# Management of soil health for sustainable vegetable production

Ian Porter
Victorian Department of Primary Industries (VICDPI)

Project Number: VG06090

**VG06090**

This report is published by Horticulture Australia Ltd to pass on information concerning horticultural research and development undertaken for the vegetable industry.

The research contained in this report was funded by Horticulture Australia Ltd with the financial support of the vegetable industry.



ISBN 0 7341 1712 4

Published and distributed by:

Horticultural Australia Ltd

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179 Elizabeth Street
Sydney NSW 2000
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# Management of soil health for sustainable vegetable production

***Horticulture Australia VG06090***

September 2007

Ian Porter, Robyn Brett and Scott Mattner

Primary Industries Research Victoria, Knoxfield Centre

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## Purpose of project:

This project details the outcomes of a 12-month study to determine priorities for funding projects on soil health in the vegetable industry.

Report completed: September 2007

## *Acknowledgments:*

The researchers gratefully acknowledge the financial support for this project from Horticulture Australia Limited (HAL), AUSVEG, the Federal Government and the Department of Primary Industries, Primary Industries Research Victoria.



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# 1. Media summary

This project conducted a 12 month review of the temperate vegetable industry to assist Horticulture Australia and AusVeg develop a strategic direction for soil health research, development and extension over the next 5 years. The project consisted of State workshops, a literature review and demonstration trials to validate tools for benchmarking soil health. As a result of the project a Vegetable Soil Health Management Program for the next 5 years has been further developed by HAL in consultation with industry and leading research agencies. Key to this program are that industry is engaged throughout the life of the program, that the research program concentrate on the bottom line for growers and that a clear strategy be developed for greater adoption and evaluation of 'best practice' soil health management.

During this project, workshops conducted in South Australia, Tasmania and Victoria in 2007 determined that the key drivers to adopt good soil health management on farm were to improve production efficiency by; 1) more effective management of inputs (water, pesticides, fertilisers, organics); 2) improvements to soil structure and water use efficiency; and 3) sustainable disease control. Better management of these aspect of soil health were seen to improve yields, profit and product quality on farm, whilst minimising environmental costs and natural resource protection.

To achieve these outcomes the four key priorities for future research and extension were identified:
1) to measure and benchmark good farm practices for improved soil health
2) to measure and understand the impact of crop rotations and tillage on soil structure, erosion and disease suppression;
3) to better manage organic inputs and organic carbon for improved soil health and water use efficiency of soils;
4) to extend information that would drive adoption of "best practice" soil health management in three areas: management of biological and chemical inputs into farming systems and management of physical inputs, especially tillage and water use efficiency.

In addition, a literature review that positioned Australia's soil health commitment in vegetables against soil health investment in other areas and industries was also conducted. A global shift in environmental funding toward soil health (after air and water quality) was identified, with key research already conducted in the cotton and grains industries in Australia. A willingness by the vegetable industry to participate in soil health activities is seen as a significant step towards future food security and environmental sustainability.

Finally, demonstration trials were conducted on properties of two key vegetable growers to test the rigour of in excess of 35 potential soil health indicators. Through these trials, a selection of chemical, biological and physical soil health indicators were identified for use in future research trials.

# 2. Introduction

Worldwide, declines in soil health have been attributed to land clearing largely for agricultural purposes, with soil physical and chemical factors such as erosion, acidity and salinity being the main documented effects. Soil biological factors that relate to soil health have been given little attention, mainly because they are generally and comparatively poorly understood. This is despite science understanding that the biological, physical and chemical attributes of soil are closely entwined and that soil function is largely dependent on interactions between the three. In recent years, a holistic or "ecosystems" approach to soil health management has been evolving, but understanding of the biological component of the trilogy is still far behind understanding of soil physical and chemical factors.

Whilst some agricultural industries (eg dryland agriculture, cotton) have tried to understand and begin to act upon the implications of an ecosystems approach to soil health, others, such as the Australian vegetable industry have only recently recognised the importance of this issue. This project represents part of the first stage of soil health research in Australian vegetable farming. Its aim was to gain a greater understanding of potential environmental gains from improved soil health, and to provide direction for future research and extension activities that will make positive changes to soil health at the vegetable farm level.

In 2006/07 the vegetable industry allocated funds to undertake research into soil health. Three levels of activity were initiated, and together they comprised a Soil Health Program for the Vegetable Industry. The three activities were:

- QLD DPI were allocated funds for a 2 year project to understand soil health limitations, identify improved management techniques and to determine what information vegetable growers need to implement plant and soil health strategies, "Vegetable Plant and Soil Health – VG06100"
- VIC DPI were allocated funds in 2006/07 to undertake a review of national and international soil health policies and literature, and to undertake a gap analysis of research requirements for future soil health work. The aim of the project was to identify current knowledge, research and development gaps, and to identify preliminary research priorities for soil health for the Australian vegetable industry. The outcomes of the project are reported here;
- External Government funding was provided to the vegetable industry, through AusVeg, to develop a practical guide for soil management. The project "Ute Guide & Soil Health Interpretation Courses for Vegetable Growers" has funding into 2007/08.

# 3. Methodology

The current project contained three distinct activities that were jointly directed toward developing a strategic plan for future soil health research. The first activity was a literature review that put into context the position of Australia's vegetable industry against soil health in other Australian industries, and internationally, both at a farm and catchment level.

The second activity was to conduct a series of national workshops, where growers, researchers, industry development officers, catchment management authorities, and anyone else with a vested interest in the future of soil health and agricultural production, could play a role in determining the priorities for future research in soil health in vegetables. By drawing on the vast breadth and depth of knowledge that was brought together at each of these meetings (Tasmania, Feb 2007; South Australia, Feb 2007 and Victoria, August 2007), a strategy for future soil health research and extension was developed.

The final activity that was conducted during this project was two demonstration trials on growers' properties, where a wide range of soil health indicators were rigorously tested for their robustness in determining soil health outcomes of differing soil management practices. Selection of properties was based on management styles, with a conventional vegetable farm being compared with a farm with a philosophy of lower inputs and long term sustainability. Ten sites were selected for differing crop, disease and management histories, compared with a native grassland control and a non-production area control.

# 4. Soil health in the Australian vegetable industry: a review of soil health literature and policy.

## 4.1. Introduction

This review represents part of the requirement of project VG06090 to provide a context for future soil health research in the vegetable industry. In addition a series of workshops were conducted in key regions throughout Australia to determine areas of soil health research which can add gains to on farm and catchment management issues.

Worldwide, declines in soil health have been attributed to land clearing largely for agricultural purposes, with soil physical and chemical factors such as erosion, acidity and salinity being the main documented effects. Soil biological factors that relate to soil health have been given little attention, mainly because they are generally and comparatively poorly understood. This is despite science understanding that the biological, physical and chemical attributes of soil are closely intertwined and that soil function is largely dependent on interactions between the three. In recent years, an holistic or "ecosystems" approach to soil health management has been evolving, but understanding of the biological component of the trilogy is still far behind understanding of soil physical and chemical factors.

## 4.2. Soil health in vegetables

Whilst some agricultural industries (eg dryland agriculture, cotton) have tried to understand and begin to act upon the implications of an ecosystems approach to soil health, others, such as the Australian vegetable industry have only recently recognised the importance of this issue. This review represents part of the first stage to gain a greater understanding of the broader environmental context, and direction for how to make positive changes at the farm level.

As a major exporter of agricultural produce ($17.6 billion value annually according to the National Land and Water Resources assessment in 2001) Australia makes a significant contribution to global food security. The main driver of agricultural producers, however, is not feeding the world, but making an economic profit. In simple terms, profit is threatened by declines in soil health that can be attributed to:
(i) physical factors (eg erosion that results in removal of topsoil and the nutrients contained therein);
(ii) chemical factors (eg salinity or acidity that provide suboptimum growing conditions for crops, and have follow-on effects on uptake of nutrients); or
(iii) biological factors (eg outbreaks of diseases and pests that result in lower or poorer quality yields).

To combat these threats, crop management practices have traditionally revolved around high inputs, and growers have been contributing to soil health decline due to either lack of understanding or lack of other options. A recent study by Pung et al 2003, identified intensive farming practices as being able to mask the effect of poor soil health, with the challenge being to improve soil health whilst reducing management inputs. They suggested that an evaluation of economic cost-benefits might encourage lower inputs and acceptance of lower yields, as well as improving economic and environmental sustainability.

On the northern Adelaide Plains, ground water problems have been recognised as substantially contributing to loss of soil structure, soil salinity, waterlogging and restricted water cycling (Stevens 2002).

In the mid-1990s the Northern Adelaide Plains Land Management Group (NAPLMG) in collaboration with Primary Industries and Resources South Australia (PIRSA) ran a project to investigate the decline and loss of horticulture production on the Northern Adelaide Plains. They found there were seven key causes of crop decline or loss:

- Soil salinity
- Soil sodicity
- Extremely low organic carbon, <1%
- Low nutrient holding capacity in many soils
- Poor or no soil structure
- Excessive and imbalanced fertilisers
- High cost of commercial compost

They also found that the level of available nutrients changes with soil type or texture, organic matter, soil salinity, sodicity and irrigation water. From this project, a “Soil and Plant Nutrition Training Program” has been developed in conjunction with Rural Solutions SA, and funded by NHT and FarmBis.

Irrigation management has also been shown to affect soil health. A study of irrigation requirements for vegetable growing on the Swan Coastal Plain in Western Australia (Lantzke, 2003) identified optimum irrigation design as critical to soil health. The study found that poor irrigation design lent itself to over-watering, which in turn increased fertiliser demands due to leaching, which in turn had a detrimental effect on the cropping soil and the greater environment. They concluded that optimum irrigation design could increase grower profitability, reduce nutrient losses and increase water use efficiency.

Soil health not only affects grower profitability. Human health, as a consequence of consuming produce, may be affected by poor soil health. For example, chloride concentration in soil, either due to salinisation of soil, or irrigation with salty water, was found to be a major contributor of cadmium uptake of vegetables in a study by McLaughlin (1996). In another study of heavy metals in agricultural soils, Barry (1997) determined the concentration of eleven heavy metals (arsenic, cadmium, cobalt, chromium, copper, mercury, molybdenum, nickel, lead, selenium and zinc) in horticultural soils in Queensland. The study found that total concentrations of all of the tested heavy metals fell within the internationally reported ranges. Cadmium, however, was reported as accumulating faster in horticultural soils than in non-horticultural soils.

In contrast to these studies that have identified many grower practices as contributing to soil health decline, marketable yield and soil quality were improved by the addition of compost to vegetable production in field trials in Western Australia and Victoria (Paulin 2005). Compost can positively contribute to the biological (microbial biodiversity), physical (soil structure) and chemical (nutrient) capacity of soil. Adoption of compost as a soil ameliorant, however, has not been widespread. The barriers to adoption in general have been inconsistent availability of suitably matured compost, cost and difficulties with altering fertiliser programs (Paulin, 2005).

## 4.3. Australia’s perspective on soil health

In Australia, the Federal Government (Department of the Environment and Water Resources) reports on the condition of the environment every five years. These “State of the Environment” Reports are conducted under a number of themes (atmosphere, biodiversity, coasts and oceans, human settlements, inland waters, land, natural and cultural heritage, Australian Antarctic Territory) and assess environmental information to monitor trends for governments.

The states also conduct State of the Environment Reports. Whilst some states (NSW, Tasmania) have been conducting these reports for the past 10 years, Victoria’s first report is currently in preparation.

State of the Environment reports have been supported by the National Land and Water Resources Audit (1997-2002) funded by the Natural Heritage Trust and Land and Water Australia. The aims of the Audit are to “provide data, information and nationwide assessments of Australia’s land, water and biological resources to support sustainable development”. The audit is continuing to June 2008 under agreed strategic directions which are predominantly concerned with collecting and managing data that will inform natural resource management decision-making.

Agriculture is the biggest land use in Australia, covering 61.5% of the country (Beeton et al 2006). The topic of soil health first appeared in the State of the Environment reports in 2006. Under the land theme, Beeton et al (2006) proposed that substantially more work was required to improve the condition of Australian soils. Soil carbon, soil salinity and soil acidity were identified as the three main areas of concern for soil health.

Previously soil erosion had been the key soil health issue to be discussed in the land theme of the State of the Environment Reports (Hamblin, 2001, Gleeson and Dalley, 2006). The average rate of annual soil loss in Australia is estimated at 7 t/Ha across all land uses and almost 13 t/Ha for vegetable production areas (Hamblin, 2001). The estimated rate of soil replacement by organic decomposition, by comparison, is estimated at 0.5 t/Ha/year (Gleeson and Dalley, 2006).

In Australia, widespread soil acidity is recognised as a major factor affecting soil health, and has been of such great concern that an independent inquiry into the status of soil acidity was launched in 2002. The Victorian Parliamentary Inquiry into Soil Acidity (Environment and Natural Resources Committee, 2004) found that soil acidity was being exacerbated by land management practices. Of broader interest, the report identified a number of other soil health issues of concern for Victoria: soil fertility, structural decline, erosion, loss of organic matter and salinisation. Critically it proposed that these issues should not constitute distinct research priorities but rather they should be addressed in a coordinated manner.

The inquiry alerted the Victorian government to the economic importance of soil health and prompted the development of a soil health framework at the policy level (Towards a Soil Health Framework for the Department of Primary Industries Background Paper (Allaway 2006)). The focus of the paper is directed mainly at agriculture, but it is acknowledged that "soil health is concurrently an environmental, economic and social concern, being a fundamental component of healthy landscapes, economic prosperity and social well-being in rural and regional areas".

