# TARGET
## on establishment

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. The machinery solutions shall also be key in 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.

SMI Soil Management Initiative

The UK Soil Management Initiative is an independent organisation created to promote by information transfer and advice the adoption by UK farmers and advisers 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.

SMI was set up as a non-profit making Limited company in January 1999. It draws on the experience and research of its members to provide solutions to pressing problems caused by poor soil management. It is funded by the EU LIFE fund as well as member organisations. 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 efforts of the national and associates lobbies European Government for change and support.

# TARGET
## on establishment

## Management

1 Policy

2 Soil structure

3 Soil health

4 Soil care

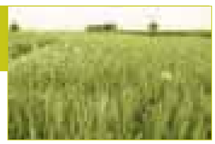
5 Climate change

6 Machinery

7 Trash

8 Cropping & agronomy

9 Weeds



10 Fertility

SMI

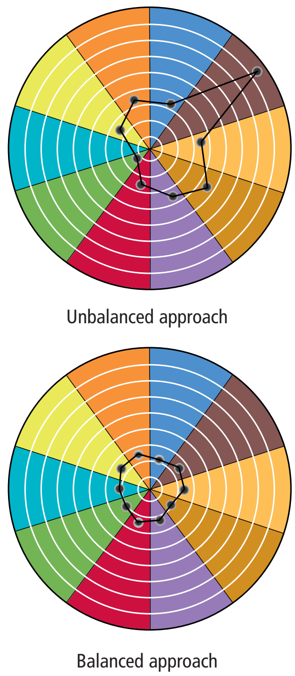
*Innovation for the future of farming*

VÄDERSTAD

Over the last five years the importance of good soil management has slowly climbed up the political agenda. In 1999 a MAFF funded survey by SSLRC showed that 44% of arable land is at risk of water erosion, with erosion taking place on moderate slopes on heavy soils and gentle slopes on sandy soils with an estimated 2.3mt of top-soil lost annually. DEFRA and The Environment Agency both published documents in 2004 clearly showing the importance of soil management and protection of our water resources. EU efforts to control soil erosion and soil degradation have brought in a requirement for cross compliance - a tool to bring about environmental benefit from payment to farmers as opposed to production subsidy. From January 2005 farmers will be obliged to meet new targets which include maintaining/ building soil structure and organic matter and minimising soil erosion as part of their cross compliance terms within the new Single Farm Payment. The Environment Agency will be policing the new Water Framework Directive to minimise pollution of watercourses from land based operations. With the encouragement of economic drivers crop establishment methods are under-going radical change, with some 42% of arable land now under conservation tillage systems. So the need for best practice is never more vital to British farmers.

This book, produced by SMI and Vaderstad, is designed to be both a working guide and reference document. It provides information for understanding and informed decision making by growers and agronomists, but is not intended to provide advice. The chapters are written by specialists in their field to be practical and informative, and each chapter ends with a table of actions and space to make notes of your learning's. Each author is providing their own viewpoint within a framework of SMI collaboration.

The book is focussed around a 'target' concept, carried from the start through each chapter to the conclusion. This is to focus attention on the importance of individual factors affecting soils and establishment, which are covered in each chapter, but also balance the management of these factors. From experience this thorough balanced approach is the most successful overall, particularly when adopting conservation tillage systems. Bad management in one area can unbalance the whole system leading to poor performance of yield and profit, but




**Target score concept**

could lead to bad erosion.
Using the target concept, fields can be scored 1 (best) - 9 (worst) with respect to each factor and the scores plotted on the target. When the score dots are all joned up, the smaller the area in the centre the more balanced your management and the more sustainable your system (Figure 1). These plots can be used to monitor performance from now and be reviewed at a future date to check progress.

# 1 Policy

In 2005, a number of existing agricultural subsidies will be replaced by a new Single Farm Payment which results from reforms to the European Union's Common Agricultural Policy (CAP) agreed in 2003. DEFRA tells us that implementing last year's reforms to the Common Agricultural Policy is central to England's strategy for sustainable farming and food and that farmers will have greater freedom to farm to the demands of the market as subsidies will be decoupled from production.

**Mark Hall**
Strutt and Parker

Ten major CAP payment schemes will be replaced by one new Single Farm Payment and at the same time environmentally friendly farming practices will be "better acknowledged and rewarded".

| To claim single farm payment in 2005, a farmer must: |
|---|
| • Be in occupation of land (minimum 0.3 hectares) for a minimum period of 10 months starting any time between 1st October 2004 and 30th April 2005, the choice being at the farmer's discretion. |
| • Meet cross compliance conditions from January 2005. |

"DEFRA tells us that implementing last year's reforms to the Common Agricultural Policy is central to England's strategy for sustainable farming and food."

## What is cross compliance?

Receipt of the Single Farm Payment is conditional on meeting various statutory, environmental, food safety, animal/plant health and animal welfare standards. There are two types of cross compliance.

1. The farmer must comply with 19 existing EU directives and regulations covering aspects of environment, public, animal and plant health, food safety and animal welfare - called statutory management requirements (SMR).

2. Farmers will also need to maintain land in good agricultural and environmental condition (GAEC).


Photo 1.1

Member States have been given the flexibility to define the detailed GAEC measurements within a framework focusing on the protection of soil, habitats and landscape features, but must set standards for all these issues. Failure to comply with SMR and/or GAEC, which apply to all agricultural activities across an entire holding, could result in the reduction or exclusion of payments. Penalties for non compliance are defined by the European Commission as:

| |
|---|
| **a) Negligence:** not more than 5% of aid payments will be lost in this cace. |
| **b) Repeated non compliance:** not more than 15% of aid payments will be lost in this cace. |
| **c) Intentional non compliance case:** not less than 20% of aid payments will be lost in this cace. |

DEFRA tells us that "the base line standards set for England are relatively light requirements representing a mixture of 'common sense' farming practice and support for existing legislation, which should help drive an improvement in the economic and environmental performance of English agriculture".

As agriculture is a devolved subject, English, Scottish, Northern Irish and Welsh departments will take slightly different approaches to defining cross compliance conditions so to reflect regional, environmental and agricultural characteristics.

A broad framework has been announced for cross compliance with much detail still awaited.

## Statutory Management Requirements (SMR)

It remains to be seen what exactly these requirements will be. DEFRA propose taking a "light touch" approach. 18 of the 19 regulations are already in existence. The 19th SMR relates to a new piece of EU legislation concerning sheep identification and is unlikely to add much to previous demands.

We can, however, make some assessment of the requirements that are likely to be included within the SMRs. The EU Regulations outline the 18 original directives:

| a) Applicable from 1st January 2005 | b) Applicable form 1st January 2006 | c) Applicable from 1st January 2007 |
|---|---|---|
| 1. Conservation of wild birds.<br>2. The protection of groundwater against pollution caused by certain dangerous substances.<br>3. Protection of the environment and particular of the soil where sewage sludge is used in agriculture.<br>4. Protection of water against pollution caused by nitrates from agricultural sources.<br>5. The conservation of natural habitats and wild fauna and flora.<br>6. The identification and registration of animals.<br>7. Compliance with the regulations concerning ear tags, registers and passports for the identification and registration of bovine animals.<br>8. Compliance with regulations concerning labelling of beef and beef products. | 9. Compliance with the regulations of placing of plant protection products on the market.<br>10. Prohibition on the use in stock farming of certain substances having a hormonal or thyrostatic action.<br>11. Compliance with the regulations concerning the requirements of food law. The establishment of a European Food Safety Authority and procedures in matters of food safety.<br>12. Compliance with the rules for the prevention, control and eradication of BSE.<br>13. Measures for the control of foot and mouth disease.<br>14. Measures for the control of other animal diseases.<br>15. The control and eradication of blue tongue. | 16. Compliance with minimal standards for the protection of calves.<br>17. Compliance with the directive concerning minimal standards for the protection of pigs.<br>18. Compliance with the directive concerning the protection of animals kept for farming purposes. |

"DEFRA have highlighted a number of areas which will satisfy their requirements that land is kept in a good agricultural and environmental condition."

## Good Agricultural and Environmental Conditions (GAEC)

DEFRA have highlighted a number of areas which will satisfy their requirements that land is maintained in good agricultural and environmental condition. These are:


Photo 1.2

The protection and maintenance of soil.
The protection of:
- hedges and water courses
- landscape features
- public rights of way
- moor land habitats

The management of:
- hedgerows
- stone walls
- permanent pasture
- land not wholly in agricl. production

The use of 6 to 10m set-aside strips.
The prevention of overgrazing.

## Protection and Maintenance of Soil

(The ouline given below was correct as of 1st October 2004)

This forms one of the key parts of the cross compliance standards and requirements. DEFRA promised to publish new guidance this autumn for farmers to read, retain and follow. In 2006 farmers will be expected to produce whole farm risk based soil management plans with the implementation of these plans starting in 2007. The three main areas that DEFRA are concentrating on are:

| a) Soil erosion: |
|---|
| In particular the treatment of land following the harvesting of combinable crops. This must over the following winter have either crop or green cover, stubble or be primary cultivated (plough, disc or tine) only unless the succeeding crop requires earlier cultivation. |

| b) Soil organic matter: |
|---|
| Protect and build soil organic matter through best practice and inclusion of FYM, trash, long-term grass and cover crops. |

| c) Soil structure: |
|---|
| Protection of soil structure through best practice with aim to build over time. Farmers are advised against carrying out any operations on saturated soils or in standing water. |

"In 2006 farmers will be expected to produce whole farm risk based soil management plans."

## Overgrazing

The current controls on overgrazing semi-natural vegetation that require an assessment of the condition of vegetation will remain in place. Where there is evidence of damage, advice will be given on limits to stocking rates and if necessary, these will be imposed to prevent further damage.

## Hedgerow Management

Cutting of hedges will not be permitted between 1st March and 31st July with the exception of that which is necessary for access or health and safety reasons.

## Protection of Permanent Pasture

Permanent pasture is defined by the European Commission as land that has been under grass for at least 5 years and

Photo 1.3

has not been ploughed for other crops in that time. To meet the EU Regulations, DEFRA have put in place a control mechanism to ensure that the national area of permanent pasture is not reduced by more than 5% of the total area of agricultural land. Afforestation of permanent pasture is generally exempt from this requirement providing it has been assessed under the existing Forestry Environmental Impact Assessment Regulations.

## Set-aside Management

There will be few changes to the current set-aside management rules. The percentage of land to be set-aside will be 8% in 2004/5 outside a severely disadvantaged area. It is likely a small percentage of clover will be permitted in seed mixes to encourage biodiversity. Also farmers will have the option to put all or part of their set-aside land into narrow (6-10 metre) 'environmental' strips next to wet ditches, rivers, lakes, Sites of Special Scientific Interest, woodland and hedges.

## Hedge and Water Course Protection

Farmers will be required to establish a 2 metre uncultivated strip as a protection zone along hedges and water courses. The 2 metres is measured from the centre of a hedge or ditch with a minimum of 1 metre from the top of the ditch bank required. The introduction of this will be delayed until the beginning of the next planting season (i.e. July 2005).

**Protection of Landscape Features**
Compliance with existing legislation protecting a wide range of habitats and landscape features will be required. These include:

- Tree Preservation Orders.
- Hedgerow Regulations.
- Environmental Impact Assessments.
- Schedule Monuments Legislation.
- SSSI legislation under Wildlife and Countryside Act.
- Heather and Grass Burning Regulations and the Forestry Act.

Photo 1.4

**Protection of land not wholly in agricultural production**
Farmers will be required to ensure that land no longer in production remains classed as agricultural land under the Single Farm Payment Scheme. Notifiable weeds will need to be controlled so that land will be capable of being returned to production by the next growing season at the latest. An inspector should be able to easily identify eligible land and undertake measurement of it.

**Protection of rights of way**
Public rights of way must not be obstructed or disturbed. However, farmers may plough the path or right of way so long as the path is reinstated within any prescribed time limit. Stiles and gates must be maintained.

**Protection of stone walls**
These must not be removed or damaged without consent from the relevant authority. Consent will only be granted where there are particular extenuating circumstances.

**Protection of moor land**
Compliance with the Heather and Grass (Burning) Regulations will be required. More information on this is expected soon.

Photo 1.5

## Soil protection and management

Of all the elements of GAEC outlined above, it would appear the protection and maintenance of soils is a high priority with DEFRA and the Environment Agency. DEFRA published 'The first Soil Action Plan for England: 2004-2006'. This outlines a number of Core Actions which will affect farmers:

**"Farmers will be required to ensure that land no longer in production remains classed as agricultural land."**

1) DEFRA will review the Code of Good Agricultural Practice for the Protection of Soil and amend or replace it as required by 2005.

2) DEFRA will work with the farming industry to examine current and all lawful means of encouraging voluntary change in soil management. This will be reviewed in 2006.

3) DEFRA will work with partners to fund further research on the relationships between farms, soil management practice, physical characteristics, function of soils and the impacts e.g. on diffuse water pollution and flooding. Again this will be reviewed in 2006.

4) With the Forestry Commission, DEFRA will examine the scope for inclusion of soil issues in the England Wood land Grant Scheme as work progresses during 2004.

5) DEFRA will consider with English Nature and other partners the benefits which might arise from the establishment of a national series of benchmark sites for soil bio-diversity.

6) DEFRA will work with the Environment Agency and other partners to continue to examine a range of policy options for the control of sediment and soil bio-nutrient losses to water.

7) DEFRA will work with partners to re-examine current soil management advice, to take account of the potential impacts of inappropriate management on flooding, water and air quality.

8) DEFRA will seek to negotiate the proposed revisions to the Sewerage Sludge Directive to ensure that controls on the application of sludge to land recognises the potential benefits, while ensuring that sludge does not impair the long term functioning of soils.

9) DEFRA will seek during negotiations on the proposed Bio-waste Directive to agree arrangements which encourage the return of organic material to the soil (respecting natural soil diversity and retaining long term functions).

**"In 2006 farmers will be expected to produce whole farm risk based soil management plans."**

The Environment Agency sets out its own priorities for action in its document 'The State of Soils in England and Wales'. It states that meeting environmental objectives for water and air also depend on good soil management and that sustainable land management practices are required which are economically viable and environmentally responsible particularly in agriculture.


Photo 1.6

In England and Wales, erosion is estimated to move some 2.2 million tonnes of arable top soil annually. The Agency state that eroded silt can smother river bed gravels harming aquatic plants and vertebrates and the eggs of fish. It is estimated the main causes of structural damage and erosion in soils are:

1) Intensive cultivation particularly when soils are compacted by heavy machinery or left exposed to heavy rain.

2) Heavy trampling of soil by sheep and cattle, and routing by free range pigs.

3) Poor forestry practise, for example during road construction and harvesting.

4) Runoff from urban land especially building sites.

In addition to erosion, nutrient loss from farmland is seen as a major source of water pollution particularly from nitrogen and phosphorus.

## Soil erosion risk in England and Wales

The Environment Agency go on to point out that the loss of nitrate from agricultural soils is causing failure of the Drinking Water Standard in some groundwater sources and is contributing to eutrophication in estuaries and the sea. Despite the designation of Nitrate Vulnerable Zones, reduction of nitrate leaching is "slight" and "further controls are needed in many areas".

So the pressure is on to become more aware of soil management practices and control the use of pesticides and fertilisers. The need for self regulation and commitment is evident. If farmers do not achieve the goals themselves, regulatory tools such as cross compliance will become more onerous in the future. Farmer supported organisations such as the Voluntary Initiative and the Soil Management Initiative are pushing hard to prevent this from happening.

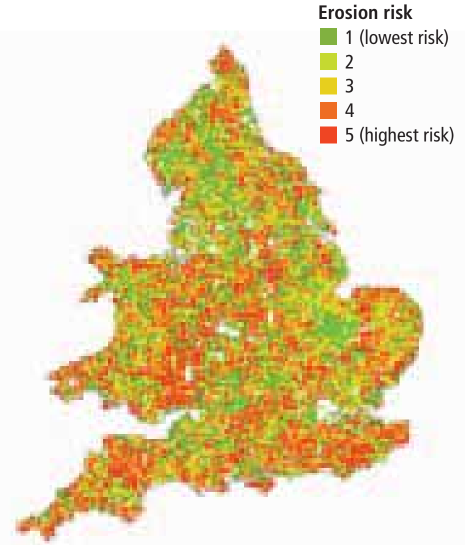



**Figure 1.1** Erosion risk map based on slope, soil texture and carbon levels (LandIS database)

"Despite the designation of Nitrate Vulnerable Zones, reduction of nitrate leaching is "slight" and "further controls are needed in many areas".

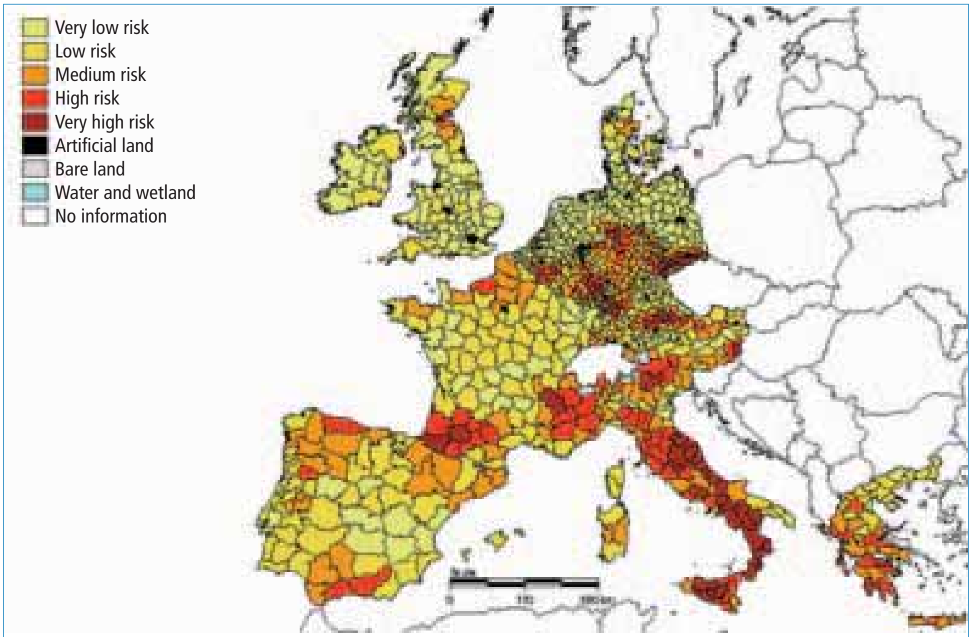
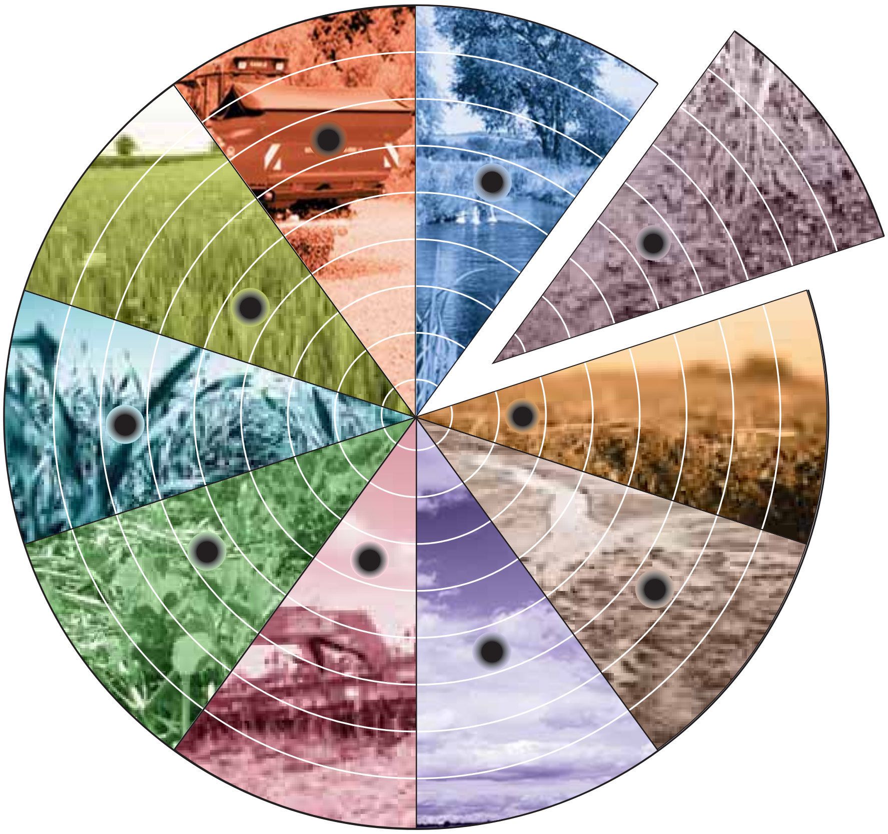



**Figure 1.2** Annual soil erosion risk (integrated by EC nuts regions).

| Action points on policy | Learning/notes |
|---|---|
| • Anticipate requirements of GAEC and SMR as regards protection and maintenance of soil<br>• Meet cross compliance conditions from 1st January 2005<br>• Minimise soil erosion<br>• Maintain and build soil organic matter content<br>• Maintain and improve soil structure<br>• Understand and care for your soils and their importance to crop production and their management to environmental protection<br>• Prepare a risk based soil management plan in 2006 for implementation in 2007 | |



# 2 Soil structure

Good soil structure is fundamental to both profitable crop production, but also environmental protection, ensuring water, air, root and worm movement in the soil. Intensive farming and cultivation can degrade soils and not only takes a considerable expense and many years to correct but can cause pollution of our rivers. New cross compliance measures are intended to protect this vital resource. This chapter provides an overview of structure, what to look for and a proven assessment method (Visual Soil Assessment).

**Mark Littleford**
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Technical support

**Graham Shepherd**
Visual Soil Assessment
New Zealand

**Paddy Johnson**
PJASOC
Independant soil consultant

## Soil physical fertility

This is often dependant on soil structure and involves five important properties:

• Rainfall acceptance by the soil and the ease with which excess water is drained from the soil.

• Storage of available water and the ease with which roots can retrieve it.

• Mineralisation of organic matter in soil, which involves temperature, oxygen, moisture supply and biological activity.

• Seed germination and early population establishment - influenced by packing of soil around the seed and interaction between soil temperature, moisture and pests and disease.

• Crop growth - dependant on root penetration and extraction of water and nutrients in phase with the development needs of the crop.

"Soil organic matter plays a major role in promoting aggregation of light soils and stability in medium textured soils."

Photo 2.1

Soil organic matter plays a major role in promoting aggregation of light soils, gives stability in medium textured soils and mellowness and friability to heavy soils.

## Soil structure

The structure of a soil is the result of a number of different processes:

**1. Freezing/Thawing**

When ice forms in the soil, the particles are pressed together and bind to each other, resulting in mechanically formed aggregates and a finer tilth.

**2. Wetting/Drying**

In clayey soils, structure can develop through repeated wetting and drying. Many clay crystals have a lattice structure and as water molecules enter the lattice, the crystal expands and forces other soil particles to aggregate together. When the clay crystal loses water on drying it contracts but the newly formed aggregates are left intact. This action can break down clods and leave a finer tilth.

**3. Chemical processes**

Humus compounds, carbonates and iron and aluminium compounds can produce considerable stabilisation of the aggregates by acting as binding materials. However, recurring soil tillage reduces the stability of soil aggregates. It is important to encourage biological activity, which will produce the binding materials.

**4. Earthworms**

Earthworms play an important role since they both create wormholes and stimulate the activity of micro-organisms. At least in the short term, the worms increase the stability of aggregates by producing mucus and other binding agents.

**5. Plants**

The uptake of water by plants causes aggregates to be formed by soil drying. The plant roots also increase the amount of organic material in the soil and create root channels. Water is lost from the soil surface through evaporation and through transpiration from the crop leaves. If the aim is to dry out a wet soil to depth, a growing plant with a large leaf area is much more effective than leaving the soil bare.

**6. Drainage**

Effective drainage is a basic requirement for homogenous soil drying and therefore aggregate formation.

Photo 2.2

**7. Manure and Liming**

Regular applications of lime, farm yard manure and other organic materials are beneficial for both aggregate formation and aggregate stability, since they generally promote the activity of soil fauna and soil micro-organisms and thereby improve soil structure. This effect reaches far beneath the top-soil, as long as there is no barrier to root growth.

Photo 2.3

**8. Machinery**

Trafficking by heavy machinery often causes soil compaction, particularly when the soil is in a wet and plastic condition. Soil compaction means that the pore volume in the soil is reduced and it is usually the larger pores that are lost. This reduces the free movement of water through the soil and movement of air to plant roots, which also have more difficulty in penetrating the soil. Machinery managed correctly can also help to restore compacted structure.

**9. Cultivation Effect**

Soil cultivation exerts a further effect on structure formation. This effect differs depending upon the soil cultivation strategy employed. Often a denser layer is formed at the base of the cultivated layer, regardless of the techniques used, but the depth can vary.

Photo 2.4

**10. Result**

The result of all these processes is a soil profile that often has finer aggregates at the surface and coarser aggregates at depth. All the processes have an effect on the top-soil, while their effect at depth varies. This is how the soil looked before agricultural techniques were employed.

"The result of all these processes is a soil profile that often has finer aggregates at the surface and coarser aggregates at depth.."

## What constitutes poor/good soil structure?

| | Poor | Good |
|---|---|---|
| **Aggregates** | Platy<br>Angular blocky<br>Prismatic | Granular<br>Sub-angular blocky |

| | Poor | Good |
|---|---|---|
| **Profile** | Dense angular/ blocky structure<br>Few pores<br>Restricted rooting<br>Few vertical, more horizontal cracks | Open granular/ loose blocky structure<br>Lots of pores and worm holes<br>Widespread rooting to depth<br>Widespread cracking/ fissuring |

"Good soil structure comprises an open granular, or loose blocky structure with lots of pores, widespread rooting, and cracking in the soil."

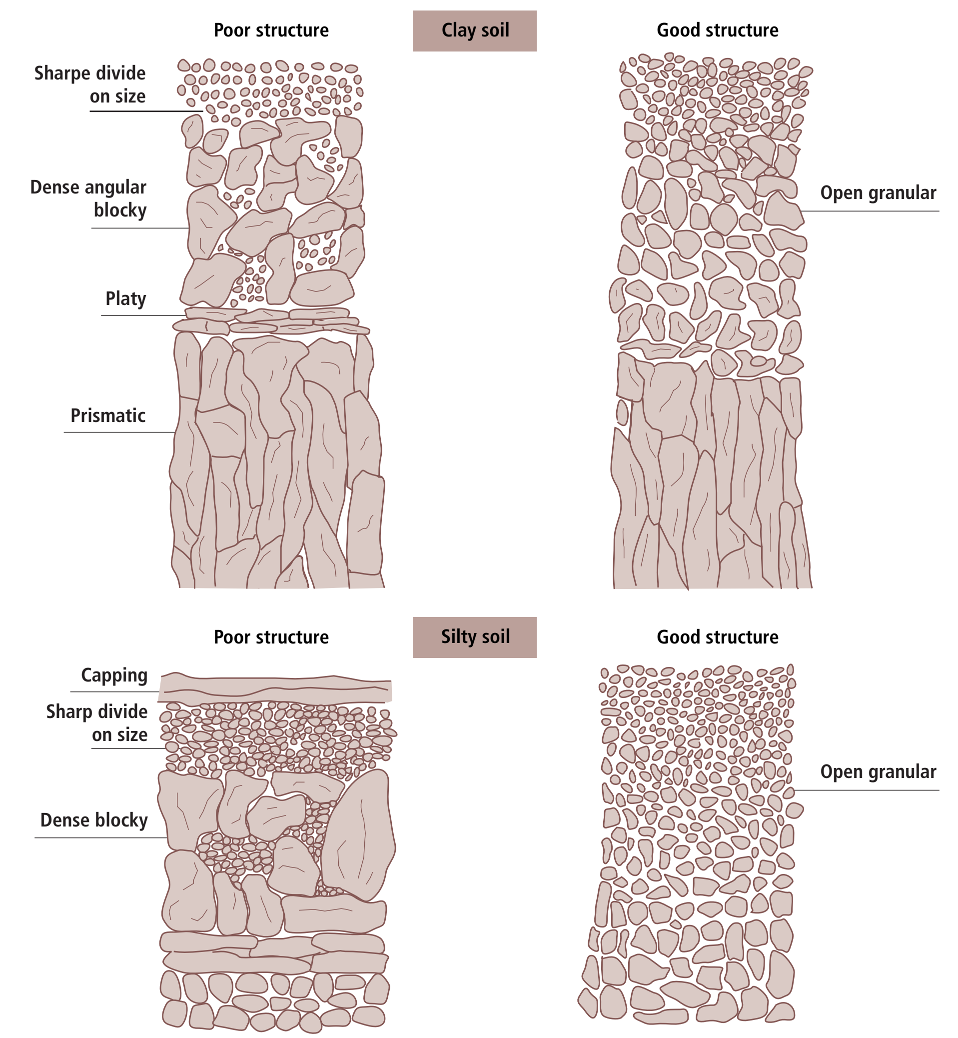



**Figure 2.1** Comparison of poor structure/ good structure profiles

**Results of poor structure include:**

- Plough/ disc pans and smearing
- Compaction- no pores/ roots/ worm channels
- Very loose soil
- Regular run-off/ soil erosion
- Surface capping
- Poor drainage
- Anaerobic/ smelly soil layers
- Poor rooting and yields

## Structure maintenance and improvement

On difficult land, particularly if slow draining and weakly structured, the aim at all stages should be to keep the land in as satisfactory a drainage condition as possible. In this way, the extent of soil and crop damage is minimised in the event of long periods of wet weather or intense rainfall periods.


