Northern Rivers Soil BMP Guide

Vegetables

Best Management Practices for Soil Health

Cudgen Plateau Vegetable Soil Health Project

tropo

Tweed Richmond Organic Producers' Organisation

Landcare SoilCare Inc

Australian Government
Department of Agriculture, Fisheries and Forestry
National Landcare Programme

NSW DEPARTMENT OF PRIMARY INDUSTRIES

Northern Rivers CMA CATCHMENT MANAGEMENT AUTHORITY

Landcare Richmond Landcare Inc

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What is soil health?

Soil health in agricultural ecosystems is indicated by a living dynamic ecology providing the needs for healthy plants.

The components of these are:
- adequate air/water balance,
- micro and macro-organism activity and
- appropriate nutrient availability.

They are influenced by:
- soil texture and structure,
- mineral levels,
- organic matter cycling,
- topsoil depth and
- freedom from harmful substances.

Dave Forrest 2007

INTRODUCTION AND BACKGROUND

INTRODUCTION

The ***Northern Rivers Soil Best Management Practice (BMP) Guide - Vegetables*** has been developed by growers for growers. It offers practical guidelines to improve and maintain soil health for better production and environmental outcomes. The Soil BMP is a 'living' document and as such can be edited and updated as we further our understanding of soil processes on vegetable farms.

The BMP Guide supports the ***Northern Rivers Soil Health Card - Vegetables*** (SHCV). The SHCV provides 10 straightforward visual tests for landholders to assess soil health using simple equipment and can be carried out by the farmer in the field. For information on how to obtain the SHCV refer to the 'WANT TO KNOW MORE' section of this document.

BACKGROUND

The Alstonville Plateau Landscape soil commenced production some 20 million years ago when Mt Warning ceased erupting. Under the high rainfall conditions the plateau soil weathered and leached and the rainforests, the 'Big Scrub', grew.

When the first European settlers came to the area they saw lush forests – a teaming biomass of vegetation- supported by the underlying red soil. Fertility and productivity in the Big Scrub depended on nutrient cycling. Nutrients were held in the organic matter on the forest floor which was recycled to the soil.

The prized plateau soils, known as Krasnozems or Red Ferrosols, are relatively high in organic matter (18–20 %) in their natural state in rainforests. Nevertheless on clearing, organic matter declines rapidly to less than 7% within a few years and as low as 2 or 3% if the soil is cultivated and left exposed for long periods (Hungerford 1995). Once cleared these soils have diminished nutrient and organic matter levels compared to the original forested condition.

ALSTONVILLE PLATEAU LANDSCAPE SOILS

Krasnozems/Red Ferrosols formed from basalt parent material under conditions of high rainfall. They are red-brown to orange in colour depending on organic matter content, generally a well structured clay but with localised stoniness. The good structure facilitates high water infiltration, good drainage and aeration. They are commonly deep topsoils (2m+) but have poor chemical properties, e.g. low pH, trace elements and other minerals and nutrients.

Chocolate soils formed from basalt parent material under conditions of lower rainfall. Topsoils are shallow (<1m), brown to black in colour with a loamy clay or clay overlying a paler heavy clay. The subsoil is poorly drained. These soils have good mineral content, but with a high magnesium to calcium ratio making soil structure less stable.

Podsolic soils formed from sedimentary deposits of sandstone, mudstone or shale. The topsoils are shallow (75mm), highly erodible grey to brown loam overlying poorly structured yellow to red clay subsoils. They are infertile with low mineral content, low pH, poor structure and low organic matter.

Alluvial soils vary widely in their features depending on parent material. They are usually fertile because they are composed of eroded topsoil from catchment, but physical properties vary from well-drained loams to poorly structured clays.

Excerpted from Soil Landscapes of the Lismore-Ballina 1:100,000 Sheet

STRENGTHS & WEAKNESSES OF ALSTONVILLE PLATEAU LANDSCAPE SOIL

'STRENGTHS'

The greatest asset of the plateau landscape soil is structure. In good condition it has the following characteristics which makes it physically ideal for plant growth:

- loose and friable (A friable soil is well aerated and allows for good root growth.),
- high permeability to both air and water,
- reasonable ability to hold water that can be accessed by plants (plant available water content),
- low soil strength when moist (allows for easy root penetration in the soil).

This good physical structure allows water to infiltrate easily through the soil. It is not prone to water logging except in low lying areas. It also provides a favourable environment for soil biological organisms to flourish.

Nevertheless, if the soil is not protected it is moderately to highly susceptible to erosion depending on slope and rainfall. Also because of the mineralogical nature of the soil (i.e. the soil lacks minerals that allow it to shrink and swell) once it is structurally damaged, by compaction, for example, it is very hard to repair.
The plateau soil is not saline or sodic.

'WEAKNESSES'

The majority of the 'weaknesses' of the plateau soil are as a result of its formation and use under high rainfall conditions. The plateau soil is weathered and leached and consequently has the following characteristics:

- **Low soil pH:** Soil pH affects the availability of nutrients and chemical species to plant roots. The plateau soil is 'naturally', moderately to strongly acid and has the potential to induce:
  - aluminium and manganese toxicity; manganese toxicity, for example, affects the metabolism of plants causing yellowing and death of leaf tissue.
  - calcium, magnesium and molybdenum deficiencies once pH is below 5 ($CaCl_2$).
  - reduction in phosphorous (P) availability leading to less root growth and less ability for oil accumulation in the kernel.
- **Moderate to low ability to hold nutrients:** the 'mineral' soil, that is the soil without organic matter, humus etc, has a moderate to low cation exchange capacity (CEC), which means it has limited ability to hold nutrients. Low soil pH contributes to a low nutrient holding capacity. The CEC can be improved by the build up of organic matter and humus in the soil.
- **Low exchangeable Calcium (Ca) and Magnesium (Mg):** At pH below 5, Ca and Mg become deficient and plant growth will be limited as a result.

Soil pH will continue to drop particularly under acidifying conditions of high annual rainfall and use of acidifying fertilisers such as ammonium phosphate.

ISSUES FOR SOIL HEALTH ON VEGETABLE FARMS

Alstonville Plateau Landscape soils have a variable history of soil erosion and other degradation issues due to prior land management practices. The area's high rainfall along with any current unsustainable farm management practices increases the potential for erosion and nutrient leaching.

THE MAIN ISSUES THAT IMPACT ON SOIL HEALTH AND SUBSEQUENTLY VEGETABLE PRODUCTION ARE:

· loss of valuable topsoil and topsoil organic matter due to past and present management practices, i.e. clearing, cultivation and erosion.
· declining soil fertility if topsoil and soil organic matter decline or are lost.
· decreasing soil pH (less than pH 5 ($CaCl_2$) and associated toxicities (aluminium toxicity) and deficiencies (lack of calcium and magnesium; reduction in soil microbial activity) from leaching rainfall conditions and use of certain nitrogenous fertilisers.
· breakdown of soil structure by machinery operations, particularly when the soil is wet and with high intensity rainfall.

Many of the past and ongoing issues for soil health can be remedied.
Some things I can change or influence as a farmer are:

· I can assess and monitor the health of my soil by utilising the tools such as the Soil Health Card.
· I can then determine, prioritise and manage the risks to soil health on my farm.
· I can maximise soil cover and minimise soil erosion on my farm.
· I can manage my farm to reduce impacts on the structure of the soil.
· I can improve plant nutrition by managing soil conditions (chemical, physical and biological) and use of fertilisers and other soil conditioners.
· I can provide soil conditions to encourage and promote beneficial soil organisms.

Considerations for soil health on an established farm.
(see Appendix 1 for new vegetable paddocks)
· Carry out Soil Health Card tests to assess soil health.
· Take soil samples for laboratory testing.
· Determine the issues that impact on soil health e.g. ground cover.
· Develop a long-term soil management plan to address the issues.

BMP 1 – MANAGING SOIL EROSION

SOIL HEALTH CARD TESTS: GROUND COVER, INFILTRATION, SOIL STRUCTURE AND EROSION

WHY IS SOIL EROSION IMPORTANT TO ME AS A FARMER?

The topsoil has the best soil structure, contains most nutrients and has the highest level of soil biological activity and root density. As such it needs to be protected and conserved for vegetable productivity. Managing the farm to prevent erosion will maintain the production value of the farm and the asset value of the land.

- Topsoil erosion may be incremental with only millimetres being removed in one event but over time the healthiest part of the productive capacity is removed.
- High rainfall events are typical of the region so proactive measures need to be taken.
- Erosion means loss of nutrients, topsoil and crop. This is a direct cost to the farmer, as well as the cost to repair damage and bring the productive capacity back.

