Department of **Employment, Economic Development and Innovation**

Soil health for vegetable production in Australia



Compiled by the Department of Environment and Resource Management and the Department of Employment, Economic Development and Innovation

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Part 1: Introduction to soil health

What is 'soil health'?

Some people think of 'soil health' as the biological capacity of soil (i.e. its function as a vital living system that sustains plants, animals and humans). Others treat soil simply as a medium to hold up a plant while we apply fertilisers, water and crop protection products to obtain maximum yield.

This manual takes a holistic view of soil health by considering the interaction of physical, chemical and biological soil properties (see below). The balance and stability of these components are what make a healthy soil.

In Australia, vegetables are grown on a wide range of soil types, so it is important to understand the characteristics and constraints of each of these soils—only then can we get the best from the soil for crop production.

Understanding your soil type and how to manage it will help you maintain long-term soil health and minimise soil loss and degradation.

Physical, chemical and biological soil properties

Physical soil properties relate to the size and arrangement of soil particles and the movement of air and water in the soil. 'Soil texture' and 'soil structure' are two important physical properties that influence many other soil characteristics.

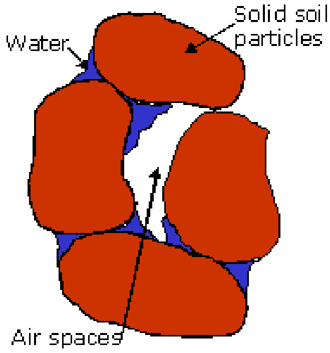
Chemical soil properties relate to nutrients held on soil particles, contained in soil organic matter and dissolved in the soil water.

A standard soil analysis measures a range of chemical soil properties including pH, electrical conductivity (EC), cation exchange capacity (CEC), organic carbon, organic and mineral forms of nitrogen, extractable phosphorus, exchangeable potassium, calcium and magnesium and extractable micronutrients.

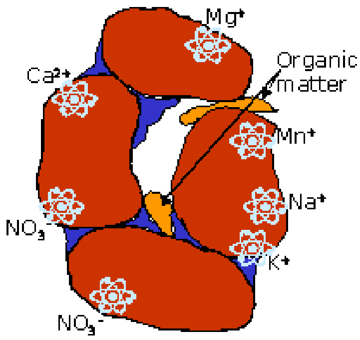
Biological soil properties relate to living soil organisms and their relationships with each other and with their main food source—soil organic matter. Organisms living in the soil include microbes such as bacteria and fungi, nematodes, insects and larger burrowing animals such as earthworms.

A healthy soil contains huge populations of microbes, with estimates typically being 100 million bacteria and 7 m of fungal strands per 1 g of soil. A few of these organisms attack plant roots and these have traditionally received the most attention from farmers and researchers—often to the detriment of the soil's other beneficial living organisms.

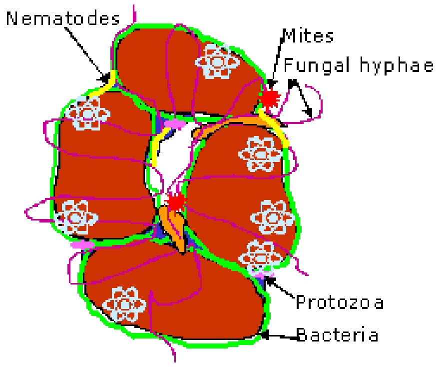
Physical soil properties



Chemical soil properties



Biological soil properties



About this manual

This manual aims to take the mystery out of managing soils to keep them healthy.

It includes:

- a guide to identify the types of soil you are working with, a review of their common constraints and suggestions on how to manage these constraints
- new ways to assess standard soil analysis results (what information are you already collecting that can help assess and improve the health of your soil?)
- suggestions for additional soil measurements that could help track changes in soil health.

Part 2: Know your soil and its constraints

The first step for successfully managing your soil is to know what type of soil you are dealing with. There are three main ways to identify your soil type:

1. Use 'do-it-yourself' (DIY) soil classification.
2. Use formal soil classification.
3. Use soil maps.[1]

Do-it-yourself (DIY) soil classification

The DIY method gives you a rough classification based on four soil characteristics:

1. soil texture
2. soil pH
3. dispersion and slaking characteristics
4. soil colour.

