

# VISUAL SOIL ASSESSMENT



VOLUME 1

Field guide for cropping and pastoral grazing  
on flat to rolling country

Graham Shepherd

## **VISUAL SOIL ASSESSMENT**

### **Volume 1: Field guide for cropping & pastoral grazing on flat to rolling country**

T. Graham Shepherd

Landcare Research  
Private Bag 11 052  
Palmerston North  
New Zealand

## **BIBLIOGRAPHICAL REFERENCE**

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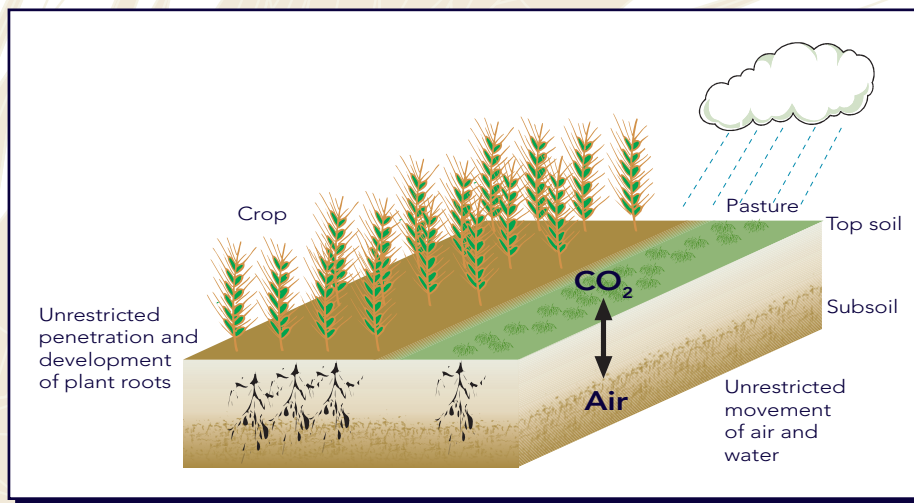




# INTRODUCTION

## THE QUESTION – To profit or to pug?

The soil's physical properties are vital to the ecological and economic sustainability of land. They control the movement of water and air through the soil, and the ease with which roots penetrate the soil. Damage to the soil can change these properties and reduce plant growth, regardless of nutrient status. Decline in soil physical properties takes considerable expense and many years to correct, and can increase the risk of soil erosion by water or wind.



**The primary functions of the soil are to provide plants with air, water, nutrients and a rooting medium for growth and physical support.**

Safeguarding the soil resource for present and future generations is a key task of land managers. Loss of soil quality (soil degradation) can significantly affect the environmental sustainability of the soil, and the economic sustainability of farming businesses.

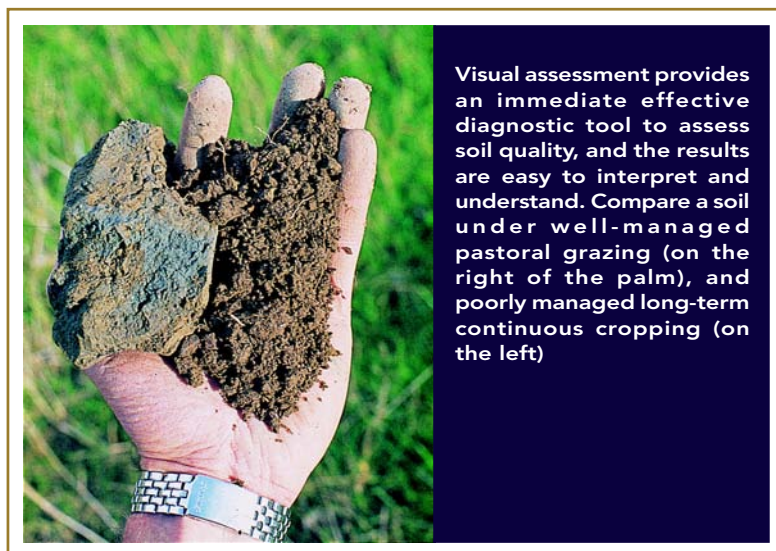
There is more to measuring soil quality than just assessing carrying capacity, crop yield or soil fertility. Often, not enough attention is given to:

- ▶▶ the basic role of soil quality in efficient and sustained production
- ▶▶ the effect of soil quality on the farm's gross profit margin
- ▶▶ the long-term planning needed to sustain good soil quality
- ▶▶ the need for land managers to be able to identify and predict the effects of their short- and medium-term land management decisions on soil quality.

As a land manager, you need reliable tools to help you make decisions that will lead to sustainable land management. The way you manage your farm has profound effects on your soil, and your soil has profound effects on your long-term profit.

## THE ANSWER – Visual soil assessment (VSA)

Many physical, biological and, to a lesser degree, chemical soil properties show up as visual characteristics. Changes in land use or land management can markedly alter these. Research in New Zealand and overseas shows that many visual indicators are closely related to key quantitative (measurement-based) indicators of soil quality.



These relationships have been used to develop VSA. The VSA Field Guide has been developed to help land managers assess soil quality easily, quickly, reliably and cheaply on a paddock scale. It requires little equipment, training or technical skills. Assessing and monitoring soil quality on your farm with VSA, and following guidelines for prevention or recovery of soil degradation, can help you develop and implement sustainable land management practices.

### The VSA method

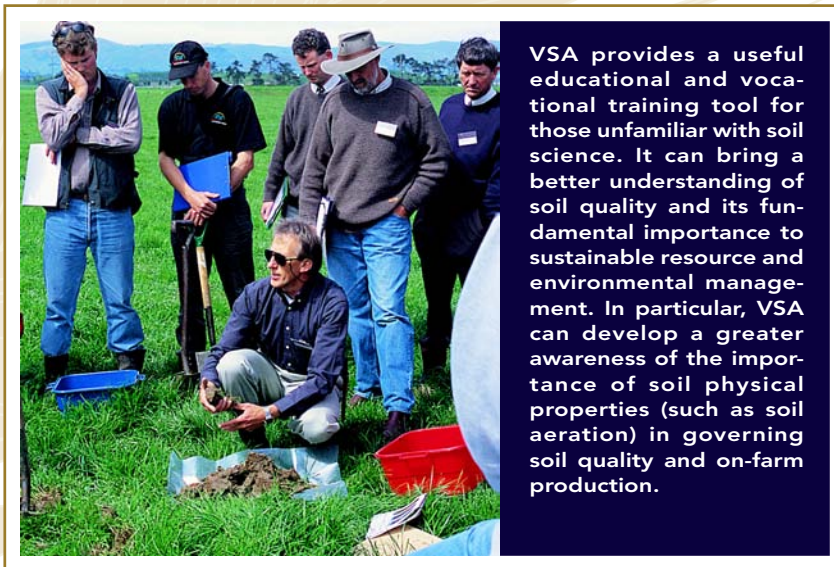
VSA is based on the visual assessment of key soil 'state' and plant 'performance' indicators of soil quality, presented on a score card. Soil quality is ranked by assessment of the soil indicators alone. It does not require knowledge of paddock history. Plant indicators, however, require knowledge of immediate crop and paddock history. Because of this, only those who have this information will be able to complete the plant indicator score card satisfactorily.

Plant indicators extend or qualify the soil quality assessment to allow you to make cause and effect links between management practices and soil characteristics. By looking at both soil indicators and plant indicators, VSA links the natural resource (soil) with plant performance and farm enterprise profitability. Because of this, the soil quality assessment is not a combination of the 'soil' and 'plant' scores. Rather, the scores should be looked at separately, and compared.



The following examples illustrate the practical application of VSA:

- ▶ A farmer records good crop yields and, as a result, thinks 'things are fine'. But on applying VSA, the farmer discovers that the soil quality score is moderate, and realises that the number of passes for cultivation, the need for weed and pest control, and the fertiliser requirements, have been increasing over time, along with the cost. With this knowledge, the farmer can make choices so that appropriate future management can lead to reduced input costs, increase profitability and improve soil quality.
- ▶ A farmer wants to expand cropping by leasing or buying additional land. VSA can provide important information about the soil quality of the land under consideration, which can help the farmer decide whether to lease/buy, or look for an alternative block of land.



VSA provides a useful educational and vocational training tool for those unfamiliar with soil science. It can bring a better understanding of soil quality and its fundamental importance to sustainable resource and environmental management. In particular, VSA can develop a greater awareness of the importance of soil physical properties (such as soil aeration) in governing soil quality and on-farm production.

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### Visual scoring (VS)

Each indicator is given a visual score (VS) of 0 (poor), 1 (moderate), or 2 (good), based on the soil quality observed when comparing the paddock sample with three photographs in the field guide manual. The scoring is flexible, so if the sample you are assessing does not clearly align with any one of the photographs but sits between two, a score in between can be given, for example 0.5 or 1.5. An explanation of the scoring criteria accompanies each set of photographs.

Because some soil factors or indicators are relatively more important for soil quality than others, VSA provides a weighting factor of 1, 2 or 3. For example, soil structure is a more important indicator (a factor of 3) than clod development (a factor of 1). The score you give each indicator is multiplied by the weighting factor to give a VS ranking. The total of the VS rankings gives the overall ranking score for the sample you are assessing. Compare this with the score ranges at the bottom of the page to determine whether your soil has good, moderate, or poor soil quality.

The soil quality assessment is not a combination of the scores from the soil and plant score cards. Placing the soil and plant indicator scores of soil quality side by side at the bottom of the plant indicator scorecard should prompt you to look for reasons if there is a significant discrepancy between the soil and plant indicators. The soil management guidelines for cropping and pastoral grazing (Volume 2) can help you do this.

## CARRYING OUT THE ASSESSMENT

### The VSA tool kit

The equipment needed for the VSA 'toolkit' is simple and inexpensive. It comprises:

- ▶▶ **1 spade** – to dig out a 20 cm cube of topsoil.
- ▶▶ **1 plastic basin** (approx. 35x35x19 cm) – to contain the soil when carrying out the drop shatter test.
- ▶▶ **1 hard square board** (approx. 26x26x1.8 cm) – to fit the bottom of the plastic basin on to which the soil cube is dropped for the shatter test.
- ▶▶ **1 heavy duty plastic bag** (approx. 74x49 cm) – on which to spread the soil, after the shatter test has been carried out.
- ▶▶ **1 VSA field guide (weather proof)** – to make the photographic comparisons.
- ▶▶ **1 pad of score cards** – to record the visual score (VS) for each indicator. Separate pads are needed for cropping and pastoral grazing on flat to rolling land. The soil and plant score cards have been printed back-to-back. See examples on pp 13 & 14.