Left: A cut-off drain above the cultivated area diverts water to the grassed waterway. The silt-trap in the foreground collects eroded soil from the cultivated paddock. Photo: David Forrest

HOW DO I MANAGE SOIL EROSION?

1. MANAGE WATER FLOW.

Control surface run-on.

- Divert water away from the block to reduce run-on.
- Divert water to safe disposal area such as a flat open space with 100% ground cover or a body of water.

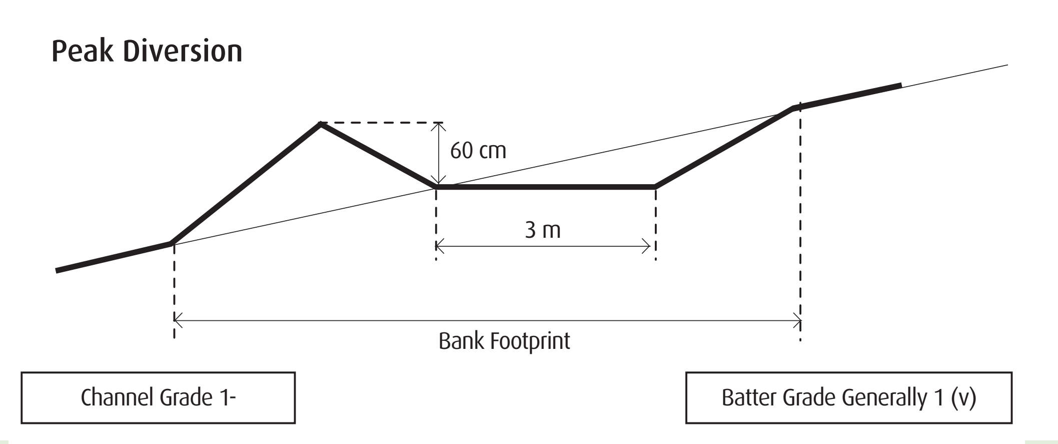
- **Control surface run-off.**
- On slopes greater than 8%, surface drainage structures e.g.; contour and diversion banks and inter-row drains can help to safely dispose of run-off water to stable waterways. By shortening slope lengths these structures can reduce impacts on erosion.
- On slopes greater than 15%, traditional run-off controls are often not suitable. Consult a qualified soil conservation specialist for advice.
- Plan crop schedule to have established crops or green manures on steeper ground for likely high rainfall times.
- Use mulch where possible to protect soil surface structure from raindrop impact.
- See Appendix 1 – Considerations for soil health when establishing a new vegetable block.
- Use 3% off contour mounded rows where possible to stop water build up in the block.
- Convey run-off across the slope at regular intervals, down-slope via diversion drains discharging into natural water courses or formed grassed waterways.
- Where the potential for extreme erosion is evident consult a qualified soil conservation specialist for advice.

- Do not cultivate in natural drainage ways or immediately next to them.

- In drainage lines use grass species with above ground runners or stolons such as Kikuyu and couch because they are ground hugging with the ability to spread.

- On easily erodible plateau soil, sloping land with intense rainfall events, 90 – 100% ground cover is necessary in the inter-row area. In drainage ways 100% cover is required.

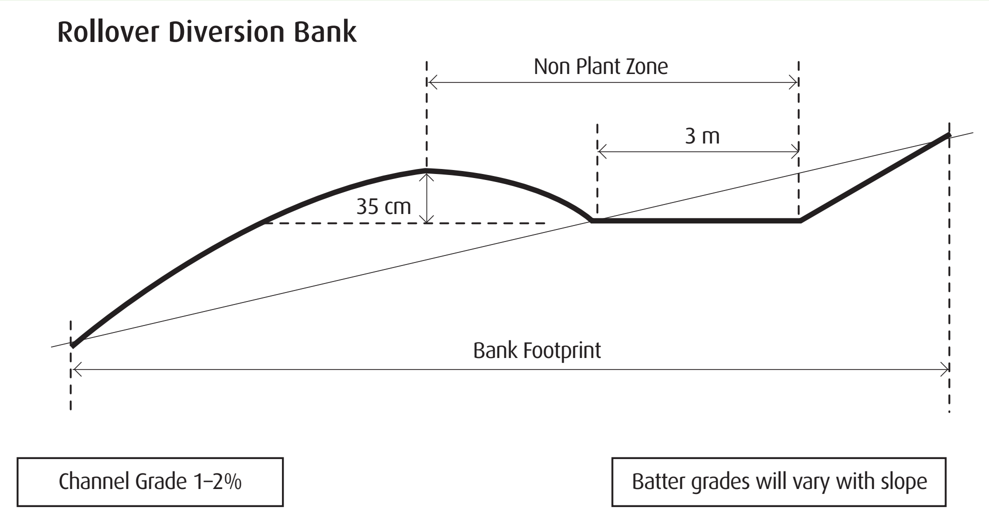
Left: Grassed waterway.
Photo: J Luethi



'Peak diversion banks are used to divert external run-on water and are not generally used in-crop as machinery cannot function over them.'

Excerpted from 'Cultivation Management on the Dorrigo Plateau', Northern Rivers CMA.

Peak Diversion Bank
Photo: Excerpted from 'Cultivation Management on the Dorrigo Plateau' NRCMA



'Rollover diversion banks are wider and flatter than peak diversion banks. Rollover diversion banks should only be used where it is desired that machinery continually cross the bank. Rollover banks can generally only be constructed on slopes up to 15% giving batter slopes around 1 (vertical): 8 (horizontal).'

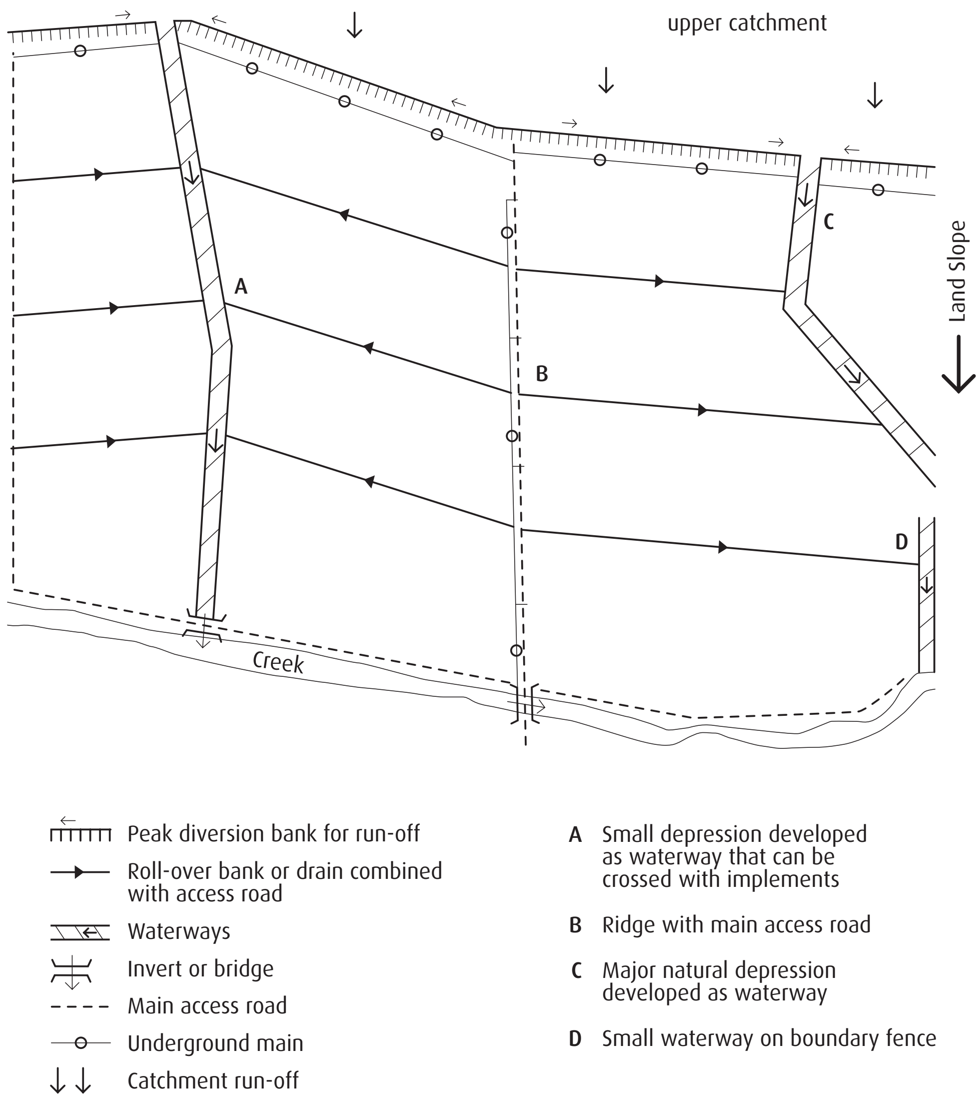
Excerpted from 'Cultivation Management on the Dorrigo Plateau', Northern Rivers CMA.