The four soil characteristics of texture, pH, dispersion and slaking, and colour can be determined for the top 30 cm of your soil, but checking deeper will let you look at more of the soil profile and highlight subsoil characteristics such as mottling (indicates waterlogging), clay layers and plough pans that have important effects on root development.

We also recommend getting a standard soil analysis test done by a reputable laboratory. It will provide information on the nutrient status of your soils and allow you to better manage your fertiliser program. Soil testing laboratories accredited by the Australasian Soil and Plant Testing Council (ASPAC) are listed at www.aspac-australasia.com

Before you can determine each of these soil characteristics, you will need to select a sampling site on your farm. You may need several sampling sites to cover the range of soils on your property. Perform the following steps:

- **Select a representative site for each soil type on your property.** Avoid areas such as row ends that may be compacted from turning vehicles. Clues for identifying different soils are changes in surface colour and/or texture and position in the landscape (e.g. ridge, mid-slope, lower slope or creek flat position).
- **Record the location of your representative site(s).** This allows you to return to that spot to check changes in soil health over time. Recording the location with a GPS unit is an ideal way of achieving this.
- **Take a soil sample.** A spade is a useful tool for exposing the soil to a depth of 30 cm—the rooting depth of many vegetable crops. To check to a depth of 50 cm or more you will need a soil auger or, better still, a backhoe or excavator to dig a pit. Don't run the machinery over the area you want to test and make sure there are no underground cables and pipes where you plan to dig.

Note: Selecting a representative site to determine the soil type is different to taking a soil sample for pH and nutrient analysis. The latter requires taking several soil samples across a production block of the same soil type and bulking these together to give an 'average' surface soil sample.

Warning

Check the location of underground telephone and electric cables, and water pipes before digging a pit.

Dial 1100 or visit www.dialbeforeyoudig.com.au

1. Soil texture

Soil texture describes the relative amounts of sand (large particles), silt (medium particles) and clay (small particles) in the soil (see Table 1).

Texture is an important soil property because it affects nutrient- and water-holding capacity, porosity, aeration, water movement through the soil profile, structure, likelihood of compaction and resistance to root penetration and acidification.

Table 1. Soil texture

Sandy soils	90–100% sand particles by weight
Loams	Similar amounts of sand, silt and clay particles, but can range from sandy loams (with a higher proportion of sand particles) to clay loams (with a higher proportion of clay particles)
Clays	More than 35% clay particles by weight, with medium to heavy clays containing over 40% clay by weight

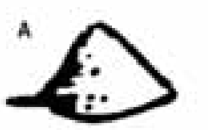
1 Some regional government offices may have soil maps for your region; however, these can sometimes be limited. Only the first two ways to identify your soil type are described in this manual.

To determine soil texture:

- Take a spoonful of soil in one hand and add water slowly while working the soil until it becomes sticky.
- Try to roll the soil into a ball.
- If you can make a ball, try to make a cylinder (or rod).
- If you can make a long cylinder (or rod), try to bend the soil into a 'U' shape without forcing it.
- If you can make a 'U' shape, try to make a ring.

Table 2 indicates soil texture based on the result.[2]

Table 2. Using shapes to determine soil texture (includes common soil constraints)[3]

Soil texture	Description	Shape	Constraints
Sand	The soil stays loose and separated and can only be accumulated in the form of a pyramid.		• low water-holding capacity; seedlings can wilt because of a rapidly drying soil surface • low nutrient retention; excessive leaching of nutrients (particularly nitrate, potassium and sulphate) • acidity • extremely low phosphorus fixation • low organic matter content.
Sandy loam	The soil contains enough silt and clay to become sticky and can be shaped into a fragile ball.		
Silty loam	Similar to the sandy loam, but the soil can be shaped by rolling it into a small, short cylinder. Soil has a 'silky' feel.		• hard-setting/surface sealing if texture is fine sandy loam or silty loam • prone to compaction.
Loam	Can be rolled into a 15 cm long (approx.) cylinder that breaks when bent.		
Clay loam	Similar to loam, although the cylinder can be bent into a 'U' shape (without forcing it) and does not break.		
Fine clay	The soil cylinder can be shaped into a circle, but shows some cracks.		• excessive/prolonged wetness • prone to compaction.
Heavy clay	The soil cylinder can be shaped into a circle without showing any cracks.		

