Chapter 1 Land and soil management

Objective – to minimise soil degradation and loss from the property

Farm businesses should always implement management practices that maintain or improve soil condition.

To achieve this objective, horticulturalists need to consider issues such as:

- 1a Soil erosion caused by water;
- 1b Soil erosion caused by wind;
- 1c Soil structure;
- 1d Salinity;
- 1e Soil acidity and alkalinity; and
- 1f Sodicity.

The priorities for soil management vary depending on soil type, topography of the land, surrounding environment, previous land use and climate. The priority given to the soil management practices discussed in this section will vary from farm to farm and between production regions.

References to help determine your soil management priorities:

- For access to key sets of Australian soil information visit – Australian Soil Resource Information System www.asris.csiro.au
- For information on soil and land resources visit – Australian Collaborative Land Evaluation System www.clw.csiro.au/aclep/
- For climate information visit – Bureau of Meteorology www.bom.gov.au

Further references and resources can be located at the end of this chapter.

Objective – to minimise the potential for water to erode soil on the property

Soil erosion caused by water happens when water contacts exposed and/or unstable soils (soils with poor structure). Erosion can happen as a consequence of heavy rain or excess irrigation, or when drainage water from paddocks, roadways and areas around sheds and buildings moves across the land. In tree crops, shaded soil under the tree canopy can be eroded during intense rainfall events because there is little groundcover. In some regions, low-lying ground can be subjected to regular flooding. Waterways can also be subject to erosion, with negative impacts on downstream water quality (see Topic 2b – Water quality).

The likelihood of soil erosion by water and the control measures needed depend on vegetation cover, soil type and texture, soil stability (structure) and the type of horticultural activity.

Evidence of soil erosion caused by water may include:

- Rills or gullies;
- Turbid water in farm dams or leaving the property, and soil build up on fencelines or at the bottom of slopes.

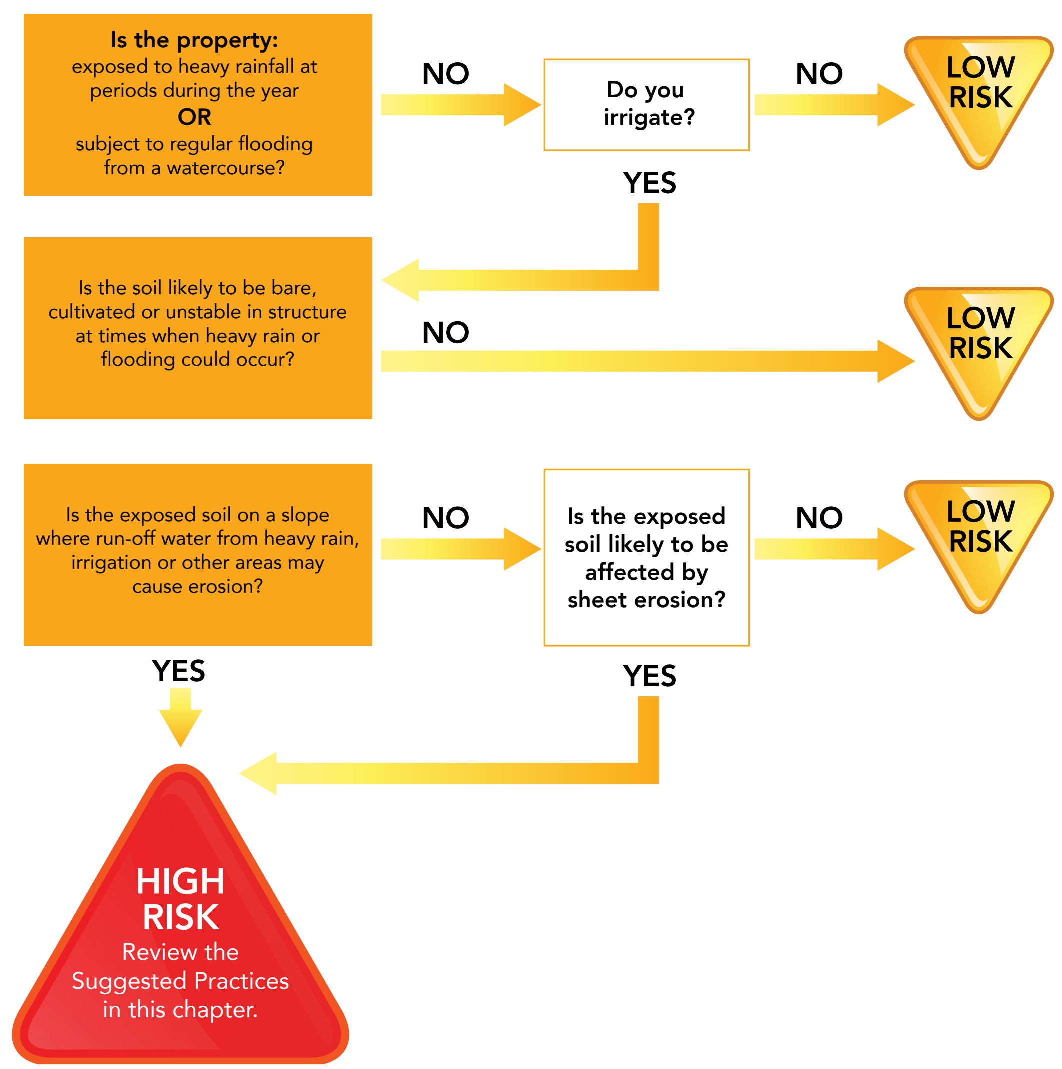
To manage soil erosion caused by water, you need to identify sites on your property that are at risk, assess the level of risk and, if necessary, put in place control measures. There are a number of key strategies you can employ, including maintaining soil cover, controlling run-off water, improving soil structure and establishing sediment traps.

Further references and resources can be located at the end of this chapter.

Horticulture Australia

1a Soil erosion caused by water

Risk assessment



LOW RISK – You probably don't have a significant problem in this area. You may like to read the Suggested Practices to check your understanding of the issue.

HIGH RISK – You need to take some action. Read the Suggested Practices for that chapter.

Further references and resources can be located at the end of this chapter.

Horticulture Australia

Review checklist

To go straight to the worksheet for this chapter click here.

Relevant legislation and regulation

Legal requirements are subject to change. Regularly check with Federal, State and Local authorities for updated requirements. See here for links.

Suggested practices

Maintaining soil cover

Soil cover protects the soil from erosion by reducing the displacement (movement) of soil particles caused by rain or overhead irrigation droplets, and by slowing the movement of water across the site.

Types of soil cover include:

- Grassed waterways on drainage and sump areas;
- Inter-row groundcovers in orchards, vineyards and ground crops;
- Green manure/cover crops planted between (in space and time) commercial crops;
- Organic mulches, plastic, slashed inter-row material or crop residues spread over the exposed soil; and
- Products such as PAM (polyacrylamide), PVA (polyvinyl acetate) or molasses that bind soil together.

Managing soil cover

Control measures may include:

- Avoiding soil tillage (where possible) during times of the year when heavy rainfall events are likely, especially in tropical areas;
- Avoiding cultivation of light sandy soils subject to regular flooding;
- Using minimum tillage systems that minimise mechanical disturbance of the soil;
- Using permanent bed systems that improve soil structure and soil stability through maintaining or improving soil organic matter levels;
- Planting green manure or cover crops during the period between commercial crops to cover the soil and increase soil organic matter levels for improved soil structure, stability and fertility; undersowing or planting in the inter-row area at the same time as commercial crops;
- Leaving crop residues (where possible) on site until the site is next required;
- Minimising the time soil is left exposed between harvest and planting of the next crop; and
- Establishing permanent grass or vegetation cover on areas that are not cropped.

Further references and resources can be located at the end of this chapter.

Horticulture Australia

1a Soil erosion caused by water

Controlling run-off water

Controlling the direction of flow, volume and speed of run-off water on the site can minimise soil erosion. Long, gentle slopes are just as prone as short, steep slopes. Good planning and drainage design before planting can prevent problems later.

Control measures may include:

- Utilising the natural contour lines (natural topography) of the property, where possible; cultivating rows across the slope of the land rather than up and down the slope, when practical and safe to do so;
- Establishing cut-off drains or banks (also known as diversion banks/drains) to divert and prevent water from other areas coming on to the site;
- Establishing contour drains/moulds/bunds to collect and slow run-off from site; establishing diversion drains to control excess water flow on and around exposed sites; establishing v-drains in inter-row areas to divert water to grassed waterways and away from exposed areas;
- Establishing grassed irrigator runs and waterways to control run-off water collected by contour drains, diversion banks and roads;
- Interrupting long slopes with a cut-off drain or grassed/mulched rip lines;
- Establishing in-paddock structures such as sediment basins and sumps along drainage pathways;
- Installing and maintaining barriers such as sediment netting, filter strips or secured straw bales in water drainage channels;
- Mulching rip lines;
- Positioning access roads on ridge lines or on the contour. If possible, on relatively flat ground, construct access roads so they are higher than surrounding cultivated land;
- Ensuring all measures work with natural watercourses within and adjacent to the area being managed; and
- Considering the likelihood of excess rain or potential flooding events and managing or avoiding associated run-off when establishing new horticultural sites, particularly where major groundworks are concerned.

Improving soil structure

Organic matter is an essential component of a healthy soil because it increases the soil's nutrient and water holding capacity, improves the soil structure and provides a food source for soil organisms. Adding organic matter increases soil resistance to erosion.

Organic matter can be increased with practices such as:

- Applying compost or manures or;
- Leaving organic matter on the soil surface as mulch;
- Growing fallow crops between crop rotations or interrows;
- Applying organic by-products, such as greenwaste;
- Reducing cultivation;
- Avoiding high rates of nitrogen fertilizer; and
- Encouraging earthworm activity, which incorporates organic material deeper into the soil.

Further references and resources can be located at the end of this chapter.

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Establishing sediment traps

Sediment traps or ponds (also called silt traps or ponds/sediment retention basins) aim to hold run-off water long enough to allow soil particles to settle. They can be small ponds or weirs, or large dams that capture and re-use run-off water. Artificially constructed wetland systems may be established to capture sediment and remove the nutrient in run-off waters.

Filter strips are areas of vegetation that catch sediment and nutrients in water that are flowing to a watercourse. Generally they run alongside watercourses or across a depression. They are not effective if the water is deep enough to flatten the vegetation and is not slowed down. Slopes of more than 10% are unsuitable for filter strips as the water moves across the ground too rapidly for sediment to be caught by vegetation.

Monitoring and recording

Erosion caused by water can be monitored by:

- Visual inspection;
- Assessing water turbidity; and
- Assessing soil erosion losses.

Visual inspection

Immediately after a rainfall event, look at how run-off is flowing across the farm. Is erosion occurring? How dirty (turbid) is the water?

Inspect the property for signs of scouring (drainage lines, channels) or for silt accumulation around plants or other obstructions.

Photographs can be useful to record problem areas (e.g. drainage lines, rills, gullies, prone slopes) before and after control measures are implemented.

Assessing water turbidity

Turbidity is a measure of water clarity or 'murkiness'. Soil particles in water increase the turbidity.

In addition to a visual inspection of water leaving the property or returning to farm dams, a turbidity tube can be made and used to gauge basic changes in water turbidity. Turbidity meters are also available for more precise assessments.

Turbidity tube

A turbidity tube is a length of clear pipe with a clear bottom. The general idea is to determine the depth at which you can no longer see through the water. This is an indicator of turbidity.

