Soil Health Strategy for Corangamite Region

Discussion paper

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Soil health strategy for Corangamite CMA discussion paper

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Abstract

This discussion paper addresses the need by Corangamite Catchment Management Authority (CCMA) for authoritative advice on soil health in the region and appropriate actions to manage soil issues. The role for the CCMA is clarified and approaches to management of soil health are reviewed. The context of the Victorian Catchment Indicators program in relation to soil condition monitoring is explained and opportunities for introducing soil monitoring are discussed. Soil issues and the status of soils information in the region are tabulated and the lack of consistent baseline data acknowledged. Recommendation is made that the CCMA, in developing an approach to soil health in the region, should adopt a supportive partner role with industry and government by engaging the regional agricultural and forest industry sectors in good soil management. A generic need for a more managed approach to soil erosion in the region is recognised. The development of an indicator monitoring program associated with targets for soil health is seen as premature, expensive and having a high risk of failure, it is therefore not recommended as a priority investment area for the CCMA.

Introduction

Corangamite Catchment Authority require technical direction for the support of soil health issues within the region through the regional catchment strategy. The CCMA have determined a need for a soil health action plan which will focus on significant soil issues and adopt an appropriate monitoring and evaluation program which is based on assessment of soil health indicators.

A discussion paper has been requested with the following terms of reference:

- Discussion of the major soil health issues in the region
- Discussion of priorities associated with these issues
- Recommendations for actions and strategies that are required to address the issues and priorities identified.
- Context of the Statewide Catchment Indicators program and the potential links for a CCMA soil health strategy.

Definitions and context

The terms “soil health” and “soil quality” have been used frequently over the last decade worldwide in a range of different contexts. General usage of the terms has evolved around practitioners (farmers, land managers) adopting the term ‘health’ and scientists and researchers preferring the term ‘quality’. The distinction is a broad one and is by no means a rule. The end point of the discussions, from either side, is to provide an over-riding concept that summarises the ideas embodied in good soil management, sustainable use of soil resources, and understanding of the ‘functional’ properties of soils.

Scientists working on soil quality have attempted to define more precisely the functional properties of soil, and a good working definition of soil quality is:

> “ The capacity of a soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality, and promote plant and animal health.” (Doran and Parkin 1994)

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Indicators, indices and monitoring

An indicator is a measurable parameter of a system that can be used to represent the condition of the system or its ability to perform system functions. A good indicator is sensitive to change, easily measured, has a clearly defined and repeatable methodology, is easily interpreted (not subject to system 'noise') and ideally, is reversible (sensitive to improvement as well as decay). Thus pH is an example of a good soil indicator as it is sensitive to change, can be measured consistently and easily and can be related to the soil's capacity to support plant growth.

An index is usually a value on a relative scale that has no meaning *per se* but can be used to judge system conditions comparatively in space or time. For example, students are graded by summing marks achieved in assignments and exams but the grade awarded to a student does not give an indication of what precisely the student knows or does not know, it merely indicates their overall performance relative to other students and to a desired standard.

Monitoring is the periodic repetition of measurements made on a site or population in order to track any changes that occur in condition of the system being monitored.

Using single soil quality indicators related to specific soil functions

Many indicators for soil quality have been suggested and discussed in the scientific literature and cover a range of physical, chemical and biological soil properties (Brussard et al 2002; Doran, Molina and Harris 1994; Gregorich and Carter 1997; Hamblin 1998, 1999; Pankhurst 1999; MacEwan and Carter 1996; Walker and Reuter 1996). There is still debate but reasonable agreement about the suite of indicators that would comprise a minimum dataset for assessment of soil quality and methods for measurement. However, baseline data are lacking and, although there is recognition of the importance of chosen indicators, there is little knowledge of thresholds or rates of change particularly with respect to biological indicators of soil health. There is therefore a need for research to determine the relationships between indicator values and performance of soil functions.

The search for a simple index of soil health

Combining measures into a single index that can be used as a long term monitoring aid is an attractive proposition and has been achieved to a degree in other fields. The index of stream condition (ISC), which aggregates a number of individual indicators of stream condition, is a good Victorian example (Catchment and Water Division, 2001). Such an index would appear to work well where individual indicators are related but gives rise to problems when they are not. If the former is the case an improvement in score always correlates with improvement in condition, if the latter is the case a score improvement could be achieved if a single factor increases sufficiently to outweigh decreases in other factor conditions. Single combination indices are therefore dogged by problems associated with methods of combination of parameters (e.g. summative, divisive etc) and weights applied to individual factors. Such is the case with the search for a soil index.

During the development of the Victorian Catchment Indicators (Catchment and Water Division, 2001) program a working group[2] from government and University attempted the task of developing a soil health or soil quality index as suggested in the terms of reference provided by consultants for that project. Some progress was made towards this end but the proposed initial setup cost and ongoing monitoring costs were prohibitive within the budget of the funding division of NRE (Catchment and Water). There

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[2] John Williamson / Nathalie Baxter (convenors), Graydon Finlay, Mark Imhof, Austin Brown [NRE]; Professor Robert White [Uni. Melb]; Richard MacEwan [Uni. Ballarat]; Ian Sargeant [consultant].

was also a lack of confidence in the ultimate value of such an exercise. While it is highly desirable to have a suite of indicators that could be measured periodically to provide a composite index of performance and support a monitoring program for "soil health", this is probably not achievable with any great sophistication. McKenzie and Chartres (2001) concluded that:

> " Soil quality, therefore, is not a particularly helpful concept in designing a system to measure and monitor the condition of soil across the Australian continent because appropriate protocols have not been established for soil quality *per se* and may not be feasible."

Given this background it is challenging to imagine that the CCMA would ever be in a position to resource either the development of a soil health indicator monitoring tool, or to implement, in any effective way, a monitoring program. By effective, I mean something that can practically deliver an outcome for improvement in soil health let alone do that in a cost effective manner.

How a soil health program fits with the CCMA vision

The vision for the Corangamite region (CCMA 2002) embodies a number of principles which can be supported by a soil health strategy:

A healthy environment – the term healthy is used here in a similar fashion to "soil health". The general functions of the biophysical environment with regard to supporting vegetation, harvesting and maintaining clean water supplies, and absorbing waste products without degradation of the primary resource correspond well to the ideals of a healthy soil.

Sustainable economic use of natural resources – with regard to the soil as a natural resource, management is required that ensures the capacity of the soil to support ecological functions for future generations. Achievement of this objective requires an understanding of the science of soil, the variability of soils in the regional landscapes, their capacities for use and vulnerability to degradation.