## THE PROCEDURE

### 1. When should soil quality assessment be carried out?

The following recommendations are given as a general guide:

- ▶▶ **For cropping soils** – Test once a year after harvest and before cultivation. You could make a second test after the final cultivation to check the condition of the seedbed.
- ▶▶ **For pastoral grazing soils** – Test once a year in late winter or early spring.

VSA can be carried out effectively and reliably over a range of soil moisture levels, a characteristic that enhances the robustness of VSA as a tool. However, we suggest that you carry out the VSA when you judge that the soil is at the correct moisture content for cultivation, or is sufficiently dry to prevent compaction and pugging by wheel traffic and stock treading.

If you're not sure, apply the 'worm test'. Roll a 'worm' of soil on the palm of one hand with the fingers of the other until it is 50 mm long and 4 mm thick for cropped soils and 2 mm thick for pastoral soils. If the soil cracks before the worm is made, or if you cannot form a worm (for example, if the soil is sandy), the soil is suitable for testing. If you can make the worm, the soil is too wet to test. (See details in Volume 2.)

As long as the soil moisture condition is right, test at a similar time each year. This will make your results more comparable from year to year.





## 2. Setting up

It is important to be properly prepared to carry out soil quality assessments.

- ▶ **Time** – Allow about 20 minutes per site. The assessment process takes about 15 minutes to complete the soil indicator score card, and five minutes to complete the plant indicator score card for each site. Sample three or four sites in the paddock for a representative assessment of soil quality.
- ▶ **Reference sample** – Take a small soil sample from under the fence. The paddock to be sampled will have had a history of grazing or cropping. Taking a spade-depth sample from under a fenceline where there has been little if any cultivation or treading, allows you to see the relatively unaltered soil. This helps you give the correct visual score to the *soil colour matrix* indicator.
- ▶ **Sites** – Select sites that are representative of the paddock. When carrying out paddock assessments, avoid areas such as headlands or loading areas, which may have had heavier traffic than the rest of the paddock. VSA can also be used, however, to assess the effects of high traffic loading on soil quality; wheel tracks in row crops, for example, can be selected and the results compared with low traffic areas.

It is important to record the position of the assessment sites in your paddock accurately so you can come back to them for future monitoring. The simplest way to do this is to note the number of paces along a fence line from the paddock gate, and in from the fence line.

- ▶ **Set up the gear.** At the chosen site, put the square of wood in the bottom of the plastic basin, and spread out and anchor down the plastic bag beside it.

## 3. Site information

Complete the site information section at the top of the score card. Then record any special aspects you think relevant in the notes section at the bottom of the reverse side of the score card (for example, wet weather at harvest last season; soil heavily pugged by stock grazing stubble; topsoil blew off two years ago, etc.).

## 4. Carrying out the test

- ▶ **Take the test sample.** Dig out a 20 cm cube of topsoil with the spade. If the topsoil is less than 20 cm deep, trim off the subsoil before moving on to the next step. The sample provides the soil from which most of the soil state indicators are assessed.



The drop shatter test – Drop the same test sample a maximum of three times from a height of 1 m (waist height) onto the wooden square in the plastic basin. Then transfer the soil onto the large plastic bag and grade so that the coarsest clods are at one end and the finest aggregates are at the other end (as shown in the “Instructions” sections).

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- ▶ **The drop shatter test.** Drop the same test sample a maximum of three times from a height of 1m (waist height) onto the wooden square in the plastic basin. Transfer the soil onto the large plastic bag and grade so that the coarsest clods are at one end and the finest aggregates are at the other end (as shown in the ‘instructions’ sections, pages 17 and 57).

Systematically work through the score card, assigning a visual score (VS) to each indicator by comparing the soil laid out on the plastic bag with the photographs and description in the relevant section of the field guide.

## 5. The plant indicators

You can normally complete the plant indicator score card at the time you carry out the soil indicator assessment, by comparing your recollection of crop development or observations of the pasture, with the photographs in the field guide manual. But some plant indicators, such as the degree and nature of root development and grain development, cannot be assessed at the same time as the soil indicators. Ideally, these should be assessed at plant maturity.

The plant indicators are scored and ranked in the same way as soil indicators: a weighting factor is used to indicate the relative importance of each indicator, with each contributing to the final determination of soil quality. The ranking score is the total of the individual VS rankings in the right-hand column.

## SPECIAL USES OF VSA

The VSA procedure can be used to assess particular characteristics, and at any depth. For example:

- ▶ **During winter, there was severe pugging of the top 10 cm of topsoil.** Instead of taking one 20 cm cube of topsoil, take two 20x20x10 cm samples from 0 to 10 cm depth and combine to form a single sample. Take another two 20x20x10 cm samples from 10 to 20 cm depth and again combine to form a single sample. Test each combined sample separately and compare the results. The comparison will demonstrate the degree to which the upper part of the topsoil has been damaged by treading compared with the lower topsoil.
- ▶ **A plough pan layer is suspected at 10–20 cm depth** – Again, as described above, take two combined samples from 0 to 10 cm depth, and two combined samples from 10 to 20 cm depth, test separately and compare the results. The comparison will demonstrate whether the plough pan is significant or not.

## USING THE VSA RESULTS

VSA allows you to assess soil quality in a paddock but does not solve any identified soil quality issues. Once soil is degraded, it can take a long time (sometimes decades) to recover. To help land managers preserve or improve soil quality, guidelines are included in Volume 2 for the sustainable management of cropping and pastoral grazing on flat to rolling country.



# VISUAL SOIL ASSESSMENT



Of soil quality under cropping





# SCORE CARD

## Visual indicators for assessing soil quality under cropping

### SOIL INDICATORS

Land use:

Site location/Paddock name:

Date:

Soil type:

Textural qualifier:  Sandy  Loamy  Clayey

Moisture condition:  Dry  Slightly moist  Moist  Wet

Seasonal weather conditions:  Dry  Wet  Cold  Warm  Average

Visual Indicator of Soil Quality	Visual Score (VS) 0 = Poor condition 1 = Moderate condition 2 = Good condition	Weighting	VS Ranking
Soil structure & consistence (Fig. 1, p.17)		× 3	
Soil porosity (Fig. 2, p.19)		× 3	
Soil colour (Fig. 3, p.21)		× 2	
Number and colour of soil mottles (Fig. 4, p.23)		× 2	
Earthworm counts (Fig. 5, p. 25)		× 2	
Tillage pan (Fig. 6, p. 27)		× 2	
Degree of clod development (Fig. 7, p. 29)		× 1	
Degree of soil erosion (wind/water) (Fig. 8, p. 31)		× 2	
<b>RANKING SCORE (Sum of VS rankings)</b>			

Soil Quality Assessment	Ranking Score
Poor	< 10
Moderate	10 – 25
Good	> 25

If your soil quality assessment is moderate or poor, guidelines for sustainable management are given in Volume 2, Part One.

# SCORE CARD

Visual indicators for assessing soil quality under cropping

## PLANT INDICATORS

Visual Indicator of Soil Quality	Visual Score (VS) 0 = Poor condition 1 = Moderate condition 2 = Good condition	Weighting	VS Ranking
Crop emergence (Fig. 9, p. 35)		× 2	
Crop height at maturity (Fig. 10, p. 37)		× 3	
Size and development of the crop root system (Fig. 11, p. 39)		× 2	
Crop yields (Fig. 12, p. 41)		× 3	
Root diseases *		× 1	
Weed infestation *		× 1	
Surface ponding *		× 2	
Production costs (fertilizer, tillage, etc.) * (Fig. 16, p. 49)		× 2	
<b>RANKING SCORE (Sum of VS rankings)</b>			

\* Perceived

Soil Quality Assessment	Ranking Score
Poor	<10
Moderate	10 – 25
Good	>25

### SUMMARY

Ranking score		Do the soil and plant scores differ? If so, why?
SOIL INDICATORS	Plant indicators	

NOTES:



# **INSTRUCTIONS FOR ASSESSING SOIL QUALITY UNDER CROPPING**

## **SOIL INDICATORS**

## SOIL INDICATORS

### Soil structure and consistence under cropping

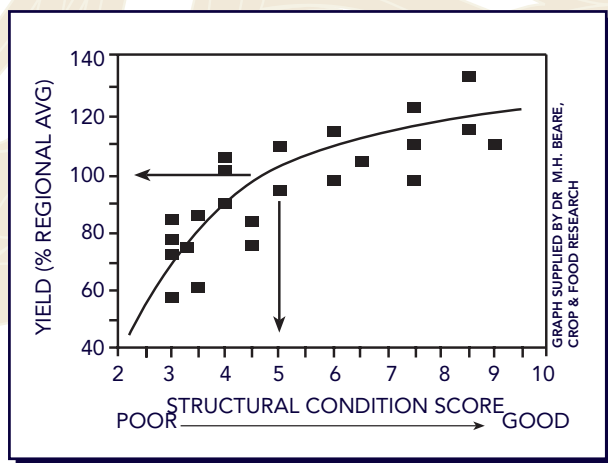
- ▶▶ Remove a 20 cm cube of topsoil with a spade (between traffic-free rows).
- ▶▶ Drop the soil sample a maximum of three times from a height of one metre (waist height) onto the firm base in the plastic basin. If large clods break away after the first or second drop, drop them individually again once or twice. If a clod shatters into small (primary structural) units after the first or second drop, it does not need dropping again. Don't drop any piece of soil more than three times.
- ▶▶ Part each clod by hand along any exposed fracture planes or fissures.
- ▶▶ Transfer the soil onto the large plastic bag.
- ▶▶ Move the coarsest fractions to one end and the finest to the other end. This provides a measure of the aggregate-size distribution. Compare the resulting distribution of aggregates with the three photographs opposite.