Further references and resources can be located at the end of this chapter.

Horticulture Australia

1a Soil erosion caused by water

To measure turbidity:

- Collect a water sample in a clean bucket without disturbing sediment from the bottom of the dam or stream;
- Assess the water sample as soon as possible after collecting;
- Place the turbidity tube on a white piece of paper or card that has a cross or other mark on it;
- Shake water sample and pour into the tube until the cross or mark on the card can no longer be seen when viewed from the top (i.e. looking down through the water);
- Record the height of the water in the tube;
- The lower the height of water, the greater the turbidity;
- This may indicate there is a large amount of sediment in your farm run-off and action may be required to stabilise soils or reduce run-off.

The tube and card need to be stored to prevent the tube from getting scratched and the mark on the card from fading.

Assessing soil erosion losses

Place a piece of 100 x 50 mm timber, or similar, on the ground and, over time, look at the amount of soil that accumulates behind it.

Pegs with depth markings can be placed in silt traps to measure the amount of accumulated silt. Paddock records can also be useful to demonstrate groundcover/cropping history during times when high rainfall is usually expected.

References and resources

For access to relevant references and further resources click here.

Further references and resources can be located at the end of this chapter.

Horticulture Australia

Objective – to minimise the potential for wind to erode soil on the property

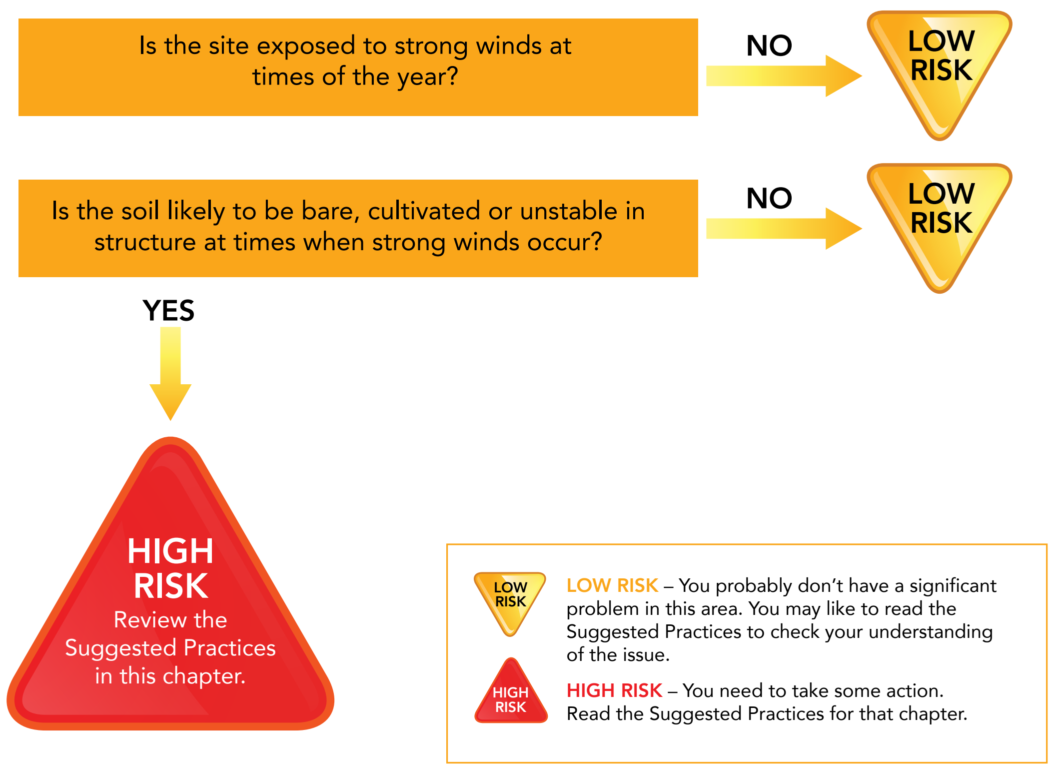
Soil erosion caused by wind happens when wind contacts exposed (uncovered) and unstable soils (soils with weak structure) at speeds that can physically move soil particles. Minimising the area of exposed soil and reducing the wind speed are the keys to minimising soil erosion. Once wind erosion starts, it is hard to control and repair. Prevention is best.

Evidence of soil erosion caused by wind may include:

- Dust;
- Rills or gullies on light or sandy soils;
- Exposed subsoil and rocks (rocks appear to be 'rising to the top' of the paddock);
- Exposed roots of trees and shrubs (long-lived vegetation); and
- Soil and/or organic matter (such as twigs and grass) building up against the side of fences or hedges.

To manage soil erosion caused by wind, identify the sites on your property that are at risk, assess the level of risk and put control measures in place if needed. There are a number of key strategies you can employ, including maintaining soil cover, controlling wind speed and improving soil structure.

Risk assessment



Further references and resources can be located at the end of this chapter.

Horticulture Australia

Review checklist

To go straight to the worksheet for this chapter click here.

Relevant legislation and regulation

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Suggested practices

Maintaining soil cover

Soil cover protects the soil from erosion by minimising soil exposure to the physical force of the wind. Types of soil covers include:

- Grass or native vegetation on areas that are not cultivated;
- Inter-row groundcovers in orchards, vineyards and ground crops;
- Under-tree groundcovers and mulchers in orchards;
- Green manure/cover crops planted between commercial crops; and
- Organic mulches, plastic, slashed inter-row material or crop residues spread over the exposed soil.

Managing soil cover

Control measures may include:

- Avoiding soil tillage (where possible) during times of the year when high winds are likely; planting green manure or cover crops during the period between commercial crops to cover the soil and increase soil organic matter levels for improved soil structure, stability and fertility; undersowing or planting between rows at the same time as commercial crops;
- Using cover crops for germinating seedlings;
- Leaving crop residues (where possible) on site until the site is next required;
- Minimising the time soil is left exposed between harvest and planting of the next crop; and
- Establishing permanent grass or vegetation cover on areas that are not cropped.

Moderating wind speed

Controlling wind speed on the site can minimise soil erosion.

Constructing or planting a shelterbelt/windbreak will slow the velocity of wind across a site (shelterbelts/windbreaks should be designed to allow 30-50% of the wind to pass through). The protective effects from a shelterbelt/windbreak reduce with distance away from it (protection extends no more than 20 times the height of the shelterbelt/windbreak).

Vegetation shelterbelts/windbreaks also provide wildlife habitat, assist in minimising spray drift and reduce the visual and noise impacts of site activity and can have an influence in high water tables.

Further references and resources can be located at the end of this chapter.

Horticulture Australia

Improving soil structure

The wind will not pick up soil particles greater than about 0.5 mm. To control wind erosion keep soil aggregates greater than this size. This is relatively easy for soil heavier in texture than loamy sands. However with sands, especially water repellent sands, this is not possible and adequate ground covers are required.

Plenty of organic matter in the soil will strengthen soil structure and make it less prone to wind erosion.

Strategies to improve soil structure may include:

- Using minimum-tillage systems that minimise mechanical disturbance of the soil and improve soil;
- Structure and soil stability by maintaining higher soil organic matter levels;
- Using permanent bed systems that improve soil structure and soil stability by maintaining soil organic matter levels; and
- Incorporating organic matter into the soil to build up soil organic matter levels.

Other management strategies

Irrigation can be applied immediately prior to, or during, wind events to increase the cohesion between soil particles, thereby reducing erosion.

Cultivating so as to leave a rough, raised and very uneven surface can also reduce erosion.

Planning when setting up new sites, particularly where major ground works are concerned, should include consideration of the likelihood of wind extremes and managing or avoiding the periods when they are likely to occur. Using remnant vegetation or shelter belts within or adjacent to the new site can minimise soil erosion.

Monitoring and recording

Erosion caused by wind can be monitored by:

- Visual inspection, or;
- Assessing soil erosion losses.

Visual inspection

Wind erosion can be visually assessed – have a look at an exposed site with light soils on a windy day! However, the effects of erosion are often subtle and require an extended period of time to become obvious. In this case it may not be possible to clearly distinguish between the causes of erosion, but an understanding of your own property, soil type and weather patterns should help you determine the most significant influences so that appropriate control measures can be instigated.

Further references and resources can be located at the end of this chapter.

Horticulture Australia

1b Soil erosion caused by wind

Visual signs of erosion include:

- Rills or gullies;
- Exposed subsoil;
- Exposed rocks (rocks appear to be ‘rising to the top’ of the paddock);
- Exposed roots;
- Piles of organic matter such as twigs and grass forming ‘debris dams’; and soil and organic matter caught in or building up against sides of fences.

Use of satellite imagery (to assist in mapping eroded areas), GPS (to pinpoint exact locations for measurement) and photography are good ways to more accurately record changes over time.

Assessing soil erosion losses

Measuring wind erosion can be difficult because of its patchy nature.

Natural benchmarks

For longer-term monitoring in some situations, use natural benchmarks such as big rocks or trees – mark the soil height now, and then check the soil height over time to see if it changes.

Be careful when selecting a natural benchmark (for instance rocks may be moved by livestock or cultivation).

Alternatively, choose a natural benchmark that has a ‘soil mark’ and measure the distance between this soil mark and the current soil level to gauge the erosion that has taken place up until now.

Erosion pin

An erosion pin is a metal bar driven into the ground with a portion protruding for a known height (e.g. 5 cm). Monitor the distance between the top of the pin and the soil surface over time.

Erosion pipe

An erosion pipe is like an erosion pin except that it contains soil that will not be affected by erosion. Monitor the distance between the soil height in the pipe and that surrounding it.

Be careful where you site the pin or pipe so that results are not affected by ploughing or other soil cultivation activities.

DustTrak technology

DustTrak devices use laser technology to measure Atmospheric Particulate Concentration: the concentration of dust particles in the air. The data obtained with this device is used to compare erosion events within and between years.

References and resources

For access to relevant references and further resources click here.

Further references and resources can be located at the end of this chapter.

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Objective – soil structure is suitable for root growth, water infiltration, aeration and drainage needs of the crop

Deep well-structured soils grow the best crops. A well-structured soil has pores, channels and spaces between aggregates (clumps). Water can drain quickly, roots go through the soil easily and there is no hard crust on drying.

Degraded soil has a high proportion of small particles with few water stable aggregates. The reduction of pore size and continuity results in massive blocks that restrict root growth and plant productivity. Compacted soil requires more cultivation to prepare a seedbed and this additional cultivation causes further deterioration in soil structure.

Crop yields increase dramatically when soil improves. In Australian horticulture, crops grown on the poor soil types average 10t/ha and those grown on the best soils can achieve yields of 50t/ha. The cause of low productivity in irrigated agriculture lies in coalescence, a soil hardening process, and consequent low root activity, which also restricts what happens above the ground. The best soils overseas remain loose, soft and porous even after centuries of growing crops.

To maintain and improve good soil structure you should establish an appropriate crop rotation, increase organic matter in the soil and follow good tillage practices.

Risk assessment

Further references and resources can be located at the end of this chapter.

Horticulture Australia

Review checklist

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Suggested practices

Cultivation method

Most tillage for fruit and vegetable crops occurs prior to planting to enable suitable contact between the soil and the planted material. This primary tillage is an important part of initial land preparation and cannot really be avoided. Secondary tillage operations should be minimised where possible.