## 4.4. International perspective on soil health

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The leading global organisation in the area of land management is the United Nations (UN). The UN has a history of investment in soil related issues through the Food and Agriculture Organisation and the United Nations Environmental Programme. Soil survey, land evaluation and soil conservation are the dominant themes in the work of the UN and FAO with soil quality and soil health implied rather than explicit. The FAO soils bulletins published since 1965 and the land and water bulletins published since 1995 contain substantial scientific knowledge and support for soil management. In particular early publications on soil survey and land evaluation (FAO 1967, 1976) provided the context for more specialised advisory bulletins (FAO 1983, 1985), integrated land use planning (FAO 1995) and the use of indicators (FAO 1997). Many of these publications are available as electronic documents through the FAO web pages (http://www.fao.org/publishing/). The FAO literature is largely directed towards less developed countries, focussing on extremes of degradation, issues affecting food and water security and using land within its capability.

The UN has also been an important agents for policies concerning soil and land management, significant milestones being the World Soil Charter (FAO 1982), Agenda 21, and the United Nations Environmental Programme's strategy for land use management and soil conservation (UNEP 2004). The latter proposed an ecosystem approach relating land and soil issues to other environmental focal areas, building on the 1982 World Soil Charter (FAO 1982) which had called for commitment by governments and international organisations to manage the land for long term advantage rather than short term expediency.

### 4.4.1. New Zealand

New Zealand has a significant history of work in soil quality and soil health. The 1991 Resource Management Act (RMA) Section 35 requires Regional Councils to report on the "life supporting capacity of soil" and whether current practices will meet the "foreseeable needs of future generations". Protocols for monitoring land and soils were established in a six year trial commonly known as the '500 Soils Project' (Sparling et al. 2004), and an interpretive framework for reporting at a regional scale was developed (Lilburne et al. 2004). The 500 soils project was evaluated by Hill et al (2003) who recommended that seven soil quality properties (total C, total N, mineralisable N, pH, Olsen P, bulk density and macroporosity) validated in the work should form part of any soil quality monitoring programme. The requirements of the NZ RMA for reporting on soil quality at national and regional scales have parallels with Australian partnership agreements for NRM but, up to this point, there has not been the equivalent investment in monitoring Victorian soil condition. Lilburne et al (2002) have described the strong relationship between legislation, policy and science for soil quality in New Zealand. The situation in Victoria, Australia, is such that legislation (the CaLP Act of 1994) and soil health policy (DPI 2006) are also aligning with funding to provide science to implement that policy.

### 4.4.2. SLURI

Recent developments in New Zealand have seen a rebirth of soil science in the form of a 'Sustainable Land Use Research Initiative' (SLURI), a national centre for maintaining and managing New Zealand's soils (NZ Agencies 2004). This is effectively a collaborative venture devised by separate Commonwealth Institutes (HortResearch, AgResearch, Crop and Food Research, and Landcare Research) in order to gain government support for soils research.

SLURI's five priority areas (http://www.sluri.org.nz/index/page/25) for new science are:

- Intensification and Soil Functioning - Tools to ensure maintenance of soil services in the face of pressure from increasing inputs.

- Managing Land-use Change – Provision of knowledge to assess the performance of land-uses now being carried out on soils not formerly used for these purposes, and the prediction of plant performance to express certain traits or qualities.
- Resilience under Change – New system designs to sustain existing land-uses in the face of the exigencies created by increasing climate variability and extreme weather events.
- Valuing the Natural Capital of Soils – Research is required to assign value to the natural capital of our soils and waters to underpin rational land-use decision-making and resource allocation by industry and policy makers.
- Landscape Designs – Tools are required to integrate and scale-up our understanding of enterprise and sector behaviours across the mosaic of land-uses to permit equitable resource allocation and sustainable coexistence of land uses.
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### 4.4.3. Europe and the UK

The European Union has recently prioritised soil health in the same way that it prioritises the protection of air and water resources. A substantial policy document (Van-Camp et al 2004) that makes up the 6th Environmental Action Plan outlines three areas of major concern for soil health and incorporates them into policy. The three areas identified as of most concern to soil health in Europe are:

- Erosion – compaction, floods and landslides, salinisation
- Organic matter – biodiversity
- Research **–** sealing (refers to sealing of soil surfaces by urban infrastructure, and subsequent loss of biodiversity and soil function).

Five technical working groups comprised of experts from EU member countries were formed to thoroughly explore the issues, and their reports are available in the document. The working groups report around a two stage structure so that 1) the problem is defined and 2) scenarios to address the issues, the objectives and targets, the means selected to achieve the objectives, their timetable and relevant monitoring tools are defined.

In the UK, parallel initiatives have been developed for England, Wales and Scotland with strategies for soil quality or soil health being recently adopted (DEFRA 2004, SEPA 2006).

### 4.4.4. Canada

The Canadian Government have been active in the monitoring and management of soil health. Twenty-three benchmark sites were set up across Canada in 1989 to monitor soil quality under representative farming systems and landscape conditions. Measurements of key soil properties relating to land use and land management were made over several years and provided baseline data in 1995 for future monitoring. Results of the program were reported as a strategic framework for soil health in 1995 (Acton and Gregorich 1995).

The report concluded that new government policy for soil conservation was needed, aimed at achieving sustainable agriculture with the understanding that agro-ecosystems are part of the broader environment. This reflects changes elsewhere in the world where soil conservation programs focussing on soil loss and erosion management have broadened their approach. Acton and Gregorich (1995) also acknowledged the issue of scale and proposed that soil management programs are best designed at the farm level, integrating management practices to suit specific, local soil needs.

Within Canada, the State of Alberta has shown the greatest uptake of the national strategy. Alberta has had a soil health monitoring program in place since 1997 and there is considerable documentation of this program available on line (Alberta Government 2006). Key documents prepared recently in this program are:

- A description of site selection and sampling protocols for the Alberta benchmark sites (Cannon 2002).
- An extensive review by Winder (2003) describing 52 environmental/soil monitoring programs from around the world.
- A review synthesising literature on soil quality indices (current to December 2003) to inform recommendations for use in the Alberta Environmentally Sustainable Agriculture (AESA) Soil Quality Program (Hall 2003).
- A review of soil quality indicators with implications for Alberta's agro-ecosystems (Bremer and Ellert 2004).

### 4.4.5. USA

Research and extension for soil quality and soil health have been prevalent in the USA since the early 1990s and much of the early literature on soil quality originates from the USA. Seminal publications such as those by the Soil Science Society of America (Doran and Jones 1994; Doran et al. 1996) set the scene for much of the language and approaches to soil quality and soil health adopted internationally. At the time of these publications the USDA Soil Quality Institute produced a range of fact sheets and technical notes on soil quality that were widely available via the world wide web. Much of the work has been highly practical in nature and geared to the development of quality score cards and assessments for use on farm, with several of the states developing their own applications. A recent review by Wienhold, Andrews and Karlen (2004) emphasises the potential for a broadly based soil quality index .

## 4.5. Australian Projects in Soil Health

Over the past few years, a number of projects or initiatives that have a soil health theme have been funded in agricultural industries in Australia. Several of them are listed below.

### 4.5.1. Grain and Graze

The Grain and Graze projects are collaboratively funded by Meat and Livestock Australia, Grains Research and Development Corporation (GRDC), Australian Wool Innovation Limited and Land and Water Australia. They aim to encourage mixed farming as a way to combat declining soil health, herbicide resistance and rising water tables. The projects are conducted at a regional level, but fall under four national topics (feedbase supply and demand, whole-farm economics, social considerations, and biodiversity) that reflect priorities defined by regional producers (Anon 2006).

### 4.5.2. Healthy Soils for Sustainable Farms

The Healthy Soils for Sustainable Farms Program is a major soil health initiative managed by Land and Water Australia and funded by the Department of Agriculture, Fisheries and Forestry through the Natural Heritage Trust, and GRDC. It is a 5 year, $5 million program with 10 projects:

- Soil Health – Leaving a legacy for South eastern Australia
- Sustainable soil management workshops for Queensland broadacre cropping industries
- Improving soil health in Western Australian farming systems
- Ute guide and soil health interpretation courses for vegetable growers
- Managing landscapes – matching soils, climate and enterprises
- Healthy soils module for a sheep producer’s best practice package
- Defining and promoting soil health for sustainable production systems
- Accelerating adoption of integrated soil management practices in irrigated cotton and grain
- Delivering workshops on low input farming approaches to soil health management
- Sustainable farming practices in the mid-Loddon sub-catchment

### 4.5.3. Our Rural Landscapes

Our Rural Landscapes (ORL) was an initiative of the Victorian Government aimed at developing innovative technologies for the sustainable development of Victoria’s agriculture sector. The ORL initiative envisaged four possible future landscapes:

- Environmentally-balanced intensive production systems that achieve dramatic improvements in resource efficiency
- Perennial-based extensive production systems that better match ecosystem processes
- Biologically attuned extensive production systems for low rainfall environments that utilise perennial and annual species
- Viable systems for small-farm landscapes valued for both agricultural production and environmental products and services (eg landscape amenity, biodiversity)

Five key projects and 14 sub-projects were funded under the ORL initiative. The key project relating to soil health was “Understanding and protecting the soils of our rural landscapes” which aimed to use genetic techniques to characterise Victoria’s soils and develop a biological soil health test (Anon 2002).

### 4.5.4. Cotton Industry

Soil health has been a priority for the cotton industry for several years, with many projects funded by the Cotton Research and Development Corporation (CRDC) focussing on nutrition and soil physical fertility. More recently the industry has been investigating the relationship between soil biology and soil fertility. An extensive survey was conducted with 30 cotton growers to assess their understanding of various aspects of soil health, what they have done to enhance soil health, and identify gaps in knowledge (Shaw 2005). Many gaps for further research or extension were identified, but some of the key ones from growers’ perspectives were:

- better understanding of soil biology
- managing and measuring microbial activity in relation to organic matter breakdown, nutrient cycling and disease management
- the effect of farming practices on the soil biota
- better understanding of herbicides (residues and run-off)
- improving VAM populations through better management
- measuring soil health using indicators

### 4.5.5. The CRC for Plant-Based Management of Dryland Salinity and the CRC Future Farm Industries

The CRC for Plant-Based Management of Dryland Salinity (2001-2007) aimed to reduce salinity problems by restoring the balance between rainfall and plant water use. It brought together 11 partners (Charles Sturt University, Commonwealth Scientific and Industrial Research Organisation, Department of Agriculture and Food Western Australia, Department of Conservation and Land Management Western Australia, NSW Department of Primary Industries, Department of Primary Industries Victoria, Department of Primary Industry and Resources South Australia, Department of Sustainability and Environment Victoria, Department of Water, Land and Biodiversity Conservation South Australia, The University of Adelaide, the University of Western Australia) to address the CRC’s goals. As the CRC for Plant-Based Management of Dryland Salinity draws to a close, a new CRC (Future Farm Industries (CRC FFI) has been approved and will concentrate on innovative farming practices to address issues such as reduction of salinity damage, enhanced biodiversity and better adaptation of land uses (www.crcsalinity.com).

## 4.6. Why should governments be interested in soil health?

The main drivers of soil health are:

- Population growth and subsequent demand for produce
- Human health (eg heavy metal accumulation in edible produce)
- Environmental health (air, water, land)

### 4.6.1. Population growth

Doran (2002) regarded soil health as of paramount importance for protecting the future of agricultural food production, in view of the growing population and declining quality of agricultural soils. Global projections for human population food requirements by 2050 indicate that these will be at least double their present levels (FAOSTAT 1998). Given the limited availability of land and water, most of the increase in production will have to be met from existing soil and water resources or from marginal agricultural land. Pressure on the soil resource will therefore inevitably increase along with associated pressure on ecosystem services dependent on soil.

### 4.6.2. Human health

Heavy metal accumulation in edible produce can result in health problems for consumers. Cadmium, in particular, has been identified as a potential threat to human health via vegetable consumption. Cadmium is an element that occurs naturally in soil and rock, and phosphorus-containing fertilisers can be high in cadmium (depending on the source of rock phosphate used in manufacturing) (Vegenotes 2003). Regular surveys of vegetable product are conducted to monitor for levels of cadmium (and other chemical residues). Soil salinity has been linked to increased uptake of cadmium in vegetables (McLaughlin 2006) whereas alkaline soils tend to reduce the amount of cadmium available (Vegenotes 2003). Some vegetables are more susceptible than others to cadmium uptake. Reducing inputs of superphosphate fertilisers and reducing agronomic practices that contribute to salinity are considered to be the best ways to control cadmium uptake by crops (Vegenotes 2003).

Monitoring of pesticide residues in fruit and vegetables at market is conducted regularly. In NSW a survey conducted by NSW Agriculture, Horticulture Australia and Sydney Market Authority between 1997 and 2000 found that 10% of samples contained at least 50% of the maximum residue level (MRL), and 5% exceeded the MRL. Where it was possible to trace back to the cause of the high residue levels, the major cause was incorrect use of pesticides (incorrect application, rate or withholding period) or using a pesticide on a crop for which it was not registered (www.agric.nsw.gov.au).

### 4.6.3. Environmental health

In Australia, State Governments have been interested in environmental health from a catchment management perspective and have established a number of natural resource management (NRM) groups. Previously NRM groups were focused on repatriation of degraded landscapes, but recently have begun to adopt a more holistic, ecosystems approach to management (Department of Primary Industries, 2006). This is an important shift in protecting and providing for the sustainable use of broad landscapes. These landscapes may encompass land that is utilised for different purposes and may affect neighbouring native vegetation, river and coast health, air quality and biological biodiversity.

The protection of Australia's coastal and river systems from eutrophication, caused partly by nutrient run-off from agriculture (leaching, water erosion, animal waste) is a priority for government. The issue has been addressed within the context of water projects (Land and Water Australia's National Eutrophication Management Programme and the National River Contaminants Programme) and is an example of how soil health in an agricultural context is part of a larger environmental issue. Similarly, in Queensland, protection of the marine environment of the Great Barrier Reef has been an incentive to evaluate soil health in horticulture.