A smaller footprint – maximal and optimal use of the soil resource is an essential objective in the achievement of smaller ecological footprints. Farming system improvements are needed to make full use of stored soil water, optimise the biological activity to retain and recycle nutrients, and increase economic gains per hectare without excessive use of fertilizer imports or loss of soil. The CCMA working in partnership with agricultural industry in the region can help to achieve this objective by supporting the science and practice underpinning potential improvements.

A planned landscape – planning decisions should take account of the long term value of soil and land resources without comprising land to developments that limit future choices over land use. Additional interpretation of soil and landform mapping can support such planning decisions.

Cohesive, innovative communities – a soil health strategy entailing partnerships between landholder, CCMA, industry and science is an important component of a regional program to achieve this objective. Agriculture is the dominant land use in the region and the triple bottom line objectives (social, economic, environmental) will have to be addressed through the viability of the region's agricultural enterprises.

Partnership between community and government – the CCMA are a pivotal group in the partnership needed to achieve sustainable land management, the role of partnerships are crucial to the success of an soil health strategy.

Role of the CMA in soil management intervention

Given the range of soil management issues that potentially need to be addressed, the CCMA needs advice on where they can most strategically put their effort. There is a prevailing economic argument that there should only be intervention where there is market failure (the market won't pay for it) or there are spillover effects (e.g. offsite as in siltation, eutrophication, salinisation). So in this way of thinking, soil management incentives that have positive water quality or salinity outcomes could and should be supported by the CCMA, whereas those that only apparently affect the profitability of the farm should not (e.g. chemical fertility decline, soil acidification). It would be economically defensible for the CMA to always and only use the market failure 'rule' to determine the level of CMA investment in particular issues, programs or projects. Alternatively, the CMA could adopt a standpoint lateral to (higher than?) that of economic rationalism by taking an overall responsibility or sponsorship for all issues relating to soil and catchment health in the region. Many soil management issues are poorly understood with regard to their offsite or even on site impacts – general relationships can be proposed but quantitative evidence is hard or impossible to find. Because of this ambiguity and uncertainty it is preferably that the CMA tend towards duty of care rather than economic rationalism in determining responsibilities.

It is acknowledged that the CMA is one of many partners in land management, however the CMA sits with an integrated responsibility and perspective in contrast to the other partners in the region such as local government, industry groups, and individual property owners.

Targets, the RCS and soil health – a cautionary note

There is currently a hiatus between the level of problem elucidation at board or IC level (as represented by the RCS) and the types of activity supported by the CMA that address elements of regional programs. This is essentially due to knowledge gaps[3] relating to: inventory of the region's resources; the resource condition; and functional relationships between landscape and land use. Acting on programs without closing this hiatus can result in premature expenditure of funds on activities that are less than efficient in achieving the higher level RCS objectives.

Such a situation is exemplified in the history of the Victorian salinity program. This has attempted to deliver on-ground solutions to perceived salinity problems without adequate, regionally relevant information about processes. The on-ground activity focus has therefore tended to be spatially defined following generalised political debate, driven by a sense of urgency for capture of funds and only informed by loose hydrologic conceptual models. There have been benefits from the disbursement of funds to on-ground works. However, these benefits have largely been lateral to the central problem being tackled (reduction of salinity). Monitoring and evaluation of the program's impacts would show positive results with respect to individual awareness, skills in tree planting, pasture improvement, and community involvement, but little or no impact on groundwater levels or extent of discharge areas. This brings into question the validity of the program's primary objective rather than the value of the program itself. Had the program been defined with the lateral outcomes as primary objectives then it would be seen as extremely successful.

There is a lesson in this that must be learned and applied. An overall mission for soils in the region might be stated as, "bring about an improvement in soil health and protection of soil resources in the region through implementation of improvements in soil management". Setting of measurable targets for soil management, especially where these may depend on changing the average value of a soil property (e.g. "average surface soil pH in the basalt plains will be above 5.5 by 2005") in the CCMA region needs to be

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[3] In the current draft RCS 2002-2007 (Thomas and Colliver 2002, p73) reference is made to the NAPSWQ expectation that resource condition targets will be established by October 2004. Defining of targets requires closure of these knowledge gaps. Inventory, process description and projection are therefore essential activities for the CMA to support if targets are to be in any way realistic or achievable.

tempered by knowledge of the achievable. Targets set by the CCMA cannot be realistically set within the arena of outcomes over which the CCMA have little to no control, i.e. adoption of changed practices. There are also great difficulties in setting targets for soil structure (e.g. soil organic matter levels, soil aggregate stability, bulk density) as the associated properties are not easily measured or interpreted.

Options for monitoring

Soils are extremely complex systems, variable in space and time, sensitive to management (land use and associated practices) and to weather conditions. McKenzie, Henderson and McDonald (2002) have comprehensively summarised the issues associated with soil monitoring and given sound recommendations with respect to implementation in Australia and stress the need to define the purpose for monitoring, contrasting two principle purposes:

- reducing risk in decision making
- improving process understanding.

Monitoring must be given context. Selection of monitoring parameters (indicators) and sites requires recognition of spatial relevance (land and land use that each monitoring site represents) and understanding of processes that influence soil change at this site (including rate, sensitivity, reversibility).

An evolving consensus is moving towards acceptance of soil pH and soil carbon levels as the two properties most amenable to monitoring.

Review of approaches adopted elsewhere

Soil health strategies

A good Victorian example of a soil health strategy is the draft North East Soil Action Plan (NESHAP) developed for the north east region CMA (Hollier et al 2001). The development of this strategy took 2 years and was funded by Catchment and Water Division. The strategy summarised soil condition across the region particularly with respect to: acidity, soil structure, erosion, and salinity and defined a specific program to deal with each of these. In general monitoring of program success was through numbers of people undergoing training and adopting best management practices (BMPs) rather than measurable outcomes relating to soil properties. The cost of implementation for the NESHAP was estimated as $9.5 million to be shared roughly equally between Federal, State and Regional funding sources and a small (4%) contribution proposed from the private sector. The development of the draft NESHAP was aided by the history of soil related research in the region (particularly soil acidity and soil structure) and contributions to the document by regional experts. The plan includes a program of monitoring of soil properties at 30 reference sites distributed across different environments and land uses, however, the monitoring is open ended research rather than relating to indicator targets. A reasonable effort has gone into identifying partners in cost sharing and links to other plans and strategies for the region.