Rollover diversion banks shall be used to intercept and divert 'run-on' water from cultivated land where the length of slope above the cultivated paddock is greater than:

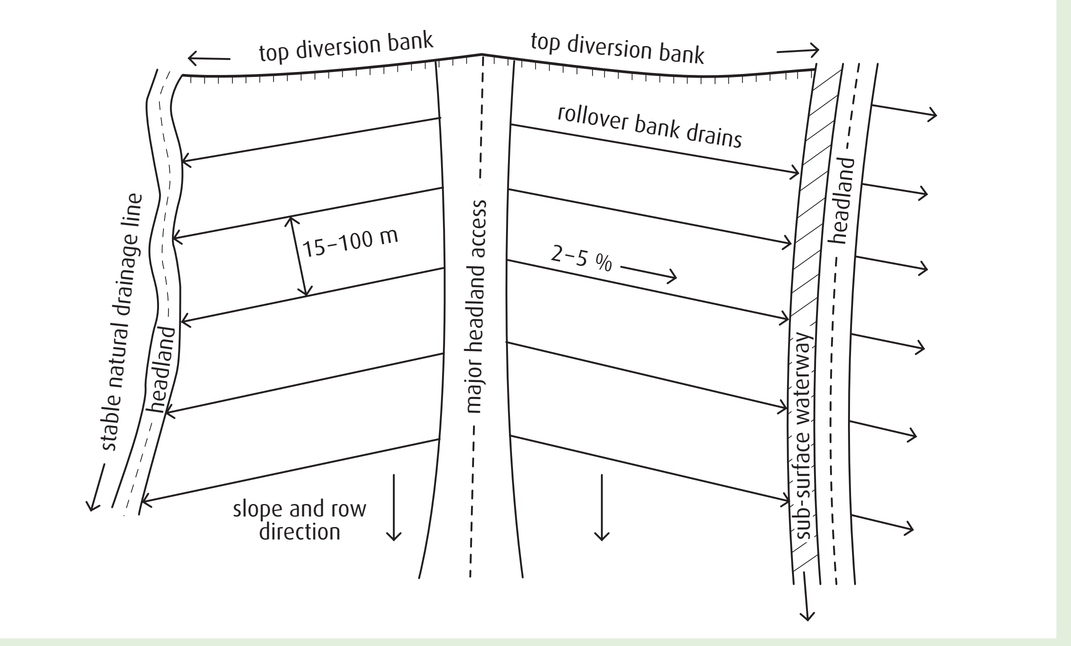
- 100m on slopes up to 5%
- 75m on slopes up to 8%
- 50m on slopes up to 13%
- 15m on slopes greater than 13%

Photo: J Luethi

A planned farm layout



Field design and layout for slopes.



Rollover bank intervals need to be closer on slopes greater than 8%.

Graphic adapted from NSW DPI publications.

2. SCHEDULE GREEN MANURE PHASE INTO ROTATION.

Maintain living ground covers to provide the best protection against loss of soil because they slow down run-off water after rain and allow water to infiltrate into the soil.

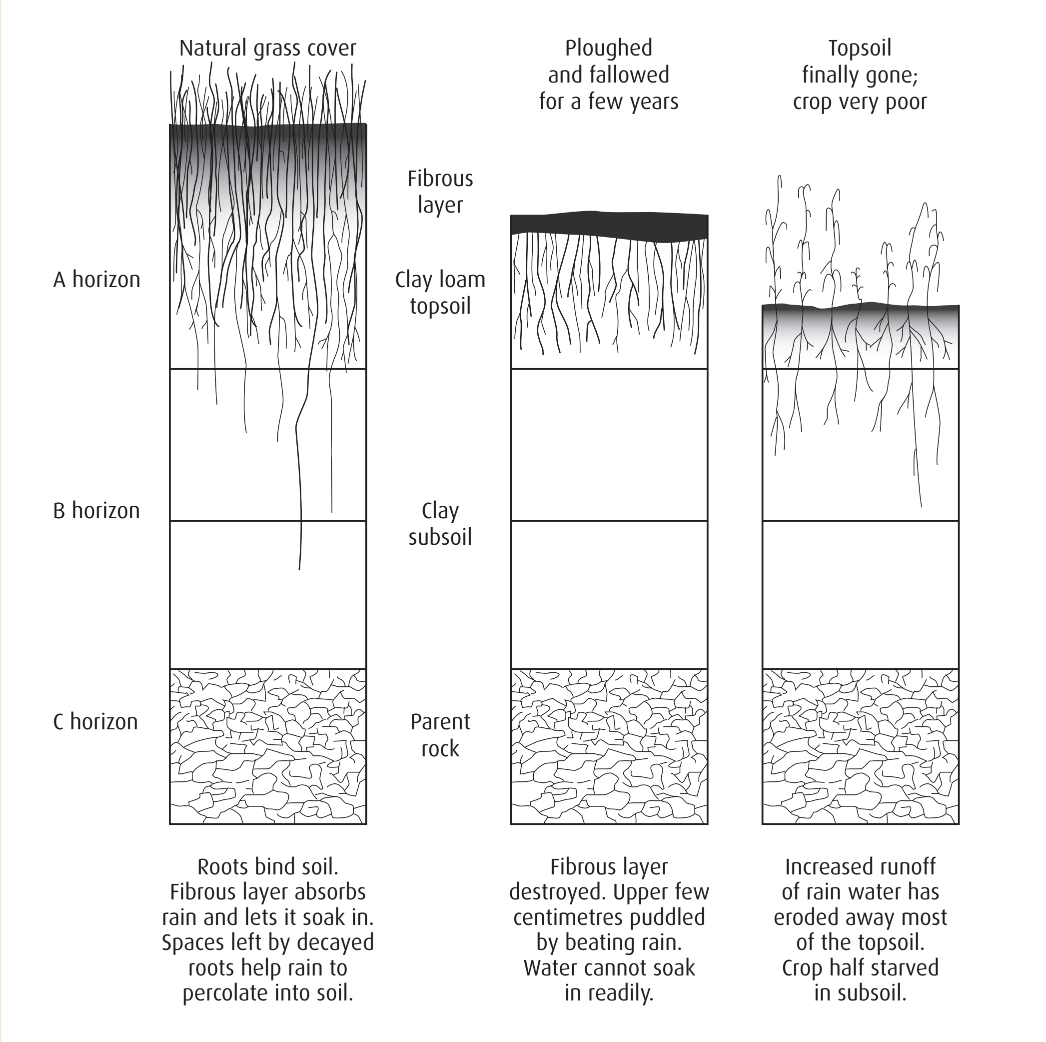
Types of 'green'manures that could be used:

- Sorghum
- Crotalaria
- Dolichos Lab Lab
- Cowpea
- Vetch
- Peas
- Lupins
- Oats

Established green manures:

- are highly resistant to erosion,
- support soil structure,
- support nutrient cycling,
- support soil biology,
- support nitrogen fixation and nutrient cycling,
- provide large amounts of organic matter to the soil in a cost effective way.

How does cultivation increase the risk of erosion?