Urban encroachment on traditional market garden regions has immediate implications for soil health and environmental health. The necessity of vegetable production areas to be close to urban centres for efficiency of distribution means that the relationship between vegetable farms and urban sprawl is likely to intensify. There have been many reported incidences of spray drift from production areas affecting urban populations, and in California, for example, the use of some agricultural chemicals is capped, in order to protect the public from excessive chemical exposure.

## 4.7. Why should farmers be interested in soil health?

The major driver of practice change on farm is economic profit. Growers are also more likely to implement changes that are less time-consuming or difficult (Maganov *et al,* 2003). Not only does increased profitability act as an incentive for farmers to be involved with environmental decisions, in many cases it is the only way that they can afford to be involved (Anon 2002). Farmers need to be convinced of the benefits and value to their economic activity before adopting an ecosystems approach to land management rather than the current approach which is focused on production goals (Allaway 2006).

Unlike other Australian states and territories, most of Victoria's agricultural production occurs on private freehold land rather than on leased crown land (Allaway, 2006). Therefore, in Victoria land is an economic asset and the health of soil (as a key factor related to the productivity of the land) is one of a number of ways that the commercial value of the land may be affected (Allaway 2006).

Farmers can make decisions that both improve the health of soils and reduce their economic expenditure. Pung et al (2003) proposed that the cost of high inputs administered by growers to compensate for poor soil quality is not necessarily recouped by productivity increases. They suggested that cost-benefit analyses may indicate that lower inputs, and acceptance of lower yields, might be more economically sensible as well as being more environmentally sustainable.

An improved understanding of soil health will enable growers to select crops that are best-suited to their soil types under changing environmental scenarios. For example, the use of recycled water in the Werribee Irrigation District has resulted in higher salinity levels in the irrigation water. Choosing more appropriate cultivars would enable growers to maintain productivity in these circumstances (Engleitner, et al, 2006).

## 4.8. Priorities for future research in soil health in vegetables

Although projects have been conducted to respond to specific issues in parts of the vegetable industry (eg assessment of soil degradation in Northern Adelaide production areas), there has not been any work to establish the level of vulnerability of other key vegetable regions. Given that most of Australia's land is fragile, and that erosion via wind or water in vegetable production is estimated at twice the national average, it is imperative that the impact of tillage, traffic and irrigation on soil structure for these highly disturbed systems is evaluated and understood.

Currently vegetable producers spray up to 20 times a year. The cost of the sprays averages about $100/Ha plus labour and fuel for application, and therefore constitutes a high monetary and environmental cost. Pung et al (2003) suggest that the high monetary input of pesticides and agronomic practices does not necessarily result in added profit even if yields are increased. This suggests that growers are trapped in a cycle of relatively poor understanding of soil health and somewhat misguided economic decision-making. Innovative projects that develop a greater understanding of microbial communities and how they may be manipulated to suppress disease and reduce chemical inputs would be of immense value to the industry and to protection of the broader catchment.

Physical and chemical indicators of soil health are relatively well understood compared with biological indicators. The cotton industry identified biological indicators of soil health (and fertility) as a priority for future research. The vegetable industry, with its high inputs and high levels of pathogens would also benefit from evaluating and understanding biological soil health indicators such as microbial biodiversity and how the functional groups of microorganisms impact on crop health.

There is much that vegetable growers could learn from the cotton industry's approach to soil health. Ninety-five percent of the cotton industry has been introduced to Best Management Practices (BMP) that implement management practices that protect the environment. The next stage for the industry is to introduce certification that growers are using BMP, and direct BMP towards the broader catchment. Almost $7 million has been invested into the industry over the past 11 years to reach this point.

A meeting of National Vegetable Industry Researchers was held in Brisbane from 12-14th December 2006. Participants included soil scientists, DPI extension staff, industry members, HAL and an internationally recognised soil health scientist from the USA. Outcomes from the meeting were communicated to the vegetable IAC to assist with priority setting for 2007/08.

At the meeting a Soil Health Workshop was conducted to identify the key soil health issues and the following points were raised:

- There is widespread interest in soil health but the issues are complex, with the biological, chemical and physical components of the soil all needing to be considered
- The meaning of "soil health" is unclear, poorly understood, poorly defined
- Information is lacking within the soil biology area
- Industry and researchers need support to integrate and understand the interactions within the soil and between soil and plant health
- There are a number of specific technical issues within the soil health area that need to be addressed, including organic practices
- Data collection on a broad scale, of practices, indicators and impacts off farm, is limited
- There is a need to collate and disseminate outcomes from previous research to other industries and to growers

Grower perspective was considered and it was identified that:

- The economics of different soil management practices need to be identified to give growers an account of the most effective practices for their situations
- Grower participation in soil health research is essential from the outset of each project
- The impact of soil health on yield and fruit quality needs to be identified
- Site specific interpretation is important
- The ability to make soil quality comparisons over time, including changes to carbon, needs to be available
- The disease suppression potential of soil health needs to be investigated

The initial recommendations from the Soil Health Workshop that should be considered when setting priorities for future research were:

- That an audit be conducted across industries of all past research to determine which industries can benefit most from changes to soil health and what gaps exist. This was partly addressed within project VG06090 but requires analysis of other programs such as those being conducted by the Grains industry and Land and Water
- That regions most at risk from soil health issues be identified
- That future projects have a multidisciplinary focus;
- That a mechanism be explored where government and industry provide some incentive/recognition for industries having a good soil health focus;

- That a review of offsite impacts be conducted to define the benefits of healthy soils;
- That soil health issues be linked to climate change issues where necessary;
- That grower accreditation continues and that programs such as Enviroveg are acknowledged and used appropriately; and
- That key drivers for soil health should be to improve efficiency of nutrient and pesticide use and reduce flow through systems, especially nitrogen management and impact on marine systems e.g. Barrier reef, Port Phillip Bay, etc.

The key outcomes that were identified by the workshop participants for future research were:

- To develop a standard set of physical, chemical and biological indicators so that future research can be coordinated and standardised
- To determine benchmarks so that the benefits/disadvantages soil health research can deliver on farm and to catchments is measurable
- To identify the drivers of soil health change to ensure grower involvement and participation
- To ensure that farm scaled production is linked to catchment outputs
- To ensure that economic analyses are included in all future research programs
- That the impact of tillage and traffic on compaction, and the usefulness of permanent bed systems compared with non permanent systems need to be addressed and understood
- To develop a set of useful biological indicators and use them to measure changes to soil health that suppress pests, diseases and weeds and reduce pesticide use
- A need to address labile C as a good indicator of soil health and to determine the best sources of organic C inputs
- To correlate cost effectiveness of inputs into farm systems with good soil health practices

Following the Soil Health Workshop in Brisbane, a series of workshops were conducted in southern Australia, with key growers, agronomists and researchers contributing to priority setting for future research.

At these workshops, the main contributors to soil health decline in vegetables were identified as:

Physical factors

- short crop rotations,
- poorly managed soil structure (including effects of farm traffic),
- poorly managed organic matter,
- soil erosion (due to water run-off on steep land, causing loss of nutrients, topsoil, biological material, organic carbon and soil structure),
- production in vulnerable/marginal regions,
- poorly managed irrigation

Biological factors

- pests and diseases,
- low levels of microbial biodiversity

Chemical factors

- over-use of agrochemicals

.

The priorities for future research and extension in southern Australian vegetable growing were identified as:

- Linking farm practices with catchment management
- Economic analysis of current systems compared with reduced input farming
- Grower participation and education
- Benchmarking practices
- Rationalisation and standardisation of soil health monitoring tools
- Reduction in agrochemicals
- Collation and dissemination of soil health information from other industries to vegetable growers
- Collection and evaluation of information on practices, indicators and off-farm impacts.

## 4.9. Conclusions

Development of soil health policy is a relatively recent undertaking for Australian governments. National auditing and reporting has established something of a baseline for our understanding of the levels of damage to soil (eg erosion, acidity, salinity). Recently a number of government funded initiatives and projects have commenced to educate landholders, reduce the impact of farming on the environment, or improve the sustainability of farms. However, very few have undertaken research that would enhance or improve our understanding of the intricate relationship between the physical, chemical and biological components of soil, or their impact on crops and crop health, and ultimately address the government “drivers” for investing in soil health.

Due to a lack of emphasis on the importance of soil health, the majority of vegetable growers have been slow to implement strategies for improving soil health. This is in contrast to efforts that have been made in this area by the cotton industry and in dryland agriculture. According to Pung et al (2003) there is little in economic returns or improved yield to justify the high inputs that are implemented in vegetable farming. Despite this, growers continue to aim for higher yields and subsequent improved profitability, by high input farming. For intensive production like vegetables, there has been little attempt at understanding soil ecology, or implementing changes that will protect the soil and catchment for a sustainable farming future. Many growers are therefore cycling between high inputs to control diseases, weeds, and pests, and to improve yields, and exacerbating their soil health decline by not understanding the impact of their activities. There is real opportunity for research to enhance the health of vegetable soils, and to have positive impacts on crop productivity, human and catchment health, and economic and environmental sustainability of the industry.

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# 5. National workshops

Three National workshops were conducted to review soil health capability and prioritise research needs to assist the Australian Vegetable Industry with the development of a five-year strategic plan for sustainable soil health.

## 5.1. Soil Health National Workshop – Devonport, Feb 2007

### 5.1.1. Attendees

| Name | Affiliation |
|---|---|
| Chris Russell | Simplot R & D |
| Steve Welsh | State IDO |
| Bill Cotching | TIAR |
| Leigh Sparrow | TIAR |
| Shane Broad | |
| John McPhee | DPIW |
| Doris Blaesing | Serve-Ag Pty Ltd |
| Guy Robertson | Cradle Coast NRM |
| Peter Fisher | PIRVic |

| | |
|---|---|
| Frank Hay | TIAR |
| Hoong Pung | Peracto |
| Susan Lambert | Virologist |
| Ian Young | Grower |

### 5.1.2. **Presentations and Presenters**:

The workshop commenced with presentations giving an overview of soil health research and development projects in Tasmania:

Bill Cotching (TIAR) – "Soil –Physical Issues"

John McPhee (DPIW) - "Controlled Traffic"

Hoong Pung (Peracto) – "Soilborne Diseases and Soil Management"

Guy Robertson (Cradle Coast NRM) – "Catchment Management issues and what Landcare and NHT are"

Doris Blaesing (Serve-Ag Pty Ltd)– "Nutritional Issues"

### 5.1.3. Discussion and workshop notes

After the speaker presentations, the workshop attendees were asked, ' Why should HAL invest in soil health?'

(Why is soil health important to the vegetable industry?)

To initiate discussion, the following list was presented to the attendees:

- Sustainable disease control
- Image/reputation
- Profit
- Maintain/improve yields
- Offset environmental problems associated with current methods (ie reduction of N, P flow, pesticides, protect rivers and marine environments
- Soil structure
- Erosion
- Salinity
- Improved water holding capacity
- Population biodiversity
- Organic C

From the discussion generated by this list, six priority areas for further research, development and technology transfer were identified:

1. Land use (includes crop rotation)
2. Education (of farmers to help them understand how to implement soil health)
3. Improve soil structure
4. Soil erosion
5. Maintain and improve/ sustain yields
6. Organic C

The attendees were then split into two groups, asked to discuss each of the six priority areas, and to suggest some strategies for tackling the problem.

**1. Land use / crop rotations**

- A need to preserve rotations so that traditional crops are not lost
- A need to understand the diversity of rotations and demonstrate productivity for soil health (ie what different crops contribute to, or remove from, the health of soil)
- How do the components of crop rotations contribute to 'best practice organic C levels'
- What are the economics and practicalities of crop rotation?

***What needs to be done in this area?***

- A survey to determine the diversity of rotations – are they changing, in particular diminishing?
- Develop a model with appropriate validation, to determine suitable 'best practice' rotations with respect to organic C
- Conduct a literature review of what is known regarding selection of rotations
- Conduct a survey of industry to assist determination of 'best practice' rotations

**2. Farmer education**

- How do you engage with farmers?
- How to improve relationships with farmers

***What needs to be done in this area?***

- Find the selling point (economics)
- Clarification of messages to make information more accessible

**3. Improve soil structure**

- It was noted that considerable effort and energy is required to rectify problematic soil structure. It was suggested that $3 million per year was lost from the Tasmanian potato industry due to poor soil structure (cloddiness)
- Poor soil structure leads to decreased yield
- Bigger, heavier machinery that reduces workloads and allows bigger farms to be operational contributes to the loss of soil structure

***What needs to be done in this area?***

- Identify methods of rejuvenating soils (carbon, erosion, traffic, rotation)
- The relationships between structure, carbon and yield need to be understood, and these relationships may be soil specific

**4. Erosion**

- It was suggested that growers currently accept loss of topsoil and associated nutrients
- Other problems include contamination of water ways

- It is generally believed that there is no economic gain to be made by doing anything about erosion except on steep slopes
- Erosion is accepted as being an intermittent event in the landscape

***What needs to be done in this area?***

- Growers need to manage risk of erosion
- Evaluate no-till farming methods to reduce erosion
- Evaluate ground cover crops to reduce erosion
- Evaluate the predictability of erosion events in relation to crop rotations
- Estimate cost of erosion

**5. Organic Carbon**

- Organic carbon levels have been declining over time
- Critical threshold levels are unknown
- Organic carbon is known to be a major driver of soil processes

***What needs to be done in this area?***

- Carbon is related to structure and structure is related to yield, but how is carbon related to yield?
- What are the roles of carbon pools in soil health?
- Develop ways to improve and maximise organic carbon
- How to capture more carbon in soil (80-90% is lost as CO2)

**6. Maintain yields**

- Farmers have long been compromising soil health to increase yield (via high inputs)
- The system is being driven from the input end
- Yields are compromised by soilborne diseases

***What needs to be done in this area?***

- Need to develop programs that decrease inputs and decrease costs even if yields also decrease (don't need such high yields/profits if cost of farming is less)
- Need to establish long term trials to compare what happens in the long term with what happens in the short term when inputs are reduced
- Need to measure decline in yields and analyse inputs
- Need to collate data that already exists in this area
- Need to develop sustainable, profitable systems, rather than focussing only on yield

At the end of the workshop, attendees were asked to make a final comment regarding the soil health program:

- The challenge is to get landholders to implement soil health changes
- Extension work should be a priority

- Need to answer some of the questions around structure and organic C – a PhD program?
- Useful to have demonstration farms for grower education
- Useful for HAL and Natural Resource Management groups to co-invest in soil health
- We don't know the impact of our suggestions on the economics
- Demonstration trials are really important, but some things, like organic C take decades to prove (eg organic C can go down for 10 years before positive changes take effect)
- A driver for grower adoption of soil health could be disease control and measure soil suppressiveness, and manipulate soils for suppressiveness
- Need to co-invest with other groups to maximise outcomes
- We need to develop ways to get better use of water, better disease control and better extension programs.