A less developed example of a soil health strategy is the draft North Central Dryland Soil Health Strategy (NCDSHS) (Wilkin 1999). This did not have the input that the NESHAP benefited from and is needy of science and interpretation. The Goulburn Broken catchment equivalent document has only been sighted in partly completed draft form (Goulburn Broken Catchment Management Authority 2002)

Farmer based soil health assessment

Soil quality or soil health assessment kits and score cards have proliferated over the last decade (e.g. USDA 1999). These are designed to support farmers in measuring and monitoring soil health on their farms and therefore have the potential to be highly relevant to the individual manager both functionally and spatially. However, unless strongly supported and regulated to ensure consistency and quality of measurement, such approaches are limited with respect to supporting any regional or national monitoring program.

Soil issues in the Corangamite Region

The Corangamite Region has a diversity of geology and climate that has resulted in a variety of landforms, soils and associated land uses. Soil degradation issues can be summarised simply as those affecting soil chemistry (soil chemical fertility), soil structure, and soil loss. Some issues have been summarised in table 1.

Currently, an inventory and map of soil-landforms in the region is being compiled at a scale of 1:100,000. This will provide better scale information on distribution of soils than currently available and will assist in identifying management needs in the region with respect to different land uses. Chemical characterisation of soils in the survey work is restricted in that samples analyses are only taken from a few soil pits in the region. Understanding of the spatial variability of soil properties, especially chemical properties, within single map units requires a statistical approach to soil sampling and analysis that is not affordable in large regional soil surveys. Some potential may exist through spatial analysis of data held by State and private laboratories, however the spatial resolution of such data is limited to postal districts rather than being specifically located at paddock scale (privacy issues and nature of data collection). It is difficult therefore to present a finely resolved map even of something as straightforward as soil acidity.

Slattery and Hollier (2001) have presented some data and projections for soil acidity in the region but these should be treated as indicative only (Fig 1.)

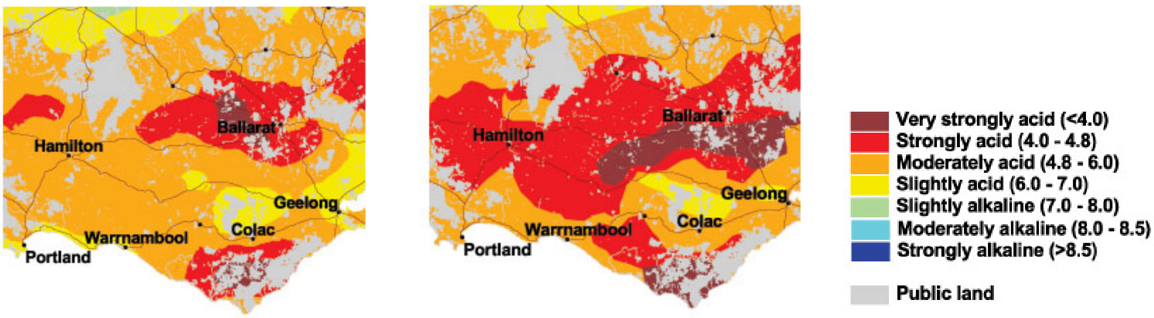

Figure 1. Surface soil pH, current (left), and projected 2050 (right) in the Corangamite region.

Table 1. Soil degradation issues, extent and opportunities for management

Issue	Extent	Opportunities
Soil Erosion by water – no officers in DPI funded or who have capability to carry out proper assessments or design engineering works.	Widespread spot occurrences of gully and tunnel erosion in the region in a range of soils and landscapes. Particularly in the hill country of the Western and Southern Uplands.	Need process for handling erosion inquiries, register of appropriate consultants, engineers and earthmovers.
Mass movement, landslides and soil creep	Landslides have been studied in detail in the region by Peter Dahlhaus, so the extent of these in the region is very well understood. They are largely confined to particular geology in the south and south west of the region.	Landslides and soil creep are geomorphic processes that are largely independent of land use or management. Engineering options (dewatering) exist for landslide prevention but may be uneconomic. Development of infrastructure in landslide prone areas must be strictly controlled to minimise risk to property and life. Education of landholders with respect to understanding how to live in environments prone to landslides is needed. Training of DPI field staff is also needed.
Soil erosion by wind	In some seasons there is considerable movement of soil material by wind, particularly from the basalt plains (bare ground in summer) and the sandier soils of the coast and northern slopes of the Otways used for horticulture. Movement of coastal dunes in the SE of the region has in the past interfered with infrastructure, covering roads at Barwon Downs.	Maintenance of soil cover and reduction of wind fetch are crucial tools in preventing or reducing soil loss by wind. A general understanding of pasture management, wind breaks, tillage impacts should be incorporated in any soil training package. Coastal management has evolved considerably in the last 30 years. There may yet be a role for CMA in encouraging conservation practices through partnerships with local government and DPI.
Soil Structure decline and poor soil structure in dairy pastoral systems.	Pugging, compaction and associated waterlogging are common in the higher rainfall pastures of the region. Particularly those on the clay soils of the Gellibrand Marl (Heytesbury) and Basalt.	Dairy Industry has most potential to make progress on this issue. The wet soil management initiative in regional dairy industry has been running for a number of years. (contact Graeme Ward, DPI, Warrnambool.
Soil structure decline, poor soil structure and associated soil loss in sheep/beef pastoral systems. Compaction, baring and pulverizing of the soil surface are the result of intensive treading by hard hooved animals.	Fine sandy loam soils are particularly vulnerable to this type of damage.	Changes in grazing practice, e.g. cell grazing, can have a positive effect in reducing this type of degradation through maintenance of ground cover. However cell grazing entails more intense treading which may increase short term compaction effects in some moisture conditions. Understanding soil dynamics in these systems should be the subject of research.