Machinery can cause compaction, so the following points should be considered:

- Minimise traffic in the paddock;
- Keep trucks to headlands;
- Use low weight spray rigs;
- Consider the effects of axle load, tyre width and inflation pressure, aiming to maximise weight distribution; and
- Make contractors aware of compaction issues.

Consider using a minimum-tillage approach such as tramlining or semi-permanent beds.

When choosing cultivation, consider the crop stage, soil moisture and soil condition. Rotary hoes are generally used to pulverise the soil for primary tillage. Along with disc cultivators, they should be used as sparingly as possible as their use leads to reduced soil organic carbon and soil compaction. Tyned and non-inverting implements are kinder on the soil structure.

Blunt tools can also add to compaction. Use sharp and correctly adjusted tools to till the soil. Use implements that mainly apply an upward force to the soil.

Minimise the number of soil workings.

Avoid overworking with powered implements. Consider using semi-permanent beds.

Cultivation timing

The soil moisture content during tillage has an important effect on soil structure. Where the water content is too great, the soil acts like plasticine, smearing and compacting with tillage and traffic. Don't go onto paddocks with machinery when the soil is wet. Similarly, soils can be too dry to work, requiring excessive amounts of energy to produce a seed bed.

Further references and resources can be located at the end of this chapter.

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Cultivation timing cont.

Ideal moisture levels depend on soil type and texture. You can check by working some soil from the plough layer in your hands. If the soil is too wet it will work like plasticine, if it is too dry it will be hard to work and tend to shatter to dust.

Remedial action

If a hard pan or compaction layer is present, then additional cultivation may be needed depending on whether the cause is cultural or due to sodicity (see Topic 1f – Sodicity). If the condition is not due to sodicity, cross-ripping under the correct soil moisture levels will help to shatter the pan, loosening and breaking clods that will break down further when exposed to the weather.

Deep ripping needs to be done early enough to allow weathering, or else try to leave your deepest working to last in the soil preparation sequence, because after ripping the soil is highly susceptible to recompaction.

The benefits of deep ripping can be short term (~1 year) unless actively growing roots enter the fracture lines.

A sodic soil has an exchangeable sodium percentage (ESP) of more than 6. This means that sodium comprises more than 6% of the total exchangeable cations in the soil.

Soils with shallow sodic subsoils should not be ripped. This can bring sodic soils to the surface and create problems with surface crusting (see Topic 1f – Sodicity).

Increasing organic matter

The terms soil carbon, soil organic carbon and soil organic matter are often used interchangeably, but have distinct meanings. It is important to understand the differences. See glossary. Soil carbon is dealt with below in organic amendments.

Soil organic matter refers to the matter found in the soil associated with living things, such as living organisms, fresh residues, well rotted organic matter, silica-occluded plant carbon (phytoliths), charcoal, nitrogen, sulphur, phosphorus and compounds beneficial to horticultural production and soil health in general, such as plant promotant chemicals.

Increasing organic matter through use of crop rotations, such as rye grass, and green manure crops promotes good soil structure. Stubbles and crop residues can also be returned to the soil.

Ryegrass in orchards

In south eastern Australia it is important that fruit growers encourage winter grass in their orchards. Grass /grassroots:

- Adds organic matter to the soil;
- Opens the surface of the soil to let irrigation water in;
- Keep the soil loose, soft and porous;
- Penetrate into the subsoil, producing pores and increasing stability;
- Helps dry the soil in wet winters; and
- Forms a mulch in summer to reduce high soil temperatures.

Further references and resources can be located at the end of this chapter.

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1c Soil structure

Grass is much better at doing these things than clovers or weeds. Rye grass is the most effective of all the grasses. Ryegrass is suited to the climate of this area and in fact is a weed here. It will self seed each year if managed properly and will grow well. It has been demonstrated that rye grass develops a rhizosheath of soil particles adhering to each rye grass root. The soil within the rhizosheath builds up organic matter, arising from root exudates, root hairs and microbial organisms, all in very large numbers. These eventually become organic matter. An important property of the rhizosheath is that organic matter within it is protected from oxidation. Under rye grass, organic matter quickly builds to 8%, the level required to prevent soil coalescence. Fruitgrowers should note that full potential for increasing yield and quality relies on tree management as well as soil management. Tree management on soil that has become more responsive after treatment, may require changes to such practices as pruning and reduction of the leaf to fruit ratio.

Building soil organic carbon

The organic carbon content of soil is defined by the balance between inputs of carbonrich material (plant growth and additional material) and losses through decomposition, erosion and product removal. Where inputs are greater than losses, soil organic carbon increases.

Table 1 below summarises management practices that increase soil organic carbon by providing carbon inputs or decreasing carbon losses from the soil. The first seven management activities listed are appropriate and feasible for horticultural systems.

Table 1: Management practices to increase soil organic carbon. Source: Cox et al (2012).

Activity	Provides C inputs	Reduces C losses
1. Increase plant (biomass) production by applying sufficient nutrient and water	✔	
2. Retain stubble/crop residue	✔	✔
3. Reduce fallow periods	✔	✔
4. Include opportunity crop/rotations/ manure crops green	✔	✔
5. Apply high carbon amendments such as compost, biochar, some manures	✔	
6. Reduce erosion		✔
7. Reduce cultivation		✔
8. Introduce farm forestry	✔	
9. Improve pasture management	✔	✔

Further references and resources can be located at the end of this chapter.

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Carbon-rich soil amendments such as mulch, compost and biochar offer horticulture the benefit of improved soil condition and potential for carbon trading for the most stable forms. See Energy & Greenhouse Gas Management Chapter.

Biochar application to soil, for example, has been shown to:

- Alter chemical functionality such as soil Cation Exchange Capacity (CEC), pH and nutrient availability;
- Improve the physical properties of the soil, particularly aggregation, water retention, water use efficiency, and reduce tensile strength in hard setting soils;
- Modify the biological functionality by providing a habitat for microorganisms due to its highly porous nature or by altering substrate availability and enzyme activities on or around biochar particles;
- Suppress some soil-borne diseases; and
- Increase yields (when used in conjunction with fertilisers).

Current methods of biochar incorporation use surface application, then mechanical incorporation into the topsoil, a method suitable for most annual and semi-permanent orchard crops. Alternative incorporation methods need to be developed to introduce biochar into permanent perennial horticultural crops without damaging existing root systems. Possible methods include coring using modified turf aerators, and combining biochar with a mulch material for surface application.

However, it is difficult to generalise the impact of biochar on soil properties due to this range of biochar production variables and biochar's complex interactions with soil organisms, chemical elements and physical structure. Considerable uncertainty still surrounds the use of biochar in farming systems given the range of production processes, the types of biochar, and the variety of soil types in horticulture.

Adding carbon-rich amendments to soils is becoming increasingly common in horticulture, but is only really effective when the amendments are selected for a purpose. Growers need to be clear whether they are addressing a specific soil constraint (e.g. lack of nutrients), or want to build soil organic carbon. Organic amendments unsuited to a particular soil, site or production type may have detrimental effects on the soil or environment.

For more information on biochar see HAL/NSW DPI publication on biochar in horticulture (2012) http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0008/447857/DPI-BioChar-in-Horticulture.pdf.

Crop rotation

Using rotations and green manure crops will provide short-term soil structure benefits through better soil aggregation. This helps optimise the soil's water-holding capacity, ability to hold nutrients, workability and water infiltration.

Rotating crops also assists soil structure, with crops such as grasses and legumes increasing the spaces or pores through the soil. Deep-rooted crops can also recycle excess soluble nutrients like nitrate and sulphur from deeper in the soil and these crops add organic matter as the deep roots eventually break down. Roots help break up the soil and create pores to assist with movement of water through the soil.

Further references and resources can be located at the end of this chapter.

Monitoring and recording

Soil compaction can be assessed by determining how difficult it is to dig.
The assessment should bear in mind any short-term tillage and effects of soil moisture.

Spade test

The following scale can be used:

Hand	Soil that can be dug easily by hand has a poor structure or is very sandy. Maintain and improve structure by increasing organic matter. Use minimum tillage for all crops.
Spade	Soil that can be dug easily using a spade has good or very good structure.
Standing on spade	If you have to stand on the spade, the soil may be compacted or have high clay content. Aim to break up compacted areas and improved drainage.
Jackhammer	This soil is highly compacted or has a very high clay content. Good management is required to improve the drainage. Consider long-term or permanent crops/pasture.

Record the result of spade test.

Penetrometer (screwdriver) test

A simple test of compaction is to see how far you can push a screwdriver into the soil using reasonable hand pressure. It is a way of simulating the difficulty that roots have pushing through the soil. Try it after decent rainfall or irrigation.

Visual assessment

Soil compaction affects the ability of plant roots to penetrate the soil and root systems are often stunted. Dig up some plants and assess their root systems and also assess the overall vigour of the plants. Stunted or sharply bent roots mean small, feeble, low-yielding plants that are prone to drought. It can be useful to compare roots from different areas, such as under fencelines where compaction may be less.

Take a closer look at the clods and aggregates. Many large clods mean the soil will need to be kept wetter to allow roots to penetrate. Sharp angular aggregates with smooth faces indicate poor structure. Well-structured soils have a range of aggregate sizes (2 -10 mm), with irregular or rounded shapes and porous faces.

Look for areas where water ponds. Ponding is a way of measuring compaction and soil structure. Water lying around in the paddock means that there are few soil pores in and below the plough level. Soil compaction is one cause of this.

Further references and resources can be located at the end of this chapter.

Soil test

Organic matter content can be included on regular soil tests. Natural levels of organic matter in the soil depend on factors such as climate, site drainage and soil texture. A heavy soil will generally have higher levels of organic matter than light, sandy soils.

Measured as organic carbon content, an approximate guide is as follows:

- Very low (below 1%)
- Low (1 - 2%)
- Satisfactory (2 - 4%)
- High (above 4%)

References and resources

For access to relevant references and further resources click here.

Further references and resources can be located at the end of this chapter.

Objectives

- **horticultural activities are managed to ensure soil or water salinity problems are not created or exacerbated**
- **horticultural production does not contribute to local, catchment or regional salinity problems**

Salinity refers to the presence of soluble salts in soil or water. For the irrigator, there are 'good' salts and 'bad' salts. The good salts are the nutrients like nitrate, potassium and calcium because plants need to take up large quantities for growth. Bad salts include sodium and chloride; they are not required for plant growth and in some circumstances can build up to high levels in the soil and harm plant growth.

These salts may be naturally occurring, coming from the parent material from which the soil was formed. Other sources of salt can be rainfall, overuse of mineral fertilisers or poultry manure, or the use of saline irrigation water. Saline irrigation water may result from salts percolating out of naturally salty soil into waterways or groundwater, or from seawater intrusion into coastal groundwater. Seawater intrusion is usually a result of excessive groundwater drawdown from irrigation, or lack of groundwater recharge due to drought.

Primary salinity is naturally occurring, while secondary salinity is the result of human activity. In the context of these guidelines, salinity should be taken to mean secondary salinity.

Salinity can dramatically reduce agricultural productivity, as high salt levels can limit crop growth and even kill plants. Salinity makes it more difficult for plants to extract water from the soil. Salinity also has impacts beyond agriculture as it can affect infrastructure such as roads and buildings. Salinity reduces the diversity of native plants and animals and is linked to environmental degradation such as soil erosion, deteriorating water quality in streams, rivers and groundwater and loss of riparian vegetation.

The development and progress of salinity tends to be highly complex. Water table levels and potential salinity problems and discharge points may vary considerably. This will depend on the site conditions, groundwater processes and land management practices.