**GOOD SOIL STRUCTURE** is vital for growing crops. It regulates soil aeration and gaseous exchange rates, the movement and storage of water, soil temperature, root penetration and development, nutrient cycling, and resistance to structural degradation and soil erosion. It also promotes seed germination and emergence, crop yields and grain quality.

The effect of soil structure on crop yields is shown in Figure 16 (page 49), and in the graph below. Crop & Food Research have shown that soils with structural condition scores under 5 have a high risk of yielding below the regional average. Soils with scores higher than 5 tend to yield at or greater than the regional average.

Structural condition scores are based on the size, porosity and relative abundance of soil aggregates and clods. Soils with low scores have large, dense clods or fine unaggregated particles; those with high scores have a nutty, well-aggregated porous structure.

Good structure also increases the window of opportunity to cultivate at the right time, and minimises tillage costs in terms of tractor hours, the number of passes required to prepare a seedbed, and the size of the tractor and implements required.



**FIGURE 1: Visual scoring (VS) of soil structure and consistence under cropping**



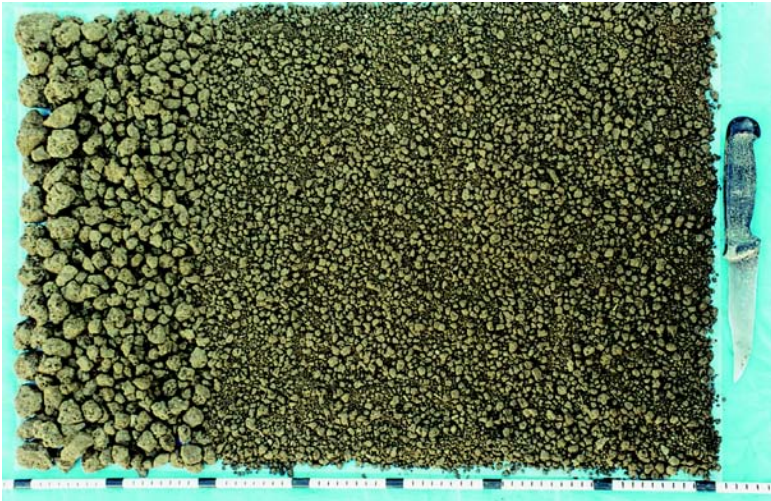
**POOR CONDITION VS = 0**

Soil dominated by extremely coarse, very firm clods with very few finer aggregates



**MODERATE CONDITION VS = 1**

Soil contains significant proportions of both coarse firm clods and friable, fine aggregates



**GOOD CONDITION VS = 2**

Good distribution of friable finer aggregates with no significant clodding



## SOIL INDICATORS

### Soil porosity under cropping

- ▶▶ Remove a spade slice of soil from the side of the hole created by taking the 20 cm cube of topsoil, or take a number of clods from the soil structure and consistence test.
- ▶▶ Examine the sample for soil porosity by comparing against the three photographs opposite.

SOIL POROSITY, and particularly macroporosity (the number of large pores), influences the movement of air and water in the soil. It is important to assess soil porosity as well as aggregate size distribution. Soils with good structure have a high porosity between and within aggregates, but soils with large structural units may not have macropores and coarse micropores within the large clods, and therefore may not be adequately aerated.





**FIGURE 2: Visual scoring (VS) of soil porosity under cropping**



**POOR CONDITION VS = 0**

No soil macropores are visually apparent within compact, massive structureless clods. The clod surface is smooth with few cracks or holes, and can have sharp angles



**MODERATE CONDITION VS = 1**

Soil macropores between and within aggregates have declined significantly but are present on close examination of clods showing a moderate amount of consolidation



**GOOD CONDITION VS = 2**

Soils have many macropores between and within aggregates associated with readily apparent good soil structure

## SOIL INDICATORS

### Soil colour under cropping

- ▶▶ Compare the colour of a handful of soil from the soil structure test with the soil taken from under the nearest fenceline.
- ▶▶ Using the three photographs below, compare the relative change in soil colour that has occurred.

As topsoil colour can vary markedly between soil types, the photographs illustrate the trend rather than the absolute colour of the soil.

SOIL COLOUR CHANGES give a general indication of trends in soil organic matter levels under cropping. Soil organic matter plays a pivotal role in regulating most biological, physical and chemical processes in soil, which collectively determine soil health. It promotes infiltration and water retention, it helps to develop and stabilise soil structure and cushion the impact of wheel traffic and cultivators, and it reduces the potential for wind and water erosion. Organic matter is also an important source of, and major reservoir for, plant nutrients. Its decline reduces the fertility and nutrient-supplying potential of the soil; nitrogen and phosphorus requirements for crops increase markedly, and other major and minor elements are more readily leached. The result is an increased dependency on fertiliser input to maintain nutrient status.





**FIGURE 3: Visual scoring (VS) of soil colour under cropping**



**POOR CONDITION VS = 0**

Soil colour has become significantly paler compared with under the fence line



**MODERATE CONDITION VS = 1**

The colour of the topsoil is somewhat paler than under the fence line, but not markedly so



**GOOD CONDITION VS = 2**

Dark coloured topsoil that is not too dissimilar to that under the fence line

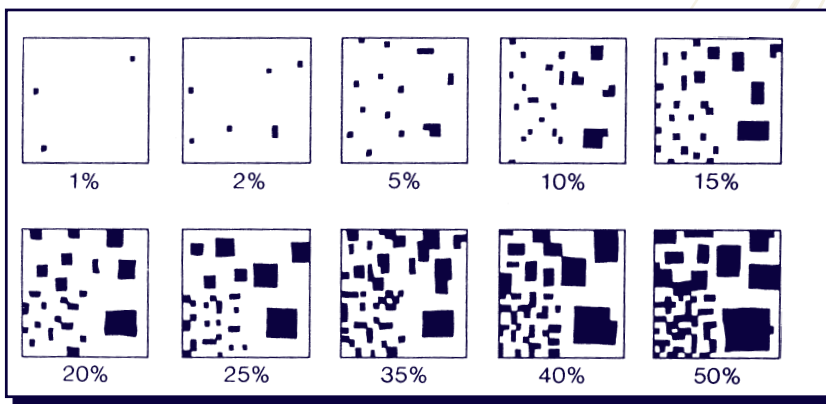
## SOIL INDICATORS

### Number and colour of soil mottles under cropping

- ▶ Assess the number, size and colour of mottles by comparing the side of the soil profile, or a number of soil clods from the soil structure test, with the three photographs opposite.

Mottles are spots or blotches of different colour interspersed with the dominant soil colour.

The percentage chart below will help you determine the percent of the soil occupied by mottles.



THE NUMBER, SIZE AND COLOUR of soil mottles provide a good indication of how well the soil is aerated. Loss of structure reduces the number of macropores and coarse micropores that conduct air and water. With the loss of pores, oxygen in the soil is reduced, and carbon dioxide builds up. As oxygen depletion increases, orange, and ultimately grey, mottles form. A high proportion of medium and coarse grey mottles indicates that the soil is waterlogged and starved of oxygen for a significant part of the year. Poor aeration and the build-up of carbon dioxide and methane reduce the uptake of water by plants, and induce early wilting. They can also reduce the uptake of plant nutrients, particularly nitrogen, phosphorus and potassium, by wheat and maize. Poor aeration also retards the breakdown of stubble and other organic residues, and can cause reactions that form chemicals toxic to plant roots.





**FIGURE 4:** Visual scoring (VS) of **number and colour of soil mottles** under cropping



**POOR CONDITION VS = 0**

Soil has abundant to profuse (>50%) medium and coarse orange and particularly grey mottles



**MODERATE CONDITION VS = 1**

Soil has common (10–25%) fine and medium orange and grey mottles



**GOOD CONDITION VS = 2**

Mottles are generally absent.

## SOIL INDICATORS

### Earthworm counts under cropping

- ▶▶ Sort carefully through the soil sample used to assess soil structure, and count the earthworms found in a 5 minute search. Earthworms vary in size and number depending on the season, so for year-to-year comparison earthworm counts must be made at the same time of year, and preferably during the winter. The class limits for earthworm numbers given opposite are based on the probability that you will find only two-thirds of the worms present during a 5-minute search.

(Earthworm numbers are commonly reported on a square-metre basis. A 20 cm cube sample is equivalent to 1/25 square metre and so the number of earthworms counted should be multiplied by 25 to convert to a square-metre basis. If your sample depth is only 0-10cm, the same class limits and conversion factors apply, because common earthworms are most abundant in the upper topsoil.)

**EARTHWORMS PLAY A MAJOR ROLE**, through their burrowing, feeding and casting, in decomposing and cycling organic matter, and in supplying nutrients. They can also improve soil porosity and aeration, water infiltration and conductivity, aggregate size and stability, reduce surface crusting, and increase root growth and subsequent grain yield.





**FIGURE 5:** Visual scoring (VS) of earthworm counts under cropping



Visual score (VS)	Earthworm counts (per 20 cm cube of soil)
2	>8
1	4-8
0	<4



## SOIL INDICATORS

### Presence of a tillage pan under cropping

- ▶▶ Examine the lower part of the topsoil and compare with the upper topsoil. This can be done *in situ* or by removing a spade slice from the side of the hole exposed by removing the 20 cm cube extracted for the structural assessment.
- ▶▶ Compare against the three photographs opposite.

WELL-DEVELOPED TILLAGE PANS can impede the movement of water, air and oxygen through the profile, increasing the susceptibility to water logging and erosion by rilling and sheet wash. Well-developed tillage pans are difficult for roots to penetrate, and can cause roots to grow sideways, restricting vertical root growth and development. This reduces the ability of the root system to take up water and nutrients.



