Vegetable Industry Development Program

Soil Health

What is Soil Health?

Soil health refers to the ability of the soil to achieve its full potential and be productive under the intended land use. Healthy soils have favourable physical, chemical and biological properties that promote plant health and maintain environmental quality. The three characteristics of soil health are:

- physical
- chemcial
- biological

Physical soil health refers to the friability and hardness of the soil. A physically healthy soil does not have hard pans or hard setting surfaces. It holds water well, drains well and does not restrict root growth. You can assess physical health in the field using a spade; there also are a range of measurements that can be taken in the field or laboratory.

Chemical soil health means that nutrients are in balance and available to the crop, the acidity/alkalinity is in the desired range and there are no problems with salinity or sodicity. Chemical soil health can be measured by conducting a soil test.

Biological soil health refers to soil life. A healthy soil has more soil organisms than an unhealthy soil of the same type. Crop residues break down more easily and the chemical and physical health is better. You can assess biological health in the field by checking for organisms and comparing the smell and feel of the soil. A high organic matter or carbon content for your soil type usually means a healthy soil.

Why is it important?

A healthy soil is 'fit for purpose'. This means, it is easy to work, friable, holds water and nutrients well and is free-draining. It allows for abundant, healthy root growth and good crop establishment. Crops grown on healthy soils have less disease and weed pressure than crops grown on soils with health limitations. A healthy soil saves effort and money.

Key Messages

- A healthy soil is sustainable, productive and profitable
- Soil health constraints (e.g. salinity, compaction) refer to limitations in soil function; they will reduce plant growth and health and therefore the potential yield of crops
- Soil health can be assessed in the field or through a laboratory test using a range of chemical, physical and biological indicators
- Management of soil health is intended to overcome limitations of the soil and prevent the occurrence of future problems

Photo: Example of soil with friable structure and good root development (Cornell University)

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Good Soils

"Good soils" are productive within their natural limitations of soil type and climate, and tend to have a range of desirable characteristics in common as described in the table below.

What? (Soil Properties)	Why? (Importance)	How? (Management Techniques)
Good organic matter (OM) / carbon content for the respective soil type.	Stabilises soil structure, provides energy and nutrients, increases soil fertility and water relations.	Avoid or shorten fallow periods, use minimum tillage, controlled traffic, stubble retention, and green crops. Add quality manures, composts or mulches.
Loose, friable structure.	Important for root growth, movement of air and water, and crop establishment.	Add gypsum, lime, manage OM, use controlled traffic, minimum till, and tap rooting plants.
Good water holding and drainage.	Stores and supplies water to the plant. Prevents waterlogging and nutrient leaching.	Add gypsum or OM, control traffic to minimise compaction, use raised bed and drainage channels.
Active soil life.	Needed for nutrient recycling, crop residue decomposition, and good soil structure.	Retain stubble, use cover crops and groundcover, manage OM, add lime to achieve pH of 5-7.
Supply of nutrients.	Needed for plant and microorganism health and growth.	Supply fertilisers, manage OM, lime to achieve pH of 5-7, rotate with legumes, improve structure and soil life.
Free from pests and diseases.	Ensures plant health and productivity.	Rotate crops, use integrated pest management (IPM) and all of the above.

Some properties are very easy to change using simple management solutions. Incorporating lime into the soil easily alters the pH. Reducing tillage traffic and improving organic matter management will soon improve structure and soil life.

Other properties can be very difficult or impossible to change. Soil texture is impossible to change – a heavy clay soil cannot be made into a sandy loam, or vice-versa. On the other hand, it is possible to alter soil structure by adding gypsum and deep ripping.

Photo: Example of an unhealthy soil (left) and healthy soil (right) which has loose, friable structure and good levels of organic matter (Cornell University)

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Poor soils

"Poorly functioning soils" are unhealthy and have properties that restrict plant growth, negatively impacting on the sustainability and profitability of vegetable farms. There are a number of common soil constraints that cause decline in soil health and crop production.