Rising water tables are one of the main causes of salinity. Crop and annual pasture plants use less water than perennial native vegetation, therefore allowing more water to travel down past the root zone and into the groundwater beneath the surface. This extra water makes the water table rise. As the water rises it dissolves the salts that are naturally in the soil, so the rising water becomes salty, contaminating the land and surface water. Rising water tables can also bring salt into the root zone, which may not be leached out of the soils by rainfall or irrigation. Evaporation from water tables within two metres of the soil surface also causes salt accumulation in the root zone and can dramatically affect plant productivity.

Undulating landscapes tend to have specific groundwater discharge points, resulting in discrete areas of salinity that can vary in severity and area. In contrast, rising water tables in flat landscapes tend to affect larger areas and salinity can be a more regional issue.

More recent studies indicate that the dryland salinity occurrences are closely related to naturally occurring salinity. With the rising water tables after the higher rainfall, salt is again being expressed on the surface in high-risk salinity catchments. Consequently, the expression of dryland salinity in the landscape is cyclical – related to rainfall.

Further references and resources can be located at the end of this chapter.

Salinity cont.

Salt movement and salinity outbreaks in landscapes dominated by sandy soils tend to be rapid (<10 years) and severe compared to landscapes with many metres of sub-surface clays. Salt movement in clay landscapes is buffered by the clay and may take decades, or even centuries, to flow through the system.

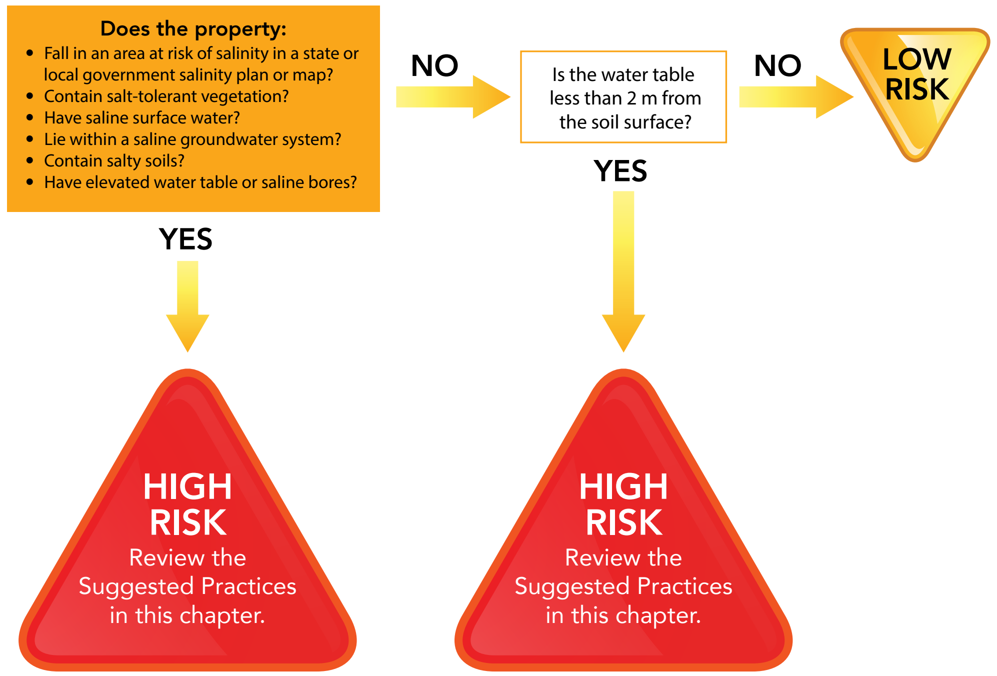
To manage salinity it is important to understand whether it is caused by rising groundwater, irrigating with saline water or saline soils. Sites on a property that are at risk need to be identified, the level of risk assessed and control measures put in place if needed.

There are a number of key strategies in relation to managing salinity including:

- Careful site selection;
- Understanding the source/cause of salinity;
- Monitoring salt levels in irrigation water and adjusting irrigation strategies where
- necessary; and
- Minimising rising water tables through appropriate drainage/use of vegetation.

Risk assessment

GROUNDWATER AND SOIL SALINITY

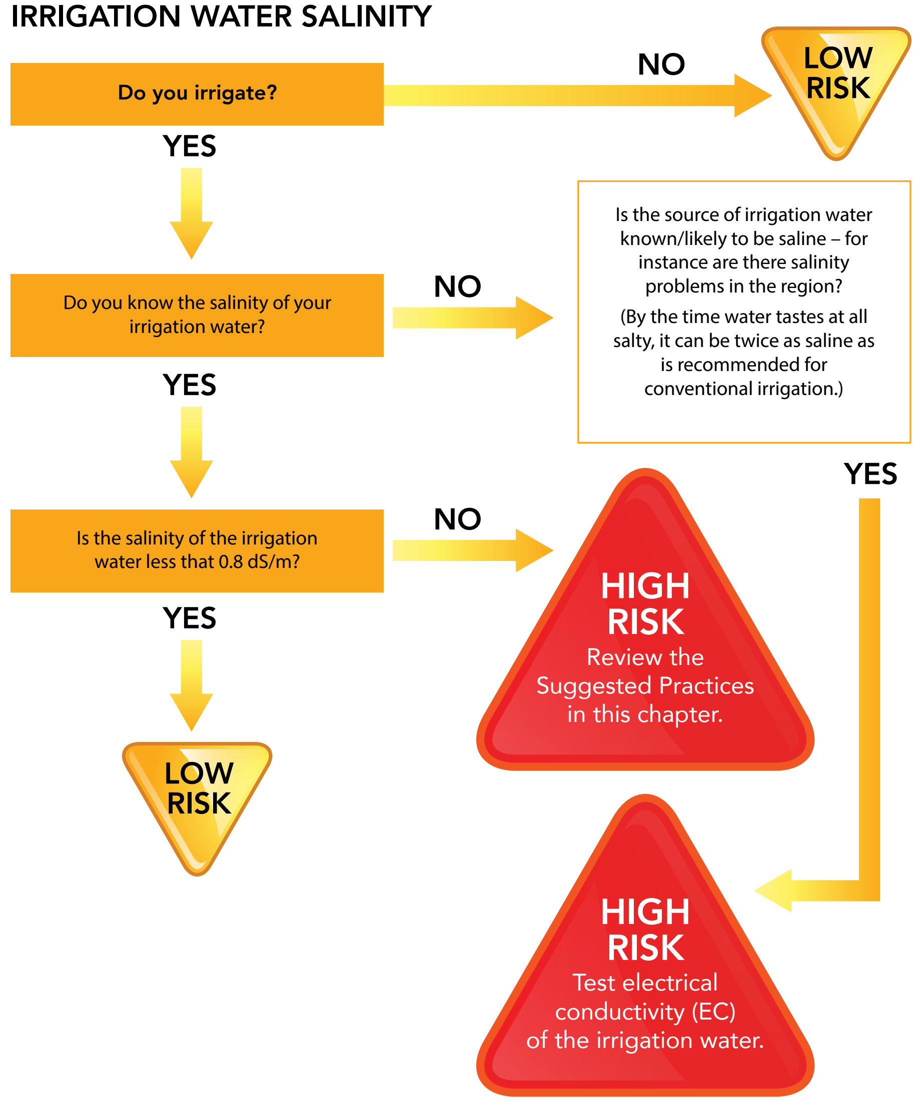


Further references and resources can be located at the end of this chapter.

Horticulture Australia

1d Salinity

IRRIGATION WATER SALINITY



LOW RISK – You probably don't have a significant problem in this area. You may like to read the Suggested Practices to check your understanding of the issue.

HIGH RISK – You need to take some action. Read the Suggested Practices for that chapter.

Further references and resources can be located at the end of this chapter.

Horticulture Australia

Review checklist

To go straight to the worksheet for this chapter click here.

Relevant legislation and regulation

Legal requirements are subject to change. Regularly check with Federal, State and Local authorities for updated requirements. See here for links.

Suggested practices

Always avoid salinity problems in preference to attempting rehabilitation. Key considerations in avoiding salinity include choosing the right site and then employing good soil/water management strategies, combined with diligent monitoring.

Site selection

When choosing sites, consider the likelihood of salinity problems. Undulating landscapes tend to have specific groundwater discharge points, resulting in discrete areas of salinity that can vary in severity and area. In contrast, rising water tables in flat landscapes tend to affect larger areas and salinity can be a more regional issue.

Check for visual indicators of salinity problems, such as:

- Salt-tolerant vegetation; and
- Bare soil or salt scalds.

A soil survey or Electro Magnetic (EM) survey can help identify, assess and help manage saline soils and water.

Understanding the source

If salinity problems exist or are suspected, it is important to understand the source of the problem. Salinity can be due to saline irrigation water, groundwater salinity or soil salinity.

Irrigation water salinity

Salts dissolved in water can be easily measured by testing for electrical conductivity (EC). A small, hand- held meter is invaluable for checking the salinity of irrigation water and monitoring changes through the season. If irrigation water exceeds an EC of 0.8 dS/m (this is equivalent to 500 ppm or 500 kg of salt in 1 megalitre of water) a full chemical analysis, interpreted by a technical expert, should be undertaken and professional irrigation management advice sought.

If salinity is present, depending on the actual EC level and the soil type, consider implementing the following:

- Irrigate at night to avoid high evaporation rates which cause salts to concentrate;
- Avoid leaf contact (e.g. Use drip and not overhead sprinkler);
- Maintain low soil moisture deficit (making it easier to flush salts from the root zone);

A megalitre of irrigation water that has a salinity level of 1 dS/m will deposit 640 kg of salt.

dS/m stands for deci-Siemens per metre and is a measure of electrical conductivity, and therefore a measure of salinity

Further references and resources can be located at the end of this chapter.

Horticulture Australia

1d Salinity

- Ensure good subsurface drainage;
- Shandy/dilute saline water with less salty supplies; and/or
- Consider growing salt-tolerant crops.

These practices will usually only be beneficial for a short time. It is important to consult a specialist for more site-specific assistance.

Some salinity benchmarks (in dS/m)

Distilled water = 0
Absolute limit for people = 2.5
Desirable limit for people = 0.83
Limit for mixing herbicides = 4.7
Tastes salty (depending on the ions present) = 1.7
Seawater = 55+

Table 1.2: Tolerance of plants to salinity in irrigation water. Source: Australian and New Zealand Guidelines for Fresh and Marine Water Quality – Volume 1: Paper 4 - Primary Industries (2000)

Crop	EC **(dS/m) threshold for crops growing in		
	sand	loam	clay
Apple	2.0	1.2	1.7
Avocado	2.3	1.3	0.8
Beans	1.9	1.0	0.6
Beet	6.5	3.7	2.0
Broccolli	4.9	2.8	1.6
Carrot	2.2	1.2	0.7
Cucumber	4.2	2.4	1.4
Eggplant	3.2	1.8	1.0
Grape	3.3	1.9	1.0
Grapefruit	3.0	1.7	1.0
Lettuce	2.7	1.5	0.9
Olive	5.0	2.9	1.7
Onion	2.3	1.3	0.8
Orange	2.9	1.7	1.0
Pea	3.2	1.8	1.0
Peach	4.7	2.7	1.6
Pepper	2.8	1.6	0.9
Potato	3.2	1.8	1.0
Rockmelon	4.6	2.6	1.5
Tomato	3.5	2.0	1.2
Zucchini	7.3	4.2	2.4

** EC is a measure of the salinity of the irrigation water. The threshold is the salinity level above which yield decline is likely to occur. The threshold is lower on soils with higher clay content because plants have to work harder to extract water from these soils to start with. Saline irrigation water makes it harder again.