Photo 2.5 Courtesy of the Environment Agency

**Reduced and timely cultivations**

Do no more than is needed for the crop in question and at the right time to suit conditions.

**Wheel slip**

Carry enough ballast to give good traction, use the correct tyres at the correct pressures and keep draught to a minimum.

**Grass and FYM**

Heavy dressings (not exceeding rules/ local restrictions) of farm yard manure or the use of 2-3 year grass or Lucerne leys can be effective in repairing damage to soil following arable cropping in successive wet years. (Pans easily stop grass roots and compaction must be removed prior to ley establishment).

**Lime and fertilisers**

Good structure is encouraged by maintaining a neutral or alkaline reaction in the soil.

**Crop root architecture**

Different crops root in different ways and this is beneficial to structure. The continuity of pores and cracks depend on the soil's aggregation, plant root action and faunal activity. The individual mineral particles that form an aggregate are bound to each other by colloidal material, such as clay particles, humus compounds or the mucus residues left by micro-organisms. Even a small clay content and a moderate humus content gives sandy soils some aggregate structure. Aggregation often improves the aeration and water holding capacity of the soil, makes cultivation easier and allows better water and heat utilisation.

"Aggregation often improves the aeration and water holding capacity of the soil and makes cultivation easier."

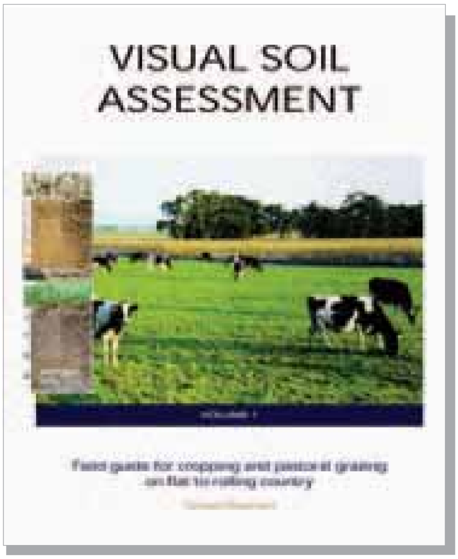
## Importance of drainage

The rate of water movement of drainage water depends upon the continuity of size of pores and cracks within the soil profile and the permeability of the slowest layer. In well-structured soils, the permeability is fast enough to prevent excessive water build-up. In sandy soil, most of the water moves vertically through the whole profile, removing soluble nutrients as it goes. In structured soils such as clays, water movement is mainly through structural cracks and fissures, so by-passing much of the soil.


Photo 2.6

Environmental and economic sustainability of arable farms can be greatly influenced by soil quality. The visual soil assessment method (VSA) provides land managers with a simple tool to assess and monitor soil quality. Visual soil properties are diagnostic of soil quality, and provide an effective and immediate way to assess soil quality quickly and cheaply in the field.

The VSA is based on the visual scoring of key biophysical indicators of soil quality, and incorporated on a score-card. The soil indicators are supported by plant 'performance' indicators that link soil condition to crop production. The indicators are underpinned by extensive research and are linked to economic performance. Soil indicators used are generic, and have the advantage of being largely independent of soil type. This enables VSA to be applied throughout the world.




"Environmental and economic sustainability of arable farms can be greatly influenced by soil quality."

The VSA Field Guide contains many easy-to-use comparison pictures like these that allow the Visual Score of an indicator, in this case soil structure and consistence under cropping, to be assessed.

**Good Condition**

**VS=2**

Good distribution of finer, friable aggregates with no significant clodding.

**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.

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

- 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 the condition of their short and medium-term land management decisions.

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.

**Photo 2.7** 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 (right of palm), and under poorly managed long-term continuous cropping (left).

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.

VSA 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.

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.

**Photo 2.8** 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 (suchas soil aeration) in governing soil condition and on-farm production.

## The VSA Method

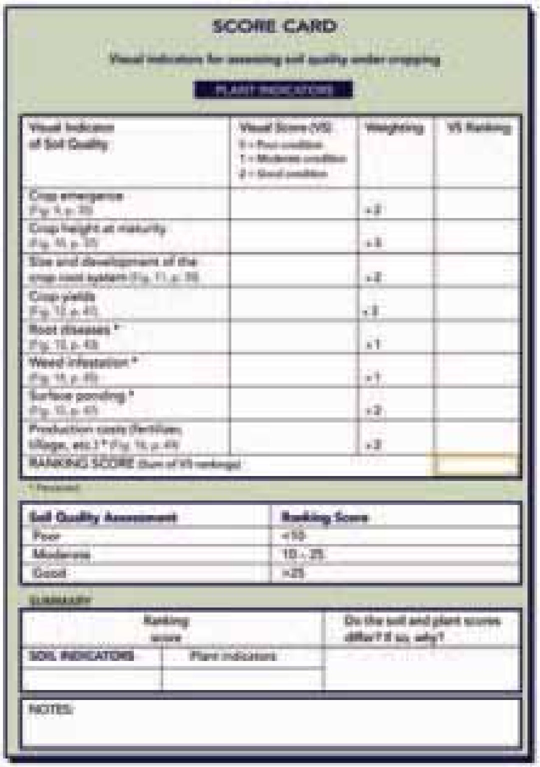
**Visual Scoring (VS)**

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

"Research shows that many of the visual indicators are closely related to key quantitative indicators of soil condition."

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.



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 | | x2 | |
| Crop height at maturity | | x3 | |
| Size and development of the crop root system | | x2 | |
| Crop yields | | x3 | |
| Root diseases * | | x1 | |
| Weed infestation * | | x1 | |
| Surface ponding * | | x2 | |
| Production costs (fertiliser, tillage, etc.) * | | x2 | |
| RANKING SCORE (Sum of VS rankings) | | | |

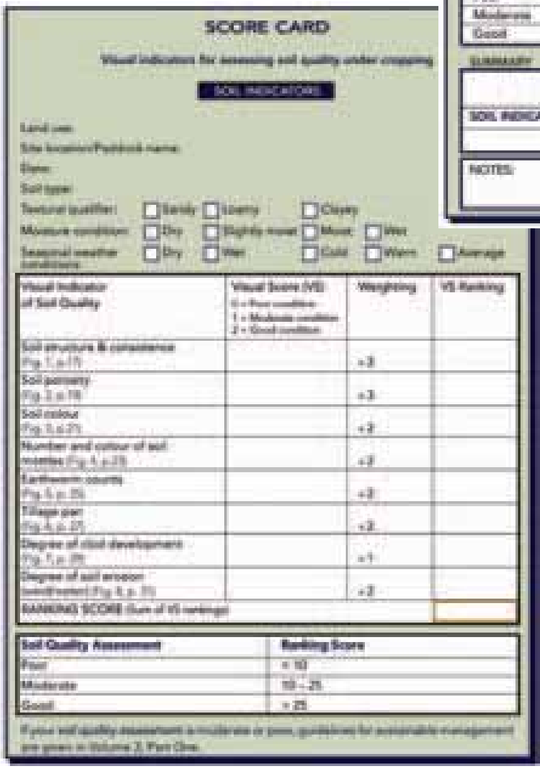
| Soil Quality Assessment | Ranking Score |
|---|---|
| Poor | <10 |
| Moderate | 10 - 25 |
| Good | >25 |

SUMMARY

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

NOTES:

"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."



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 | | x3 | |
| Soil porosity | | x3 | |
| Soil colour | | x2 | |
| Number and colour of soil mottles | | x2 | |
| Earthworm counts | | x3 | |
| Tillage pan | | x2 | |
| Degree of clod development | | x1 | |
| Degree of soil erosion (wind/water) | | x2 | |
| RANKING SCORE (Sum of VS rankings) | | | |

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

For example, soil structure is a more important indicator (factor of 3) than clod development (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 toolkit

**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 a 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 scorecards - to record the visual score (VS) for each indicator. Separate pads are needed for cropping and pastoral grazing on flat to rolling land.

## 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.
- For grassland 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.

### 2. Setting Up

**It is important to be properly prepared to carry out soil condition 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.
- Sites - 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 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.

**"The assessment process takes about fifteen minutes for each sample."**

### 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; top-soil blew off two years ago, etc.).

### 4. Carrying Out The Test

- Take the test sample - Dig out a 20 cm cube of top-soil with the spade. If the top-soil is less than 20 cm deep, trim off the sub-soil 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.

**Photo 2.9** The drop shatter test in action. The sample is dropped a maximum of 3 times from a height of 1 m (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.

## 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 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.

**Good Condition**
**VS=2**
Well established crop with uniform emergence

**Moderate Condition**
**VS=1**
Some failed areas with moderate overall emergence

**Poor Condition**
**VS=0**
Very patchy crop with uneven emergence and signs of stressing

"The way you manage your farm has profound effects on your soil, and your soil has profound effects on your long term profit."

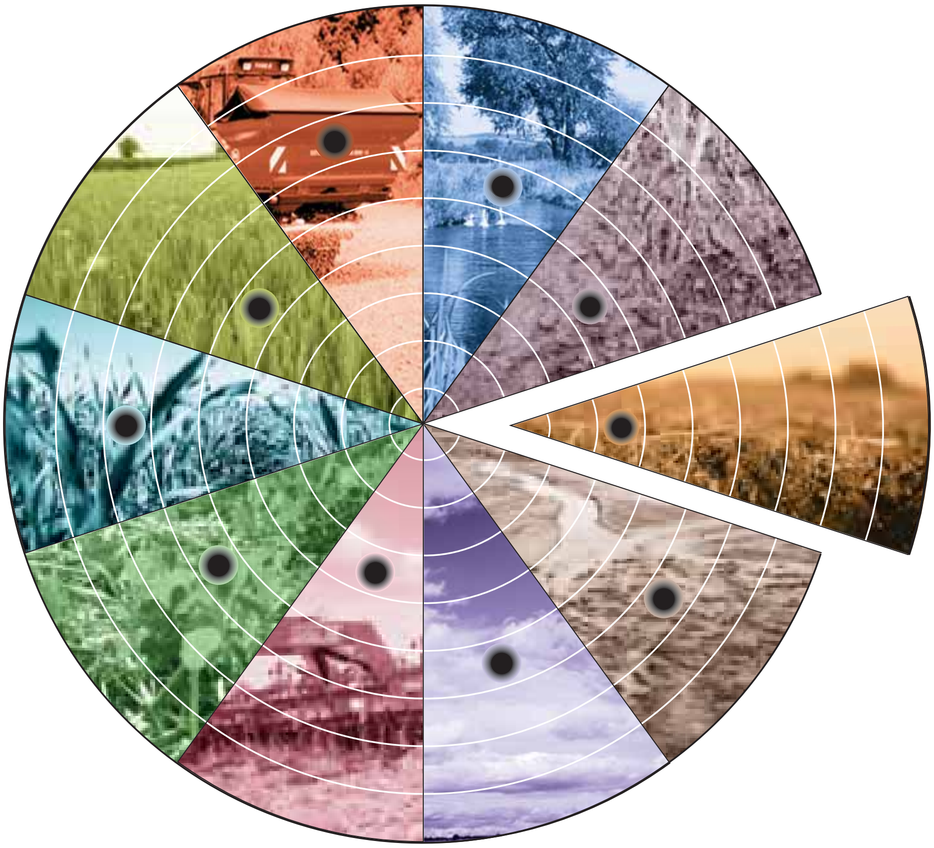
## Using the VSA Results

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. To help land managers preserve or improve soil condition, guidelines are included elsewhere in this publication.

| Action points on soil structure | Learning/notes |
|---|---|
| • Examine your soil by field and assess:<br>- good/ poor structures<br>- problems<br>- causes<br>• Obtain a copy of the VSA guide<br>• Use VSA to visually assess your soils by field<br>• Build soil health<br>• Care for your soils | |

**Target on soil structure**

1) Maintain and build soil structure
2) Do not carry out field work on water logged/ wet fields



# 3 Soil health

The soil ecosystem has been defined as a life support system composed of air, water, minerals, flora, fauna and micro-organisms, all of which interact and function together. Thus, soil is a dynamic system that contains a diverse range of soil micro and macro-organisms that contribute to maintenance and improvement of soil health and structure. Soil structure, soil microbial activity and biodiversity are, therefore, inextricably linked and play a major role in many natural processes that ultimately determine agricultural productivity. However, these processes are influenced and greatly affected by different soil cultivation practices.

**Dr Vic Jordan**
Independant consultant
AAE bioservices

**Dr Alastair Leake**
Director of Allerton Research
and Educational Trust

Improved soil management, whether better plough practice or minimum tillage systems, must be urgently addressed, for intensive soil cultivation results in loss of soil fertility, soil erosion by water and wind, deep soil compaction, reduced water infiltration and root penetration, reduced organic matter content and increased $CO_2$ emissions through oxidation of organic matter.

## Soil conservation tillage systems

"The importance of a diverse and productive soil fauna has long been recognised as essential."

Studies on conditioning the soil and incorporating crop residues in one pass without inverting the soil have shown, over time, considerable soil structural and quality benefits together with many ecological and environmental

Photo 3.1

advantages. The importance of a diverse and productive soil fauna has long been recognised as essential in nutrient recycling and improving soil structure through soil conditioning processes. Soil organic matter and its position within the soil profile is one of the main factors controlling biodiversity of soil fauna. With soil conservation tillage crop residues are incorporated into the top 10 cm soil with at least 30% retained on the soil surface. This encourages a different range of organisms compared to a traditionally cultivated, plough-based system in which residues are completely buried to plough depth.

## Soil structure

The way the available physical, chemical and biological elements in soil interact determines soil structure. Soil components are mixed or separated creating a structure in which water and nutrients can circulate or be stored so that ecological functions can take place. The role of organic matter is most important, as its decomposition mainly produces simple forms of nutrients from complex organic molecules that may be used by plants and soil organisms, or may be lost through leaching or gaseous flux. These nutrient exchanges between organic matter, water and soil represent soil fertility that must be maintained for efficient crop production.

## Soil fauna

This can be divided roughly into three groups namely, the microfauna the mesofauna and the macrofauna, each contributing to soil health in different ways.

**Microfauna (e.g. Protozoa, Nematodes)**
Inhabit the soil solution and utilise organic compounds of low molecular weight. They contribute to the formation of a stable soil structure as filamentous

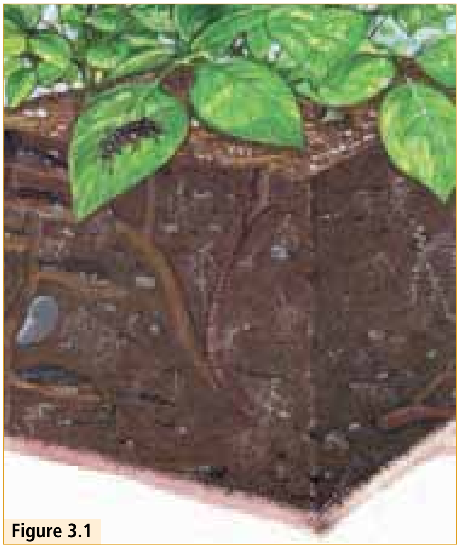


Figure 3.1

SMI

fungi and actinomycetes entrap soil particles to form aggregates that are stabilised by polysaccharides, lipids and proteins from microbial degradation of plant residues and soil humus. In agricultural soils, some of the microfauna are responsible for nutrient recycling. Soil cultivation has a considerable impact on the soil microfauna. In conservation tilled soils, soil organic matter is greater and more concentrated near the soil surface. This encourages soil microbial activity leading to improved aggregate stability. Nematodes additionally perform a diverse range of functions in soil. Although most is known about plant parasitic nematodes, the free-living forms can feed on bacteria and other microflora thereby contributing to nutrient recycling.

**Mesofauna (e.g. *Enchytraeidae, Collembola*)**
Inhabit the pore system and feed upon fungi, decomposed plant material and mineral particles. They principally contribute nutrient recycling and create micro aggregates that provide soil structural stability. Plant debris is decomposed into a form suitable for breakdown by the mesofauna, and the mineralisation process is started. Potworms *(Enchtraeids)* are usually most abundant in arable soil, living on or

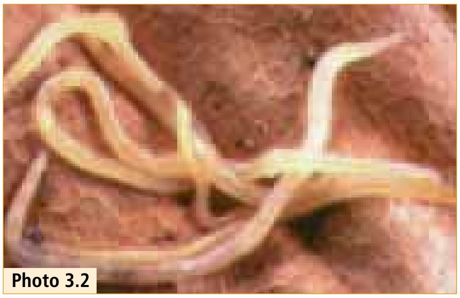


Photo 3.2

within the soil solution. They contribute to nutrient recycling, help distribute soil organic matter, graze on other micro-organisms and help the creation of a stable soil structure. Although they were assumed to be relatively unaffected by cultivation because of their small size and high reproductive rates, potworms were most abundant near the soil surface where conservation tillage was practised but are more evenly distributed in ploughed fields. Mites *(Collembola)* also play a part in nutrient recycling but this mainly occurs when organic manures that encourage fungi replace inputs of inorganic fertilisers. The increased diversity and abundance of mites in some experiments has been attributed to the use of non-inversion tillage.

**Macrofauna (e.g. *Gastropoda, Lumbricidae, Arachnida, Lepidoptera, Coleoptera, Diptera,*)**
Live between soil micro-aggregates feeding upon the soil substrate, soil microflora and fauna, soil organic matter and surface flora and fauna.


Figure 3.2

Earthworms *(Lumbricidae)* can influence soil chemical and physical properties either directly or indirectly. The physical structure is modified by the creation of burrows, which can penetrate the subsoil and aid drainage. This, combined with the binding ability of casts, decreases the risk of erosion. Transportation of soil by earthworms ensures good mixing of organic matter, micro-organisms, spores, pollen and seeds thereby creating humus. Earthworms also directly alter the nutrient content of the soil by mechanically breaking down organic matter and encouraging microbial

**"In conservation-tilled soils, soil organic matter is greater and more concentrated near the soil surface."**

activity. As a consequence nitrogen is released. Earthworm populations are directly influenced by soil cultivation but the impact varies between species and is influenced by other soil factors and climatic conditions. Plough-based, complete inversion tillage, especially if followed by frost or dryness, exposes earthworms to predation and desiccation and is especially damaging to deep burrowing species. Non-inversion, conservation tillage, combined with the return of crop residues and additional organic manures, can substantially increase earthworm densities. Deep burrowing species are especially encouraged. Long term research has shown that, where non-inversion tillage was adopted, earthworm numbers and diversity were maintained or improved relative to a plough-based system in which they declined. When averaged over a 10-year period earthworm biomass was 36% higher with non-inversion tillage.

"Research has shown that, where non-inversion tillage was adopted, earth-worm numbers and diversity were maintained or improved."

Individual earthworm species differ in their response to different cultivation systems. Numbers of *Allolobophora chlorotica, Lumbricus festivus, Lumbricus rubellus* and *Lumbricus terrestris* averaged over all years were significantly greater in non-inversion tillage systems compared to plough-based systems. Average differences for other species were not significant, although in most years numbers of *Aporrectodea longa, Lumbricus castaneus* and *Octolasion spp.* were greatest in non-inversion tilled soil but there were no consistent differences between cultivation systems for *Aporrectodea caliginosa* and *Aporrectodea rosea*. Whilst the cultivation methods used and the number of crop establishment passes were probably the main factors affecting earthworm populations, the abundance and distribution of some species may also have been influenced by the amount of soil organic matter. During the monitoring period (1995-2000), 13 species of earthworms were recorded in the system comparisons with *Aporrectodea caliginosa* and *Allolobophora chlorotica* the most dominant species. These and other species that normally live in temporary burrows close to the soil surface formed about 80% of the total earthworm population extracted, with the larger deep burrowing species, such as *Aporrectodea longa* and *Lumbricus terrestris*, representing <20% of the total extracted.


Photo 3.3

**Gastropods, isopods and myriapods**

The gastropods, isopods and myriapods are considered the most sensitive to soil cultivation and, as a consequence and with the exception of slugs, are rare in agricultural soils. Where present they consume and bury green organic matter and their faeces encourage microbial activity leading to the formation of soil aggregates and humus. These groups are encouraged by non-inversion tillage because crop residues remain available on the surface and physical structure is retained, facilitating movement.

Large soil organisms, e.g. earthworms that are enhanced by conservation tillage, aid these functions by mixing plant material into the soil. One group (Epigeic earthworms) that live in the superficial soil layers feed on undecomposed plant litter, another group (Endogeic earthworms) forage below the surface in horizontal connecting burrows and ingest large amounts of soil rich in organic matter. These two groups markedly affect decomposition of dead plant roots. The third group, the larger Anecic earthworms (e.g. *Lumbricus spp*), build permanent vertical burrows that extend deep into the soil and not only do they feed on surface debris/litter but also play a major role in decomposition of organic matter and soil formation. The burrowing activity of earthworms also provides channels (macro pores) for water and air circulation and oxygen diffusion in the root zone. The shallow dwellers increase overall soil porosity, whereas the deep burrowers increase water infiltration, which may suggest accelerated leaching of herbicides to groundwater.

## Macro pores

Whilst it is well known that macro pores are more abundant in minimum tilled and direct drilled soils due to greater earthworm activity, the transport processes within them are difficult to elucidate, as is accelerated pesticide transport though earthworm burrows. This may be due to specific properties of pesticides and interacting processes such as adsorption or degradation. Furthermore, retention of herbicides within earthworm burrows, by the highly enriched organic and microbial lining, has also been demonstrated thereby minimising groundwater pollution.

## Soil and predatory arthropods

Soil supports a wide diversity of predatory arthropods, predominantly from the beetles *(Coleoptera)* and spiders *(Arachnida)*. These reside all or part of their lives within fields and are generally vulnerable to cultivation. Cultivation may effect survival directly by causing mortality whilst also having indirect effects by modifying habitat and the availability of prey. Whilst many studies have specifically examined the effect of ploughing compared to non-inversion or conservation tillage on soil macro-arthropods, results have been inconsistent. Carabid beetles are the most frequently studied organisms in these investigations because many species reside all year round within arable fields and are sensitive to the type and timing of cultivations.

Photo 3.4

## Soil physical, microbiological and chemical parameters

The improved soil physical, micro-biological and chemical parameters, as a result of soil conditioning by minimum tillage, also have implications for the fate, degradation and translocation of organic herbicides. Research has shown that isoproturon degrades faster under soil conservation tillage than under traditional ploughed land and mainly attributed to greater adsorption from higher soil organic matter content and increased microbial activity favouring the degradation of isoproturon to its metabolite monomethyl-isoproturon, rather than total mineralisation with production of $CO_2$ hence reducing susceptibility to leaching.

"The burrowing activity of earthworms also provides channels for water and air circulation and oxygen diffusion in the root zone."

"Total carbon loss from ploughed land was five times higher than from unploughed land."

## Oxidation of organic matter

It is also known that ploughing and intensive cultivation causes oxidation of organic matter which releases carbon dioxide ($CO_2$). Twenty percent of the $CO_2$ released globally is estimated to come from soil processes or changes in land use. Soil organic matter acts as the reservoir for organic carbon and this element is constantly alternating from solid


Photo 3.5

form in plants and soil and gaseous form in the atmosphere. The contribution of agriculture to global warming will depend on two main variables. The first is the direct consumption of fossil fuels used to manufacture equipment, inputs, the cultivation of crops and emissions from livestock enterprises. The second is the relative level to which plants and soils can sequester carbon and operate as a sink for $CO_2$.

Carbon stocks of agricultural soils are generally depleted through vegetation clearance, drainage and cultivation. To increase soil organic carbon (SOC) farmers need to increase levels returned as crop residue, FYM, grass or covercrop to soil and decrease decomposition rate. Whilst different crop residues decompose at different rates, the most persistent SOC residues are those with high lignin content (e.g. straw). Physical disturbance (cultivation) and mixing of soil, exposes aggregates to disruptive forces thereby affecting the decomposition processes. By increasing the soil surface area and continually exposing new aggregates to wetting/ drying and freeze/ thaw cycles, cultivation makes normally physically protected inter-aggregate soil organic matter available for decomposition. This results in respiration and the release of $CO_2$. Research from USDA (1998) has shown that after 19 days the total carbon loss (as $CO_2$) from ploughed land was 5 times higher than from unploughed land. Therefore, the use of soil conservation tillage for crop establishment helps to reduce $CO_2$ emissions. As a consequence, farmers in North America are being paid by power companies to change from ploughing to minimum cultivation in an attempt to reduce greenhouse gas emissions and "global warming" (Kyoto Agreement; 1997) and are creating a new commodity "Carbon Credits".

This may well form part of future agri-environmental measures/schemes in UK and EU.

## Soil loss and Carbon Sequestration

Land utilisation is confronted with a serious need for the protection of the soil resource, landscape, climate and water quality more strongly now than ever before.


Photo 3.6

Traditional agriculture, based mainly on intensive soil cultivation is the main cause of soil degradation as frequent soil disturbance operations increase erosion by water and wind, increase the likelihood of compaction, reduce organic matter content of the soil, with the consequent relatively high emission rates of $CO_2$ through fast biological oxidation of this organic matter.

A calculation for the 15 European States showed that of the 81.5 million ha of arable land, 13 million ha (16%) were at much risk for erosion. The soil loss rate by plough tillage (16t ha$^{-1}$ yr$^{-1}$) is equivalent to ca 209 Mt ha$^{-1}$ corresponding to a loss of 60,000 ha$^{-1}$ yr$^{-1}$ from the 25cm top-soil layer. If this area had a modelled share of tillage systems for soil management (e.g. 30% direct drill - 3.9 million ha; 40% non-inversion tillage - 5.2 million ha; 30% ploughed - 3.9 million ha) then the potential soil loss reduction (by >90% from direct drill, by >60% from non-inversion tillage) would provide a potential soil loss reduction across the EU-15 Member States of 107 M t yr$^{-1}$ (49%) equivalent to an arable layer (25cm) of 30,372 ha$^{-1}$ yr$^{-1}$ (Tebrugge; pers comm.)

Perhaps, the role of agriculture in the sequestration of atmospheric $CO_2$ into the soil should be the key factor in the slowing down the process of climate


Photo 3.7

change. It is well known that intensive cultivation results in extra $CO_2$ emissions whilst direct drilling reverses this process. Furthermore, it is known that after 20 to 30 years of intensive soil cultivation soil organic matter content is reduced by about half. It could also be added that the increase in agriculture mechanisation in the last few decades (more and more powerful tractors) has made this situation worse.

It is widely believed that the increased atmospheric concentration of greenhouse gases (GHGs) is contributing to the process of climate change and global warming. On a global scale, only about 5% of all $CO_2$-emissions originate from agriculture (OECD 2001). Intensive and complete soil inversion tillage (ploughing) causes approximately 6-times higher consumption of fuel compared to direct drilling, and also hastens decomposition of organic matter released as $CO_2$ (Figure 3.3). This results in the production of additional carbon dioxide, which is emitted into the atmosphere and contributes to global warming.

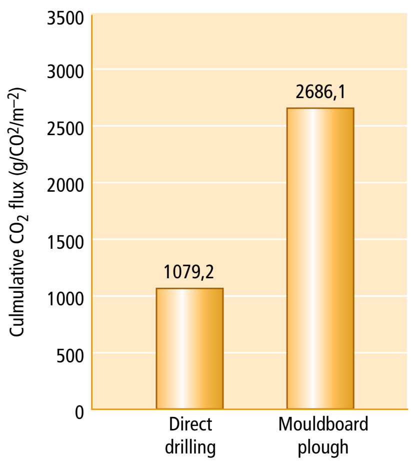



**Figure 3.3** Long term study July 14-October 9, 1988. Cumulative loss after 87 days (Tebrugge, Per. com.)

Trials in the USA showed that 5 times more $CO_2$ was released after ploughing than direct drilling (Reicoski, 1998), but that consolidation immediately after cultivation reduced $CO_2$ flux from soils by 50-80% dependent on cultivation method (Reicoski, 2001).

"It is known that after 20-30 years of intensive soil cultivation soil organic matter content is reduced by about half."

"For every tonne of carbon lost by decomposition of organic matter, approximately 3.7 tonnes of $CO_2$ are emitted into the atmosphere."

Repeated mouldboard ploughing reduces the supply of soil organic matter and related amounts of $CO_2$ (approx. 1000 mg $CO_2$ 100 g soil-1) are emitted into the atmosphere.

The loss of organic matter by microbial oxidation after ploughing is assumed to be 10-times higher than the loss caused by soil erosion. For every tonne of carbon lost by decomposition of organic matter, approximately 3.7t $CO_2$ are emitted into the atmosphere. In the case of conservation/ reduced/ non-inversion tillage, the soil carbon content increases on average by about 0.77 t/ha$^{-1}$/yr$^{-1}$ thereby decreasing $CO_2$-emissions by 2.8 t/ha$^{-1}$/yr$^{-1}$.

