2. Dairy Soil Management System (DSMS)

The DSMS provides a practical and user-friendly system for monitoring and managing your soils. The DSMS was developed by farmers, consultants and researchers through a project funded by the MAF Sustainable Farming Fund. The DSMS measures physical, chemical and biological properties of soils which, when tracked over time, will show how soil health or condition is changing. The DSMS was developed to

- Describe soil properties on a farm as they relate to their performance, capacity and capability.
- Provide information on soil management and a way to help land managers handle management decisions.
- Be a practical system that shows how management affects soils.
- Identify the strengths and limitations of many management strategies for handling cattle when soils are prone to damage.

By bringing together strategies that are commonly used by dairy farmers to minimise the risk of un-necessary soil and pasture damage, it is easy to choose a strategy that most suits your farm. The DSMS can also be used as a Quality Assurance (QA) system for NZ dairy farms to demonstrate sustainable soil management practices. This tool will help you sustain or improve the soil health and enhance your farm business as well as the environment.

Environment Southland provides free on-farm site specific advice to farmers and land owners in Southland on various farm management activities, including soil health management. Participants from other regions may contact their respective regional council for further details.