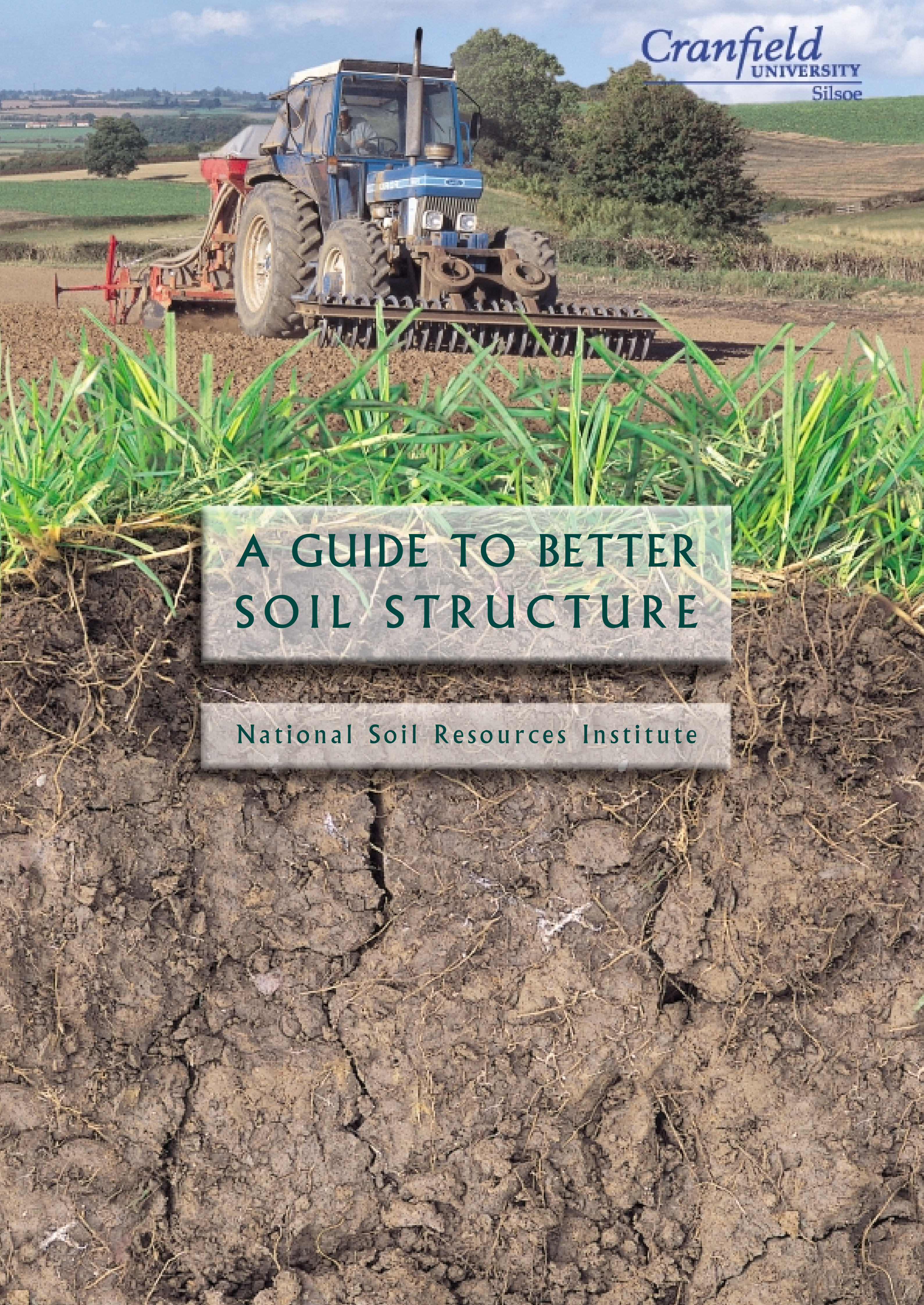


Cranfield UNIVERSITY Silsoe

A GUIDE TO BETTER SOIL STRUCTURE

National Soil Resources Institute

BACKGROUND

With increasing agricultural and horticultural intensity, soils are becoming more vulnerable to the threat of deterioration. If this loss of structure is not put right, then soils are unable to sustain good productivity.

Most land managers appreciate the risks, but because the problems are usually unseen below ground and difficult to assess properly, many fail to put them right.

This booklet is principally aimed at farmers, growers and landowners who recognise the need for better soil management.

It starts by identifying the ideal target soil structure to ensure good plant growth and at the same time physically support stock or farm equipment.

It then helps the soil manager identify the structure that he has within the field before providing guidance on how a better structure can be achieved and then maintained.

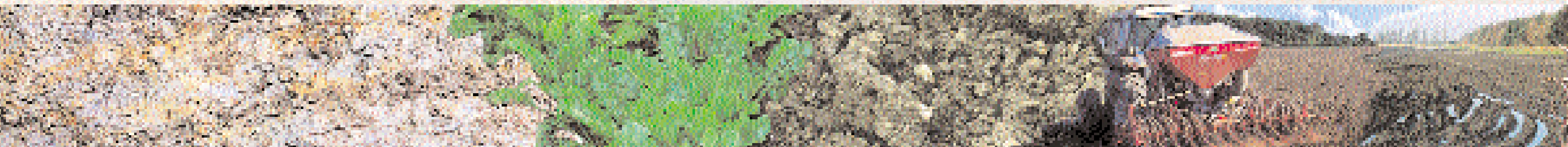
'A Guide to Better Soil Structure' is based on MAFF funded project: SP0305: "A national soil vulnerability-based framework for provision of farm-specific guidance on the management of soil structure" carried out by the Soil Survey and Land Research Centre (SSLRC), Scottish Crops Research Institute and the Institutes of AgriTechnology and Water and Environment - Cranfield University at Silsoe.

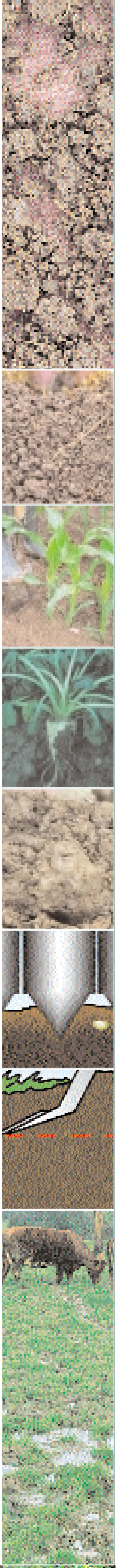
It complements advice given in the Codes of Good Agricultural Practice for the Protection of Soil, Water and Air.

The National Soil Resources Institute has been created at Cranfield University by the amalgamation of SSLRC with staff of the Institutes of AgriTechnology and of Water and Environment, with the aim of creating a single multi-disciplinary institute focused on sustainable soil and land management.

The financial help of the Department for Environment, Food and Rural Affairs (DEFRA) in the printing and publishing of this Guide is gratefully acknowledged.

> "Go upon the lande that is plowed and if it synge or crye or make any noyse under they fete then it is too wet to sowe. If it make no noyse and will beare thy horses, thanne sowe in the name of God."
>
> 16TH CENTURY HUSBANDRY GUIDE





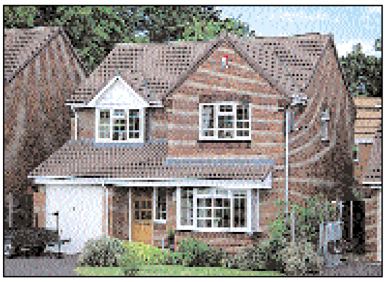
CONTENTS

WHAT IS SOIL STRUCTURE?

Many people tend to confuse a soil structure with texture. A soil's texture is the bricks (a mix of sand, silt and clay), which when stuck together with organic matter and other natural "mortar" make up the larger all-important structural blocks. The structure of the soil is the arrangement of blocks around which the roots grow and air and water move.

Just like our houses, a soil is made up of a number of different 'building' blocks, which are described according to their shape and size using fairly easily defined terms such as blocky or granular, fine or medium.

While there is little farmers can do to modify the texture of the soil, they can influence the way the soil is structured.