A calculation for the 15 European States shows that less micro-biological oxidation and decomposition of carbon occurred using Direct Drilling on 40% of the EU-15 arable land (29 million ha) and could deliver a reduction of $CO_2$-emission of 82.7 Mt/yr$^{-1}$ (Tebrugge; ECAF *pers comm.)* which is nearly 10% of the total $CO_2$-emission from energy consumption in 1998 in Germany or 3% in the EU-15 respectively. Energy providers in Canada already use this fact and pay farmers practising no-tillage (direct drilling) approximately 20 Euro ha$^{-1}$ (12.5-25 US dollars) to meet their environmental responsibility with regard to decreasing $CO_2$-emissions. Contracts have been made at present in Canada with 400 no-till farmers, which allow energy providers to buy 2.8 million tons of 'non emitted $CO_2$'.

Pollution concerns must also not ignore the fact that production of crude oil and burning of 100 l of diesel fuel produces 303 kg $CO_2$-greenhouse gases. This means, for traditional plough-based crop establishment, that seedbed preparation, seeding and stubble cleaning (51 litres fuel ha$^{-1}$) on 72.5 million ha arable land in the EU releases circa 13 million tons of greenhouse gases, mainly as $CO_2$. Direct Drilling on the other hand (using 6.8 litres fuel ha$^{-1}$), even if applied on only 40% of the EU-arable land, would

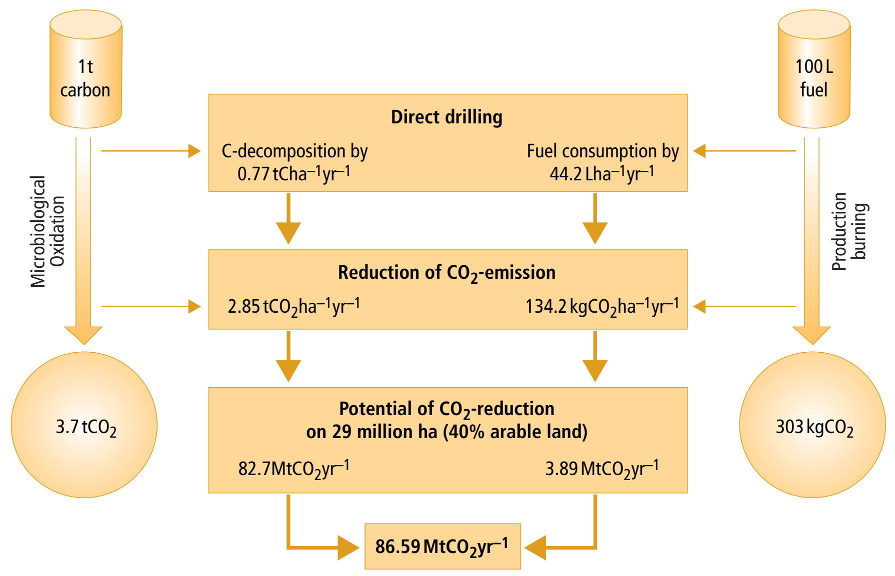



**Figure 3.4** Potential of reduction for $CO_2$ -emissions in the EU by Direct Drilling (Tebrugge, 2001)

lead to $CO_2$-emission reduction of 3.89 million tons by less fuel consumption. This, together with less $CO_2$ emission by reduced carbon decomposition and reduced fuel consumption, provides a potential reduction for $CO_2$ emissions from arable land in the EU in the order of 86.6 Mt $yr^{-1}$. This would be about 25% of the Kyoto-agreement for reduction of $CO_2$ emissions in the EU-15 up to year 2012.


Photo 3.8 Direct drilled wheat


Photo 3.9

"There is substantial evidence that conservation tillage methods of crop establishment sequester carbon in the soil and protects climate by less $CO_2$ emission"

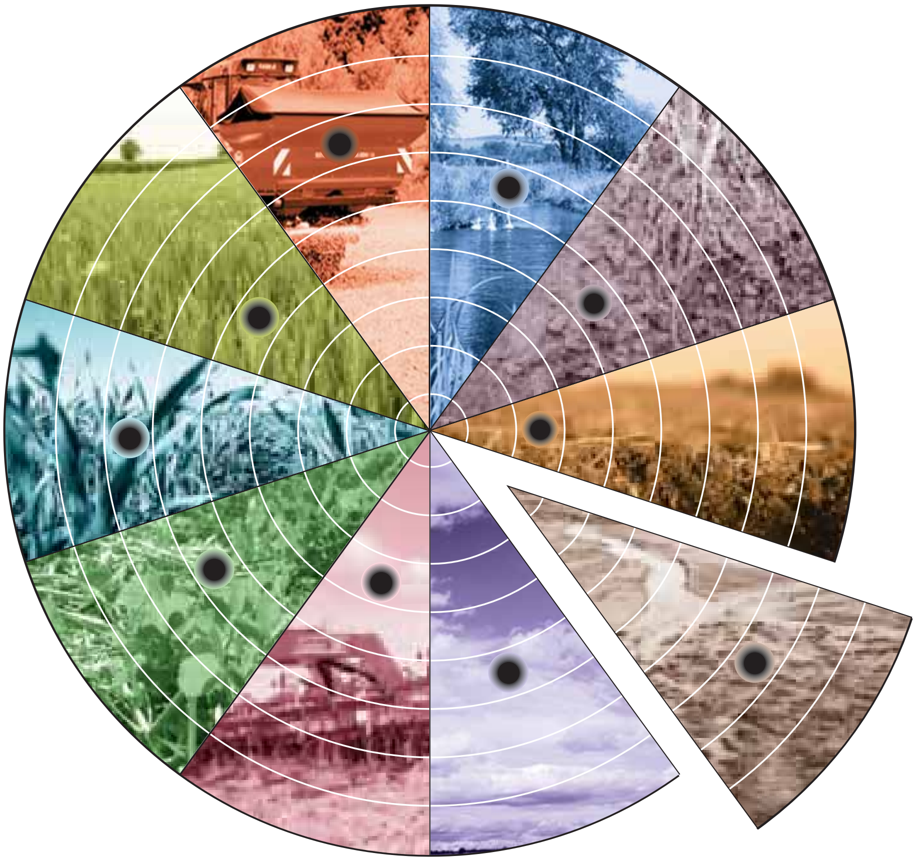
Thus it is possible, using alternative crop establishment methods, to fulfill the Kyoto-agreement within 4 years if we can, by clear and robust research, demonstrate that some alternative agricultural practices can lead to substantial reductions in $CO_2$ emission. There is substantial evidence from North America and some EU countries that Conservation Tillage methods of crop establishment sequester carbon in the soil and protects climate by less $CO_2$ emission.

Present global estimates show 48 million ha are cultivated using no-tillage direct drilling systems (approximately 70% of arable land in the EU). This means a global decrease for $CO_2$ emissions, solely from the reduced consumption of fossil fuels of 6.4 million t/$yr^{-1}$. Also to be added are 137 million t/$yr^{-1}$, not emitted as $CO_2$ because of the accumulation of soil organic carbon (0.77 t/$ha^{-1}$/$yr^{-1}$) in no-tillage systems.

| Action points on soil health | Learning/notes |
|---|---|
| • Reduce intensity and number of cultivations<br>• Reduce use of plough inversion where possible<br>• Practice soil conservation tillage where appropriate<br>• Consolidate soil after cultivation<br>• Incorporate and build organic matter in soil<br>• Build soil fauna<br>- in particular earth worms | |

**Target on soil health**

1) Comply with the stubble burning in agricultural regulations; Crop Residues (burning) Regulations 1993
2) Maintain and build soil organic matter
3) Maintain and build soil health as this builds good soil structure

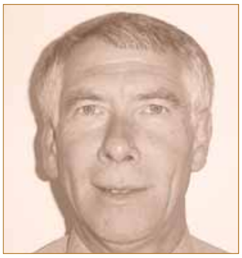


# 4 Soil care

Gordon Spoor
Soil Scientist

The importance of soil structure for crop development has been clearly identified and this now needs to be put into the context of crop production, which also involves machine operations both within and on the soil. These operations load the soil in various ways changing its state, with the risk that some physical problems may arise with serious implications for crop performance, production costs and timeliness. The essence of good soil management and care is to maintain and improve soil structure, whilst minimising the risks of soil physical problems developing. If problems do develop, they need rectifying as quickly and efficiently as possible.

David Thomas
Drainage Surveyor



Peter Debenham
Michelin Tyres

The major types of soil physical problem likely to develop, together with the soils most susceptible to them, can be identified as follows:

| Potential problem | Most susceptible soils |
|---|---|
| Soil structure degradation | All |
| Soil compaction | All |
| Under-consolidation | All |
| Water-logging | All |
| Surface capping | Low organic matter fine sands and silts |
| Wind erosion | Low organic matter fine sands and peats |
| Water erosion | Fine and medium textured soils on slopes |

"The essence of good soil management and care is to maintain and improve soil structure."

The optimum management approach should follow a two pronged attack:

- Preparing and leaving soil conditions to meet crop requirements, but also offering maximum resistance to damage from subsequent operations.
- Executing the necessary operations in such a way as to minimise the risk of unfavourable and unwanted conditions developing.

**Photo 4.1** Sub-surface pan

The aim of this chapter is to review the potential problem areas, identifying possible management approaches for avoiding or minimising the problems and where appropriate, indicating ways of alleviating them. Working with the soil rather than against it has a particularly important part to play and hence soil characteristics and behaviour related to minimising risks are considered first. The most important considerations are the influence of soil moisture status and packing density on soil strength, and the soil drying and weathering characteristics.

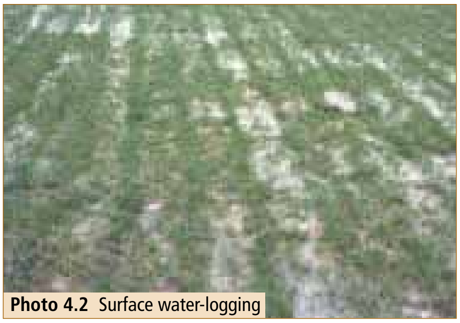


**Photo 4.2** Surface water-logging

## Soil characteristics and behaviour

### Soil strength

This is a critical factor in almost all the potential problem areas. When soil moisture contents are high, the strength of both the soil mass as a whole and that of individual soil structural units/aggregates is low, increasing soil vulnerability to compaction, structure breakdown and smearing (Figure 4.1).

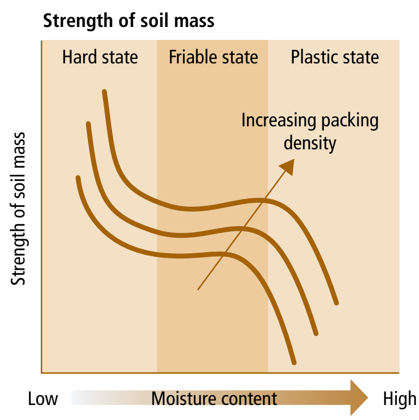



**Figure 4.1** Shows how the strength of the soil mass changes with both moisture content and its packing state (packing density).

In the friable moisture range, the range ideal for seedbed preparation, soil strength is relatively high, but it decreases rapidly beyond, as moisture content increases moving into the wetter plastic range. Strength at low moisture contents can be very high, particularly in clayey soils (Figure 4.2). The other factor influencing strength is the soil packing state, the denser the packing the stronger the soil at all moisture contents. Loose soils at high moisture contents are particularly vulnerable to compaction.

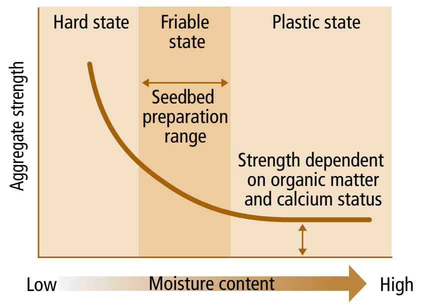



**Figure 4.2** illustrates how aggregate strength changes with moisture content, the aggregates being very strong at low moisture contents and weak at high. Their strength at high moisture contents is very dependent upon their organic matter and calcium status, if these are low, the aggregates are exceedingly weak. Structure degradation is most likely to occur at these high moisture contents.

### Changes in soil strength with depth

Examining the packing state of soils at different depths, reveals a common feature in almost all soils, this is higher density conditions just below current or former ploughing depth. This zone, the pan layer, often has rather poorer soil structure and is frequently considered undesirable. Providing, however, roots, air and water can move through it, it must be considered as an asset for traffic support, helping protect the sub-soil from the compacting tendencies of large surface applied loads.

### Changes in strength with time

Whenever soil aggregates are disturbed they become weaker and time is required for them to regain their original strength (Figure 4.3).

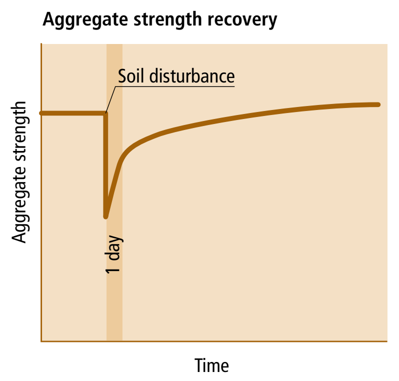



**Figure 4.3** shows strength regain is rapid initially, often 60 - 70% of the loss being recovered during the first day, but in some situations it may take months for complete recovery to occur. In certain situations, therefore, there could be benefits in delaying a subsequent operation for a short period, to allow significant strength recovery.

**"Whenever soil aggregates are disturbed they become weaker and time is required for them to regain their original strength"**

## Soil drying and timing of operations

Drying occurs on bare soils through both downward drainage and upward evaporative losses to the atmosphere. Both mechanisms are, however, limited in what they can achieve, this impacting on the delay time before operations can start following wetting.

On the lighter soils, drainage will lower moisture contents directly into the workable friable moisture state. This is not the case on many of the medium and heavier soils, where further evaporative drying is required to bring moisture contents into the friable range. Unfortunately, this evaporative drying (Figure 4.4) does not extend much beyond a relatively shallow surface layer.

The implication of this drying behaviour for the onset of soil working after wet periods is that there are benefits to be gained in terms of reduced damage risk, from delaying operations until drainage reduces moisture contents to field capacity and surface drying has occurred. Once, however, this equilibrium state has been reached, there is little or no additional benefit to be gained from further delay, for moisture contents will not change in the absence of soil disturbance. Considerable care will be needed when proceeding, since the soil will be very vulnerable to compaction and possibly structure damage. Appropriate prevention measures will need to be adopted to prevent damage.

"The more frequent the wetting & drying cycles, the more rapid the improvement in soil structure."

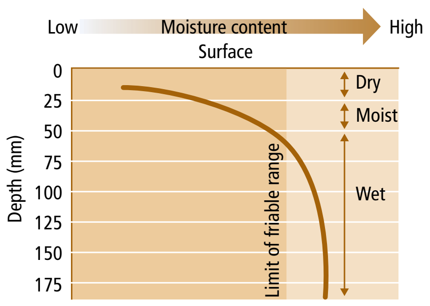



**Figure 4.4** shows the moisture distribution with depth in a well drained clay soil, after 3 days of good drying weather. The profile indicates the development of a dry surface layer some 25 mm thick, overlying a moist friable layer a further 35 mm in thickness, below which moisture contents remain high in the wet plastic range. The moisture contents at depth are the limiting moisture contents achievable through sub-surface drainage, the field capacity condition. Little further drying occurred after this time, despite good drying conditions due to the dry surface layer effectively inhibiting further upward moisture loss.

## Soil weathering

The weathering behaviour of soils plays a particularly important role in structure development and in re-structuring damaged soils. The main benefits arise from the swelling and shrinkage behaviour of the clay fraction on wetting and drying. The more frequent the wetting and drying cycles, the more rapid the improvement. Without swelling and shrinkage there would be little structural development in the sub-soil. Significant drying to moisture contents below field capacity at depth can only occur through water abstraction by roots. In situations, therefore, where deeper root development is impeded, mechanical measures and/or drainage to overcome the impedance will be well rewarded. The cracking benefits in terms of improved root development and profile drainage arising from severe sub-soil shrinkage in dry years, can remain for many years, providing sub-surface drainage is good.

## Minimising and alleviating potential soil physical problems

### (1) Soil compaction

**Tyres, wheelings and trafficking**

Soil vulnerability to compaction is dependent upon both its packing state and moisture status, and if undesirable excess compaction is to be avoided, then the choice of tyre, working pressures, and operating practice should be adjusted to suit the conditions.

**Planning a Strategy:**

Tyre selection should not be an afterthought or considered a bolt on retro-fit. All machine changes / purchases should include the tyre choice as a primary concern for the complete specification. Operation changes and working methods should consider the total working specification for the prime mover with implement(s) and associated tyre needs. Axle loads and operating speeds should be examined at the specification stage to ensure suitable tyre sizes can be fitted to achieve desired ground pressures. Consider tractive weight for prime mover, axle loadings and the HP needs at wheels for ensuring work rates and operational effectiveness.

## Tyre choice:

### Which is the right tyre?

Correct tyre choice should consider:

- The applications to which the tyres will be mainly used;
  - Primary cultivation: requiring grip and traction.
  - Top work: requiring grip and floatation.
  - Harvesting requiring grip and high load capacity at low ground pressure.
  - Road work requiring Sustained higher speed capability with good comfort and handling.
  - Yard work requiring Abrasion resistance and high load capacity.
- The axle and imposed "tyre load" in full operating state as tyres pressured at the top of their range or beyond their specification to support the load will not perform adequately and may even fail.
- Operating speeds both at work and in transport mode.
- Torque input at wheels and available machine HP.
- High traction requirements are usually better served by tall tyres.
- High flotation requirements are usually better served by wide tyres.
- Typical "Optimum" tyre pressure for a correctly specified tyre is about 1 bar.
- Ground pressure is the sum of the tyre pressure + a casing factor (usually about 2 psi for a quality radial construction tyre).
- Wheel load is supported by the air inside the tyre;
  - Tyre internal volume will determine tyre pressure needed.
  - For a given load a "Lower" volume tyre will require a higher pressure.
  - Conversely a "Higher" volume tyre will require a lower pressure.
- Tyre "type" suitability (casing and tread/lug design:
  - tractive or flotation), with advice from a tyre specialist.
- Radial tyres can provide more even ground pressure.

"Don't assume operating equipment standard fitment will be suitable, it often isn't!"

### Impact of tyre choice for grain trailer wheels (tractor, trailer, loading kept the same)

Conventional tyre

Low Ground Pressure tyre

Compaction in wheeling

No compaction in wheeling

**Wheelings:**

Tractive weight necessary for optimum vehicle tractive effort should be determined and correctly distributed between vehicle axles to reduce wheel slip and soil damage.

Tyre casing construction and the effectiveness in putting down an even footprint will greatly influence the degree of wheeling. Radial construction tyres have the ability to place a more even distribution of ground pressure and a larger footprint than other construction methods.

To avoid excess compaction, the pressures exerted on the soil by traffic have to be adjusted to suit the conditions. Typical pressure range of an agricultural tractor tyre is 0.5 to 1.6 bar and the optimum low pressure range is below 1 bar. Guideline recommended tyre inflation pressures are shown (Figure 4.5) for agricultural radial ply tyres to minimise the excess compaction risk under different soil conditions.

"Effectiveness in putting down an even footprint will greatly influence the degree of wheeling"

**Photo 4.3** Evidence of wheelings from previous operations

The result of high tyre pressures on soft (often un-consolidated) ground, compounded by poor tyre selection and high rates of wheel slip, can be reduced by using tyres adequately specified for the imposed loads and speeds of work.

The period of highest risk of soil damage is at and after harvest, when trafficking is at high intensity. A variety of machine types, trailers, trailed implements and cultivators are in use when soils are often moist or wet and less stable before they dry and consolidate.

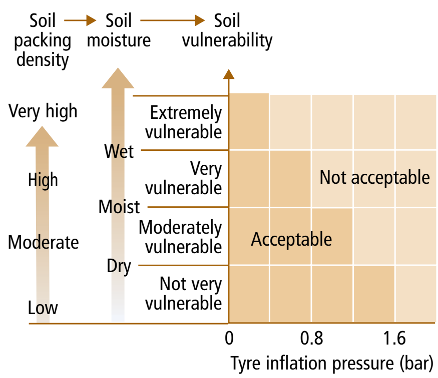



**Figure 4.5** Provides guideline recommended tyre inflation pressures for agricultural radial ply tyres to minimise the excess compaction risk under different soil conditions.

Examples of the recommended inflation pressures for different soil situations are as follows;

| Situation | Vulnerability class | Inflation pressure (bar (psi)) |
|---|---|---|
| Early spring, when the cultivated layer is weak and moist | 'extremely' | 0.4 (6) |
| Later in season after some settlement and drying | 'very' | 0.8 (12) |
| Firm dry conditions | 'moderately' | 1.2 (18) |
| Very firm and dry | 'not particularly' | 1.6 (24) |

Whilst higher inflation pressures can be tolerated under very dry and firm conditions, the above guidelines have been developed to minimise the risk of sub-soil compaction. They are based on the principle that the pressure applied to the sub-soil should not exceed the pressures applied in the past. Past pressures have been of the order of 1.6/ 2.0 bar (25/ 28 psi) from wheeled tractors ploughing in the furrow bottom and sub-soils have stabilised under these pressures, forming the stronger pan layer.

Whilst it is realised that inflation pressures currently in use, particularly for harvesters, transport vehicles and slurry tankers, are often considerably higher than the recommended pressures, future machine developments will need to adapt, through tyre selection and wheel arrangements, to allow the high loads to be carried on soils safely. There are some heavy machines (weighing up to 40 tonnes) which meet these guidelines and whilst they compact the top-soil, the sub-soil is unaffected. Topsoil compaction, whilst undesirable, is much easier to alleviate than sub-soil compaction.

In selecting new machines, particular attention should be paid to the operating tyre inflation pressures and in work, pressures should always be checked and kept to a minimum for the job in hand, in line with the tyre manufacturers recommendations.

Example of correct tyre choice and set-up to minimise soil damage (Figure 4.6).

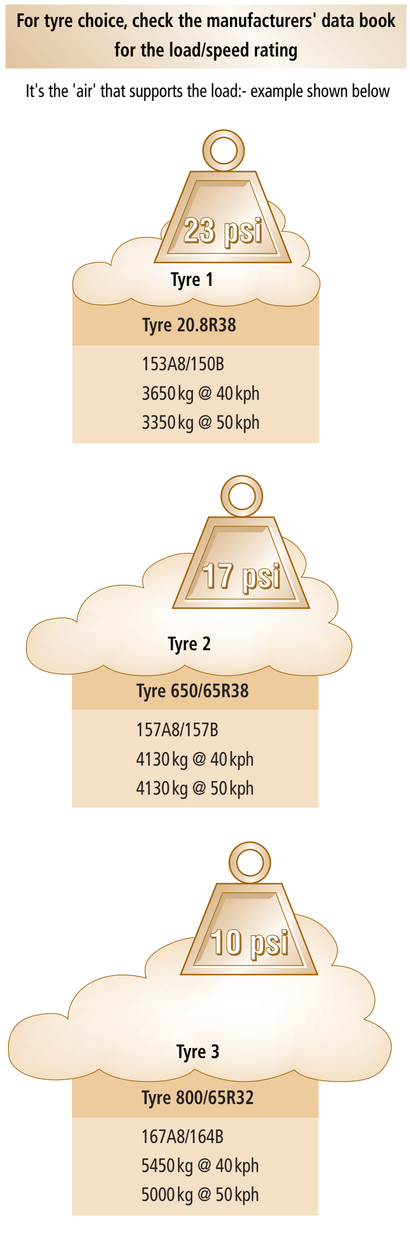



**Figure 4.6** Example of correct tyre choice and set-up.

**"Tyre inflation pressures should always be checked and kept to a minimum"**

**Tyres v Tracks?**

With correct choice, set-up and use, both tyres and tracks can offer lower ground pressure working and minimise soil compaction damage. However, due to high pressures which arise under the rollers of tracked vehicles and the frequency of uneven load distribution along the track, the effective ground pressure of these vehicles should be taken as double the pressure calculated by dividing the track contact area by the vehicle weight.

Photo 4.5

Compaction testing conducted by Ohio State University in 1995 (SAE 952098) show properly inflated radial tyres to be superior to rubber tracks for controlling soil compaction as illustrated below:-

**Percent decrease in air permeability in soil with tyre or tracked wheelings.**

| | Common tyre pressure | Track alternatives | | Correct tyre pressure |
|---|---|---|---|---|
| | John Deere 8870<br>Dual 710/70R38 tyres<br>24 psi front and rear | Cat Challenger<br>Rubber tracks<br>25" wide | Cat Challenfger<br>Rubber tracks<br>35" wide | John Deere 8870<br>Dual 710/70R38 tyres<br>7 psi front/6 psi rear |
| 6" deep | 88% | 78% | 62% | 52% |
| 18" deep | 36% | 26% | 21% | 11% |
| Average | 68% | 55% | 42% | 34% |

"Poor tyre choice with a good machine will give a poor result but good tyre choice with an adequate machine will give a good result."

## Best Practice

**Tyre choice and operation;**

- Poor tyre choice with a good machine will give a poor result, but good tyre choice with an adequate machine will give a good result.
- Remove any un-necessary machine ballast / weight to reduce tyre load.
- Weigh machine when laden to determine tyre load for pressures.
- Pressure tyres for imposed load, torque at wheels and for speeds of operation.
- Regularly check tyre inflation pressures to ensure pressures are maintained.
- Repair accidental tyre damage to "approved" Industry standards to ensure tyre service life.

Photo 4.4

**Field operating practices;**

Compaction risks can be minimised, through reducing the applied pressures and loads, reducing the number of wheelings and taking advantage of stronger soil conditions. These practices, with possible applications in different situations, can be summarised as follows;

- Aim to work as much as possible on undisturbed soil surfaces with higher strength.
- Where appropriate consolidate loose conditions immediately to provide more support for subsequent operations.
- Operate at higher speeds with lower draught, this is more effective in reducing compaction than the reverse situation, particularly if the latter is accompanied by higher tractor wheel slip.
- Maximise implement working width and minimise the number of passes.
- Adjust implements carefully to avoid creating new problems which require further attention.

In circumstances where it is not possible to operate at the desired inflation pressures, consider modifying working practices as follows:

• Reduce the maximum payload carried by harvesters and transport equipment, to allow tyre pressures to be reduced to or towards the desired levels.
• Utilise lower pressure trailers for in-field crop collection, discharging into larger higher inflation pressure trailers at headlands for road transport.
• Make more use of existing traffic lanes, such as tramlines, for transport when fully laden, so limiting the spread of compacted areas.

Where on-land ploughing is not possible, the use of lower pressure wide section tyres, even though wider than furrow, will assist in reducing the risk of sub-soil compaction.

**Compaction alleviation**

Compaction problems usually occur within the top 30 cm of soil and it is well worth checking in the field to confirm whether they are present. No benefit will be gained from soil disturbance if there is no problem to alleviate. In fact disturbance will only make the soil more vulnerable to compaction, whilst increasing fuel use, production costs, drying the soil and reducing earthworm numbers.

Where there are clear indications of severe restrictions to root, air and water movement, alleviation measures will be required. These measures must alleviate the problem without producing a loose soil condition, which would be particularly vulnerable to re-compaction. The prime aim in the alleviation operations must be to generate fissures through the compacted zone, without significantly loosening the soil between them. The firm higher density conditions remaining between the fissures will provide the necessary support for subsequent operations.

The required type of disturbance can be generated by lifting the soil mass with a sub-surface blade and allowing it to flow up and over the blade so that soil bending occurs, placing the soil in tension and creating soil fissures (Figure 4.7). These fissures are largely vertical and as such are considerably more resistant to subsequent closure by surface traffic than horizontal cracks.

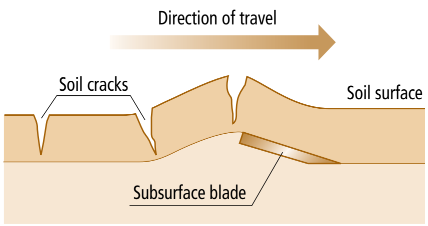



**Figure 4.7** Mechanical fissuring

"The greater the working depth & the higher the moisture content, the greater the wing lift height required to generate the fissures."

Appropriate tools for inducing this type of disturbance are sub-surface blade/ wing type implements (Figure 4.8)

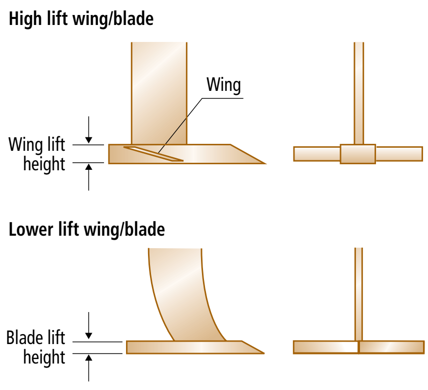



**Figure 4.8** Sub-surface tool types

The degree of fissuring achieved depends upon the lift height of the wing, working depth and soil moisture conditions. The greater the working depth and the higher the moisture content, the greater the wing lift height required to generate the fissures. Using implements with fixed wing lift heights, working depth needs to be adjusted until the appropriate degree of cracking is achieved. Working depth should ideally be just below the problem area, unless slightly deeper working is required to produce the desired type of soil disturbance. Such fissuring may not be possible or advisable under wet soil conditions, but it can be achieved when conditions are moist. This type of fissuring can be satisfactorily achieved at higher soil moisture contents than general soil loosening.

"Any increase in soil profile aeration by mechanical means will accelerate organic matter decline."

