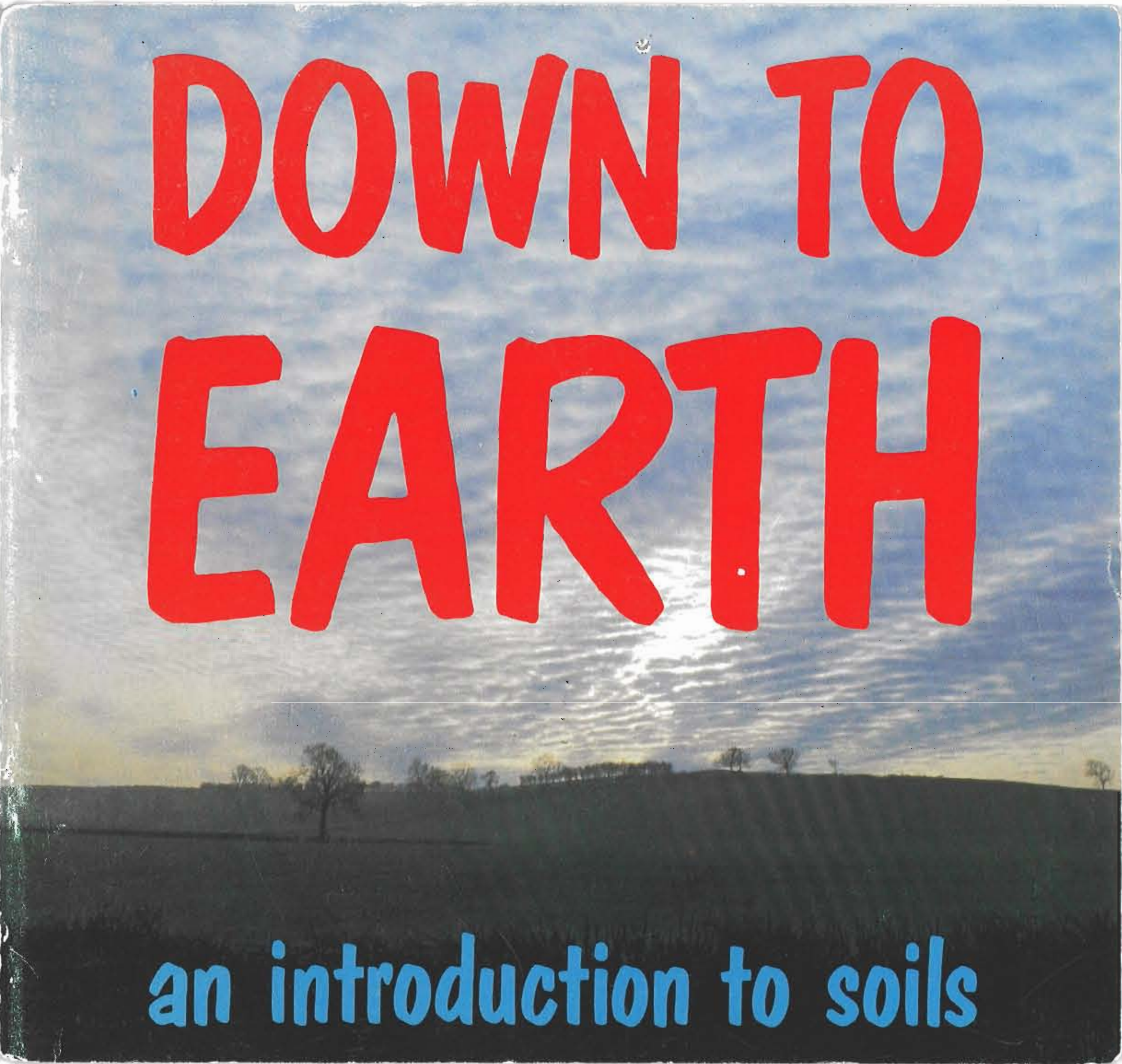
DOWN TO EARTH



an introduction to soils

DOWN TO EARTH

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FOREWORD
by
David Bellamy

Living soil! It is the Earth's most precious resource. Why, that's how the planet got its name. Not that the sea is unimportant, for it is the source of both the rain which waters the dry continents and also the process of creative evolution which clothed the land in a mantle of living green. Without soil, however, there would be little or no life on land, and without land life there would be no soil.

The word 'Earth' conjures up something very special – the blue-green spaceship on which we live, or in its more limited meaning, the cool, soft, damp, brown-red, infinitely variable substance which covers the alien harshness of bare rock and nurtures the roots of the smallest herbs and the mightiest trees.