TEXTURE	STRUCTURE	SOIL STRUCTURE
		
		

THE IMPORTANCE OF SOIL STRUCTURE

SOIL STRUCTURE IS IMPORTANT BECAUSE......

it is the plumbing system for the soil which controls

- water flow
- air flow

it provides space, and a protected home, for

- roots
- germinating seeds
- soil fauna (macro and micro)

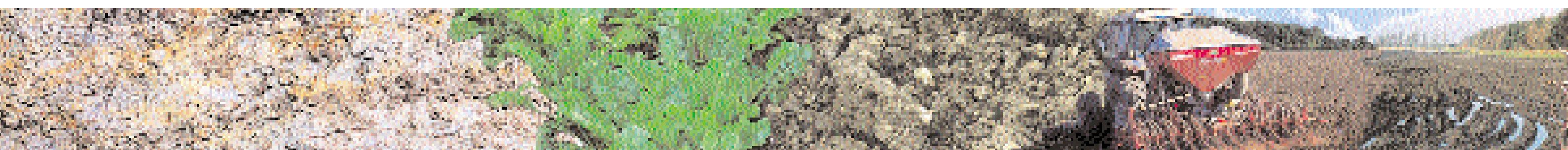
it affects farming operations

- trafficability of machinery
- ease of cultivation
- response of the soil to tillage and stocking

it affects the impact of land use on the environment

- amount of run-off and erosion
- amount of nutrients lost in drainage, run-off and/or erosion from the soil
- amount of pollutants lost from farms in erosion, run-off and/or drainage.

If all is going well, then you won't notice any problems; however, when soil structure is poor, then crop yield and quality suffers, erosion occurs, and tillage, fertiliser spreading and spraying operations are affected.
A poor soil structure will reduce crop and farm profits by restricting plant performance and increasing the cultivation costs needed to correct matters.



STRUCTURAL CHANGE

Soil structure changes naturally due to weather related factors such as wetting and drying and freezing and thawing. Thus the different composition and orientation of the structures within a soil vary with depth and also crop stage during the season.

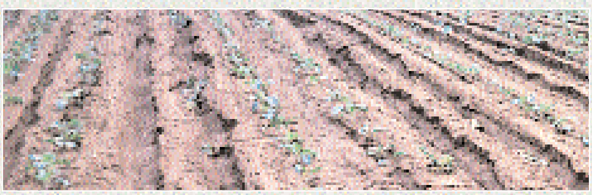
Recent research by Cranfield University at Silsoe shows that the extent of a soil's natural deterioration during arable cultivation over the season is largely governed by its texture. The results suggest that texture is as important as organic matter and root exudates (natural sticking compounds).

If a soil has a high clay content, the structures are more tightly formed and thus less likely to be broken apart and to slump. Natural processes, such as freezing and thawing in the topsoil, can also help these soils to recover. Sandy and silty soils have less well defined structures and are more likely to slump, especially if they have been subject to excessive cultivation and have been weakened.

Structure stability can be defined as the resistance of the soil structure to external factors such as water. Soils that naturally have a good structure in the long term have a 'stable' soil structure; those that would naturally lose all aggregation have an 'unstable' structure. Maps prepared by SSLRC show the distribution of stability in topsoils based on a classification of topsoils according to their risk of slumping.

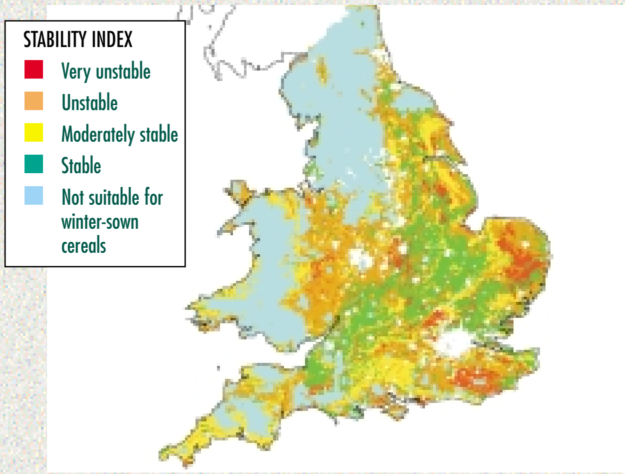
Similarly a classification of UK arable and managed grassland topsoils according to their 'structural regeneration' has been derived. It applies to soils that have suffered compaction damage by implements or livestock and can be defined as the tendency of a soil to revert naturally to their former porosity, density and strength after compaction.

Soil compaction results from complex interactions between soils, machinery (load, type and dimension of pneumatic tyres, inflation pressure, vehicle speed, wheel slip, number of passes), crops, weather conditions and field history. The recovery of a compacted soil is greatly influenced by swelling and shrinkage in soils with sufficient clay contents and by frost action. In areas where soil freezing in winter is only slight or absent, the effects of wheeled traffic are likely to persist for several years.



WATER EROSION

STABILITY OF TOPSOIL STRUCTURE



• STABLE SOILS

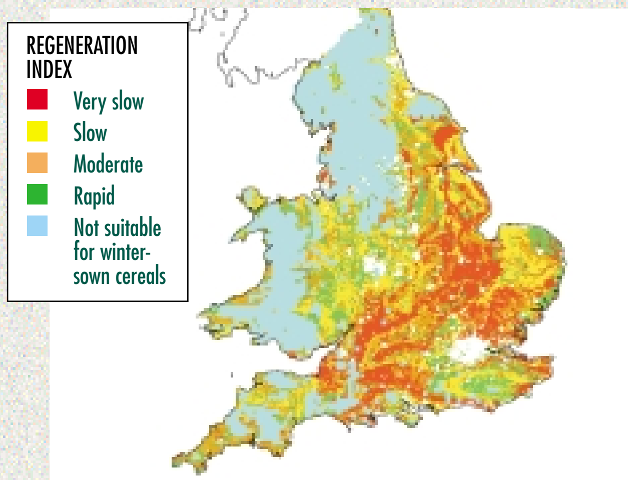
- High clay content
- High calcium carbonate content
- Favourable organic matter content
- Favourable drainage
- Favourable biological activity

• UNSTABLE SOILS

- Fine sands or silt texture
- Poor drainage
- Low organic matter content
- Sodium-rich clay

Management and weather related factors will affect the extent of deterioration of a soil's structure.

ABILITY TO RECOVER FROM STRUCTURAL DAMAGE



• DAMAGE IS CAUSED BY

- Excessive cultivations
- Untimely operations
- Shallow rooted crops
- Spring cropping
- Heavy rain
- Wet harvest

• DAMAGE IS REDUCED BY

- Timely operations
- Cold winter - frosts
- Dry weather during spring
- Dry harvest

THE OPTIMUM STRUCTURE

The only real opportunity a farmer has to modify a soil's structure is during the period between crops. As a result, every autumn and spring much labour and machinery time is spent on topsoil and subsoil cultivations.

The extent and nature of every cultivation operation should vary according to the soil's current state and the structure that you are aiming for to support the following crop.

Some operations may be needed from the point of view of burying stubble/crop residues or reducing the weed burden, but in general the aim is to provide the right environment for seed germination and long term root growth.

Get it wrong by using an inappropriate piece of cultivation equipment when the soil is too wet or too dry and you will do more harm than good.

In reality, pressure of work particularly when drilling early to maximise yield potential or after late-lifted roots before the winter means that a soil's structural condition is often compromised.

Furthermore, as the season progresses, faced with the need to get on the land for timely application of fertilizers, pesticides, etc., structural deterioration is a distinct possibility.

In a typical arable field, the volume of air spaces decreases from drilling to harvest and the soil density increases. Density also varies according to cropping (Figure 1). Part of this increase is due to natural causes: clods disintegrating on wetting and filling up coarser pores, and the passage of machinery compacting the soil.

FIGURE 1: THE EFFECT OF MANAGEMENT ON SOIL DENSITY

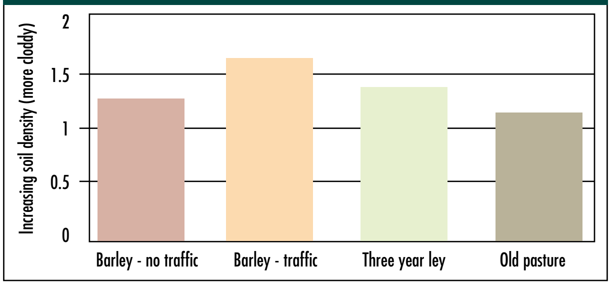
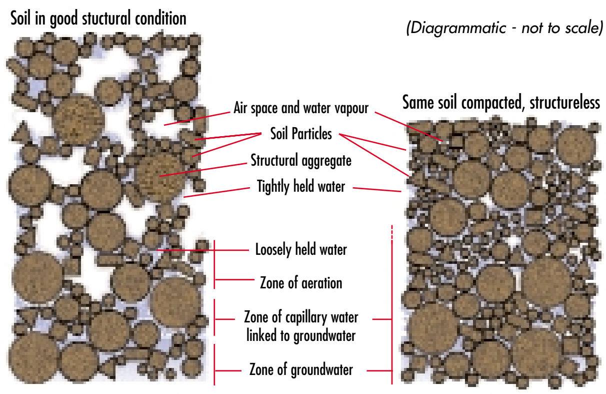


FIGURE 2: COMPACTION EFFECTS ON SOIL STRUCTURAL CONDITIONS



In general, a well-structured topsoil will have a continuous network of pore spaces to allow drainage of water, free movement of air and unrestricted development of roots. A subsoil can be well-structured but also allow water to permeate slowly.