The uniformity of fissuring across the field is dependent upon tine spacing and this should be adjusted to ensure the complete soil mass in the problem area is lifted. Tine spacing of between 1.5 and 2.0 times working depth, depending upon moisture conditions and wing width, are usually required to achieve this and also leave a level soil surface. Ideally, this fissuring operation should be carried out as late as possible in any sequence of field operations, to reduce the risk of re-compaction from subsequent wheelings.

**Photo 4.6** Good root growth = no compaction

Impedance to root development in the pan area at depth needs to be treated in the same way, generating a limited number of fissures through the impeding zone. Field checks need to be made to identify whether this is a problem area and the best indicators of problems in such a check are root development and signs of water-logging, rather than the condition of the soil structure. The most appropriate time for checking is during the active growing season when root development can be readily identified. If roots have moved through and are proliferating below the higher density area, then the pan is best left undisturbed to maximise sub-soil protection. Impedance caused by these denser pan type layers is rarely found in the clayey soils, swelling and shrinkage creating larger pores. It is rather more common in the sands and silts, where there is little soil movement. The maintenance of permeability and rootability of these pan areas is very dependent upon former stabilised root channels and channels created by earthworm activity. Feeding earthworms on and in the surface layers is an excellent way to encourage them to move up and down and so maintain these pan layers in a satisfactory rootable condition.

### (2) Structure degradation and structure improvement

Organic matter levels have tended to fall in many arable soils over recent years. Such falls have increased the susceptibility of structural aggregates to break-down through machine loading and natural causes. Any increase in soil profile aeration by mechanical means will accelerate this organic matter decline and hence excessive and unnecessary tillage must be avoided.

Soil structural aggregates, whatever their organic matter level, are most vulnerable to breakdown at higher moisture contents where they are weakest. They can be broken through direct loading, by cutting and through natural forces.


Photo 4.7 Water-logged soil

Breakdown through direct loading requires the aggregates to be forced against a relatively strong base and hence such breakdown usually occurs close to implement working depth, the aggregates being loaded against the stronger undisturbed soil below. Almost all implements can cause problems of this nature. The leading edges of plough shares and tines wear into a parabolic shape, so that their bottom surface tends to force soil downwards. Similarly the backward sloping rear faces of curved discs do likewise. The sliding action of discs and a slipping tractor wheel create further structural damage. The net result of these actions at high moisture contents is local aggregate breakdown, which tends to manifest itself as a thin smeared zone some millimetres in thickness at working depth. Aggregate breakdown through direct loading only occurs within the soil mass when the compacting forces are particularly excessive.

In weak structured soils, structure collapse can occur through prolonged wetness, causing the whole soil mass to slump with the loss of the important larger conducting pores. Soils most prone to this type of degradation are those with high fine sand and silt contents, coupled with low organic matter levels.

In weak structured soils, structure collapse can occur through prolonged wetness, causing the whole soil mass to slump with the loss of the important larger conducting pores. Soils most prone to this type of degradation are those with high fine sand and silt contents, coupled with low organic matter levels.

Conservation tillage aims to increase soil organic matter over time by incorporation of crop residue from a good crop rotation in the top 10 cm of soil with less intense cultivation followed by good consolidation.

**"As a soil wets up, the fine tilth, due to capillary action, is very reluctant to release water into the larger pores beneath."**

**Minimising the consequences of smearing effects**

Smeared surfaces, particularly if extensive, can prove to be very effective barriers to downward root and water movement. Their influence can, however, be easily alleviated immediately after their formation, by fitting a narrow tine behind the offending implement, to work just slightly deeper and hence break the


Photo 4.8 Plough smear

smear. Such tines are available for fitting behind discs and plough shares and need only work a few centimetres below disc or share working depth. Unless the smeared zones are very extensive, they tend to be less of a problem in clayey soils, since a relatively small moisture change induces some shrinkage which disrupts the smeared area.

**Structure improvement**

Structure improvement can only occur through the action of natural processes (Figure 4.9). The role of mechanical operations is to facilitate these processes where necessary. In situations where root and water movement is impeded, tillage has a part to play in initiating the improvement process. In other circum-stances tillage should be kept to a minimum, to avoid accelerating the organic matter loss and disruption of natural root and earthworm channels. These channels are particularly important for providing the necessary aeration, water movement and root development conditions for structure improvement through the swelling and shrinkage processes.

"Except where root and water movement is impeded, tillage should be kept to a minimum to avoid accele-rating organic matter loss and disruption of natural channels."

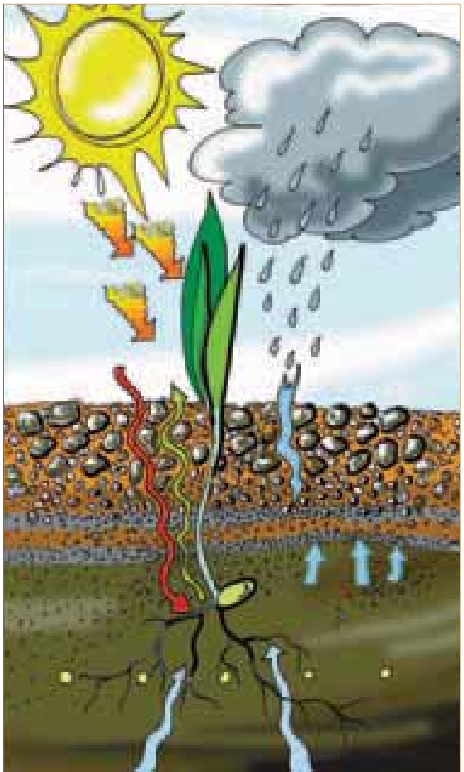


**Figure 4.9** The natural processes of weathering

**(3) Under-consolidation**

Under-consolidation can prove to be just as serious a problem as over-consolida-tion/ compaction but for rather different reasons. Apart from its deleterious ef-fect on crop establishment and mineral uptake, it can have a major influence on moisture retention, timing of operations and soil susceptibility to compaction.

The more open the soil, the more rapid the moisture loss from the shallow surface layers, which can be critical in drying situations for the rapid establishment of shallow seeded crops. Conversely during wetter periods, low density open surface conditions when above more consolidated soil tend to hold more water and this combined with their low strength, can severely delay the commencement of subsequent operations following rainfall. Leaving soils in a well consolidated condition, particularly when further work or seeding is required in the short term, is an excellent form of weather-proofing, regardless of whether weather conditions are to become wet or dry. Care is, however, needed with respect to the degree of consolidation appropriate on the less structurally stable soils in over-wintering situations. Here, too much consolidation in autumn may induce excessive slumping by spring, increasing the spring work required, with consequent establishment delays and often less satisfactory seedbeds.

Presses are most satisfactory for consol-idating at depth and rolls in the shallow surface layers. On soils which are diffi-cult to consolidate, attention needs to be given to the primary disturbance opera-tion. If soil disturbance is required, high speed operations tend to open up the soil excessively, making subsequent consolidation even more difficult.

### Water-logging

Water-logging problems can arise through compaction and smearing disrupting and/or closing the larger continuous conducting pores, through the preparation of too fine a surface tilth and through malfunctions in the sub-surface drainage system (Figure 4.10).

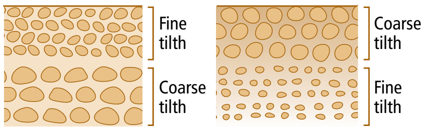



**Figure 4.10** Illustrates the impact of too fine a surface tilth where there is a sharp divide to a coarser tilth below, containing large pores and fissures. As such a seedbed wets up the fine surface tilth, due to capillary action, holds water and impedes downward flow.

Moisture contents in the top layer need to build up until some of the larger pores within the fine tilth are filled. It is only at this point that water pressures are such as to reduce the surface tension forces low enough to allow water to move downwards. The net result of this is that in certain cases, the top layer becomes almost saturated and waterlogged despite there being free draining conditions below. Such a condition could develop with any tilth preparing tillage operation, but the greatest risk occurs following power harrowing operations.

The solution is not to produce too fine a tilth relative to conditions below and the risk can be further reduced by providing some mixing between the two layers. The latter can be achieved by fitting slightly deeper working tines behind the power harrow rotors, to bring up some larger soil units into the surface layer and allow fines from the surface to fall into the lower layer.

### Surface capping

**Photo 4.9** Water run-off and sheet erosion

Low organic matter content fine sand/silty soils are most prone to surface capping. Raindrop action destroys the very weak surface soil aggregates, releasing individual soil particles. The individual soil particles under the wet conditions then flow together, to be bound very tightly to one another by capillary forces on drying, so forming a strong surface crust. The risk of this condition developing can be minimised by leaving as coarse a surface tilth as possible together with some surface trash. The coarser the tilth, the lower the risk of complete structure collapse, some larger soil units being left intact. When such larger units are present within the mass of individual soil particles, excessively strong cap development is prevented. Whilst this course of action may prove satisfactory under moderate intensity rainfall conditions, it is unlikely to be sufficient under high rainfall intensities. Trash acts to lessen the impact of raindrops, maintain an open surface and aid water infiltration. Soils are at extreme risk under high intensity rainfall, particularly if the storm occurs soon after drilling and before the weakened soil has had time to regain its strength after disturbance. There is little that can be done to prevent complete surface structure breakdown and severe crusting in these situations.

Whilst the crusts tend to crack with time into smaller units which can be moved aside by the emerging seedlings, this cracking may be too late in cases where

"Trash acts to lessen the impact of raindrops, maintain an open surface and aid water infiltration."

"Water erosion can be a serious problem on light and medium soils in sloping areas."

the crop was just about to emerge. Some relief can be achieved in this situation by using a vertical knife to create a plane of weakness alongside the seed row, as soon as possible after the soil becomes trafficable in the wheel ways. This weak plane increases the chances of the emerging seedling being able to displace the crust. In the long term, organic matter build up will significantly reduce the capping risk but this could be a long term process, surface trash helps earlier.

Photo 4.10 Capping

**Wind erosion**

Low organic matter content sandy soils and peat soils are at greatest risk from the point of view of wind erosion. Soil loss on mineral soils only occurs in the presence of soil units within the size range 0.1 - 0.5 mm diameter and these need to be rolled before they lift off into the air. Relatively coarser soil tilths can, therefore, assist in prevention as can rough soil surfaces which restrict rolling. Cambridge rolling sandy soils when moist produces fairly stable small soil ridges containing small aggregates/clods.

Photo 4.11 Wind erosion

This ridged surface can be directly drilled through at a later date, leaving most of the ridges intact. Providing the ridges are set up as closely as practical to approx. 90° to the expected direction of the erosive winds, they can be very effective in reducing if not preventing blow, as can use of an Aqueel roller.

Peat soils do not blow appreciably if the surface layer is moist. In situations where the sub-soil is moist, rolling with a heavy roller increases upward capillary water movement and this assists in moistening the surface. The establishment of a shelter crop before the economic crop is established is, however, a more reliable approach. The shelter crop can be established at a time when severe surface drying is unlikely and can be sprayed off later to avoid competition with the desired crop.

Photo 4.12 Run-off/ sheet erosion

**Water erosion**

Water erosion can be a serious problem on light and medium soils in sloping areas, causing soil structural damage through raindrop splash and transporting soil in runoff water. Soil protection can be achieved using cover crops or surface mulches, which offer possibilities for crops such as forage maize, but not for crops like potatoes. Equipment is available (Aqueel roller) for forming small depressions within the soil surface to increase the temporary water storage capacity, so increasing the time available for infiltration, hence reducing runoff risk.

Major water flow and soil transport problems can arise in tramlines and furrows which run down a slope. Whilst routing these across the slope could solve the problems, such measures are not particularly practical on compound slopes and they can introduce harvesting difficulties with crops such as potatoes. More appropriate techniques in these situations would be based upon the use of measures such as grassed strips, beetle banks and vegetated water -ways which can be driven over and through. These can be positioned to reduce the lengths of the runoff areas and to transport any runoff waters down slope at non erosive velocities. Such measures will become increasingly more appropriate and acceptable in the future and can be designed to maximise environmental benefits as well as serving the important function of erosion control.

**Cultivation method**

All the factors mentioned above are important regardless of the type of cultivation practiced. However, particular care must be taken when moving from relying on the plough to conservation tillage techniques as there is a risk that compaction will build up. This can happen on unstable soils previously loosened by the plough, or in the vulnerable layer between the old/new tillage depth (over first 1-2 years). Any compaction present should be alleviated prior to adopting conservation tillage or compaction will remain or worsen and adversely affect the adoption of the new system.

Under longer-term well managed use of conservation tillage soil structure often improves over 4-5 plus years with increased; organic matter, biological activity, stability, friability, porosity, water infiltration, trafficability and reduced risk

Photo 4.13

## The importance of land drainage

Crops need soil to supply nutrients, water and air. To allow full root exploration all crops need a minimum of 100 cm of open, well-structured soil. This permits excess water to drain away in winter but retains crop-available water in summer to help overcome drought stress. At the same time air can travel readily into the sub-soil.

To quote a Yorkshire farmer; “successfully farming land is like looking after a baby–keep it well fed and its bottom dry”. Much of the arable land in the UK has soils with a significant proportion of clay, or is low lying and flat with outfall ditches which may discharge via pumping stations. In order to achieve the desired conditions these fields usually require underground pipe drainage systems to assist movement of surplus water away to the open ditches and watercourses.

Work to improve soil water conditions goes back to at least Roman times. Installation of clay tile pipe schemes has been widespread for the last 200 years

"To allow full root exploration all crops need a minimum of 100 cm of open, well-structured soil."

or so. Most fields in lowland England which would benefit will have had schemes of some sort installed, and drainage contractors often find evidence of several old systems.

**Pipe Drainage Systems**

The traditional clay tiles have been almost invariably been replaced in new schemes by corrugated plastic. Installation of a layer of gravel over the pipe, to assist percolation of water through the sub-soil into the drain, has been facilitated by the machinery now available. This type of scheme, allied with mole ploughing or sub-soiling, keeps soil water under control more effectively than the older systems.

"It is well worthwhile marking all drain outfalls with a substantial stake."

**Photo 4.14** Trenching machine

In the early days of plastic pipe drainage there was a tendency to replace 3 inch diameter tiles with 50mm or 60mm diameter plastic pipe for reasons of economy and on the basis that the old drains never ran full anyway. However larger pipes allow a greater margin of safety against silting up and irregularities in grading. It is preferable to use 80mm diameter as the minimum and this is now more frequently done.

Plastic pipes in coils up to 150m in length also facilitate rapid installation by trenchless machines. However, such machines could damage old drains which were still working and leave wet holes in the fields which had to be subsequently excavated and made good. Hence trenching machines have held their own, as they enable old drains to be seen and connected up as necessary.

**Ditch Systems**

Regardless of the type of drainage system, it is fundamental, but often overlooked, that drains should have a clear discharge at the outfall ditch to avoid blockages and poor flow leading to water-logging in the fields. Drains often cannot run because ditches become neglected, silted up and overgrown, or have had trees planted on the banks (Photo 4.15). Regular maintenance of ditches should be an absolute priority and that means leaving the ditch clear of obstacles to enable efficient machine work.

It is well worthwhile marking all drain outfalls with a substantial stake. This acts as a reminder to keep them free of obstruction and a warning to avoid damage when cleaning out the ditch.

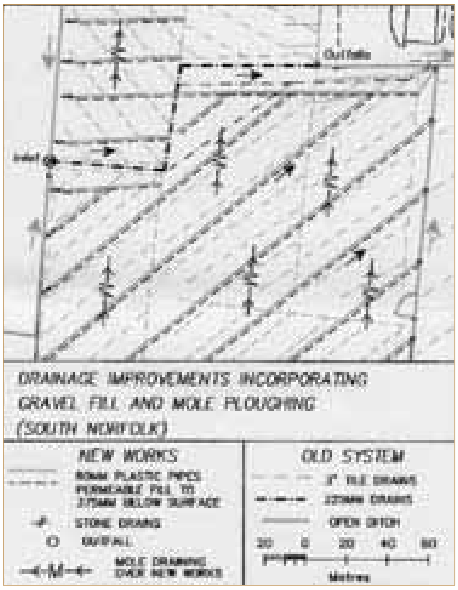
**Photo 4.15** Ensure ditches are not blocked

It also makes it easy to locate the drains for investigating problems, or if clearance of the pipes, either by use of rods or with a jetting machine, is to be done.

**Drainage Plans**

Many hedges were removed and ditches piped during the last major phase of grant aided schemes which were installed during the 1950-1980 period. This saved on maintenance and increased the area for production. However it has made the pipe drainage systems more

complex and less accessible in the event of subsequent work being required (which is more likely to happen 20 or more years after installation).
The retention of record plans is particularly important for extensive pipe systems as compared with single drains running direct to the ditch. Records of where drains are tend to get lost over the years, especially when land changes hands. It is unfortunate that plans of grant aided schemes are no longer safely held in government offices, and that many have been destroyed.




Modern Computer Aided Drawing technology can be used to scan and store old drainage layout plans. This has the advantage that records of recent schemes can easily be added to the master version. Hence everything that has been done in any particular field can be readily plotted on a single up to date plan (as plan above) to be consulted as and when required for investigating problems and designing new works.

**Soil management**
I leave until last the bugbear of arable farming which can cause the most sophisticated drainage system to fail. It is of course, damage, and even collapse, of soil structure by compaction and smearing, from operating machinery on the land in wet conditions when the soils are most vulnerable.

Moreover, light sandy and silty soils, normally regarded as free draining, can exhibit drainage problems where cultivation pans have formed.

How many times have the old Ministry Drainage Officers been asked to advise on sorting out wet fields and found on digging down with a spade that the lower soils were quite dry but the water on top could not drain away.

Clearly cultivations and harvesting have to be done and there will be times when conditions are not ideal. The existence of a well maintained drainage system, with stone backfill over the pipes, will give remedial work the best possible chance of success.


Photo 4.16

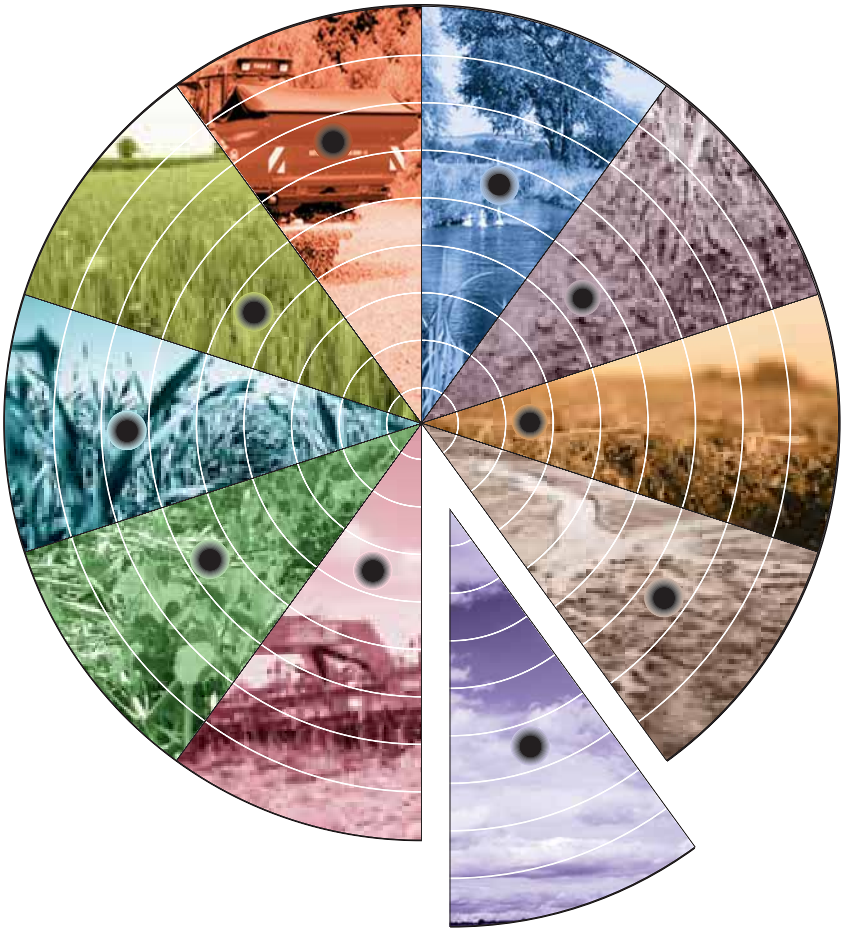
**"The bugbear of arable farming which can cause the most sophisticated drainage system to fail is damage & collapse of soil structure from operating machinery in wet conditions."**

| Action points on soil care | Learning/notes |
| --- | --- |
| • Improve knowledge<br>• Identify current problems:<br>- Soil degradation<br>- Compaction<br>- Under consolidation<br>- Capping<br>- Poor root development<br>- Water-logging<br>- Erosion<br>- Drainage<br>- Wheelings<br>• Understand potential solutions<br>• Target priority problems<br>• Implement best practice<br>- Adapt to suit conditions<br>- Care with adoption of root tillage<br>- Alleviate compaction with well set-up implement and/or encourage worms<br>- Leave a course seedbed with trash included on unstable sands/silts<br>- Consolidate in an appropriate manner<br>- Improve water infiltration<br>- Check problem is resolved | |

| Action points on drainage | Learning/notes |
| --- | --- |
| • Review drainage records by field<br>• Make/ update a drainage plan<br>• Clean out ditches on a regular basis<br>• Check drain outfalls are clear and ditch allows water flow<br>• New drains to be 80mm diameter<br>• Mark drain outfalls with a stake<br>• Avoid tilling /working under wet conditions as smearing/ compaction will result stopping water infiltration<br>• Check and resolve soil damage<br>• Use sub-soiling/ moling to encourage flow from field to drain if needed | |

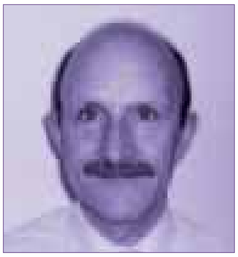
**Target on soil care**

1) Draw up & implement a soil improvement plan to minimise the risk of soil erosion
2) Do not work wet soils
3) Ensure either crop/green coat is present on land over winter or land is left rough with primary cultivation only
4) Build and maintain soil organic matter



# 5 Climate change

When looking at the impact of weather and climate change on soil management, a useful approach is to consider the available work days, or AWD's. An AWD is a day when fieldwork is possible, usually when the soil is dry enough to bear the weight of a tractor without damaging the soil and it is not raining. For operations such as spraying or fertiliser spreading, wind speed will also be a factor. When a soil is fully wet, it is referred to as being at field capacity.



**David Harris**
ADAS Consulting Limited

## Available Work Days

These are governed by climate and soil type. High rainfall and heavy soils both reduce AWD's. Weather type also affects AWD's; prolonged light rain can frustrate progress as can damp, still days after rain; by contrast, a short, sharp shower followed by sunny conditions with a breeze will often allow a rapid return to fieldwork.

AWD's vary fairly reliably across the country; the east, particularly the area around Cambridgeshire to Essex is the driest whilst the west, particularly on the hills is the wettest. Perhaps the most important time for AWD's is the cultivation period over late summer through to the autumn. The number of AWD's for England and Wales from 1st September to field capacity are shown on the following table and figure, taken from the model, ECOMAC. The table shows the driest, wettest and middle areas of the UK.

"In western areas, AWDs are limiting, with the emphasis on completing autumn drilling before soils become too wet."

| | Soil | Workdays: 1st Sept to field capacity For normal, dry and wet autumns | | |
|---|---|---|---|---|
| Area | Texture | Normal | Dry | Wet |
| 10 (Driest) | Light | 54 | 62 | 27 |
| | Medium | 28 | 45 | 17 |
| | Heavy | 24 | 51 | 3 |
| 5 (Middle) | Light | 78 | 81 | 56 |
| | Medium | 60 | 73 | 45 |
| | Heavy | 39 | 74 | 24 |
| 1 (Wettest) | Light | 98 | 105 | 84 |
| | Medium | 84 | 101 | 67 |
| | Heavy | 80 | 95 | 63 |

**Table 5.1** AWD's for areas 1,5 and 10 for England and Wales (from ECOMAC) for light, medium and heavy soil in normal, dry and wet seasons

In recent years, cost pressures have lead to changes in the approach to cultivations, with the emphasis being on reduced energy input and speed of covering the ground to maximise the acreage covered and make best use of prevailing conditions. This has come about because farm sizes have increased in order to spread overhead costs while the availability of labour has reduced. Hence the size and work-rates have had to increase and the number of passes to achieve acceptable quality seedbeds and the amount of soil disturbance both reduced.

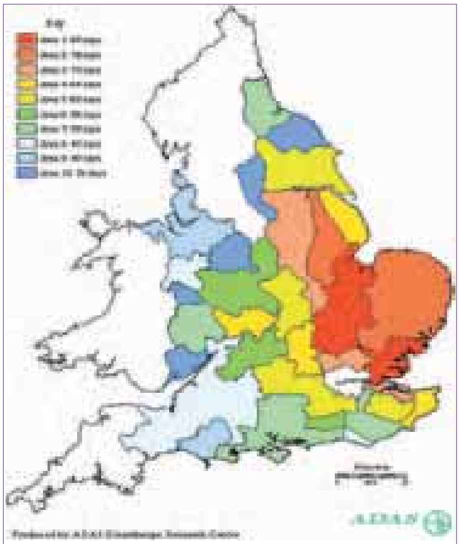


**Figure 5.1** Available work day areas from 1st September to field capacity for medium soils in England and Wales

In general, most work is still completed according to agronomic targets, for example drilling date for maximum yield that is by early to mid October for the main crop, winter wheat. In western areas, AWDs are limiting, with the emphasis on completing autumn drilling before soils become too wet.

By contrast, dry areas in the east often have days to spare, with field capacity not being reached until early December in the driest areas. The only autumn crops drilled near the time when soils reach field capacity are those which follow roots. Soils may be relatively dry at this time, but there is an increasing risk of soil damage and erosion to a relatively small proportion of land.

In this situation conservation of soil moisture may become increasingly important to ensure germination and early crop growth. Crops sown into dry seed beds will show un-even germination across the field which gives rise to management difficulties later because plants and weeds within the crop are at different growth stages. Seeds, which fail to germinate, are at risk from predation and pathogen attack. Where germination is significantly delayed a yield penalty may result because the effective sowing date is late or because sub-optimal plant populations establish.


Photo 5.1

The only autumn crops drilled near the time when soils reach field capacity are those which follow roots. Soils may be still relatively dry at this time, but there is an increasing risk of soil damage and erosion to a relatively small proportion of land.

Many farmers see this as an occupational risk of farming, but if soil is vulnerable to erosion, it is a hazard that should be avoided and legislative demands will become stricter in this area. Late cultivations are all right in a dry autumn, but you should keep your eye on how wet the soil is becoming and the likely number of AWDs left to avoid leaving bare land vulnerable. Most farmers know when it will take only an inch of rain to put paid to effective crop establishment for the rest of the winter and they are also aware of the cost of increasing working capacity to avoid late cultivations. These costs will be in terms of higher machinery costs, overtime, lost yield from the root crops and increased pressure on the establishment and husbandry of earlier sown autumn crops.

## Impact of climate change

As we seek to take a sustainable approach to farming, it will be increasingly important to avoid leaving soils vulnerable to extreme weather. In future, changes in the pattern of AWDs will be increasingly relevant. Climate change is likely to bring the following important changes:

- A longer growing season
- Drier summers
- An increase in autumn and winter rainfall
- A reduction in frost days
- A large increase in days with temperatures over 25°C

Our geographical location means our climate will still vary and although weather records seem to be broken regularly, extremes are not expected to change a great deal in scale, although they will increase in regularity. This means that we will probably have more droughts and more heavy rainfall events, which in turn mean there is a greater risk of soil erosion particularly in the late autumn.

Any fieldwork will have to be well planned in terms of soil moisture, the time available and the likely weather during and following the work. The following comments refer to the average situation, but all years will vary.

> "It will be increasingly important to avoid leaving soils vulnerable to extreme weather."

Our unpredictable springs are likely to continue. Coming out of a wetter winter, early work, such as spraying for wheat bulb fly or Alternaria, will be more risky. Spring nitrogen applications will be vulnerable to increased risk of run-off from increased rainfall, but temperatures will be higher and the season will start earlier. This may be good news for root growers with less bolting risk for sugar beet and an earlier start for potato crops. Correct cultivation techniques and timing will be important to reduce the risk of soil erosion from heavy rainfall.

"It will be important to consider a range of cultivation techniques to achieve timely drilling of autumn sown crops."


Photo 5.2

Summers are likely to be drier and warmer, meaning less wet weather diseases like Septoria. The dry conditions will make combining easier, but leave seedbeds very dry. This will mean that weed seeds will be less likely to germinate early on, reducing the ability to deal with the threat of herbicide resistant weeds such as black-grass by using a stale seedbed technique.

Autumn conditions will vary depending on location, but conserving moisture will be important. Soils will probably be drier at the start of autumn and wetter sooner. Some land will still need to be ploughed rotationally, but the challenge will be to get autumn crops established before heavy rainfall later in the autumn. There will be increased pressure on the time available for cultivations with so much land being too hard and dry to cultivate efficiently after harvest. Whilst it may be necessary to wait until some rain has occurred, the work will need to be done in a shorter time. This situation suits conservation tillage techniques which move less soil at shallower depths, conserve moisture, facilitate better rooting and allow faster output. However, the onset of earlier wetter conditions in autumn may mean the plough is needed for later crops, or a shift to spring drilling on more difficult heavy soils.

