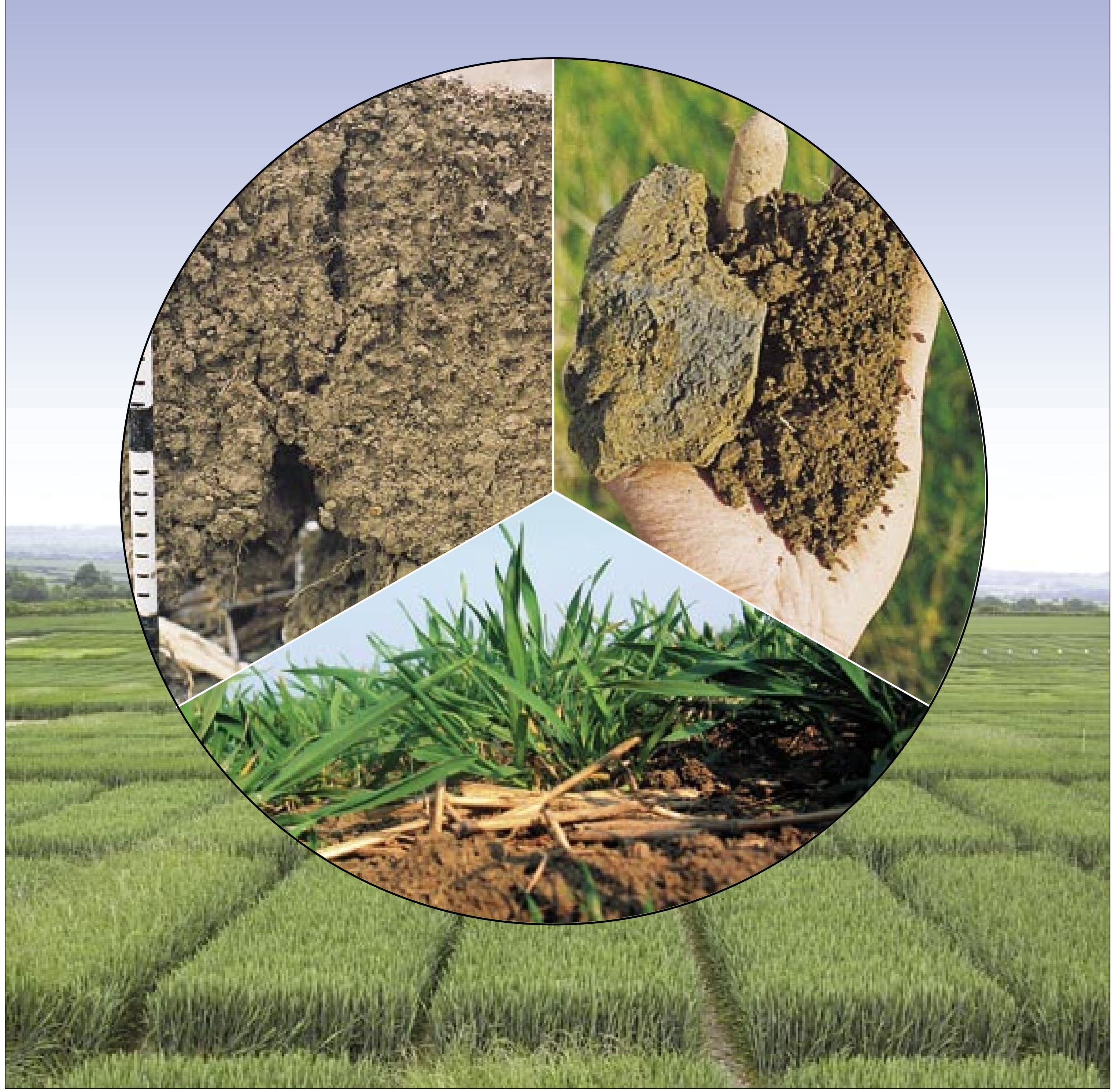
VÄDERSTAD

SMI

Visual Soil Assessment

VISUAL SOIL ASSESSMENT



VÄDERSTAD

Innovation for the future of farming

SMI Soil Management Initiative

Väderstad is a fast developing company where innovation and excellent customer relations are high priorities. Väderstad has its sights set firmly on maintaining its position as a leading manufacturer of seed drilling and cultivation machinery for the progressive grower, providing cost-effective solutions and concepts in an increasingly competitive agricultural environment. Machinery solutions are key to the improvement of soil quality, minimising pollution and erosion, and enhancing wildlife on farms.