Guidance is available on crop tolerance for water salinity, however this is highly dependent on soil types and the degree of associated waterlogging. Expert advice should be sought.

Further references and resources can be located at the end of this chapter.

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Groundwater salinity

To minimise the chances of salinity problems, the water table should be kept two metres or more below the soil surface. In some areas this is an issue that requires regional management, such as establishing spear points, tile drains or groundwater pumps to increase the depth of the water table.

The water table should also be monitored over time to check if it is stable or rising. If the water table is high (within 2 m) then artificial subsurface drainage may be needed. If water tables are not yet high but are rising, subsurface drainage may be needed in the future. Also work on improving irrigation efficiency.

Soil salinity

Salinity levels in the soil are measured in a 1:5 soil solution (1 part soil to 5 parts water). These are called EC 1:5 readings. A reading of <0.2 dS/m is usually safe for horticultural crops. The heavier the soil texture (e.g. clay) the more sensitive the crop is. Thus EC 1:5 readings need to be adjusted for soil texture to reflect how happy the plant actually feels in the soil. The adjusted measurements are called 'saturation extract' or EC. For major horticultural projects, it is recommended that EC values are measured directly rather than the approximate conversions. A few laboratories in Australia provide this service.

In some cases, applying a 'leaching fraction' when irrigating may be necessary to flush salts through the soil profile. However for leaching to be effective, good drainage is needed and a plan for safe disposal of the saline drainage water must also be in place. Consider growing or changing to salt tolerant crops or varieties. Further advice should be sought from a specialist.

Sometimes high soil salinity can be found when the water table is low and the salinity of the irrigation water is also low. In these instances check the leaching efficiency of the irrigation system. Also check your fertiliser program – certain fertilisers such as muriate of potash can have a strong influence on soil salinity.

High salinity can be found on the edge of wetted areas or in other dry spots. Also check for poor drainage of soil and seek expert advice. Careful management of the soil chemistry is needed when saline, sodic soils are drained.

Soil salinity tolerance of horticultural crops:

Table 1.3 is a list of thresholds expressed as the electrical conductivity of soil water (ECsw) for maximum production of major horticultural crops, and likely yield reductions from higher salinity levels. These values were calculated using the relationship between soil saturated paste electrical conductivity (ECe) and the salinity by the suction cup soil water extractor developed by SARDI. The SARDI suction cup water extractor is now marketed under the brand name of SoluSAMPLER by Sentek Sensor Technologies (www.sentek.com.au).

http://www.environment.gov.au/resource/australian-and-new-zealand-guidelines-fresh-and-marine-water-quality-volume-1-guidelines

Further references and resources can be located at the end of this chapter.

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Table 1.3: Horticultural crop thresholds. Source: Biswas et al. (2009).

Crop	Threshold for maximun production[2&3] (ds/m)	Threshold for reduced yield levels (ds/m)
	100% yield	75% yield
Orange	3.4	6.6
Grapefruit	3.4	6.6
Lemon	3.4	6.6
Apricot	3.2	5.2
Peach	3.4	5.8
Carrot	2.0	5.8
Onion	2.4	5.6
Potato	3.4	7.6
Tomato	5.0	10.0

NOTE: These values are a guide only and can vary with soil type, leaching potential, irrigation method and plant age.

The term leaching fraction refers to the application of water to the point where water percolates down a soil profile.

Irrigation management

In areas affected – or at risk of being affected – by salinity irrigation requires careful management. It is a good idea to seek professional advice before developing an irrigation system in these situations.

Applying a leaching fraction can flush salts out of the topsoil. Rainfall may act as a leaching fraction. However, excessive leaching fractions can worsen the process of salinisation by causing the water table to rise, so they need to be carefully managed.

Monitoring the level of soil moisture provides a means of checking water table depth as well as efficiency of irrigation (see Topic 2a – Irrigation efficiency).

Improving drainage

Improve drainage in saline areas, particularly if salinity problems are associated with a rising water table and saline groundwater. If soils are waterlogged, removing excess water can help leach of salt from the root zone to lower levels in the soil profile. Consideration must be given to management of the drainage water.

Cut-off drains can divert and remove surface water that would otherwise become groundwater recharge. Surface drains should be stabilised with fencing and vegetation cover.

Raised beds with adjoining furrow drains can improve surface drainage and salt leaching. Sub-surface drainage can reduce waterlogging and increase the leaching of salt. Care is needed when considering drainage options as drains in dispersive soils can lead to soil instability and severe erosion.

Further references and resources can be located at the end of this chapter.

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Vegetation cover

Vegetation can assist in preventing and managing salinity, particularly salinity associated with rising water tables.

Deep-rooted plants can assist in preventing rising water tables, by utilising water deep in the soil profile.

Maintaining vigorous plants will help use rainfall, preventing excess water soaking through the soil surface.

If salinity problems already exist, salt-tolerant tree species can be established to assist with water utilisation and gradual lowering of the water table.

Monitoring and recording

If you are beginning a new project or irrigating a new area, undertake the required investigation to determine the risk of salinity problems arising or to find existing problems.

If salinity problems exist or there is a risk of them developing, a monitoring program should be developed based on a salinity survey and specialist advice. The program needs to be tailored to suit the specific site.

From then on it is a matter of monitoring in areas where salinity issues occur. It is recommended you measure and record:

- Soil salinity (electrical conductivity, chemical composition of the salts and em survey);
- Trends in the salinity of irrigation water and groundwater;
- Trends in the depth of the water table;
- Salinity (sodium and chloride) in leaf samples; and
- Photographic points to track changes in scald area and severity.

A low-cost approach to monitoring for salinity is detailed over the following pages. This may not be appropriate for your situation, particularly if dealing with high-value perennial crops where a more detailed analysis of the salinity risk would be warranted.

Monitoring the water table

Equipment needed – a small 50 mm drilling rig (borrow or hire), a few lengths of 40 mm diameter PVC pipe and a bundle of steel posts.

Select suitable sites for monitoring stations

If you don't have any visible sign of salt-affected land, choose a site that is convenient for monitoring (i.e. not in the middle of land you will be regularly working up) and that could be at risk of salinity.

If you have a salt scald, choose a monitoring station where the boundary is suspected of spreading, and if possible where the boundary is easy to identify. Two or three monitoring stations for each area of salt-affected land should be sufficient. For each monitoring site, mark the boundary of the affected area with steel posts 10-20 m apart, exactly on the salt boundary, so that you will easily see any change in the boundary over time.

Further references and resources can be located at the end of this chapter.

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Establish the monitoring stations

At each monitoring station, drill holes (about 50 mm in diameter) with a hand or power auger to a depth of 2 m. If you have salt-affected land, locate the holes across the salinity boundary so that at least one hole is in the unaffected area, one is in the obviously affected area and one is on the boundary.

Use 3 m lengths of 40 mm PVC pipe (Class 6) to line the holes. Cut slots in the bottom metre with a fine-bladed hacksaw. When the pipe is in the hole, pack clay or cement grout around it at ground level to prevent inflow of rainwater. Keep rain out of the top with an upturned jam tin or old bucket. Identify the hole by a number on the top of the pipe. Prevent stock rubbing against the pipe by driving a steel post into the ground next to it or cutting the pipe off short, 20-30 cm above ground level.

Determining the depth of the water table

After establishing the monitoring sites, leave the holes for at least three weeks before measuring the depth to the water table from the top of the pipe. Subtract the height of the pipe above the ground surface to calculate the depth to the water table below the ground surface. Use a metric tape measure with a small wash basin plug wired on the end to detect the water surface by sound.

If no water is detected in a 2 m deep hole, it is unlikely that the land is in immediate danger of salt encroachment. Capillary rise (wick action) of saline water to the soil surface only operates from water tables that are 2 m deep or shallower in most soil types.

If the water table is 1.5 - 2 m below ground level, the soil surface must be considered at risk. If the depth to the water table is less than 1.5 m there may well be indications of salt on the surface.

With the water table at 1 m or less, salting is practically inevitable. In the worst cases, the water table level in the pipe may rise above ground level, indicating upwards pressure in the water table.

Soil profile sampling

Take soil samples from near each hole during dry months. Sampling should be conducted down the soil profile, ideally to a depth of at least 2 m.

Label each sample clearly with the number of the hole and depth. Get the soil samples analysed for electrical conductivity. Sites should be sampled every six months to three years depending on the results and risk of rising water table.

Take water samples

Using a weighted dipper on the end of a piece of cord (or a submersible pump), take a sample of groundwater. Have this sample analysed for electrical conductivity.

Long-term monitoring

To detect whether the water tables are rising, falling or stationary over a period of years, check water table depths regularly and record or graph them. The most suitable time for measuring depths is in dry months, when the risk of capillary rise is greatest. It is a good idea to take measurements across the seasons to establish the range of water table heights.

Annual checking of the saltland boundary between the steel posts will also indicate whether the problem is getting worse, is stable or is retreating. Take photographs to record changes.

References and resources

For access to relevant references and further resources click here.

Further references and resources can be located at the end of this chapter.

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Objective – soil pH is maintained within the optimum range for crop production

Soils can be naturally acid or alkaline. Soil pH may also change with irrigation, fertiliser and crop management practices. As soil pH changes, the availability of soil nutrients may also change. Therefore it is important to monitor soil pH changes over time.

Soil acidity

Soil acidification is a major land degradation issue, which can lead to reduced availability of nutrients, lower yields and fewer crop options. Soil acidity can be naturally occurring and can be made worse by prolonged and heavy use of nitrogen fertilisers like sulphate of ammonia and MAP (monoammonium phosphate). It can also be exacerbated by the removal of hay and alkaline materials.

The speed with which soil becomes acidic depends on many factors including soil type, soil texture (sandy soils become acidic more easily), organic matter, cation exchange capacity, the amount of crop product removed and the type of fertiliser used.

Older and more highly weathered soils are likely to have become acidic due to the natural processes of time and weathering. Calcium and, in particular, magnesium can be leached out of the soil profile under these conditions, contributing to acidity.

Acid sulphate soils - defined as soils with a pH reading below 5.5 - are formed when seawater or sulphate-rich water mixes, in the absence of oxygen, with land sediments containing iron oxide and organic matter. Acid sulphate soils are commonly found less than 5 m above sea level. Mangroves, salt marshes, floodplains, swamps, wetlands, estuaries and brackish or tidal lakes are ideal areas for acid sulphate soil formation.

The presence of acid sulphate soil may not be obvious on the soil surface as it is often buried beneath layers of more recently deposited soils and sediment.

When exposed to air due to drainage or disturbance, these soils produce sulphuric acid, which in turn can release toxic quantities of iron, aluminium and heavy metals.

Soil alkalinity

Alkaline soils have a pH greater than about 7.5 or a high sodium content, or both.