Depending on location and soil type, it will be important to consider a range of cultivation techniques to achieve timely drilling of autumn sown crops. Where winter cereals are planned following root crops, there will be an increased risk of exposure to soil erosion the later cultivation takes place. In such cases, it may be better to plan for a spring crop and leave the soil surface undisturbed for the winter. In most cases, this will mean accepting a smaller gross margin for the following crop. However, even if a winter cereal crop were to be established, increased problems with weeds, pests and diseases and poor soil conditions through a wet winter are a real threat and a spring crop cereal may do better.


Photo 5.3

In the west, drier conditions at the end of summer may improve matters in terms of getting the work done. However, in the east, it will mean increased costs, using more overtime, fuel and steel to get crops drilled at the optimum time unless operations are carefully planned. Weeds will be less likely to germinate pre-drilling, which will both reduce the likelihood of being able to use stale seedbeds and increase the reliance on post-emergence herbicides.

There is a risk of a rise in cultivation and crop protection costs due to less time being available for autumn crop establishment. However, it is important that growers adhere to good soil care principles to protect both soil and the environment from changes in climate.

In order to mitigate against the effects on cropping which may arise from climate change it may become necessary for farmers to pay closer attention to their soil structure. With longer periods of hotter and drier weather and spells with greater rainfall the ability of the soil to buffer these events may be critical for soil and yield preservation. A soil which is able to absorb more water during periods of heavy rainfall will reduce the likelihood of runoff while replenishing water reserves deep in the soil structure.

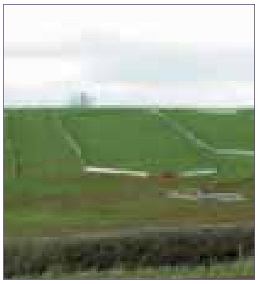

Photo 5.4

The crop can then draw upon this water during dry conditions. This provides a more cost effective solution to providing adequate water to crops during drought than building reservoirs and irrigation systems. Furthermore catchments which are able to absorb higher levels of rainfall will reduce flooding in downstream catchments. In recent years the cost of such flooding has been substantial to society both in the cost of prevention and the cost of clearing up where prevention strategies were ineffective.

The absorptive capacity of soils can be increased through a number of methods. Most obviously is the avoidance of compaction, which can occur due to trafficking, the presence of plough pans in plough based cultivation systems and surface compaction which can occur under direct drill systems. Building soil organic matter can assist also. This can be achieved by returning crop residues and livestock wastes back to the soil, incorporating grass, green manures or catch crops in the rotation or by reducing soil organic matter mineralisation by reducing tillage intensity. Besides increasing soil quality and adsorptive capacity Soil organic matter increases soil biological activity, including earthworm numbers and biomass. These can have a huge effect on soil porosity by creating burrows from the surface down to sub-soil layers. In soils which have been direct drilled for many years these can mitigate against the effect of surface compaction by acting like a sieve and carrying water away. The incentive to increase soil organic matter may increase as governments seek to find sinks for carbon dioxide to meet with Kyoto protocols. Power generating companies may need to find ways to offset emissions and paying farmers to increase soil organic matter may provide a useful method.

**"There is a risk of a rise in cultivation and crop protection costs due to less time being available for autumn crop establishment."**

SOWAP
SOIL & WATER PROTECTION



### Introducing SOWAP

SOWAP Soil and Water Protection is a collaborative effort by industry, non-governmental organisations (NGOs), academic institutions and farmers to address the environmental, economic and social concerns arising from the practice of conventional agriculture.

Initially working in the United Kingdom, Belgium and Hungary, SOWAP will test a range of site-specific soil management methods, based on the concept of conservation tillage. It will look at the economics of the operations as well as effects on erosion and pesticide and fertiliser run-off. Birds, earthworms and aquatic invertebrates are some of the biodiversity indicators the project will measure.

- Three year, £4 million project co-funded (50:50) by EU Life and Syngenta;
- The main components of the project are environment, economics and society.

### Environment

A key area of interest for SOWAP is the environment. Work is being carried out in three main areas:

**1. Soil**

'Soil is a vital resource, increasingly under pressure. For sustainable development it needs to be protected' EU Soil Protection Communication.

SOWAP seeks to meet this objective by promoting better management of the soil and thereby limiting soil erosion.

Soil erosion plots will be used to:

-Compare conventional, farmer and SOWAP practice

-Measure sediment, pesticide and nutrient loss and runoff from these systems

Microbial biomass and diversity will also be assessed.

**2. Water**

Soil disturbance produced by tillage creates silty water that drains into streams, ditches and ponds.

Working on ploughed and conservation tillage catchments, SOWAP will evaluate stream biodiversity and levels of nutrients and pesticides.

**3. Biodiversity**

Key biological indicators will assess the impacts of differing land management practices on ecosystem sustainability.

Counts of foraging farmland birds will be undertaken.

Abundance and availability of seed and invertebrate food resources will also be assessed. Earthworm numbers will be important indicators of soil 'health'.

### Economics

The economic viability of the practices assessed will be vital to their acceptance and uptake by farmers.

A comparison of the agronomic practices accompanying the various soil management systems will also be key to achieving farmer approval.

Cost-benefit analysis of the various operations undertaken at farm scale will be evaluated.

### Society

A diverse group of stakeholders committed to sustainable land management have come together to support the SOWAP project.

The SOWAP project will benefit:

- Farmers - demonstrating practical options and offering advice;
- EU and Government - generating comprehensive data to support policy development;
- Academia and NGOs' - developing understanding and stimulating new research

### Communication

A main aim of SOWAP is the dissemination of information. To encourage interaction with interested parties all information from the project will be freely available at www.sowap.org

Active dissemination of the information from the project will also take place through workshops, open days, farmer extension work and through WOCAT (World Overview of Conservation Approaches and Technologies), etc.

### Organisations Involved in SOWAP

| | | |
|---|---|---|
| Cwi Technical | Cranfield University, Silsoe | Väderstad |
| FWAG | Syngenta | WOCAT |
| Harper Adams University College | The Allerton Trust | Yara (UK) Ltd |
| Hungarian Academy of Sciences | The Ponds Conservation Trust | RSPB |
| National Trust | University of Leuven | Agronomica |

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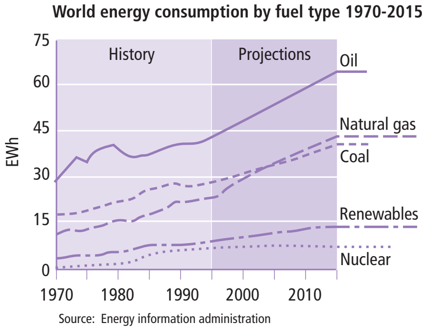
### Energy from our farms

During the coming 5-year period farming will undergo major change. Agriculture could gradually develop a new branch, which in the long term could become as important as the current food production aspect. An improved standard of living in large parts of the world such as China, India and other countries will bring about a drastic increase in the demand for fuel. Rising energy prices, continued unrest in the Middle East, increased awareness of the finite nature of oil reserves and increased knowledge of the greenhouse effect will drastically alter public perception of energy supply and thus also of agriculture. Countries, companies and individuals will all begin looking for alternatives to fossil fuels with growing determination and they will begin looking to agriculture.




### Environmental effects

So far, not all countries have signed up to the Kyoto Agreement, which regulates future emissions of $CO_2$. Large countries such as the USA have still not accepted the terms of this agreement. Global warming is now widely accepted by most, but some countries including the USA want more evidence. It is reasonable to expect a swing in opinion, which will probably have a strong influence on the need to find alternative fuels. Pollution and the greenhouse effect will be among the strongest motives for seeking alternative sources of energy.

### The farmer as energy producer

The farm can produce energy in a number of ways. The following are only a few examples:

- Cereal grain can be converted to ethanol. Large amounts of ethanol can be produced from practically every type of cereal (perhaps even from straw in the future). Around 3.5 kg of wheat produces 1 litre of ethanol and nearly 1 kg of animal feed. Brazil has long had a huge programme producing ethanol for vehicle fuel, mainly using sugar cane. In Brazil, there are several approaches to this, one being to run the vehicle on pure ethanol, another to mix it with petrol. In many countries ( e.g. India, Iran and others), work is being carried out on 'gasohol' projects in which ethanol is being produced for mixing with petrol, commonly at rates up to 20%. There are many failures behind these few successes, but in time, more work will almost certainly be done on finding alternatives. In Europe, enormous amounts of grain will be produced in the former Eastern Bloc, and it will probably be difficult to sell this grain on the world market. Ethanol production can be a welcome way of using such grain.

- Grain can be used for production of 'green gas'. In Sweden, there is currently an interesting project on 'dry fermentation' of grain into gas, which is used as a fuel for vehicles. For the past decade, buses in Swedish cities have been using gas obtained by fermentation, with slaughterhouse waste as a former substrate. A great potential for cereal grain can develop here.

- It has long been possible to use vegetable oil for the production of a diesel-like fuel, RME (rape methyl ester). Technically, the production system is very simple. However, there have been a number of problems, for example in Austria which was one of the original producers of RME-fuel, mainly from sunflower oil. The current increase in petroleum prices will bring a new perspective to this issue and the potential must be regarded as great.

- Combustion of grain in a burner is an increasingly attractive option. This procedure is very cost-effective in Sweden but in countries with lower petrol taxes it is less lucrative. It generally uses low-quality grain with a low market value. By summer 2004, it is estimated that 1000 households will be warmed using grain and experiences are generally positive. A considerable potential can be seen in countries with a relatively large heating requirement.

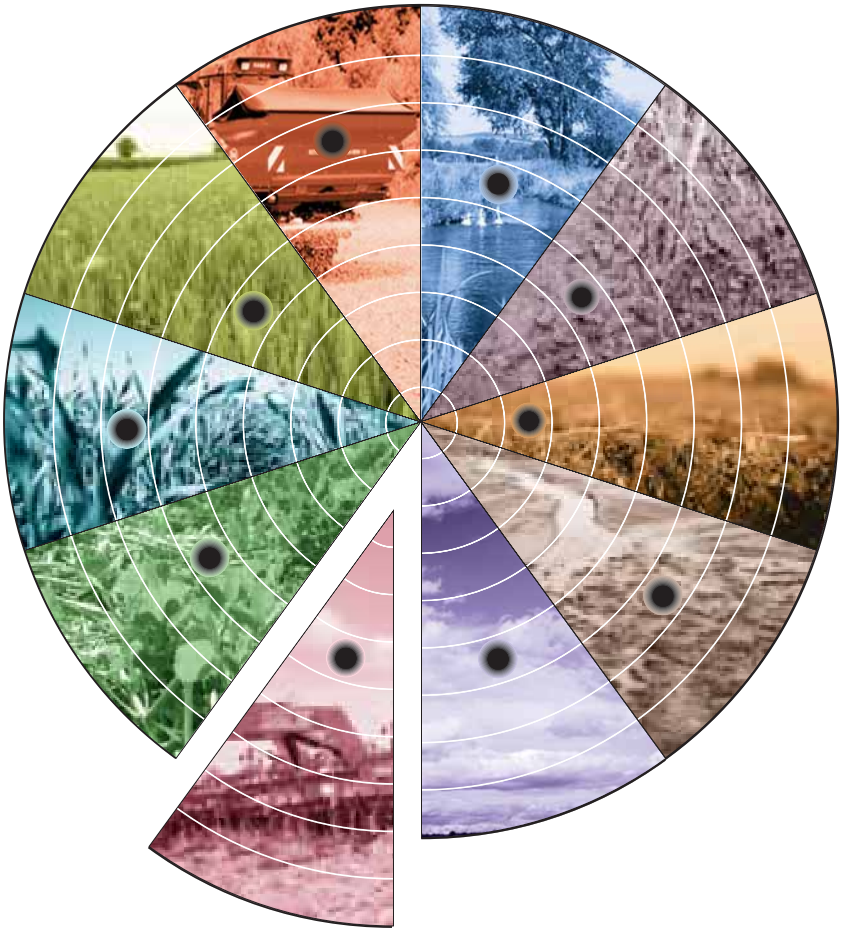
### The future

The above only hints at an impending change in political decisions. In the long-term, the matter is a taxation issue, since alternative energy sources are currently tax-free in the EU.

| Action points on climate change | Learning/notes |
| --- | --- |
| • Note likely local changes in climate that may affect you<br>• Assess AWD's in your locality against workload and performance<br>• Implement strategy to solve likely issues by good planning;<br>- Insufficient AWD's<br>- Weed control if stale seedbeds or pre-emergent timings prove impractical<br>- Cultivation in hard dry soils in late summer<br>- Appropriate cultivation during autumn<br>- Protection of soil against erosion due to heavy rainfall<br>- Weather-proofing soils with good infiltration and water holding capacity through winter<br>- Shorter autumn window for good establishment<br>- Moisture conservation in late spring to early autumn | |

**Target on climate change**

1) Implement measures to reduce soil erosion risk and protect soil structure
2) Fields after combinable crops must have crop or green cover, be left in stubbles, or be rough cultivated over winter unless the succeeding crop requires the land to be cultivated
3) Consider climate change as a factor in your Soil  Management Plan



# 6 Machinery

There is never just one way or approach to achieve a profitable farming business. However, the costs must stack up for both labour and machinery in particular and cost, timing and efficient crop establishment are at the hub of the wheel. Whilst we have in general little control over the prices we receive compared to many other industries, we have a much greater opportunity to control and monitor our production costs, and the potential savings are substantial.

**John Bailey**
TAG Consulting
Machinery consulant

**Steve Townsend**
Steve Townsend and Co.
Independent tillage consulant

VÄDERSTAD

It is useful to compare the farm with standard data such as Cambridge Costings. It is just possible to be high in one area and low in another and so catch up "lost ground" but it's much easier to stay at least in line throughout and hopefully ahead under most of the following and other more detailed categories. Compare with your own figures:

| Costs | £/hectare | | | | |
|---|---|---|---|---|---|
| | Mainly cereals | | Mixed cropping | | Insert your own farm figures |
| | All farms | Top 10 | All farms | Top 10 | |
| Farm Output | 647 | 768 | 1055 | 2040 | |
| Variable Costs | 202 | 197 | 354 | 533 | |
| Crop & Stock Gross Margin | 448 | 571 | 701 | 1507 | |
| Non Agricultural Income | 91 | 215 | 126 | 184 | |
| Total Gross Margin | 542 | 792 | 832 | 1693 | |
| Machinery & Power | 170 | 211 | 238 | 345 | |
| Unallocated Contract | 32 | 16 | 41 | 54 | |
| Labour | 95 | 64 | 187 | 324 | |
| Farmer's Manual labour | 33 | 82 | 29 | 43 | |
| Total Fixed Costs | 504 | 505 | 717 | 1019 | |
| Net Farm Income | 38 | 287 | 115 | 674 | |

Source:- Cambridge University Costings 2001/2002

"The importance of fixed costs cannot be overstated, as they represent up to 70% of the output including non farm income."

Other classifications are available such as arable with pigs and dairying. The importance of fixed costs cannot be overstated, as they represent up to 70% of the output including non farm income. It is not possible to reduce some costs such as rents in the short term as they are not under our immediate control, but others such as labour and machinery which in turn represent about 2/3rds of fixed costs are prime target areas.

The opportunities for making savings in variable costs are limited and potentially risky. For mainly cereal farms both variable costs and labour costs have remained at about £200 and £100 per ha respectively for the last 15 years showing the enormous strides the industry has made.

The actual course followed and the methods used vary enormously according to; soil type, the inherent yield potential, whether the farmer is a tenant or owner occupier and personal preferences. Making the utmost use of the ability of the farmer or manager and the work force is also vital.

## Labour and machinery targets (mainly cereal farms)

The combined labour and machinery figures for mainly cereal farms need to be reduced from £300 -350 per hectare to £200 -250 per hectare as follows depending on the farm size.

| Farm Size | Labour and machinery cost £/ha | Labour cost £/ha | Machinery cost £/ha |
|---|---|---|---|
| **Medium sized farms e.g. up to 250 ha** | £250 | £90 | £160 |
| **Larger Farms over 600 ha** | £200 | £60 | £140 |

Within these target figures a cereal establishment cost of £100 plus per ha, based in most cases on a plough system, is too high. There is just insufficient left over to cover combining, fertilising, spraying and hopefully the very necessary, but often neglected, hedging, ditching and drainage. Costs are intermingled and inseparable from establishment times, the number of cultivation passes, and the cost of regular full time staff involved and so the number of tractors required. Hence

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adopting more minimal non-ploughing techniques, on at least a proportion of the acreage is a must with little if any choice.

It is much more difficult to give guideline figures for root crop farms, especially potato and vegetable businesses, but farms growing sugar beet that contract out the harvesting ought to be able to match cereal farm targets.

## Labour Costs

Regrettably this needs to be in line. For mainly cereals farms the range found in practice is from perhaps 200ha to 500 ha per regular employee. A figure of 300ha is a reasonable compromise between the economics and reasonable expectations and workloads for an individual. These figures ought to include the proportion of the farmer or manager's time doing manual work e.g. 1/2 to 2/3rds of his or her time at manual rates. Traditionally root crops and livestock have been a sensible and practical way to utilise labour more evenly throughout the year. Now increasingly non farming enterprises are giving a welcome variety to the farming scene and in some cases the farming side of the business produces much less than half the income.

Analysing the manual labour on an individual farm based on £22,000 per employee might be as follows:-

| | |
|---|---|
| Owner/manager (manual element) | £14,500 (2/3rds) |
| Employed labour (2 workmen) | £44,000 (all their costs) |
| Father at harvest time (say) | £4,000 |
| Student | £3,000 |
| Total | £65,500 |

Based on 1,000 ha this would represent £65 per ha which is difficult to achieve. For most farms £75 per ha is a more realistic target.

## Machinery Costs

A breakdown of machinery costs frequently shows:-

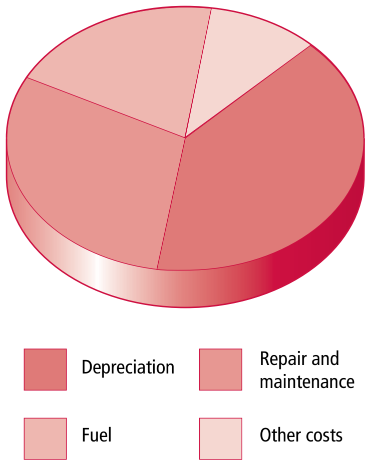



**Figure 6.1** A breakdown of machinery costs

For most farms depreciation is the killer figure, arising from a combination of too many under utilised machines where the value does not match the true farm demands. For other farms repairs and maintenance can be higher than depreciation, often due to a lack of suitable and planned re-investment over a period of years. This is generally of some concern as the figures are often an under estimate, not truly reflecting the labour costs of maintaining the machinery (the many happy or unhappy workshop hours when there can be more pressing outside priorities!).

Currently machinery costs on most mainly cereal farms hover around the £200 per ha figure but can be reduced to £140-160 per ha in most cases. However, its far from easy and will involve considerable changes both in the farm approach and when machines are replaced. Saving costs inevitably involves taking greater but hopefully sensible "risks" compared to the present more "comfortable" status quo.

**"The combined labour and machinery costs for mainly cereal farmers need to be reduced to £200 - £250 per hectare dependent on farm size."**

There are opportunities on most farms to make considerable savings but these need to be planned, cohesive and achievable in the medium term at least. In many cases it follows on from labour savings or retirements. The major cost areas are; 1) number and size of tractors, 2) to a lesser extent combines and 3) increasingly the capital spent on new cultivation machinery and drills. Tractors are used every day of the year impinging on almost every operation and so they need to be of the right size, number and reliability to suit the farm. The annual hours worked is a very practical reflection on how important the tractor is to the farm and whether it should be bought new or second-hand, replaced more frequently or allowed to continue into old age! In many cases hiring extra tractors in the autumn makes good economic sense.

**"The annual hours worked is a very practical reflection on how important the tractor is to the farm and whether to buy new or second-hand and when it should be replaced."**

There are possibly three tractor categories on farms. Tractors doing at least some cultivation work frequently work out at 0.75-0.1.0hp/ha but this figure ought to include hire tractors.

**Main line cultivation tractors**

There are usually 2 tractors working to an extent in tandem frequently covering more than 800 hours per annum and kept for perhaps 4000-5000 hours. With very large tractors there may be only one operated on a shift basis. Because of the need they can be maintained on contract and ought to be bought new or very nearly new. Buying slightly larger tractors than absolutely essential further speeds up work rates making the most of the time windows and the labour available. For many one man bands they can be an absolute boon.


Photo 6.1

**Support tractors**

These are usually smaller but increasingly about 140 hp on larger farms, doing a variety of jobs from grain trailer work to fertilising and spraying. They ought ideally to do not less than 500 hours per annum and will most likely be bought second-hand. On many root crop farms and some mixed farms these tractors cover 1000 to 1200 hours per annum and then ought to be bought new.


Photo 6.2

**Very old standby tractors**

Some farms may have "pensioned off" yard tractors and tractors used for irrigation pumps, grain blowers etc. In value terms they represent petty cash. The value ought to match the need. Tractor and driver figures are the major part of most cultivations and drilling operations making up 50-80% of hourly or per hectare costs. Having an appropriate basic cost is an essential first step to controlling field operation costs. Tractor costings including fuel range from about £9 per hour for the oldest smaller active tractors through to as much as £45 per hour for a less than fully utilised large rubber tracklayer. It is crucial that these costs are properly worked out and known.

Whilst no particular farm size can possibly utilise all their machinery to the full, sharing machinery and the increased use of contractors are excellent ways of more fully using machinery capacity to the benefit the industry as a whole. A well used machine is typically 1/3rd cheaper on a per ha or hourly basis.

## Cultivations

Being critical and more actively looking for non ploughing opportunities within the rotation is open to all farmers. But, the volume of straw present is a major consideration as are the soil type and weather conditions. Most farms, large or small, need to consider a cost effective alternative method of establishing cereals, especially after break crops where there is little straw residue. Baling more straw would help but the market is limited in many parts of the country and the price paid for straw is often too low when set against the nutrient value of returning straw to the land and possible soil compaction damage and delays in subsequent cultivations. It's much better where there is a "straw for muck" relationship.

"The real aim is to reduce the average establishment cost over the whole farm by gradually introducing new techniques."

## Cultivation Systems

There are many options and a range of costs and times for a complete establishment system is as follows:-

| System | Max. depth (cm) | # passes (incl. drill) | Cost (£/hectare) | Times(Mins/ha) |
|---|---|---|---|---|
| Ploughing | 15-30 | 4-5 | 90-125 | 100-250 |
| Heavy discing | 8-15 | 3-4 | 70-90 | 60-70 |
| Solo type (disc and tine) | 15-18 | 2-3 | 65-70 | 40-50 |
| Carrier or Horsch type | 5-8 | 3-4 | 50-70 | 30-60 |
| Scratch (one pass) & drill | 3-5 | 2-3 | 30 | 30 |
| Direct Drill | 0 | 1 | 25-50 | 15-30 |

In most cases the higher number assumes a roll after drilling

Such a table can be misleading;

(a) The costs do not always initially come down significantly because of the investment in new tractors and equipment, but careful and appropriate choice and use, investment/ sharing/ contracting can minimise the cost.

(b) Time required does drop and this is crucial allowing more land to be cultivated in the autumn under good conditions.

Photo 6.3

(c) The annual savings in staff and tractors etc. and/or the extra land which can be worked gives the real and quantifiable savings; an employee plus a modest tractor means a saving of at least £28,000 per annum.

The real aim is to reduce the average establishment cost over the whole farm by gradually introducing new techniques. Closer examination on a field by field basis, ideally prior to harvest, is needed to decide what cultivations are possible and necessary. Undoubtedly this means less land will be ploughed, but the speed of the change will vary according to the soil type, cropping, the field weed status and the personality of the farm manager or farmer!

The farm drill needs to be as adaptable as possible working on ploughed or minimum tilled land with straw present and direct drilling on an opportunity basis. For most cultivator drills this is not truly direct drilling as cultivation tines or discs in front of the coulters can mean considerable soil disturbance.

## Managing the Changes

Having said there is a definite need to move to less ploughing, many or even most of the smaller to medium sized farmers are still very hesitant. Some of the main concerns are:-

"Farming as a whole has no choice but to go down the minimum tillage route where more appropriate."

• Scepticism over the 1970's, the wet autumns, heavier soil in general, the volume of straw following a heavy wheat crop, slugs and weed control are all frequently raised.

• Fear of the land going to a pudding with wet weather. There are conflicting experiences over the wet autumns, some saying the land drains very well, others the absolute opposite. The condition of the sub-soil must be right before you go down the min till path and it is wrong to make the soil surface too fine too soon.

• Most believe that minimal tillage crops produce lower yields. This is not necessarily true indeed some trial work shows the opposite. Care and a higher level of management is fundamental - It's not easy to save £20 per ha in machinery costs it's very easy to lose this in yield even with wheat at £70-75 per tonne (futures for Winter 2004/5, LIFFE 19/10/04).

• All re-investment needs to be well justified and part of a medium to longer term plan so that it fits into the right system for the farm and at a cost the farm can afford. The annual machinery re-investment as a whole on mainly cereal farms, net of trade-ins, should be of the order of £70 per ha. There are now a range of cultivators and drills on the market, both new and second-hand, well suited to minimum tillage cultivations and a wide range of pockets. There is also the choice of sharing with a neighbour or contracting in.

Photo 6.4

## Summary

In practice time savings of 25% are common and sometimes as much as 40% can be achieved. Initial per ha cost savings can be of a lower order due to the cost of new machinery, but don't forget the very significant annual savings in tractors and staff. Going too far in the wrong circumstances or on the wrong soil type will not pay, thereby prejudicing or putting yields in jeopardy. Don't forget the extra management ability and patience needed to make minimum cultivations work well. Farming as a whole has no choice but to go down the minimum tillage route where more appropriate. A more open mind is needed to take a little, but not too much risk, by reducing the number of cultivation passes and the % of the land ploughed. Finally, learning quickly from experience has never been more important.

## Tillage decision making

As mentioned earlier there is a direct correlation between the type, depth and number of operations during crop establishment and costs.

When reviewing current systems/ policy growers should pressure test by asking themselves; 'why am I cultivating?'

The answers are many but fit into two main areas:
• Agronomic reasons
• Mechanical reasons

## Agronomic reasons for cultivation

There are many reasons given including; Weed control, Trash management, Crop volunteer control, Pest control, Seedbed preparation, Pan busting and improved drainage. The first four are covered in more detail in other chapters so let look more closely at seedbed preparation particularly by soil type. Pan busting and drainage are covered in detail in the section on Soil care.

Soils can be classified under two headings; naturally self-structuring and those that are not.

Self-structuring soils have medium to high levels of clay which expand and contract, causing cracking, through cycles of wetting and drying over the seasons thus providing a natural form of cultivation. Such soils naturally stabilise into peds or columns of soil at depth and a granular structure near the surface, which allow root penetration and water movement, two indicators of good soil structure.

Other self-structuring soils would be ones with high levels of chalk or calcium present. Calcium has the effect of flocculating the soil particles into larger particle sizes or groups, which we see as 'crumb-like', the make up synonymous with good soil structure. High calcium soils tend to be light and have poor moisture holding abilities, but good capillary action, though self-structuring soils can contain both high clay and calcium i.e. chalky boulder clay.

"Self-structuring soils have medium to high levels of clay which expand and contract, causing cracking, through cycles of wetting and drying over the seasons."

## Selecting cultivation options

| Pick number that fits your situation and refer to text below. | Primary tillage | Heavy clay | High calcium | High sand | High silt |
|---|---|---|---|---|---|
| | Plough | 1 | 2 | 5 | 6 |
| | Minimum | 3 | 4 | 7 | 7 |

## Cultivation of self-structuring soils

**Plough based system**

**Key Strategy: - Use natural tilth**

**1. Medium to High clay content soils:**
• Need natural weathering to produce tilth.
• Use consolidation to crush large clods to aid the weathering process and to weather proof the soil by allowing better drying through the soil profile.
• Plough as shallow as possible to reduce clod size.
• Avoid over cultivation and producing too fine a tilth, which can dry out at the surface and leave wet compacted soil underneath

**Plough based system (cont)**

**2. High calcium soils:**
- Plough as shallow as possible to minimise moisture loss.
- Consolidate soon after ploughing to retain moisture and aid capillary action.

**Non inversion system**

**3. Medium to High clay content soils:**
- Keep cultivations in the natural tilth zone at the top of the soil.
- Use a top down approach if more than one pass is being used.
- Deal with plough/ cultivation pans after or during first cultivation passes to reduce clod formation.
- Consolidate after cultivation.
- Cultivate soon after harvest to make use of natural moisture.

**4. High calcium soils:**
- Cultivate soon after harvest to make use of natural moisture.
- Cultivate shallowly to retain moisture.
- Consolidate after cultivation to retain moisture and aid capillary action.

## Cultivation of non self-structuring soils

**Plough based system**

**Key Strategy: - Soil stabilisation**

**5. High sand soil**
- Plough as shallowly as possible whilst removing surface compaction.
- Plough as close to drilling as possible particularly for spring crops.
- Consolidate to stabilise soil soon after ploughing.
- Avoid overworking the soil (leave a medium quality seedbed) to minimise risk of capping.

**6. High silt soils**
- Follow procedures for high sand soils as above.
- Use consolidation to avoid hard lump formation.

