VISUAL SOIL ASSESSMENT

VOLUME 2

Soil management guidelines for cropping and pastoral grazing on flat to rolling country

Graham Shepherd, Craig Ross, Les Basher and Surinder Saggar

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VISUAL SOIL ASSESSMENT

COURTESY OF PIONEER BRAND SEED

PART ONE

Soil management guidelines for cropping

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Volume 2

Part One: Soil management guidelines for cropping.

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The following guidelines for sustainable cropping are taken from the publication cited below. For further information on recommended management practices for sustainable cropping, please refer to: *Soil management guildelines for sustainable cropping* T.G. Shepherd, C.W. Ross, L.R. Basher and S. Sagger. Lincoln, N.Z.: Landcare Research New Zealand; Distributed by Manaaki Whenua Press, 2000

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INTRODUCTION

These guidelines are designed to be used in conjunction with Volume 1, Field Guide for cropping and pastoral grazing on flat to rolling country. If the visual soil assessment (VSA) of your farm shows that soil structure is deteriorating, these guidelines will suggest management practices to repair the damage. If VSA indicated your soil is in good condition, use the practices in these guidelines to keep it that way.

Good management practices minimise or prevent the degradation of arable soil resources. As these resources are finite and non-renewable, their sustainable management is of prime importance. Sustainability is a balance between production, degradation and conservation, where maintenance of the productive capacity is critical.

This alluvial soil has a high structural vulnerability. It shows the rate and degree of structural degradation that can occur if management practices do not suit the soil type. To have a profitable and sustainable cropping practice it is not necessary to maintain the same soil conditions under cropping as under pasture. A significant change from pastoral conditions, however, will indicate the effects of your current management practices on your soils.

These guidelines provide methods to sustain soil condition by looking after soil structure and soil organic matter. They cover issues of soil compaction, erosion and loss of soil organic matter, but not fertiliser, pesticide, herbicide and pollutant issues.

Soils vary markedly in their vulnerability to structural breakdown. For example, soils from volcanic ash and soils with iron and aluminium oxides have a low structural vulnerability. On the other hand, soils from river alluvium and wind blown (loess) deposits have a high structural vulnerability. Finer soils (with silty clay loam, silty clay and clay textures) tend to be more vulnerable to structural damage than their coarser textured (silt loam and sandy loam) counterparts. Your farm management practices need to match the limitations and potential of your soil types.

Soil structure can have a marked effect on your crop production. Soils with large, dense clods or fine unaggregated particles will probably yield below the regional average. Soils with a nutty, well-aggregated porous structure tend to yield at or greater than the regional average.

GOOD SOIL MANAGEMENT – protecting your gross margins

The principal objective of any cropping programme is profitable production that can be sustained without damaging the environment. Good management maintains soil structure in a fine aggregated, loose and porous state. Good structure promotes water and air movement and extensive root development. As a result, production costs can be kept to acceptable levels and high yields can be maintained.

- Good soil structure lowers your tillage costs because it lowers resistance to ploughs and tillage implements as they pass through the soil. It also gives you more 'spring field work-days' where conditions are suitable for ploughing and cultivation.
- Good soil structure gives you good and even seed germination and emergence and unrestricted root development, leading to good plant growth and vigour. Quick, even establishment and vigorous crop growth will reduce weed infestation.
- Good soil structure reduces the susceptibility of your crop to root diseases and insect pest attack, and at the end of the season will give you good crop yields and grain quality, and a uniform ripening rate.
- Good soil structure will preserve your topsoil by minimising soil erosion, reduce your fertiliser requirements, and give you higher gross margins.

SUSTAINING YOUR SOIL RESOURCES

Monitor your soil

Monitoring changes in soil conditions using the VSA method, and adopting appropriate good soil management practices enable you to maintain your soil in healthy condition.

The management practices recommended here will allow you to crop your soil to its maximum capability. Cropping intensively mines your soil of nutrients and organic matter, and deteriorates soil structure if you do not replenish nutrients and organic matter, and carefully time your tillage operations. Shifts in soil health are often gradual and require ongoing monitoring and vigilance.

Manage your soil structure

Use no-till methods of sowing

No-till methods conserve soil structure and soil aeration, and improves infiltration and drainage. No-till conserves soil moisture in the seed zone, and maintains soil organic matter and biological activity (including earthworm populations) at levels similar to those under pasture.

Because no-till methods use fewer tractor hours, you save on both time and fuel. Reducing wheel traffic reduces soil compaction. No till eliminates the risk of creating tillage pans or plough pans.

Modern coulter designs have eliminated many of the problems associated with early no-till drills

No-till methods retain a firm soil surface, improving trafficability and reducing planting delays due to wet weather. The firm surface also reduces soil erosion, and provides opportunities for more management options. For example, the paddock can be stocked until shortly before sowing.