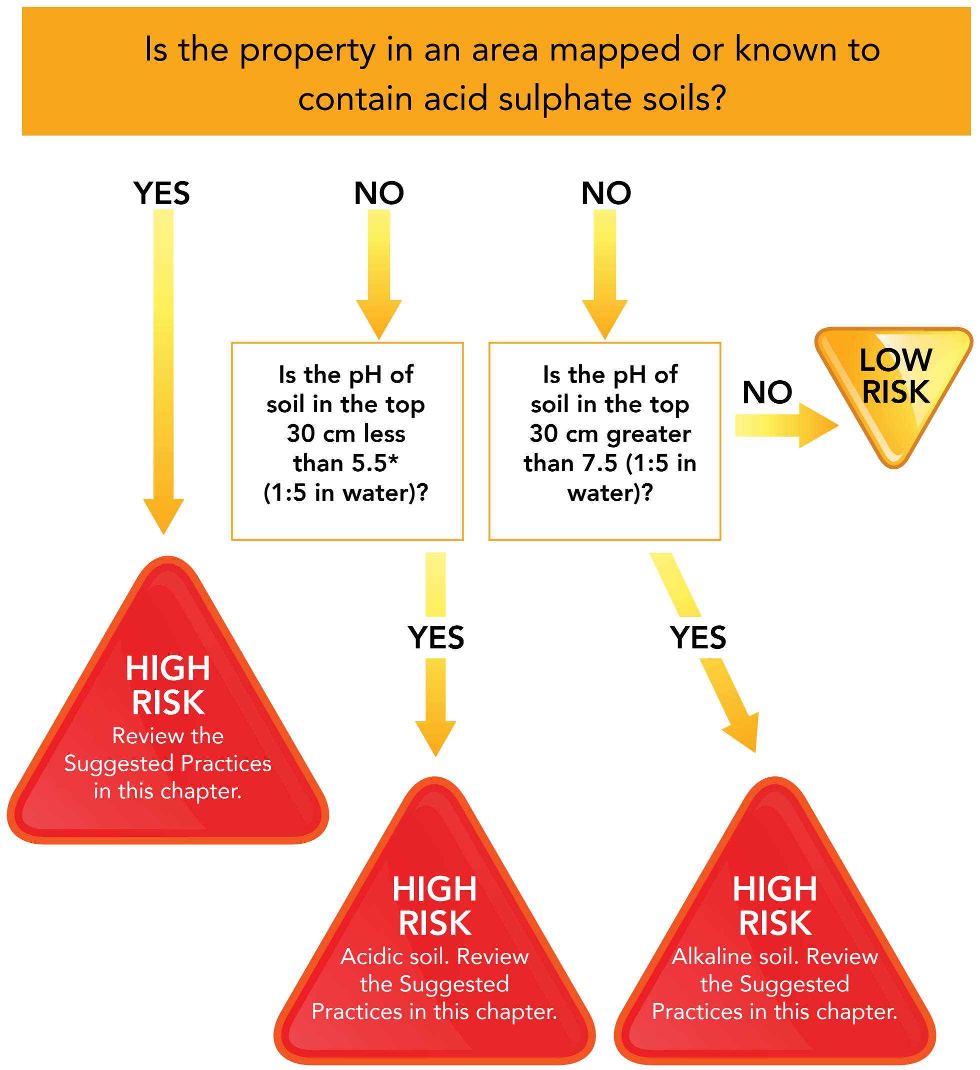
Alkaline soils may be deficient in zinc, copper, boron and manganese. Soils with an extremely alkaline pH (>9) are likely to have high levels of sodium.

Some soils in the semi-arid and arid regions have naturally high pH caused by significant quantities of free calcium carbonate. Irrigated well/bore water may also contain significant quantities of calcium carbonate.

Further references and resources can be located at the end of this chapter.

Horticulture Australia

Risk assessment



* There are some exceptions to this limit, a few plants on some soils grow best below pH 5.5.

LOW RISK – You probably don't have a significant problem in this area. You may like to read the Suggested Practices to check your understanding of the issue.

HIGH RISK – You need to take some action. Read the Suggested Practices for that chapter.

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Horticulture Australia

Review checklist

To go straight to the worksheet for this chapter click here.

Relevant legislation and regulation

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Suggested practices

Soil acidity

Lime or dolomite is usually added to maintain soil pH within a desirable range and can reverse the acidifying process in surface soils. Soil testing can help determine the correct rate to apply. Over-application can take years to remedy and can decrease uptake of nutrients by plants. It is usually easier to apply lime before planting. Thorough incorporation improves results, although incorporating lime into subsoil layers is difficult.

Not all soils can be maintained at pH 5.5 or above. Unless acidic soils are already cultivated and acid tolerant crops are to be grown, consider leaving them in their natural state, as drainage and cultivation can cause extreme acidification. If this occurs, liming is often expensive and often fails to achieve a lasting increase in pH.

Nitrogen leaching is a common form of soil acidification; reducing nitrogen, reducing leaching or using less acidifying forms of nitrogen can assist in reducing soil acidification. In some fertilisers the conversion from the applied form to one the plant can take up is a process that acidifies the soil. The acidification potential of different fertilisers is:

- Severely acidifying – ammonium sulphate and monoammonium phosphate (MAP);
- Moderately acidifying – diammonium phosphate (DAP);
- Slightly acidifying – urea and ammonium nitrate; and
- Non-acidifying – potassium nitrate, calcium nitrate and composted poultry manure.

Nitrates are highly mobile under the influence of high rainfall or over-irrigation and will readily leach in permeable soils. This process can cause further soil acidification and contamination of surface and groundwaters.

Legumes or nitrifying crops can also contribute to soil acidity.

Soil acidity can also develop under drip irrigation where soils are highly leached.

Further references and resources can be located at the end of this chapter.

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The following approaches should be considered:

- Efficient nitrogen application in order to applying smaller amounts of fertiliser more often. Fertigation (that is, applying fertilisers through irrigation systems) is one technique that can help match fertiliser application more effectively with crop demand and also allows for use of soluble fertilisers like potassium nitrate and calcium nitrate;
- Increase organic matter in order to help to buffer soil from pH changes; and;
- Do not drain, clear or expose acid sulphate soils in order to prevent mobilising the acids and toxic elements in the profile.

Soil alkalinity

Alkaline soils need to become more acidic. One way of achieving this is to use fertilisers such as crushed sulphur and some ammonium-based nitrogen fertilisers.

Elemental sulphur combines with oxygen and water to become sulphuric acid. This process can take some time and its effect on soil pH will depend on how much free calcium carbonate there is as this acts as a buffer.

Monitoring and recording

A check of the soil pH is an ideal way of monitoring the change in acidity of soils over time. It is important that pH is determined in soil samples taken to a depth of at least 60-80 cm to represent the root zone, and because surface lime applications often only increase pH to the depth the lime was incorporated. When collecting samples, be careful to separate the 0-15 cm and 15-30 cm samples from the deeper layers so that the acidity profile can be identified.

You can also measure pH with a simple test kit available from rural merchandise stores. The kit uses colour to indicate the pH level and is easy to use. It measures pH in water and not calcium chloride, so the results may be different from laboratory tests conducted by your local provider.

Soil water extraction tubes can be used to collect soil water samples at different depths for analysis of pH as well as other factors such as salinity and nitrates.

References and resources

For access to relevant references and further resources click here.

Further references and resources can be located at the end of this chapter.

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Objective – soil permeability is adequate for water infiltration and drainage needs of the crop and erosion of sodic soils is minimised

Sodic soils are those where the amount of sodium held on to the clay particles is 6% or more of the total cation exchange capacity.

Sodic soils have an unstable structure and are poor places for plants to grow.

Following rain or irrigation with fresh water, clay particles in sodic soils force each other away, because of the sodium bound to the clay. This causes the soil to disperse, leaving a cloudy suspension.

Soil sodicity and soil salinity are often related because both involve sodium – a metal element widespread in Australian soils. Sodicity may be the more obscure problem, but it is a more widespread form of land degradation. It affects nearly a third of all soils in Australia (including one-third of all agricultural soils) and can cause poor water infiltration, low water storage, toxicity, surface crusting or sealing and waterlogging.

Many duplex soils (sandy topsoil over clay) in Australia have sodic clay subsoils. The structure of the subsoil clay is described as prismatic or columnar, which is hostile to plant roots. Tunnel erosion is also a risk on slopes with sodic clay subsoils.

The impacts of sodic soils extend to water catchments, infrastructure facilities and the environment. Run-off from sodic soils carries clay particles into waterways and reservoirs causing water turbidity, or cloudiness.

Further references and resources can be located at the end of this chapter.

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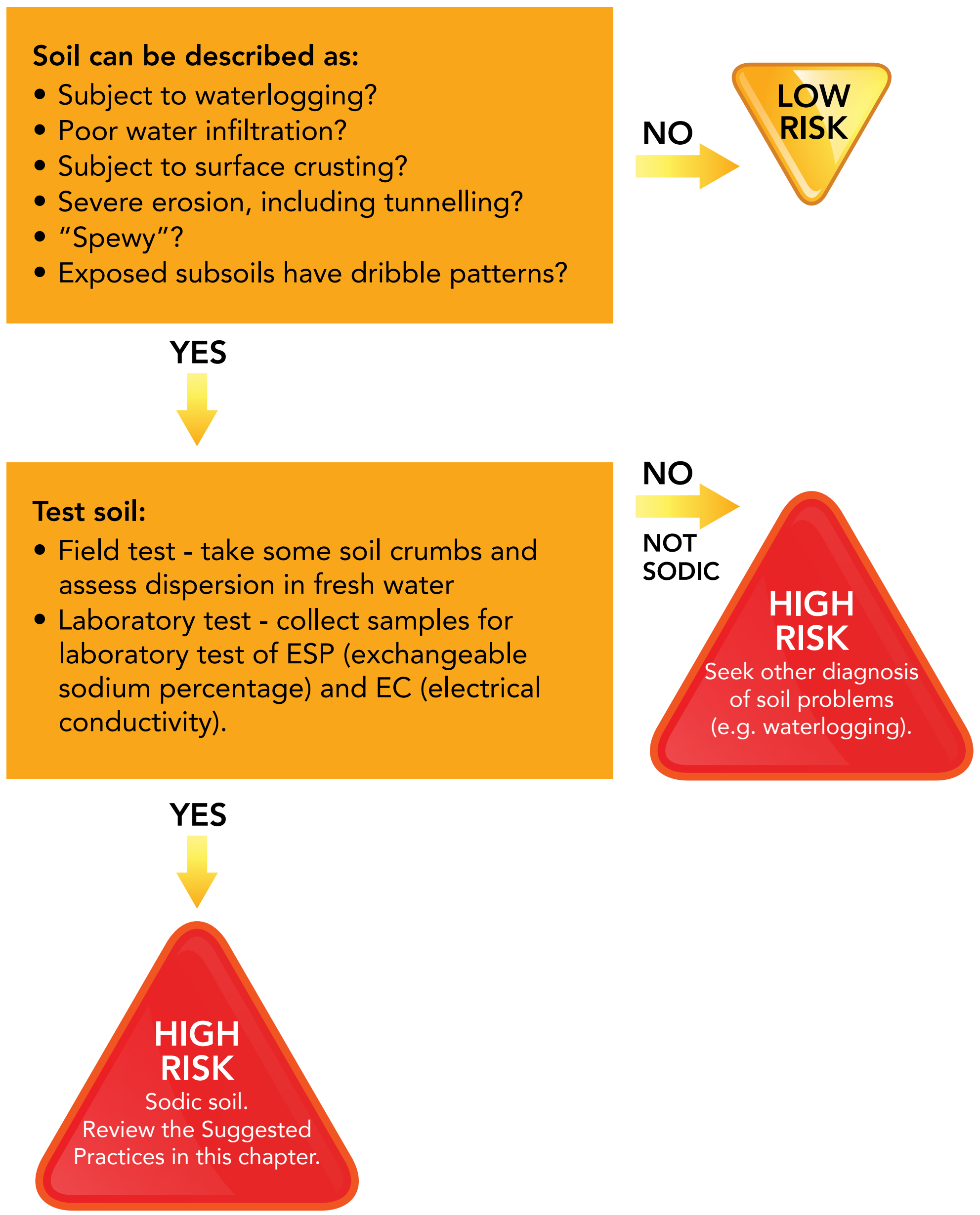
Risk assessment



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Review checklist

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Suggested practices

Improving sodic soils is not straightforward. Good soil management practices will generate as much benefit as high-input, costly remedial action, especially if the soil is in reasonable condition to begin with. Practices such as minimising tillage and compaction, returning large amounts of organic matter to the soil and improving surface drainage should be the first consideration before undertaking specific remedial action.