**FIGURE 6:** Visual scoring (VS) of the presence of a **tillage pan** under cropping



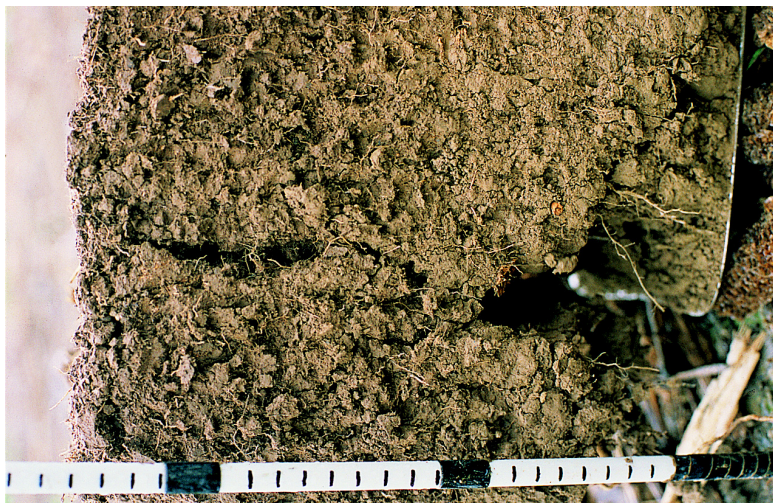
**POOR CONDITION VS = 0**

Very firm to hard, well-developed tillage pan in the lower topsoil, showing severe consolidation with no structure, no macropores and few or no cracks



**MODERATE CONDITION VS = 1**

Firm, moderately developed tillage pan in the lower topsoil showing clear zones of consolidation but including areas with weakly developed structure, cracks, fissures and a few macropores



**GOOD CONDITION VS = 2**

No tillage pan with a friable, clearly apparent structure and soil pores throughout the topsoil

## SOIL INDICATORS

### Degree of clod development under cropping

- ▶▶ Assess the degree of clodding on the soil surface between rows by comparing it against the three photographs opposite.
- ▶▶ Consider also the amount of tillage and time that was required to prepare the seedbed. Some soil clods may slake during rainfall so, to be meaningful, several assessments should be made up to crop maturity.

THE DEGREE OF CLODDING depends on many factors, including recent tillage, water content at the time of tillage, the shear strength of clods and the quality of the soil structure. The loss of soil structure and the subsequent formation of clods reduce the quality of the soil tilth, impair seed germination and emergence, and reduce crop yields and grain quality. Very cloddy soils indicate that the soil has become so degraded that it cannot maintain a fine aggregated seedbed throughout the growing season. The size, density, and strength of soil clods increase with increasing loss of soil structure, so careful timing and considerable additional energy is needed to break them down to the required seedbed. This usually means that more intensive methods of cultivation and a greater number of passes are needed.





**FIGURE 7:** Visual scoring (VS) of the **degree of clod development** under cropping



**POOR CONDITION VS = 0**

Soil dominated by coarse, very firm clods with fewer finer aggregates. Clod resistance is high and the window for cultivation is very narrow



**MODERATE CONDITION VS = 1**

Soil contains significant proportions of both coarse firm clods and friable, fine aggregates. If cultivation is not carefully timed, clods show significant tillage resistance



**GOOD CONDITION VS = 2**

Good distribution of the friable, finer aggregates with no significant clodding. A good seedbed is readily prepared

## SOIL INDICATORS

### Susceptibility to wind and water erosion under cropping

- ▶▶ Assess, based on your knowledge of the area or visual observations during the season, whether the amount of wind erosion during and after cultivation has become a concern.
- ▶▶ Take into account the size of the dust plume or clouds raised by cultivation, and whether the material stays within the paddock, within the farm, or is blown into the surrounding district (see opposite).
- ▶▶ Determine the severity of water erosion by augering or digging holes to compare the difference in topsoil depths between the crest and footslope, and by observing the amount of rill and sheet erosion, and sedimentation into adjacent drains and streams.

THE SUSCEPTIBILITY OF A SOIL TO WIND EROSION depends on factors including soil moisture, and wind velocity, surface roughness and particle size. Soils that have low amounts of organic matter and have lost their soil structure through compaction and over-cultivation are pulverised to dust on further cultivation, making them vulnerable to wind erosion if unprotected. Wind erosion reduces the productive potential of soils through nutrient losses, lower available water-holding capacity, and reduced rooting volume and depth. Research has shown that an extra 25 mm of water stored in the soil has the potential to increase maize yields by approximately 600 kg/ha. Wind-blown material deposited after a strong north-westerly wind in north Canterbury has been shown to contain high levels of Ca, K, Mg, and N. Available P levels present were equivalent to a loss of 73 kg of superphosphate per hectare. The water erodibility of soil on sloping ground is governed by factors including the amount and intensity of rainfall, and the soil infiltration rate and permeability. The latter two are governed by soil structure.





**FIGURE 8: Visual scoring (VS) of susceptibility to wind & water erosion under cropping**



**GOOD CONDITION VS = 2**

Wind erosion is not a concern: only small dust plumes emanate from the cultivator on windy days. Most wind-eroded material is contained within the paddock. Water erosion is not a concern as there is only a little rill and sheet erosion. Topsoil depths in footslope areas are <15 cm deeper than on crests



**MODERATE CONDITION VS = 1**

Wind erosion is of moderate concern where significant dust plumes can emanate from the cultivator on windy days. A considerable amount of material is blown off the paddock but is contained within the farm. Water erosion is of moderate concern with a significant amount of rilling and sheet erosion. Topsoil depths in footslope areas are 15–30 cm greater than on crests, and sediment input into drains/streams may be significant



**POOR CONDITION VS = 0**

Wind erosion is a major concern. Large dust clouds can occur when cultivating on windy days. A substantial amount of topsoil can be lost from the paddock and deposited elsewhere in the district. Water erosion is a major concern, with severe rilling and sheet erosion occurring. Topsoils in footslope areas are more than 30 cm deeper than on the crests, and sediment input into drains/streams may be high

COURTESY OF DAN BLOOMER

COURTESY OF DAN BLOOMER







# **INSTRUCTIONS FOR ASSESSING SOIL QUALITY UNDER CROPPING**

## **PLANT INDICATORS**

## PLANT INDICATORS

### Crop emergence

- ▶▶ Assess the degree and uniformity of crop emergence within a month of sowing by comparing the number and height of established plants with the three photographs provided.

GOOD SEED GERMINATION AND PLANT EMERGENCE depend on factors that include the quality of soil tilth at the time of sowing and during the weeks immediately following. Soils that have poor structure through compaction and over-cultivation can resettle and consolidate rapidly after the seed bed has been prepared. Impeded water and air movement through the soil can give rise to small areas low in oxygen (anoxic zones). These produce chemical and biochemical reduction reactions, the by-products of which are toxic to plants. These anoxic zones and poor soil aeration reduce seed germination and plant emergence. As a result, bare patches and poor and uneven early growth are commonly observed throughout paddocks that have poor soil structure. Young plants can also show off-colouring of leaves and moisture stress.

The loss of soil structure can reduce crop establishment of barley from 315 to 131 plants/m<sup>2</sup>, and grain yields from 6.7 to 3.9 t/ha. Corn germination slows, and plant populations also decrease. Seedling mortality of winter cereals can be high if the soil is waterlogged for more than 3 to 4 days between germination and emergence.



**FIGURE 9: Visual scoring (VS) of crop emergence under cropping**



**GOOD CONDITION VS = 2**  
Good emergence and plant establishment, with few gaps along the planting row and crop showing an even height



**MODERATE CONDITION VS = 1**  
Moderate emergence and plant establishment, with a significant number of gaps along the planting row and a significant variation in seedling height



**POOR CONDITION VS = 0**  
Poor emergence and plant establishment, with a large number of gaps along the planting row and a large variation in seedling height

### Crop height at maturity

- ▶▶ Measure crop height and height variability when the crop has reached maturity. Your observations of crop growth and vigour during the growing season may also provide a useful indication of seedbed condition. In a good season, under non-limiting conditions, a cultivar should grow to a particular height, with about a 10–15% variation. Allowances should be made for exceptionally good seasons and for poor seasons.

ALTHOUGH IT DEPENDS ON CLIMATIC FACTORS, the cultivar, soil fertility and time of sowing, crop height and variability in crop height at maturity can be useful visual indicators of soil quality. This is particularly useful if agronomic factors have not limited crop emergence and development during the growing season. The growth and vigour of grain crops depend in part on the ability of the seedbed to maintain an adequate soil tilth throughout the growing season. Poor soil aeration and resistance to root penetration as a result of structural degradation reduce plant growth and vigour, and delay maturity.





**FIGURE 10: Visual scoring (VS) of crop height at maturity under cropping**



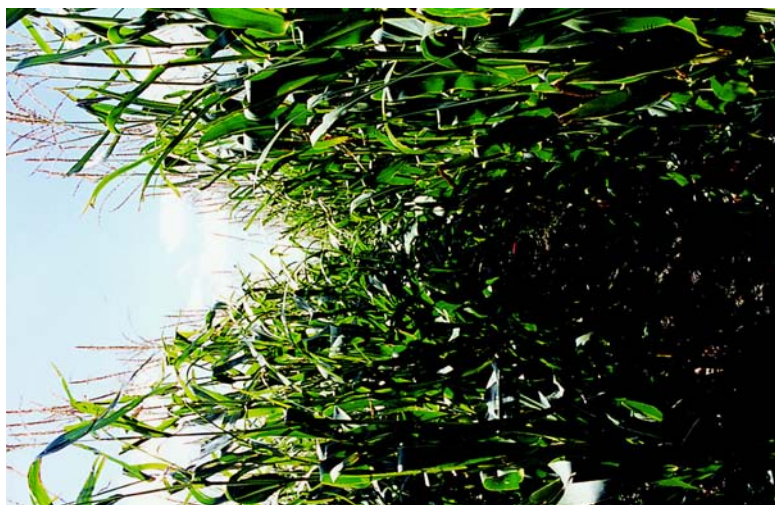
**POOR CONDITION VS = 0**

Crop heights are very uneven and patchy and well below maximum height at crop maturity. Crop height for maize, for example, is generally between 1.2–1.7 m at maturity (chest height).



**MODERATE CONDITION VS = 1**

Crop heights are significantly below maximum and show moderate variability in height at crop maturity. Crop height for maize, for example, is generally between 1.8–2.2 m at maturity



**GOOD CONDITION VS = 2**

Crops are at or near maximum height, with little variability in height at crop maturity. Maize crops, for example, are generally between 2.3–2.7 m at maturity

## PLANT INDICATORS

### The size and development of the crop root system

- » Determine size and development of the root system, ideally at plant maturity, by carefully prizing the plant out of the soil and gently shaking it to remove adhering soil from the roots. Compare the root system against the three photographs opposite.