On the other hand, no-till methods have some disadvantages. If the paddock has a degraded soil structure through over-cultivation and compaction, or has an uneven surface, germination may be poor. If growing conditions are not ideal, crop growth may be uneven, and there is a greater risk of crop failure. It is a technique that suits some soils more than others.

Because plant material from previous pasture or crops is not broken down before sowing, soil nitrogen may be temporarily unavailable. Because the soil is undisturbed, pest and disease problems may increase, and fertilisers and pesticides are more difficult to incorporate into the soil.

Converting to no-till is not free. It requires new machinery and new skills. Agrichemicals are also required, particularly herbicides to remove plant growth before sowing.

Adopt minimum (reduced) tillage systems

If you think no-till methods are unsuitable for your conditions, try reducing your tillage. Spray pasture with herbicides and fallow for a short period before cultivating. This will reduce the number of passes needed to prepare a seedbed. Don't overwork the ground, particularly with powered harrows and rotary hoes that are hard on soil structure. Less cultivation reduces the risk of creating tillage or plough. Ideally, use a

The preparator[1] – a one-pass cultivator with two sets of double-row Danish mixing tines, a front roller and a bar crumbler at the rear

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single pass cultivation with multiple implements attached, or with a one-pass cultivator. Don't cultivate more deeply than you need to.

Light (silty) soils require less intensive cultivation than heavy (clay) soils. Fine seedbeds do not always relate to good soil structure. They can turn to 'concrete' as the soil consolidates and dries.

Cultivate at correct moisture levels

Primary cultivation should be done when soils are not too wet. Ploughing when the soils are wet prevents the soil fracturing, and causes smearing and the formation of thin plough pans that reduce infiltration of water.

To assess if soils are suitable for primary cultivation, take a piece of soil (half the volume of your index finger) and press firmly to form a pencil with your fingers. Roll the soil into a 'worm' on the palm of one hand with the fingers of the other until it is 50 mm long and 4 mm thick. Exert sufficient pressure with your fingers to reduce the diameter of the worm to 4 mm in 15 to 20 complete forward and back movements of the fingers. Conditions are suitable for cultivation if the soil cracks before the worm is made, or you cannot form a worm (for example, in sandy soils). The soil is too wet to cultivate if you can make the worm.

Conditions are right for **secondary cultivations** for seedbed preparation when clods can be easily broken in the hand or when spade slices dropped from waist height shatter readily to finer aggregates. Cultivation at the right soil water content maximises breakdown of clods, helps to preserve soil structure, and allows seedbed preparation with a minimum of passes.

The 'worm' test

Many New Zealand soils are 'Sunday Soils', too wet to cultivate on Saturday and too dry on Monday.

Clods that are too dry won't break down with further cultivation to give a fine seedbed. If cultivated too wet, clods will simply deform and pancake under wheel traffic.

Good timing is essential to prepare a good seedbed and help maintain soil structure by encouraging the soil to fracture along natural fissure planes.

Cultivating at the right soil water content

Soil cultivation when it is too dry.
No further reduction in clod size

Select cultivation implements that minimise structural damage

A good combination might be a disc ripper for primary cultivation, followed by a multi-tine harrow for secondary cultivation. Implements like rotary cultivators and some power harrows cause more structural damage than tined cultivators.

Disc ripper primary cultivator

COURTESY OF GARY SIM, CLARK FARMING GROUP

Multi-tine/harrow secondary cultivator

COURTESY OF VADERSTAD, NZ CROSSBOARD

If lack of capital limits the range of tillage and sowing equipment available, consider using contractors with the appropriate machinery. Using contractors will reduce the need to buy new machinery, but may limit your ability to carry out operations at the optimum time.

Manage vehicle traffic to avoid soil compaction

Vehicles with high ground pressures compact the soil, especially when the soil is very moist. Tillage machinery on wet soils also damages soil structure.

Minimise traffic. Reduce the number of vehicle passes by, for example, using wide tillage implements and combining them in tandem. Plan field traffic carefully by suitably positioning entrances to fields and having special transport lanes, so that vehicles are confined to designated tracks. Within the field, limit the area affected by wheel traffic by, for example, using tram lines, wide wheel based machinery or gantries.

Wheel traffic from traditional cultivation practices can cover more than 80 percent of the field. Damage to soil structure by wheel traffic when the soil is too wet is often hidden by the smoothing action of harrowing and drilling operations, but effects below the surface interfere with root development, crop establishment and crop growth.

Side-dressing and, particularly, harvesting under wet conditions can cause massive soil structural damage. If the soil is wet at harvest time, you will have to decide whether the potential loss from delaying harvest outweighs the cost of damage to the soil structure.