## 5.2. Soil Health National Workshop – Adelaide, Feb 2007

The aim of the workshop was to identify the priorities in soil health for future research and extension for the Adelaide vegetable growing region.

### 5.2.1. Attendees:

| Name | Affiliation |
|---|---|
| Ann McNeill | University of Adelaide |
| Kathy Ophel-Keller | SARDI |
| Samuel Stacey | University of Adelaide |
| Rob Murray | University of Adelaide |
| Paul James Senior | Hort Consultant, Rural Solutions SA |
| Brian Hughes | Landcare |
| Jim Kelly | Arris |
| Maria Yfantidis | Grower Veggies on the Run |
| Craig Feutrill | State IDO |
| Greg Walker | SARDI |
| John Pitchford | Grower |
| William Allen | Grower |

### 5.2.2. Workshop Program: (Venue: Coach House Meeting Room, Waite Institute)

9.00 – 9.15 Overview of Soil Health Program – HAL: Ian Porter

9.15 – 10.15 Presentations of South Australian research capabilities with a focus of involvement in the vegetable industry

10:15 – 10:30 "Catchment management issues and what Landcare and NHT are" Brain Hughes

10:30 – 12:00 “Soil - Physical Issues”
“Soil Chemistry Issues”
“Soil borne Disease and Soil Management”
“Successful adoption and practice change”
12.00 – 1:00 Overview of possible direction of soil health research including identification of gaps
1.00 – 1.15 pm Where to now?

### 5.2.3. Discussion and workshop notes

The key drivers for embracing farm management changes that would address soil health were identified as:

- Nutrient management and new technologies
- Improve water efficiency
- Increase in organic carbon
- Sustainable disease control
- Improve soil structure
- Benchmarking good agricultural practices
- Extension

The workshop attendees were then divided into two groups to discuss the main activities that could be considered to address the key drivers and these are listed below.

**1. Nutrient management and new technologies**

This was considered the key driver as an estimated 50% added nitrogen is presently lost (via leaching or volatilisation) from systems under cultivation.

- More information about effective fertiliser practices and new fertiliser products (includes agronomy of these products to ensure they don't have negative soil health effects)
- More effective Application technologies
- Information on snake oils and alternative products (eg. humic acids, composts, trichodermas etc)
- Manures and composts (biosolids also but these currently can't be used in SA)
- Nutrient and disease interactions

**2. Improve water efficiency**

This was considered to be a key driver as there is an estimated 10% decrease in yield due to poor water quality.

- From SA perspective controls on the amount of water available will force improved water use efficiency.
- Monitor and understand root growth
- Moisture levels (water potential) and their relationship to soil structure decline (reducing the impact of irrigation on soils)
- Salinity affects water use efficiency
- Growing more from less water

- Which are the best rotations/green manures/composts for water retention?
- Comparisons between conventional vs no till or minimum tillage.

**3. Increase in organic carbon**

A key driver was that up to 80% of carbon losses occur in the first till. In labelled C tests 50-80% of organic C is lost in first year. Other factors to consider were:

- Increasing organic carbon for disease control and water use efficiency
- Rotation crops (green manures)
- Composts, which one?
- No or minimum till vs conventional

**4. Sustainable disease control**

The estimated dollar cost of inputs for controlling disease is $200-2000/ha.
Estimated that 70% of soil health/soil structure is due to the beneficial organisms in the soil.

- Effect of rotations on soil inoculum and soil biota generally
- Trialing biological controls
- Importance of healthy plant for combating diseases
- Develop relationship between soil biology profiles and soil disease

**5. Improve soil structure**

A comment was made that it was estimated that 70% of soil health/soil structure is due to the beneficial organisms in the soil. Other factors requiring research and extension:

- Tillage (methods, frequency and timing of tillage)
- Importance of correct moisture during tillage operations; importance of irrigation for soil structure (eg. drip irrigation is great for water conservation but not for soil conservation)
- Importance of controlled traffic

**6. Benchmarking good agricultural practices**

- Learn from what systems work (understanding principles)

**7. Extension**

- Tap into high level of information present in other industries
- Provide lists of soil health capabilities in each state
- Provide regional expert groups

## 5.3. Soil Health National Workshop – Melbourne, Aug 2007

### 5.3.1. Attendees

The workshop was well attended with approximately 25 local growers (including Peter Schreurs, Tom Schreurs, Russell Lamattinas, Fosters, Kelly, Cochranes vegetable farms) and representatives from Horticulture Australia (Alison Turnbull), AusVeg (Helena Whitman), ARRIS (Jim Kelly), Industry IDOs (Craig Murdoch, Alison Anderson) and nine Victorian and QLD DPI staff.

### 5.3.2. Workshop Program: (Venue: Amstel Golf Club, Cranbourne) - 28th August, 2007

***Agenda*:**

4.00 - 4.10 Overview of Soil Health Program – HAL: A. Turnbull

4.10 - 4.20 Introduction to Workshop - Ian Porter

4.20 - 5.00 **Presentations of vegetable soil health research and extension:**

Robyn Brett - Update of the Victorian soil health project “Management of Soil Health for Sustainable Vegetable Production.

Tony Pattison - Sub-tropical vegetable soil health: An update of the VegPaSH project

Helena Whitman - The Soil Health Ute Guide and EnviroVeg

Mark Imhof - What you should know about the National Land and Water projects and relevance to the Vegetable Industry

**5.00 - 5.20** *Soil health in other industries - Benefits to Vegetable Growers:*

Peter Fisher - Gains to the tomato industry through better management of chemical and physical aspects of soil health

Scott Mattner - Gains to the strawberry industry through better management of soil biology.

**5.40 - 7.15** **Workshop*:** Setting Up a New Soil Health Program for the National Vegetable Industry: What research and extension activities are needed?

**7.15 - 7.30** Where to now and workshop closure?

***** During the workshop session growers were asked to identify the key drivers that would entice them to adopt changes to management that would impact on soil health. Growers were asked to contribute their ideas, which were written down and stuck onto a wall. They were then asked to select the six that were their highest priority.

### 5.3.3. Discussion and workshop notes

**Key Drivers of Soil Health:**

The six top drivers for embracing changes to management that would impact on soil health were identified as:

- Water use efficiency
- Less inputs for higher yields
- Soil sustainability
- Soil structure (eg. clods)
- Higher productivity
- Drainage

**Key outcomes for soil health**

Using a similar format to that for identifying drivers, growers were then asked to identify the key outcomes from changes to soil health management at the farm level and at the catchment level.

Growers were able to identify seven key outcomes for soil health at the farm level, as follows, but were unable to identify any at the catchment level:

- Improved soil structure
- Improved water use efficiency
- Reduced inputs, increased profit
- Improved product quality
- Reduce disease
- Biodiversity
- Drainage

Growers were then separated into syndicate groups and were asked to identify up to three priority research or extension activities that would address the gaps between the present and the identified soil health outcomes.

**1. Improved soil structure**

The common theme between grower responses was a recognition of organic carbon as integral to soil structure, but wanted direction on how to achieve higher organic carbon – what to use, how to use it, cost-effectiveness.

Under this topic, growers also identified that the first crop is always the best – how to replicate this?

Some growers identified gaps in education and training with regard to recognising a problem with soil structure and how to fix it, and to understand the relationship between soil structure and practical management options.

**2. Improved Water Use Efficiency**

The common theme was the need for information about alternative irrigation types and scheduling and how these would impact on WUE.

Growers also wanted information on how different types of irrigation impact on other soil processes and management, costs and advantages of different types of irrigation, flexibility of watering systems to cope with different types of crops, and trial of drip irrigation for different crops.

**3. Reduced inputs, increased profits**

Two themes prevailed under this topic: growers wanted to improve their nutrient management practices and understanding of plant requirements, and were interested to learn more about tillage and how tillage practices affect input costs such as nutrients, fuel and labour.

Other areas of interest were in precision agriculture (soil mapping), repair of compacted sites and alternative inputs that would reduce costs.

**4. Improved product quality**

The common theme under this topic was in post-harvest management of produce, particularly with regard to disease management.

Other topics that were raised included selection of varieties, improved (faster) soil monitoring and nutrient management.

**5. Reduction in disease**

Growers wanted management options for specific disease problems (nematodes, Sclerotinia, scab and bacterial wilt of potatoes, Fusarium), and more information on understanding soil suppressiveness, rotations for disease suppression, IPM and the relationship between soil health and crop health.

**6. Biodiversity**

Growers wanted information on how carbon pools, tillage, incorporation of organic matter and other farm management practices affect soil biodiversity.

**7. Better Drainage**

The common theme under this heading was how to manage soil structure to improve drainage. Other queries related to the impact of crops on drainage and treatment for drainage water (desalinisation).

## 5.4 Key Drivers for the National Vegetable Soil Health Strategy

The table below groups the priority areas in soil health that growers at the 3 State workshops considered important criteria to be delivered by a National Soil Health Program in the Vegetable Industry (Table 5.1). These criteria were used to develop the key outcome areas (see Section 7) for which investment should be considered by AusVeg and Horticulture Australia during development of a national strategy.

**Table 5.1 Priority drivers and outcomes required from a National Soil Health Program**

| Key Drivers | Tasmania | South Australia | Victoria | Priority Score |
|---|---|---|---|---|
| **1. Productivity, benchmarking** | Higher productivity | i). Benchmarking good agricultural practices<br>ii).Sustainable disease control<br>iii). Better nutrient management and development of new technologies | i). Higher productivity<br>ii). Less inputs for higher yields | **3** |
| **2. Soil structure and tillage** | Soil erosion and improve soil structure | Improve soil structure | i). Improve soil structure<br>ii) Soil sustainability | **3** |
| **3. Organic Carbon** | Increase organic C | Increase organic C | – | **2** |
| **4. Water Use** | – | Improve water use efficiency | i). Improve water use efficiency<br>ii). Improve drainage | **2** |
| **5. Education** | Education to improve understanding of soil health | Education to improve understanding of soil health | – | **2** |
| **6. Land Use** | Land use (including better crop rotation) | – | – | **1** |

## 5.5 Research Gaps to address in a National Soil Health Program

The table below lists ideas put forward at National workshops for consideration of future investment to improve the knowledge and outcomes from a National Soil Health Program in the Vegetable Industry (Table 5.2).

### Table 5.2 Key research ideas raised at State Workshops on Soil Health

| Key Drivers | Key Research Ideas |
|---|---|
| **1a. Productivity, benchmarking** | • Need to focus on development of sustainable, profitable systems, rather than focussing only on yield ie. develop programs that decrease inputs and decrease costs even if yields also decrease<br>• Need to establish long term trials to compare what happens in the long term with what happens in the short term when inputs are reduced<br>• Need to collate data that already exists in this area<br>• Tap into information prepared by other industries<br>• Provide list of soil health capabilities in each State and then provide regional expert groups |
| **1b. Sustainable disease control** | • Develop understanding of rotations and on soil biology and population levels of pathogens<br>• Develop relationship between soil biology profiles, soil suppressiveness and crop disease<br>• Continue trialling of biological controls<br>• Develop understanding of healthy soils to combat disease |
| **2. Soil structure, erosion and tillage** | • Identify methods of rejuvenating soils (carbon, erosion, traffic, rotation)<br>• Consider further controlled traffic and no till programs<br>• Develop knowledge of correct moisture levels during tillage operations<br>• Develop manual to describe how to achieve higher org C- What to use, how to use it and its costs effectiveness?<br>• Evaluate the predictability of erosion events in relation to crop rotations (eg. under cover crops)<br>• Relationship between tillage methods and input costs |
| **3. Organic Carbon** | • Carbon is related to structure and structure is related to yield, but how is carbon related to yield?<br>• What are the roles of carbon pools in soil health?<br>• Develop ways to improve and maximise organic carbon<br>• Develop methods to capture more carbon in soil (80-90% is lost as $CO_2$)<br>• Determine the role of increasing Org C on disease control and WUE<br>• Which composts assist Org C the best?<br>• Compare effects of no till and Conventional on Org C. |

| | |
|---|---|
| **4. Water Use** | • Monitor and understand impact of WUE on root growth and yield<br>• Understand moisture levels (water potential) and their relationship to soil structure decline (reducing the impact of irrigation on soils)<br>• Understand how salinity affects water use efficiency<br>• Provide information on irrigation scheduling with alternative methods and how these affect WUE<br>• Determine which are the best rotations/green manures/composts for water retention?<br>• Compare WUE between conventional vs no till or minimum tillage. |
| **5. Education** | • Find the selling point (economics)<br>• Provide methods on how to recognise decline in soil health<br>• Clarify messages to make information more accessible |
| **6. Land Use** | • A survey to determine the diversity of rotations – are they changing, in particular diminishing?<br>• Develop a model with appropriate validation, to determine suitable ‘best practice’ rotations with respect to organic C<br>• Conduct a literature review of what is known regarding selection of rotations<br>• Conduct a survey of industry to assist determination of ‘best practice’ rotations |

# 6. Demonstration trials

## 6.1. Aim

The aim of the demonstration trials was to test the rigour of a broad range of soil health indicators and to determine which indicators could discriminate changes to farm management practices.