Graphic: NSW DPI

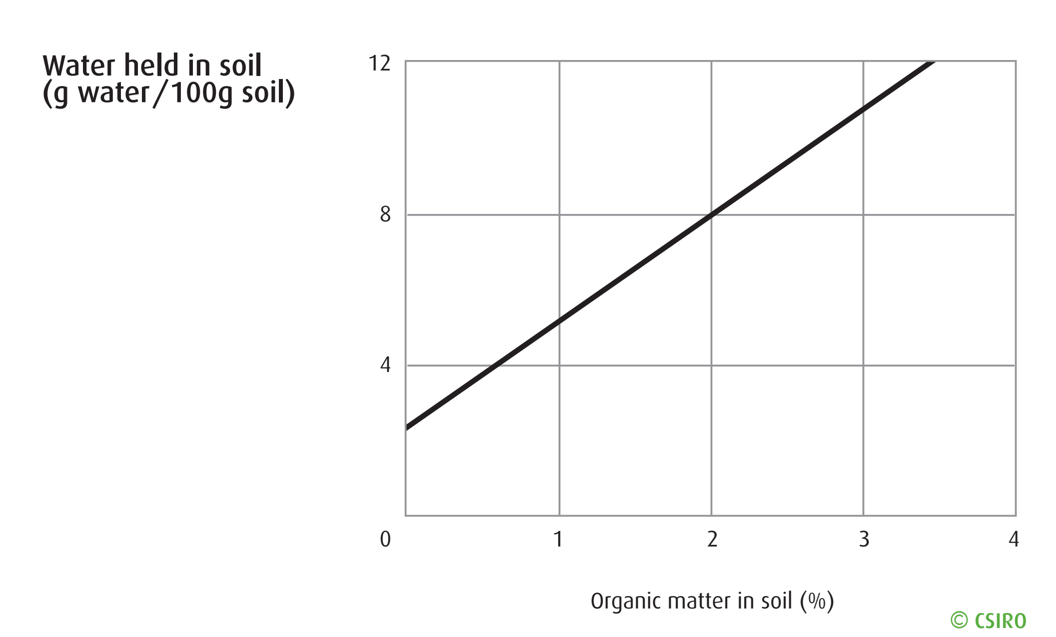
3. MAINTAIN MULCH COVERING WHERE POSSIBLE.

Mulch needs to be coarse to resist rapid breakdown and allow good aeration.

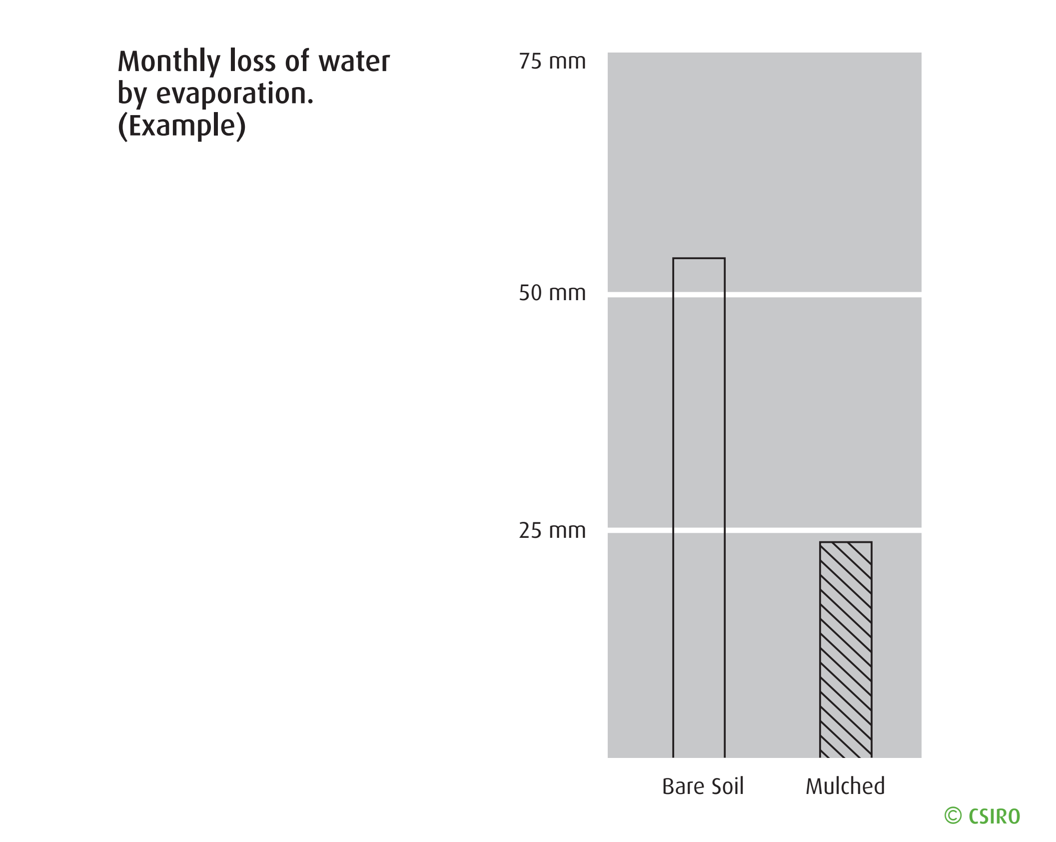
Types of mulch that could be used:

- grass or crop stubble,
- chopped up cane tops,
- waste husk material,
- chipped prunings,
- compost,
- artificial materials,
- killed green manure.

Photo: D Forrest



Excerpted from *Discovering Soils Series: Organic Matter and Soils*, CSIRO Publishing.



Excerpted from *Discovering Soils Series: Organic Matter and Soils*, CSIRO Publishing.

5. BE AWARE OF CURRENT ENVIRONMENTAL AND LEGAL RESPONSIBILITIES FOR:

- **Soil loss as laid out under:**
- NSW Protection of Environment Act
  http://www.austlii.edu.au/au/legis/nsw/consol_act/poteoa1997455/

- NSW Soil Conservation Act
  http://www.austlii.edu.au/au/legis/nsw/consol_act/sca1938215/

- Water Management Act
  http://www.austlii.edu.au/au/legis/nsw/consol_act/wma2000166/

- **Approval or licence requirements to carry out certain types of earthworks.**

Left: Soil erosion is a pollution event for the waterways receiving turbid, nutrient- laden material.
Photo: NSW DPI

BMP 2 – MANAGING SOIL STRUCTURE

SOIL HEALTH CARD TESTS: GROUND COVER, PENETROMETER, INFILTRATION, STRUCTURE

WHY IS SOIL STRUCTURE IMPORTANT TO ME AS A FARMER?

A well structured soil is critical to plant health. It allows water, nutrient and air movement; provides channels through which roots grow; resists soil crusting and compaction; provides habitat for soil organisms and is resistant to erosion.

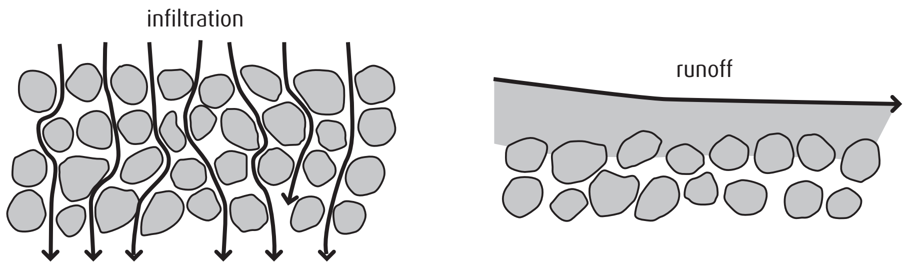
Good Soil Structure

Poor Soil Structure

Photos: I Biggs

Soil compaction is a result of compressed structure which means:

- less air, water and root space is available. There are less sites for nutrient storage and there is less area for roots to access so plant nutrition (more fertiliser required) and plant growth are compromised (Refer to the art of bonsai).
- less water is stored in the soil. There is less space between the soil structural groups so the total volume that the soil can hold is depleted. The soil dries out sooner and can't hold as much in reserve when recharged.
- drainage rate is impeded in compacted soils so water moulds have longer periods of anaerobic conditions that favour their growth. Root rot limits nutrient and water uptake, so production is less.
- water infiltration rate is much lower so there is less water penetrating into the soil and more run off, resulting in less effective rainfall. Surface compaction also increases slippage of machinery.



Changes in water-flow pattern due to soil crusting.

Excerpted from Building Soils for Better Crops, 2nd Edition, published by the Sustainable Agriculture Research and Education (SARE) outreach office, USDA.
For more information about SARE and sustainable agriculture, see www.sare.org.

Examples of the effect of mulching on the rate that water moves into soil (mm water per hour)

Soil	Mulched	Bare soil
Sandy loam	23	8
Silty loam	25	6
Silty clay loam	13	4

Excerpted from *Discovering Soils Series: Organic Matter and Soils*, CSIRO Publishing.

Soil compaction reduces pores or spaces in the soil which restricts:

- plant root movement,
- water infiltration and storage,
- air circulation,
- nutrient availability,
- biological activity and
- plant health.

Compaction restricts water infiltration.

Photo: D Forrest

HOW DO I MANAGE SOIL STRUCTURE?