Harvesting under wet conditions

Tracked harvest bin

COURTESY OF DAN BLOOMER, HAWKES BAY REGIONAL COUNCIL

Soil compaction can be reduced by using low ground-pressure machinery, for example tractors fitted with low inflation-pressure dual wide tyres or tracked wheels, grain harvest bins and farm trailers fitted with tracks, or lightweight vehicles with low axle loads.

Soil compaction by tractors can be reduced by tine cultivating behind the wheels to a depth of at least 10 to 15 cm.

Subsoiling to break pans

Check for tillage pans. See VSA Field Guide Volume 1, Figure 6 (pp. 26–27). A root mat or a sudden change in hardness and structure, with very firm lower topsoils or upper subsoils often indicates the presence of a pan. Pans usually occur immediately below the tillage depth.

Sub-surface pans can occur naturally, but are often caused by tillage. They limit root penetration, forcing roots to grow horizontally and thicken, a response known as 'right-angle syndrome'. Implements such as rotary hoes form pans much more rapidly than discs and ploughs. Pans do not form under no-tillage, or under tine or spiked cultivators.

Subsoiling is beneficial for structurally degraded and compacted soils, and where there are tillage pans. It loosens the soil, allowing better air and water movement, and making it easy for plants to establish extensive root systems.

The aim of subsoiling is to crack any tillage pans or compacted subsoil as much as possible. It is best done when the soil is slightly moist and friable, and preferably going into a drying period in spring. Do not subsoil in wet conditions because soils will not shatter and crack.

Right-angle syndrome of roots and root mat (see insert) with an underlying tillage pan

Subsoiling when soils are too dry is expensive as it requires a lot of power and time. Dry soil tends to heave upwards rather than cracking. The best moisture conditions for subsoiling are the same as those for primary and secondary cultivation (see 'worm test' on page 10).

Install artificial drainage

Installing tile, mole, or perforated plastic pipe drains on poorly drained soils will reduce water logging, improve soil drying, increase rooting depth, and increase the number of days in spring when your paddock can be worked.

Minimise stock-treading damage

Remove stock from the paddock before the soil gets wet – before it reaches field capacity[2] or wetter.

Use crop rotations to suit your soil

Soils that are susceptible to compaction and structural damage need longer pasture phases and shorter crop phases in the rotation.

Include a restorative phase – perennial ryegrass and ryegrass/white clover, pasture leys, and green residue crops such as oats, mustard, or winter-active legumes (e.g., sullar, lupins). These have vigorous root systems that act as 'biological repairers'. Soil structural development is promoted by binding particles into aggregates, creating new drainage paths. As well as restoring soil structure and organic matter, pasture and green crops break crop disease cycles.

2. As a rule of thumb, field capacity is the moisture content after 48hrs of drainage from saturation

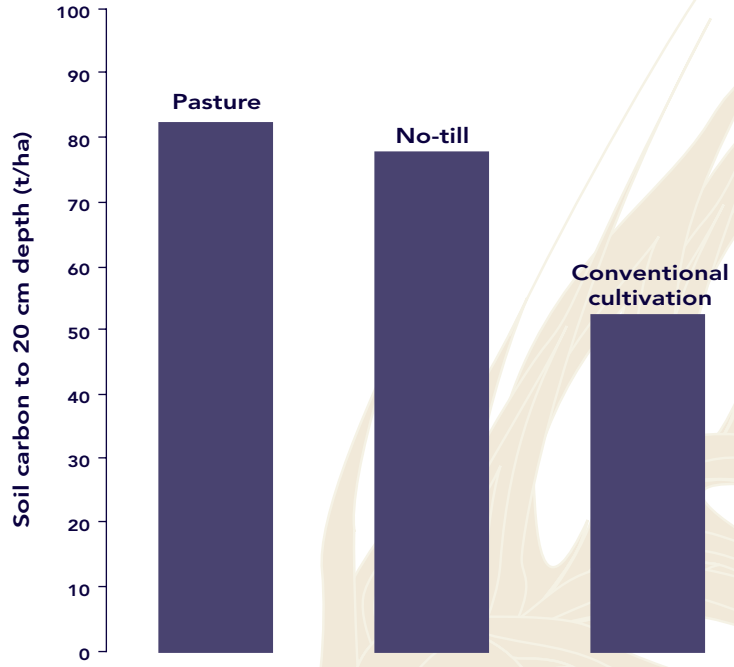
Manage soil organic matter (OM) levels

Soil OM regulates soil physical, chemical and biological conditions.

Organic matter acts as a 'glue' holding soil aggregates together. Loss of organic matter contributes to loss of soil structure and makes the soil less resilient (i.e. reduces its ability to recover). As SOM contains 95% nitrogen, 90% sulphur and 40% phosphorous, its decompostion can provide an important source of plant nutrients. The conservation of soil OM under no-till compared to conventional cultivation is due partly to minimum soil disturbance and higher residue inputs.