Located in the town of Väderstad, near Stockholm in Sweden, the family-owned firm manufactures more than 4,000 machines each year from its 25,000 square metre production facility, which are delivered to markets throughout the world.

Drawing on the experience of customers as well as their own resources, the Väderstad mission is to continue to promote the rationalisation of arable farming methods in Europe, through sound design, innovation and technology.

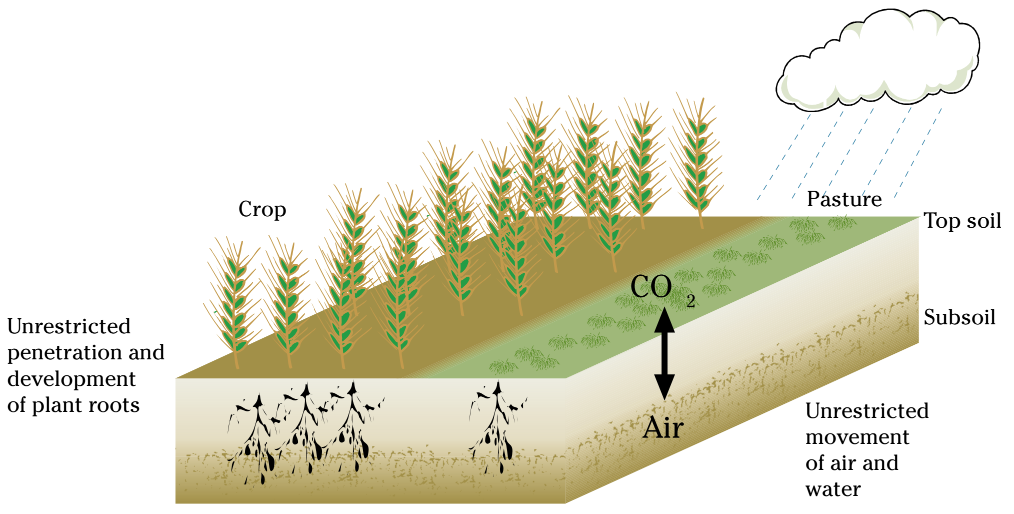
The UK Soil Management Initiative is an independent organisation created to promote, by information transfer and advice, the adoption of systems designed to protect and enhance soil quality. Agronomic and economic benefits may then be accrued whilst also improving the environment through reduced soil erosion and water pollution.

Set up in January 1999, SMI draws on the experience and research of its members to provide solutions to pressing problems caused by poor soil management. It was originally funded by the EU LIFE fund as well as member organisations but is now a voluntary club. SMI is part of the European Conservation Agriculture Federation (ECAF) which is made up of individuals from the eleven national associations working across Europe to implement sustainable soil management. ECAF co-ordinates the efforts of the national and associate bodies and lobbies European Government for change and support.

The Question?

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 can penetrate the soil. Damage to the soil can change these properties and reduce plant growth, regardless of nutrient status. Decline in the physical quality of the soil can take considerable expense and many years to correct, and can increase the risk of soil erosion by water or wind.

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



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

> "A decline in the physical quality of the soil can take considerable expense and many years to correct."

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

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

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 shows that many of the visual indicators are closely related to key quantitative (measurement-based) indicators of soil condition.

The VSA Method

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

Visual assessment provides an immediate, effective diagnostic tool to assess soil condition, and the results are easy to interpret and understand. Compare a soil under well-managed grassland (on the right of the palm), and under poorly managed long-term continuous cropping (on the left).

The VSA method has been developed to help land managers assess soil condition easily, quickly, reliably and cheaply on a field scale.

These relationships have been used to develop VSA. The VSA method has been developed to help land managers assess soil condition easily, quickly, reliably and cheaply on a field scale. It requires little equipment, training or technical skills. Assessing and monitoring soil condition 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.

Plant indicators extend or qualify the soil quality assessment to allow you to make cause and affect 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 that 'things are fine'. However, upon application of the 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 a reduction of input costs, increase profitability and improve soil quality.
- A farmer wants to expand cropping by renting or buying extra land. VSA can provide important information about the soil quality of the land under consideration, which could help in making decisions.

Visual Scoring (VS)

Each indicator is given a visual score (VS) of 0 (poor), 1 (moderate), or 2 (good), based on the soil condition observed when comparing the field 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 condition 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.