Go out! It is there in the garden or in the park. Take up a handful of good earth, feel its texture, sense the myriad of life within, and replace it with all the care that our most precious and important natural resource deserves.

Now wash your hands. It is a pity that a synonym for soil is 'dirt', a word which conjures up the idea of soiling the most dextrous of hands and the ablest of minds, those two attributes which have set us aside from all the other products of creative evolution. The pioneers who first opened the potential of the cereal belt of North America were the first to call it 'dirt' – ironically, these 'dirt' farmers soiled its image and theirs. It was their pioneer success which made it blow away. Soil regarded as 'dirt' thus became dust, and bankrupt farmers had to move out to the promise of untouched soils in pastures new.

Yet human minds are as fickle as the seasons through which the farmer tries to maintain his crop. In the last fifty years the world, which depends on those same soils for its daily bread, pasta and corn, has forgotten the lessons of the dust bowls – has once more made soil a dirty word and is now hell bent on its destruction, and hence upon the annihilation of life on Earth. Every minute the world loses 150 acres of forest, and with the trees go much of the soils, washed away to choke and clog rivers and estuaries with mineral silt. Today soil erosion and degradation is more widespread than ever. More than one third of the Earth's arable land is at risk of becoming a desert, because of human misuse of soil.

All this adds up to the appalling statistic that ON AVERAGE EVERY ACRE OF THE WORLD'S LAND SURFACE LOSES 8 TONS OF SOIL PER YEAR, WHILE THE MAXIMUM RATE OF SOIL FORMATION IS ONLY 5 TONS PER ACRE PER YEAR. This is crass stupidity, international vandalism, 'resourcicide', call it what you will, and it cannot be allowed to go on.

Yes, we are killing the living mantle of the Earth that feeds us. There is, however, one bright light, one ray of hope at the end of this dark tunnel – soil is living and it is a slowly renewable resource. The more people who understand this fact and know about soil and its importance, the quicker will this ultimate stupidity be stopped. "KNOW ABOUT SOIL? BUT SOIL IS BORING." Whoever said that, please read this book and take in the Down to Earth exhibition. I think that you are going to find it one of the most fascinating subjects on Earth.

David Bellamy
Bedburn, December 1983.

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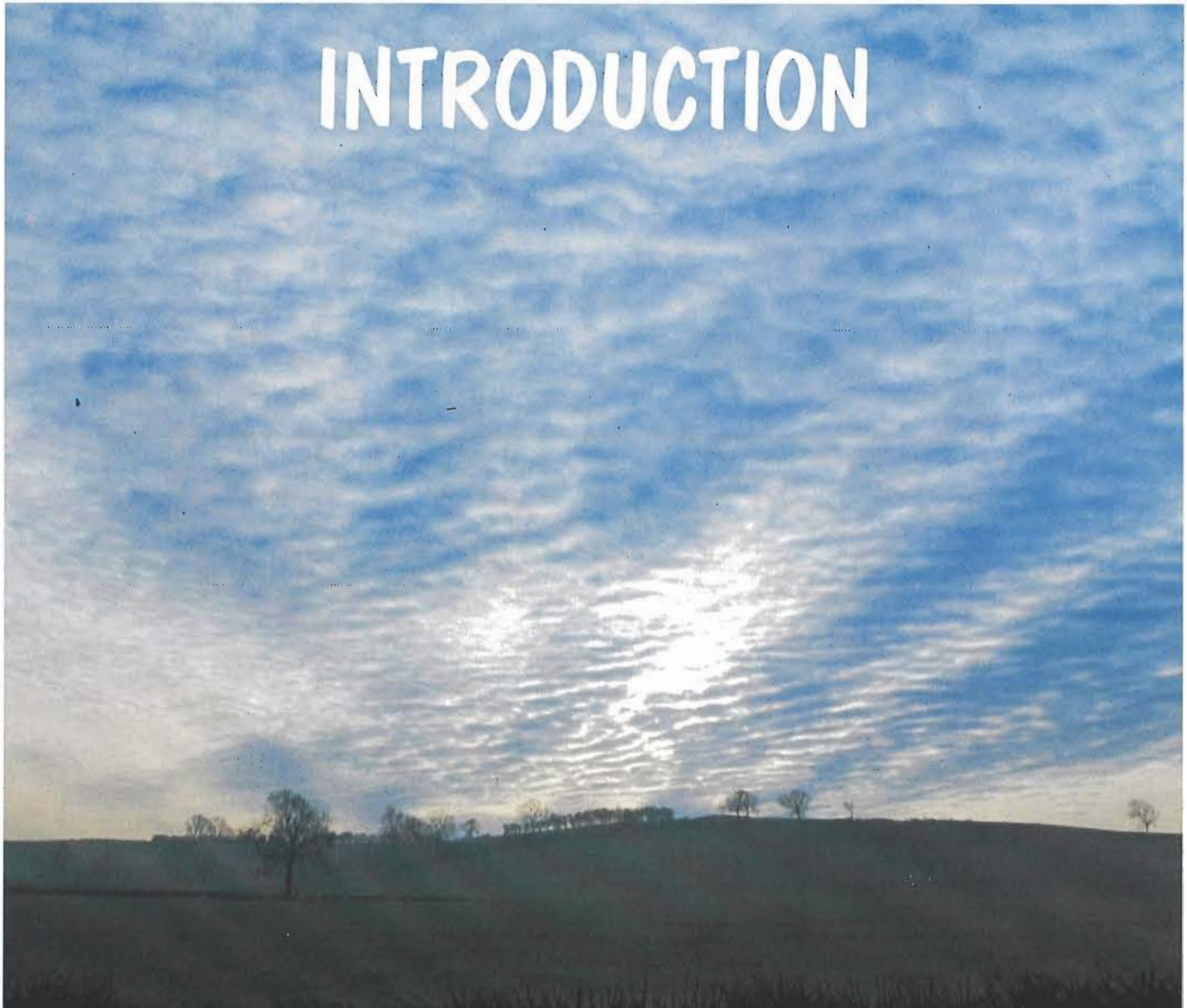
INTRODUCTION