**Non inversion system**

**7. Sand or silt soils**
- Use previous crop roots/ trash to stabilise soil structure and prevent capping.
- Cultivate as shallow as possible close to drilling to maintain an open soil structure.
- Avoid over cultivation or consolidation to leave a medium quality seedbed to avoid capping.
- If sub-soiling do operation as close to drilling as possible to avoid de-stabilising the soil before the new crop has a chance to put new roots through the soil.

## Mechanical reasons for cultivation

This is an area where a great deal of savings can be made.

Growers should ask; 'am I cultivating for the drill or any other machine rather than for the good of the crops?'

Drilling is most commonly where this situation is found. Conventional Suffolk coulter based drills require the soil to have a very low shear strength so that they can work properly and give the even seed depth required. This fact also means that they are restricted on forward speed, reducing output, with the very low resistance springs that are normally used on these coulters. Greater control of seeding depth is possible by joining up 2-4 coulters on a unit and providing springs with higher resistance. The space between the coulters do not allow for any significant trash to pass through the drill with out it blocking demanding that at the very least straw is baled and requiring cultivation's to remove all potential trash problems. In this case ploughing is really the only practical technique that can be used to allow these drills to work by removing the trash well enough. Using drills that restrict the flexibility of cultivation and risk soil damage through over cultivation should be avoided at all costs.

When reviewing systems growers should look at today's modern cultivator drills, which have the flexibility of coulter design that can operate in direct drilling, minimum tillage and ploughed situations and not to be forced down one particular primary cultivation route. Because of their ability to work in harder soil conditions, that would be found in direct drilling, these drills offer the benefits of speed without coulter bounce, and a more even seed placement. Both features provide a step forward in efficiency that would be useful to today's growers. To qualify as a cultivator drill it should be able to exert at least 100 kg of pressure on each coulter.

Photo 6.5

"Am I cultivating for the drill or any other machine rather than for the good of the crops."

## Sub-soiling

(covered in more detail under 'Soil Care')
There are only two reasons for cultivating deep; to remove pans, or to improve drainage.

**Plough based systems**
Working soils when they are too wet is one of the easiest ways of creating a pan and the deeper you cultivate the wetter soils are generally. So if ploughing is carried out then special attention should be given to monitor potential pans and when they would require attention. Digging and having a look is the only way. The main problem in dealing with pans is sub-soiling when the soil is too wet. If the soil can be moulded into a ball then sub-soiling is going to be ineffective. If the soil has cracked at any time in the growing season then this action has probably done as good a job as any mechanical means. Moling would be the best alternative when clay soils are too wet to sub-soil, but would only deal with drainage issues not compaction.

**Non-inversion systems**
Sub-soiling is probably required to break up any plough pans that could be present at the start of changing to minimum tillage.

Be very careful on unstable soils i.e. sands & silts as sub-soiling can produce more problems if stability is lost and the soil packs down tighter than before.

Once sub-soiling has been carried out and if due care is given to when cultivation's are carried out with suitable tyre or tracked equipment then further sub-soiling should only be needed under exceptional circumstances in a minimum tillage system.

"The key to consolidation is to press the soil back to as close to its original form before any cultivation was carried out."

## Consolidation

Consolidation technology is one of the areas where significant developments have been made in both plough and non-plough based cultivation systems over the last 10-15 years.


Photo 6.6

The key to consolidation is to press the soil back to as close to its original form before any cultivation is carried out. Untouched stubble can be the most weather proof state unless there is surface compaction after maize harvest in which case there is a high risk of soil erosion.

**Plough based systems**
Increasing the weight of press wheels and pressing as a separate pass to the plough has enabled framers to move away from expensive powered cultivators and use this action to weather proof soils and enhance natural weathering forces by increasing the area open to the elements. The new types of shouldered presses are heavy enough (1-1.5 tonne/metre) to consolidate to the depth required in plough based systems as opposed to the older types pulled with the plough which only helped with tilth production.

To consolidate power-harrowed land on light-medium soils prior to planting, or over-wintered ploughed land, the Aqueel is a useful tool as it provides not only consolidation but also indentations to aid water infiltration and minimise erosion due to water or wind.

**Non-inversion systems**
As mentioned before, consolidation in these types of system is one of the major differences between modern non-inversion systems and those of the past. The ability to weather proof cultivation's in this system has never been better. Depth of tillage in this system has the biggest bearing on what type and weight of press or roller should be used.

If cultivating deeper that 10cm then a combination of a press and ring roller will give the best results. On heavy soils with 7-10cm depth a press is still ideal, but if the depth is shallower than 10cm on light-medium soils then the press is not required and sufficient consolidation can be done with just a ring roller. Presses should be in the weight range of 1 - 1.5 tonne/metre and the ring rollers between 0.6 - 0.8 tonne/metre.

CAUTION - in the need to cut the number of field operations some machines combine cultivation and consolidation elements in their design. Sufficient consolidation is achieved with slow moving deep working machines which don't travel too fast. However, these machines can travel over 12 kph which is too fast to give sufficient consolidation to weather-proof the soil and would require a separate rolling operation to get the level of consolidation required.

## Tine and disc cultivators

Tines tend to produce a more natural tilth and do not have the forcing/slicing characteristics associated with discs. There are, however, soil types and occasions when discs are better.

## Plough based systems

Tines form an integral part of the success of modern shouldered presses when mounted in front of the press wheels. Apart from the cultivating action they impart on the soil they do much to level the soil which is critical in any cultivation system.

## Non-inversion systems

As we are using tines or discs as our primary cultivators then more time should be spent looking at the various attributes they both have to ensure we have the best possible cultivator for the soil types we have.

**Photo 6.7** Small disc

**Discs**

- Give good penetration on heavy/hard soils. Particularly important to consider when moving into a minimum tillage system. They can also smash stones.
- Good mixing of crop residue but they don't spread residue well.
- Accuracy, older type V form discs are difficult to set for accurate depth. This has largely been over come by the modern small disc & press combination machines now on the market.
- Large discs do not level as well as tines.
- Large discs have a higher power requirements/metre than tines.
- Because of their slicing action concave discs can be prone to pan formation under adverse wetter conditions particularly on silt and clay soils.

**Photo 6.8** Big disc

**Tines**

- Tend to produce a more natural tilth; keep the crumb and trash in the top of the soil better than discs, with good spread and levelling.
- Not ideal to use on heavy/ hard soils that crack, as they tend to pull up hard lumps, but otherwise provide good depth control.
- Stones may be pulled up by tines and need strategic picking to protect the combine harvester.
- Cheaper to run requiring less power/metre.
- They are prone to smearing if working soil too deep or when wet depending on the 'foot' used.

**Disc & tine combinations**

Combination disc and tine machines are justified on farms of a significant size and are well suited where there is a need for a significant amount of sub-soiling/ deep cultivation each year as in a contract operation or for starting large scale minimum tillage - in either case where soil and weather conditions may not be ideal for discs alone.

"Tines tend to produce a better more natural tilth and do not have the forcing/slicing characteristics of discs."

## Current tillage and crop establishment trends in UK

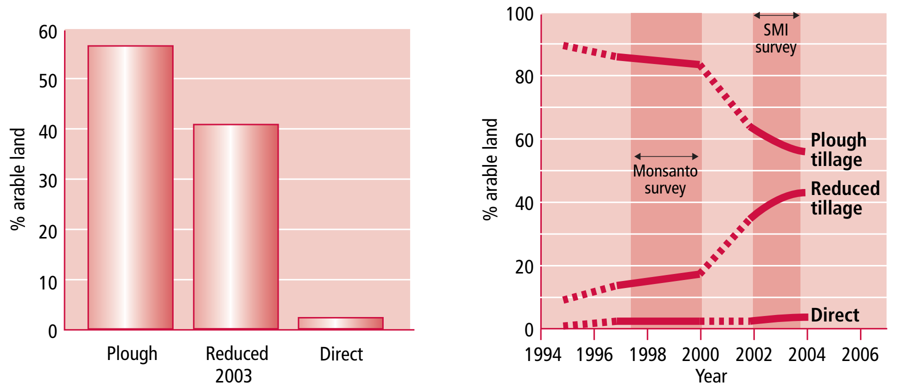



**Figure 6.2** SMI completed a survey of 200 farmers in December 2003, the results of which are presented graphically . The survey was stratified to represent arable cropping in England and Scotland by county and farm size with respect to wheat growing. Farms were mixed livestock and arable or arable alone and were of at least 250 acres.

**Action points on machinery planning**

- Know your costs so you can target savings and changes.
- Reduce the number of tractors and spare machines to suit the system needed to establish crops allowing for weather.
- Target for combined labour and machinery costs: £200-250/ha.
- Target workload: 300ha per employee.
- Target labour costs: £75/ ha.
- Target for machinery costs on mainly cereal farms: £140-160/ha.
- Target for annual machinery reinvestment costs: £70/ ha.

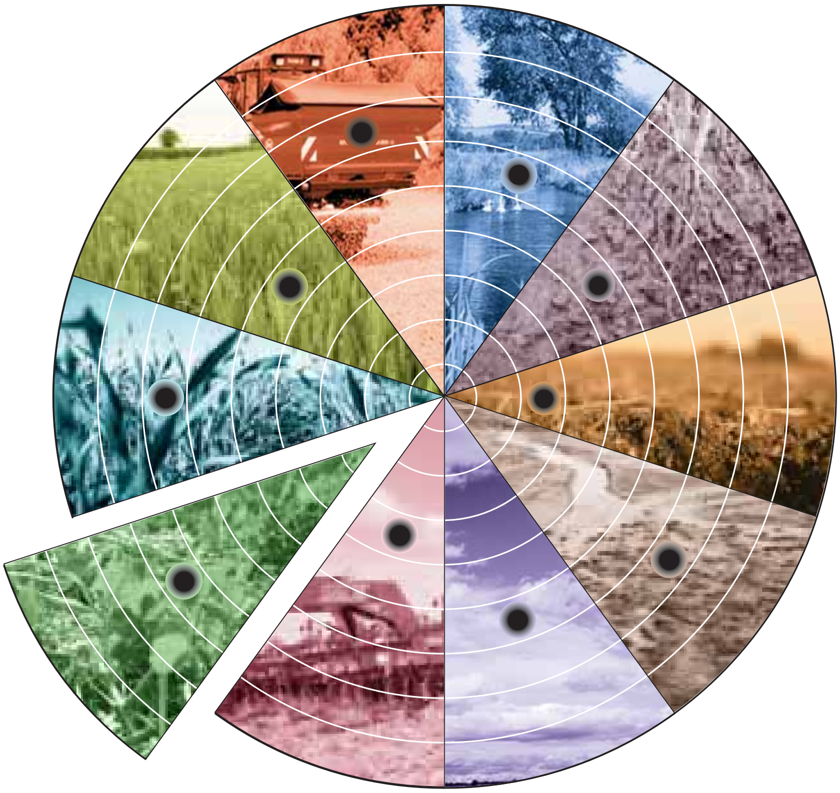
**Action points on decision making**

- Why am I cultivating?
- Decide on cultivations appropriate to the soil type
- Review the seed drill - is it appropriate to minimise the number of passes/ soil damage?
- Choose a drill that fits 85% of the time (soil type, rotation, straw volume).
- Cultivate and if needed sub-soil and always consolidate.

**Learning/notes**

**Target on machinery**

1) Do not cultivate soils when they are wet/ saturated or if you can roll a 'soil worm' at cultivation depth.



# 7 Trash management

Jim Bullock
Farmer

Many of the problems associated with non-inversion tillage and direct drilling can be directly attributable to poor crop residue management. Using a plough based cultivation system, the effects of poor crop residue management are hidden underground but the effects of anaerobic decomposition can still reduce crop performance and impact soil health.

## Introduction

Symptoms of poor crop residue management are most evident in a non inversion tillage system, but can impact under any tillage system, and include;

• Difficulties with primary cultivations (blockages and uneven penetration).
• Unsatisfactory stale seed-bed (poor weed control inter-crop).
• Drilling problems (Hair-pinning with disc drills and blockages with tined machines under adverse/ wet conditions).
• Difficulties drilling in a wet season (soil does not dry out under areas of high crop residue concentration).
• Increased slug and pest problems
• Uneven crop establishment.


Photo 7.1

• Stunting and yellowing (resulting from reduced availability or uneven uptake of nutrients)
• Poor weed control in crop due to interception of residual herbicides by large amounts of unevenly spread crop residue
• Reduction in overall crop performance (Yield loss)


Photo 7.2

"The effects of anaerobic straw decomposition can still reduce crop performance and impact soil health."

## Planning & Rotation

When changing to a system of non-inversion tillage, crop residues play a very important role in the success or failure of the system. In the short term excessive crop residue can be classed as a nuisance, but in the longer term it becomes an asset. Higher levels of organic material in the upper layers of the soil structure have numerous benefits including:

• Improved soil structure, resulting from increased earth worm activity.


Photo 7.3 Increased earthworm activity

• Improved water infiltration, leading to reduced runoff and off-site pollution.
• Improved workability and trafficability of difficult soils.
• Carbon storage.
• Increased biological activity.


Photo 7.4 Increased biological activity

When planning the change to non inversion tillage crop residue management is just one of the elements to be considered, but the actual system to be used will be dependant on the complete cropping system.

Long runs of high yielding cereals where the straw is incorporated will be more difficult to manage than a cropping system based on first wheats following a broad-leaved break crop, particularly if some of the breaks are spring sown.
Most growers recognise that a balanced rotation is essential for the long term health of the soil. However, economics are often a greater driving force, and it has to be recognised that short term profitability probably figures higher on the list of most farmers, than the environmental implications. From a crop residue management view-point, particularly if direct drilling, a cropping system based on alternating cereal and broad-leaved crops has the most to offer;

- Rotation of non fragile and fragile residue.
- Varied quantities of residue.
- Residues with different carbon/ nitrogen ratios.


Photo 7.5 Spring oilseed rape

- Different drilling and harvesting dates
- Longer inter-crop periods allow improved residue decomposition.
- Drill a spring sown crop.


Photo 7.6 Spring beans

## Crop Varieties

Whilst the choice of crop variety will primarily be based on it's market, value, and outlet together with yield potential and disease resistance, other agronomic considerations are important. Standing ability, earliness of flowering/ripening, straw length and straw strength all impact crop residue management. Cereal varieties that are short strawed, have good lodging resistance, and have the ability to ripen evenly (no green straw) would be the first choice from a crop residue management point of view.

## Straw Management

**PGR's**

Most cereal crops are routinely treated with PGR's to shorten and strengthen the straw, allowing for nitrogen levels to be used that will optimise yields and grain quality. When planning a crop residue management policy, if the straw is not going to be baled and removed, the planned use of PGR's will obviously be beneficial in improving the ratio of grain to straw production and maintaining an upright crop that eases harvest and chopping.

## Harvest Management.

The use of in-crop glyphosate was initially promoted as means of reducing grain moisture by desiccating green crop and annual weeds, advancing and speeding up the harvesting operation. But, for crop residue management there are a number of advantages;

- Harvest can be advanced by seven days or more, allowing more time for cultivations and crop residue decomposition.
- The crop is dead at harvest reducing the amount of green material passing through the combine improving the ability of the straw chopper to chop and and spread the residue.

"A cropping system based on alternating cereal and broad-leaved crops has the most to offer."

• Treated and chopped straw breaks down faster.

The diagram below (Figure 7.1) illustrates the main points discussed in the following text as regards decision making on trash management.

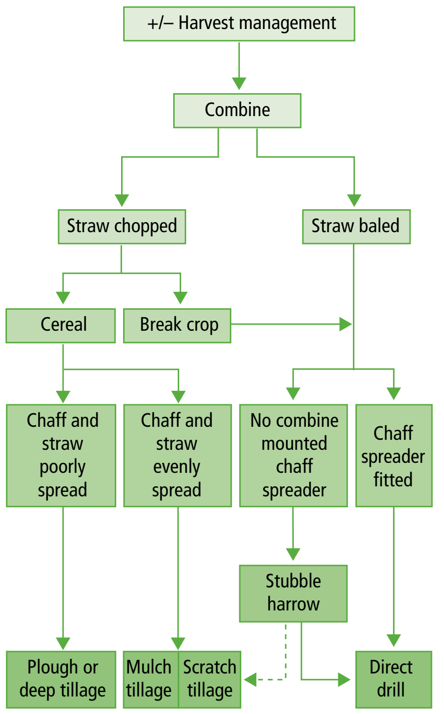


**Figure 7.1** Trash management decision chart

"Although straw chop length is important so is the degree of laceration."

### Straw chopping

Chop length is determined by:

• Crop being chopped (OSR v cereal).
• Cutting height (ratio of remaining stubble to chopped straw).
• Straw moisture content (ripeness, weather, time of day).
• Sharpness and type of chopper blade (plain or serrated).
• Chopper speed and knife spacing (newer combines have choppers with higher knife speeds and narrower blade spacing).
• Forward speed (crop flow through combine).
• Topography of land (hills take more power = poorer chop).

| Chop length | Time for decomposition |
|---|---|
| Milled (1mm) | 14 days |
| 0.5 cm | 29 days |
| 1 cm | 30 days |
| 2 cm | 47 days |
| 5 cm | 54 days |

Source: Harper

Although chop length is important so is the degree of laceration, as it helps the soil microbes attack the straw surface which in turn speeds up decomposition. For this reason some growers fit serrated knives to their combine straw choppers. Not only does this reduce maintenance (sharpening) but it aids residue breakdown.

Alternatively, an option considered by some growers in the UK and a system promoted by Avarlis in France, is to leave a long stubble then to return and re-chop the stubble and straw as a separate operation. The advantages of using such a system include:

• Increased combine output (forward speed increased by 1 km/hour leaving a 30cm stubble as opposed to one of 15 cms).
• Over an area of 100 ha this can save 1 to 1.5 harvesting days which may be worth £11.50/ha.
• The straw is often more efficiently chopped and redistributed when it has dried out and has become more brittle.
However, there is the extra cost and time involved with a separate straw and stubble chopping operation.
• It may take as long as 4 days to re-chop 100ha.
• The cost using a 4.8 metre vertical axis rotary chopper on a 120 - 140 hp tractor would be in the region of £ 20/ha.

**Chaff spread & tillage**

The chaff created by a high yielding wheat crop can be a greater challenge than the straw. Wheat chaff falls to the base of the stubble and can hold large amounts of moisture which will impede the soil drying in a wet season, not to mention encouraging slugs.

Break crops such as oil seed rape and pulses can create a high loading on the combine's sieves which will in turn lead to high concentrations of material being windrowed behind the combine.

As combines become larger so it becomes more difficult to re-distribute the straw and chaff evenly in anything other than wind-free conditions.

These problems can be minimised if you:

• Fit the combine with an effective chaff spreader; Newer designs that incorporated the chaff with the straw (John Deere/ Case) have the advantage of giving the chaff a greater velocity improving the spread. The Claas Lexion ensures a good chop and spread of straw and chaff across the width of the header. Ideally the chaff spreader should be capable of operation even when the straw is being windrowed.

Photo 7.7

• Use a straw harrow immediately after harvest when the straw and chaff are still dry and the stubble has not become brittle. This should be used a minimum angle of 45 degrees to the direction of the combine. 'Stand alone' rakes are available but incorporating the operation with the first cultivation is obviously desirable.

Photo 7.8

• Tined cultivators will aid the redistribution of straw and chaff so long as the tine spacing is not too wide - balance between spacing and blockages (Rexius with Raptor tines or Horsch FG cultivator).

Working on the basis that 1cm of cultivation depth is required for every tonne/ha of crop residue. To avoid problems such as nitrogen lock-up and the allelopathic effect (natural chemicals or toxins from related plant types inhibiting germination and growth) it is essential that all crop residues are evenly spread so as to avoid unnecessary cultivations.

Photo 7.9 Evenly spread crop residue

For example: the badly spread residue of an OSR crop could create residue strips behind the combine containing large amounts of crop residue (7.5 tons/ha) which would require deep cultivations

"As combines become larger so it becomes more difficult to re-distribute the straw and chaff evenly."

(7.5cms) to dilute the previously mentioned problems. However, in between these rows there would be little or no crop residue (1.25 tons/ha), requiring far less tillage depth (1-1.25 cms). To ensure that the subsequent crop was unaffected the entire field would have to be cultivated to the greater depth (7.5cms). Had the crop residue been evenly spread, at say 3 tons/ha, the overall cultivation depth could be reduced to 3 cms saving time and cost.

For successful crop establishment the seed needs to have good seed to soil contact. This can be achieved in a number of ways:

"The greater the depth of cultivation the heavier the reconsolidation will need to be."

• In a clean till (Plough based) system the seed will be placed in soil with all the crop residues placed some 15 to 20 cms below the drilling depth.
• Where mulch-seeding is practiced, the seed will be sown into a mixture of soil and crop residue, but the residue will be diluted having been mixed with up to 15cms of surface soil.

Photo 7.10

• For scratch-till (Photo 7.10) and direct drilling to be successful the crop residue will remain on the soil surface or in the top 5cms and the seed will be sown into undisturbed soil beneath the residue.

With all cultivation systems timely re-consolidation of the soil is essential not only to reduce moisture loss, but to re establish capillary action in a dry season.

The greater the depth of cultivation the heavier the reconsolidation will need to be.

• A plough based system will generally require a double press or heavy packer on most soil types.

Photo 7.11 Plough tillage

• In a mulch-till system again a double press or heavy packer will be required if the working depth is more than 10 cms. For shallower working depths a heavy Cambridge roll may be sufficient.

Photo 7.12 Deeper disc tillage

• Where only shallow surface cultivations are to be practiced in particular on lighter soil types a Cambridge roll or the packer integrated into the cultivator will be sufficient, to reconsolidate the soil, to initiate crop residue decomposition.

Photo 7.13 Scratch-till

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Guidance on the best fit for different tillage systems in different rotations is given in the diagram below.

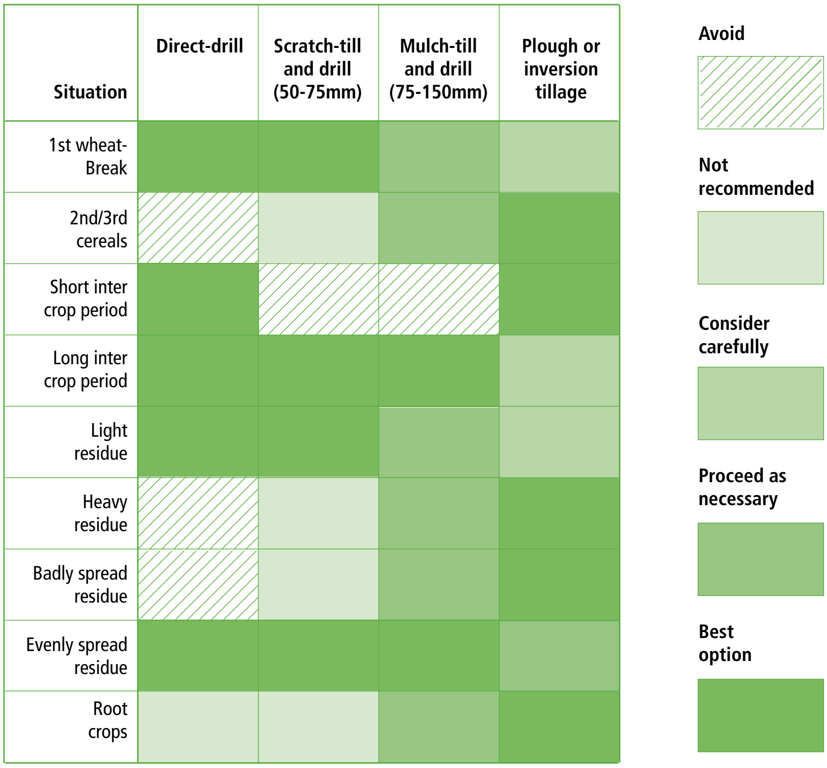



**Figure 7.2** Tillage decision chart

> "Any additional organic matter, whether it be animal manure, sewage sludge or industrial waste will improve soil organic matter and aid workability."

## FYM

Any additional organic matter, whether it be animal manures, sewage sludge or industrial waste, will improve soil organic matter and aid workability. But, as with any residue it must be applied evenly and the greater the amount applied the more cultivation depth required to dilute any toxic effects.

Any added organic material applied to arable land must only applied in accordance with the latest NVZ regulations.

Farm yard manures & slurries should be incorporated as soon as feasibly possible if the nutrient values of the products are to be fully utilised. It changes from being waste disposal operation into nutrient management, which not only benefits the following cash crop but reduces potential nuisance in the form of smell and runoff.

Photo 7.14

### Cover crops

One of the functions of growing a cover crop is to produce residue at a time when the land would otherwise be bare. In time the residue can be incorporated to improve soil organic levels. Most cover crops are chosen for their low C/N ratio (15 to 20) and fragile residue type which makes them easy to incorporate.

All cover crops should be destroyed before they set seed (flowering or very soon after) either chemically (glyphosate) or mechanically, and should then be incorporated so as not to interfere with the following cash crop. Discing is the most satisfactory mechanical method. Direct drilling into a chemically destroyed cover crop is a possibility but requires attention to detail and good slug control. (Photo 7.14)

"One of the functions of growing a cover crop is to produce residue at a time when the land would otherwise be bare."

| Action points on trash management | Learning/notes |
|---|---|
| • Consider how to incorporate crop residues and FYM to build soil organic matter.<br>• Use a balanced rotation with ideally alternating cereal and broad-leaf crops<br>• Equipment, cropping techniques available determines cultivation option<br>• Ensure you can chop and spread straw and chaff well<br>• Ensure good soil: seed contact<br>• Cover crops are also a good source of crop residue | |

**Target on trash management**

1) Maintain and build soil organic matter
2) Comply with the Stubble Burning in Agricultural Regulations– Crop Residues (burning) Regulations 1993

# 8 Cropping & agronomy

The change in agricultural land use from balanced rotational cropping within mixed farming systems, to large areas of continuous arable production, has been one of the main responses to meet past policy requirements for increased production. However, such systems have created problems such as pollution and reduced biodiversity requiring a re-appraisal of cropping systems. Whilst crop choice is much dependent upon location and soil type, optimum farm structure is also market-driven and conventional cropping patterns are usually determined by selection of the most profitable crops for the farm unit. Crop diversification on the other hand helps to spread workload since establishment and harvesting times vary according to crop type.

**Dr Vic Jordan**
Independant consultant
AAE bioservices

**Dr Alastair Leake**
Director of Allerton Research and Educational Trust

"Crop cover protects the soil from wind and rain, especially in erosion-prone areas ."

## Crop rotation

With current farming principles and practices, focus is directed to the entire farm as the basic unit with crop rotation a key factor. Crop selection in balanced cropping sequences offers the most effective indirect method of pest, disease and weed control whilst helping to maintain soil structure and fertility. Crop rotation should be diverse, where ideally no single crop species occupies more than 25% of the farmed area and no crop group (e.g. cereals) more than 50%. Further more, due consideration should be given to the different physical and chemical contributions of the crops grown (e.g. biomass potential, rooting characteristics/ root architecture, structure, rooting capacity, soil cover index, susceptibility to different pest, disease and weed groups as well as nutrient off take and transfer, and nitrogen need).


Photo 8.1

In designing appropriate crop rotations, different crops are characterised with regard to their potential role using a multifunctional set of demands. For a crops physical contribution, crop cover and rooting characteristics were seen as having a major effect on soil health and structure. Crop cover protects the soil from wind and rain, especially in erosion-prone areas thereby minimising adverse environmental impacts. Bare soil during the autumn-winter (the maximum leaching) period is undesirable, therefore it is best to establish crops and crop cover in early autumn for the protection of soil and water resources. Similarly, the rooting characteristics of crop groups can affect soil condition and workability. Crops with long tap roots (e.g. Oilseed rape) help to "naturally cultivate" soil and vining and combining crops are less damaging to soil than lifting root crops. Rotations also increase yields overall, build soil organic matter and improve soil fertility. The ideal crop rotation in a conservation tillage system involves alternating cereal crops with legume, pulse or oil seed crops. This type of rotation produces differing amounts and types of residue (fragile vs. non-fragile) and thus make crop residue and trash management easier.

Therefore, rotation is the key to success in reduced tillage systems. It determines how you manage crop residues and trash, how you manage weeds and volunteers and how cheaply and cost effective you can establish your crops. First wheat after break crops raise some fundamental issues and provide management solutions. First wheat after set-aside is likely to be the easiest and cheapest option; as after the crop has been destroyed it is possible to cultivate during summer and even apply a broad-spectrum herbicide just prior to drilling. First wheat after oilseed rape is often direct-drilled but this may raise potential trash and slug concerns. Chopping oil seed rape residues does not give an even spread of trash therefore a cultivation to incorporate in the soil surface may be required. Grass weeds are usually not of great concern as they have been well


Photo 8.2

controlled in the previous crop and slug damage is minimised by drilling at 4cm. This technique is helpful in reducing volunteers since rape seed shed during the harvesting operation germinates and can be sprayed off prior to drilling the subsequent crop.