## 6.2. Materials and methods

**1. Vegetable Soil Health Sampling Strategy, 2007**

**Sampling method:** Sampling sites were divided into at least 5 replicates. Thirty soil cores were randomly taken from each replicate within the sampling site to a depth of 10 cm, pooled, bagged and stored at 4ºC.

**Sampling Sites:**


Figure 1: Vegetable production regions on aeric podosols in Cranbourne, Victoria and sampling sites for demonstration trial (arrow)

**Measurements of Soil Parameters:**

**Biological characteristics:** Total fungi, total bacteria, gram negative bacteria, pseudomonads, nematodes (total free-living, parasitic, fungal and bacterial feeders, omnivores), biological activity (FDA), microbial respiration;

**Chemical characteristics:** Soil nutrients (N, P, K, S, Na, Mg, Ca), pH, EC, organic matter

**Physical characteristics:** Soil aggregation, particle size analysis

**Details of the Sites selected:**

Two main farms were used for site selection of 9 different sampling sites. Four sites with different histories of organic carbon management were selected at Farm A and five from Farm B.

Farm A:

TS1 (Site 1, etc.)

- Conventional farming practices (nutrient and pesticide inputs as required)
- 8 weeks post-fumigation metam sodium
- History of low organic carbon content
- sown to 6 week old spinach at sampling

TS2

- Conventional farming practices
- No fumigation
- History of low organic carbon content
- No crop

TS3

- No farming practices (relatively undisturbed)
- Roadside strip containing native trees and introduced grasses

TS4

- Conventional farming practices
- No fumigation
- History of high organic carbon
- Recently transplanted to celery

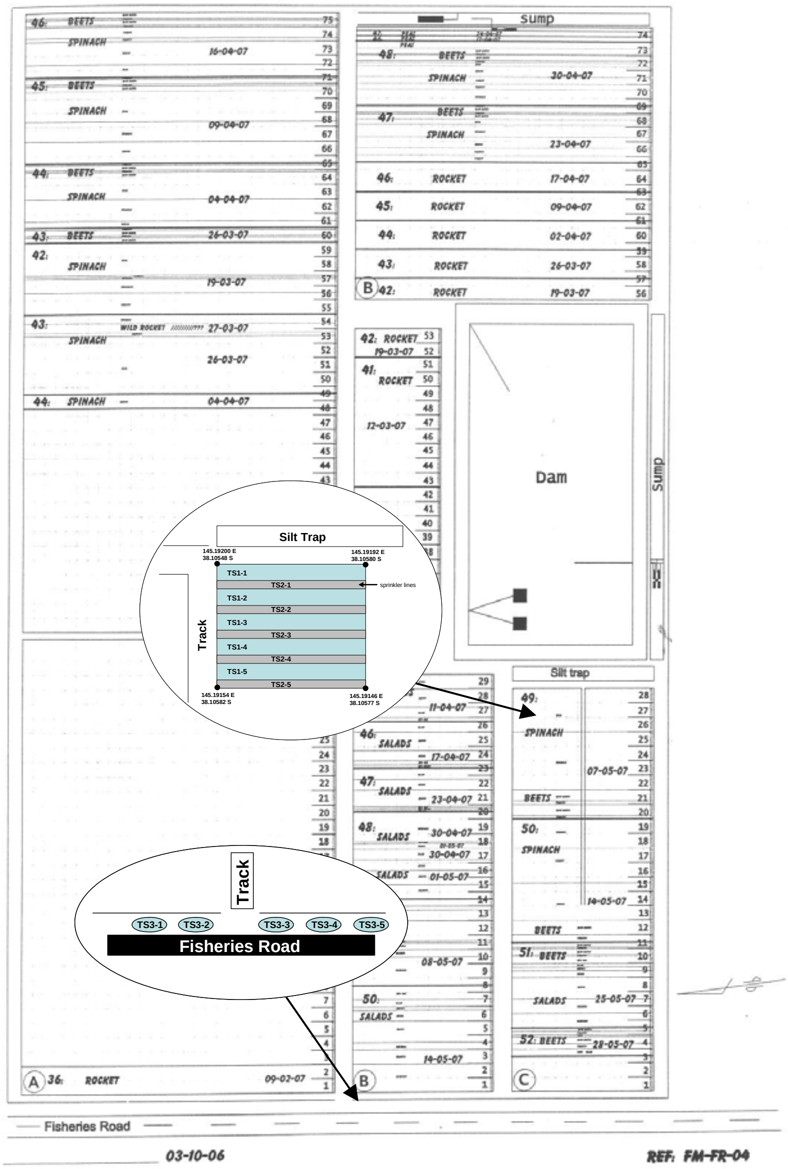


Figure 2: Locations and plans for sampling sites TS1, TS2, and TS3.

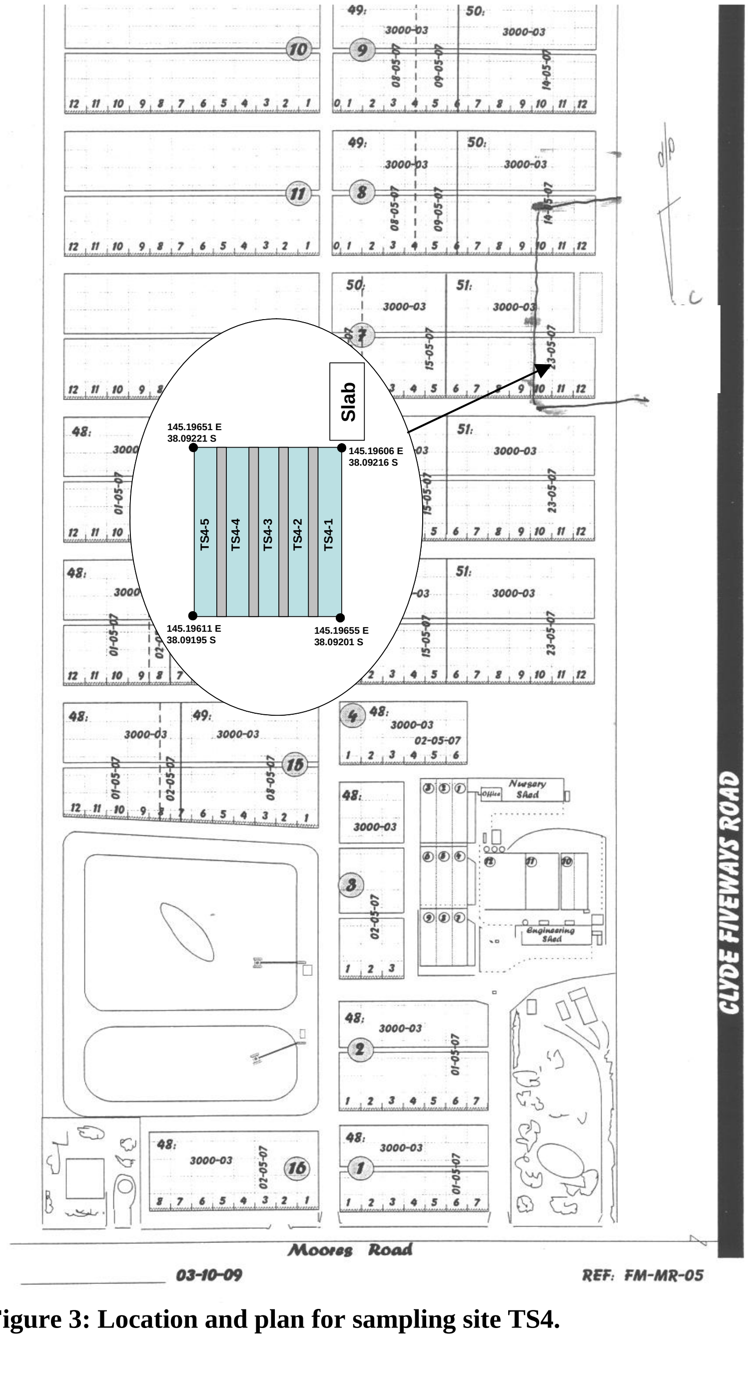


**Figure 3: Location and plan for sampling site TS4.**

**Farm B Site Details:**

PS1 (site 1, etc.)

- Sustainable farming practices (low inputs of nutrients and pesticides)
- No fumigation
- History of high yields
- Recently harvested leeks

PS2

- Sustainable farming practices
- No fumigation
- History of poor yields, disease present
- Leeks ready to harvest

PS3A

- Sustainable farming practices
- No fumigation
- History of high yields
- History of low organic carbon
- Leeks recently harvested

PS3B

- Sustainable farming practices
- No fumigation
- History of poor yields
- History of low organic carbon
- Leeks at harvest

PS4

- Sustainable farming practices
- No fumigation
- History of high yields
- History of high organic carbon
- Recently harvested Kohl Rabi

PS5

- No farming practices (relatively undisturbed)
- Drain-side strip containing native trees and introduced grasses

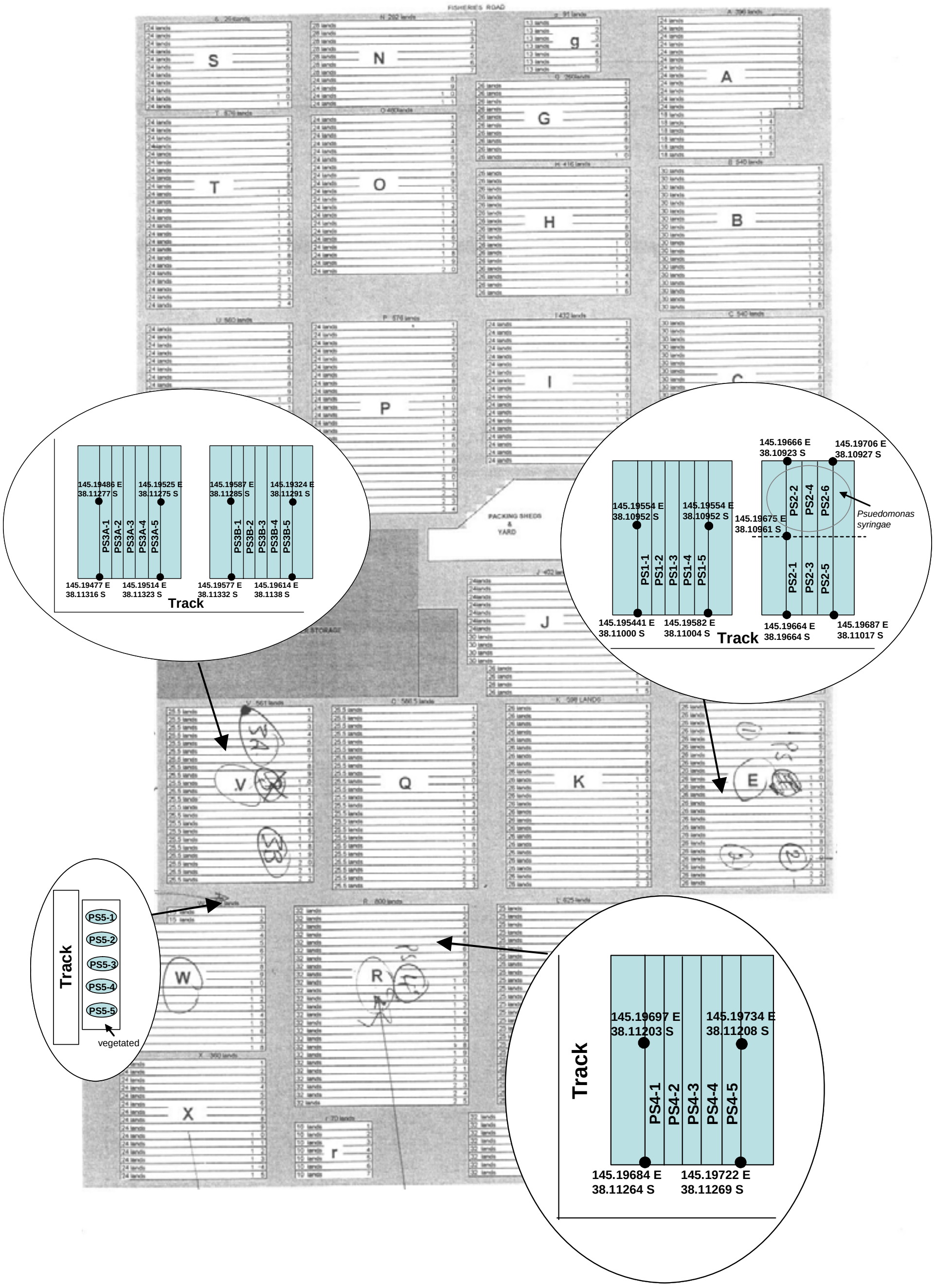


**Figure 4: Locations and plans for sampling site PS1-5.**

## 6.3. Results and discussion

Collected data were subjected to Analysis of Variance using the Genstat statistical package (version 9.1) and are summarised in Tables 1 and 2.

Nematode populations and feeding groups were particularly good soil health indicators because nematodes responded rapidly to available food sources. Disturbance to soil from farm management practices (eg tillage, planting, harvest) altered the balance of microorganisms in soil and favoured populations of aerobic bacteria. The increase in bacteria numbers was reflected in nematode populations, with an increase in the relative abundance of bacterial feeding nematodes. Samples that were taken from sites that had not been recently disturbed showed a greater balance between different sub-sets of microorganisms (bacteria, fungi, nematodes) that could be interpreted as showing greater biodiversity (Figure 1). Microbial populations, microbial activity and respiration all supported observations of nematode populations and were therefore considered useful biological soil health indicators.

Measurements of nutrients were also demonstrated to be useful indicators of soil health. Nutrient management on farm was demonstrated to be in excess of requirements for crop growth, particularly for phosphorous, at all managed sites (Figure 1). The two non-production sites, PS5 and TS3 were the only two sites where phosphorous levels did not exceed recommended levels. High levels of phosphorous on farm could potentially have a detrimental effect on the broader catchment. Growers were generally unaware and surprised by these results when they were presented at the Cranbourne workshop.