Problem	Solution
Salinity (presence of salts, especially chloride in soil or water) due to natural conditions, land use change or irrigation water quality.	Often a whole-catchment issue involving a range of new farming practices, tree planting and drainage. On individual farms change irrigation practice and follow all soil health management suggestions from the previous table. Also increase soluble calcium, potassium and phosphorus inputs. Get local advice!
Sodicity (presence of excess exchangeable sodium).	Add gypsum or lime, often in combination with deep ripping at the right conditions; follow all soil health management suggestions from previous table, also increase soluble calcium, potassium and phosphorus inputs. Get local advice!
Acidity (low pH).	Add lime and either incorporate at the surface or deep-rip.
Alkalinity (high pH).	May be a sign of sodicity or high limestone levels, use acidifying fertilisers, ensure good supply of phosphorus, potassium, magnesium and trace elements.
Poor structure – compaction, waterlogging, hard setting.	Use amendments such as gypsum, lime and organic matter (OM). Use practices such as controlled traffic, minimum tillage, rotation with tap-rooted plants, deep ripping and raised beds. Follow all soil health management suggestions from previous table.
Soil-borne pests and diseases.	Apply integrated pest and disease management and follow all soil health management suggestions from previous table.
Erosion.	Use vegetative cover, windbreaks, contour drainage lines, grassed headlands, and improve soil structure.
Low organic matter (OM) content.	Increase OM (see 'Good Soils').
Limited nutrient availability.	Improve chemical fertility (see 'Good Soils').

These constraints will lead to reduced crop growth and yields and excessive money and effort spent on inputs and land management.

Soil Health Research: Economic and environmental benefits can be gained from soil health management

Researchers at DPI Victoria are currently investigating the best physical, chemical and biological tests to measure improvements in soil health, whilst providing higher yields and maximising profit. The aim of the project is to benchmark soil health and provide the horticulture industry with a scorecard that can help improve soil health.

They have found that there are a range of soil health practices that have environmental and economic benefits for growers. These practices include slow release ammonium fertilisers, organic amendments and biofumigant crops and simple changes such as reductions to fertiliser and pesticide programs.

Three year field trials on 25 sites across southern Australia have shown increased yields and profits resulting from the use of more environmentally-friendly practices. In broccoli crops, different soil health practices have resulted in yield increases of up to 16 per cent and profit gains of up to $6,000 per hectare, compared to standard grower practice.

Results from these trials will help vegetable growers develop better management options to improve soil health for yield and profit and assist future sustainability.

For more information on this project contact Dr Ian J Porter, DPI Victoria on (03) 9210 9222 or ian.j.porter@dpi.vic.gov.au.

You can also view the latest project updates online at the Vegetable Growers Association of Victoria website at http://www.vgavic.org.au/pdf/VG07008_Soil_Health_brochure.pdf

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Identifying and assessing components of soil health

Soil health encompasses the physical, chemical and biological properties of a soil. It is the interaction of these three properties that sustain productivity.

It is important that you can identify and understand the soil types on your property (and their limitations) so that they can be managed appropriately. Indicators that measure the soil's physical, chemical and biological properties are used to benchmark soil health and measure the impact of management changes. As discussed previously, research is currently underway to benchmark soil health and provide the horticulture industry with a scorecard that can help improve soil health (see section on previous page on Soil Health Research).

Physical properties of a soil include type, depth, texture, structure and strength. They can be measured using soil physical tests and improved by following the suggestions in the previous tables for 'Good Soils and Poor Soils'.

Component	Description	Rule of Thumb
Texture	Texture is the proportion of sand, silt and clay. This proportion determines soil type and natural limitations of the soil.	Talk to your local advisor about appropriate soil management techniques for your soil type.
Penetrometer resistance	Penetrometer resistance gives information on the strength and hardness of the soil. A spade or metal rod can be used on-farm to check and compare penetration resistance. High resistance means the soil has poor structure; it is difficult to manage, dries and waterlogs quickly and has a restricted root zone.	Compacted soils or sodic soils with surface crusting will have high penetrometer resistance (greater than 2 MPa*). **The level of resistance is dependent on moisture content and technique used at time of measurement.*
Bulk density	Bulk density is a measure of the density and porosity of the soil. Usually soils with high penetration resistance also have a high bulk density.	Poorly structured soils have high bulk density (1.6 - 1.9 g/cm^3) and low porosity.
Aggregate stability	Aggregate stabiliy is another indicator that usually correlates with penetration resistance and bulk density. Soil that have been overworked, have low organic matter and/or sodicity are also likely to have poor aggregate stability.	You can check aggregate stability by putting a lump of soil on a saucer with water. The quicker and more completely the lump disintegrates, the poorer the aggregate stability.
Water holding capacity or plant available water	This measures water available to the plant and is an indicator of the porosity, density and overall structure of the soil.	Water holding capacity will vary according to soil texture. For example a well structured loam should be able to hold approximately 200mm of plant available water in 1 metre of soil but a fine sand may only hold approximately 50mm.
Infiltration	Measures how quickly water enters the soil and how quickly it can drain; it also is an indicator of soil structure.	Compacted soils with high penetration resistance and bulk density, and soils with poor aggregate stability usually have poor infiltration rates and low levels of plant available water. Both indicators have to be measured using specialised equipment in the field or laboratory.