Once basic good soil management practices are adopted then attention can be turned to the sodicity problem itself. If sodic soils are identified or suspected seek professional advice.

Application of gypsum

Calcium in the form of gypsum can be added to sodic soils to improve their structure. Gypsum may also be applied to the soil via the subsurface drip irrigation system.

Gypsum improves soils in two ways. The first is a short-term benefit. The calcium salts in the gypsum increase the salt level in the soil solution around the clay particles. This prevents dispersion of sodic clays and promotes aggregation.

The second effect is a longer-term one. Sodium ions held on the clay particles are swapped with the calcium ions from the gypsum. This helps reclaim the soil and allows the displaced sodium ions to be leached out below the root zone.

The gypsum can be applied to riplines to help stabilise fracture lines, or broadcast and either incorporated or left on the surface. The best option depends on the nature, depth and extent of soil sodicity. Other factors to consider are soil pH, soil salinity, irrigation water quality, drainage, irrigation systems and the horticultural enterprise being undertaken. Because there are many factors to consider when dealing with sodic soils, it is advisable to seek professional advice.

It should also be remembered that gypsum adds to the overall salinity of soil water (though not in proportion to the amount used) so under pre-existing saline conditions, large applications should be made after completion of the growing season. Certainly it is better to apply smaller amounts annually rather than large, infrequent applications; this reduces opportunities for structural decline. The amounts required depend on the quality of irrigation water and soil type but are generally in the order of 5-10 t/ha in irrigated permanent plantings.

Further references and resources can be located at the end of this chapter.

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Application of lime

Lime (calcium carbonate) can also be used if the soil is not alkaline. However lime does not have the short-term benefits of gypsum.

Generally sodic soils take many years to improve using lime and gypsum. In the meantime it is important to manage these soils appropriately:

- Minimise tillage and avoid aggressive, deep working;
- Maximise returns or additions of stubble and organic manures to stabilise structure and maintain permeability;
- Install surface drains and cutoff drains to minimise waterlogging. Consider raised beds;
- Sodic soils can be irrigated with slightly saline water. Fresh water will maximise dispersion. Seek professional advice, as this can have negative effects on plant health due to increase in sodium and chlorine levels; and
- Avoid deep ripping – unless soils are stabilised with gypsum, the fracture lines will collapse during the first full saturation, resulting in a more compacted and impermeable state than prior to ripping.

Technical advice should be sought to identify the suite of management options that are relevant and practical for the management of sodic soils in your particular situation.

Monitoring and recording

Monitoring of soil physical properties and sodium levels is required to check the results of your management strategies.

Test the surface and the subsoil separately to determine the distribution of any sodicity problem.

- Collect samples from both the surface and the subsoil using a 5 cm soil auger or similar. Place the samples in clean buckets, one bucket for the subsoil and one for the surface soil;
- Collect samples randomly from a minimum of five locations over a uniform 1-2 ha representative area of the paddock;
- If it isn't clear where the subsoil begins, take a sample from the top 10 cm of the soil profile. Then take a second sample from somewhere deeper in the profile, within the range of 20-60 cm below the surface;
- Spread the soil from each bucket into a thin layer on a clean plastic sheet. Place in a well- ventilated location to air-dry, which may take several days;
- You need pieces of soil approximately 1 cm in diameter for this test. If necessary, break the air-dried soil into pieces and then mix thoroughly;
- From each surface and subsoil sample weigh 100 gm of soil into a clean 600 ml glass jar with lid;
- Measure out 500 ml rainwater or distilled water to give a 1:5 ratio of soil to water. Gently pour this water down the side, without disturbing the soil at the bottom;

Further references and resources can be located at the end of this chapter.

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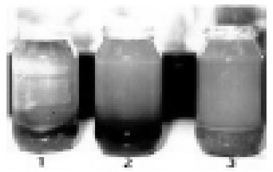
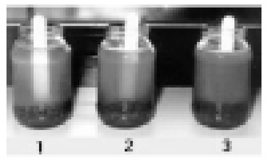
- Invert the jar once, slowly and gently, and then return to its original position (avoid any shaking). Then let stand for four hours, with no vibrations or bumping; and
- Check the suspension above the sediment at the bottom of the jar:
  Place a white plastic spoon or spatula in the solution (without stirring) to assist in determining the level of sodicity. Score the cloudiness using the following scale:





Estimating turbidity (soil sodicity) in a 1:5 soil/water suspension:

1. Clear or almost clear – not sodic
2. Partly cloudy – medium sodicity
3. Very cloudy – high sodicity

Estimating turbidity using spatula visibility:

1. Plastic spatula visible – not sodic
2. Plastic spatula partly visible – medium sodicity
3. Plastic spatula not visible – high sodicity

- Make up another soil suspension and repeat the process if unsure. Record the results.

A laboratory test for ESP (Exchangeable Sodium Percentage) and salinity of both surface and subsoil will provide the necessary information to decide management options.

For more on salinity monitoring information see 'Sodicity – a dirty word in Australia, Activity 1, A field test for sodicity', Australian Academy of Science.

References and resources

For access to relevant references and further resources click here.

Further references and resources can be located at the end of this chapter.

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(web links accurate as at 11 February 2014)

Note: A number of Horticulture Australia Limited (HAL)-funded project final reports have been identified as references within this document. This is by no means representative of all the research & development (R&D) or final reports available in this area. For full list of HAL final reports visit the HAL website www.horticulture.com.au. Alternatively, contact HAL or your peak industry body for more information on research & development outcomes specific to your industry.

NATIONAL DATA SETS AND GUIDELINES:

Agricultural Production Systems sIMulator (APSIM) www.apsim.info
This website contains a suite of modules which enable the simulation of systems that cover a range of plant, animal, soil, climate and management interactions.

ApSoil www.apsim.info/Products/APSoil.aspx
This tool provides access to a database of soil water characteristics enabling estimation of Plant Available Water Capacity for individual soils and crops. It covers many cropping regions of Australia and is regularly updated. It is designed for use in simulation modelling and agronomic practice.

Australian and New Zealand Guidelines for Fresh and Marine Water Quality – Volume 1: Paper 4 - Primary Industries (2000)
http://www.environment.gov.au/resource/australian-and-new-zealand-guidelines-fresh-and-marine-water-quality-volume-1-guidelines
This resource outlines the requirements for fresh and marine water quality. This version (2000) is currently being revised, with next version to be released mid-2014 – see www.environment.gov.au/topics/water/water-quality/national-water-quality-management-strategy

Australian Bureau of Statistics http://www.abs.gov.au/ausstats/abs@.nsf/featurearticlesbytitle/1DF2ACCC5071A76ACA2569DE00267E5A?OpenDocument
This reference outlines some statistics for soil erosion.

Australian Collaborative Land Evaluation System www.clw.csiro.au/aclep/
This website is a national collaborative approach to Australian land and soil resources. This includes the agreed Australian Soil Classification framework www.clw.csiro.au/aclep/asc/index.htm

Australian Soil Resource Information System www.asris.csiro.au
This website provides online access to publically available information on soil and land resources.

AUSVEG, Healthy Soils http://ausveg.com.au/Default

Saltland Genie www.saltlandgenie.org.au/all-about-saltland/unit-4-plant-and-animal-performance/nderstanding-salinity-and-waterlogging.htm
This website provides up to date information resulting from the National Dryland Salinity Program (1993 – 2005), national Sustainable Grazing on Saline Lands initiative, but built on wider work from the CRC for Plant-based Management of Dryland Salinity, and the National Land & Water Resources Audit.

SoilMapp www.csiro.au/soilmapp
This resouce provides direct access to best national soil data and information from the Australian Soil Resource Information System (ASRIS) and ApSoil, the database behind the agricultural computer model: Agricultural Production Systems SIMulator (APSIM).

SoilQuality http://www.soilquality.org.au
This website provides links to chemical, biological and physical calculation tools, as well as capturing soil quality information within a number of selected regions within WA, TAS, SA, QLD, and NSW only.

Soil Science Australia **www.soilscienceaustralia.org**
This website is the official site for the peak body on soil science.

STATE - SPECIFIC LINKS

NSW – Department of Primary Industries
Soil erosion www.dpi.nsw.gov.au/agriculture/resources/soils
Soil structure - SoilPak for Vegetable growers www.dpi.nsw.gov.au/agriculture/horticulture/vegetables/soil/soilpak
Soil acidity www.dpi.nsw.gov.au/agriculture/resources/soils/acidity
Salinity www.dpi.nsw.gov.au/agriculture/resources/soils/salinity
General horticulture resources www.dpi.nsw.gov.au/agriculture/horticulture

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NT - Department of Land Resource Management
www.lrm.nt.gov.au/soil#.UncCWqVtzjA

QLD – Queensland Government
http://www.qld.gov.au/environment/land/soil/
Soil pH www.nrm.qld.gov.au/factsheets/pdf/land/l47.pdf
WetlandInfo http://wetlandinfo.ehp.qld.gov.au/wetlands/index.html

SA – Primary Industries and Regions South Australia
Soil erosion www.pir.sa.gov.au/pirsa/more/factsheets/soil
General horticulture resources www.pir.sa.gov.au/horticulture
Irrigation and soil http://www.sardi.sa.gov.au/water/irrigation_management/soils

TAS - Department of Primary Industries, Water and Environment
Soil erosion www.dpiw.tas.gov.au/inter.nsf/WebPages/TPRY-5YW4WC?open
Field Mapped Land Capability Maps and Reports www.dpiwe.tas.gov.au/inter.nsf/WebPages/TPRY-6BF9EF?open
Soil structure www.dpiw.tas.gov.au/inter.nsf/ThemeNodes/EKOE-4ZG6PP?open
Hamlet, A.G (Ed) 2002, Soil Management – A Guide for Tasmanian Farmers, DPIWE Tasmania www.dpipwe.tas.gov.au/inter.nsf/Attachments/TPRY-68TVRC/$FILE/Soil%20Guide.pdf

VIC – Department of Environment and Primary Industries
Soil and water http://www.depi.vic.gov.au/agriculture-and-food/farm-management/soil-and-water
Soil erosion www.dpi.vic.gov.au/agriculture/farming-management/soil-water
Soil – Victorian Resources Online http://vro.dpi.vic.gov.au/dpi/vro/vrosite.nsf/pages/soil-home
General horticulture resources http://www.depi.vic.gov.au/agriculture-and-food/horticulture
Regional focus – Gippsland Soil Directory www.wgcma.vic.gov.au/index.php/component/content/article/45/284-the-gippsland-soil-trial-directory.html