The indicators that were evaluated in these demonstration trials proved to be useful tools for measuring changes in crop production practices and could be used in future trials for benchmarking crop and soil quality.

| | | Property 1 | | | | Property 2 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 1 | 2 | 3A | 3B | 4 | 5 |
| History | crop | 6 wk spinach | Fallow | Pasture (native) | Celery transplant | Leeks incorporated | Leeks mature | Leeks incorporated | Leeks mature | Kohl rabi incorporated | Control |
| | | | | | | | | | | | |
| | Yield | Medium | Medium | - | High | High | Low(dis) | High | Medium | High | Low |
| | Fumigation | ++ | - | - | + | - | - | - | - | - | - |
| | Organic matter | Low (1.7%) | Low (1.7%) | unknown | High (3.7%) | Low ? | Low ? | 0.9% | 0.9% | High (2%) | Low ? |
| Biological tests | | | | | | | | | | | |
| FDA (mg F/g DW) | | 26 | 23 | 39 | 20 | 26 | 21 | 25 | 16 | 25 | 20 |
| $CO_2$ (µg/g soil) | | 541 | 478 | 642 | 432 | 486 | 394 | 568 | 375 | 490 | 315 |
| Nematodes Bact feeders (%) | | 93 | 91 | 47 | 90 | 98 | 54 | 98 | 72 | 97 | 59 |
| Fungal feeders (%) | | 2 | 3 | 49 | 10 | 1 | 22 | 2 | 17 | 3 | 35 |
| TFLN (no./g dw soil) | | 7 | 15 | 8 (+ path) | 43 | 88 | 4 | 73 | 5 | 40 | 2 (+ path) |
| Dil. Plates Total bact (log no./g DW soil) | | 7.0 | 6.8 | 6.0 | 6.7 | 6.9 | 6.4 | 6.6 | 6.3 | 6.8 | ND |
| Total fungi (log no./g DW soil) | | 3.3 | 2.6 | 3.9 | 3.5 | 3.8 | 3.4 | 3.3 | 2.8 | 3.5 | ND |
| Gram negative bacteria (log no./g DW soil) | | 6.05 | 6.15 | 5.61 | 5.96 | 6.40 | 5.39 | 6.41 | 5.52 | 6.39 | ND |

Table 1: Summary of biological indicator data from Soil Health Demonstration trial, Cranbourne 2007

| | Property 1 | | | | Property 2 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 1 | 2 | 3A | 3B | 4 | 5 |
| History/crop | 6 wk spinach | Fallow | Pasture (native) | Celery transplant | Leeks incorporated | Leeks mature | Leeks incorporated | Leeks mature | Kohl rabi incorporated | Control |
| Yield | Medium | Medium | - | High | High | Low (dis) | High | Medium | High | Low |
| Fumigation | ++ | - | - | + | - | - | - | - | - | - |
| Organic matter | Low (1.7%) | Low (1.7%) | ? | High (3.7%) | Low ? | Low ? | 0.9% | 0.9% | High (2%) | Low ? |
| Chemical tests | | | | | | | | | | |
| Total N (g/100g) | 0.14 | 0.14 | 0.17 | 0.33 | 0.11 | 0.1 | 0.08 | 0.07 | 0.15 | <0.05 |
| Total C (g/100g) (opt 2.9-5.8) | 1.8 | 1.7 | 2.6 | 3.4 | 1.5 | 1.5 | 1.0 | 1.0 | 2.2 | 0.6 |
| Avail N ($NH_4$) (mg/Kg) | 1.54 | 1.50 | 3.36 | 2.16 | 1.30 | 1.08 | 1.08 | 1.02 | 1.40 | 1.16 |
| Avail N ($NO_3$) (mg/Kg) | 19.20 | 13.22 | 29.40 | 16.00 | 31.80 | 12.20 | 23.40 | 8.56 | 22.60 | 6.02 |
| Avail P (mg/Kg) (opt 20-30) | 142 | 120 | 10 | 256 | 95 | 82 | 86 | 62 | 58 | 12.5 |
| Avail K (mg/Kg) | 162 | 112 | 170.2 | 310 | 344 | 248 | 122 | 77.2 | 220 | 60.2 |
| Avail S (mg/Kg) | 30.4 | 10.8 | 45.8 | 38.8 | 31.6 | 46 | 15.6 | 12 | 6.1 | 11.4 |
| % OM | 3.3 | 3.3 | 4.7 | 6.4 | 2.8 | 2.7 | 1.9 | 1.7 | 4.0 | 1.2 |
| EC dS/m | 0.18 | 0.11 | 0.35 | 0.21 | 0.21 | 0.24 | 0.13 | 0.10 | 0.12 | 0.07 |
| pH ($CaCl_2$) | 6.54 | 6.34 | 4.86 | 6.52 | 6.66 | 6.22 | 6.44 | 6.52 | 6.62 | 5.08 |

Table 2: Summary of chemical indicator data from Soil Health Demonstration trial, Cranbourne 2007

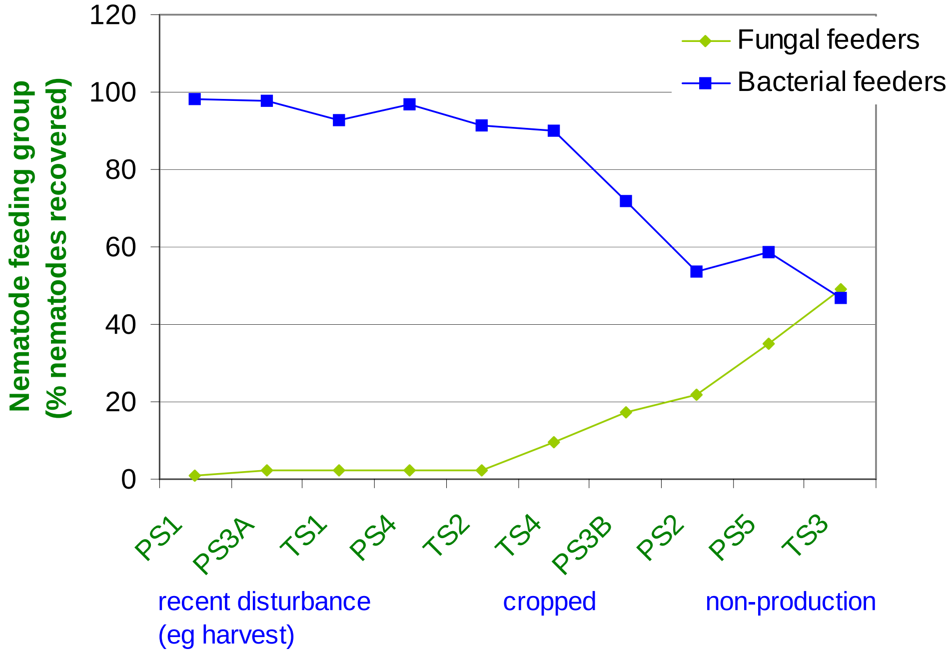


**Figure 5:** Nematode populations were dominated by bacterial feeders at sites that had been recently disturbed, compared with a balance between fungal and bacterial feeding groups at sites that that had not been recently disturbed.

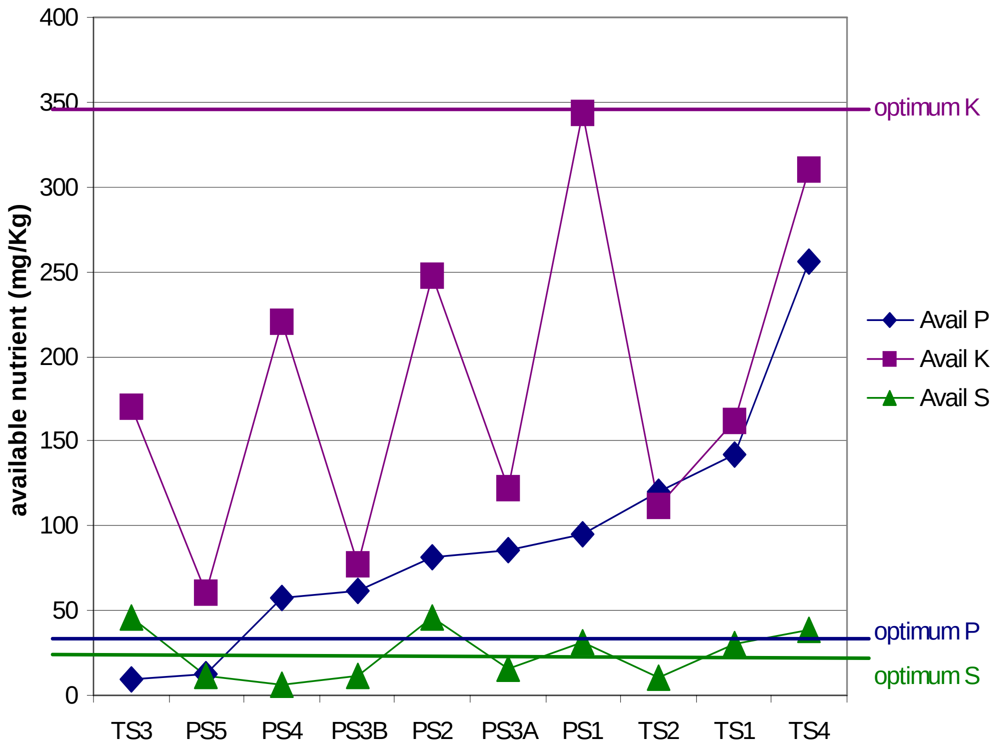


**Figure 6**: Measured levels of available phosphorous, potassium and sulphur, compared with recommended levels, at the demonstration sites at Cranbourne, 2007. At all production sites, phosphorous was recorded at levels substantially higher than recommended for vegetable production.

# 7. Development of a strategic plan for soil health research and extension

## 7.1. Background

The three activities conducted in this project (literature review, workshops and demonstration trials) identified gaps in research and extension for soil health in the vegetable industry, and provided preliminary evaluation of 35 indicators for on-farm soil health practice change. The major outcome for the project was that it provided a list of key drivers as to why the growers wanted investment in soil health (Section 5) that could be sued as information to set Strategic direction for better soil health management within the National Vegetable Industry.

During the course of the project a "Soils Reference Group" was formed to monitor activities in soil health, and to set specific priorities for future research and extension. Through the stimulus of this group a strategic plan, the "Vegetable Soil Management Program 2007-2012" (VSMP) has been developed to guide soil health research and extension funding for Horticulture Australia and the vegetable industry over the next five years (see Section 7.3).

Vegetable growers, like most farmers, increasingly have to juggle a range of externalities that make agriculture far more complex than growing the largest crop at the cheapest cost. Some of the recent pressures on growers include: pesticide withdrawal due to residues in the environment, off-site effects of fertilisers, soil erosion and soil structural decline, reductions in water availability and greenhouse gas emissions and the resulting changes to climate. Many of these pressures have forced growers to reconsider the environmental costs of their farming practices and how those practices will undermine long term productivity.

Soil is one of the most valuable resources on farm, and maintaining good soil health is vital for prosperous and sustainable production. Soil health involves the concept of balancing the biological, chemical and physical components of soils so that crop health and yields can be maximised and sustained over the long-term.

Horticulture Australia identified soil health as an immediate priority for funding in the vegetable industry in 2006/07. This was in response to industry concerns and National Policy papers that show that poor management of soil health can lead to large losses in productivity, increased disease, and long term damage to catchments. Consequently, preliminary funds were allocated to:

- QLD DPI (HAL project VG06100) to undertake research in sub tropical horticulture to understand soil health limitations, identify improved management techniques and to determine what information vegetable growers need to implement to improve plant and soil health management;
- DPI Victoria (HAL project VG06090) to undertake a scoping study that reviewed literature and government policy on soil health in agriculture, identified gaps in knowledge of soil health and prioritised further soil health research for the vegetable industry;
- AusVeg, (funded by LWA) to develop a practical guide for soil management in the vegetable industry ('the Ute Guide') and develop an accredited course in soil health for vegetable growers.

DPI Victoria has since prioritised soil health as a key research priority from July 2007 onwards, dependent on the successful establishment of a soil health program within the National vegetable industry.

The literature review conducted in this project (VG06090) identified erosion, acidity, salinity and water use efficiency as issues that are important to agriculture in general, and that there has been limited research conducted relating specifically to soil health in the vegetable industry. At the workshops conducted throughout Australia (Queensland, Tasmania, Victoria and South Australia) in 2006/2007, the vegetable industry and researchers identified the following gaps as priorities for future research and extension in the vegetable industry:

1. to measure and benchmark good farm practices for improved soil health
2. to understand the impact of crop rotations and tillage on soil structure, erosion and disease suppression
3. to better manage organic C for improved soil health and water use efficiency
4. to extend information that would drive adoption of ‘best practice’ soil health management in three areas: management of biological and chemical inputs, management of tillage, and water use efficiency.

The Soils Reference Group has identified the key outcomes of a five-year soil health program as:

1. Improved production efficiency of the National vegetable industry by ensuring that physical, chemical and biological inputs (eg. water, pesticides, fertilisers and organics) are managed on farm. This will lead to improvements in yields, profit and product quality, while minimising environmental costs and contributing to sustainable practices that has implications for protection of natural resources in the long term.

2. Extension of information to drive adoption of the ‘best practice’ soil health management in three key areas; management of inputs into farming systems (chemical and biological), management of tillage (physical) and improvements in water use efficiency.