No-till systems maintain soil OM levels

Soil organisms and organic matter under no-till are similar to those under pasture. The conservation of soil OM under no-till compared to conventional cultivation is due partly to minimum disturbance of the soil.

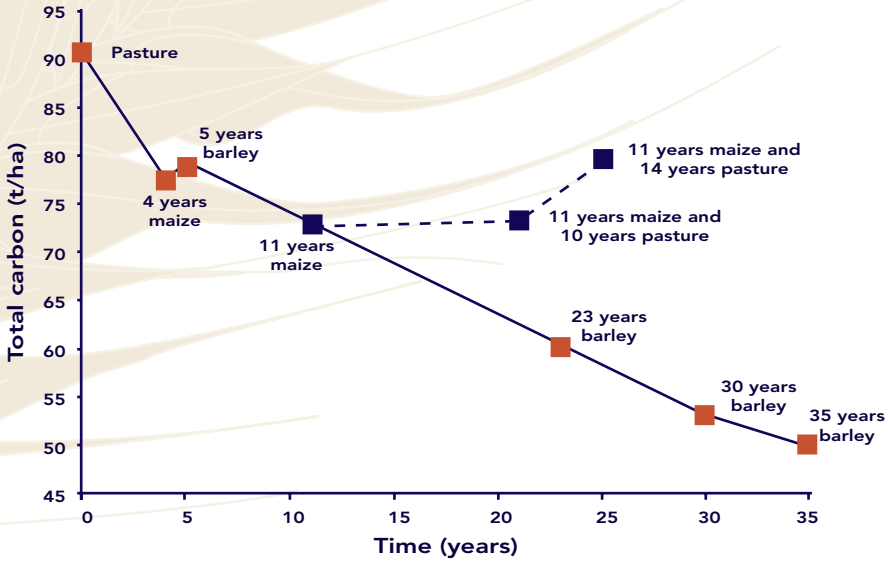


Carbon (Soil OM) levels under pasture, no-till and long-term (35 years) conventional cultivation

Cultivation reduces soil OM levels

Cultivation exposes more surfaces to aeration. This increases the decomposition of organic matter by soil organisms.

Monitor soil organic matter (carbon) levels on your farm. Test a long-term pasture and compare it with your cropping paddocks. Ask for an organic carbon test every 4 to 5 years as part of your routine soil testing programme.

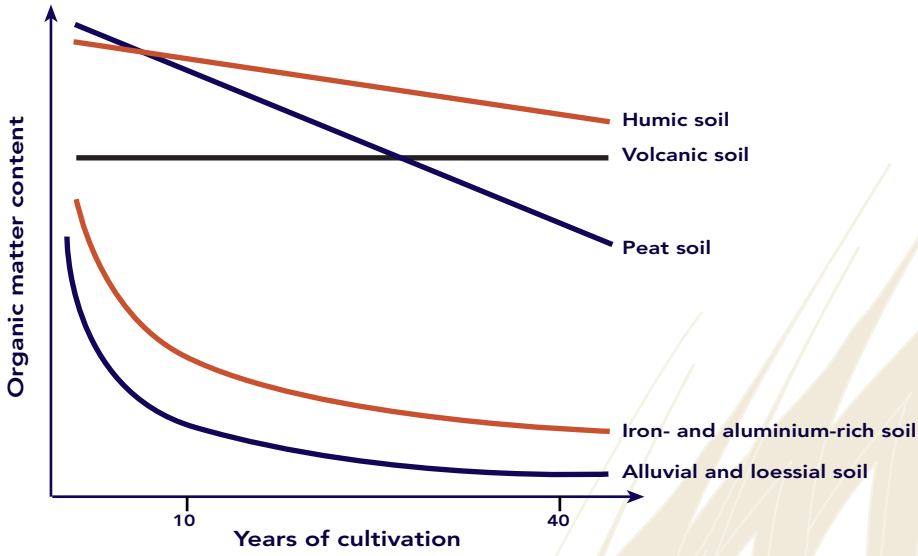


Total carbon as tonnes per hectare in the topsoil (0-20 cm) of the Kairanga silty clay loam under different land uses

The graph shows the rapid decline in total carbon in the first 4 to 5 years of cropping, and the very slow recovery of carbon after 10 years of pasture following 11 years of maize. Recovery of organic carbon begins to improve after about 10 years of pasture.