Table 1. (contd)

Issue	Extent	Opportunities
Soil structure decline and associated soil loss as a consequence of tillage in dry conditions.	Loam topsoils in the region are particularly vulnerable to over tillage, breaking down to a 'flour' easily blown by wind or washed by excessive rainfall prior to crop or pasture establishment.	Adoption of low till or no till cropping systems (bed systems once established) and appropriate timing of tillage in pasture renovation or crop preparation. Working with industry groups or general land manager training packages are needed to ensure the causes of this degradation are understood and avoided.
Soil structure decline associated with degradation of sodic soils. Dispersion of sodic soils leads to erosion and pollution of waterways.	Subsoil sodicity is extensive in the region, surface subsoil sodicity is less extensive.	Identification of sodic (dispersive) soils and amelioration with gypsum are established management tools but this may not be widely known. Much of the raised bed cropping activity is occurring on sodic soils but the SFS group are pretty enlightened about this limitation and its remedy.
General soil structure decline associated with all aspects of cropping. Compaction of surface and subsurface (pans), loss of structural stability, water erosion of exposed soil (rainfall and irrigation).	Widespread.	Southern Farming Systems – soil structure in raised beds currently subject of GRDC funded research Good general advice can be given but extension is limited at present. Working with industry groups such as SFS and CHIPS offers most opportunity.
Soil acidification.	Acid soils are common in the region. This topic has been addressed in detail by Slattery and Hollier (2001). The spatial data are only based on supposed relationships with the soils associated with the land systems dataset. This dataset is old and therefore not reliable for estimation of current soil condition.	Soil testing and use of lime to ameliorate soil acidity are the known management tools. However, liming may be uneconomic in some enterprises. Evaluation of capacity to lime land in different enterprises will highlight whether there is need for concern in the region.
Potential acid sulfate soils. Some recent sediments high in pyrite have the potential to generate sulphuric acid if drained. There are also some instances of exposed overburden high in pyrite generating acid seepage and runoff.	Recent mapping by NRE has identified some potential acid sulfate soils in the SE coastal fringe of the region.	Education and awareness of the problems associated with acid sulfate soils must be targeted at planners and developers in susceptible areas. Quarrying / mining operations must be controlled with respect to exposure and oxidation of pyritic overburden. Codes of practice in mining industry should address this but enforcement may be necessary. Rehabilitation measures to protect water quality will be needed at affected sites – liming and submergence are known management tools.
Soil fertility decline via nutrient removal and organic matter degradation is a worldwide issue in agricultural soils.	All removals (crop and animal products) deplete nutrient stocks in soils so this is an extensive agricultural issue.	More profitable farm enterprises have capacity for adoption of soil nutrient balance management practices through regular soil, plant tissue, and animal testing. Currently focus is on NPK (S) and little else.

Knowledge and gaps

A proliferation of reports over the years in which maps of land condition can be found gives the illusion that we know more than actually do. Land systems data at 1:250,000 have been interpreted to provide coarse scale information on the vulnerability of soils to degradation and these interpreted outputs continue to reworked. These data were used in supplying maps and statistics for Office of the Commission for the Environment (1991), regional landcare plans in 1993 and CaLP board catchment condition reports in 1997. There is very little primary data, except in the case of salt affected land, on the real condition of the land resource.

Baseline data

Data for soils in the region are currently being updated and completed through the land resource assessment project[4]. The output of this project will be an inventory of soils for the region, their main physical and chemical properties, and maps of soil distribution in relation to landform and geology at a scale of 1:100,000. This information is crucial to a soil health monitoring program and would be used to stratify the region with respect to selection of monitoring sites, ensure statistical reliability in soil sampling programs, and provide context for soil quality differences. The base data can be used to derive maps of potential soil and land degradation and provide the basis for land capability mapping. However, survey and recording of the actual condition of the soil and land resource is not part of the current project. Baseline data to use in setting resource condition targets and monitoring of soil health are therefore limited.

Understanding of processes and relationship of soil health to land use practices

There is a body of generic knowledge that can be drawn on to understand soil degradation (e.g. acidification, structure decline) and there is a corresponding body of knowledge relating to soil management to address most degradation issues. However, there is little in the literature that can guide us in relation to setting targets for soil condition.

Recommendations

Based on the discussion in this paper, recommendations, particularly with respect to priorities for investment, can be made in a general sense only. Consultation with stakeholders including private landholders, industry groups and government is essential in the development of a successful suite of actions. Given the lack of readily available resource condition information and limited knowledge of industry perspectives on soil issues the author of this paper can only guess priorities for action. The principal inventory of issues have been tabulated in table 1 with some comments, however the top five guesses for soil priority issues, in alphabetical order are:

a) Acidity. Acidity and acidification of soil is inevitable in high rainfall environments. Most of the region's soils are naturally acid at the surface. However, this is probably the least important issue of the four for CCMA since it is largely a factor affecting productivity and therefore managed by the market. The NESHAP gave high priority to acidification and had recommendations to subsidise laboratory testing of pH and aluminium, and to investigate partnership with industry for regional bulk storage and distribution of agricultural lime. CCMA region need better data on the condition of soil pH and the regional significance of this issue.

b) Erosion. Since the demise of the Soil Conservation Authority and the meteoric rise of salinity as an issue there has been little to no coordinated management of soil erosion issues. The new

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department has inadequate available engineering expertise for design or supervision of construction of control structures and no program budget. A rebuilding of the SCA is not recommended but a higher level of management is needed, both of information and of practical response. As a minimum, record keeping integrated with GIS is needed. Additionally, a register of certified practitioners competent in erosion assessment and remedial work should be maintained by the DPI and CMA. As erosion has serious offsite impacts as well as onsite productivity impacts it obviously a priority for the CCMA. An assessment of regional erosion activity is needed to allow a more objective, rather than *ad hoc*, approach to funding of on ground works.

c) Salinity. The dryland salinity program has been well resourced in comparison with other issues. This has focussed on responding to the "use water where it falls" philosophy and reduction of recharge. Lately, this focus has shifted towards productive use of saline lands and "living with salt". The understanding of saline soils and their management is critical to the CCMA region. The issue is linked to soil sodicity (a soil structural issue) and to erosion (by wind and by water). A soil health program cannot therefore operate in isolation from the salinity program.

d) Structure. Decline of soil structure has long been touted as the most extensive soil degradation issue for agriculture and forestry. This decline is attributable to a number of processes, including: carbon or organic matter decline, excessive tillage, animal and vehicle traffic, and tillage in inappropriate moisture conditions. The symptoms include: hard surface soil, poor aggregation (cloddy, floury, unstable in water), surface crusts, and subsurface hardpans, all of which lead to poor plant emergence, poor root growth, and, in some cases, erosion. Understanding of the influences on good soil structure and encouraging these through BMPs must be seen as a priority but this is a difficult issue to measure directly.

e) Waterlogging. The south west is recognised as a wet part of the state with waterlogging a major limitation to cropping and to pasture production. Management of wet soils is a priority recognised by the regional dairy industry (WestVic Dairy) and by cropping groups (Southern Farming Systems). Removal of surface and subsurface water from affected paddocks has great benefit to the production systems but has potentially damaging off site impacts. As a soil management issue this is the most contentious. This above all other issues is the one likely to give the CCMA most political strife. There is good regional expertise on in-paddock solutions but no regional context for water disposal (poorly developed surface drainage network and no strategy for rural drainage[5]).