[2] Alternatively, you could include texture as a test in your next laboratory soil analysis.

[3] Adapted from EUROCONSULT (1989).

Table 3. Soil constraints associated with soil texture

Soil texture type	Common constraints
Sandy soil	• low water-holding capacity. Seedlings can wilt because of a rapidly drying soil surface • low nutrient retention. Excessive leaching of nutrients (particularly nitrate, potassium and sulphate) • acidity • extremely low phosphorus fixation • low organic matter content.
Loam/clay loam soil	• hard-setting/surface sealing if texture is fine sandy loam or silty loam • prone to compaction.
Clayey soil	• excessive/prolonged wetness • prone to compaction.

Note: If your soil profile has an abrupt increase in clay content in the subsoil (duplex soils) then the common constraints are:

- excessive/prolonged wetness in the surface soil due to the impermeable clay subsoil
- hard-setting/surface sealing if surface soil texture is fine sandy loam or silty loam
- low plant-available water-holding capacity if surface soil texture is sandy
- low nutrient retention if surface soil texture is sandy.

2. Soil pH

The pH is a measure of a soil's acidity or alkalinity on a scale from 0–14, with 7 being neutral. Soils with a pH greater than 7 are alkaline, while those with a pH less than 7 are acidic. Measuring pH determines the concentration of hydrogen ions (H^+) in the soil solution.

Soil pH is a standard measurement that is generally reported in standard soil nutrient analyses from reputable laboratories. Laboratories determine soil pH using either water or calcium chloride as the solution with soil, which may give different pH readings. Be sure you know which method has been used for your pH test. The result will be indicated as either pH^{water} or pH^{CaCl2}

You can do your own soil pH measurement in the field using a portable pH meter.

Choosing the right equipment

If you plan to do your own soil pH measurement, it is wise to invest in a good quality pH meter. Remember to calibrate your meter before each use by testing with supplied buffer standards of pH 4.0 and pH 7.0.

Each pH meter may have slightly different calibration methods, so check the manufacturer's instructions carefully.

If you intend to do a lot of pH samples it may be worth investing in a pH meter that has been specifically designed to work with soils, as soil solutions can be abrasive to some components in pH meters.

Collecting your soil sample

To collect a representative soil sample for pH measurement:

- Take a handful of soil to a depth of 10 cm from several sites of the same soil type across a paddock in a random 'Z' pattern. In a clean plastic bucket, thoroughly mix the samples together.
- Take your sample for testing from this mixed batch.
- Prepare a mixed sample for each different soil type.

Testing your soil sample for pH

What you need	Steps to follow
• digital balance to weigh soil (accurate to 0.1 gram) • screw top jars • deionised (distilled) water • pH meter • soil collected from across the paddock mixed together. 	• Before starting, calibrate the pH meter according to the manufacturer's instructions. • Weigh a screw top jar and record the weight. • Weigh 30 g of soil into the jar. • Add 150 mL by volume or 150 g by weight of distilled or deionised water to the jar and screw on the lid. Shake the jar vigorously for 1 minute. • Allow the water to settle for 30 seconds. Take a reading from the upper half of the suspension with the pH meter and write the results in a recording sheet. • Rinse the pH meter with distilled water between measurements. When you have completed your final measurements, store the meter as directed by the manufacturer. If you do not have a balance to weigh soil, then use just enough water to make a saturated paste of the soil sample. Carefully insert the pH meter into the paste and take a pH reading. This pH value will be lower (by up to 0.5 of a pH unit) than pH determined by the method described above, but can be used as a guide to the soil's pH. **Note:** Soil paste is abrasive and may damage the bulb of the pH meter.

Soil pH has significant effects on the availability of many nutrients. Low or high pH makes some nutrients unavailable and causes others to be released from soil particles in toxic quantities. Typical constraints associated with soil pH are shown in Table 4.