Organic matter loss varies with soil type

The texture of your soil, and the type of clay minerals it contains will affect how quickly it loses organic matter over years of cultivation. Organic matter loss is faster in light soils than heavy soils. Volcanic and calcareous soils lose organic matter slowly, but peaty soils lose organic matter rapidly when drained and cultivated



OM content vs years of cultivation for different soil classes

Ways to maintain or increase soil OM levels

There are ways you can improve your soil's organic matter content. Some of these are:

- Use no-till systems.
- Include 1 to 2 years of pasture for every 4 to 5 years of cropping.
- For medium- and long-term continuous cropping (more than 10 years), allow 3 years of pasture for each year cropping.
- Grow green manure crops, rather than leaving a bare fallow between crops.
- Graze forage crops in-situ.
- Retain crop residues rather than removing or burning them.
- Incorporate other organic materials, e.g., composted bio-solids, farm compost, straw, chicken manure, sawdust, appropriate industrial wastes, into the soil.
- 'Seed' with earthworms. Earthworms help break down plant residues into soil organic matter, and mix it through the topsoil.

A green crop of oats after it was cut and incorporated into a degraded soil. The crop was allowed to self-sow, and cut and incorporated into the soil for a further two seasons to help restore the soil structure

Is mixing in a little subsoil OK?

Subsoil contains virtually no organic matter and therefore has limited value for crop growth. It takes the incorporation of about 20 green manure crops to raise organic matter of one centimetre of subsoil to a reasonable level, and hundreds of dollars per hectare of applied fertiliser to correct the nutritional deficiencies of subsoil. Diluting your topsoil with subsoil is an expensive practice, yet it is unavoidable if there is soil erosion.

Prevent or minimise soil erosion

Soil loss can occur gradually by water and wind erosion, or rapidly by sheet wash, flow or rill erosion during major storms, often at unexpected times of the year. There may be several years between major storms, and it is easy to forget how devastating they are, and how important it is to apply the complete range of good soil management practices as insurance – year in, year out.

Soil erosion control depends on three principles:

a) Reducing the potential of water and wind to cause erosion by
   - stopping water getting into paddocks
   - removing water safely from paddocks
   - reducing water and wind speed

b) Creating stable seedbeds that resist erosion by water and wind.

c) Maintaining a protective groundcover

Assess the erosion potential of your paddock

The erosion potential depends on slope, seasonal weather patterns, and soil properties such as infiltration rate, aggregate size, aggregate stability and surface roughness of the seedbed.

Topsoil eroding to the plough pan from a single rain storm

Ways to prevent or minimise soil erosion

- Avoid cultivating slopes steeper than 12 degrees.
- Use no-till cropping.
- Cultivate and plant along the contour or at a slight angle to it.
- Adjust planting layout to minimise erosion potential. Make the final sowing pass at right angles to the wind and water.
- Divert runoff from drains, roads, tracks and headlands away from arable paddocks. Intercept open drains to prevent water reaching scouring velocities. Bench headlands to divert water from the fields.

A fine seedbed orientated up and down a slope has a high erosion risk

Drain embankment at the top of the paddock to prevent overflow

Benched headland diverts water from the top of the paddock, reducing the risk of erosion

Within-paddock contour drain limits water erosion

- Create stable waterways for removing surface water from paddocks. Break long slopes by contour intercept drains, and establish broad, shallow grassed waterways.
- Use strip cropping to provide protection from wind erosion.
- Avoid very fine seedbeds, and use surface roughness to reduce erosion. A wide range of aggregate sizes on the surface promotes infiltration, slows down surface run-off, and protects the surface from the blasting impact of wind and large droplets of rainfall or irrigation.
- Protect the ground surface by minimising the time the soil surface is exposed to wind and water. Grow cover crops, and time tillage carefully (preferably no-till where conditions are suitable). Leave crop residues on the surface during high erosion risk periods, and then incorporate them into the soil.

Only slight rill erosion where crop residues were incorporated

Severe sheet wash and rill erosion where crop residues were not incorporated

- Minimise compaction and ensure adequate water infiltration. Ripping wheel tracks reduces the effects of compaction on infiltration.

Slow infiltration and subsequent runoff along unripped wheel tracks leads to greater erosion potential than ripped wheel tracks with no runoff

Ripping wheel tracks is best carried out when the soil is too dry to roll a 'worm' according to the test described earlier