It is worth pointing out that all of the above issues are to some extent hydrologically driven. The over-arching knowledge need in dealing with any of these issues, and particularly in managing land use change, is the whole area of soil and landscape hydrology. This is also the critical area of understanding for other important catchment issues such as nutrient movement.

Making decisions about priorities

CCMA are faced with choices for investment in catchment management. These choices include the issues that have to be addressed, the manner in which they should be addressed, and the places where they should be addressed first.

Determining maximum or multiple benefits

The salinity program is a good example of a single issue program that has had multiple benefits. While it may not have achieved a measurable reduction in salinity, there have been many catchment benefits derived from the improvements in land management recommended under the program. Soil quality or soil health provides a good conceptual rallying point for a number of soil and land management issues. However, unlike salinity which can be measured directly and easily

[5] A rural drainage review was carried out five years ago for the state – has progress been made on this?

(Electrical conductivity, salt loads, productivity penalties, area affected), soil health cannot be measured or indicated easily. Adopting a soil quality framework for analysis of individual issues and their mutual relationships is useful as a way of dealing with complexity of the soil-agro-ecosystem. Specific soil quality or soil health outcomes can also be related to more generic programs such as river health. This is illustrated in appendix 3 (MacEwan 1998) by an example for the dairy industry. Matrices of relationships between issues and programs are useful tools to illustrate, visually, where multiple benefits may be achieved. There are now also well developed tools for multi-criteria analysis which can be applied to cost benefit analysis of a range of land management issues across a triple bottom line (see, for example; DTLR 2001; and, Beinat and Nijkamp 1998).

Land Use Impact Model (LUIM)

Spatial priorities can be determined using the Land Use Impact Model (LUIM) developed by NRE for the Victorian Catchment Indicators program. LUIM is currently being used to model distribution of soil degradation issues and their relationships to land use in SW Victoria. Final reporting[6] from this project is due early in 2004. The model uses soil and land capability information and expert knowledge of land use practices and impacts to map relative risk of degradation. Output of the LUIM is in the form of maps indicating the relative risk of different forms of degradation under a suite of land use practices, actual or potential. This output can be effectively used to develop spatial priorities for action. The model runs within a GIS but incorporates a measure of certainty/uncertainty as a component of the input data. LUIM can therefore also be used to select priority areas for closing knowledge gaps. LUIM is in continuous development and current research, in a portion of the Goulburn Broken catchment, is being applied to a spatial analysis of landscape scenarios, policies (regional planning, agriculture, conservation) and biodiversity outcomes.

Condition, importance of stream reaches in the region and their vulnerability to off site impacts from land use practices would important data layers to incorporate into LUIM or any other spatial assessment of priority areas for improvement in soil management.

Approaches worth pursuing

Ultimately, a balance in resource allocation has to be struck between encouraging or implementing the obvious, gathering better data, and developing a robust monitoring methodology for the program. The region can be stratified on the basis of geography and industry.

Activities must be industry relevant and specific – need a production context

There are five major industry groups in the region which are, fairly specialised geographically. Each has its own slant on a generic set of problems and because of this it is better to work with these specific groups rather than work with mixed groups.

1. Broadacre cropping excluding irrigation.
2. Horticulture including market gardening and potato growing.
3. Dairy including irrigated dairy.
4. Wool and beef.
5. Forestry.(Already have codes of practice with soil protection content.)

A soil health strategy must engage these industries and their associated communities of practitioners. Each of these industries faces important challenges in relation to soil management

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and therefore have ownership already of some of the issues. They also have existing support in their own industry programs and research activities although these are not generally focussed on soil health *per se.* Extension activities focussed exclusively on messages about good soil management, conservation, environmental values etc., will be poorly received.

Technical training and developing monitoring skills

Recent experience in projects on Environmental Management Systems (EMSs) has shown that landholders can be made very receptive to monitoring the farm environment in quite a detailed manner provided they are given sufficient support. Up to now the EMS projects implemented in the region have had only a minor soils component. Farmers have also demonstrated real interest in quite technical aspects of soil and landscape if this is fostered (Abbott 2002; MacEwan and Dahlhaus 1996).

Soil score cards, EMSs

A partnership approach to development of industry specific, regionally relevant soil quality assessment kits or score cards is needed. These can be embedded in broader EMSs or exclusively soil focussed. However, they will need to be developed from within the industry groups with a productivity or economic justification. There is potential for these to be quite sophisticated if the science is there to back up the methods and interpretation of results. A good example is the 'soil conditioning index' a tool that can predict the consequences of cropping systems and tillage practices on the trend of soil organic matter (USDA 2002). Organic matter is a primary indicator of soil quality and an important factor in carbon sequestration and global climate change, hence the SCI links production and environmental benefits.

Addressing knowledge gaps

Assessment of resource condition is a priority. Without this information there is no baseline to justify a program (do we have a problem?) or to measure program progress (how bad is it now?).

Support industry based research into soil management

Some knowledge gaps are more subtle and require medium and long term research to tackle. For example, much of the region has 'hostile' subsoils, naturally presenting poor soil quality for plant growth and also prone to erosion. These soils limit production so the issue is really one that rests with particular industries and the economic challenges that these limitations present. However, because of the potential benefits to better water management (recharge, sediment movement, nutrient leakage) it is appropriate for the CCMA to support research into subsoil management. Both the dairy industry and cropping industry have current research in soil management.[7] Potentially the presence of the CCMA as a research partner or collaborator on a research submission (e.g. to GRDC) will strengthen the application.

Establish technical support for CCMA

Perhaps the greatest knowledge gap is how to move forward on this complex issue. The CCMA need more substantial technical support in this area than has been available in the past. Projects such as the Corangamite region land resource assessment and the LUIM provide a level of information that provides a platform for the real work of the future. We need an improved understanding of the processes in the landscape and the interactions between landscape function

[7] Is the CCMA aware of these, or partner to all or any of these? Are there any needs that are not being met, e.g.with regard to research activities.

and land use, then we need to respond to this environment in a planned and intelligent manner. Interpretation of this base information is an expert task.

Don't rush into monitoring

Designing a monitoring program would be a good start for a long-term evaluation of processes and land management performance. However, this would require substantial resourcing. There are no government programs that support substantial long-term monitoring of soil condition and until there are, it does not seem appropriate for the CCMA to make this a priority at the expense of practical, industry-focussed soil management projects.