1. MAINTAIN SOIL COVER TO MINIMISE EROSION.

- This is set out in **BMP 1**.

2. MINIMISE IMPACTS OF MACHINERY.

- Limit usage of machinery to essential operations when the soil is moist as soil structure is more easily compressed at those times.
- Use lighter machinery with turf tyres as this has less compactive effect.
- Minimise cultivation operations for seedbed preparation.
- Cultivate only when the soil moisture content is right.

3. LIMIT HERBICIDE AND SALTY/ACIDIC FERTILISER USE.

- Limit the frequency, type and area for herbicide application.
- These materials lower soil biology levels interfering with the maintenance and development of soil structure.

4. REHABILITATE SOIL COMPACTION LAYERS WITH ORGANIC MATTER ADDITIONS AND MECHANICAL MEANS.

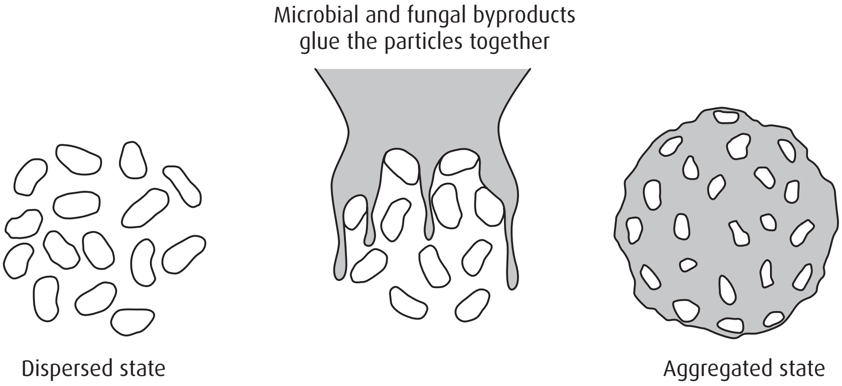
- Plan for green manure phases in crop rotation.
- Plant appropriate deep rooting species that will help break up the layer.
- Maintain ground cover as it assists in rebuilding soil structure.
- Ripping after cultivation can remove compacted layers as long as it is done at the right moisture content.
- Be aware that mechanical techniques to reduce compaction often give only temporary effects. A longer term option may be to instigate management practices that reduce the incidence of compaction.
- Include longer term crops in the rotation where possible to allow time for soil structure to redevelop.

5. MAINTAIN GROUND COVER BETWEEN CROPPING CYCLES.

6. PROMOTE SOIL BIOLOGICAL ACTIVITY.

- This is set out in **BMP 4**.

Soil fauna can have a major influence on soil structure by movement of soil particles during burrowing by larger species, mineralisation and incorporation of organic matter. The influence of soil fauna on the structure of soils may be local, such as within an ant nest or termite mound, or extensive, as by earthworms.



Soil biology provides many eco-services.
Microbial exudates glue soil particles to improve soil structure.
Excerpted from the ATTRA website: http://attra.ncat.org/attra-pub/soilmgmt.html

7. INCREASE ORGANIC MATTER INPUTS.

Organic matter improves:

- soil structure,
- soil's ability to hold nutrients,
- water infiltration,
- water holding capacity,
- regulates soil temperature,
- biological activity.

BMP 3 – MANAGING SOIL HEALTH FOR PLANT NUTRITION

SOIL HEALTH CARD TESTS: GROUND COVER, DIVERSITY OF SOIL LIFE, ROOT DEVELOPMENT, SOIL PH, LEAF COLOUR

WHY IS SOIL MANAGEMENT IMPORTANT TO PLANT NUTRITION?

Vegetable crops need a consistent supply of nutrients to maintain plant health and good production. High organic matter levels are necessary to maintain and increase nutrient storage and availability for general soil health and consequently for vegetable production. Nutritional stress lowers energy availability for the plant. Yield falls proportionally to the level of stress.

The ability of the roots to access nutrients is limited by topsoil depth, structure, soil moisture content, humus levels, biological activity, nutrient tie-up, nutrient presence and additions.

HOW DO I MANAGE SOIL HEALTH FOR PLANT NUTRITION?

1. DETERMINE SOIL AND PLANT NUTRITION REQUIREMENTS.

· Using the soil sampling guide (see Appendix 5), provide soil samples to a recognized soil laboratory for analysis.
· Conduct the Soil Health Card (SHC) tests.
· Prepare a soil and plant nutrition plan based on laboratory analysis and Soil Health Card results.

2. INCREASE AND MAINTAIN HIGH LEVELS OF ORGANIC MATTER. THIS ENSURES MAXIMUM NUTRIENT CYCLING BY:

· increasing biological activity and biodiversity,
· increasing organic carbon levels,
· improving nutrient holding and exchange,
· improving root health due to better soil structure,
· improving water infiltration, holding and drainage,
· ‘unlocking’ phosphorus.

3. MANAGE SOIL PH.

A number of long-term chemical factors operate in bare soil strips on vegetable farms. A major problem is soils becoming more acid. In one local orchard, pH dropped from 6.3 to 4.3 in 4 years and eventually declined to 4.0 as a result of leaching and the acidifying effect of ammonium sulfate nitrogen fertiliser.

- Ameliorate low soil pH to improve activity of soil organisms. A high level of biological activity maintains minerals in the nutrient cycle; fungal hyphae are major stores of calcium. Good microbial activity ensures release of nitrogen and sulphur from organic matter.
- Maintain humus or soil organic carbon levels to buffer against fluctuation in pH and reduce aluminium toxicity.
- Supply calcium.
- Use appropriate forms of fertilisers to reduce acidification.
- Use with caution and in small amounts if using highly soluble acidic or salty fertilisers. They supply high levels of nutrient but can affect soil chemistry and biology negatively. This can lessen soil health by lowering existing biological biodiversity limiting the availability of nutrients in the soil.

At pH below 5.0 there may be:

- reduced microbial activity affecting release of nitrogen and sulphur from organic matter,
- high phosphorus fixation,
- reduced nodulation of legumes,

deficiencies of the elements:
- calcium
- magnesium
- molybdenum
- boron

toxicities of:
- aluminium
- manganese in solution

4. APPLY FERTILISERS AND SOIL AMENDMENTS APPROPRIATELY.

- Apply fertiliser at appropriate times and under conditions that facilitate uptake without leaching. Leaching nutrient contaminates the water cycle and causes off farm problems.
- Maintain fertility by replacing nutrients removed by harvest, leaching and nutrient fixation.
- Protect the roots and soil from strong nutrient solutions. Root hairs can be killed by strong nutrient solutions and if leached they can leave the soil more acidic by combining with alkaline elements including Ca, Mg and K.
- Supply minerals such as calcium additions to improve soil structure by increasing grouping of clay particles. This also improves the soil pH for soil organisms increasing capacity for worm activity, whose tunnelling improves soil structure.
- Ensure phosphorus is available as it is an important mineral for soil organism energy metabolism.
- As part of a vegetable nutrition program bulk or pelleted poultry manure and compost provide organic matter as well as nutrients. Encouraging vigorous ground cover between cropping cycles provides on site mulch and nutrient cycling as well as protecting soil structure and minimising erosion.

5. BE AWARE OF SOIL MOISTURE CONTENT.

- Improve the water holding capacity of the soil with additions of organic matter carbon.
- Supplementary irrigation maintains soil biological activity and nutrient uptake into roots, minimising nutritional stress.
- Apply fertiliser under soil moisture conditions that facilitate uptake without leaching.
- Use slow release or organic fertilisers.
- Use acidic/salty fertilisers at low rates.
- Substitute fertigation and foliar applications for side dressings.