Crops following beans also present few difficulties because beans are easy and cheap to grow, neither weed control nor trash management is a problem and establishment is easy, even with direct drilling. Winter beans are often broadcast on the soil surface and ploughed down and the weathered soil which results forms an ideal seedbed for establishing wheat using minimum tillage. First wheat after oats, on the other hand, is a more complex and challenging option. A good chop and spread of oat residues is absolutely essential. The field must be level and the crop harvested as low as possible. An alternative would be to cut high (to increase harvest throughput) then use a set- aside mower to chop and spread residues. If harvest is early enough, a single cultivation then drill may be sufficient, with an effective herbicide to deal with potential weed and volunteer problems. Wheat following potatoes is not difficult in dry years, with two cultivations, a roll and drill sufficient. Wet years present particular problems with root crops since deep ruts are created during the harvesting operation. Often the best option is to wait for soil conditions to improve and follow with a spring drilled crop. Bad compaction is best removed by sub soiling when conditions allow, less severe damage can be remediated by ploughing once field conditions have improved. Spring crops can also be highly beneficial to weed control since autumn germinating species such as black-grass

## Disease Management

Photo 8.3

Soil conservation, non-inversion and reduced tillage systems often leave much greater amounts of crop residues on or near the soil surface. Whilst this, in cereal monoculture and short rotations, may increase the potential for disease carry over from one crop to the next, these effects may be much reduced in both more balanced cropping sequences and rotations that include a more diverse range of crop species through differences in host specificity of pathogens.

Farmers that adopt reduced tillage systems minimise the risk from disease by more careful management of crop residues during the intercrop period, alternating cereals with broad leaved-crops together with other husbandry techniques such as more precise seed placement and delayed drilling.

## Pest & Diseases

During the past 5 years there has been a gradual move from complete soil inversion by the traditional plough towards soil conservation/non-inversion tillage systems that leave previous crop residues on or near the soil surface. Whilst these practices contribute greatly to and deliver many environmental benefits, they also save time and money in crop establishment costs. However, the presence of surface residues from previously infected crops may be expected to influ-

**"Rotation is the key to success in reduced tillage systems. The ideal crop rotation involves alternating cereal and broadleaf crops."**

ence pest and disease incidence and affect their control requirements, especially those that are soil-borne or trash-borne and splash dispersed.

Despite these apparent concerns, the effects of cultivation practices on arable crop diseases are variable, depending largely on the disease itself, how it behaves between and within crops and how it reaches, infects and spreads. The source and prevalence of infective inoculum, combined with host plant susceptibility and the weather conditions that may favour infection and epidemic development, determine the incidence and severity of disease from year to year.

"The diseases most influenced by different cultivation practices are those whose pathogens are either soil-borne, or those that survive on previously infected crop residues."

The diseases most influenced by different cultivation practices are those whose pathogens are either soil-borne, as fungal hyphae, or those that survive on previously infected crop residues that remain on or near the soil surface. These cover a range of diseases that infect roots, stems, leaves and ears of most arable crops.

In cereals, the stem based and soil borne diseases such as eyespot, sharp eyespot, take-all, wheat leaf stripe and Fusarium spp. are most likely to be influenced by cultivation methods together with the foliar diseases that originate from over wintering stubble (e.g. wheat Septoria, Barley leaf blotch and net blotch; Perenospora, Phoma and Sclerotinia on oilseed and some ear diseases of maize).

Photo 8.4

## Diseases of Wheat

**Eyespot *(Pseudocercosporella herpotrichoides/ Tapesia yallundae*)**

This pathogen survives saprophytically on previously infected culms that remain on, or in the soil surface from year to year. Primary infections arise from splash-dispersed spores produced on these infected culm bases. Complete inversion of culms by ploughing is effective in reducing infection potential, providing the culms decompose in soil. But ploughing up partially- or un- decomposed straw from the previous year will still present a threat as buried infected crop remains are still capable of producing viable spores. As a result, in wheat dominated systems, or where cereal crops are grown intensively, ploughing will not decrease eyespot inoculum as effectively as it will the inoculum of other trash-borne pathogens.

Photo 8.5

It is normally assumed that infection risk of a field is directly related to the amount of infected debris on or in the soil surface. However, a very small amount of infective debris is sufficient to initiate eyespot infection- as little as one infected culm/10 m2 can, under favourable weather conditions, initiate damaging levels of infection. Furthermore, as eyespot spores are produced, over a wide temperature range, from October through to the end of March in most years infection can occur on 83% of the days when rain falls during this period, eyespot epidemics are unlikely to be limited by amounts of surface inoculum/infected crop debris. It was originally considered that first cereals after a non-host break crop would not be at risk to eyespot, but re-inversion of non-decomposed residues by deep ploughing and the occurrence of the "perfect stage" of the pathogen led to revision of this hypothesis.

The "perfect" stage *(Tapesia yallundae)* has now been found with apothecia detected on leaf sheaths of culms in spring. These release wind-borne ascospores which have a greater dispersion capacity for more widespread and later infections.

Rapid decomposition of infected culms can be encouraged by shallow incorporation using soil conservation tillage practices. These encourage the activity of soil biota, especially those micro-organisms that enhance cellulytic breakdown and promote the decomposition process.

Different soil management and crop establishment methods within cropping sequences can also help reduce eyespot risk. Direct drilling a break crop such as oilseed rape after wheat should help exhaust the inoculum source by allowing eyespot spores to discharge onto this non-host crop. Many long-term, continuous cereals experiments have shown that more eyespot-infected culms remain on or near the soil surface following direct drilling or non-inversion, conservation tillage than after ploughing. However these different crop establishment practices have no significant effect on eyespot incidence in autumn nor in severity of infection later in the season to justify additional fungicide intervention.

**Wheat leaf blotch/glume blotch**
***(Septoria tritici/S. nodorum)***
The most potentially damaging trash-borne diseases of wheat crops in the UK, and indeed across Europe are usually the foliar diseases caused by Septoria spp. Whilst glume blotch is known to be seed-borne, first infections by both wheat leaf and glume blotch originate from air-borne ascospores released either from leaf and straw debris or standing stubble from previously infected crops and are wind spread over great distances. Usually, infection is greater and frequently more severe in crops during the autumn where chopped straw and stubble is incorporated by tine cultivation rather than a plough-based system.


Photo 8.6

Although surface crop debris is an effective source of disease inoculum, sufficient remains in well-ploughed fields to initiate autumn infection. Although there may be cultivation method and crop establishment differences in incidence and severity of autumn disease, these responses are usually short-lived such that by spring there are no consistent effects of straw incorporation method on these diseases.

**Wheat leaf stripe**
***(Cephalosporium graminearum)***
An important and locally destructive disease of successive winter wheats, especially in the wetter regions of Northern Europe.

**"Direct drilling a break crop such as oilseed rape after wheat should help exhaust the inoculum source by allowing eyespot spores to discharge onto this non-host crop."**

"Most winter cereals and several grasses are susceptible but symptoms are less distinct and may well pass undiagnosed."

The fungal pathogen that causes wheat leaf stripe multiplies rapidly and sporulates profusely on straw residues on or in the soil surface under warm, damp conditions. It is also soil-borne, surviving on most dead and decaying plant material in soil. This pathogen infects through the roots, more so where root systems have been damaged either naturally or by soil fauna, and fungal threads penetrate the vascular system causing a blockage in the water and nutrient conducting tissues. The fungus also produces a toxin; this apparently prevents chlorophyll formation in leaves and, thus, induces yellowing thereby creating the typical leaf stripe symptoms. First symptoms are usually seen from mid-May as yellow interveinal stripes, bordered by brown necrotic stripes on all leaves of mature plants. Severely infected shoots die prematurely, usually after heading but before grain filling. The appearance of the resulting "whiteheads" may well be confused with take-all symptoms. Most winter cereals and several grasses are susceptible but symptoms are less distinct and may well pass undiagnosed.

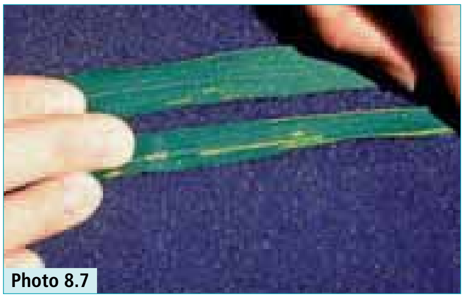


Photo 8.7

As the fungus is present and persists in diseased straw, straw chopping prior to incorporation may increase disease spread within fields thereby increasing risk. Although wheat leaf stripe is a disease of minor importance in the UK, damaging levels of disease have occasionally occurred in fields where straw had been incorporated by ploughing to varying depths for at least four years, or where crops have been direct-drilled into standing stubble or into chopped surface straw residues. Thus, the incorporation of diseased straw by various cultivation practices may, over time, increase the importance of this disease.

Wheat leaf stripe control strategies should consider ways to reduce the soil-borne disease risk either by alternating spring and winter-sown crops, maintaining a grass-weed free soil and/or using a more balanced and less cereal-dominated crop rotation. However, as the pathogen is more prevalent on crop debris that remains on or near the soil surface, deep ploughing of infected residues is considered the most effective control strategy although this conflicts with soil conservation practices for environmental protection.

**Wheat Tan Spot**
***(Pyrenophora tritici-repentis)***
This disease also survives between crops as a saprophyte in the previous years infected straw. During the post harvest period and in autumn, fruiting bodies (perithecia) are initiated on straw that remains on the soil surface and reach maturity in spring when ascospores are released to infect leaves. If diseased straw is incorporated or buried by deep ploughing, the development of these fruiting bodies is much reduced or even prevented due to the antagonis-


Photo 8.8

tic activity of micro-organisms in the soil microflora. Conversely, infection opportunities and disease potential are greater where much infected straw remains on the surface from year to year. Wheat tan spot is still considered a disease of minor significance in major wheat growing areas of the world but a move to reduced tillage (accompanied by a ban on straw burning as in some EU Member States) may create severe epidemic risk.

## Foliar pathogens of Barley

Although powdery mildew and the rusts are commonly found on winter barley crops in the UK, cultivation practices may indirectly affect the incidence of these diseases because the main infection source is air-borne conidia released and spread from barley volunteers - "the green-bridge" effect. Therefore, any cultivation/ crop establishment system that encourages the presence of barley volunteers will increase risk.

Photo 8.9

Greater numbers of powdery mildew conidia have been measured above ploughed areas one month after sowing than above those established with non-inversion tillage or direct drilling methods. Research has shown powdery mildew to be most severe in autumn in ploughed fields, less in those established with non-inversion tillage and least in direct-drilled plots. This response was explained, in part, by differences in plant habit. Leaves of plants established in plough-based systems were more erect in autumn compared to the more prostrate habit of those in non-inversion tilled systems, thereby acting as more efficient receptors of air-borne spores. However, by early spring, there was no difference in disease incidence and severity irrespective of the cultivation and crop establishment method, or whether straw was chopped, incorporated or burnt.

**Barley leaf blotch and net blotch *(Rhynchosporium secalis; Pyrenophora teres)***

The most severe and yield-limiting trash-borne diseases affecting leaves of winter barley crops are leaf blotch and net blotch. Whilst both diseases may also be seed-borne, autumn infection originates mainly from splash-borne spores released from leaf and straw debris from previously infected crops.

In successive winter barley crops, however, studies on the effect of ploughing or direct drilling with three methods of straw disposal (burn, baled and removed or chopped in situ) on infection frequency and severity of net blotch revealed that prior to cultivation, only straw burning significantly reduced the number of spores produced and released from crop remains. Thereafter, where ploughing had effectively buried surface residues, irrespective of the method of

Photo 8.10

**"Research has shown powdery mildew to be most severe in ploughed fields."**

straw disposal, no spores were caught for at least three weeks. Subsequently, there were substantially fewer spores than in direct drilled crops. All direct-drilled barley plants were infected within 27 days of sowing, whereas 42 days had elapsed before all plants sown in ploughed areas were diseased.

In summary therefore, no consistent effects, outbreaks, unforeseen disease problems, or increases in any foliar disease of winter barley could be directly attributed to the different cultivation /straw disposal practices adopted in these studies.

"Take-all severity was significantly more severe where wheat was established using complete soil inversion."

## Soil-borne Pathogens

In addition to diseases that survive in crop residues on or in the soil surface, soil-borne root-infecting pathogens are also influenced by different soil cultivation and crop establishment methods as they survive either saprophytically in the soil or as long-lived resting spores.

**Wheat Take -All**
***(Gaumannomyces graminis)***
This pathogen survives as mycelium mostly in root or stem residues of cereal/ grass hosts from where it grows and makes contact with seedling roots. The fungal threads that grow through the soil enter roots directly causing the initial infection. First symptoms usually appear as small black lesions (spots) that may then extend along the whole root length resulting in root rot. If infection is severe, the whole plant may eventually die. Take-all symptoms on mature plants ("whiteheads") in one years' crop do not indicate the risk of severe disease in the following wheat crop. This is because the amount of soil-borne inoculum and the prevailing weather (warm autumn temperatures) are the main determinants of risk to the following crop. The pathogen is a poor saprophyte and survives in root residues that largely decompose. The time taken for root residues to decompose before a new crop is sown has a marked influence on future infection potential; this is the main reason why delayed sowing (late October) may decrease risk.


Photo 8.11

Most take-all inoculum from previously infected crops is present near the soil surface. Therefore, complete soil inversion by ploughing is likely not only to delay contact with young wheat roots but also enhance microbial degradation of straw residues that may limit pathogen survival. Soil conservation tillage (non-inversion) and no-tillage (direct drilling) techniques might be expected to differentially affect the incidence of take-all by altering the distribution of diseased residues in the soil profile. Non-degraded infected crop residues that remain on or near the soil surface where the seed is sown, or in the rooting zone just below the soil surface may enhance the likelihood of root infection. Theoretically, therefore, take-all might be expected to be more severe after minimum/ non-inversion cultivation techniques. However, HGCA-funded research that measured take-all incidence and severity ratings in continuous winter wheat on three contrasting soil types at Andover, Biggleswade and Cirencester which compared ploughing, non-inversion tillage and direct-drill systems showed somewhat conflicting results. Whilst initially take-all incidence was greatest in direct-drilled plots and least in ploughed plots one month after sowing, by early spring these differences were less evident. Furthermore, measurements in spring also showed that infectivity of crop debris in the top 10-cm soil had declined more rapidly in non-ploughed soil than in ploughed soil, presumably reflecting the greater activity of antagonistic microflora. Overall, and at all sites, take-all severity (% "whiteheads") at harvest was significantly more severe where wheat was established using the plough than where crops were established using non-inversion tillage or direct drilled.

**Sharp Eyespot**
***(Rhizoctonia cerealis)***

Although sharp eyespot is a common disease of winter cereals in the UK, se

Photo 8.12

verely infected crops are rare and economically damaging levels occur sporadically, when the disease directly weakens the stem. Whilst plants may be attacked at any growth stage, early infections can result in pre- and post emergence plant death in seedlings or stunting and reduced tillering resulting in crop thinning. Later infections appear to have a limited effect on yield providing the crop does not lodge.

The sharp eyespot fungus is a typical soil-borne pathogen whose persistence is aided by its wide host range. Young seedlings are infected by direct penetration of leaf sheaths from fungal threads that grow through the soil. Depending upon the extent of successive leaf sheath penetration, infection will be carried up the plant as the stem extends. Dry autumns and light soils allow more extensive fungal growth in soil thereby increasing infection opportunities. Wet autumns and waterlogged soils, on the other hand, induce lyses of the fungal threads thereby reducing soil colonisation and infection. This could, in part, explain the greater incidence of sharp eyespot in ploughed soil than in minimum tillage and less disturbed soil. Following ploughing, upper soil layers have a lower soil moisture content and better initial aeration, more favourable for fungal growth.

**Foot rot/Ear blight**
***(Fusarium spp.)***

At least four Fusarium species commonly attack winter wheat by invading roots, stem bases and ears where they may cause substantial losses in yield and grain quality in some years. All species can be both seed- and soil-borne and can survive in straw, soil organic matter and plant debris. Infection can either occur directly from the seed or from soil borne hyphae, or from spores released from diseased tissue and spread to upper plant parts by wind or rain splash. Nevertheless, there is limited evidence to demonstrate the contribution of these various inoculum sources to disease out-

Photo 8.13

"All Fusarium species can be both seed- and soil-borne and can survive in straw, soil organic matter and plant debris."

breaks, making it difficult, to attribute effects and responses directly to differences cultivation systems or to other agronomic practices.

**Barley Yellow Dwarf Virus**

BYDV is, arguably, the most important virus disease of cereals in the UK, and is most damaging at early stages of crop growth. Transmission is by autumn migration of winged aphids bringing the virus from grasses and other cereals into crops. In most years infectious aphids are present before the end of September, thereby placing early sown autumn crops at greatest risk from BYDV and most likely to need an insecticide spray. The numbers of infective winged aphids flying into crops usually slows during mid-late October; therefore crops that emerge after this time are at less risk.

"There is limited evidence to demonstrate the contribution of these various inoculum sources to disease outbreaks."


Photo 8.14

Research into the interactions between straw disposal, cultivation methods, sowing date and pesticide need suggested ways of improving control of BYDV whilst reducing costs and protecting wildlife. As an example, in a year with particularly high risk of BYDV infection in south-west England, winter barley established either by direct-drilling or by non-inversion tillage showed substantially lower levels of BYDV infection than winter barley sown after ploughing. Two mechanisms are thought to be involved; firstly, fewer winged aphids settle on non-ploughed crops because the presence of surface crop residues reduces the contrast between young seedlings and the soil background which is important for aphid recognition of host plants; secondly, larger numbers of predators (Carabid and Staphylinid beetles and Linyphiids - "money spiders") are present in non-ploughed fields in autumn reducing aphid survival and the secondary spread of the virus at the critical early phase of crop establishment.

## Diseases of Oilseed Rape

**Downy Mildew**
***(Peronospora parasitica)***

In many European member states, downy mildew is an important disease of oilseed rape. Severe attacks can occur, especially in autumn and, when cool and moist weather prevails, infection may continue until early flowering. Symptoms of downy mildew appear as ill-defined, irregular areas on leaves, with lower leaf surfaces covered by white or grey mycelium. Infected pods may show light brown spotting or may be covered with sparse grey/white fungal threads. Severe foliar attacks can cause premature leaf death and cause premature ripening.


Photo 8.15

The disease can survive as oospores in decaying previously infected debris and on the lower surfaces of oilseed rape volunteers. Although non-inversion tillage or direct drilling is often used to establish oilseed rape there have been few

SMI

reports to show that these practices influence infection or spread.

**Stem Canker**
***(Phoma lingam/Leptosphaeria maculans)***
This disease is more commonly known as 'blackleg'. Symptoms usually appear as light brown spots with yellow margins on leaves in autumn and pycnidia are often seen in the centre of these spots. Severe autumn infections often lead to premature leaf death and infection on stem bases may enlarge in spring and completely girdle the stem. Infections on upper stem parts may be light brown spots with dark brown margins. Similar symptoms may occur on pods. Autumn infection occurs from either ascospores or from pycnospores released from infected plant debris during warm, moist weather. Where non-inversion tillage is


Photo 8.16

used for crop establishment, infection arises mainly from ascospores whereas pycnospore infection is likely to be the main infection source where early and deep ploughing is used. It is considered that although different establishment methods leave varying amounts of infective surface crop debris they are unlikely to impact greatly on initial infection.

**Stem Rot**
***(Sclerotinia sclerotiorum)***
Sclerotinia is common wherever oilseed rape is grown and can cause substantial yield losses. The pathogen has a wide host range; many common arable weeds (e.g.mayweed, cleavers and deadnettle) are susceptible. Symptoms are usually found after flowering as white-grey spots on main stems and branches. Infected plants ripen prematurely or die giving patches of "white heads" in oilseed rape


Photo 8.17

fields. Infected stems contain irregular shaped black sclerotia that either fall on the soil during harvest or stay within stem cavities as surface trash after harvest. These sclerotia, whether within plant tissue or not, can stay viable for seven to ten years. Sclerotia germination is more frequent and synchronous in the top-most soil layers from which small light brown apothecia are produced and emerge above soil level. Spores are released from these and are wind dispersed to leaves, stems and flowers of oilseed rape. Warm temperatures, adequate soil moisture and high humidity in spring favour infection. Research has shown that more apothecia emerged from soil in non-inversion tilled fields following oilseed rape in spring than in adjacent fields that were traditionally ploughed. Nevertheless, as these spores are dispersed vast distances, sufficient were released from both cultivation methods to infect rape crops within a 10km radius.

**Dark Leaf Spot**
***(Alternaria brassicae)***
Alternaria is regarded as one of the major diseases of this crop and affects both leaves and pods. However, incidence and severity of attack is very much dependent on prevailing warm humid weather. If

**"Severe autumn infections of Stem Canker often lead to premature leaf death and infection on stem bases."**

fection is severe, substantial yield losses can occur and seed is likely to be infected.


Photo 8.18

Initial autumn symptoms are usually small brown-black circular spots with yellow margins on leaves that later enlarge producing light and dark brown concentric zones. Older leaves have larger lesions with alternating dark and light brown areas. Main stems may show light grey flecks and pods may be covered with small black circular areas. Whilst the pathogen may be seed-borne, it also survives on infected plant debris lying on or within the soil surface layers. First infection usually occurs from spores produced on crop debris and stubble. Infection of leaves, stems and pods can occur throughout autumn, spring and summer. There is little scientific evidence to show that cultivation practices are likely to contribute to greater risk of this disease.

"Both slugs and their main natural enemies are soil dwelling and as a consequence cultivations can markedly affect their numbers and behaviour."

**Light Leaf Spot**
***(Cylindrosporium concentricum/ Pyrenopeziza brassicae)***
This disease is considered a major yield-limiting disease, especially in UK, France and northern Europe. Symptoms are usually seen from late autumn onwards as small white spots/patches leaf surfaces. During early spring, spots coalesce and become light brown with a white sporing fringe. If severe, leaf distortion occurs but not premature leaf fall. Infection of pods can also occur which results in stunted, distorted and malformed pods, premature ripening and pod shatter.

The pathogen survives on crop debris where conidia are produced and dispersed by wind and rain during autumn to infect young plants and leaves. Although apothecia may be found on crop debris from late spring until early autumn, this infection source is considered of minor importance in the life cycle of the disease. Although different cultivation practices distribute and leave various amounts of crop debris in or on the soil from one year to the next, there is no evidence to show they are likely to influence the level of infection.

## Pest control aspects

Pest management is important in reduced tillage systems because increased levels of surface crop residues harbour harmful pests. Surface residues, however, also provide an ideal habitat for beneficial insects, especially predators of key pests, thus providing a balance in the predator-prey relationship that prevents pest levels worsening.

**Slugs**
Slugs can thrive in a wide range of soil types and have become worldwide pests on many arable field crops. Both slugs and their main natural enemies are soil dwelling and, as a consequence cultivations can markedly affect their numbers and behaviour.

Slugs, particularly *Deroceras reticulatum* and *Arion spp.* are important pests of cereals in Western Europe. Not only do they graze and defoliate seedlings but, more importantly, they kill seeds by eat ing out the young embryo. Slugs live both on the soil surface and in the soil at considerable depths but are most commonly found in the top 10 cms of soil under mild and moist conditions.


Photo 8.19

Slugs are often thought to be a problem in crops where cultivation systems other than traditional ploughing takes place. A study done in Germany comparing the abundance and activity of slugs in trial plots of winter oilseed rape that had been established by non-inversion tillage, direct drilling or after ploughing showed increased abundance and activity of four species of slug in the reduced tillage plots, and especially those direct drilled. Similar studies in UK also showed a greater tendency for slug damage (plants killed) in minimum tillage systems than in ploughed systems. However, where seed is planted deeper (4cm) and the soil consolidated after drilling, there were no significant differences in damage to crop seeds and seedlings between ploughed and minimally tilled fields. With slugs, a pronounced decline in slug populations is usually associated with ploughing and subsequent cultivations. Slug damage to cereals can also be considerably reduced by cultural measures designed to prevent slugs from reaching seeds (e.g. fine, well consolidated seed-beds and deeper seed placement) or, on heavy land, by drilling cereals at 4 cms into coarse cloddy seedbeds

Slug populations, on the other hand, usually increase in the presence of straw residues, especially in the absence of ploughing, although heavy soils ploughed in dry conditions can exacerbate slug problems. However, with the implementation of selective cultural measures (rolling after the first post harvest cultivation) and encouragement of polyphagous predators, it is possible to counteract the risk of slug damage on crops grown in rotation. A wide range of natural enemies including birds, mammals and spiders attack slugs and predation by Carabid beetles has been recognised as very important in arable fields.

Therefore, cultivation systems determine the slug control strategy. Slug risk, in general, is highest with direct-drilled systems where, particularly in dry conditions or situations where slot closure is incomplete, it is best to drill slug pellets with the seed. Although this increased risk to slugs occurs, adopting the appropriate pest management strategy (seed placement and drilling depth) allows reductions to be made in molluscicide inputs.


Photo 8.20

Depth of drilling, where seed placement can be precise, reduces predation by slugs in two ways; firstly the seed is less accessible at this depth and secondly, moisture is greater and usually more even than in plough based systems. This ensures faster germination, although not necessarily crop emergence, thereby reducing the vulnerability of the endosperm, the constituent part favoured by slugs.

**"Where seed is planted at 4cm and soil consolidated after drilling there were no significant differences in damage to crop seeds and seedlings between ploughed and minimum tilled fields."**

Certain seed dressings are also repellent to slugs. Where a wheat crop is sown early, before mid-September, and stale seedbed herbicides have worked well, insecticide seed dressings deter slugs as well as eliminating the need for the application of autumn insecticide against BYDV.


Photo 8.21

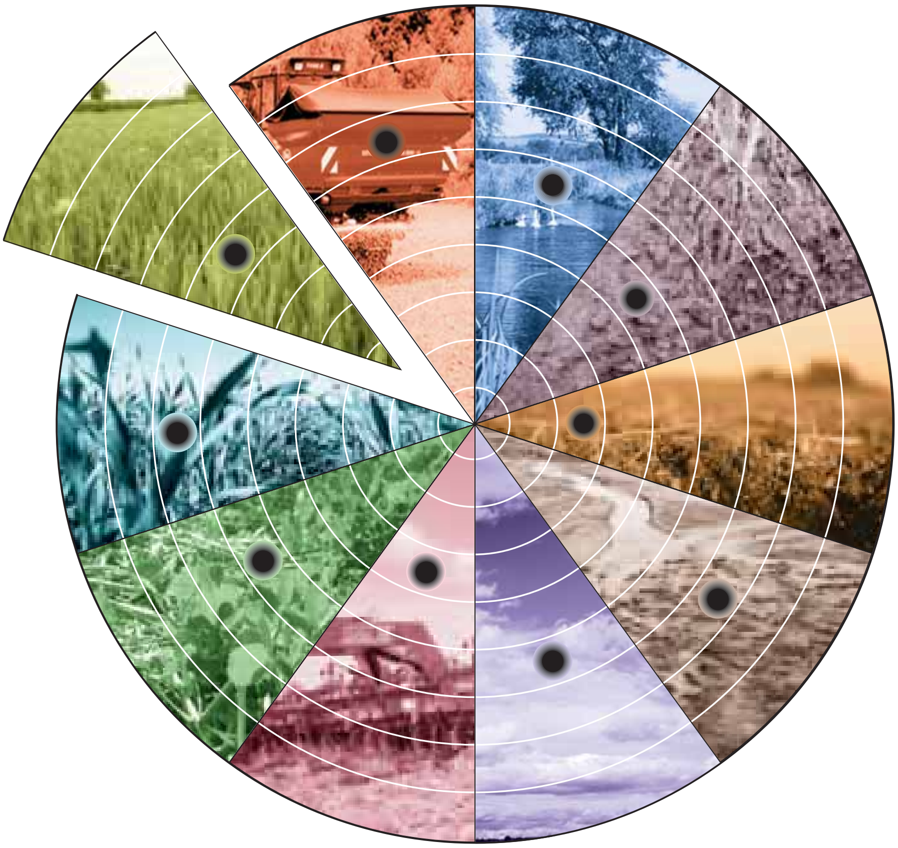
The use of Cambridge or flat rolls (after direct drilling) is imperative under all cultivation systems where slug populations are high, and in situations of high slug pressure. They represent a cost effective operation at ca £7.00/ha per pass, two passes being more effective. Where wheat follows crops that are known to give rise to increased numbers of slugs (e.g. oilseed rape or grass leys), and where the season has also been favourable for slugs, varietal resistance should also be considered.

"The use of Cambridge or flat rolls (after direct drilling) is imperative under all cultivation systems where slug populations are high ."

| **Action points on cropping & agronomy** | **Learning/notes** |
| --- | --- |
| • Check current rotations are sufficiently diverse to facilitate balanced agronomy; pest, disease and weed management; build soil organic matter, fertility and structure<br>• Use cover crops to protect soil in winter from damage/ erosion by wind or water, but also to improve soil structure in and after set-aside or early harvested crops where necessary<br>• Conservation tillage systems necessitate higher levels of management, timeliness and attention to detail<br>• Judicious ploughing can reduce certain soil/ trash borne diseases<br>• Where take-all, true or sharp eyespot are common, utilising conservation tillage techniques is useful<br>• Where slugs are a risk, seedbed consolidation after cultivation and drilling, combined with accurate drilling at 3-4cm into a good seedbed, are very useful in reducing damage. | |

**Target on cropping & agronomy**

1) Use balanced rotations and appropriate choice of crop to build soil organic matter and improve soil structure across seasons
2) After combinable crops fields must have crop or green cover, be left in stubbles or be rough cultivated over winter



# 9 Weed Management

Weed management is a vital part of crop protection. Get it right and you have flexibility to farm the way you want. However, if you get it wrong you could be forced to change perhaps in ways you don't want back to plough, or into spring crops, or spend a fortune on herbicides to try to clear up out of control grass weeds. The best way of being in control is to base your weed management on thorough planning and good decision making

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VÄDERSTAD

# 9 Weed management

Planning and decision making should be based on a thorough knowledge of weed type and species, weed biology, situation (cropping, weed problems, resistance) and available control measures to develop best practice for your situation working with your agronomist. The most important weeds to consider are the annual grasses, but first let's dispense with the sometimes troublesome perennial grasses.