The **biological properties** of a soil refer to the properties of the organic component including living organisms and carbon fractions. These properties can be measured using soil biological tests outlined below.

Component	Description	Rule of Thumb
Soil organisms	Include insects, worms, bacteria and fungi which reflect soil structure and chemical fertility. Biological health reflects soil health.	There is currently no 'rule of thumb' measurement availble for the appropriate number of soil organisms in your soil.
Organic matter content	This reflects soil fertility, structure and diversity.	It should be between 2-4%, depending on soil type.

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Soil chemical properties relate to the interaction of chemical components among and within soil particles. Soil chemical tests include:

COMPONENT	DESCRIPTION	RULE OF THUMB
pH	Measure of acidity or alkalinity.	Preferred range for vegetables is 5.5 - 8
Cation exchange capacity (CEC)	Reflection of soil fertility and structural stability. Soils with low CEC have a relatively low inherent fertility and may lose nutrients easily through leaching.	The desirable concentrations (cmol(+)/kg) of the main exchangeable cations inlfuencing plant growth are: • Calcium (Ca): greater than about 1.5 • Magnesium (Mg): more than about 0.4 • Potassium (K): more than about 0.3 • Sodium (Na) as close as possible to 0 • Aluminium (Al) as close as possible to 0
Nutrient analysis	Gives the concentrations of major plant nutrients such as Nitrogen , Phosphorus, Sulphur or Potassium and trace elements such as Zinc, Iron, Copper, Manganese and Boron.	Discuss your nutrient analysis results with your local advisor. Phosphorus is applied to vegetable crops at 10 - 110kg/ha, potassium at 0 - 140 kg/hectare, calcium (as lime) at 0 - 5 tonnes/hectre and magnesium (as dolomite) at 0 - 4 tonnes/hectare, depending on soil test values and the crop to be planted.
Exchangeable sodium percentage (ESP)	ESP indicates sodicity. The ESP is measured as part of CEC and may be reported as sodium (Na) % of CEC.	A sodic soil has an ESP greater than 6.
Electrical conductivity (ECe)	ECe indicates salinity. The ECe is measured from saturated soil. Most laboratories report the EC derived from a 1:5 soil solution. This EC is about 10x lower than ECe i.e. levels greater than 0.2-0.4 dS/m indicate potential salinity issues. Chloride levels above 200mg/kg are also a good indicator of salinity.	Non-saline soil has an ECe less than 2 dS/m. A soil with an ECe greater than 8 dS/m is considered highly saline.
Electrochemical stability index (ESI)	ESI is an indicator of whether soils with high ESP will be prone to surface crusting and hard setting.	If greater than 0.05 soil is generally stable. If less than 0.05 soil may be unstable.

Note: rule of thumb measurements are approximate only and have been sourced from the Healthy Soils for Sustainable Vegetable Farms Ute Guide (Project Leader: Helena Whitman).

You can't manage it if you can't measure it! These indicators allow you to describe the functions of the soil and determine if soil health is being maintained or improved. It is important to keep good records and monitor trends. Get local advice if you are not sure.

Once the condition and limitations of the soil is known, a soil management strategy can be decided on. Each vegetable grower will require a management strategy tailored to his or her own unique situation.