Revisit earlier commitments

The regional CaLP strategy (Corangamite Catchment and Land Protection Board 1997) identified soil management as one of five key action areas (Appendix 1). The first aim under this action area was to appoint a working group to carry out a review and develop a program for soil management in the region. This has not been implemented. A public workshop was also nominated to discuss options. While there have been two "soil summits", both of which were worthwhile in their own right, these were 'show and tell' sessions rather than debate over issues and methods to move forward.

Conclusion

The Corangamite Catchment Management Authority should consider the support of training through industry partnerships rather than attempting to embark on monitoring of soil indicators. The former is likely to bring rewards for the industries involved and for soil health and for water quality. The worth of the latter approach has yet to be demonstrated anywhere in the world. This paper covers some important issues, in many instances these have been dealt with all too briefly. Request is made that this document should be used as intended – as a discussion paper – as it is not purported to be a strategy or an action plan itself.

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Glossary

Definitions and usage for specific terminology in this paper.

Index	A numerical scale or system of scoring the overall state or condition of a resource.
Indicator	A measurable parameter which is sensitive to change (positive and negative) and represents a functional property of a system that is being monitored.
Soil health	General condition of the soil with respect to holistic performance in an agricultural or ecological system.
Soil quality	"The capacity of a soil to function within ecosystem boundaries, to sustain biological productivity, maintain environmental quality, and promote plant and animal health." (Doran and Parkin, 1994). Generally used to describe constituent physical, chemical and biological soil constituents.

Appendix 1

Extract from Corangamite Regional Catchment Strategy 1997.[8]

Focus activity 5. Soil management

ACTION

AIMS	1. Appoint a working group to research and review all information and issues related to soils and develop a soil management program for the region. As a preliminary step, a public workshop to discuss options and activities will be held allowing other interested groups and individuals to contribute. 2. Commence implementation of program by 1997/98.
RESPONSIBILITY	NRE to create group derived from universities, State Chem Lab, CMA, rural industry groups and the farming community.
PRIORITY AREA	Identify areas of landholder interest.
EVALUATION	Review activities and program results annually.

Outcome

Ensure that the deterioration of the soil resource is minimised and production enhanced.

Background

Definitive explanations about the role and importance of soils and soil behaviour in wider catchment processes are not readily available to the community who manage this resource. Other than on soil erosion and salinity very little work is being done in the region to understand the complexity of interrelated soil issues such as waterlogging, erosion, structure decline, salinity, acidity and fertility.

Costs and benefits

The economic impact of soil degradation, as with the issues themselves, is very difficult to explain accurately. With the exception of figures on soil salinity and acidity, vague estimates of extent are all that is currently available. Salinity is estimated to cost $1.15 million per year in lost pasture and crop production, and associated salinisation of water costs industry and residents up to $770 000 annually. The only cost estimated for acidity suggests that to ameliorate acidity in grazing and dairy areas may reach figures of $26.6 million. Despite limited explanations, it is clear that soil degradation issues are restricting the productive capacity of the region and contributing to a range of wider environmental problems like pest infestations, water quality decline, flooding and declining biodiversity.

A better understanding of soils and soil behaviour in wider catchment processes is fundamental to achieving sustainable production, as an objective of the Strategy. The lack of knowledge on this topic restricts detailed discussion on possible soil management projects, but as an initial step the Board suggests the formation of a working group that can identify the issues and gaps and outline a program for implementation in 1997/98. The indicative costs suggested to establish a soil management program are far less than current estimates for production loss. Going further than this and assessing its cost-benefit results in unsubstantiated speculation.

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[8] Corangamite Catchment and Land Protection Board (1997) Corangamite Regional Catchment Strategy June 1997.

However, the Board expects that cost-benefit information would become available through the soil program. in the establishment phase, it is important to integrate suggested soil management activities with successful existing operations such as the Salinity Program, Southern Farming Systems, Target 10 and research work carried out by local universities. This will help form a more coordinated approach to understanding soils in the region, prevent duplication and reconcile where gaps exist.

Appendix 2

Extract from Slattery and Hollier (2001)[9]

Assessment of future risks for soil acidity in the Corangamite region.

Soil types	Current land use	Acidity threats
Yellow duplex soils, 60%	Dryland pasture, uncleared, forestry, dryland cropping.	Significant amounts of poor pasture are being converted to raised bed cropping. This will increase acidification rates due to greater product removal nd incresed water movement through the soil profile. With higher profits though, the ability to spread lime will also increase.
Friable leached earths; 15%	Dryland pasture, uncleared dryland cropping.	Cropping on these soils can occur without raised beds; increased productivity on these soils will result in higher acidification rates.
Dark duplex soils; 10%	Dryland pasture, horticulture, dryland cropping.	Raised bed cropping is increasing in this area and will be moderately acidifying if lime is not applied.
Loam 5%	Dryland pasture, uncleared.	These soils are strongly acidic and their acidification potential under current pasture practice is high. Changing landuse to cropping or horticulture is the greatest threat to acidification.
		Uncleared areas acidify slowly under native vegetation.
Sand 5%	Uncleared, dryland pasture, forestry.	Forestry is cause for concern on this soil type given the poor buffering capacity of this soil and will probably cause subsoil acidity due to cation removal.
		Acid sulfate soil potential exists at Anglesea, pollution of waterways if urban and industrial development disturbs pyrite sediments.

[9] Slattery B, Hollier C, Eds. (2001). Acid soil strategy for Victoria. Commissioned report for DNRE, GBCMA, NECMA and VFF. NRE, Rutherglen.

Appendix 3

Discussion Paper: PMDL Sub-program 3, Soil Management

Sustainability of soil resources in the Australian dairy industry is not addressed directly by any existing programs although there are dairy industry projects that could be redefined in this context. This document presents, for discussion, a framework for delivery of an integrated program of soil management objectives on dairy farms, and is a summary of a report prepared for DRDC as part of the *Protection and Management of the Dairy Landscape* (PMDL) program development.

Introduction

Soil management for sustainability in the dairy industry is the overall aim in sub-program 3 of the PMDL program. Protection of the soil resource will be emphasised more than in past soil related programs which have had productivity increases as their main objectives.

Achievements of outcomes in this sub-program depend on the development and adoption of Best Management Practices (BMPs) for dairy pasture soils. Good soil management is the means both to soil protection and to optimising production. However, without data that show production benefits resulting from BMPs their adoption will be slow and will depend on the good will, altruism and economic health of individual farmers.