VSA can provide important information about the soil quality of the land under consideration, which could help in making decisions.

The VSA can bring a better understanding of soil condition 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 condition and on-farm production.

Carrying out the Assessment

VSA Toolkit

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

- 1 spade – to dig out a 20cm cube of topsoil.
- 1 plastic basin (approx. 35x35x19cm) – to contain the soil when carrying out the drop shatter test.
- 1 hard square board (approx. 26x26x1.8cm) – to fit the bottom of the plastic basin on to which a soil cube is dropped for the shatter test.
- 1 heavy-duty plastic bag (approx. 74x49cm) – on which to spread the soil, after the shatter test has been carried out.
- 1 VSA field guide – to make the photographic comparisons.
- 1 pad of scorecards – to record the visual score (VS) for each indicator.

The Procedure

1. When Should Soil Condition Assessment be Carried Out?

The following recommendations are given as a general guide:

- For arable-cropped 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.

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, it is suggested that the VSA is carried out when it is judged that the soil is at the correct moisture content for cultivation, or is sufficiently dry to prevent compaction by wheeled traffic.

If you are 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 50mm long and 4mm thick for cropped soils. If the soil cracks before the worm is made, or you cannot form a worm (e.g. if the soil is sandy), the soil is suitable for testing. If you can make the worm, the soil is too wet for testing.

As long as the soil moisture content 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 one hour per field. The assessment process takes about 15 minutes for each sample, and you should sample three or four sites in each field.
- Reference sample – Take a small soil sample from an un-cultivated area. The field to be sampled will have had a history of grazing or cropping. Taking a spade-depth sample from an area of the field boundary where there has been little if any cultivation or treading, allows you to see the relatively unaltered soil. This helps with giving the correct visual score to the *soil colour matrix* indicator.
- Sites – When carrying out field assessments, avoid areas such as headlands or loading areas, which may have had heavier traffic than the rest of the site. VSA can also be used, however, to assess the effects of high traffic loading on soil quality; tramlines, for example, can be selected and the results compared with low traffic areas. Select sites that are representative of the field.

  It is important to record the position of the assessment sites in your field accurately so that you can come back to them for future monitoring.
- Set up the equipment - 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 scorecard. Then record any special aspects you think relevant in the notes section at the bottom of the reverse side of the scorecard (for example, wet weather at harvest last season; soil heavily poached by stock grazing stubble; topsoil blew off two years ago, etc.).

4. Carrying Out The Test

- Take the test sample – Dig out a 20cm cube of topsoil with the spade. If the topsoil is less than 20cm 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 1m (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.

Systematically work through the scorecard, 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 scorecard 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 drop shatter test. The sample is dropped a maximum of three times from a height of 1m (waist height) onto the wooden square in the plastic basin. The soil is then transferred onto the large plastic bag and graded so that the coarsest clods are at one end and the finest aggregates are at the other end.

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, and the contribution of each to the final determination of soil condition.

Using the VSA Results

VSA allows you to assess soil condition in a field but does not solve any identified soil condition issues. Once soil is degraded, it can take a long time (sometimes decades) to recover. Information regarding the maintenance and improvement of soil structure is included in 'Target on Establishment'.

Score Card

Visual indicators for assessing soil quality under arable cropping

Soil Indicators

Land Use:

Location/Field Name:

Date:

Soil Type:

Texture: ☐ Sandy ☐ Loamy ☐ Clayey ☐ Silty

Moisture Content: ☐ 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 & Consistency		X 3	
Soil Porosity		X 3	
Soil Colour		X 2	
Number & Colour of Soil Mottles		X 2	
Earthworm Count		X 2	
Tillage Pan		X 2	
Degree of Clod Development		X 1	
Degree of Erosion		X 2	
Ranking Score (sum of VS rankings)			

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

Score Card

Visual indicators for assessing soil quality under arable 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		X 2	
Crop Height at Maturity		X 3	
Size & Development of the Root System		X 2	
Crop Yields		X 3	
Root Diseases		X 1	
Weed Infestation		X 1	
Surface Ponding		X 2	
Production Costs		X 2	
Ranking Score (sum of VS rankings)			

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

Ranking Score		Do the plant and soil scores differ and why?
Soil Indicators	Plant Indicators	

Soil Structure and Consistency

- Remove a 20cm 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 box. If large clods break away after the first or second drop, drop them individually again once or twice. If a clod shatters into small units after the first or second drop, it does not need dropping again. Do not drop any piece of soil more than three times.