THE IMPORTANCE OF SOIL ORGANIC MATTER

In conventional arable agriculture, particularly in stockless production systems, the sole reliance on mineral fertilisers or infrequent use of manure has in some areas resulted in a reduction in soil organic matter content, structural stability, earthworm and microbial activity.

Micro-organisms have long been implicated in mediating soil structural stability, in particular fungi that may form and stabilise aggregates.

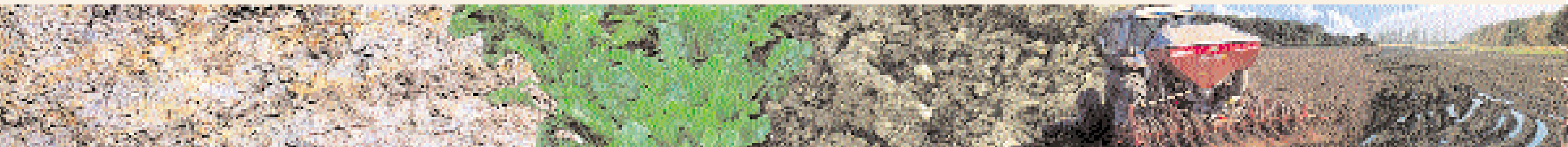
Evidence suggests that tillage can have an effect over the degree to which certain microbes influence soil structural parameters. For instance, ploughing soil leads not only to the disruption of the soil mass, but also to the breaking up of fungal hyphae. Direct drilling, on the other hand, maintains structural integrity and fungal hyphae to a greater extent.

It has been shown that a favourable balance between water and oxygen availability (typical for well-aggregated soils and/or soils with optimised organic matter content) results in high soil microbial activity.

Recent research by the Scottish Crops Research Institute at Dundee has found that:

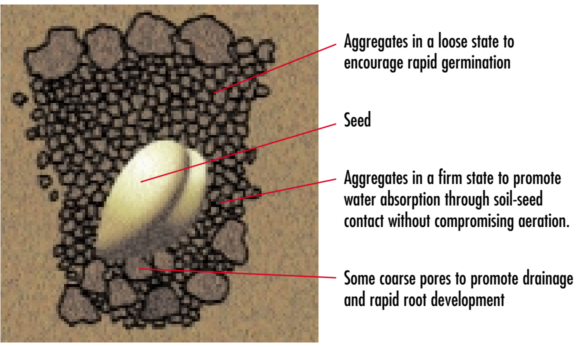
- Direct-drilled soils appear to be more friable than ploughed soils.
- Increasing nitrogen levels appeared to reduce friability for most of the ploughed and direct drilled samples.
- The aggregates taken from permanent grassland had the lowest friability.

It is suggested that these differences were due to both microbial activity and root growth. It is beneficial to have highly friable peds but friability at aggregate scale can cause problems.



SEEDBED STRUCTURE

FIGURE 3: IDEAL SEEDBED STRUCTURE



A good seedbed should allow you to drill to a uniform depth, placing the seed in contact with the soil so that it can take up water easily. However, the soil must also be well aerated to ensure good germination.

Seedbed conditions should allow smooth operation of the drill, providing good depth and seed spacing control, good seed/soil contact and minimal crop residues within the seed slot.

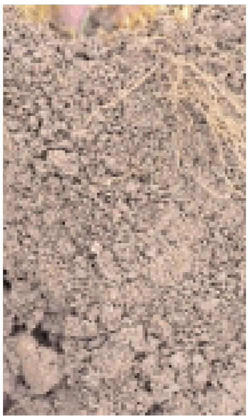
In addition, the soil above the seed must remain sufficiently loose for the seedling to grow up through the soil, and the pore space around the seed must contain sufficient large pores to maintain good aeration and to allow the easy growth of rootlets (Figure 3).

Prolonged waterlogging immediately after drilling can be very detrimental to crop health. In cereals for example, long-term damage occurs after nine days of waterlogging, with crop death after fourteen. Once the seeds are growing, damage will occur more quickly.

In wet conditions, it is essential that there is an adequate distribution of coarse aggregates, and hence pores, within the tilth directly below and to the side of the seed, to promote free drainage and rapid root development.

TOPSOIL STRUCTURE

The plough layer extends below the seedbed to approximately 30 cm depth - together they form the topsoil.



Here the structure will very much depend upon the natural texture of the soil and its strength. A heavier, clay soil is likely to have stronger aggregates that are larger and more difficult to break. A sandy or light loam soil will have less rigid aggregates that can be easily broken.

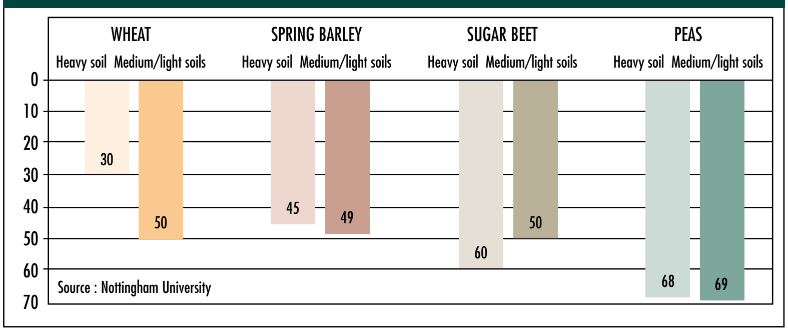
A well-structured topsoil should encourage rooting, airflow and drainage between the seedbed and the underlying subsoil. It will be a mix of aggregates, which should not be too large and be relatively loosely packed.

SUBSOIL STRUCTURE

Once below 30 cm depth, soil structure very much depends on natural weathering processes, the texture of the soil and its drainage status. Roots from some crops can penetrate to depths of 1 metre and beyond if the conditions are ideal.

Any land drainage operations or secondary (subsoiling or moling) treatments that help maintain a freely drained, aerated state will enable roots and biological activity to stabilise and improve the subsoil.

FIGURE 4: SUSCEPTIBILITY TO TOPSOIL COMPACTION - % YIELD REDUCTION



EXAMINING SOIL STRUCTURE

All that is needed is a spade, a penknife and careful observation. Topsoil structure can be examined by simply digging out a 'spit' of soil. It is useful to compare different soils and land uses.

Simply push the spade into the surface soil around three sides of a square (see diagram and photographs opposite) - then, on the final dig, remove the spit of soil and, keeping it on the spade, gently lay it on the ground.

Examine the soil looking at the roots and the structures. Prise them apart using a knife or your fingers and notice their shape, strength and development. Sometimes it is also useful to bang the spit of soil on the ground and see how it breaks.

DIGGING DEEPER

To examine structures below plough depth, widen the hole and take a second spit out at lower depth, remove and examine in the same manner.

Alternatively dig a bigger pit by hand or with a mechanical digger, taking care not to create too much smear on the side you decide you will examine. This should preferably be the side in direct sunlight as this provides a better light.

Holes need not be large, but should go down to at least 60 cm. Gently pick away at the side of the pit you are examining and note rooting and soil structures.

As most soils are quite variable a number of holes per field will be necessary. Gateways and headlands will have different problems from the rest of the field.

Data from sensors such as electro-magnetic induction (EMI) and/or yield mapping may provide information on the scale and magnitude of soil variation and on the key management boundaries within the field. If so, then field sampling may be targeted more cost-effectively within those fields where significant variation seems to occur. Use any available clues and evidence to target your sampling.

Topsoils should be examined when moist, preferably in the spring or early summer. This is when bright white roots are most obvious and probably at their greatest depth.

IDENTIFYING SOIL STRUCTURES

The identification of different structures requires little more than care and attention to the details being examined, and common sense. Follow the guidelines below and check soils against the illustrations on pages 12 to 13. At all times try to identify those areas in the soil that are not right. Note what the problems are and then consider the cultivations needed to put them right (see page 14).