Development of a *land ethic* to underpin soil and water management in the dairy industry is therefore a key to achievement of the PMDL program which essentially redefines Landcare for the dairy industry and can build on National, State and local initiatives in the ‘landcare movement’.

The recommendation is that DRDC adopt a catchment and whole farm planning approach for implementation of soil quality and water management. This should be regionally focussed, adopting priorities recognised in regional plans for the dairy industry and responding to environmental issues that concern planning groups (for example, the Catchment Management Authorities in Victoria). The Regional Dairy Committees or Boards will need guidance, facilitation and technical support to enable implementation of the PMDL. Training of dairy advisory staff and dairy farmers in many aspects of soil management will also be needed.

Soil management issues, significance and desired outcomes

Seven principal outcomes have been identified for this sub-program and are discussed under the headings below. The relative significance of issues affecting each outcome is briefly outlined and action for DRDC suggested. Overlap between issues and other PMDL sub-program objectives are indicated.

1 Minimal loss of soil from dairy farms

Soil loss, via water or wind erosion, is uncommon in the dairy industry because there is relatively permanent pasture cover: the roots bind the soil, and the pasture grasses break the impact of raindrops and slow the overland flow of surface runoff. It is therefore relatively insignificant as a soil degradation process in the dairy industry. However, there are some regional exceptions, for example, there are instances in southern Victoria where landslips or tunnel erosion are a characteristic of the landscape.

Erosion risks are highest following over grazing and soil damage, during renovation of pastures, or, when soil is bared in fodder cropping. Stream bank erosion is more generally a problem and requires management of run off from lanes and the maintenance of riparian vegetation which is an issue for sub-programs 2 and 5 (*Water use on and water movement from dairy farms* and *Fostering positive community and market attitudes to dairying*). There are overlaps with sub-program 4 (*Prevention of nutrient movement from dairy farms)* because of nutrient attachment to soil particles.

BMPs are readily available for minimisation of soil erosion and no research is needed. DRDC should review and update existing codes of practice and recommendations for soil erosion control and edit them for dairy farmers. Such re-worked codes should be incorporated with those for dairy waste management, nutrient management, farm layout and laneway construction, design and use. Information should be of a level that would allow the dairy farmers to make a good assessment of hazards and risks.

2 Either pasture systems that reduce rates of acidification, or the regular use of lime to correct pH

Soil acidification is a significant issue for the dairy industry. Nitrate leaching from natural fixation and N fertilisers in high rainfall areas combine with alkalinity losses due to product removal. Subsoil acidification is the most serious threat to sustainable soil management for a number of reasons. It is very hard and expensive to correct; it may go on relatively unnoticed if soil sampling analysis is carried out only on the top ten centimetres; and there is evidence of irreversible processes of mineral degradation in strongly acid soils.

Liming is accepted practice but may not be sufficiently used across the dairy industry. Productivity responses cannot be generalised because of regional variations and this can affect the adoption of liming. The opportunity exists for DRDC to build on the LWRRDC national soil acidification work by developing decision support systems for managing soil acidity specifically in the dairy industry and encouraging adoption of soil monitoring and liming. The fertiliser companies and lime suppliers are significant potential allies in any extension program on soil acidity. Because of the long term nature of pH changes, DRDC should also support maintenance and monitoring of long term research plots.

3 Well-structured soils

Soil structure management is probably the most significant general issue for any soil used for dairying. This outcome is strongly related to soil loss, wet soil management and soil biological health, and, because of its influence on water and nutrient movement, it is also important for sub-programs 2 and 4 of the PMDL.

‘Good’ soil structure for dairy pastures is a compromise between a number of functions: soil must be open and soft to encourage root growth and water and air movement, but needs to be strong enough to support animals. The main degrading influences are intensive treading, particularly in moist or wet conditions, and inappropriate type or timing of tillage. Soil sodicity is a confounding factor in some areas. The issue of organic matter in maintenance of soil structure is probably insignificant in dairy soils because there are adequate inputs from pasture roots.

Soil structure is not well appreciated as an important aspect of dairying, and renovation of structurally damaged soil is not an advanced art in dairy pasture management. Type of tillage, implement geometry, working depth, timing and soil moisture conditions all act together to determine success or failure in dealing with soil structural problems. Diagnosis of specific conditions of structure decline and the delivery of appropriate remedies requires research and development. DRDC should liaise with New Zealand soil scientists in AgResearch who are researching this issue in their pasture systems.

4 Specific practices and guidelines for managing wet soils

Wet conditions increase the vulnerability of soil to structural damage and have the potential to encourage erosion and affect water quality in catchment streams. Wet soil problems are aggravated by inappropriate timing, intensity and duration of grazing, and by poor irrigation scheduling or expansion of irrigation onto unsuitable soils. Their management is a priority in Victoria and Tasmania, with the need recognised elsewhere. This issue overlaps sub-programs 1, 2 and 4 of the PMDL program and is related to outcomes on soil loss, soil structure and soil biota in this sub-program.

The topic has been recently reviewed and options defined for WestVic Dairy. Options are to improve soil conditions by drainage, or to control grazing and minimise damage. BMPs can be developed but drainage practice will be soil and regionally specific. Productivity benefits have been demonstrated through research programs but the economics are still uncertain. There is a considerable extension task to carry out in this area which will only succeed if there is technical support. DRDC should take a leading role in driving an advisory system. There are no effective links to other industries with the issue being dairy industry specific, insofar as the problem is tolerated more widely in other grazing sectors (wool and beef).

5 Minimal build-up of chemical residues (or other undesirables such as sodium)

Minimising soil contamination (accumulation of elements or compounds not normally found in soil) and soil pollution (accumulation of excesses of naturally occurring elements and compounds) is the least tangible outcome in this sub-program. Its significance is unknown, although contamination and pollution will probably be regionally specific. Accumulation of metals, pesticides, and salts, and development of sodicity can all be included in this topic. Cd and heavy metal contamination are generally low risk to animal health because of limited mobility of these elements in soil. Salinisation is dealt with by regional salinity plans in all affected parts of Australia used for dairying, but sodicity receives less attention than it deserves.

A 1998 report by the National Cadmium task force provides context for this element. DRDC could commission a low key audit of this and any potential pesticide problem, but there are sensitivities in relation to affected land. Apart from potential inputs in fertilisers, contaminating practices are not obvious and problems are more likely to be inherited from previous land use practices such as horticulture. Pollution sources as applied irrigation water or effluent disposal are more obvious. DRDC should sponsor development of a decision support system for management of sodic and saline soils in dairying, and implement it through existing networks. In some localities such as around the Kerang region this process is already quite advanced.