Figure 1: Visual Scoring of Soil Structure and Consistency under Arable Cropping.

Good Condition VS = 2

Good distribution of finer aggregates with no significant clodding.

- Part each clod by hand along any exposed fracture planes or fissures.
- Transfer the soil onto the large plastic bag.
- Move the coarsest parts 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 in Figure 1.

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 erosion. It also promotes seed germination and emergence, crop yields and grain quality.

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

Moderate Condition VS = 1

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

Poor Condition VS = 0

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

Soil Porosity

- Remove a spade slice of soil from the side of the hole created by taking the 20cm cube of topsoil, or take a number of clods from the soil structure and consistency test.
- Examine the sample for soil porosity by comparing against the three photographs in Figure 2.

Soil porosity and particularly macro-porosity (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 macro-pores and coarse micro-pores within the large clods. Therefore, they may not be adequately aerated.

Figure 2: Visual Scoring of Soil Porosity Under Arable Cropping.

Good Condition VS = 2

Soils have many macro-pores between and within aggregates associated with good soil structure.

Moderate Condition VS = 1

Soil macro-pores between and within aggregates have declined significantly but are present upon close examination of clods, showing a moderate amount of compaction.

Poor Condition VS = 0

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

Soil Indicators

Soil Colour

- Compare the colour of a handful of soil from the structure test with soil taken from the nearest uncultivated area.
- Using the three photographs in Figure 3, 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 develop and stabilise soil structure and cushion the impact of wheel traffic and cultivators and it also 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.

Figure 3: Visual Scoring of Soil Colour Under Arable Cropping.

Good Condition VS = 2

Dark coloured topsoil that is not too dissimilar to that from the uncultivated area.

Moderate Condition VS = 1

The colour of the topsoil is somewhat paler than the uncultivated area, but not markedly so.

Poor Condition VS = 0

Soil colour has become significantly paler compared with the uncultivated area.

Soil Indicators

Number of Soil Mottles

- 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 in Figure 4.

Mottles are spots or blotches of different colour, generally grey or orange, interspersed with the dominant soil colour.

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 macro-pores and coarse micro-pores 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 indicate 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. Waterlogging can also reduce the uptake of nutrients, particularly nitrogen, phosphorous and potassium by wheat and maize.

Poor aeration retards the breakdown of stubble and other organic residues and can cause reactions that from chemicals that can be toxic to plant roots.

Figure 4: Visual Scoring of Number and Colour of Soil Mottles Under Arable Cropping.

Good Condition VS = 2

Mottles are generally absent.

Moderate Condition VS = 1

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

Poor Condition VS = 0

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

Earthworm Counts

- 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, counts should be made at the same time of year, preferably in the winter. The class limits for earthworm numbers given in Figure 5 are based on the probability that only two thirds of the worms that are present will be found during a 5 minute search.

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 of Earthworm Counts Under Arable Cropping.

Visual Score (VS)	Earthworm Counts (per 20cm³ of soil)
2	>8
1	4-8
0	<4

Presence of a Cultivation Pan

- 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 20cm cube extracted for the structural assessment.
- Compare against the three photographs in Figure 6.

Figure 6: Visual Scoring of the Presence of a Cultivation Pan Under Arable Cropping.

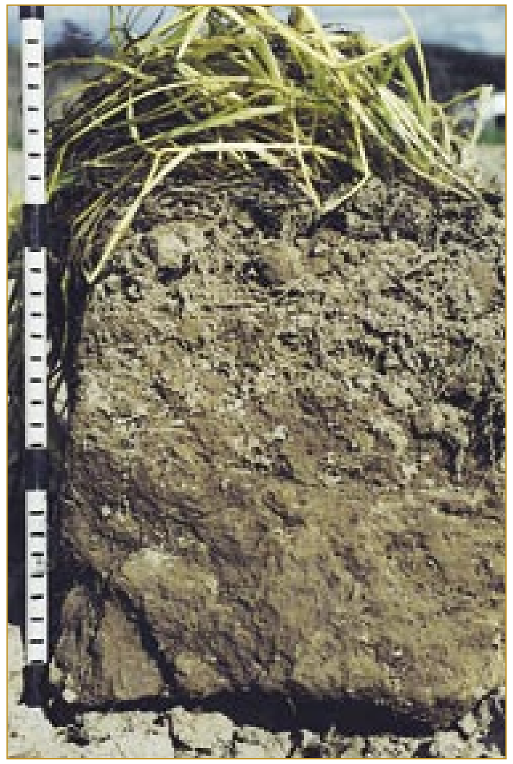
Good Condition VS = 2

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

Well-developed cultivation 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 cultivation pans are difficult for roots to penetrate and can cause them to grow horizontally, restricting vertical root growth and development. This reduces the ability of the root system to take up water and nutrients.