NOTE COMPACTED ZONES

Both during digging and by probing the pit sides with a knife look out for any hard or compacted areas.

LOOK AT THE ROOTS

Examine their depth. If rooting is restricted, or if they are balled-up or growing sideways, then there is a problem.

In a well-structured soil, the roots will be numerous and well branched with lots of fine root hairs.

LOOK AT THE STRUCTURES

Note the size and shape of the structural units at different depths. Are they too large for the crop you are growing/plan to grow; do they need to be broken up?

LOOK AT THE CRACKS

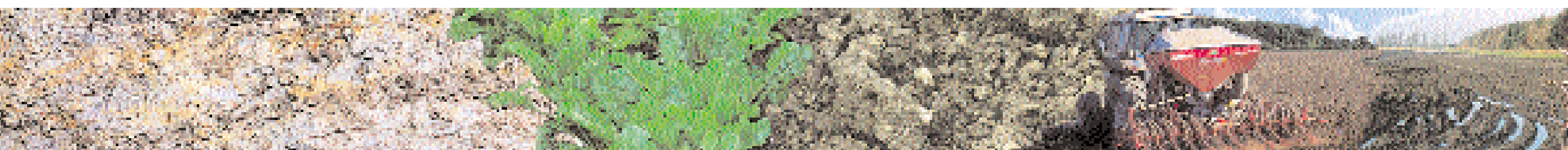
Cracks larger than 0.2 mm can be seen - these pores will allow rooting and drainage. Cracks smaller than this only hold water - they don't drain.

LOOK FOR WORM HOLES

Earthworms will only live in well-aerated soils. Their channels help drainage, aeration and rooting.

LOOK FOR EVIDENCE OF CULTIVATION

Look to identify the depth where previous cultivations have taken place and examine what effects this has had on the soil e.g. crop residues, plough pans.



POOR STRUCTURES

Few Pores Within Aggregates

Mainly large or dense angular blocks, or compact material with few vertical cracks which are difficult to break apart (clods).

PLATY AGGREGATES

Within a soil, this flattened structure impedes roots and holds up water. Any fissures tend to be horizontal. Common in heavily trafficked topsoils.

ANGULAR BLOCKY

These blocks can fit very tightly together and leave few pores for roots to exploit and air to move through.

COLUMNAR

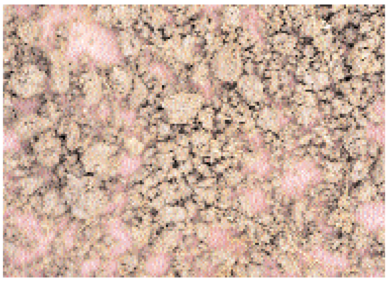
Shaped blocks which may allow plenty of air, water and root movement through the soil, but do not allow roots to penetrate the aggregates; often found at depth, these structures are usually large and associated with heavier soils and zones which are poorly drained

Tilths created by power harrows are unstable fragments or even dust rather than structural aggregates.

GOOD STRUCTURES

Well-formed, small porous aggregates, with rounded edges. They can normally easily be broken when moist, between the finger and thumb.

GRANULAR



Crumbly, small imperfect almost spherical structures - the ideal seedbed.

SUB-ANGULAR BLOCKY

Larger, more rounded blocks.

A STRUCTURAL INDEX

IT MAY HELP TO ASSESS THE SOILS IN DIFFERENT FIELDS OR AREAS OF FIELDS AS FOLLOWS:

	CLAYEY AND LOAMY SOILS	SANDY SOILS
POOR	plough layer is dense and consists of large clods; roots only in cracks; top 6 cm has angular aggregates; dense below 6 cm	almost single-grain structures; little cohesion; collapsed top layer; compacted lower layer; surface capping very thin but very effective at stopping emergence of seedlings and infiltration of water
MODERATE	plough layer has large, but porous, aggregates; top 7 to 8 cm small porous blocks, denser below	slight cohesion of particles; moderate aggregation; some collapse
GOOD	plough layer is mainly porous crumbs with few dense aggregates	entire plough layer is stable crumbs and few dense aggregates

SOIL PROBLEMS

SOIL COMPACTION

When soil is compacted the natural porosity is markedly reduced so that in severe cases water and air movement and root development are restricted.

Factors that add to compaction are:

- Field operations carried out when the soil is too wet
- Heavy equipment - the heavier the equipment, the drier the conditions required unless different tyres are used (see page 19)
- Emphasis on early sowing or drilling (particularly in the spring)
- Reducing the number and extent of tillage operations
- Wheeling in furrow bottoms when ploughing.

Effects of cultivation pans and weakly structured layers:

Poor germination: waterlogging in the topsoil rots seeds, reduces the soil temperature, excludes air and encourages the production of gases toxic to plants.

Poor response to fertilisers: because roots can't fully exploit the soil, plants can't get the nutrients they need. Waterlogging also causes fertiliser nitrogen to be changed into gases which are lost to the air.

Traffic damage: damaged structure increases the risk of wheel slip and rutting, causing further damage.

Crop diseases and pests: Plants weakened by waterlogging are less resistant to disease and pest attack and need additional sprays.

Droughtiness: shallow-rooting plants cannot obtain sufficient moisture and are quick to wilt.

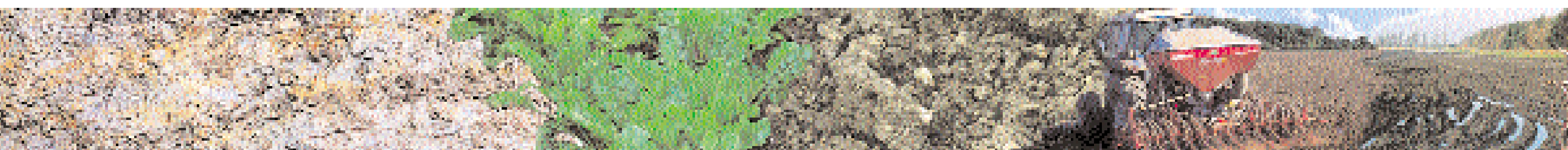
OTHER EVIDENCE OF

PLOUGH PANS OR WHEELING PANS

These are discrete layers caused where equipment has exerted a well-defined localised pressure on the soil. Often the structure of these layers is formed of thin plates resulting from the smear of rubber tyres or metal on the soil.

UNDER-CONSOLIDATION

If soils are too loose, poor seed-to-soil contact can result in poor germination and emergence. Manganese deficiency can also be a consequence. Rolling helps overcome this, but soils should not be over-consolidated or compacted.



IMPEDED SOIL DRAINAGE

The result of ineffective drainage is to restrict field operations, making it difficult to create good structure. Indeed, any soil or soil zone that is saturated for a length of time will become less well structured naturally.

It is difficult to correct the structure of a soil that rarely dries out and/or has poor under-drainage. Thus, if waterlogging is noted, any remediation may be less than satisfactory and at best only temporarily solve the wetness.

Recognising Ineffective Drainage

Problems of ineffective drainage are usually obvious in the field:

- Fields are slow to dry out
- Land is quick to return to a waterlogged state
- Patches of poor crop growth - normally N-deficient, yellow leaves and restricted rooting
- Increased pest and disease damage
- Excessive grass weeds
- Poaching and rushes on grassland
- Mottled orange/grey soil colours may indicate intermittent waterlogging

A poorly drained soil when waterlogged is at more risk of compaction; conversely compaction will increase the risks of waterlogging. The only realistic way to break the vicious circle is to re-drain the land and/or carry out secondary treatments, such as subsoiling, moling, ditching or drainage repairs.

STRUCTURE DAMAGE

SURFACE CAPPING

Rainfall on fine, naturally unstable soils can lead to slaking or running together of the surface into an impenetrable cap of up to 5 mm thickness. This can restrict seedling emergence. SSLRC work has recently revealed that caps restrict infiltration of rainwater to about 1 mm per hour, so causing serious runoff and erosion.

ANAEROBIC LAYERS

These are grey or black coloured zones often associated with severe compaction, the ploughing down of discrete layers of manures or crop residues in wet conditions. These can smell foul and severely restrict rooting. They need to be cultivated out.