6 Large and active populations of soil biota so that organic matter breaks down rapidly, releasing nutrients for pastures, and maintaining soil structure.

Soil biology is one of the most complex, least studied and least well understood aspects of soil science or soil management. While it is well appreciated that soil biota perform a number of important functions, we do not know much about the dynamics of the populations. High rates of fertiliser use, irrigation, and intermittent but intense grazing with large additions of urine and faeces all combine to provide a unique soil ecosystem in dairy pastures. Original research is therefore needed if this system is to be understood, as most soil biological work has been carried out in cropping systems. Monitoring of soil biological condition still requires the selection of appropriate indicators and methods. This is a research area that is unlikely to be adopted unless supported by DRDC. Opportunities to collaborate with, or adopt, New Zealand research methods should be investigated.

7 Chemically fertile soils with appropriate balances of essential macro and micro nutrients to maintain quality of pasture and support animal health.

While plant nutrition is a concern of dairy farmers who are intensive users of fertilisers, the question of maintenance of soil chemical fertility is a separate issue. Refinement of guidelines for NPK applications, related to expected increases in milk from pasture, is an expected outcome of current and future pasture research but this will not necessarily result in sustainable management of soil fertility. Nutrient reserves and natural replacement (weathering, recycling) should be related to measurements of nutrient removal in a nutrient balance for dairy pasture systems on different soils. Potential 'crashes' in reserves or availability of essential macro or micro nutrients can be anticipated and avoided by nutrient replacement. Nutrient cycling via the soil ecosystem and impact of fertilisers on this system also need to be understood.

Relationships between outcomes and sub-programs

The inter-dependency of issues and outcomes presents a somewhat complex picture of the soil management needs for the PMDL. However, the positive side of this is that measures taken to achieve any major outcome will inevitably go part way to fulfilling other objectives. A matrix of the relationships between outcomes and between these and the other bio-physical sub-programs is shown in table 1.

Table 1. Relative inter-dependency of outcomes within PMDL sub-program 3 and with objectives of the water use and nutrient movement sub-programs.

Degree of inter-dependence: ▓ strong ; ▒ moderate ; ░ slight.

	Water use	Nutrient movement							
1 Minimise soil loss	▓	▓	**1**						
2 Reduce acidification	░	░	░	**2**					
3 Maintain soil structure	▓	░	▓	░	**3**				
4 Manage wet soils	▓	▓	▓	░	▓	**4**			
5 Prevent contamination	▒	░	░				**5**		
6 Maintain soil biota	░	░	▒	░	▒	▒	░	**6**	
7 Maintain chemical fertility	░	▓	▓	▓	░	▒	▓	▒	**7**

Soil quality framework for integration of issues and activities

DRDC should integrate soil management activity by focussing on soil quality or soil health in the dairy industries. Diverse issues need a focus and the term *soil quality* is increasingly being used internationally and nationally to provide that focus. The concept of soil quality complements current Federal government initiatives such as the *National Soil and Water Audit*, and the *Dryland Farming Systems for Catchment Care* program (indicators of catchment health). A dairy soil quality program would therefore be well situated to tap into wider resources in terms of technical support and funding base if developed in parallel.

Soil quality has been defined as:

> ‘The capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation.’

A soil quality framework adopts a functional approach to soil, emphasises sustainability, and can be industry specific.

Soil functions for dairying and sub-program 3 outcomes

The use of land for dairy pastures imposes a number of functional demands on the soil which must:

- Support plant growth.
- Provide healthy fodder that is free of contaminants and contains appropriate balances of macro and micro-nutrients.
- Absorb, store and recycle nutrients from fertiliser and dairy wastes, acting as a repository for plant nutrients and as an environmental buffer.
- Support high intensity treading activity across a range of moisture contents and resist surface damage.
- Receive, store and transmit water which is either natural (rainfall) or applied (irrigation).

Protection and enhancement of these functions can be achieved through the outcomes for sub-program 3. The relationship between these outcomes and the soil quality functions listed above is illustrated in table 2, with relative importance represented by the degree of shading. Blank cells are deemed to indicate no relationship.

Table 2. Relative importance of dairy pasture soil quality functions for outcomes in sub-program 3 and objectives of water and nutrient sub-programs.

▓ very important; ▒ important; ░ relevant.	Outcomes for sub-program 3							Other PMDL sub-program objectives	
Functions	**1**	**2**	**3**	**4**	**5**	**6**	**7**	Water use	Nutrient movement
Support plant growth	░	▓	▓	▒	░	▒	▓	░	░
Provide healthy fodder	▒	░		▒	▓	▒	▓	▒	▓
Absorb, store and recycle nutrients	░	▒	▒	░	▓	▓	▓	░	▓
Support high intensity treading activity	░		▓	▓		▒		▓	░
Receive, store and transmit water	▒	░	▓	▓		░		▓	▒

Outcome issues: **1** soil loss; **2** acidity; **3** structure; **4** wet soil; **5** contamination; **6** soil biota; **7** fertility

Implementing a soil quality program

Land capability and condition assessment at the regional and farm scale provide the basis for soil quality monitoring and can indicate priority areas for changes in management practices. Existing regional soils data may in most cases be deficient and will need augmenting. Farm scale soil and land assessment should be encouraged by training and supporting landholders, and expanding existing PMP (Property Management Planning) processes or activities of dairy discussion groups (farm walks, soil pit days, farm planning exercises). Dairy support staff will also need training in principles of land and soil evaluation.

DRDC should appoint a coordinator to refine objectives and methodology in an overall soil quality program which must integrate all outcomes discussed here. This program will serve as the channel for negotiation concerning the dairy industry’s partnership in specific National or State initiatives, such as soil acidification or salinity. The importance of overlaps that have been indicated between soil management and other objectives in the PMDL suggests that the soil quality program should be combined with the sub-programs on water use and nutrient movement. Teams working either nationally, or regionally (supporting the development boards) can be developed according to needs. For example, two logical groupings are:

- soil structure, wet soils, irrigation and drainage, soil macro-fauna, physical aspects of nutrient movement, soil loss, PMP and farm layout.
- soil acidification, soil sodicity and salinity, maintenance of chemical fertility, soil micro-biota and nutrient cycling, chemical aspects of nutrient movement, soil contamination.

Current research in soil quality in New Zealand pastoral systems runs parallel to the objectives in this sub-program. DRDC should take a close look at this overseas work while developing coordination of an Australian dairy soil quality research, development and extension program.