Moderate Condition VS = 1

Firm, moderately developed tillage pan in the lower topsoil, showing clear zones of compaction, but including areas with weakly developed structure, cracks, fissures and a few micro-pores.



Poor Condition VS = 0

Very firm to hard, well developed tillage pan in the lower topsoil, showing severe compaction with no structure, no macro-pores and few of no cracks.

Degree of Clod Development

- Assess the degree of clod presence on the soil surface between rows by comparing it against the three photographs in Figure 7.
- Consider the amount of cultivation and time that was taken to prepare the seedbed. Some soil clods may slake during rainfall so, to be meaningful, several assessments should be made up to crop maturity.
- Note that if the seedbed is too fine, it may be at risk of slaking and therefore water erosion or ponding.

Figure 7: Visual Scoring of the Degree of Clod Development Under Arable Cropping.

Good Condition VS = 2

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

Soil Indicators

The degree of clod development depends on many factors, including recent cultivations, 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 effort 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.

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.

Poor Condition VS = 0

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

Susceptibility to Wind and Water Erosion

- Assess, based on 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 during or after cultivation, and whether the material stays within the field, within the farm, or is blown into the surrounding area.
- Determine the severity of water erosion by augering or digging holes to compare the difference in topsoil depths between the crest and the bottom of the slope, and by observing the amount of sheet and rill erosion, as well as sedimentation into surrounding drains and streams. Consider the DEFRA ELS soil management information for this assessment.

The susceptibility of a soil to wind erosion depends on factors including soil moisture and wind velocity, surface roughness, organic matter content and particle size. Soils that have low volumes of organic matter and have lost their structure through compaction and over-cultivation are pulverised to dust on further cultivation, making them vulnerable to wind erosion if un-protected. Wind erosion reduces the productive potential of soils through nutrient losses, lower available water-holding capacity and reduced rooting volume and depth.

The water erodability of soil on sloping ground is governed by factors including the amount and intensity of rainfall, the degree of slope, and the soil infiltration rate and permeability. The latter two are governed by soil structure and texture.

Soil Indicators

Figure 8: Visual Scoring of Susceptibility to Wind and Water Erosion Under Arable 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 field. Water erosion is not a concern as there is only a little rill and sheet erosion. Topsoil depths in valley areas are <15cm deeper than on crests. Deal with water erosion and wind erosion separately if both have occured. Reduce the score by one point.

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 field, but is contained within the farm area. Water erosion is of a moderate concern with a significant amount of rilling and sheet erosion. Topsoil depths in valley areas are 15-30cm 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 field and deposited elsewhere in the district. Water erosion is a major concern, with severe rilling and sheet erosion occurring. Topsoils in valley areas are more than 30cm deeper than on the crests and sediment put into drains/ streams may be high.

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 in Figure 9.

Good seed germination and plant emergence depend upon 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 re-settle and consolidate rapidly after the seedbed has been prepared. Impeded water and air movement through the soil can give rise to small areas low in oxygen (anaerobic zones). These produce chemical and biochemical reduction reactions, the by-products of which are toxic to plants. These anaerobic 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 fields that have poor soil structure. Young plants can also show discolouration of leaves and moisture stress.

The loss of soil structure can reduce crop establishment of barley from 315 to 131 plants per m^2 and grain yields from 6.7 to 3.9 tonnes per hectare. Sugar beet germination slows, and plant populations also decrease. Seedling mortality in winter cereals can be high if the soil is waterlogged for more than 3 to 4 days between germination and emergence.

Plant Indicators

Figure 9: Visual Scoring of Crop Emergence Under Arable Cropping.

Visual Score (VS)	Crop Emergence
2	Good emergence and plant establishment, with few gaps along the row and crop showing a good, even height.
1	Moderate emergence and plant establishment, with a significant number of gaps along the row and a significant variation in seedling height.
0	Poor emergence and plant establishment, with a large number of gaps along the row and a large variation in seedling height.