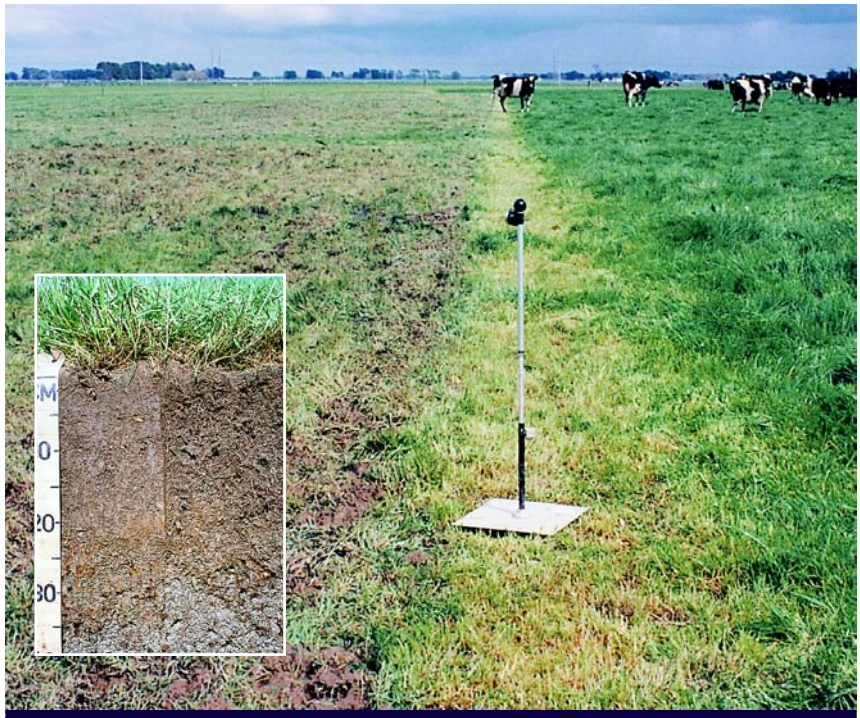
Sheet wash erosion of topsoil above a slowly permeable tillage pan

- Subsoil to break up tillage pans that may reduce water movement through the soil and increase surface runoff. Maintain good soil structure and organic matter levels to avoid surface crusting.
- Establish permanent grass strips, hedges or sediment fences to trap soil.
- Avoid cultivation on windy days. Significant amounts of soil can be lost in large dustplumes rising from cultivators during high winds.
- Plant shelter belts to protect paddocks from wind erosion.

TAKE HOME MESSAGES

- monitor soil condition
- maintain or improve organic matter levels
- consider no-tillage systems
- target tillage operations and implements to sustain soil structure
- minimise traffic impacts
- prevent soil erosion
- rotate crops to include a pasture phase
- incorporate organic residues and composted materials.

VISUAL SOIL ASSESSMENT



PART TWO

Soil management guidelines
for pastoral grazing
on flat to rolling country

VISUAL SOIL ASSESSMENT

Volume 2

Part Two: Soil management guidelines for pastoral grazing on flat to rolling country

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INTRODUCTION

A key function of good soil management on pastoral land is the preservation of soil structure. This is particularly important for the upper part of the soil profile, which is most vulnerable to treading damage. Under dry conditions, soil structure can become brittle and the topsoil can be turned to dust by treading. But treading when the soil is very moist or wet causes much worse damage.

Pugging by stock treading on wet soils is the main cause of damage to soil condition and reduction of productive potential of livestock farms. The problem is particularly severe on farms running heavy animals such as cattle and deer, and on soils with an easily damaged soil structure and slow subsoil permeability.

The rate at which water enters the soil and drains through it is determined by the structure. If the topsoil is compacted or pugged, drainage will be slow, regardless of how intensive the artificial drainage system is, or how permeable the subsoil. But soils with poor sub-surface drainage remain wet and susceptible to pugging for longer than well-drained soils. Because of this, they need careful management to protect soil quality and to maintain and increase production levels.

These guidelines will help you minimise the effects of poor drainage and pugging, and maximise production gains. They are intended to provide management options for sustaining soil health under pastoral farming. They do not cover acidification, heavy metal accumulation, insecticide and herbicide residues, or effluent and nutrient movement through the soil and into groundwater systems.

SUSTAINING YOUR SOIL RESOURCES

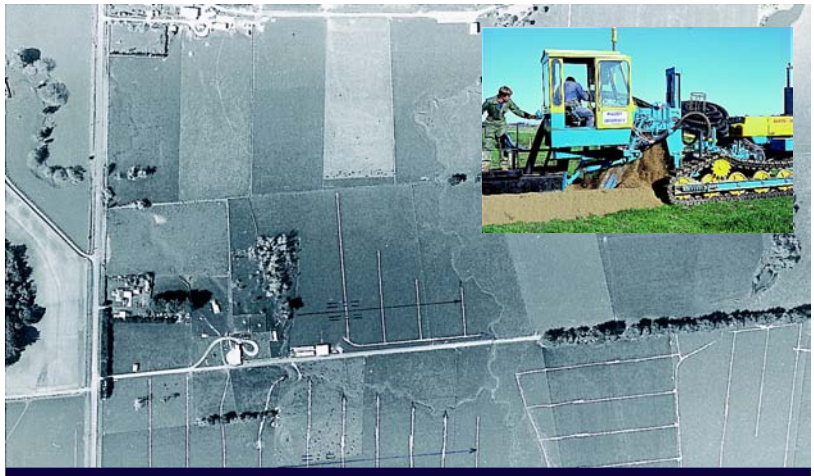
Maintain or improve soil aeration

Invest in a good soil drainage programme

Install a well-designed and implemented artificial drainage system. Good artificial drainage will give you more days in the year when soils are well aerated, and when soil is firm enough to resist compaction and pugging by livestock.