CLAY

SANDY CL

POOR STRUCTURE

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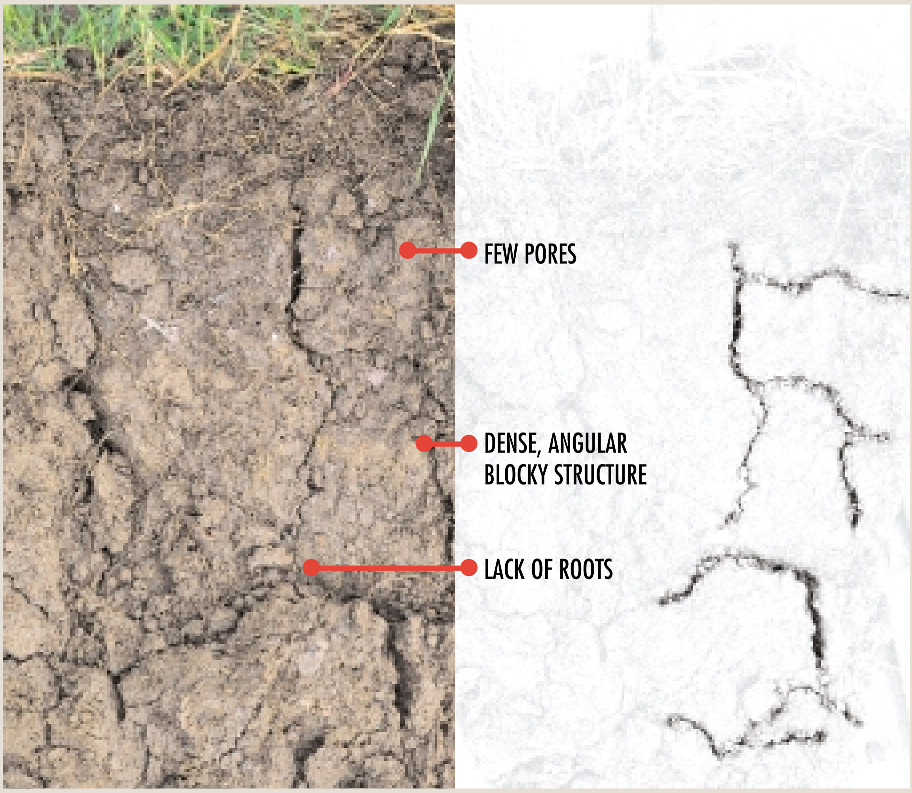
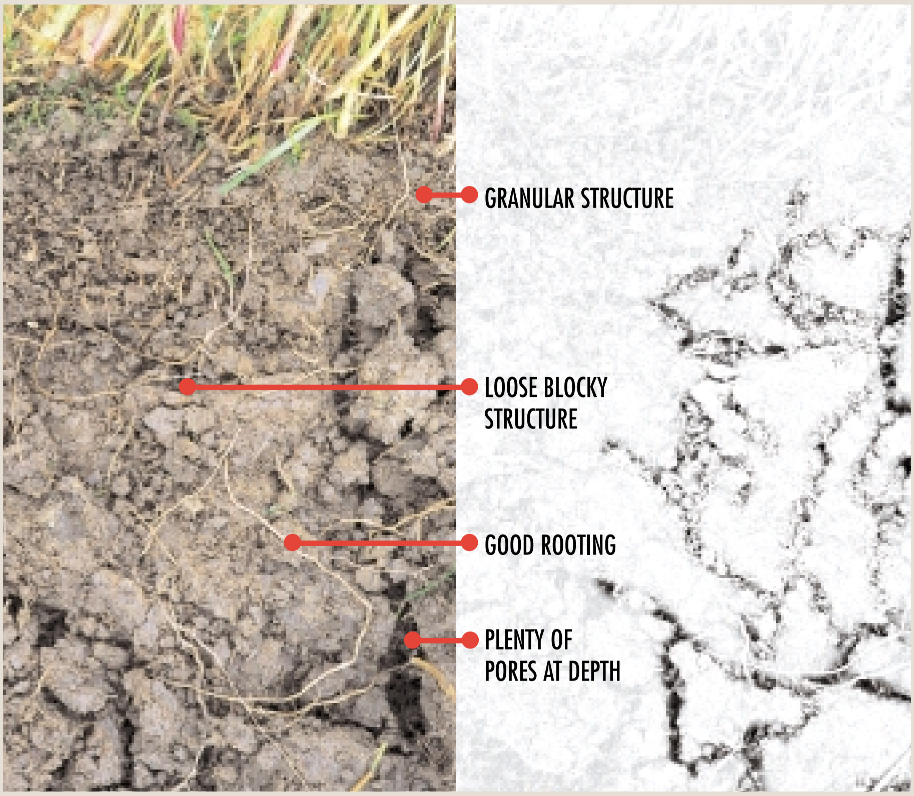