CONSOLIDATION AND COMPACTION of the seedbed restrict plant growth and vigour by restricting root development (rooting depth and root density), owing to increased mechanical resistance and impeded soil aeration. High mechanical resistance to roots limits plant uptake of water and nutrients, restricts the production of several plant hormones in roots necessary for growth, and increases the susceptibility of the crop to windthrow.





**FIGURE 11: Visual scoring (VS) of size & development of crop root system under cropping**



**POOR CONDITION VS = 0**

Vertical and lateral root development is severely restricted, with root systems showing either right-angle syndrome, over-thickening, or growth down coulters channels



**MODERATE CONDITION VS = 1**

The main root bulb is commonly 15 cm wide and 15–18 cm deep. Vertical root development is often restricted below 12 cm with right-angle syndrome not uncommon



**GOOD CONDITION VS = 2**

Unrestricted root development with the main large root bulb up to 25 cm wide and 20–25 cm deep



## PLANT INDICATORS

### Crop yield

- » Assess relative crop yield.

In a maize crop, for example, strip a number of cobs at random at crop maturity and compare cob size and characteristics against the three photographs opposite. Similar comparative assessments can be made for wheat, barley, peas and other crops. Estimate heads or pods per square metre, grains or seeds per head or pod, and size of grains or seeds. Compare these with an 'ideal' crop.

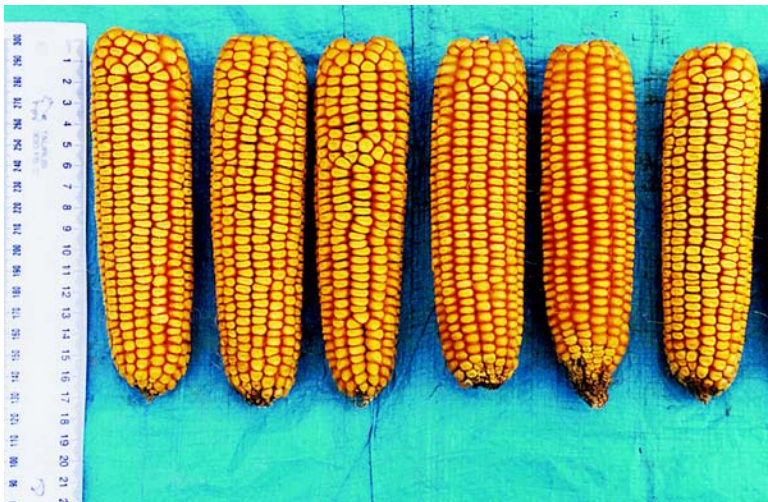
WITH A DECLINE IN SOIL QUALITY, crops can come under stress from drought, poor aeration, lack of nutrients and adverse temperatures. Toxic chemicals build up, and root growth can be mechanically impeded. This results in poor germination and emergence, poor plant growth and vigour, the need to resow, delays in sowing, root diseases, pest attack, and consequently lower crop yields. Plant stress induced by structural degradation can also affect the quality of grain by changing the amount and type of protein and starch formed, and the enzymic potential. These affect the amount of fermentable carbohydrate and the malting potential of barley, and the baking quality of wheat.



**FIGURE 12: Visual scoring (VS) of crop yield under cropping**



**GOOD  
CONDITION  
VS = 2**  
Maize cobs are large, with complete grain filling, and few moisture stress features are apparent. Cobs often vary from 18–22 cm in length



**MODERATE  
CONDITION  
VS = 1**  
Maize cobs are of medium size, often varying in length from 15–18 cm. Cobs may show occasional incomplete grain filling, and stress features are often apparent



**POOR  
CONDITION  
VS = 0**  
Maize cobs are generally small varying in length from 10–15 cm. Grain filling is invariably incomplete and stress features are very common

## PLANT INDICATORS

### Root diseases

- ▶▶ Assess the prevalence of root diseases by pulling a number of stems out of the soil and carefully examining the root system at, or any time before, crop maturity.  
Consider how commonly root diseases occur in a particular paddock from season to season (see table opposite).

POOR SOIL AERATION, high levels of soil saturation, and high mechanical resistance to root development due to soil structural degradation can increase root rot and soil-borne pathogens. They can also reduce the ability of root systems to overcome the harmful effects of pathogens resident in the topsoil. Plant diseases encouraged by degradation of soil structure include Fusarium, Pythium, Phytophthora, Rhizoctonia, Take-all and vesicular-arbuscular mycorrhizal fungi.





**FIGURE 13:** Visual scoring (VS) of **root diseases** under cropping



Visual score (VS)	Occurrence of root diseases due to soil qualities
2	Root diseases are rare
1	Root diseases are common
0	Root diseases are very common

## PLANT INDICATORS

### Weed infestation

- ▶▶ Assess the degree of weed infestation by visually estimating the number of weeds between rows at crop maturity according to the table opposite. Consider how often a given level of weed infestation occurs in the paddock from season to season, and at what level it is perceived to be a problem.

THE QUALITY OF THE SEEDBED and the use and timing of herbicide sprays influence the level of weed infestation. Soil structural degradation reduces soil aeration and the rooting potential of the crop, allowing more vigorous weeds to establish and compete with the crop. A high weed population uses a lot of the soil moisture and nutrients otherwise available to the crop. In extreme cases, weeds can shade out the crop.



**FIGURE 14:** Visual scoring (VS) of **weed infestation** under cropping



Visual score (VS)	Degree of weed infestation
2	Weeds are not common in most seasons and are not considered to be a problem
1	Weeds are common in most seasons and are a moderate problem
0	Weeds are very common in most seasons and are a serious problem



## PLANT INDICATORS

### Surface ponding under cropping

- ▶▶ Assess the degree of surface ponding.

Base your assessment on ponding present at the time, or your general recollection of the time ponded water took to disappear after a wet period, or after heavy rainfall in the winter (see opposite).

THE LENGTH OF TIME WATER REMAINS PONDED on the surface indicates the rate of infiltration into the soil, and the time the soil remains saturated. Prolonged waterlogging depletes oxygen and causes carbon dioxide to build up. Anaerobic conditions develop and induce a series of chemical and biochemical reduction reactions that produce by-products toxic to plant roots. These include hydrogen sulphide and ferrous sulphide produced by the reduction of sulphate and iron, and nitrite produced by denitrification. Organic substances can also anaerobically degrade in degraded soils, the most toxic by-products of which include ethylene, and acetic, butyric, and phenolic acids. In a word, the soil goes 'sour'. Waterlogging delays cultivation because the low load-bearing capacities of the soil increase its susceptibility to damage through deformation and excessive wheel slip. Sowing is also delayed because the seedbed is below the critical temperature for crop germination.



**FIGURE 15: Visual scoring (VS) of surface ponding under cropping**



**GOOD  
CONDITION  
VS = 2**  
No evidence of  
surface ponding after  
1 day following heavy  
rainfall on soils that  
were already at or  
near saturation



**MODERATE  
CONDITION  
VS = 1**  
Moderate surface  
ponding can occur  
up to 3 days after  
heavy rainfall on soils  
that were already at  
or close to saturation



**POOR  
CONDITION  
VS = 0**  
Significant surface  
ponding can occur  
for longer than 3  
days after heavy  
rainfall on soils that  
were already at or  
close to saturation

## PLANT INDICATORS

### Production costs

- » Assess whether production costs have increased because of increased tillage and fertiliser requirements over the years (see opposite). The assessment can be based on your broad perceptions ('gut feeling'), but reference to annual balance sheets will probably give a more precise answer.

TILLAGE AND FERTILISER INPUTS account for some of the highest costs in any cropping operation, and can increase significantly with increasing soil degradation. As degradation increases, the density and strength of the soil increases and, as a result, the soil becomes more resistant to tillage forces. Plough resistance increases so that larger tractors are required to avoid excessive wheel slip and the need to operate at slow ground speeds in a lower gear. The size, density, and strength of soil clods also increase with increasing loss of soil structure, and careful timing and additional energy is needed to break them down to a seedbed. This energy is generally applied by using more intensive methods of cultivation and by making a greater number of passes. As a result, tillage costs can increase by over 300 percent.

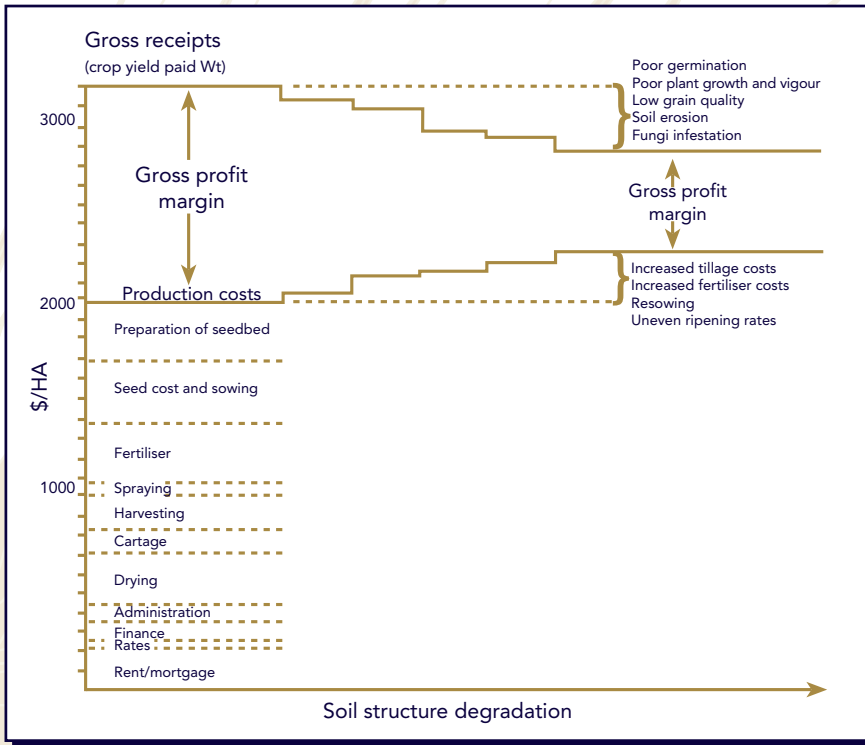
Continuous cropping using conventional cultivation techniques can give rise to a significant loss of organic matter and, as a result, can substantially reduce soil fertility and the ability of the soil to supply nutrients. Soil organic matter provides and stores significant amounts of several plant nutrients. High amounts of fertiliser are needed to compensate for the loss of these nutrients.