Maintain an effective mole draining programme. Mole draining is inexpensive ($100/ha), but effective. As a rough rule of thumb, it should be carried out every 5–7 years. The frequency of mole draining depends on soil type; drains can last for a decade on the heavier soils. The type of clay, and the soil water content at the time of, and following, moling also influence the life span of mole drains. Moles should be pulled when the soils are moist and reasonably plastic.

To assess whether soil moisture conditions are suitable for mole ploughing, use the 'worm test' described on page 31. The soil is suitable for moling if you can just make a worm 50 mm long and 3 mm thick without it cracking, and too dry for moling if the worm cracks.



An aerial photograph of a farm where the white lines show the artificial drainage system

To assess if soil moisture conditions are suitable for mole ploughing, take a piece of soil (half the volume of your index finger) and press firmly to form a pencil with your fingers. Roll the soil into a 'worm' on the palm of one hand with the fingers of the other until it is 50 mm long by 3 mm thick. Exert sufficient pressure with your fingers to reduce the thickness of the worm to 3 mm in 15 – 20 complete (forward and back) movements of the figures. The soil is suitable for moling if you can just make a worm without it cracking, and too dry for moling if the worm cracks.

Benefits of artificial drainage stem from a lowered water table and more rapid removal of water. This in turn leads to improved soil aeration, which promotes increased rooting depth, and increased root density at depth. The result is better quality pasture swards and a higher stock-carrying capacity.

A well-drained pasture should increase forage production and faster regrowth rates during wet periods. Well-drained pastures are also more likely to meet grass growth expectations in the critical early-to mid-spring period.

As well as increasing pasture production, effective drainage reduces the susceptibility of soils to compaction and deformation under treading, and increases their trafficability. Less pugging leads to better pasture utilisation, and allows a more flexible grazing plan. Well-drained soils will also reduce stock health problems such as lameness, foot rot and liver fluke brought on by wet conditions.

Over all, effective artificial drainage will give greater profitability from higher production with fewer farm inputs. Note that artificial drainage systems can facilitate effluent and nutrient movement to surface and/or ground water. For advice, contact your local Regional Council.

Aerate the soil

Aerate the soil periodically with a soil aerator. This will help rectify both capping of the surface soil (0 to 10 cm depth), and compaction in the 20 to 30 cm layer caused by treading. As well as improving surface infiltration and the movement of water through the soil, aerating the soil will bring benefits similar to those from artificial drainage.

When to aerate/subsoil. Aerating/subsoiling at the right soil water content not only maximises vertical and horizontal shattering of the subsoil, but also minimises pasture disturbance and surface heave. Soil moisture conditions are too wet for aerating/subsoiling if you can roll a 'worm' 50 mm long and 3 mm thick in the palm of your hand without it cracking (see above). Moisture conditions that are suitable for subsoiling are too dry for moling.

Soil aerators. Various aerators are available on the market; a number of these are pictured below.

Maintain earthworm numbers *See VSA Field Guide Volume 1, Figure 5, pp.64-65*

Earthworms are natural biological aerators. Through their burrowing activity, earthworms create channels and large inter-connecting macro-pores that increase the infiltration and conductivity of water and air into and through the soil. High earthworm numbers can be maintained by the selective use and careful timing of herbicide spays, by earthworm seeding and by minimising pugging.

Earthquaker[1]

COURTESY OF AITCHISON INDUSTRIES LTD

Soil aerators can significantly improve pasture growth, composition and colour

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Shakaerator

COURTESY OF FARMGUARD

Minimum pasture damage

Renovating rotor. Straight knife-like blades designed to aerate and stimulate the soil with minimal surface disturbance

COURTESY OF HUBBARDS MACHINERY LTD

Minimise treading damage

Stock treading on wet soils reduces soil pores important for water and air movement, and consequently reduces pasture root activity, density and vigour. Pasture production is reduced more by cattle treading than by sheep.

Pasture production is reduced by 30 to 60 percent by soil compaction caused by treading on moist soils. Pasture production can be reduced by 40 to 45 percent (and up to 90 percent) by soil deformation (pugging) when treading occurs on wet soils. Treading reduces pasture regrowth rates by 20 to 30 percent, and pasture utilisation by 20 to 40 percent, forcing farmers to budget for extra feed (up to 30 percent more) in the winter.

Treading reduces the quality of the pasture sward due to an increase in the area of bare ground, and the invasion of weeds and pasture species that are more water-tolerant and less desirable. Stock-carrying capacity can be reduced by 10 to 20 percent, and stock health impaired.