## Perennial grass weeds - biology and control

Whilst control can be easy, poor results are obtained when species are confused or the herbicide is applied at a bad timing.

"Avoid crop rotation of wheat-potatoes-sugar beet-wheat as this makes it hard to control perennial grasses,"

| Weed | Positive influences | Negative influences |
|---|---|---|
| Common couch | Very susceptible to glyphosate in particular in set-aside and pre-harvest, but even October stubble | Often confused with other more difficult to control perennial grasses |
| Onion couch | Susceptible to glyphosate in June/July and October | Early maturing.<br>Multiplication from seed/bulbils. |
| Creeping soft grass | Susceptible to glyphosate | Early maturing |
| Yorkshire Fog | Susceptible to glyphosate | Hairy leaves reduce uptake |
| Creeping Bent | Susceptible to glyphosate | Early maturing |
| Black Bent | Susceptible to glyphosate | Earlier maturing than Couch |
| All Perennial grasses - glyphosate | Very susceptible in period June to November when green and actively growing and not stressed | Tolerant in period January to May - due to spring growth only suppression is normally seen |


**Photo 9.1** Onion couch

Control perennial grasses pre-harvest in set-aside where minimum tillage is planned to avoid delaying autumn cultivations. But, beware early maturing grasses like Onion couch, bents and creeping soft grass that will die-back quickly particularly on lighter land.

Avoid crop rotation of wheat-potatoes-sugar beet-wheat as this makes it hard to control perennial grasses, instead use wheat-potatoes-wheat-sugar beet.

## Annual grass weeds - biology and control

| Weed | Positive influences | Negative influences |
|---|---|---|
| Annual grasses | Germinate readily in soil surface so facilitates control with stale seedbed | Germinate readily in soil surface, but if missed prior to drilling will rapidly infest crops established with reduced tillage and earlier drilling dates |
| | Early synchronous germination means easier control from stale seedbeds and early post-emergence treatment timings | Autumn winter germination means early drilled crops at most risk, need programmed approach |
| | Dry hot spring/ summers ensure grass seeds ripen and are not dormant so will readily germinate in moist seedbeds | Moist/ cool spring summers mean grass seeds are un ripe and often dormant so will not germinate in autumn stale seedbeds |
| | If big new ripe seed burden - then good plough inversion to 6" brings a clean crop and reduces the future burden by 60+% | Largely winter germinating, coinciding with predominate winter cropping |
| Barren brome and Great brome | Germinate readily in stale seedbeds all year | Selective herbicides not that effective in cereals |
| | Seeds last only 1-2 years in soil | Light enforced dormancy after several months |
| | Does not emerge from below 6" inversion | Wide ploughs do not fully invert soil and trash boards scatter seed across surface so control can be poor |
| Rye/Soft/Meadow brome | Germinate in winter stale seedbeds, but rarely in August/ September | Dormant/ unripe after harvest and needs 1 month on surface to ripen before cultivation |
| | Does not emerge from below 6" inversion | Plough enforced dormancy of unripe seeds |
| | Ripe seed lasts only 1 year in soil | Unripe seed lasts 7-10 years |
| | Easily controlled by sulfosulfuron or propoxy carbazone-sodium in wheat | Poor selective control in barley/ oats, difficult in break crops |
| Black-grass | Germinates August to May so opportunity in rotation for control | Main peak germination in November after cereal drilling puts pressure on selective herbicides, significant peak in March to complete the challenge in spring crops. |
| | Many control options, but beware FOP/ DIM/ ALS resistance in particular target site resistance | Resistance in many populations forces a broad control programme |
| | Plough is a useful tool to bury a new surface seed burden - aids control | Annual ploughing brings up 30-40% of last years seed |
| | Disfavoured by good drainage and good soil health | Favoured by poor soils, poor nutrient status, and compaction/ flooding. |
| Wild-oats | Many herbicide options available | Resistance increasingly forcing a broader control programme |
| | More herbicide options available than ever before | Seed can emerge from >6" so ploughing not a defence |
| Italian Rye-grass | Germinates easily so susceptible to stale seedbeds | Resistance in many populations forces a broad control programme<br>Germinates all year challenging the selective programme |

"To facilitate control you need to identify your specific situation to tune details and define the right control strategies."

**Photo 9.2** Barren Brome

To use the knowledge above of the grasses to facilitate control you need to identify your specific situation to tune details and define the right control strategies. In particular, if you wish to use reduced/ minimal tillage long-term then your weed control programme must be A1 to reduce the risk of weed build up and allow you to enjoy all the benefits without restriction.

## Control strategies and their fit by weed

**Drainage/ compaction problems**
Should be solved. Aim for good soil structure as this will ensure the establishment of a good competitive crop, and disfavour weeds like Black-grass that thrive in poor wet soil.


Photo 9.3 Black-grass

"Aim for good soil structure as this well ensure the establishment of a good competitive crop."

**Good plough inversion (to 6")**
Can be an effective way to remove a new surface seed population, however, it is both difficult to achieve and also important to bare in mind the dormancy status of weeds prior to ploughing so the right timing can be adopted. Plough inversion is useful for Black-grass and Ryegrass and Barren and Great Brome; however, it is no use with Wild-oats, and needs careful timing with Rye, Soft and Meadow Brome and also Volunteer Oilseed rape.

**Control outside the crop**
Regardless of tillage system practiced, a non selective herbicide like glyphosate provides the most cost effective means of control with no resistance restrictions. Use;

- Set-aside
- Pre-plant stubble
- Stale seedbed on plough or with reduced tillage as long as consolidated. Check for majority germination prior to spraying by scratching in the seedbed.

**Crop rotation**
This provides both time for stale seedbeds, but also the opportunity to use different herbicide chemistry. By spending more in break crops weed control is easier in cereals, but remember small black-grass is easier to kill. Spring crops allow more time for stale seedbeds, important for later germinating species or where seed is very dormant. Spring crops can disfavour autumn germinating grass weeds. Spring crops are possible even on heavy land as long as primary cultivations are carried out in autumn on dry soils, with light cultivation and drilling in spring after spraying out weeds. Otherwise use rotational set-aside as a strategic cleaning tool.

**Drilling date**
Should be tailored to weed pressure. Earlier drilling is fine for clean ground or after a good break or set-aside. Later drilling is advisable with second cereals and after bad weed seeding to allow time for stale seedbeds. Ideally, go after peak germination in autumn. However, before taking the final decision, weigh up the risks of your options; as on heavy ground later drilling may be impractical on wet soils, but with out of control grasses delayed autumn or even spring drilling may be the only option.


Photo 9.4 Wild-oats

### Crop competition

This is an underrated mechanism of weed control that actually exerts a major influence on the success of control strategies. Reduced seed rates have become more common, particularly for early drilling. However, to ensure a competitive crop then establishment must not be hindered by compaction, dry knobbly seedbed, excessive trash, wet anaerobic conditions or use of the wrong drill and insufficient seed. Choice of a fast developing, vigorous tillering prostrate variety that provides autumn ground cover will also help.

**Photo 9.5** Good weed management for a clean crop

"Plan best weed management practice for the situation you face."

### Selective herbicides

**Timing**

Pre/ early or spring post-emergence appropriate to weed and product

**Timely application**

Pre-emergence on a good firm moist seedbed, early post-emergence = 1-2 leaf of black-grass for most products

**Application**

High enough rate to cope with spectrum using the right nozzles

**Adjuvants**

When advised to maximise performance

**Rotation of active ingredient**

To minimise resistance

**Mixtures/ sequences/ programmes**

Vital to manage prolonged weed germination, tough mixtures of species and resistance

**Prioritisation**

To cope with tough weed mixtures and allow control later if needed as with spring brome ALS herbicides

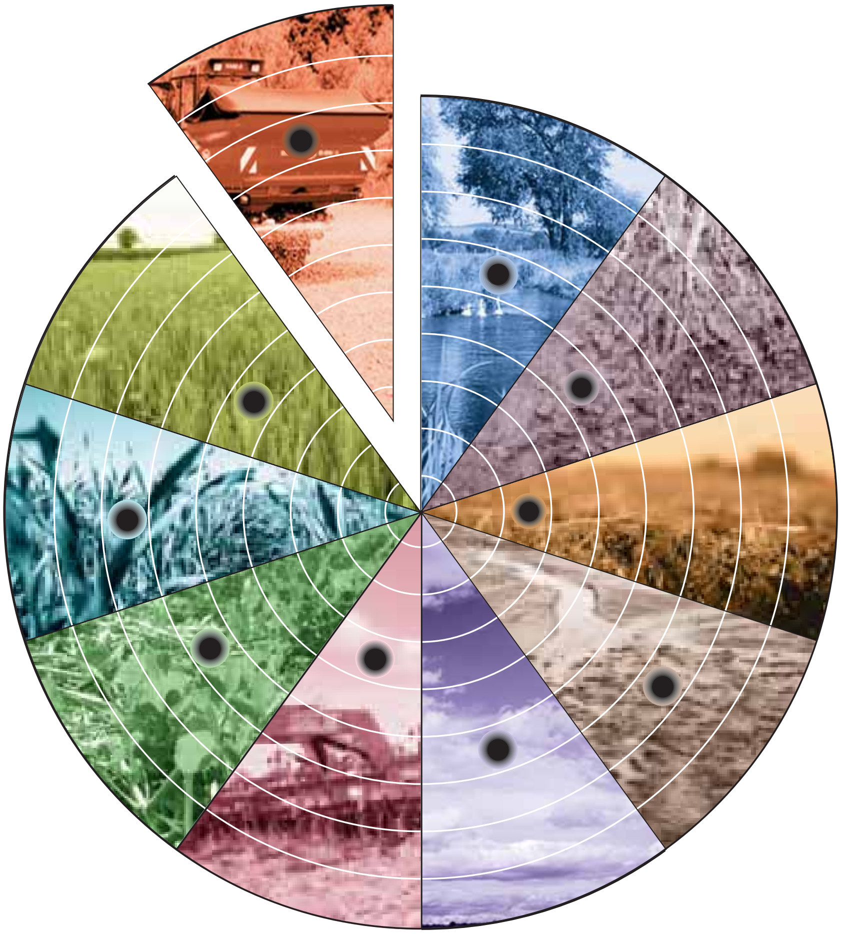
Speak with your agronomist to get detailed advice appropriate to your situation.

| **Action points on weed management** | **Learning/notes** |
|---|---|
| Identify your situation:<br>• Weed species and mixtures<br>• Map, plan for most difficult and allow for others<br>• Resistance status<br>• Dormancy status<br>• Production: tillage x depth/trash/cropping/drilling date<br>• Priorities<br>Plan best weed management strategy:<br>• Cultural controols<br>- stale seedbed<br>- rotational plough<br>- crop rotation<br>- competitive crop<br>- later drilling where appropriate<br>• Maximise control outside crop<br>• Selective herbicide programmes/mixtures | |

**Target on weed management**

Establish a 2 m buffer strip against hedges and water courses to:

1) Protect water courses/ ground water against polution by hebicides
2) Protect hedges against damage from herbicides
3) Conserve natural habitats and wild flora and fauna



# 10 Fertility

Soil fertility is important to crop establishment, not just later growth. This is particularly true when starting conservation tillage. It is vital to get the crop off to a good start- but rooting and early plant development are impeded by nutrient deficiency or reduced availability. Lower pH and poor drainage can impede nutrient uptake and need correction. Management should be based on thorough soil sampling together with knowledge of soil type, cultivation practice and cropping requirements. The most important nutrients for establishment are phosphate, potash, lime and magnesium.

**Paddy Johnson**
Independant Soil Scientist
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## Nirogen use

During the establishment phase sufficient nitrogen is normally supplied to the crop by mineralisation of nitrogen from soil organic matter and residues from previous crops. Nitrogen applied in autumn is rarely used as efficiently as that applied in spring for autumn sown crops as the crop cannot take up all the nitrogen and it is lost by leaching or denitrification. Transient nitrogen deficiency symptoms often occur where straw has been incorporated but applications of nitrogen fertiliser rarely give any economic returns. Two exceptions to this are for autumn cereals sown by direct drilling and winter oil seed rape grown where the previous cereal crop was malting barley for example.

"Ascertaining the correct amount of nitrogen to apply is important to optimise yield."


Photo 10.1

As most arable farms are within NVZ's then if you feel your crop could need autumn nitrogen you will have to justify use based on measurement of soil mineral nitrogen levels in summer. In spring, except for very early sown cereals where nitrogen applied at sowing can often be completely lost by leaching on sandy soils, nitrogen can be applied so long as the amount does not increase the osmotic potential of the soil solution to the point where germination is inhibited. Small seeded crops such as sugar beet and onions are very susceptible to this.

The greatest yield responses to fertiliser application are achieved by the accurate and appropriate use of nitrogen fertilizer. Ascertaining the correct amount of nitrogen to apply is important to optimise yield while avoiding the environmental impacts which can result from over application, or economic loss from under or over application.


Photo 10.2

It is important that nitrogen rates are assessed as accurately as possible so that excesses are not applied for two main reasons. Where nitrogen is available in excess of crop demand excessive vegetative growth can occur, disease incidence increases and the likelihood of lodging of cereals and oilseed rape becomes greater. With sugar beet excess, nitrogen increases the levels of impurities and with potatoes maturity and skin set can be delayed. The optimum quantity is best ascertained by taking into account all the factors which affect nitrogen availability. These include soil mineral nitrogen reserves, previous cropping, organic manure applications, soil type, excess winter rainfall and economic factors such as the cost of fertilizer and the value of the crop. This can be done using paper based recommendation systems, but computer based systems will help. Using such systems enables tailor-made recommendations for individual crops. New developments in remote sensing may enable nitrogen to be spread according to crop need based on green colour, but may require a reference area supplied with supra optimal nitrogen rate.

## Soil analysis

The basis for effective use of lime, phosphate, potash and magnesium during the establishment of a crop is the analysis of representative samples of soil. This means that sampling must be done carefully. Unless there is previous evidence to show a lack of variability in soil analysis in a field the area used for an individual sample should be no more than 10 hectares. When planning your soil sampling strategy look at old field maps. Where fields have been amalgamated there are possible changes in soil type and cropping history which can influence residual available nutrients. If there used to be a cattle yard in one of the old fields then almost certainly phosphate levels will be higher there and even one soil core from this area could have a large influence on the overall result of the analysis. When taking soil samples it is also wise to avoid old bonfire sites, filled in ditches, headlands (particularly where ditch spoil has been spread), sites of old muck heaps and lime dumps as these can result in the analysis giving spurious results. Don't sample within 6 months of muck spreading or applications of large quantities of fertiliser. Good soil sampling is a skilled job!

Variation in soil analysis can also come from variations in crop off-take of nutrients. High yielding areas will remove more nutrients from the sampled layer (particularly phosphate - potash can be obtained from depth and thus a 0-15cm sample may show less variation because of yield changes).

## pH levels

Variation in pH (Figure 10.1) is the most important aspect to be aware of as pH influences the availability of both major and trace elements (Figure 10.2). Low pH can cause toxicities of manganese and aluminium as well so if an overall sample has a pH close to optimum and sensitive crops (peas, sugar beet or barley for example) are to be grown spot checks should be carried out using colour indicator. The amount of lime you require to achieve your target pH will depend on the test pH, soil texture and Neutralising Value of the liming material you choose.

"Where levels of phosphate, potash or magnesium are low, crop responses to these nutrients are more likely and levels should be slowly built up."

## Potash and phophate use

Most fertiliser recommendation documents suggest that there is an optimum level of available phosphate, potash and magnesium. Where levels are low crop

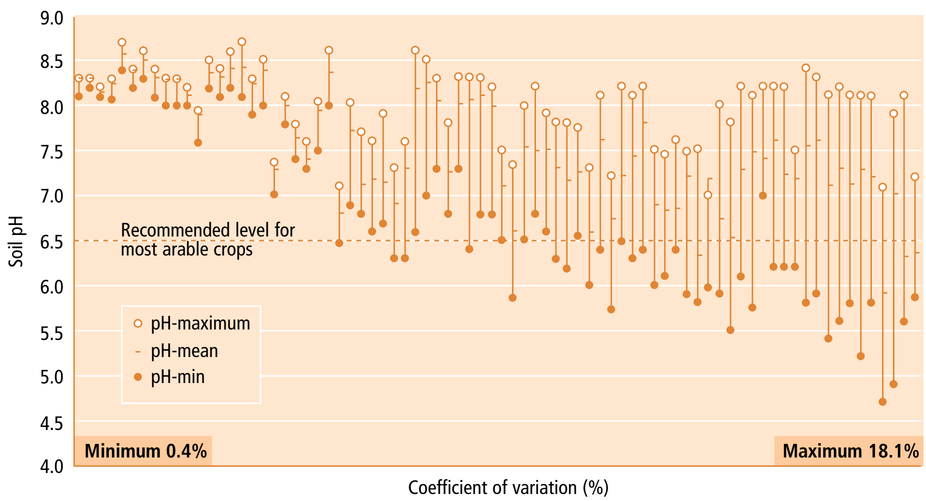



**Figure 10.1** Maximum, minimum and mean values of soil pH for each sampled field, ordered by CV% (Froment et al 1995)

responses to these nutrients are more likely and levels should be slowly built up by applying more nutrient than the crop removes. At higher levels applications for combinable crops can be omitted. A simplistic but effective philosophy is given in (Table 10.1). In all situations levels should be monitored by soil analysis at the same point in the rotation and at the same time of year. If depth of soil mixing reduces because of changes in cultivation system phosphate in particular can become more concentrated in the surface layers of the soil, this is most noticeable where crops are direct drilled and there is no rotational ploughing.

"If depth of soil mixing reduces because of changes in cultivation system phosphate in particular can become more concentrated in the surface layers of the soil."

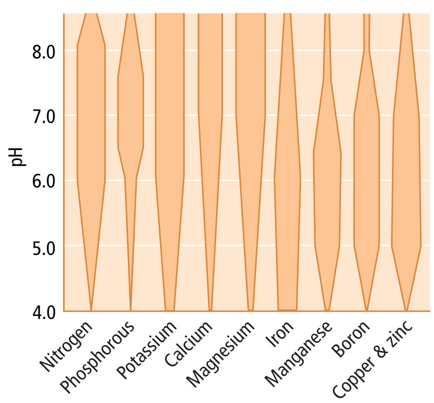



**Figure 10.2** Influence of soil pH on plant nutrient availability. After PDA-Effective use of soil analysis leaflet #4,200.

Some 54% of UK arable soils have phosphate indices of 3 and above and 25% have potash indices of 2 and above. There are many clay soils where potash is being continuously released from the CEC of the soil and clay matrix at rates sufficient to maintain moderate available levels even when no potash is applied.

**Table 10.1** Phosphate and Potash Applications for combinable crops.

| P or K soil Index | Action | Rate |
|---|---|---|
| Very low | Combine drill if possible, otherwise apply to seedbed | Above offtake to obtain yield response |
| Low | Apply to seedbed | Above offtake to obtain yield response |
| Moderate | Apply at any time | To replace offtake |
| High | Why apply? | Zero |

Once good soil levels of phosphate and potash are achieved then a balance sheet approach to these nutrients can be used. When calculating a nutrient balance for a field do not forget to take into account nutrients supplied by organic manures, composts etc. In the example shown in Table 10.2 potash applications are in balance but more phosphate is recommended than is removed. A logical approach would be to omit phosphate applications for the cereal crops altogether and possibly apply higher rates of potash to the first wheat and barley crops so no fertiliser was required following the potato crop. This might get the wheat drilled marginally earlier. On some calcareous clays using a balanced approach to phosphate manuring may result in a decrease in available soil P as it is locked up in the soil.

**Table 10.2** Phosphate and Potash balance at P Index 2 and K Index 2-

| | Yield | P required | K required | P offtake | K offtake |
|---|---|---|---|---|---|
| Wheat (straw incorporated) | 8 t/ha | 60 | 45 | 62 | 45 |
| Barley (straw removed) | 8 t/ha | 70 | 95 | 69 | 94 |
| Potatoes | 50 t/ha | 180 | 300 | 50 | 300 |
| Wheat (straw incorporated) | 8 t/ha | 60 | 45 | 62 | 45 |
| Totals | | 370 | 485 | 243 | 484 |

## Magnesium use

Although Magnesium is an essential part of the chlorophyll molecules, yield responses following applications of this nutrient in most crops are rare. Transient deficiency symptoms are common when crops are waterlogged and when cereals change from their primary to secondary root systems. Of the main arable crops only sugar beet and potatoes commonly show yield responses to the application of magnesium.

## Sulphur use

Sulphur should normally be applied with N as a top-dressing except for spring sown crops, where it can be in the base. Sulphur is the second most important fertiliser nutrient for viable cropping in much of the world. Predicting the need for sulphur is less easy than for other nutrients as soil analysis is not reliable. Light, shallow and lime rich soils tend to require sulphur. Leaf analysis can help to indicate a trend towards the need for sulphur, using either N:S ratios or the malate:sulphate test. Requirements are higher now as emissions from power stations have been reduced.

## Trace element use

Trace element problems normally occur post establishment so we do not need to address them at establishment. Manganese deficiency occurs on soils with a high pH especially those high in organic matter and is favoured by 'puffy' seedbeds - good consolidation will reduce the risk of this deficiency. The possibility of copper deficiency however can be predicted by using soil analysis, it is commonest on sandy and peaty soils.

**Photo 10.3** Manganese deficiency (c.o. ADAS)

## Base Cation Saturation Ratios (BCSR)

Most advisers and scientists in the UK work with the 'Soil Index System' for nutrient availability and fertiliser recommendations based on DEFRA Bulletin RB 209 which is based on extensive research and commercial use of many decades.

Recently, an alternative method using Base Cation Saturation Ratios is being promoted by some in the UK which analyses soil cation levels and their ratios to provide a 'soil audit' which is promoted as being more in tune with soil ecology. However, with little published research, proof of this system is limited and it is not currently thought to provide as good a scientific and practical method as the established soil index system.

" Sulphur is the second most important fertiliser nutrient for viable cropping in much of the world."

**Table 3-3** Nutrient gradient in shallow cultivated soil.

| | Direct drilled | | | Ploughed | | |
|---|---|---|---|---|---|---|
| Depth (cm) | pH | P | K | pH | P | K |
| 0-2.5 | 6.0 | 66 | 409 | 7.7 | 23 | 336 |
| 2.5-5.0 | 6.9 | 56 | 390 | 7.7 | 24 | 339 |
| 5.0-7.5 | 7.3 | 21 | 324 | 7.6 | 24 | 320 |
| 7.5-10.0 | 7.3 | 15 | 280 | 7.7 | 22 | 295 |
| 10.0-20.0 | 7.3 | 14 | 264 | 7.7 | 26 | 301 |

From Froment et al, 1995

The most important nutrient for any crop is one which is limiting yield. In most situations this will be nitrogen. Phosphate, potash and magnesium are less likely to limit yield and even when responses occur they will be less than those obtained from nitrogen.


Photo 10.4

| Actions on fertility | Learning/notes |
|---|---|
| • Ensure accurate soil sampling<br>• Ensure soil structure, field drainage, soil organic matter and soil health are in good condition/ adequate as these are the basis for good soil fertility<br>• Ensure soil pH is optimal<br>• Treat nutrient deficiencies according to soil analysis and need<br>• Ensure basal P, K and N levels are adequate for establishment, particularly when entering conservation tillage, as there can be reduced mineralisation/ availability<br>• Autumn nitrogen use should be minimal, restricted only to situations of proven need with very low soil mineral nitrogen levels within NVZ rules | |

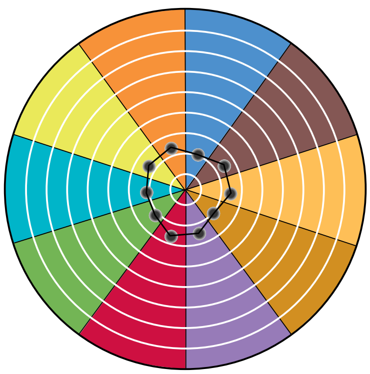
**Target on fertility**

1) Protect environment, in particular soil, where sewage sludge is used
2) Protect water against polution caused by nitrates and phosphates from agricultural sources

Through the chapters you will have found ideas to improve your practice under particular areas specific to your situation. Review your relevant learning's and implement an action plan. Assess your progress to build appropriate best management practice for your farm so as not only to meet the cross compliance requirements for environmental protection but those of profit and sustainable production.

Remember, not to just focus on those areas needing most improvement, but keep in mind the other factors that are important as a balanced approach is important to long-term success. Otherwise a new inappropriate action can throw out the benefit of previous good practice in another area. This is no more true than when making fundamental changes to the system like with crop establishment system. Although conservation tillage systems are more balanced naturally, there are many more learning's to implement to ensure best practice. Another example is in the importance of good soil health, soil structure, drainage, establishment technique and trash management with fertility in ensuring an optimum supply of nutrients to the crop.
By experience and realignment you can build a harmonious management practice that suits your local climate, soils, cropping and establishment method to maximise economic output whilst protecting the environment.

SMI continue to provide up to date advice and training at events across the country. Let us know how we can help you.



A balanced approach

# Bibliography


Brown L, Donaldson G V, Jordan V W L, Thornes J B (1996). Effects and interactions of rotation, cultivation and agrochemical input levels on soil erosion and nutrient emissions. Aspects of Applied Biology 47, Rotations and Cropping Systems, 409-412.

CAAV Website (August 2004). Mid Term Review update. Page 3

Cambridge University costings 2001/2002.

DEFRA (March 2004). The First Soil Action Plan for England: 2004 - 2006.

DEFRA (August 2004). Single Farm Payment - Information for farmers and growers in England.

DEFRA (June 2004). Common Agricultural Policy - Reform.

ECOMAC;
- Harris D (1996). Ecomac, an economic model of climate, soils, cropping and machinery in arable crops unpublished.
- Defra (2001). The timescale of potential farm level responses to climate change in England and Wales, cc0333.

Environment Agency (2004). The State of Soils of England and Wales, pages 5,7, 15.

Environment Agency website (2004). Environment Facts and Figures: Soils.

Froment et al (1995). Report to MAFF, Review of Spatial variation of nutrient in soil.

Jacobsen JS (2000). Soil Sampling, Montana State University Extension Service.

Jordan VWL and Leake AR (2004). Contribution and interaction of cultivation and rotation to soil quality, protection and profitable production. HGCA conference 2004: Managing soil and roots for sustainable production.

Jordan V W L, Hutcheon J A (2002) Influence of Cultivation Practices on Arable Crop Diseases. In: Soil Tillage in Agroecosystems (Ed A El Titi) 187-206. CRC Press Ltd.

Jordan V W L, Leake A R, Ogilvy S (2000). Agronomic and environmental implications of soil management practices in integrated farming systems. Aspects of Applied Biology 62, Farming Systems for the new Millennium 61-66.
Jordan V W L, Hutcheon J A (1997). Alternative farming methods (arable): a study of the effects of an integrated arable management system on levels of herbicide and nutrients reaching "controlled waters". Journal Environment Agency, Bristol (GB) EA-RD-TR-P-17. 65pp (1997).
Jordan VWL, Hutcheon JA, Kendall DA (1997). Influence of cultivation practices on arable crop pests, diseases and weeds and their control requirements. In: Experience with the applicability of no-tillage crop production in the West-European countries. EC Concerted Action AIR 3-CT93-1464. Ed F Tebrugge. Germany: Wissenschaftlicher Fachverlag, pp. 43-50.

OECD (2001). Environmental Indicators for Agriculture, volume 3: Methods and results. http://oecdpublications.gfi-nb.com/cgi-bin/OECDBookShop.storefront/EN/product/512001011E1

Potash Development Association (2000). Effective use of soil analysis, leaflet 24.

Potash Development Association (2003). News - Soil analysis: its interpretation and nutrient management practice. (J. Johnson and J. Hollies).

Reicoski DC (1997). Tillage induced CO2 emissions from soil. Nutrient Cycling in Agroecosystems. 49:273-285.

Reicoski DC (2001). Tillage-induced CO2 emissions and carbon sequestration: Effect of secondary tillage and compaction. Conservation Agriculture - A Worldwide Challenge - Volume 1: Keynote Contribution. ECAF, FAO. Pages 265-274.

Shepherd TG (2000). Visual soil assessment - volume 1. Field guide for cropping and pastoral grazing on flat and rolling country. Manaaki Wheua Press, Landcare Research, Palmerston North, NZ.

Shepherd TG, Ross CW, Basher LR and Saggar S (2000). Visual soil assessment - volume 2. Soil Management guidelines for sustainable cropping for cropping and pastoral grazing on flat to rolling country. Manaaki Wheua Press, Landcare Research, Palmerston North, NZ.

Tebrugge F (2001). No-tillage visions - Protection of soil, water and climate and influence on management and farm income. Conservation Agriculture - A Worldwide Challenge - Volume 1: Keynote Contribution. ECAF, FAO. Pages 303-316.

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*Target on establishment*

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