Reductions in crop yield are often not recognised as the result of the degradation of soil structure. Growers often assume that plant nutrition is at fault and increase their production costs by applying extra fertiliser.





**FIGURE 16: Visual scoring (VS) of production costs**



Visual score (VS)	Production costs
2	Tillage and fertiliser requirements have not increased significantly
1	Tillage and fertiliser requirements have increased moderately
0	Tillage and fertiliser requirements have increased greatly

Economic impact becomes more severe as soil structure declines (see figure above). As an example, maize grown for grain on well-structured soil gave gross margins in excess of \$1100/ha by maintaining production costs below \$2000/ha, and sustaining yields above 12t/ha. On degraded soils, production costs were significantly higher, and yields of 7–8 t/ha were just sufficient to break even. Gross receipts are reduced by the effects of soil erosion, poor germination and emergence, poor and patchy plant growth and vigour, root diseases, and poor grain quality. Production costs, on the other hand, escalate through increased tillage and fertiliser requirements, resowing, and uneven ripening rates. As a result, gross profit margins can decrease rapidly as yields drop and production costs rise concurrently.



# VISUAL SOIL ASSESSMENT



Of soil quality under pastoral grazing  
on flat to rolling country





# SCORE CARD

Visual indicators for assessing soil quality  
under pastoral grazing on flat to rolling country

## SOIL INDICATORS

Land use:

Site location/Paddock name:

Date:

Soil type:

Textural qualifier:  Sandy  Loamy  Clayey

Moisture condition:  Dry  Slightly moist  Moist  Wet

Seasonal weather conditions:  Dry  Wet  Cold  Warm  Average

Visual Indicator of Soil Quality	Visual Score (VS) 0 = Poor condition 1 = Moderate condition 2 = Good condition	Weighting	VS Ranking
Soil structure & consistence (Fig. 1, p.57)		× 3	
Soil porosity (Fig. 2, p.59)		× 3	
Soil colour (Fig. 3, p.61)		× 2	
Number and colour of soil mottles (Fig. 4, p.63)		× 2	
Earthworm counts (Fig. 5, p. 65)		× 3	
Surface relief (Fig. 6, p. 67)		× 1	
RANKING SCORE (Sum of VS rankings)			

Soil Quality Assessment	Ranking Score
Poor	< 10
Moderate	10 – 20
Good	> 20

If your soil quality assessment is moderate or poor, guidelines for sustainable management are given in Volume 2, Part Two.

# SCORE CARD

Visual indicators for ranking soil quality  
under pastoral grazing on flat to rolling country

## PLANT INDICATORS

Visual Indicator of Soil Quality	Visual Score (VS) 0 = Poor condition 1 = Moderate condition 2 = Good condition	Weighting	VS Ranking
Pasture composition (Fig. 7, p. 71)		× 3	
Pasture growth and regrowth rates* (Fig. 8, p. 73)		× 3	
Pasture utilisation* (Fig. 9, p. 75)		× 2	
Area of bare ground (Fig. 10, p. 77)		× 2	
Drought stress (Fig. 11, p. 79)		× 1	
Surface ponding (Fig. 12, p. 81)		× 2	
Stock carrying capacity and fertiliser use* (Fig. 13, p. 83)		× 2	
<b>RANKING SCORE (Sum of VS Rankings)</b>			

\* Perceived

Soil Quality Assessment	Ranking Score
Poor	<10
Moderate	10 – 20
Good	>20

### SUMMARY

Ranking score		Do the soil and plant scores differ? If so, why?
SOIL INDICATORS	Plant indicators	

NOTES:





# **INSTRUCTIONS FOR ASSESSING SOIL QUALITY UNDER PASTORAL GRAZING**

## **SOIL INDICATORS**

## SOIL INDICATORS

### Soil structure and consistence under pasture

- ▶▶ Remove a 20 cm cube of topsoil with a spade.
- ▶▶ Drop the soil sample a maximum of three times from a height of one metre (waist height) onto the firm base in the plastic basin. If large clods break away after the first or second drop, drop them individually again once or twice. If a clod shatters into small (primary structural) units after the first or second drop, it does not need dropping again. Don't drop any piece of soil more than three times.
- ▶▶ Separate each clod from enmeshing roots, and part it by hand along any exposed fracture planes or fissures.
- ▶▶ Transfer the soil onto the large plastic bag.
- ▶▶ Move the coarsest fractions to one end and the finest to the other end. This provides a measure of the aggregate-size distribution. Compare the resulting distribution of aggregates with the three photographs opposite.

**GOOD SOIL STRUCTURE** is vital for growing good pastures. It regulates soil aeration and gaseous exchange rates, the movement and storage of water, soil temperature, root penetration and development, nutrient cycling, and resistance to structural degradation. Good structure also increases the number of days during the year when the soil will support the hoof pressure of heavy animals without pugging.



**FIGURE 1: Visual scoring (VS) of soil structure and consistence under pasture**



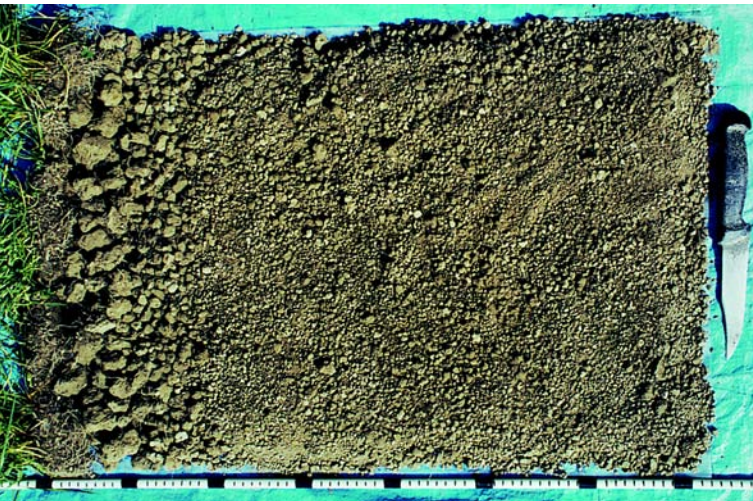
**POOR CONDITION VS = 0**

Soil dominated by extremely coarse, very firm clods with very few finer aggregates



**MODERATE CONDITION VS = 1**

Soil contains significant proportions of both coarse firm clods and friable, fine aggregates



**GOOD CONDITION VS = 2**

Good distribution of friable finer aggregates with no significant clodding



## SOIL INDICATORS

### Soil porosity under pasture

- ▶▶ Remove a spade slice of soil from the side of the hole created by taking the 20 cm cube of topsoil, or take a number of clods from the aggregate distribution test.
- ▶▶ Examine for soil porosity, comparing with the three photographs opposite.

SOIL POROSITY, and particularly macroporosity (the number of large pores), controls the movement of air and water in the soil. It is important to assess soil porosity as well as aggregate-size distribution. Soils with good structure have a high porosity between and within aggregates, but soils with large structural units may not have macropores and coarse micropores within the large clods, and may not be adequately aerated. Restricted air and water movement reduces root activity and pasture growth.



**FIGURE 2: Visual scoring (VS) of soil porosity under pasture**



**POOR CONDITION VS = 0**

No macropores or coarse micro pores are visually apparent within compact, massive structureless clods that typically show smooth faces with sharp angles, and have few cracks or holes



**MODERATE CONDITION VS = 1**

Soil macropores between and within aggregates have declined significantly but are present on close examination of clods showing a moderate amount of consolidation



**GOOD CONDITION VS = 2**

Soils have many macropores between and within aggregates associated with readily apparent good soil structure

## SOIL INDICATORS

### Soil colour under pasture

- ▶▶ Compare the colour of a handful of soil from the soil structure test with soil taken from under the nearest fence line.
- ▶▶ Using the three photographs below, compare the relative change in soil colour that has occurred.

As topsoil colour can vary between soil types, the photographs illustrate the trend rather than the absolute colour of the soil.

THE COLOUR OF THE SOIL is a useful indication of soil drainage and aeration, soil wetness from late autumn to early spring, and whether the soil is being damaged by pugging. Grey subsoil colours in loamy, silty or clayey soils suggest the soil is poorly drained. Grey soil colours in the topsoil suggest the soil is waterlogged and deficient of oxygen for long periods. Poor aeration leads to a build-up of carbon dioxide and methane, and reduces the ability of plants to take up water and nutrients, particularly nitrogen, phosphorus and potassium. Poor aeration also slows the breakdown of organic residues, and can induce chemical reactions toxic to plant roots.





**FIGURE 3:** Visual scoring (VS) of **soil colour** under pasture



**POOR CONDITION VS = 0**

Soil colour has become significantly paler due to gleying because of persistent pugging



**MODERATE CONDITION VS = 1**

The colour of the topsoil is somewhat paler due to the early stages of gleying because of moderate pugging



**GOOD CONDITION VS = 2**

Dark coloured topsoil indicating a well-aerated soil with a good turnover of organic matter



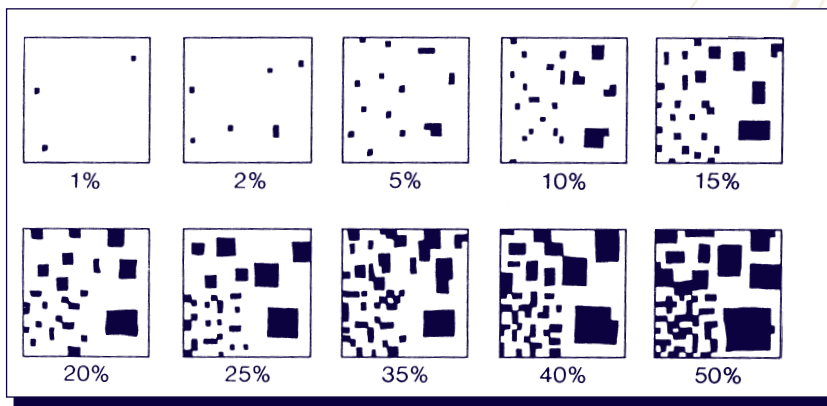
## SOIL INDICATORS

### Number and colour of soil mottles under pasture

- ▶▶ Assess the number, size and colour of mottles by comparing the side of the soil profile, or a number of soil clods from the soil structure test, with the three photographs opposite.