BMP 4 – MANAGING SOIL BIOLOGY

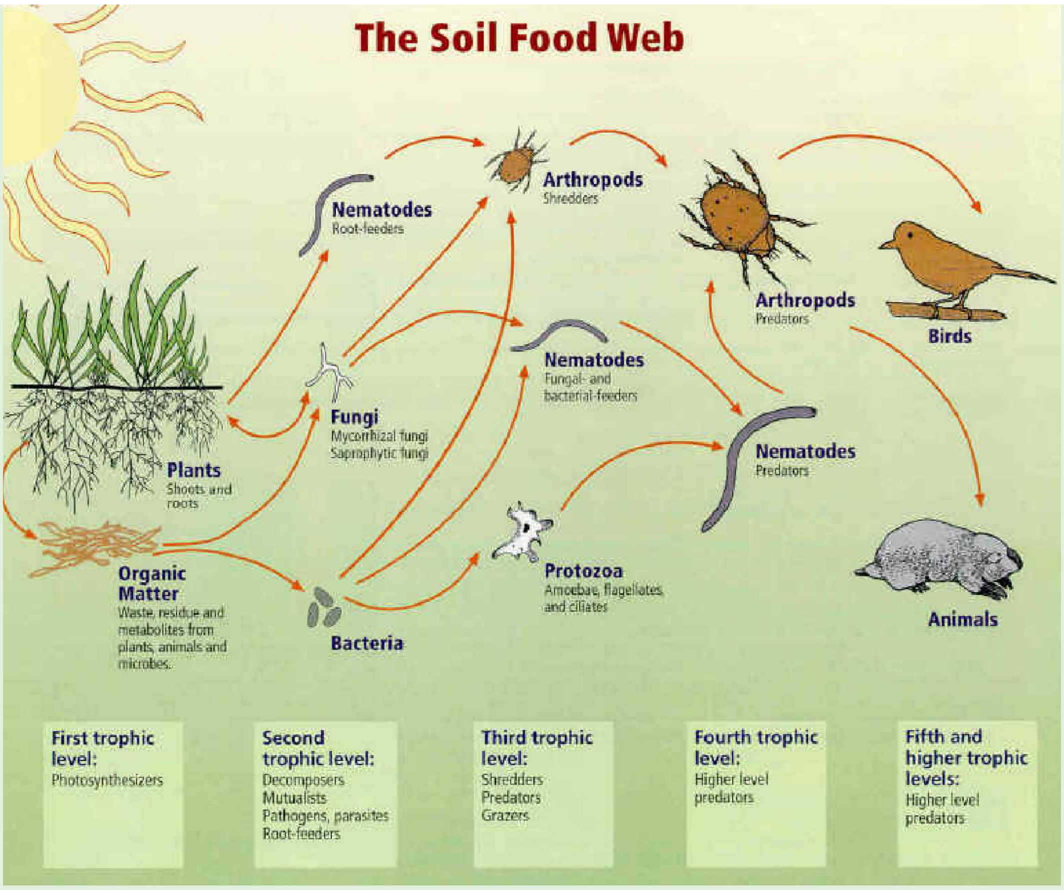
SOIL HEALTH CARD TESTS: GROUND COVER, SOIL STRUCTURE, DIVERSITY OF SOIL LIFE, ROOT DEVELOPMENT, EARTHWORMS, SOIL PH, BIO-TURBATION, CALICO STRIP TEST.

WHY IS SOIL BIOLOGY IMPORTANT TO ME AS A FARMER?

Soil organisms are nutrient managers.
They also determine many soil characteristics.

Soil biological activity sustains:

- decomposition of organic matter,
- nutrient cycling:
  - mineralization,
  - nutrient storage,
  - nutrient release,
- soil structure,
- root health,
- soil's ability to hold moisture,
- degradation of harmful chemicals,
- disease suppression.



Excerpted from Soil Biology Primer [online].
Available: soils.usda.gov/sqi/concepts/soil_biology/biology.html [Feb 2008].

HOW DO I MANAGE SOIL BIOLOGY?

1. ENSURE SOIL IS PROTECTED BY GROUND COVERS.

- Ground covers preserve soil moisture.
- Ground covers regulate soil temperature to suitable range for organisms.
- Minimise chemical use and artificial fertilisers.
- Living ground covers trap carbon on site through photosynthesis and supply nutrients and energy from root systems and vegetative growth to soil organisms. i.e. soil bacteria fix nitrogen and so add it to the soil. Use green manures and long term crops as part of the rotation.

2. BUILD UP AND MAINTAIN ORGANIC MATTER (OM) CONTENT.

- Vary the OM content. Composts, manures and mulches as well as on site or inter row material can significantly improve soil biological populations.

- Organic matter inputs can be increased through:
  - incorporating organic fertilisers into plant nutrition programs,
  - minimising herbicide and fungicide nematicide use,
  - minimising artificial fertiliser use,
  - maximising vigorous inter-row growth.

Healthy and diverse soil biological communities require:

- food from organic matter,
- root exudates,
- aerated soil structure,
- adequate minerals,
- adequate moisture.

3. REDUCE HARMFUL CHEMICAL USE, I.E. HERBICIDES AND PESTICIDES.

- Raised copper levels inhibit earthworm activity.
- High concentrations of nitrogen and chlorine in fertiliser inhibit fungi and other soil organisms.

4. SUPPORT MICROBIAL ACTIVITY.

- Maintain organic matter inputs to the soil.
- Use supplementary irrigation, if available, when soil is dry to maintain the benefits of soil biological activity.
- Supply adequate inputs of calcium and phosphorus.
  - Calcium improves clay structure, pH, cation exchange capacity (CEC) and bacterial activity supporting a food chain which releases high levels of nutrients. Calcium is stored and released by fungal hyphae maximising retention in soil and availability to plant roots.
  - Phosphorus is the mineral basis of all energy storage and use in plant and animal cells.

5. REVIEW PRODUCTION PRACTICES.

Bare soil inhibits establishment of a soil organic horizon and therefore provides a poor environment and reduced source of food for soil organisms.

- Incorporate crop and green manure residues.
- Use mulches for weed management.
- Use compost certified to the Australian Standard for soil and plant nutrition.
- Minimise the number of cultivations used.
- Build soil biological populations with long term crops or green manures as part of rotation.

Appendix 1

CONSIDERATIONS FOR SOIL HEALTH WHEN ESTABLISHING A NEW VEGETABLE BLOCK

Vegetable crops are adapted to soils which have:

- strong structure,
- free drainage,
- a high cation exchange capacity (CEC),
- high organic matter levels and
- high soil biological activity.

Site selection

The applicable Soil Health Card tests for the above will help rate suitability. Some specific issues to consider are:

- Topsoil depth can be assessed by a number of excavations to a minimum topsoil depth of 1 meter.
- Red clay loams typically have deeper topsoil and better structure than chocolate clay loams or loamy clay.
- Sandy soils have low water and nutrient holding capacity, but can be very suitable if organic matter levels are improved.
- Soil type cannot be changed but topsoil depth can be slightly modified by mounding before planting. This allows movement of excess water away from the row to a grassed inter-row with a fall designed to take it to natural drainage.
- Internal drainage, root area, nutrient availability, biological activity and nutrient balance can all be modified but on a less suitable soil type more inputs are needed to support the same level of yield. Environmental variations such as drought or persistent high rainfall pose increased risks to soil and plant health.
- Previous history of the site with reference to soil erosion or compaction, nutrient status and supplementary water availability will help rate suitability.
- Problems with water infiltration, holding capacity and drainage, root area available, nutrient availability, and soil pathogen risk can be related to soil type and previous history of use.
- Assess and test the soil for fertility, physical and biological condition using Soil Health Card tests and standard agronomic soil tests.
- Identify areas and aspects of the farm where soil conditions need to be improved or rehabilitated such as compacted soils and gully erosion.
- Prepare a soil management plan.
- Avoid planting in drainage lines.
- Avoid planting on steep slopes. Do not plant on slopes >15 % or 20%.
- Establish grassed waterways and shallow grassed drains above and within the block.
- Establish appropriate drains to handle run-on.
- North to east aspects are generally more sheltered and warmer.

Appendix 2

BMP 2 – SOIL STRUCTURE – ADDITIONAL INFORMATION

A lump of soil when broken in the hand, generally results in natural aggregates or 'peds'. The size and shape of the peds are the aspects of the soil structure.

Soil structure is the way the soil particles, sand, silt, clay and organic matter are arranged and the size and shape of gaps and channels (or pores) between them. The pores provide the space for air, water, roots, soil fauna and flora.

Exposed plateau landscape soils on vegetable farms are affected by:

· run-off that causes sheet and gully erosion,
· impact of raindrops and large water droplets that can shatter soil peds and dislodge soil particles,
· loss of organic matter,
· compaction by machinery and use of other equipment
· structural decline from over cultivation or cultivation of wet or dry soil.

Compaction, erosion, and declining organic matter levels all degrade soil structure, which results in:

· reduced rain fall infiltration resulting in increased runoff and erosion,
· reduced soil porosity, aeration and water storage,
· poor drainage and reduced trafficability,
· reduced root growth,
· declining yields,
· creation of a hostile soil environment for soil organisms.

Appendix 3

BMP 3 – SOIL HEALTH FOR PLANT NUTRITION – ADDITIONAL INFORMATION

The plateau soils are generally low in nutrients, have a low cation exchange capacity (low ability to hold nutrients) and low pH with a number of associated mineral toxicities and deficiencies. Also organic matter levels have declined to low levels where land has been cleared.