Table 4. Constraints and implications associated with soil pH

Diagnostic range (soil pH_{water})	Constraint	Implications
Less than 5.5	Acidity	• Soil pH values markedly less than 4 – will be found in peat and acid sulfate soils – may occur in extremely weathered mineral soils of low fertility – may occur in sandy textured soils subjected to highly acidifying agricultural practices, such as high application rates of ammonium-based nitrogen fertilisers, removal of large amounts of harvested product or mineralisation of nitrate from decomposing leguminous plant residues. • Aluminium or manganese toxicity is probable. • Can have deficiencies of molybdenum (because of decreased availability at low pH) and calcium, magnesium, and potassium (due to leaching losses). • May be reduced activity of some soil microbes (especially nitrifiers).
8.5 to 9.0	Alkalinity	• Zinc, iron and manganese become less available as the pH increases, whereas molybdenum becomes more available.
Greater than 9.0	Sodicity	• In this pH range, soils are strongly alkaline and dominated by sodium and magnesium carbonates. • Copper, zinc, iron, manganese, potassium and phosphorus can be deficient. • Boron can be toxic. • The soil is likely to have very poor structure and be low in available nutrients.

3. Dispersion and slaking characteristics

Dispersion is the release of clay particles into water, causing the water to become cloudy. Slaking is the spontaneous disintegration ('slumping') of soil aggregates when placed in water.

Dispersion indicates that the soil is probably sodic (sodium-rich), whereas slaking indicates that forces holding aggregates together are weak—both are signs that the soil will be susceptible to compaction and surface sealing.

Emerson dispersion test

The Emerson dispersion test is commonly used to measure the slaking and dispersion characteristics of a soil.

Note: This test is not appropriate for sandy soils as they rarely form aggregates.

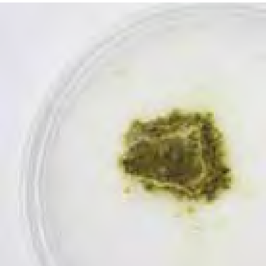
What you need	Steps to follow
• flat dish • deionised (distilled) water or the water being used to irrigate the soil • two or three pea-sized aggregates of the soil being tested • timer.	• Take two or three pea-sized aggregates and place in a dish with deionised (distilled) water or the water used to irrigate the soil. • After 5 minutes observe their appearance. • If the aggregates stay together then the soil has good aggregate stability. • If the aggregates fall apart, but the water remains clear, the aggregates have slaked. • If the aggregates fall apart and the water is cloudy, the soil is dispersive.
Dispersed soil  Slightly dispersed  Moderately dispersed  Highly dispersed	Slaked soil  Stable soil aggregate  Slaked aggregate

Table 5. Soil constraints associated with slaking and/or dispersion characteristics

Characteristic	Constraints	
Slaking	• excessive/prolonged wetness • hard-setting/surface sealing	• compaction • low organic matter content.
Dispersion	• excessive/prolonged wetness • hard-setting/surface sealing • sodicity.	• compaction • low organic matter content

4. Soil colour

Soil colour will be influenced by the minerals in the soil, the weathering of the soil, the aeration of the soil and the amount of organic matter in the soil. For example, red indicates high iron levels; darker soils tend to have more organic matter.

Some soils will have a change in the colour down the soil profile. If the colour change is abrupt the soil is known as a 'duplex soil'. A marked change in colour is often also associated with a marked change in another soil property (e.g. texture or pH).

We have grouped the major soil colours as:

- black to grey
- brown
- red
- yellow
- white (or bleached).

See Table 6 below. We have also included some comments on mottled and waterlogged colourations, along with common constraints that can be inferred from soil colour.

Table 6. Major soil colours, soil types and common constraints associated with soil colour

Soil colour	Characteristics	Constraints
Black	Soils high in organic matter. Examples: • vertosols* (cracking clays) • peat or organic soils.	• excessive/prolonged wetness • compaction • salinity • sodicity • alkalinity.
White, pale or bleached surface soil	Sandy soils. Example: podosol*.	• low water-holding capacity. • low nutrient retention. • acidity • extremely low phosphorus fixation • low organic matter content.
Red	Well-drained soils with high content of iron oxides. Example: ferrosol*.	• compaction • low water-holding capacity • low nutrient retention • acidity • high phosphorus fixation.
Yellow or Yellow-brown	Imperfectly drained to moderately well-drained soils with high content of iron oxides. Example: tenosol*.	• excessive/prolonged wetness • compaction • low water-holding capacity • low nutrient retention • acidity.
Brown	Moderate soil organic matter levels and some iron oxides. Example: dermosol*.	• no specific constraints.
Gleyed, grey or blue-grey	Nearly permanent waterlogging; anaerobic (reduced) conditions. Example: hydrosol*.	• excessive/prolonged wetness.
Mottles	Intermittent waterlogging; intermittent anaerobic (reduced) conditions.	• excessive/prolonged wetness.