Crop Height at Maturity

- Measure crop height and height variability when the crop has reached maturity. 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 plant 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 greatly upon climatic factors, the plant type, 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 tilth throughout the growing season. Poor soil aeration and resistance to root penetration as a result of structural degradation reduces plant growth and vigour, and delays maturity.

Figure 10: Visual Scoring of Crop Height at Maturity Under Arable Cropping

Visual Score (VS)	Crop Height at Maturity
2	Crops are at or near maximum height, with little variability in height at maturity.
1	Crop heights are significantly below maximum and show moderate variability in height at maturity.
0	Crop heights are very uneven and patchy and well below maximum height at maturity.

Size and Development of the Crop Root System

- Determine the size and development of the root system, ideally when the soil is still moist by carefully removing the plant from the soil and gently shaking it to remove excess soil from the roots. Compare the root systems with the pictures in Figure 11.

Consolidation and compaction of the seedbed restricts plant growth and vigour by restricting root development, 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, which are necessary for growth, and increases the susceptibility of the crop to lodging.

Figure 11: Visual Scoring of Size and Development of Crop Root System Under Arable Cropping.

Visual Score (VS)	Size and Development of the Crop Root System
2	Unrestricted root development with the main large root bulb up to 25cm wide and 20-25cm deep.
1	The main root bulb is commonly 15cm wide and 15-18cm deep. Vertical root development is often restricted below 12cm with right-angle syndrome not uncommon.
0	Vertical and lateral root development I severely restricted, with root systems showing either right-angle syndrome, over thickening, or growth down coulter channels.

Plant Indicators

Crop Yield

- Assess relative crop yield.

  Assessments can be made for all varieties of crop by estimating heads or pods per square metre, grains or seeds per head or pod and the size of grains or seeds. Harvester yield monitors could also be employed. 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 for re-drilling, delays in drilling, 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 bread-making quality of wheat.

Figure 12: Visual Scoring of Crop Yield Under Arable Cropping.

Visual Score (VS)	Crop Yield
2	Heads are large with complete grain filling and few signs of stress, pests or disease.
1	Heads are of medium size and may show occasional incomplete grain filling. Stress, pest and disease evidence is often apparent.
0	Heads are generally small and vary in length. Grain filling is invariably incomplete and stress, pest and disease features are very common.

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 field from season to season (see table in Figure 13).

Poor soil aeration, high levels of soil saturation and high mechanical resistance to root development due to soil structure 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, phytophthoria, rhizoctonia, take-all and vesicular-arbuscular mycorrhizal fungi.

Figure 13: Visual Scoring of Root Diseases Under Arable Cropping.

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

Weed Infestation

- Assess the degree of weed infestation by visually estimating the number of weeds between rows at crop maturity according to the table in Figure 14. Consider how often a given level of weed infestation occurs in the field from season to season, and at what level it is perceived to become 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 smother the crop.

Figure 14: Visual Scoring of Weed Infestation Under Arable 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

Surface Ponding

- Assess the degree of surface ponding. Base the assessment on ponding present at the time, on general recollection on the time ponded water took to disappear following a wet period, or after heavy rainfall in the winter.

The length of time that water remains ponded on the surface indicates the rate of infiltration into the soil, and the time that the soil remains saturated. Prolonged water logging depletes oxygen and causes carbon dioxide to build up.

Anaerobic conditions develop and induce a series of chemical and biochemical reduction reactions that that produce by-products that are toxic to plant roots. Organic substances can also anaerobically degrade in these soils and the soil goes 'sour'. Water logging 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. Be aware of cross compliance regulations regarding traffic on waterlogged soil.

Figure 15: Visual Scoring of Surface Ponding Under Arable 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.

Soil Indicators

Establishment Costs John Bailey, TAG Machinery Consultant.

The introduction of the Single Payment and the separation from production is encouraging farmers to scrutinize their whole production costs with renewed vigour. If farms are not to severely eat into or swallow up the payment entirely the production costs of cereals need to be no more than £60 per tonne. Only by really working out the individual farm costs for each component and particularly each machinery operation/pass can a business know just how crops compare. Sensible judgements can then be made as to whether there would be any profit at all in growing the crop or taking on further land, even if it is good high yielding land and there is no rent to be paid. Generalised “Farm Contractor” or “John Nix” text book figures are not good enough.