Mottles are spots or blotches of different colour interspersed with the dominant soil colour.

The percentage chart below will help you determine the percent of the soil occupied by mottles.



THE NUMBER, SIZE AND COLOUR OF MOTTLES indicate how well the soil is drained and how well it is aerated. They are also an early warning of a decline in soil structure, and show whether the soil is being damaged by pugging. Loss of soil structure reduces the number of channels and pores in the soil that conduct air and water. This results in a deficiency of oxygen and a build-up of carbon dioxide. As oxygen depletion increases, orange and ultimately grey, mottles form. A high proportion of grey mottles indicates the soil is waterlogged and starved of oxygen for much of the year. Poor aeration reduces the uptake of water and plant nutrients, particularly nitrogen, phosphorous and potassium. Poor aeration also retards the breakdown of organic residues, and can induce chemical reactions that form chemicals toxic to plant roots.

**FIGURE 4: Visual scoring (VS) of number and colour of soil mottles under pasture**



**POOR CONDITION VS = 0**  
Soil has abundant to profuse (>50%),  
medium and coarse orange and grey  
mottles



**MODERATE CONDITION VS = 1**  
Soil has common (10-25%) fine and  
medium orange and grey mottles



**GOOD CONDITION VS = 2**  
Mottles are generally absent

## SOIL INDICATORS

### Earthworm counts under pasture

- ▶▶ Sort carefully through the soil sample used to assess soil structure, and count the earthworms found in a 5 minute search. Pay particular attention to the turf mat. Earthworms vary in size and number depending on the season, so for year-to-year comparison, earthworm counts must be made at the same time of year, and preferably during the winter. The class limits for earthworm numbers given opposite are based on the probability that you will find only two thirds of the worms present during a 5-minute search.

(Earthworm numbers are commonly reported on a square-metre basis. A 20 cm cube sample is equivalent to 1/25 square metre and so the number of earthworms counted should be multiplied by 25 to convert to a square metre basis. If your sample depth is only 0-10cm, the same class limits and conversion factors apply, because common earthworms are most abundant in the upper topsoil.)

**EARTHWORMS** play a major role, through their burrowing, feeding and casting, in decomposing and cycling organic matter, and in supplying nutrients. They can also improve soil porosity and aeration, water infiltration and conductivity, aggregate size and stability, root growth and subsequent pasture productivity. Earthworm numbers can decline (3-fold) under severe pugging and can have adverse long-term effects on nutrient cycling, organic matter decomposition, soil structure and porosity.





**FIGURE 5:** Visual scoring (VS) of **earthworm counts** under pasture



Visual score (VS)	Earthworm counts (per 20 cm cube of soil)
2	>20
1	10–20
0	<10



## SOIL INDICATORS

### Surface relief under pasture

- ▶▶ Observe the surface relief (smoothness) of the paddock at the end of winter.
- ▶▶ Compare it with the three photographs opposite.  
Although soils are most susceptible to pugging during the wet winter months, observations of surface relief at any time of the year will give useful information on damage caused by past grazing, and its likely effects on soil quality.

**SURFACE RELIEF** shows the severity of pugging under stock treading, and indicates structural damage below the surface. Wet soil can pug severely under intensive grazing. This reduces the pores in the soil, which are important for water, nutrient and air movement, and root penetration.



**FIGURE 6: Visual scoring (VS) of surface relief under pasture**



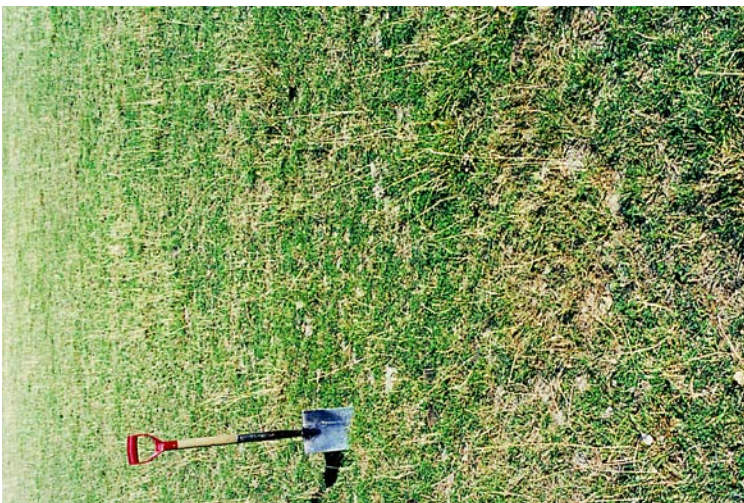
**POOR CONDITION VS = 0**

Surface is very broken and deeply incised by severe repeated treading. The terrain is difficult to walk across and care must be taken to avoid twisting ankles



**MODERATE CONDITION VS = 1**

Surface terrain is somewhat broken up and incised by occasional heavy treading events but it is not difficult to walk over



**GOOD CONDITION VS = 2**

Surface is relatively smooth and unbroken







# **INSTRUCTIONS FOR ASSESSING SOIL QUALITY UNDER PASTORAL GRAZING**

## **PLANT INDICATORS**

## PLANT INDICATORS

### Pasture composition

- » Assess the botanical composition of the pasture (the proportion of each species present) in the winter or early spring.

PASTURE SPECIES vary in their tolerance to poor soil aeration, waterlogging and pugging. Consequently, their nitrogen uptake, dry matter production and survival ability also vary markedly. *Phalaris aquatica*, tall fescue, meadow fescue, meadow foxtail, *Poa trivialis*, timothy, creeping bent, sweet grass, pennyroyal, buttercup, duckweed and dock are tolerant of waterlogging due to pugging or poor drainage. Perennial ryegrass, white clover, chewing fescue, browntop, *Poa annua*, and crested dogstail are moderately tolerant of waterlogging. Matua prairie grass, cocksfoot, sweet vernal, *Poa pratensis*, ratstail, meadow rice grass and yarrow are sensitive to waterlogging and will die out if wet conditions persist.

Pasture composition will also change according to the degree of treading damage. Ryegrass and *Poa pratensis* resist treading damage better than many other species, and often become more common in pugged pastures. *Poa trivialis*, brown top, white clover and timothy are moderately tolerant to treading. Cocksfoot, red clover and yorkshire fog, and many low fertility pasture species such as sweet vernal and chewing fescue are sensitive to intensive treading and disappear under prolonged pugging. Treading damage and the exposing of bare ground will also allow invasion by opportunist species such as white clover and *Poa annua*, more vigorous weeds, and less desirable pasture species. White clover, being stoloniferous, can rapidly colonise bare ground and become dominant in severely pugged pasture.



**FIGURE 7: Visual scoring (VS) of pasture composition**



**POOR CONDITION VS = 0**

Pastures are often dominated by species that are more tolerant of poor aeration and waterlogging due to pugging, by species such as ryegrass that are more tolerant of stock treading, and species such as white clover that quickly colonise bare ground created by severe treading. Weeds are also very common and may include pennyroyal, buttercup, duckweed and dock. Pasture composition has little relationship to the original seed mix



**MODERATE CONDITION VS = 1**

Pasture species with a range of tolerances to waterlogging and stock treading are present, and pastures may contain a number of weeds and forage herbs including dock, mayweed, pennyroyal and plantain. Pasture mix differs somewhat from that originally sown



**GOOD CONDITION VS = 2**

Pasture composition has a good mix of high producing pasture species (e.g., ryegrass, white clover and cocksfoot) and species intolerant of poor aeration and waterlogging, few weeds. Pasture composition reflects the original mix



## PLANT INDICATORS

### Pasture growth and regrowth rates

- ▶▶ Assess pasture growth and regrowth rates since the last grazing by pasture probe, rising plate or herbage cut measurements.  
If this information is not available, use visual approximations of dry matter production levels.  
For a reliable comparison, make assessments at the same time of year, preferably in early spring.

HIGH PASTURE GROWTH RATES depend on good soil structure and fertility, and on the season and seasonal weather conditions, to allow the movement of water and air in the soil. Treading damage on compacted moist soils can reduce pasture production by up to 27 percent, but on pugged (deformed) wet soils, the reduction can be as much as 45 percent. Pasture regrowth rates on wet soils can be reduced by 20–30 percent. Good dry matter production from quality pastures is needed for good dairy production. For cows to be also in good condition at calving, an adequate pasture cover of 2000 kg DM/ha is needed, and pastures need to be capable of rapid regrowth.



**FIGURE 8: Visual scoring (VS) of pasture growth and regrowth rates**



Visual score (VS)	Pasture growth and regrowth rates
2	Good pasture growth and regrowth
1	Moderate pasture growth and regrowth
0	Poor pasture growth and regrowth

## PLANT INDICATORS

### Pasture utilisation

- ▶▶ Assess pasture utilisation by the proportion of pasture that has been grazed, and by the proportion not smeared by or trampled into the mud by grazing animals (see opposite).

Assess pasture utilisation during the wet winter months after or near the end of a grazing cycle.

DEGRADED SOILS have a low load-bearing capacity. As a result, pastures on these soils are easily trampled into the mud when wet. This makes them both inaccessible and unpalatable to stock. Trampling can reduce pasture utilisation by 20–40 percent.