GOOD STRUCTURE

m 5 10 15 20 25 30



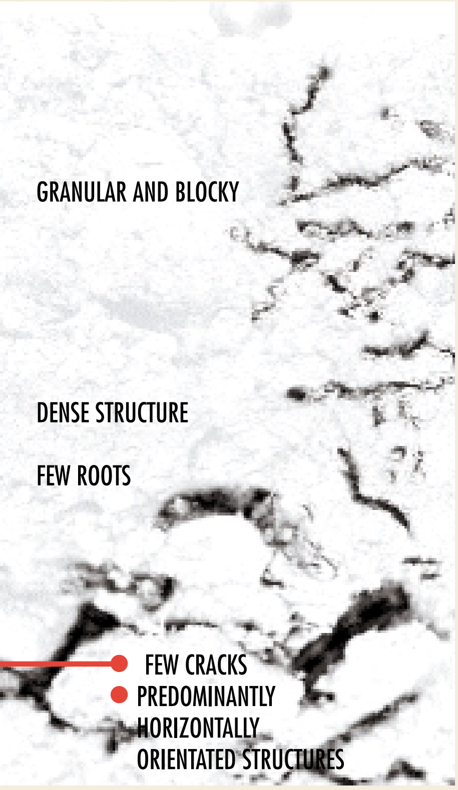
CREWE SERIES

stoneless clay - slowly permeable - prominently mottled

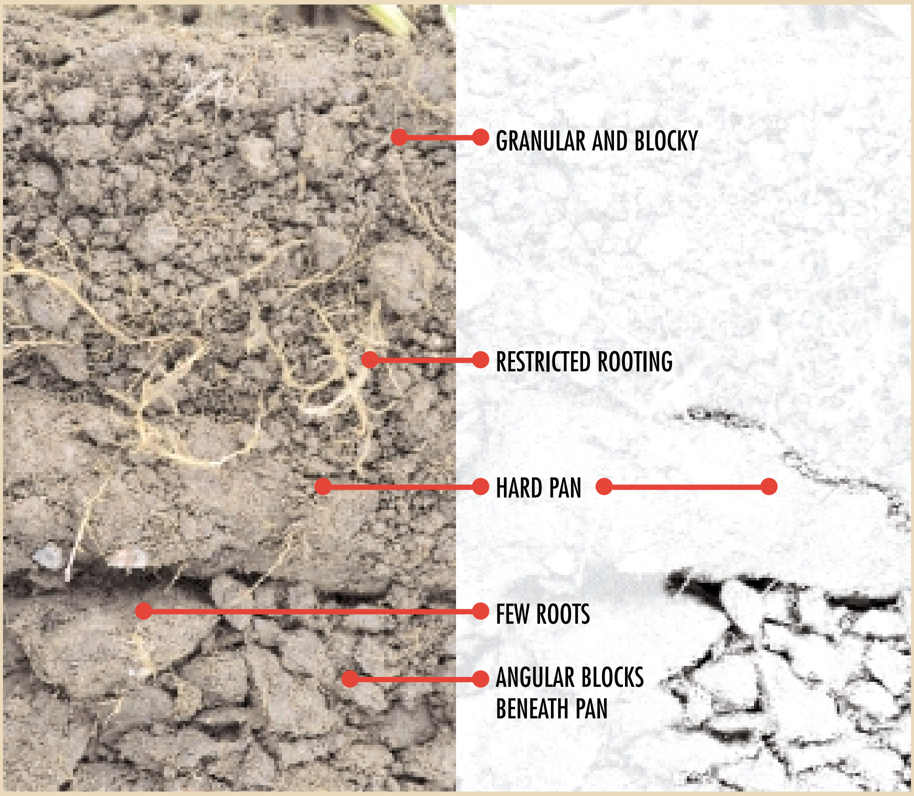
SALWIC

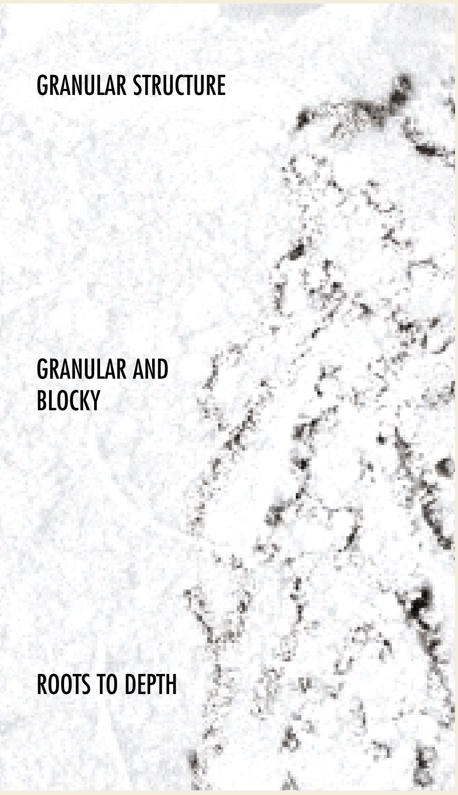
slightly stony sandy clay loam - modera

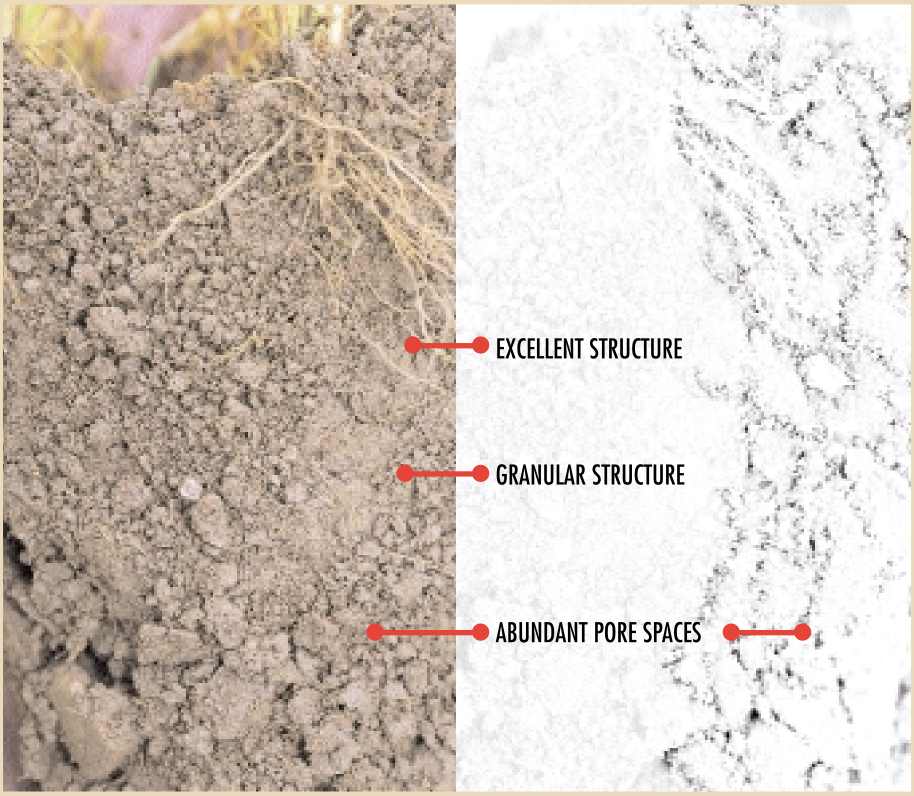
AY LOAM



SANDY LOAM







K SERIES

ely permeable - more clayey with depth

ARROW SERIES

very slightly stony sandy loam - deep permeable - loamy sand at 80cm depth

DECIDING WHAT TO DO

The most important cultivation operation is to remove any soil compaction that may be evident and so increase the volume of soil available for rooting in the following crop. If the soil structure is good, then if possible consider minimal cultivation.

There are no hard and fast rules governing the maintenance and improvement of soil structure. Much will depend upon the cultivation equipment you have at your disposal and the time available to carry out the work. However, timeliness is essential.

It is also important to set tillage equipment carefully to do the job: ensure it is working at the right depth and regularly check to see it is working effectively by digging holes.

Powered cultivators should be adjusted to run at the slowest acceptable speed, thus avoiding over-cultivation and pulverising the soil. Using a minimum of cultivation effort and power to produce the desired condition should reduce operating time and costs.

Having examined the soil, you need to decide how each part of the field that has been identified should, if needed, be cultivated to provide the ideal conditions for the following crop.

Always re-examine the soil between each operation and decide upon the next course for action: carrying out loosening, clod sorting and re-orientation operations before consolidating and levelling,

TILLAGE OPERATIONS

In general, there are five main cultivation operations: those that **loosen** or **consolidate** the soil, those that **sort** or **reduce clods** and those that **level** the soil.

The need for consolidation and clod sorting commonly occurs within the seedbed zone; clod size reduction and loosening on the other hand are needed at greater depth within the rooting zone and often into the subsoil.

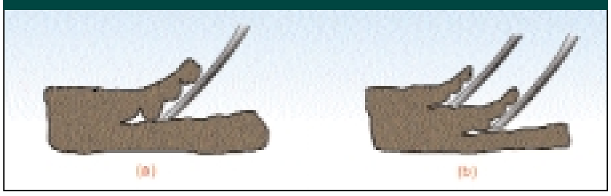
Most cultivation programmes start by getting structures right at depth - normally loosening - then look to the topsoil structure before creating the right seedbed tilth.

(1) LOOSENING

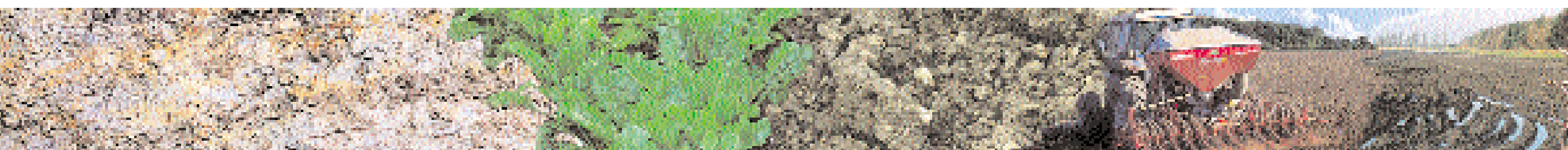
Loosening is usually carried out using forward inclined tines to encourage 'soil failure'.

The lifting and shattering action of these tines loosens compacted land with minimum draught and risk of smear in moist clayey soils. However, care must be taken to control the depth of operation and to limit the production of large, unmanageable clods. Loosening should not be carried out when clays are moist or wet.

FIGURE 5: LOOSENING USING FORWARD INCLINE TINE



The size of clods produced can be controlled by working the land progressively deeper either using multiple passes of the same tool, or by using tines of differing lengths (shallow at the front, deep at the rear (Figure 5 (b)).



(2) CLOD SIZE REDUCTION

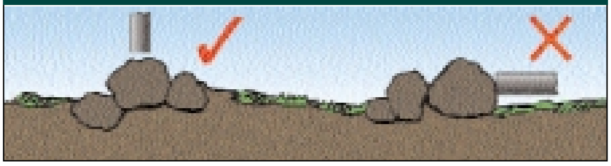
This is often necessary following soil loosening operations, which typically leave a tilth comprising large clods, which have greater strength than the bulk strength of the soil.

Three main mechanisms can be employed.

DIRECT LOADING

Uses backward facing tines or other equipment that places a downward load on the soil (rolls, levelling boards, discs) which helps to force clods against one another, so helping to break them (Figure 6).

FIGURE 6: DIRECT LOADING OPERATIONS



Soil moisture content can greatly influence the efficiency of this operation, as moist clods behave like plasticine and dry clods become too strong to break against the weaker surrounding soil.

Greater loading velocity increases structure breakdown (e.g. power harrows). However, this creates more dust and small particles and this fine material readily moves down the profile and can cause structural problems at depth.

IMPACT

Clod breakage is effected by implements striking the clods or by throwing them against something hard, using power-driven implements (e.g. power harrows or rotary cultivators).

The size of clods produced depends on rotor speed and forward speed of the tractor (e.g. a slow tractor with high-speed rotor produces fine clods).

These implements tend to break clods evenly throughout the working depth. In moist soil conditions, clod size reduction through impact tends to be more successful than direct loading.

CUTTING

Blades, discs and rotary tools can be effective in reducing clod size, particularly in moist conditions; however, there is some risk of smear in the seedbed.