Management options to minimise treading damage to pastures

- Break feed with back fencing and mobile water troughs prevents stock re-trampling previously grazed pasture.
- Adopt on/off grazing where stock are allowed onto a paddock for periods between 4 to 8 hours to eat their pasture rations before being removed from the paddock and placed on off-pasture standing areas (see below).
- Graze paddocks when soils are sufficiently dry to minimise compaction and pugging. Apply the 'worm test'. If the soil cracks before a worm is 50 cm long by 2 mm thick can be made, soils are suitable for grazing.
- Use feed pads. To retain high post-grazing levels of pasture and help save paddocks from pugging damage when wet, dairy cows can be left on feed pads for a considerable time without significant loss in condition, provided high quality supplements are available. Supplements can include maize silage with selected meals, some containing by-pass protein.

Well managed unpugged pasture

Blue/grey capping of poorly aerated upper topsoil after one pugging event

The entire topsoil is grey and anaerobic (poorly aerated) after repeated severe pugging

Although viewed by many as prohibitively expensive to construct and use, loafing and feed pads make winter management easier. Construction costs are more than offset in the medium- and long-term by seasonal production gains of up to 45 percent from dairy cows. For advice before construction, contact your Regional Council.

- Use off-pasture standing areas such as loafing pads, tracks, lane ways and woodlots (if available) for short duration stock placement by bring in supplements, if the installation of a feed pad is not financially possible.
- Preferentially graze paddocks with a high resistance to pugging, and which recover quickly. During critical wet periods, target specific parts of the farm that have free-draining (eg, sandy or stony) soils, or other soils that have a higher resistance to pugging.

Poorly drained 'wet' soils on the left and well drained 'dry' soils on the right. Fence your farm where practicable to utilise the seasonal suitability of your soils for grazing.

- Where practicable, use off-farm grazing on soils that are more resistant to pugging. Off-farm grazing can be an option if paddocks on adjacent properties have suitable soils, and are able to be leased or exchanged for a short periods when conditions are wet. Soils with a high resistance to pugging can be identified if they continue to have good condition scores for soil structure, porosity, colour and mottles under intensive grazing. See VSA Field Guide Vol. 1, Figs 1–4, pp. 56–63.

A strongly structured soil with a high soil strength and resistance to pugging

- Prevent repeated severe treading events in the same paddocks from year to year. This will prevent long-term problems developing. The consequences on a fragile soil can be seen on page 36.
- Reduce stock density during vulnerable periods of the year. Reduced stocking density reduces treading pressures and damage to soil and pastures.
- Limit the use of 'sacrifice' paddocks as much as possible. 'Sacrifice' paddocks are used to stand stock on during wet periods. The soil is severely damaged, churned to mud when saturated, and structurally very weak. As a result these paddocks are often very slow to recover, and show poor plant establishment and pasture growth for months or years afterwards.
- Sow only a summer-harvested crop if a crop cycle is planned for pastoral renewal. A winter green-feed crop or a winter-harvested crop could lead to further serious damage to soil structure and drainage systems on poorly drained soils.
- Mob-stock pugged pastures with sheep to restore the soil surface.

Damage to sacrifice paddock

Prepare pastures in advance for grazing under wet conditions

- Ensure high pre-grazing pasture levels. High pre-grazing pasture levels (2500 to 3000 kg DM/ha) increase the cushioning effect and load-bearing capacity of the soil, and its resistance to pugging. A high leaf mass has a vigorous root system below ground which also helps to provide protection.
  Low pre-grazing levels expose the more susceptible parts of plants (growing points, leaf buds and surface roots) to treading damage, and result in lower pasture production in winter and spring.

Showing high pre-grazing levels of pasture dry matter

- Where feasible, try to maintain high post-grazing levels of pasture over the winter. Leaving about 1500 to 1600 kg DM/ha on the pasture after grazing encourages faster pasture regrowth while still maintaining stock condition. This will depend on seasonal feed budget, and stock grazing and management plans.
  High growth rates and pasture levels (2000–4000kg/DM/ha) help reduce soil wetness by intercepting more rain and increasing evapotranspiration. High pasture levels also encourage earthworms near the soil surface, which open up drainage channels and improve soil aeration.

Showing high level of post-grazing pasture dry matter

- For grazing during wet periods, select paddocks with a well-developed turf mat. A turf mat can increase the penetration resistance of saturated soil, and will provide greater resistance to pugging. Pastures continuously grazed with sheep, for example, are dense and will recover from one or two cattle treadings in any one year. The presence and thickness of a turf mat depends on soil fertility and grazing management. High fertility pastures do not have a turf mat and are more susceptible to pugging.
- Establish a flexible livestock policy that can adjust the class of stock in terms of cattle:sheep ratio, and the ratio of light weight to heavier weight cattle to coincide with those months that are most vulnerable to treading damage.

TAKE HOME MESSAGES

- monitor your soil structure

soil condition

- maintain good soil aeration

- minimise treading damage