WA – Department of Agriculture and Food
Soils https://www.agric.wa.gov.au/climate-land-water/soils
Soil salinity - A simple way to monitor your saltland (2005) www.agric.wa.gov.au/PC_92345.html

Moore, G (2001) Soilguide: a handbook for understanding and managing agricultural soils. National Library of Australia. www.agric.wa.gov.au/objtwr/imported_assets/content/lwe/rpm/landcap/soilguide_introduction

LITERATURE

Alt, S; Jenkins, A; Lines-Kelly, R. (2009) Saving Soil – A landholder's guide to preventing and repairing soil erosion. Northern Rivers Catchment Management Authority, State of New South Wales through NSW Department of Primary Industries. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0008/270881/saving-soil-complete.pdf

Australian Government (2006) State of the Environment Report: Issue: Catchment scale influences - Land and vegetation condition – Erosion. Department of Environment, Canberra, ACT. http://www.environment.gov.au/node/22498 (Note: Source of information on turbidity)

Australian Government (2011) State of the Environment Report. Department of Environment, Canberra, ACT. www.environment.gov.au/topics/science-and-research/state-environment-reporting/soe-2011/soe-2011-report/5-land

Chapter 2.2 Soil | 2 Current state and trends of the land environment | 5 Land www.environment.gov.au/node/22965

Australian Online Coastal Information, OzCoasts (2013) Measuring turbidity. GeoScience Australia. http://www.ozcoasts.gov.au/indicators/turbidity.jsp

Barson M, Mewett J. & Paplinska J. (2012) Land management practice trends in Australia's horticulture industry (soil acidity and maintaining ground cover). Caring for our Country Sustainable Practices Fact Sheet 4. Department of Agriculture, Fisheries and Forestry, Canberra, ACT. http://www.daff.gov.au/__data/assets/pdf_file/0010/2148715/national-factsheet-farm-practices-horticulture.pdf

Bennett L. T., Mele P. M., Annett S. & Kasel S. (2010) Examining links between soil management, soil health, and public benefits in agricultural landscapes: An Australian perspective. Agriculture, Ecosystems & Environment 139, 1-12.

Biswas, T.; Bourne, J; Schrale, G. & McCarthy, M. (2009) Sustainable Irrigation Management Update - Salinity Management Practice Guidelines: Managing root-zone salinity for irrigated horticultural crops in winter rainfall zones of Australia. National Program for Sustainable Irrigation, Land & Water Australia, Canberra, ACT. http://npsi.gov.au/files/products/national-program-sustainable-irrigation/pn22225/pn22225.pdf

HAL

Horticulture Australia

Land and soil management - references and further resources

Bui, E; Hancock, G; Chappell, A; Gregory, L, (2010) Evaluation of tolerable erosion rates and time to critical topsoil loss in Australia, CSIRO Publishing. This report identifies regions of Australia at risk of exceeding 'tolerable' rates of soil loss.

Campbell A. (2008) Managing Australia's Soils: A Policy Discussion Paper. Department of Agriculture, Fisheries and Forestry, Canberra. http://www.clw.csiro.au/aclep/documents/Soil-Discussion-Paper.pdf

Caring for our Country (2013) Factsheet: Soil acidification in Australia, Caring for Our Country, Australian Government, Canberra, ACT. http://www.nrm.gov.au/funding/agriculture/innovation/pubs/soil-acidification.pdf

Cockcroft B. (2012) Soil Management For Australian Irrigated Horticulture. National Program for Sustainable Irrigation, Canberra, ACT. http://lwa.gov.au/files/products/national-program-sustainable-irrigation/npsi0212/npsi0212-soil-management-australian-irrigated-hort.pdf

Cork, S; Eadie, L; Mele, P; Price, R; and Yule, D. (2012) The relationships between land management practices and soil condition and the quality of ecosystem services delivered from agricultural land in Australia, Caring for our Country, Australian Government, Canberra, ACT. http://www.daff.gov.au/__data/assets/pdf_file/0008/2210597/soils-final-report-full.pdf

Cox, J. (2009) Effects of Sustainable mulching systems on soil health and production in SoilQuality http://www.soilquality.org.au This website provides links to chemical, biological and physical calculation tools, as well as capturing soil quality information within a number of selected regions within WA, TAS, SA, QLD, and NSW only.

DEFRA (2011) Protecting our water, soil and air, Department of Environment Food and Rural Affairs, UK. https://www.gov.uk/government/publications/protecting-our-water-soil-and-air

Department of Employment, Economic Development and Innovation (2011) Wetland Management Handbook: Farm Management Systems (FMS) guidelines for managing wetlands in intensive agriculture, Queensland Wetlands Program, Brisbane, QLD. http://wetlandinfo.ehp.qld.gov.au/resources/static/pdf/resources/reports/fms/fms_025_handbook_web.pdf

Department of Natural Resources, Mines and Water (2005) Land Manager's Monitoring Guide: Soil pH indicator, Department of Natural Resources, Mines and Water, QLD. http://s3.amazonaws.com/zanran_storage/www.nrw.qld.gov.au/ContentPages/2343095.pdf

Doolittle, W.E, (2004), Measuring erosion. Available from http://uts.cc.utexas.edu/~wd/courses/373F/notes/lec17ero.html. This report provides information on how to measure erosion.

ERIN (2009a) Indicative locations where improving soil and land management practices to reduce soil loss from wind erosion will provide the biggest benefits (map). Environmental Resources Information Network Canberra, http://nrmonline.nrm.gov.au/catalog/mql:2348

ERIN (2009b) Indicative locations where improving soil and land management practices to reduce soil loss from hillslope (sheet and rill) erosion will provide the biggest benefits (map). Environmental Resources Information Network, Canberra, ACT. http://nrmonline.nrm.gov.au/catalog/mql:2386

ERIN (2009c) Indicative locations where improving soil and land management practices to increase soil organic matter will provide the biggest benefits (map). Environmental Resources Information Network, Canberra, ACT. http://nrmonline.nrm.gov.au/catalog/mql:2390

Glowinski, L. (Updated 2008) The Complete Book of Fruit Growing in Australia, Hachette Australia. http://www.publish.csiro.au/pid/7098.htm (for purchase via this link).

HAL (2011) Benchmarking Soil Health for Improved Crop Health, Quality and Yields in the Temperate Australian Vegetable Industries. Horticulture Australia Limited, Sydney, NSW. www.horticulture.com.au

Hunt, N. and Gilkes, B. (1992) Farm Monitoring Handbook. University of Western Australia, WA.

Isbell, R. (2002 – revised edition) The Australian Soil Classification – Revised Edition – Australian Soil and Land Survey Handbook Series 4, CSIRO Publishing. www.publish.csiro.au/pid/3529.htm (for purchase via this link). This publication provides a hierarchical soil classification system of five categorical levels from general to the most specific: order, suborder, great group, subgroup, and family. The Australian Soil Classification describes fourteen soils orders across Australia with further subdivision under these broad groups.

Kelly, J. (2011) Australian Vegetable Industry Soil and Land Management Knowledge Exchange (HAL Project Number: VG07146). Horticulture Australia Ltd, Sydney, NSW. www.horticulture.com.au

Kelly, J. (2009) Soil and Land Management Extension Resource Manual (HAL Project Number: HG06165). Horticulture Australia Ltd, Sydney, NSW. www.horticulture.com.au

HAL

Horticulture Australia

Land and soil management - references and further resources

LEEPER, G; and UREN, N, (1993), Soil Science, An Introduction, 5th edition, Melbourne University Press. http://trove.nla.gov.au/version/44659070 (Note: link provides advice for borrowing this edition)

Maas and Grattan (1999) Salt tolerance of crops, FAO. www.fao.org/docrep/005/y4263e/y4263e0e.htm
McKenzie, N; Jacquier, D; Isbell, R; and Brown, K. (2004) Australian Soils and Landscapes – An Illustrated Compendium, CSIRO Publishing. http://www.publish.csiro.au/pid/3821.htm (for purchase via this link). This publication provides information on how soil properties and landscape processes should guide our use of the land.

McPhee J. E. (2009) Controlled Traffic Farming Systems for the Tasmanian vegetable industry (HAL Project Reference VG07058). Horticulture Australia Ltd, Sydney, NSW. www.horticulture.com.au

McTainsh G. H., Leys J. F., O'Loingsigh T. & Strong C. L. (2011) Wind erosion and land management in Australia during 1940- 1949 and 2000- 2009. Report prepared for the Australian Government Department of Sustainability, Environment, Water, Population and Communities on behalf of the State of the Environment 2011 Committee. DSEWPaC, Canberra.

Murray, R.S. (2007) A Review of Dr Bruce Cockroft's Work for Australian Irrigated Horticulture, Milestone Report 2, National Program for Sustainable Irrigation, Narribri, NSW. http://npsi.gov.au/files/products/national-program-sustainable-irrigation/pn21945/pn21945.pdf

Murray, R.S.; McCarthy, M; Grant, C, (2011) Guidelines for Managing Soil Structure in Irrigated Vineyards, National Program for Sustainable Irrigation, Narribri, NSW. http://npsi.gov.au/files/products/national-program-sustainable-irrigation/npsi2311/npsi2311-guidelines-managing-soil-structure-irriga.pdf

NPSI (2012) Irrigation Essentials Updated – Research and innovation for Australian irrigators. National Program for Sustainable Irrigation. Cotton RDC, NSW. http://npsi.gov.au/files/products/national-program-sustainable-irrigation/npsi06121/npsi06121-irrigation-essentials-updated.pdf

Pattison T., Moody P. & Bagshaw J. (2010) Soil Health for Vegetable Production in Australia. Queensland Government, Brisbane. http://www.daff.qld.gov.au/26_17025.htm

Pattison, T. (2008) Soil and root health for banana production (HAL Project Number: FR02025). Horticulture Australia Ltd, Sydney, NSW. www.horticulture.com.au

Porter, I. (2008) Management of soil health for sustainable vegetable production (HAL Project Number: VG06090). Horticulture Australia Ltd, Sydney, NSW. www.horticulture.com.au

Quirk, J, Sodic Soils, Australian Academy of Science www.science.org.au/nova/035/quirk.html

Reid G. (2002) Soil and Nutrient Loss in Macadamia Lands. (HAL Project Reference MC98011). Horticulture Australia Ltd, Sydney.

Slavich P. G. & Cox J. (2010) Improving soil and orchard floor management in macadamias. (HAL Project Reference MC05001). Horticulture Australia Ltd, Sydney.

Smith J. & Leys J. (2009) Identification of areas within Australia for reducing soil loss by wind erosion. Bureau of Rural Sciences, Canberra. http://nrmonline.nrm.gov.au/catalog/mql:2246

Soils Research Development and Extension Working Group. (2011) A stocktake of Australia's current investment in soils research, development and extension: A snapshot for 2010-11. Department of Agriculture, Fisheries and Forestry, Canberra. http://www.daff.gov.au/__data/assets/pdf_file/0003/2085816/soils-stocktake.pdf

Sylvain Z. A. & Wall D. H. (2011) Linking soil biodiversity and vegetation: Implications for a changing planet. American journal of botany 98, 517-27.

Synder, C, pH chapter of Efficient Fertiliser Use Manual http://www.pegasusk62.com/efficient-fertilizer-use-guide

Ugalde D., Brungs A., Kaebernick M., McGregor A. & Slattery B. (2007) Implications of climate change for tillage practice in Australia. Soil & Tillage Research 97, 318-30. For access to relevant references and further resources click here.

HAL Horticulture Australia