(3) CLOD SORTING

Narrow tines operating in loosened conditions tend to bring larger clods to the surface and cause fine material to move down the profile under gravity without overdoing it.

This effect can be used to some advantage in combination tillage operations by bringing large clods to the surface immediately prior to breaking them.

Power-driven rotary cultivators produce a more even distribution of clod sizes throughout the working depth.

Implements that incorporate a metal hood behind the rotor, to increase clod breakage through impact have a tendency to leave a layer of fine material at the surface.

(4) CONSOLIDATION

Consolidation is the process of bringing soil aggregates and particles closer together, reducing air-filled porosity and increasing the soil density.

Wide backward-inclined tools such as those on flat rolls and levelling boards are effective in consolidating the top 10 to 20 mm of soil (Figure 7).

Ring rolls are used where slightly deeper consolidation is required, for example, to encourage adequate soil contact around a seed (Figure 8).

FIGURE 7: CONSOLIDATING IMPLEMENTS

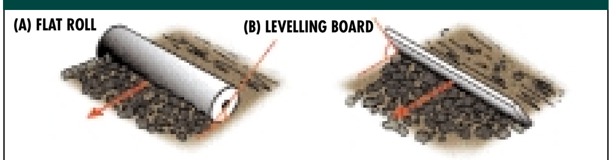
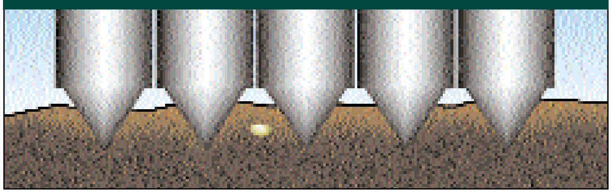


FIGURE 8: RING ROLLS



(5) SURFACE LEVELLING

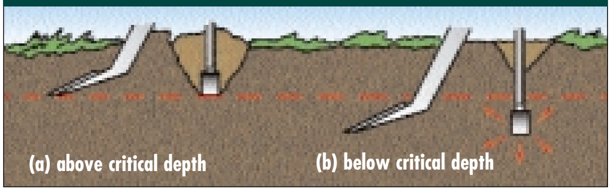
The production of a level surface following tillage operations can be achieved either through the use of wide backward-inclined blades (e.g. a levelling board) or the stirring action of numerous vertically mounted narrow tines (e.g. spike-toothed harrows or chain harrows).

DEEPER TILLAGE

Subsoil tillage normally aims to remove deep-seated compaction or natural impermeable layers, and to improve drainage and aeration through loosening when the subsoil is dry and brittle.

The success of any deep tillage operation depends upon timeliness, implement size, geometry and depth of operation.

FIGURE 9. CULTIVATIONS



Each operation, using the selected cultivation equipment, has a critical depth (Figure 9).

Any operation undertaken **above** this critical depth will result in a loosening action through brittle failure. Operations carried out **below** critical depth will result in compaction because of the sideways resistance of the surrounding soil. However, the soil moisture state is critical; if you subsoil when it is plastic, you end up with square mole channels and no heave.

As a general rule of thumb, critical depth occurs at approximately six times the individual loosening tine's width; for example, a tine foot that is 8 cm in width, will have a critical depth of around 48 cm.

REMOVING TOPSOIL COMPACTION

To break up a plough pan or compacted layer, tillage has to be carried out just below the zone that needs to be broken up.

Typically, tools of low positive rake angle are used to encourage penetration and soil lift (e.g. a chisel plough, Figure 10).

To check that a pan has been thoroughly broken across the complete soil profile, dig and examine the effects of the first pass of the cultivation equipment.

If a pan is met below the critical depth for the tillage tool, then either a wider tool or shallower leading tines can be used to reduce confining stresses ahead of the deep tines to successfully lower the critical depth.

FIGURE 10: PLOUGH PAN BREAKAGE WITH A CHISEL PLOUGH

SUBSOILING

Subsoiling is carried out to reduce compaction or unfavourable structure which extends to depths greater than 30 cm.

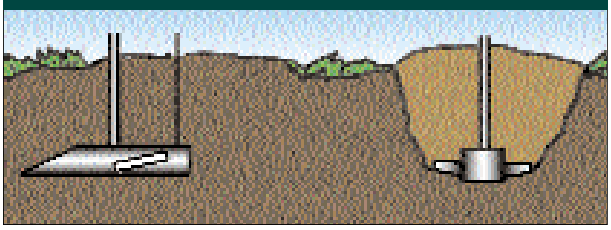
This deeper loosening can increase fissuring which improves aeration and infiltration of water, and creates a greater volume for the development of roots

These operations are carried out to encourage shatter when the subsoil is relatively dry, but not so dry that draught requirements become excessive.

Implements typically comprise a 2.5 cm thick leg with a 7.5 cm foot of low positive rake angle (25˚) to encourage penetration and brittle failure.

Commonly, wings are fitted to both sides of the foot to increase the volume of soil loosened by three to four times (Figure 11) with a corresponding increase in draught of only 20 to 30 %.

FIGURE 11: SUBSOILING

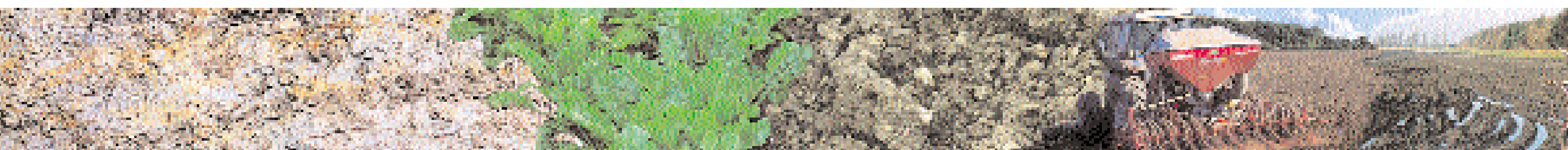


Again, shallow leading tines may be necessary to loosen the upper layers and therefore ensure that the operation is carried out above critical depth.

These operations should be undertaken only after thorough soil pit inspection to establish whether subsoiling of the whole field is beneficial. Targeting vulnerable areas within fields - for example, in gateways, short headlands and tramlines - is an alternative solution.

PLOUGH SUBSOILING

Mouldboard ploughing can produce a smearing and a compacted zone below plough depth. This can be alleviated using a small tine which extends 7.5 to 15 cm below the furrow bottom. This technique is effective when carried out under suitable conditions. The subsoil should be checked in pits before using the tine to ensure that it is suitably brittle.



REDUCED CULTIVATIONS

Minimal cultivations or direct drilling systems are options where soil conditions are suitable, the soil is structurally stable and stubble and weed disposal is not a problem.

Whereas ploughing and conventional cultivation are very forgiving systems, reduced tillage, though less demanding of time, does need a higher standard of timeliness and therefore patience.

Minimal cultivations or direct drilling systems are options where soil conditions are suitable, the soil is structurally stable and stubble and weed disposal is not a problem. It can also help improve soil structure by eliminating unnecessary loosening operations, which cause compaction or lead to moisture loss.

Trial show that reduced cultivations do not necessarily reduce yields and there is a potential saving in the establishment costs The choice of appropriate cultivation techniques and their cost implications is covered by the Soil Management Initiative brochure "A Guide To Managing Crop Establishment".

MEAN YIELD OF MINIMAL CULTIVATED CEREALS RELATIVE TO PLOUGHING

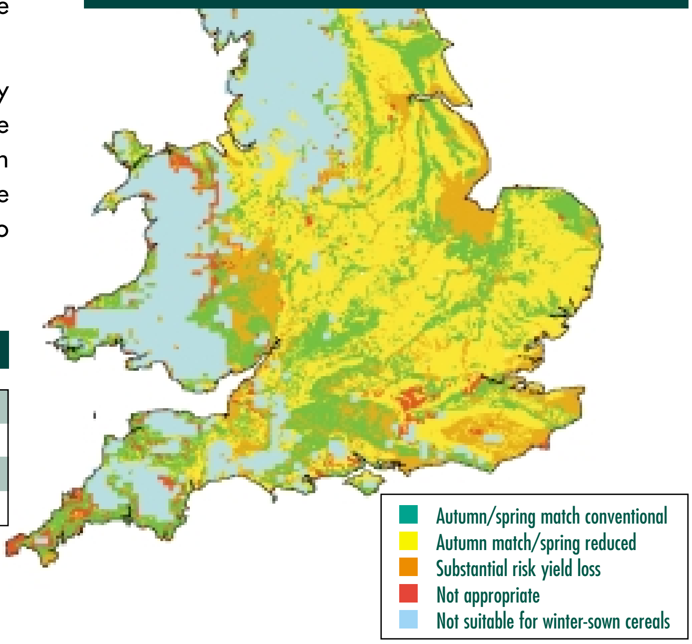
	Shallow cultivated	Direct drilled
Clays	101.5	101.3
Medium loams	100.8	99.2
Light loams and sands	101.3	98.8

(average yield after ploughing = 100)

In practice, the best cultivation approach for a given field is likely to include equipment from both systems in order to maintain timeliness. The map prepared by SSLRC (Figure 12) shows those areas where reduced tillage might succeed.