## 7.2. Proposed Key Program Areas

The gaps in research and extension identified through the Soil Health Workshops aligned well with research gaps identified through the literature review for Australian agriculture in general (soil erosion, water use efficiency/salinity), and the vegetable industry in particular (economic and environmental awareness of farm inputs that could be measured and modified through benchmarking; disease suppression; water use efficiency). Using this information, the Soils Reference Group and DPI Victoria developed a draft four-part soil health program:

### 1. Benchmarking crop health, quality, yields and profit (for both sub tropical and temperate Australia)

In the proposed program, benchmarking is the essential first step to establish whether current practices in the vegetable industry cause soil health decline. It would also identify and discriminate good practices from bad. By using a key set of tests and indicators, the project would be able to determine relationships between organic carbon and tillage on microbial biodiversity, population densities of microorganisms, soil moisture, fertiliser use, soil structure and crop yield and profit. Initial benchmarking will examine the impact of standard farm inputs, i.e. fumigation, organic matter input, tillage practices and water scheduling on the physical, chemical and biological components of soil. This information would be used to improve grower practices such as crop rotations, organic matter inputs, tillage and water. Complementary projects should be run under subtropical and temperate conditions as these fundamental relationships will be strongly influenced by climate and environment. The resultant benefits of the program on-farm are expected to be improved soil health, greater natural suppression of diseases, improved crop yield, improved water use efficiency and nutrient use efficiency consistent with such changes.

### 2. Improved management of soil erosion through improved tillage and management of organic matter

Organic carbon and its effect on the cropping environment, is considered to be one of the least well understood but most important aspects of soil health. Organic carbon is of high importance to this program because it is at the centre of many of the components that contribute to declining soil health. Organic matter is the primary food supply for all soil microorganisms and the availability of such substrate is the rate limiting factor in the determination of microbial populations. Organic matter has a direct effect on soil suppressiveness by hosting saprophytes that compete with pathogens for substrate, or by hosting mycoparasites that source pathogens for substrate. In addition, soil organic carbon improves soil structure, increasing the capacity of roots to penetrate soil and to host rhizosphere organisms, some of which have important consequences for root health and plant growth. Organic carbon is necessary for the formation of soil aggregates which stabilise soil against the forces of water, wind and compaction. Stable soil aggregation is important for maintaining the aerobic conditions necessary for healthy root growth and disease suppression.

In the USA, growers are being encouraged to reduce soil erosion, by managing soil carbon levels. It has been estimated that by managing soil carbon levels there would be an annual saving of US$8.2 billion worth of soil (USDA, National Resource Conservation Service). At one of Victoria's largest vegetable growing properties, soil erosion is such an issue that silt traps capture 200-300 truck loads of eroded soil each year costing in excess of $25,000 (*pers. comm*.).

Soil organic matter is directly affected by tillage with estimates of up to 80% loss of organic carbon during the first tillage activity. This study proposes to improve tillage practices to reduce loss of topsoil by erosion. The added benefit of reducing compaction would improve root penetration and microbial biodiversity, which in turn would enhance nutrient uptake and water use efficiency.

### 3. Good soil health practices to improve water use efficiency

Soil organic matter can hold 10 to 1,000 times more water and nutrients than the same amount of soil mineral. In a study in the UK, the application of farm manure for around 10 years resulted in a 10% increase in plant available water capacity, which directly transferred to substantially increased yield in non-irrigated potatoes, an effect that would well serve drought-affected Australian farms.

### 4. Benefits of good soil health management on climate change

Good soil health management has the potential to minimise or abate production of climate change gases both directly by reduction in nitrous oxide and carbon dioxide emissions and indirectly by reducing fuel use and energy consumption.  The latter could be by a reduction of the number of tractor passes by use of minimum tillage, or by less use of pesticides and fertiliser applications through better soil health management, or by better management of crop residues and organic matter. Good soil health may also provide a buffer from environmental disturbances, such as heat stress and drought.

## 7.3. The Vegetable Soil Management Program 2007-2012: Summary and Recommendations

The Vegetable Soil Management Program 2007-2012 (VSMP) sets out the research and extension activities and priorities needed to deliver improved production, productivity and soil management practices for the vegetable industry (see Appendix 1).  It has evolved after consultation with members of the Soils Reference Group and consideration of the outcomes of this project (VG06090).  The Vegetable Soil Management Program comprises three, with a possible fourth, research area (Soil Biology, Soil Chemistry and Soil

Physics, and possibly Organic Product) and two Communication and Extension areas (New Activities and Linkages to existing networks). Each research and extension area has been discussed and priority research areas identified.

The main recommendations from the VSMP for 2007/08 are that in addition to the existing soil health project addressing sub tropical soil health issues, two new projects be established, with a potential for other subprojects to be commissioned over the next five years. The future subprojects will encompass relevant aspects of the above-mentioned draft four-part soil health program. The two new projects that will be funded from 2007/08 are:

- VG07008: Benchmarking Soil Health for Improved Crop Health, Quality and Yields in the Temperate Australian Vegetable Industries – to identify soil management practices that demonstrate improvements to crop health, quality and yield for the vegetable industry.
- VG07146: Australian Vegetable Industry Soil and Land Management Knowledge Exchange – including the development of a soil management website focussed on making information available in a simple, easy to read format. The project is to compliment the benchmarking study.

# 8. Conclusions and recommendations

Three main activities, aimed at providing information for the development of a strategic plan for soil health management in the Australian vegetable industry, were completed within this project (VG06090):

1. A literature review that positioned Australia’s soil health commitment in vegetables against soil health investment in other areas (eg grains, cotton) and against national and international soil health policy was conducted,
2. Four workshops (Queensland, Tasmania, South Australia and Victoria) were conducted to identify research gaps and priorities for vegetable soil health in each state,
3. Two demonstration trials were conducted in Victoria to evaluated potential soil health indicators for measuring farm management effects on soil health.

Through analysis of the gaps identified within the current project workshops, literature review and demonstration trials, four priorities for future research and extension were recommended:

1. to measure and benchmark good farm practices for improved soil health,
2. to understand the impact of crop rotations and tillage on soil structure, erosion and disease suppression;
3. to better manage organic inputs and organic carbon for improved soil health and water use efficiency of soils;

4. to extend information that would drive adoption of "best practice" soil health management in three areas: management of biological and chemical inputs, management of tillage, and water use efficiency.

The recommendations outlined by DPI Victoria were developed in collaboration with the Soils Reference Group into a four part strategic plan, which was finally modified into the Vegetable Soil Management Program 2007-2012 (VSMP). The VSMP is a working document that will be used over the next five years to direct and advise soil health research and extension in the Australian Vegetable Industry.

HAL has recommended that from 2007/08, two projects will be funded, with further subprojects to be developed. The first project, *Benchmarking Soil Health for Improved Crop Health, Quality and Yields in the Temperate Australian Vegetable Industries (VG07008)*, has been directly developed from the first of the four key priorities that were identified in the current project (VG06090). To compliment this project and make current knowledge available in a usable format, the second project to be funded in 2007/08 is *Australian Vegetable Industry Soil and Land Management Knowledge Exchange* (VG07146). These two projects will be integrated with soil research and activities that are already occurring, including the Soils Ute Guide project (AUSVEG), and the tropical soil benchmarking project, Vegetable Plant and Soil Health (QLD DPI) (VG06100).

In addition to providing recommendations for future research, this project has for the first time in Australia successfully established national and international networks of soil health researchers and industry representatives (Table 8.1). The table below represents a series of researchers who have contributed strongly to the development of the program and with whom it is seen as important to include in future workshops and discussions on vegetable soil health issues.

**Table 8.1 A Network (National and International) of Soil Health Researchers interested in Vegetable Soil Health Issues**

| Contact | Location |
|---|---|
| Alison Turnbull | Horticulture Australia Limited |
| Susan Andrews | USDA |
| George Abawi & Harold van Es | Cornell University, USA |
| Tony Pattison | QLD DPI |
| Susanne Heisswolf | QLD DPI |
| Jim Kelly | ARRIS |
| Helena Whtiman | Ausveg |
| Hoong Pung | Peracto |
| Doris Blaesing | Serve-Ag P/L |

| | |
|---|---|
| Ian Porter | Department of Primary Industries Victoria |
| Scott Mattner | Department of Primary Industries Victoria |
| Robyn Brett | Department of Primary Industries Victoria |
| Peter Fisher | Department of Primary Industries Victoria |
| Pauline Mele | Department of Primary Industries Victoria |
| Kathy Ophel-Keller | SARDI |
| Greg Walker | SARDI |
| Ann McNeill | University of Adelaide |
| Samuel Stacey | University of Adelaide |
| Rob Murray | University of Adelaide |
| Steve Welsh | IDO Tasmania |
| Craig Feutrill | IDO South Australia |
| Craig Murdoch | IDO Victoria |
| Alison Anderson | ARRIS |

Finally, owing to the complexity of soil health issues, it is essential that the soil health network above maintain links with other soil health researchers in the broad acre industries in Australia particularly with the cotton and grains industry. It is also recommended that early in 2008 a workshop be held to determine how best to interpret the outcomes form soil health measurements on farm and developing a method to accurately assess the cost/benefits of any soil health management changes that are made on farm.

# 9. Appendix 1.

## The Vegetable Soil Management Program 2007-2012

The Vegetable Soil Management Program 2007-2012 sets out the research activities and priorities needed to deliver improved production, productivity and soil management practices for the vegetable industry. An overview of what the VSMP will deliver and achieve is provided below:

**VISION**

**OUTCOMES**

1. Improve production efficiency of the National vegetable industry by ensuring that physical, chemical and biological inputs (eg. water, pesticides, fertilisers and organics) are managed on farm. This will lead to improvements in yields, profit and product quality an farm, whilst minimising environmental costs, and contributing to sustainable practices which have implications for protection of natural resources in the long term.
2. Extend information to drive adoption of the 'best practice' soil health management in three key areas; management of inputs into farming systems (chemical and biological), management of tillage (physical) and improvements in water use efficiency.

**OBJECTIVES**

1. Ensure industry engagement throughout the life of the soil management program and beyond
2. Maintain a soil management research program that focuses on the bottom line for growers
3. Identify and implement a robust research program that addresses all aspects of soil management
4. Develop a strategy to facilitate with the adoption of best soil management practices within the national vegetable industry.
5. Establish activities to ensure evaluation and maintenance of a truly national program

**RESEARCH PROGRAM & EXTENSION ACTIVITIES**

A summary of the research program and extension activities are provided in the following pages. Activities listed will be prioritised over the 5 year timeframe.

**INTRODUCTION**

Vegetable growers, like most farmers, increasingly have to juggle a range of externalities that make agriculture far more complex than growing the largest crop at the cheapest cost. Some of the recent pressures on growers include: pesticide withdrawal due to residues in the environment, off-site effects of fertilisers, soil erosion and soil structural decline, reductions in water availability and greenhouse gas emissions and the resulting changes to climate. Many of these pressures have forced growers to reconsider the environmental costs of their farming practices and those practices which will undermine long term productivity.

Soil is probably farming's most valuable resource, and maintaining good soil health is vital for prosperous and sustainable production. During a series of workshops conducted throughout Australia (Queensland, Tasmania and South Australia) in 2006/2007, industry and researchers identified the following gaps as priorities for further research, 1) to measure and benchmark good farm practices for improved soil health, 2) to understand the impact of crop rotations and tillage on soil structure, erosion and disease suppression, 3) to better manage organic C for improved soil health and water use efficiency of soils. Soil health involves the concept of balancing the biological, chemical and physical components of soils so that crop health and yields can be maximised and sustained over the long-term.

Horticulture Australia identified soil health as an immediate priority for funding in the vegetable industry in 2006/07. This was in response to industry concerns and National Policy papers that show that poor management of soil health can lead to large losses in productivity, increased disease, and long term damage to catchments. Consequently, preliminary funds were allocated to QLD DPI in 06/07 (HAL project VG06100) to undertake research in sub tropical horticulture to understand soil health limitations, identify improved management techniques and to determine what information vegetable growers need to implement to improve plant and soil health management. Additionally, DPI, Victoria were allocated HAL funds in 06/07 to undertake a literature review of historical soil health research in the vegetable industry, to identify gaps in knowledge of soil health and prioritise further soil health research for the vegetable industry. A third program conducted by AusVeg, and funded by LWA, was commissioned to develop a practical guide for soil management in the vegetable industry ('the Ute Guide') and develop an accredited course in soil health for vegetable growers.

Some major outcomes that have occurred in 2006/07, leading up to the development of this Vegetable Soil Management Program include:
- All contracted parties and stakeholders have formed a 'Soils Reference Group' to monitor the progress of the above activities and set specific R&D priority areas for soil health in the vegetable industry.
- A literature review was completed. This highlighted some gaps within research and informed the development of the Soil Management Priorities set out in this document.
- Soil Health Workshops have been conducted in QLD, SA, TAS (and VIC in August 2007) to discuss soil management issues and R&D implications for vegetable industry. Attendees included soil scientists and vegetable industry members.

All these activities have highlighted the increasing need for the vegetable industry to better understand soil management and to support further soil management research. This Soil Management Program sets out the activities and priorities needed to deliver improved production, productivity and soil management practices for the vegetable industry.

## RESEARCH PROGRAM DETAIL

The literature review, four Soil Health Workshops and the technical knowledge of the Soils Reference Group all contributed to the development of the Vegetable Soil Management Program 2007-2012.
The research program incorporates all aspects of soil management, from biological, chemical and physical to the application of it on farm through knowledge exchange.
Figure 1 provides a diagrammatic representation of the research program. This includes:
- Research Program 1: Soil Biology
- Research Program 2: Soil Chemistry
- Research Program 3: Soil Physics
- Communication and Extension: new activities
- Communication and Extension: Linkages to existing networks

The diagram also identifies a fourth potential research program on Organic Production. This area has not been developed in detail, as a further review of the area, current activities and industry needs within this area is required before a formal research program can be put in place. Each research and extension area has been discussed and priority research areas identified.
In Year 1 (2007/08) of the VSMP it is proposed that two new projects be established addressing both a research need and an industry engagement/communication need. These projects are:
1. VG07008: Benchmarking Soil Health for Improved Crop Health, Quality and Yields in the Temperate Australian Vegetable Industries – to involve research program to identify soil management practices that demonstrate improvements to crop health, quality and yield for the vegetable industry. Three year program, but currently only funded for 2007/08.