Further Information

- To download a copy of the Healthy Soils for Sustainable Vegetable Farms Ute Guide please go to the AUSVEG website at http://ausveg.com.au/enviroveg/programs/healthysoil.htm
- To access tips for healthy soils, case studies on soil management, and education and training materials on healthy soils for sustainable farming systems please go to the Soil Health Knowledge Bank website at http://www.soilhealthknowledge.com.au/
- Helpful information on interpreting soil tests is provided in the book: Interpreting Soil Test Results - What do all the numbers mean? by Pam Hazelton and Brian Murphy.

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Case Study: Using organic admendments to improve soil performance

In the late 1990s a new grower in Gingin, WA producing loose-leaf lettuce adopted management practices that focused on the use of organic amendments to improve the health and performance of the soil. He regularly used amendments such as manures and compost on his loamy-sand soils.

On an adjacent block, his brother grew the same product but adopted a management approach based on fertiliser and irrigation best management practices, with no organic inputs.

Soil testing on both farms allowed the impacts of these different treatments on soil health to be measured. Compared to the farm using no organic inputs, the regular use of organic amendments resulted in:

- Increased soil organic carbon
- Increased active carbon (form used by micro-organisms)
- Improved soil water-holding capacity and nutrient holding capacity
- Higher phosphorous buffering capacity (ability of the soil to hold P)
- Less leaching of nitrate from the soil profile
- Increased soil pH to optimum levels
- Lower bulk density and higher porosity
- Improved soil aggregation
- Better nutrient retention

By regularly adding organic matter in the form of manures and compost, the lettuce grower was able to improve the health of his soil. Compared to his brother's farm, where management was best practice but no organic inputs were used, the soil had better performance in all of the key physical, chemical and biological measures of soil health.

For more information on this case study refer to the manual 'Soil health for vegetable production in Australia' by T. Pattison, P. Moody and J. Bagshaw, available from the Queensland Department of Primary Industries and Fisheries website: http://www.dpi.qld.gov.au/26_17025.htm

Case Study: Improving soil health with organic fertilisers and minimum till

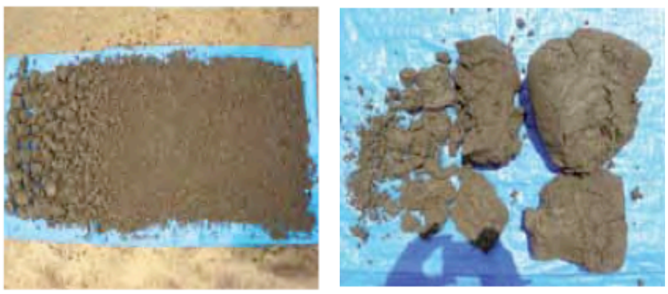
Mario is a vegetable grower in Windsor, NSW. For over eight years he has been committed to improving the health and structure of his soils. To achieve this Mario has been using organic fertilisers and reducing tillage.

After years of good soil management there has been significant improvement in Mario's soils. This can be seen by comparing key soil measurements from Mario's farm with those of a nearby property. Mario's soil:

- Has a lower bulk density and therefore increased porosity
- Increased aggregate stability, meaning soil particles do not disintegrate or disperse when wet
- Higher soil nitrate, suggesting less was lost from the soil profile by leaching
- More active soil carbon for use by micro-organisms

Practical evidence of the improvement in soil structure was seen in December 2007 when the district received prolonged wet weather. Mario was able to maintain his sweet corn crop yields, whereas his neighbour was more badly affected. This difference was attributed to the healthy soil structure at Mario's farm that allowed water and air to move easily through the soil profile.

A soil drop test three days after heavy rain – where a sample of soil is dropped from a height to see how the soil breaks apart – also showed that Mario's soil had a much better structure than other soils nearby.



Photos: Differences in response to a soil drop test (QLD DPIF)

Mario's soil (left) broke into a range of aggregates of different sizes. The other soil from a nearby property (right) formed large clods and clumps.

Thanks to Mario's long-term use of reduced tillage and organic fertilisers, he has been able to improve the structure of his soil and maintain good crop yields in the face of unfavourable weather conditions.

For more information on this case study refer to the manual 'Soil health for vegetable production in Australia' by T. Pattison, P. Moody and J. Bagshaw, available from the Queensland Department of Primary Industries and Fisheries website: http://www.dpi.qld.gov.au/26_17025.htm

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