Vegetable production relies on good levels of soil organic matter, pH, cation exchange capacity (ability to hold nutrients), calcium and available phosphorus.

High organic matter levels are necessary to maintain and increase nutrient storage and availability for general soil health and for vegetable production.

Phosphorous (P) availability is reduced in krasnozem/ferrosol soils due to the high free iron content of the soil. Acid phosphates such as super phosphate are locked up very quickly by the soil with only a 5 – 10 % recovery.

The form of P available from compost and animal manures is in an organic form. Slow release of these manures is less prone to being locked up by the soil. Also release by soil biological process maintains nutrient availability.

Soil tests and plant diagnostic techniques (leaf testing) are the best way to match fertiliser requirements. Not enough fertiliser means nutrient deficiency. Too much fertiliser can also reduce yields, and more importantly pose serious environmental risks and waste money.

Ensure nutrient cycling is maximised by increased organic matter content and increase in beneficial biological activity.

Trials using composted macadamia husk and chicken litter have shown improvements in microbial activity and water holding capacity in degraded soils. Nutrient availability and fertiliser use efficiency is increased as organic carbon levels rise in the soil.

Use green manure, mulch and compost to increase the organic matter content of the soil and create a soil environment that is supportive of soil organisms.

Appendix 4

BMP 4 – SOIL BIOLOGY – ADDITIONAL INFORMATION

Soil organisms can represent 3% of the dry matter in your soil. A single teaspoon can contain tens of thousands of different species of organisms. They include bacteria, fungi, mites, ants, millipedes, beetles, earthworm, slugs and snails. Most of these are beneficial organisms and they actively manage or out-compete soil borne diseases/ pests.

Soil organisms derive their energy and nutrients from breaking down plant and animal material. When digesting this material they release oxygen and mineral nutrients that plants can use. When the soil organisms die they decompose and release more nutrients, so are valuable contributors to soil fertility.
Soil fauna can also have a major influence on soil structure by movement of soil particles during burrowing by larger species, and mineralisation and incorporation of organic matter.

Agriculture production activities can make soils less healthy and therefore less conducive for soil organisms. These activities decrease the diversity of soil animals (number of species) and soil community structure.
Soil animals require certain soil conditions to grow and survive. Agricultural practices change soil conditions, making it harsher for some soil organisms. Changes include the following;

- Soil moisture is decreased.
- Soil temperature is increased and there are bigger fluctuations in soil temperature.
- Less organic matter is in the soil and often only from one or two plants rather than a range.
- Soil pH becomes more acidic.
- Soil is often disturbed by erosion, vehicle traffic and tillage which removes organic matter (Above information sourced from **www.soilhealth.segs.uwa.edu.au**)

In local soils, studies (**Healthy Soils in Macadamia Orchards**, Van Zwieten, see page 37) have demonstrated there have been significant declines in soil carbon content and increase in soil bulk density with decreases also in microbial activity, earthworm numbers and soil biomass in general. The same studies also showed that macadamia orchards have fewer earthworms than control plots and other subtropical production systems sampled.

Trials using composted macadamia husk and chicken litter showed improvements in microbial activity and water holding capacity in degraded macadamia soils (Van Zwieten et al). A survey of macadamia roots in a local mulch trial also found a good association between healthy trees, increased fibrous roots and mulch. This was found to be the most effective treatment in ameliorating macadamia dieback.

Soil organisms need large supplies of organic matter to live on, warmth (but not extreme heat), moisture, oxygen and a near-neutral soil pH. Many soils under rainforest and wet sclerophyll forest in Tasmania, for example, have been found to consist entirely of earthworm casts and burrows. (Laffan, Kingston 1997)

Appendix 5

HOW TO TAKE A SOIL SAMPLE FOR LAB ANALYSIS

NSW DPI guide to collecting soil samples for lab testing.

Checklist:

- Plan your soil testing with your local District Agronomist, Horticulturist or advisor.
- Collect samples with clean equipment.
- Send samples to the laboratory as soon as possible after collection.

Tools required for sampling:

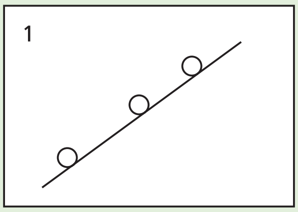
- Soil corer or spade
- Buckets
- New plastic bag or sample container (located in soil kit)
- Labels if more than one sample is collected
- Record sheet to record sample site and sample.

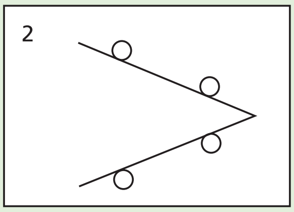
Remember a soil test is only as good as the care taken in sampling. Tools and equipment should be clean prior to sampling.

Taking a soil sample

- Look at the soils in the area you intend to sample. Submit a separate soil sample from each soil type (e.g. clay, loam or sand) and from paddocks that have been managed differently, because these factors affect fertiliser needs.
- For each sample, thoroughly mix a minimum of 20 soil cores (see following paragraph) in one bucket (the more cores taken the more reliable the sample). Fill the container supplied in the kit with the sample from the bucket. If you have collected multiple samples you can submit your samples in 500 gram bags to the laboratory. Make sure samples are clearly labelled.
- Soil cores should be collected at 0-10 cm depth. Avoid collecting the surface material such as leaf or organic matter. Deeper cores may need to be taken for the investigation of subsurface acidity and salinity or for larger horticultural crops (please contact your advisor for this advice).
- Once the samples have been collected they should be sent as soon as possible to the laboratory for analysis.

A map and written plan of the soil sampling area is essential for interpreting results and any subsequent testing. It is recommended that soil cores be collected along a fixed transect (e.g. 1 and 2). This method allows for re-testing and better monitoring of changes in fertility than random sampling. In areas where tree crops are planted samples should be collected along rows.





To obtain representative samples, do not sample from unusual sites such as: stock camps, manure patches, gateways, dams or water troughs, feedout areas, old fertiliser stockpiles, paddocks that have had fertiliser applied in the last 3 months.

Appendix 6

EXAMPLE: BIOLOGICAL FARMING NUTRITION MANAGEMENT PLAN FOR VEGETABLE CROPS

· Use mineral fertiliser such as a slow release lime and rock phosphate on an annual basis. Application can be at any time as long as there is a degree of soil moisture for biological activity to make the fertiliser available.
· Apply compost and/or chicken litter two (2) times per year to each crop.
· Use foliar fish/seaweed emulsion, which has nitrogen and a range of trace elements, which helps nutrition.
· Grow appropriate green manure crops as part of the rotation.
· Use small amounts of Potassium (K) sulfate on a more regular basis to top up K levels.

This type of regime:
· minimises leaching,
· provides a slow and steady release over the year,
· adds organic matter,
· supports soil biology,
· supplies nutrients to trees,
· improves soil structure.

WANT TO KNOW MORE?

Northern Rivers Soil Health Card for Vegetables and **Soil Best Management Practice Guide for Vegetables** are available to download from the following websites:

SoilCare Inc	http://www.soilcare.org.au
Tuckombil Landcare	http://www.tuckombillandcare.org.au

GROUND COVERS

DPI 'Soil Management in Orchards'
http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0019/167140/soil-mgt-orchards.pdf

Covercrops for Subtropical Orchards – NSW DPI
http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/119803/cover-crops-subtropical-orchards.pdf

Reducing erosion and other soil degradation in macadamia orchards
http://www.dpi.nsw.gov.au/agriculture/horticulture/nuts/soil-nutrition/soil-macadamia

Sweet smother grass – a perennial ground cover for subtropical orchards
http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0009/119844/sweet-smother-grass.pdf

Maku lotus – a legume ground cover for subtropical orchards
http://www.dpi.nsw.gov.au/agriculture/horticulture/nuts/soil-nutrition/maku-lotus

Amarillo peanut: a perennial ground cover for subtropical orchards
http://www.dpi.nsw.gov.au/agriculture/horticulture/nuts/soil-nutrition/amarillo-peanut

DPI 'Soil Erosion Solutions Fact Sheet 4: 'Groundcover'
http://www.northern.cma.nsw.gov.au/pdf/groundcover.pdf

DPI 'Shade Tolerant Ground cover in macadamia orchards'

SOIL BIOLOGY

Soil biology basics is an information series describing basic concepts in soil biology.
http://www.dpi.nsw.gov.au/aboutus/resources/factsheets/soil-biology-basics