* *The Australian soil classification* (Isbell 1996)

Soil orders—classifications and soil constraints

The system for classifying soils in Australia is known as the Australian soil classification. This information is available from soil maps, the CSIRO Australian soil classification website (www.clw.csiro.au/aclep/asc_re_on_line/soilhome.htm) or the Australian Soil Resources Information System website (www.asris.csiro.au/index_ie.html).

Soil classification information is mainly used by soil scientists who distinguish different soils to produce soil maps. They often assign local names to specific regional soil types.

The main soil orders used in vegetable production are shown in Table 7, along with their main attributes and horizon development.

Soils belonging to the same soil order have similar constraints that vegetable growers should be aware of. The soil constraints for the different soil orders are given in Table 8.

Table 7. Soil orders of *The Australian soil classification* (Isbell 1996) used for vegetable production in Australia

Soil order	Vertosol	Calcarosol	Ferrosol	Sodosol	Dermosol	Chromosol	Kandosol	Tenosol	Podosol
Typical colour	Black-grey	Grey	Red	Grey	Brown	Red	Brown	Yellow	White
Horizons	No texture change in horizons	No texture change in horizons	No texture change in horizons	Strong change in texture between horizons	No texture change in horizons	Strong texture change in horizons; B horizon pH >5.5	No texture change in horizons	No texture change in horizons	Strong colour change in horizons
Diagnostic features	Clay soils; strong cracking when dry; slick sides when wet; >35% clay	White calcium carbonate in soil; pH >8.5	Clay rich soils with high iron giving red colour	Change in texture with depth; highly dispersive	No textural contrast; well structured B horizon	Strong textural contrast; not dispersive; pH >5.5 in B horizon	No textural contrast; weakly structured B horizon	Weakly developed and typically very sandy	B horizon dominated by organic matter, iron or aluminium; highly sandy and acidic

Source: <http://www.clw.csiro.au/aclep/asc_re_on_line/soilhome.htm

Table 8. Common constraints of the soil orders of *The Australian soil classification*[A] (Isbell 1996) and the corresponding great soil group[B] in the superseded classification of Stace et al. (1968)

Soil order[A]	Great soil group[B]	Common constraints
Vertosol	Black earth, black cracking clay, grey clay	• excessive/prolonged wetness • compaction • salinity • sodicity • alkalinity.
Calcarosol	Solonised brown soil, grey-brown and red calcareous soils	• low water-holding capacity • sodicity • alkalinity.
Sodosol	Solodised solenetz, solodic soils	• excessive/prolonged wetness • compaction • hard-setting/surface sealing • salinity • sodicity • alkalinity.
Chromosol	Red brown earth, non-calcic brown soil, red podzolic, lateritic podzolic, red and brown duplex soils	• excessive/prolonged wetness • compaction • hard-setting/surface sealing.
Ferrosol	Krasnozem, euchrozem	• compaction • low water-holding capacity • low nutrient retention • acidity • high phosphorus fixation.
Kandosol	Red and yellow earths	• hard-setting/surface sealing • low water-holding capacity • low nutrient retention • acidity.
Kurosol	Red podzolic, grey-brown podzolic, soloth	• excessive/prolonged wetness • compaction • acidity.
Podosol	Podzol	• excessive/prolonged wetness • low water-holding capacity • low nutrient retention • acidity • extremely low phosphorus retention.
Dermosol	Red podzolic	• hard-setting/surface sealing • acidity.
Tenosol	Earthy sand	• low water-holding capacity • low nutrient retention • extremely low phosphorus retention.
Hydrosol	Grey podzolic	• excessive/prolonged wetness • compaction • acidity.
Organosol	Peat	• excessive/prolonged wetness • acidity.