Considering “average” and “keen” machinery costs to produce a tonne of wheat the following figures are likely:-

Although “every little helps” the main items are the cost of the whole cultivation system and the combining. Establishment costs are likely to range from £100 per hectare for a competitive plough based system on heavy land to £25 per hectare for a true direct drill cost. Smaller farms with lower machinery outputs will invariably be more. Hence it is imperative to reduce the average establishment cost from perhaps £100 to £70 per ha, by at least a proportion of non plough cultivations. Few now disagree with these changes and more are now convinced that yields can be sustained. Depending on the farm size and the soil type there may be two or more systems with inbuilt field adjustments to give these averages. Lighter land farms by virtue of higher rates of work may already be at £70 per hectare but need to further reduce these costs because yields and therefore returns are normally lower. Yield is absolutely paramount. Because there are so many variables in producing crop it is virtually impossible to deliberately budget on a lower yield offset by reduced establishment costs. Whilst it is difficult to genuinely save £30 per hectare in establishment costs it would be easy to lose this value with a lower yield e.g. 0.5 tonnes of wheat per hectare at £60 per tonne.

Table 1

Component/Operation	“Average Cost” £/ha	Keen Cost £/ha
Subsoiling (1 year in 3 stretching to 1 year in 5?)	11	8.5
Cultivation System	100	70
Spraying x 5	40	25
Fertilising x3	21	15
Combining	62.5	37.5
Carting	12	8
Totals	£246.50	£164
Cost per hectare based on an 8.5 tonne yield	£29	£19.3

Looking at the other components depending to an extent on the soil type it's likely the amount of subsoiling necessary would be reduced by less ploughing. The other costs can be gradually reduced by keeping machinery longer within reason, buying good second-hand/demonstrator replacements when required or sizing equipment more accurately for the farm needs. For instance keeping a combine another 3 years e.g. from 5-8 years or 8 years to 11 years will give very low combining costs if you have the confidence in your machine and the dealer back up in the area. Whilst the individual spraying costs are low they add up over 5 or more passes and the capital cost required to replace modern sprayers is significant. Larger trailers within the legal limits are a good long term investment reducing the number of journeys etc.

Labour

This is a major item on farms. Good quality reliable labour is essential to run a modern farm but it needs to be well utilised as far as possible throughout the year to be cost effective. Typically farms vary from about 200 hectares of mainly cereal cropping per employee to perhaps 500 hectares per employee.

There are hopefully other sectors such as livestock and increasingly non farm enterprises which at least partly occupy the staff in the winter months, so reducing the costs allocated to the cereals.

Summary

The farm labour cost is crucial if the business is to remain profitable. It is very difficult if not impossible to catch up lost ground in other areas if the labour bill is too high. Every farm needs to accurately know the production costs on a per tonne basis for each crop. Many of the break crops whilst necessary will be less profitable than wheat so be careful. Only then can the owner or manager really consider their options. Overall the farm needs to be able to produce wheat or barley at £60 per tonne. Within this figure it is certainly possible, indeed likely, that the machinery costs can be gradually reduced by £8-10 per tonne without hopefully reducing yield or timeliness.

Visual Score (VS)	Average farm establishment costs, trend over recent years
2	Establishment costs have reduced
1	Establishment costs have remained constant
0	Establishment costs have increased

Conclusion

Using the VSA technique and by referring to this guide, you will be able to carry out an accurate and reliable assessment of the soils on your farm as well as take steps towards rectifying potential problems and enhancing your soil environment. Areas of your system to consider in the future may include field traffic management, tyre equipment, timeliness of operations and establishment technique.

Using the scorecards provided, make an assessment of your soils and record your results. These will prove valuable for comparison in following years. Consider the things that have changed and may have contributed to a different result and decide whether this is a positive or negative change.

Refer to the SMI/Väderstad 'Target on Establishment' book. This covers best management practices and environmental protection through the implementation of various soil management techniques.

Through experience, assessment and realignment, you can build a balanced approach to soil husbandry, thereby maximising yield, profit and environmental benefit.

Many thanks to Graham Shepherd, John Bailey and Paddy Johnson for their contributions.
Also to Hugh Symington for editing the book and Martyn Joyce for the book design.

Landcare Research, New Zealand are gratefully acknowledged for allowing the use of the Visual Soil Assessment.

© Väderstad and Soil Management Initiative
No part of this book covered by copyright may be reproduced or copied in any form or by any means without the written permission of Väderstad or SMI.