Significant funding for this project is being provided by the Service Provider – VIC DPI (similar level of contribution to the VG industry over life of project). This is a positive example of research and industry priorities coming together to deliver practical outcomes to industry.

2. VG07146: Australian Vegetable Industry Soil & Land Management Knowledge Exchange – it will include the development of a soil management website focused on making information available in a

simple, easy to read format. The project will compliment this benchmarking study very well, as it is focused on extension of soils research. Three year program, but currently only funded for 2007/08. See Figure 2 for more detail on the knowledge exchange program.

These two projects will be integrated with soil research and activities already occurring – including the Soils Ute Guide project (Ausveg) and the tropical soil benchmarking project VG06100: Vegetable Plant and Soil Health (QLD DPI).

To achieve the VSMP vision and the outcomes, a number of subprojects will need to be commissioned and undertaken over the 5 years to deliver on key strategic research areas and extend the knowledge to growers. These will be determined after an annual review. An anticipated timeline is provided below (Figure 3).

**OBJECTIVES AND STRATEGIES**

A number of objectives and strategies have been developed to deliver the research program and ensure that industry needs are incorporated throughout the five year VSMP. These are provided in Table 1:

**Table 1: Objectives and Strategies to deliver VSMP 2007-2012**

| |
|---|
| **1. Ensure industry engagement throughout the life of the soil management program and beyond**<br>a. Understand and identify grower needs through regular forums, such as the National Vegetable Conference<br>b. Develop strategies to increase grower involvement throughout all soil management research projects (i.e. growers and industry should be engaged from the proposal development stage!)<br>c. Establish and maintain grower reference groups within regions that soil management projects are being undertaken<br>d. Engage with the Vegetable IDOs to ensure appropriate communication mechanisms are utilised to engage with growers |
| **2. Maintain a soil management research program that focuses on the bottom line for growers**<br>e. Ensure all soil management projects and practices incorporate reviews of cost effectiveness and outcomes are clearly communicated to growers, e.g. case studies<br>f. Maintain awareness of all relevant economic issues for growers in regards to implementation of soil management practices |
| **3. Identify and implement a robust research program that addresses all aspects of soil management**<br>g. All aspects of soil functions to sustain vegetable production need to be considered within all research projects to account for physical, chemical and biological interactions.<br>h. Production constraints such as climatic conditions and soil types should also be factored into research projects<br>i. Incorporate current and historical soil management projects in the program<br>j. Facilitate the development of soil research priorities and yearly commissioning process |
| **4. Develop a strategy to facilitate with the adoption of best soil management practices within the national vegetable industry.**<br>k. Establish a regular model for communicating outcomes to growers, i.e. through grower groups, service providers, newsletters, Ausveg, etc<br>l. Establishment of practical extension methods, i.e. demonstration farms<br>m. Identify barriers to behaviour change and implement actions to address these barriers<br>n. Involve supply chain operators in project process to ensure smooth transition of outcomes to commercial practice<br>o. Ensure information capture and storage (continuity) |

**5. Establish activities to ensure evaluation and maintenance of a truly national program**
p. Facilitate with the development of strong national soil health research capability.
q. Establish and maintain a representative Soils Reference Group to continuously monitor progress and ensure collaboration between research partners and industry to avoid duplication of soil management research and extension
r. Facilitate and maintain linkages with external soil management programs, such as the Land & Water Australia Healthy Soils Program
s. Establish regular communication process with stakeholders

**OUTPUTS**
The key anticipated outputs from this VSMP are:
1) Knowledge and extension tools which improve management of organic carbon and tillage practices on farm to improve water use efficiency, disease control, nutrient use efficiency and soil structure. The extension tools will assist industries knowledge on function and behaviour of soil health, and be produced in collaboration with AusVeg Healthy Soils Team and other knowledge brokers.
2) Knowledge of the impact of common inputs (eg. pesticides, fertilisers, tillage practices, water use) into vegetable cropping throughout temperate Australia and impact on growers' bottom line (ie. crop productivity and profit on farm)
3) Better understanding of the biological, chemical and physical tests that can be used to benchmark healthy soils for vegetable production systems
4) An industry document that will explain how actual soil management systems currently being employed in the vegetable industry are improving soil carbon levels, disease suppression, soil structure, water holding capacity, water movement, biological activity, and productivity. This quantitative data will be obtained by using growers' sites where contrasting practices can be compared under similar site conditions. These sites will also be used for a participatory learning process with growers and State and private agronomists.

**Figure 1:**

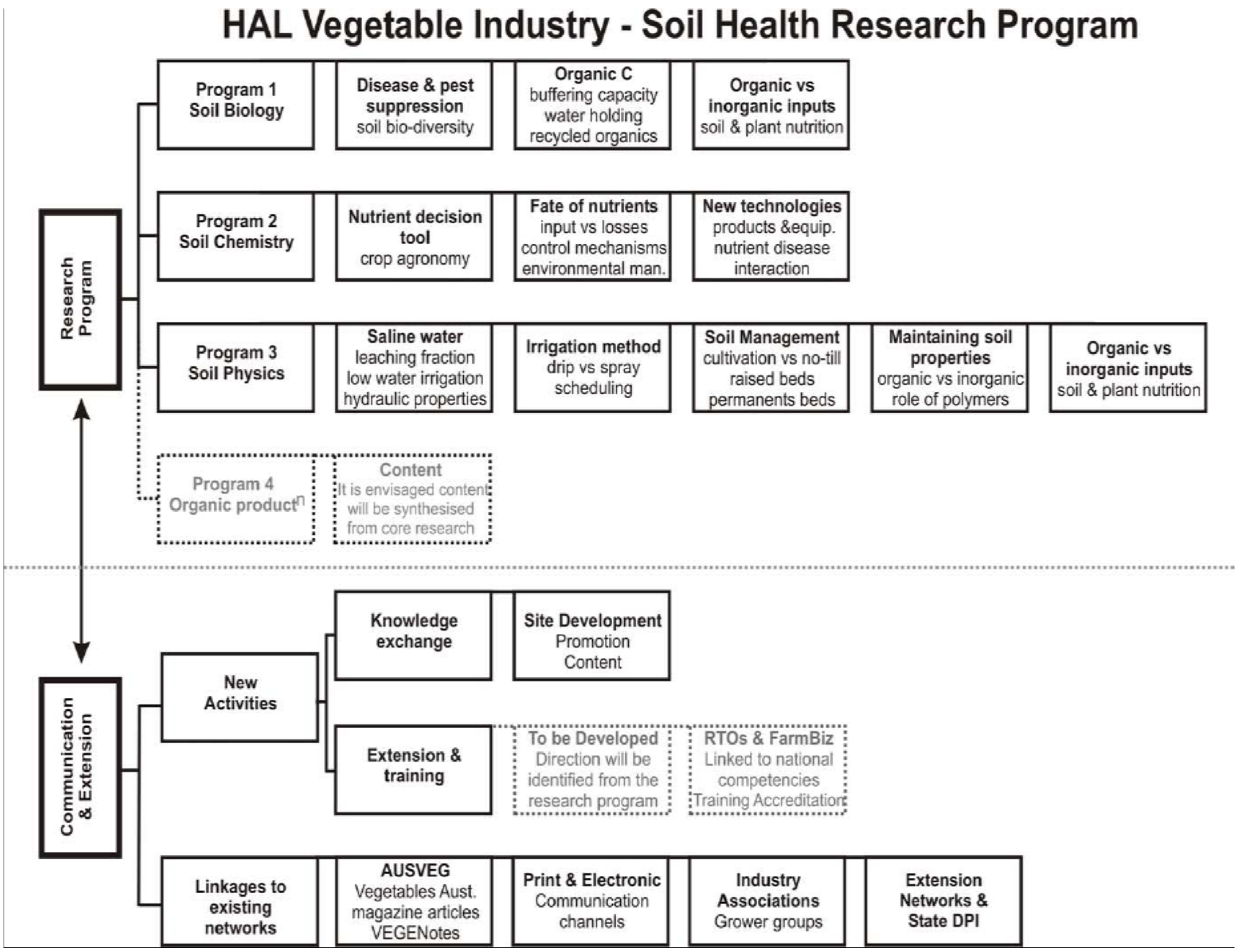
HAL Vegetable Industry - Soil Health Research Program
Research Program
Program 1 Soil Biology
Disease & pest suppression soil bio-diversity
Organic C buffering capacity water holding recycled organics
Organic vs inorganic inputs soil & plant nutrition
Program 2 Soil Chemistry
Nutrient decision tool crop agronomy
Fate of nutrients input vs losses control mechanisms environmental man.
New technologies products &equip. nutrient disease interaction
Program 3 Soil Physics
Saline water leaching fraction low water irrigation hydraulic properties
Irrigation method drip vs spray scheduling
Soil Management cultivation vs no-till raised beds permanents beds
Maintaining soil properties organic vs inorganic role of polymers
Organic vs inorganic inputs soil & plant nutrition
Program 4 Organic productn
Content It is envisaged content will be synthesised from core research
Communication & Extension
New Activities
Knowledge exchange
Site Development Promotion Content
Extension & training
To be Developed Direction will be identified from the research program
RTOs & FarmBiz Linked to national competencies Training Accreditation
Linkages to existing networks
AUSVEG Vegetables Aust. magazine articles VEGENotes
Print & Electronic Communication channels
Industry Associations Grower groups
Extension Networks & State DPI

**Figure 2:**

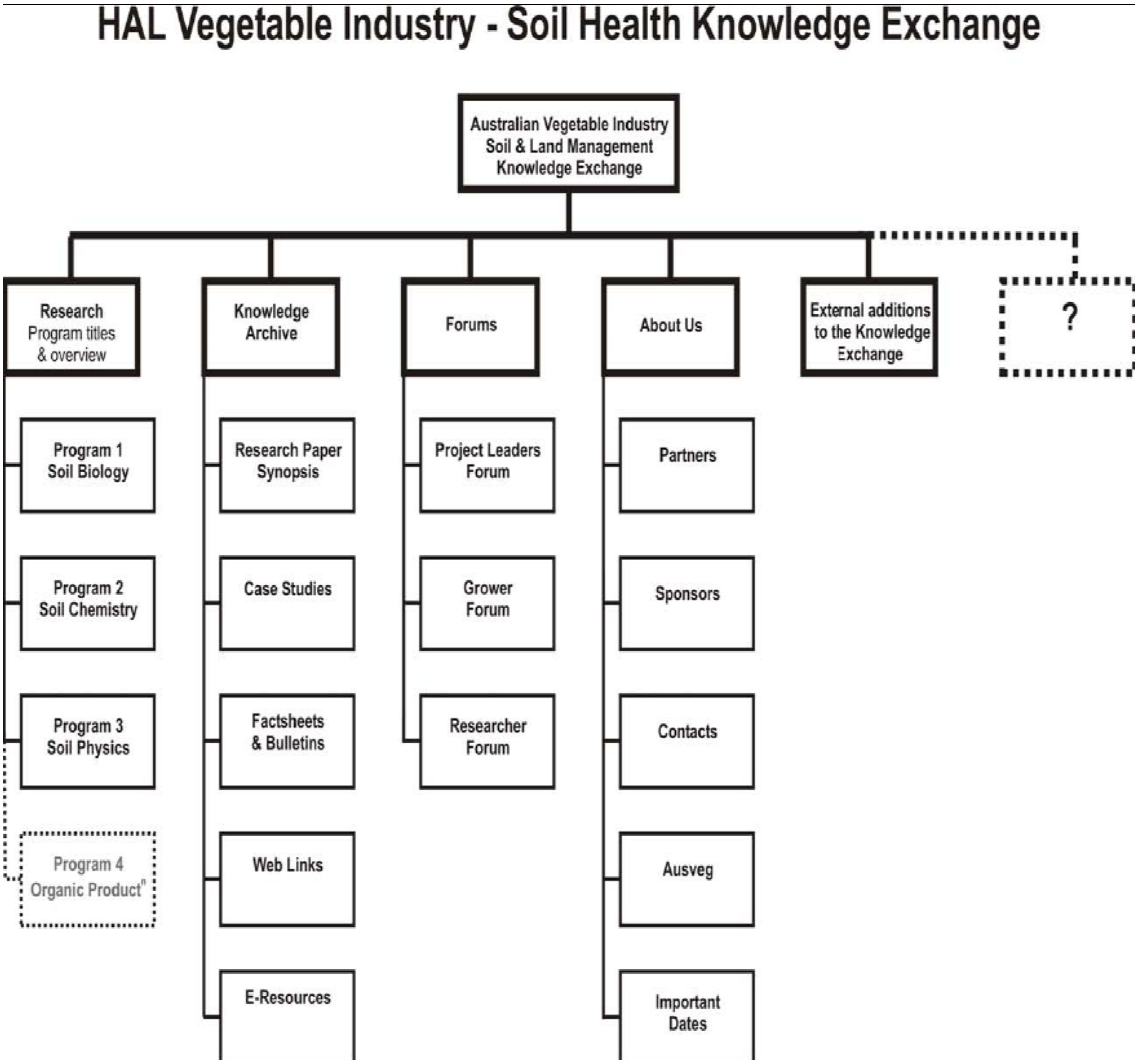
HAL Vegetable Industry - Soil Health Knowledge Exchange
Australian Vegetable Industry Soil & Land Management Knowledge Exchange
Research Program titles & overview
Knowledge Archive
Forums
About Us
External additions to the Knowledge Exchange
?
Program 1 Soil Biology
Program 2 Soil Chemistry
Program 3 Soil Physics
Program 4 Organic Product"
Research Paper Synopsis
Case Studies
Factsheets & Bulletins
Web Links
E-Resources
Project Leaders Forum
Grower Forum
Researcher Forum
Partners
Sponsors
Contacts
Ausveg
Important Dates

**Figure 3: Action Plan and Timeline for activities**