**FIGURE 9:** Visual scoring (VS) of pasture utilisation



Visual score (VS)	Pasture utilisation
2	Good pasture utilisation with only a little of the pasture being trampled into the mud
1	Moderate utilisation with a significant amount of pasture being covered by, and trampled into the mud
0	Poor utilisation with a large proportion of pasture being covered by, and trampled into the mud

## PLANT INDICATORS

### Area of bare ground

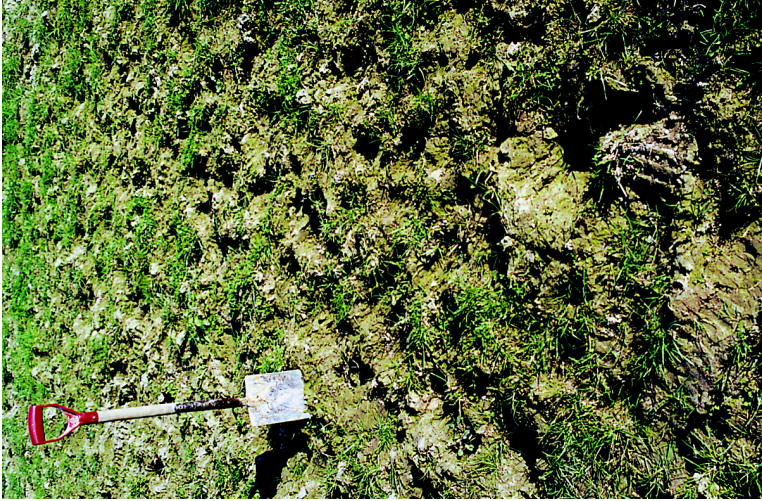
- ▶▶ Assess the area of bare ground in winter or early spring. Compare the surface of the soil with the three photographs opposite. If there is canopy closure, part the pasture with your hands and score at ground level. An assessment of an area of bare ground after a long dry period will show how much pasture has died from lack of moisture.

IN ADDITION TO STOCK CAMPING and drought effects, bare ground is formed by the physical churning up of the soil from treading and pugging. This causes leaf and stem crushing, uprooting or burial of plants, and root damage, which reduces pasture density and vigour. Weeds and less desirable pasture species can invade the resulting gaps, further reducing pasture production. Like surface relief, the area of bare ground can be a good indicator of below-ground damage.





**FIGURE 10: Visual scoring (VS) of area of bare ground**



**POOR CONDITION VS = 0**

Large areas of bare ground occur because of treading damage and the subsequent reduction in the density and vigour of pasture plants. White clover and less desirable pasture species and weeds may have invaded degraded and bare areas



**MODERATE CONDITION VS = 1**

Pasture shows significant areas of bare ground and sporadic growth with the ingestion of weeds and white clover caused by treading damage



**GOOD CONDITION VS = 2**

Pasture growth is vigorous and covers almost the whole surface area



## PLANT INDICATORS

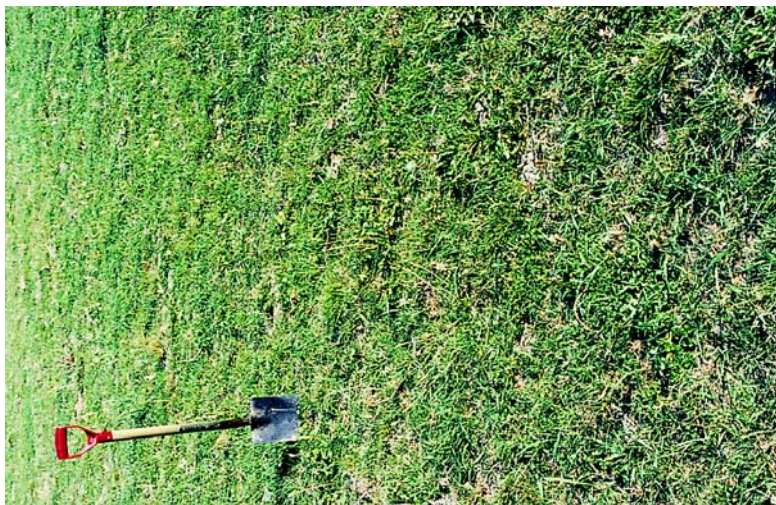
### Drought stress of pastures during dry periods

- ▶▶ Assess, from visual evidence and local knowledge, the degree to which pastures are drought stressed during dry periods by comparing the greenness of the pasture with the three photographs opposite.
- ▶▶ Assess the level of dry matter production, and whether drought-tolerant species have become dominant in the pasture sward.

THE DEGREE OF DROUGHT STRESS in dry periods depends on climatic conditions, the drought tolerance of the pasture, and the water-holding capacity of the soil. The last is governed by soil depth and texture, organic matter content, and the number and size of soil pores. Pastoral soils with a good soil structure have a large number of macropores and coarse and medium-sized micropores, and, subsequently, have a higher water-holding capacity than degraded soils with few pores.

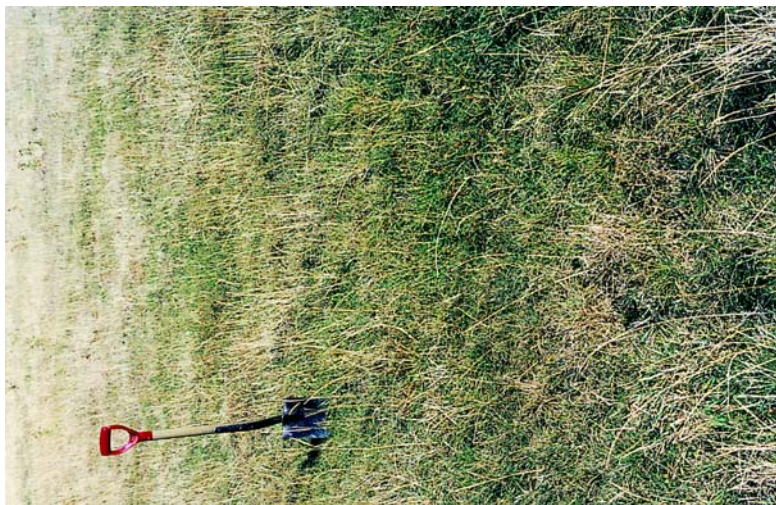


**FIGURE 11: Visual scoring (VS) of drought stress of pastures during dry periods**



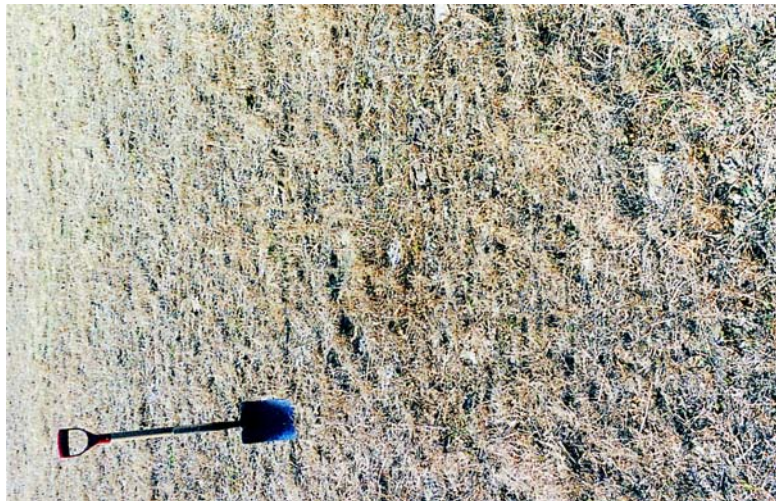
**GOOD CONDITION VS = 2**

Pastures remain relatively green, and dry matter production is able to hold on, albeit at low levels, further into dry summers. Pasture composition is dominated by ryegrass and white clover during dry periods



**MODERATE CONDITION VS = 1**

Non-drought tolerant pastures 'brown off' significantly during dry summer months, although thin green patches are still present close to the ground. Dry matter production is very low and pastures become dominated during drought by the more drought-resistant cocksfoot, tall fescue, phalaris, birdsfoot, Lotus trefoil, meadow rice-grass, rats tail and small annual clovers. Deep rooted flat weeds such as plantain and hawkbit may also be common



**POOR CONDITION VS = 0**

With the possible exception of drought tolerant species, pastures brown off completely and pasture growth stops during dry periods. Pastures die off during times of prolonged drought. With the exception of subtterranean clover and drought-tolerant species such as phalaris, pastures take a long time to come away in autumn. Soil structure becomes brittle and turns to dust under treading

## PLANT INDICATORS

### Surface ponding under pasture

- » Assess the degree of surface ponding.

Base your assessment on ponding present at the time, or your general recollection of the time ponded water took to disappear after a wet period, or after heavy rainfall in the winter (see opposite). Yellow or pale patches of pasture, or pasture lying flat over the surface indicate recent surface ponding.

THE LENGTH OF TIME WATER REMAINS PONDED on the surface indicates the rate of infiltration into the soil, and the time the soil remains saturated. Prolonged waterlogging depletes oxygen and causes carbon dioxide to build up. Anaerobic conditions develop, and chemical and biochemical reactions produce by-products toxic to plant roots. Plant-available N is lost through denitrification, pastures become pale or yellow, and photosynthesis declines. Root damage reduces nutrient and water uptake and plants can wilt and lie on the surface. Prolonged surface ponding makes soil more susceptible to pugging, and pasture plants to treading damage. It decreases pasture growth and utilisation, and can alter pasture species composition.





**FIGURE 12: Visual scoring (VS) of surface ponding under pasture**



**GOOD CONDITION VS = 2**

No ponding of water evident 24 hours after heavy rain on soils that were at or near saturation



**MODERATE CONDITION VS = 1**

Moderate surface ponding can occur for up to 3 days following heavy rain on soils that were at or near saturation



**POOR CONDITION VS = 0**

Significant surface ponding occurs for longer than 3 days following heavy rainfall on soils that were at or close to saturation. The pasture has yellowed or paled in colour in patches and lies flat on the surface

## PLANT INDICATORS

### Stock-carrying capacity and fertiliser use

- ▶▶ Assess stock-carrying capacity, based on your knowledge of the paddock.
- ▶▶ Is additional fertiliser needed to maintain stocking capacity?

PASTURE PRODUCTION can recover almost completely within approximately 6 months following moderate soil compaction. Severe compacting and pugging, however, can reduce dry matter production by up to 40–45 percent. If feed utilisation ratios are around 0.7, this decline in pasture production would reduce potential stock numbers by 10–20 percent. To offset this trend, additional fertiliser is often applied to maintain dry matter production and stock numbers.





**FIGURE 13:** Scoring of **stock-carrying capacity and fertiliser use**



Visual score (VS)	Stock-carrying capacity and fertiliser use
2	Standard fertiliser applications to maintain stock-carrying capacity
1	Some additional fertiliser is required to maintain stocking rates
0	Significant additional fertiliser is required to maintain stocking rates, especially during pinch periods