Minimal cultivation or direct drilling is best carried out on stable soils that maintain their structure throughout the season. Clays, silty clay loams or clay loams are often the best soils for such techniques. On sands and light loams and where topsoils contain many stones, these techniques are more difficult.

FIGURE 12: SUITABILITY FOR MINIMAL CULTIVATIONS



EARLY DRILLING

The trend towards earlier establishment of winter cereals in early September or even August can create structural problems or conversely offer opportunities to correct soil problems more effectively.

Cultivations carried out when the soil is in a relatively dry state will:

- reduce the risk of smearing
- provide better loosening at depth

They will however:

- need greater power to break clods
- render soils more vulnerable to slumping or re-compaction
- reduce soil moisture still further, compromising seed germination

It must be remembered that the most important day in the life of any crop is the day its seedbed is created. Forcing a seedbed in poor conditions purely as a means of getting a crop into the ground is usually a false economy. It is far better to wait until soil moisture conditions are right and, when early drilling, time may not be with you.

MAINTAINING SOIL STRUCTURE

POST CULTIVATION

Once a soil has been loosened, it is very vulnerable to compaction and can settle back into a worse state. To avoid this, keep trafficking to a minimum and use well-defined beds or tramlines, if feasible.

Secondary cultivations after subsoiling are particularly risky, so it will pay to leave as long a period as possible after deep loosening and subsequent cultivation operations to allow some natural stabilisation of the weakened soil.

TYRE SELECTION

Where possible, particularly when carrying out secondary cultivations, applying pre-season fertiliser and when drilling, use low ground pressure tyres or cage wheels.

In general, the more flexible the tyre carcass and the lower the inflation pressure, the lower the compaction.

IN-SEASON

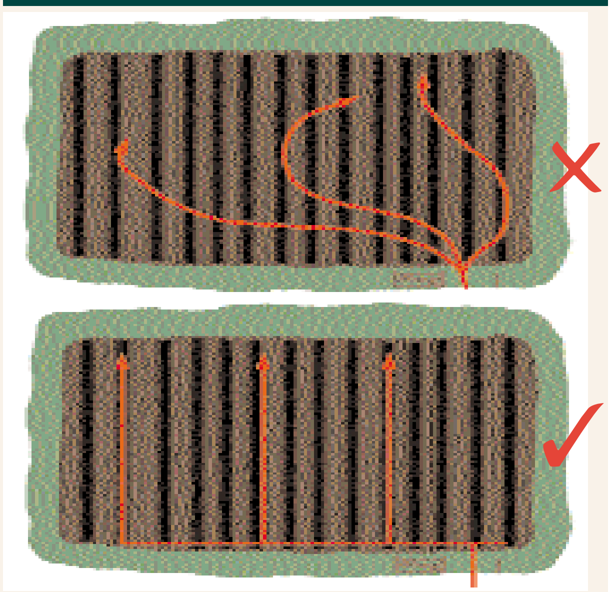
Minimise indiscriminate trafficking. Most arable and field vegetable crops will be grown using a bed or tramline system. This concentrates any compaction from agricultural machinery.

However, considerable damage can be done at harvest by tractors with laden trailers. In many cases these tractors and trailers can still run in existing tramlines where the soil has already been compacted by in-season spraying and fertiliser operations (Figure 13). Post-harvest, these areas can be corrected by using tines or subsoiler legs spaced directly behind the tractor tyres.

THE EFFECT OF PASSES ON COMPACTION

The first pass causes	50 % of compaction
Second	another 10 %
Third	a further 6 %
Fourth	a further 3 %

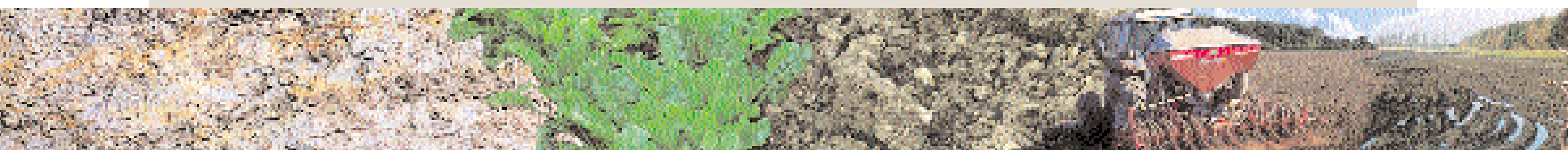
FIGURE 13: HARVEST TRAFFICKING



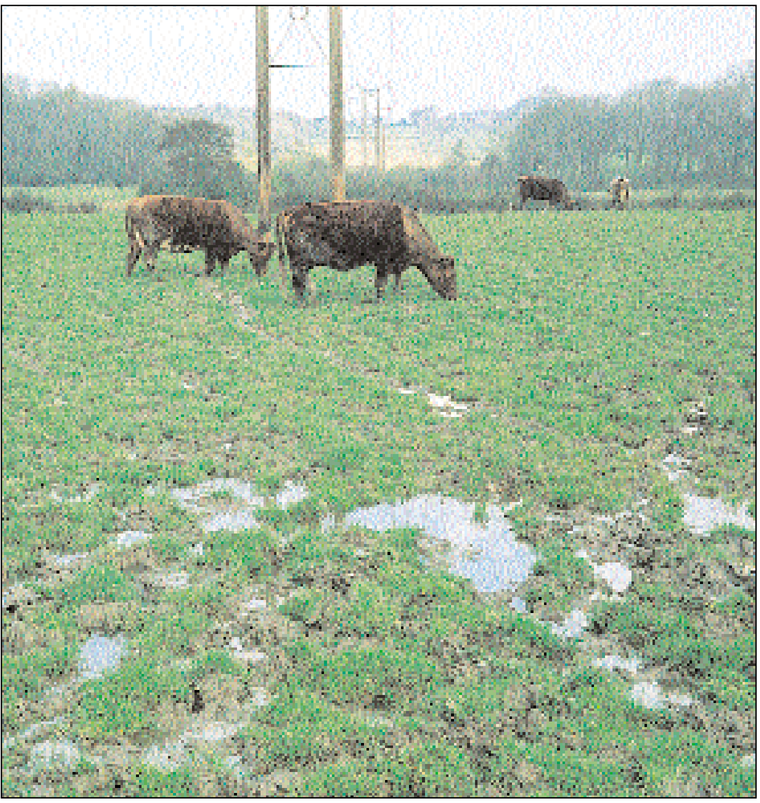
TIMELINESS

Minimise structural damage by timeliness of operations. Working soils when too wet should be avoided as far as possible. Sometimes, however, this is unavoidable. When damage is caused, it is important to recognise it and put it right as soon as possible.

Autumn-ploughed ground left to overwinter usually warms faster and is sown/drilled sooner in the spring, so yields are usually greater. Spring-ploughed ground is often cloddier, with the result that germination, emergence and herbicide action may be compromised.



SOIL STRUCTURE UNDER GRASSLAND



Grassland soils are generally well-structured. Strong root development encourages a stable soil.

Most damage is done by poaching - the compaction of soil by hooves of stock, leaving depressions which can be 10 to 12 cm deep and form an almost continuous layer of grey anaerobic soil. Ill-timed traffic by slurry spreaders and silage harvesting can also contribute to damage.

The extent of the damage relates to the rainfall, existing soil condition and the timing and density of grazing.

Poaching reduces subsequent grass growth and provides sites for weeds to occupy. It also increases soil permeability and waterlogging.

Shallow loosening - when the soil is dry enough - is the one method of correction. In severe cases, ploughing and re-seeding may be needed.

In wetter areas, shallow moling below the depth of the compaction may be possible. There is an increase in structural damage under grass due to winter grazing by sheep. Because this damage is shallow, there is some prospect of natural improvement. The real solution is proper management and sustainable stocking rates.

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