Alternatives to Copper for Disease Control in the Australian Organic Industry
http://www.rirdc.gov.au/reports/ORG/07-110sum.html

Earthworm management on NSW Northern Rivers' farms -
http://www.tuckombillandcare.org.au/projects/Worminformationflyer3-230506B.pdf

Fungicides and Soil Health
http://www.tuckombillandcare.org.au/projects/Fungicides%20and%20Soil%20Health.pdf

How to encourage soil organisms
http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0003/41637/Soil_organisms.pdf

Life in the Soil – CSIRO
http://www.csiro.au/files/files/pcz9.pdf

Soil Biology Primer
http://soils.usda.gov/sqi/concepts/soil_biology/biology.html

Soil Ecology and Management
http://www.safs.msu.edu/soilecology/soilbiology.htm

Soil Biology movies:
http://www.agron.iastate.edu/~loynachan/mov/

Soils Are Alive, University of Western Australia – Professor Lyn Abbott
http://www.soilhealth.segs.uwa.edu.au/soil_biology

GENERAL SOIL AND ORCHARD INFORMATION

Farmcare: Cultivating a better future. Code of Practice for sustainable fruit and vegetable production. (1998) Queensland Fruit and Vegetable Growers Organisation. Brisbane, Qld. Book – QDPI publication

Planning, Establishing and Maintaining Sustainable Tree Crops on NSW North Coast – Land, Soil and Water Management. Bruce Hungerford, ACOTANC conference 1995
http://www.newcrops.uq.edu.au/acotanc/papers/hungerfo.htm

Carr, A. (1986). Buying the farm for horticulture-site it right, Department of Primary Industries, Queensland.

'Healthy soils in macadamia orchards' Lukas Van Zwieten
http://www.soilcare.org.au/links/Van%20Zwieten%20Healthy%20Soils.pdf

Soil Quality Publications – US Dept of Agriculture
http://soils.usda.gov/sqi/publications/publications.html#flyers

DPI Agnote: 'How to compost on farm'
http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0003/166476/compost-on-farm.pdf

DPI Agnote: 'Using compost on macadamia farms'
http://www.dpi.nsw.gov.au/agriculture/horticulture/nuts/soil-nutrition/compost-macadamia/using-compost-in-macadamia-orchards.pdf

DPI primefact: 'Organic macadamia growing'
http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0020/191144/Organic-macadamia-growing.pdf

Soil Health.Com – general soil information with emphasis on soil biology
http://www.soilhealth.com/

NSW Department of Primary Industries publications available from:
Phone 1 800 028 374
http://www.agric.nsw.gov.au

Ag-Facts/Ag-Notes
http://www.dpi.nsw.gov.au/aboutus/resources/factsheets/agfacts_and_agnotes

Prime Fact Notes
http://www.dpi.nsw.gov.au/aboutus/resources/factsheets

Highly recommended books for basic soil information.

SOIL SENSE – NSW DPI Publications (order on-line)
http://www.agric.nsw.gov.au/reader/soil-sense-north-coast

Discovering Soils Series, CSIRO Publishing

OTHER RESOURCES

Abigail Jenkins, NSW DPI Soil Advisory Officer, Wollongbar
abigail.jenkins@dpi.nsw.gov.au

North Coast TAFE – Wollongbar, Sneaths Road, Wollongbar, NSW
(ph 02 6620 4200) Contact the Agriculture Section (Block 'D') for information on soil classes and other agriculture courses.

The most reliable sources of information on-line will be found at university and government sponsored web-sites. Suggested words and phrases for search engines: soil biota; soil organic matter; soil organic carbon; soil organisms; soil ecology; soil quality; soil health; soil fauna; earthworms; nutrient cycling.

DICTIONARY OF TERMS

BIOTURBATION:
the mixing of soil organic matter into the soil profile by organisms.

BULK DENSITY:
the measure of how tightly packed soil particles are in soil. The higher the bulk density the lower the soil pore space.

CATION EXCHANGE CAPACITY (CEC):
the capacity of soil to hold nutrients for plant use. Specifically, CEC is the amount of negative charges available on clay and humus to hold positively charged ions. Effective cation exchange capacity (ECEC) is reported for acid soils (pH<5). Expressed as centimoles of charge per kilogram of soil (cmolc/kg).

COMPACTION:
compaction occurs when forces compress the soil and pushes air and water out of it so that it becomes dense.

C:N RATIO:
amount of carbon relative to the amount of nitrogen present in organic matter.

BANKS:
Contour bank:
an earth embankment that runs across the slope following the contour of the land, with a shallow channel on the upslope side. It is designed as a barrier to surface water flow.

Graded bank:
similar to a contour bank but designed to have very slight fall along the upslope drain channel. The grade is usually 0.1–0.5%.

Diversion bank:
specially designed bank with drain on the upslope side that diverts excess water from a sensitive area. It is graded but not usually more than 3%.

EXUDATES:
soluble sugars, amino acids and other compounds secreted by roots.

GROUND COVER:
any plant or plant residue that covers the soil surface and protects it from erosion and moisture loss.

HUMUS:
organic matter that is so decomposed that it can no longer be recognised as individual components is known as humus. The highly complex compounds that make up humus are able to resist further decomposition, and therefore accumulate in the soil.

MINERALISATION:
biological process in which organic compounds are chemically converted to other simpler organic compounds or inorganic forms, such as ammonium or phosphate, by soil microorganisms.

MULCH:
any material that is placed on the surface of the soil.

ORGANIC MATTER:
anything that contains carbon compounds that were formed by living organisms. Examples include lawn clippings, leaves, stems, branches, moss, algae, any animal parts, manure, sawdust, insects, earthworms and microbes.

PEDS:
clumps of soil that stay together as one structure when soil is disturbed with minimal force, such as with a shovel.

SOIL ECOLOGY:
the study of interrelations among soil organisms and between organisms and the soil environment.

SOIL FOOD WEB:
the inter-connected community of organisms living all or part of their lives in the soil.

SOIL ORGANIC MATTER:
the total organic matter in the soil. It can be divided into three general pools: living biomass of micro-organisms, fresh and partially decomposed residues (the active fraction) and the well-decomposed and highly stable organic material. Surface litter is generally not included as part of soil organic matter.

SOIL PH:
a measure of the acidity or alkalinity of soil. The scale range is from 0 (most acid) to 14 (most alkaline) with 7 as neutral. Soil pH can be measured in water or calcium chloride ($CaCl_2$). If pH is measured in water it is .5 to .8 higher than if measured in $CaCl_2$.

SOIL STRUCTURE:
the spatial assembly of the soil particles of sand/silt/clay and the spaces between them; the size, shape and arrangement of these aggregates.

WATER HOLDING CAPACITY:
the amount of water that can be held in soil against the pull of gravity.

ACKNOWLEDGEMENTS

SoilCare Inc thanks all the vegetable growers who, in their concern for soil health, volunteered their time and expertise to ensure the production of this resource would be useful and relevant for farmers.

Vegetable Industry Participants:

- Rod Bruin, Tyalgum
- Hamish Brace, Tyalgum
- Tony Lattanzi, Cudgera
- Rob Miles, Uki,
- Richard Mitchell, Carool
- Avi Mishtler, Byangum
- Doug Paddon, Cudgen
- Lynne Paddon, Cudgen,
- Michelle Stephens, Cudgen

SoilCare would like to thank individuals who donated photographs.

SoilCare would like to acknowledge and thank the following community, commercial and government organisations:

Richmond Landcare Inc for accounting services; Jackie Luethi, Community Landcare Coordinator, and Jerry Ryan (Soil Link Pty Ltd) for facilitation.

Walsh EMS Pty Ltd, Joanne Walsh for input into the development of the initial draft document.
Dr. J.J. Webber - Jos Webber for input into the second draft document.

CSIRO Publications for graphics.
NSW Department of Primary Industries - Abigail Jenkins, Soils Advisory Officer, for facilitation.
NSW Department of Primary Industries for graphics and guide to collecting soil samples.
North Coast TAFE Wollongbar - Dave Forrest and Phil Harvey for facilitation.
Northern Rivers Catchment Management Authority - Simon Proust, for facilitation.
US Dept. of Agriculture - Sustainable Agriculture Research & Education office, for graphics.

For more information about this document contact: info@soilcare.org
Download Northern Rivers Soil Health Cards and Soil Best Management Practice Guides at:
SoilCare Inc http://soilcare.org
Tuckombil Landcare http://www.tuckombillandcare.org.au