Soil is essential for many of man's activities. It is also a basic part of the natural environment. The development of man since Stone Age times has been closely linked with a growing ability to manage the soil.

Soil, together with the plant life it supports, the rock on which it lies, and the climate it experiences, forms a finely balanced natural system. We first began to adjust this balance in our favour by changing the vegetation – by felling trees to clear patches of land for cultivation, and by burning grass and shrubland to encourage new growth which fed grazing animals. In time, man learnt to make small environmental changes by diverting rivers, saving water in ponds, or building small dams to supply the soil with water during periods of drought; and more recently by planting shelterbelts of trees to prevent the soil being blown away.

At an early stage in man's cultivation of the soil, areas of land were cleared of natural vegetation and cultivated for a short time. Once exhausted, the site was abandoned and left to revert slowly to the original vegetation, while cultivation shifted to a newly cleared site. The development of stable societies and an increasing population encouraged cultivation to continue at one place for longer periods. Some method had to be found to replenish the soil, so that it could continue to support crops. One approach involved leaving the soil uncultivated for a number of years, allowing it to replenish its store of plant nutrients naturally. Another approach required the addition of organic waste from the household or animals directly on to the soil; this remained the normal method until relatively recent times, but the past century has seen it eclipsed by the development of inorganic fertilizers. At first, these consisted simply of ground up rock material (in some cases treated by simple chemical processes). However, in the last thirty years or so there has been an enormous development in the range of inorganic fertilizers, offering a wide variety of plant nutrient inputs. It is now possible to alter the nutrient supply from fertilizers on the basis of information concerning the type of crop to be grown, and what was previously grown at that location.

Mankind cannot survive without the soil. Soil produces our food and many of the fibres for our clothing, while providing a base for our homes and for many other activities. Yet in spite of this dependence, we often treat soil as if it were an inexhaustible resource which needs no caring for. This 'taking the soil for granted' has led, in both the past and present, to catastrophic effects. The soil is *not* an unlimited resource, to be wasted by poor or inappropriate use. Every effort is needed to make successful and sustainable use of the soil. It is foolish to destroy, in a few years of ill use, a soil which has developed naturally over hundreds, thousands or even millions of years. This is by no means an argument against *all* development of the soil, but successful development of the land must take account of the nature of the soil – be it for growing crops, animals or trees; for building; or for extraction of rocks and minerals from beneath the soil. Following the extraction of coal, gravel, limestone, etc., it is essential that restoration is undertaken, including that of the soil to its pre-extraction state.

Mankind's developing use of the soil is often recorded below or within the soil itself, in the form of archaeological remains.

Soil is a vital component of the natural environment. The manner in which it has developed, and is still developing, must be understood if we aim to minimise its destruction and maintain it for future generations. Without an uncontaminated soil, life in the manner we know it is unsustainable.

WHAT IS SOIL?

Different things to different people

Depending upon the context, the word 'soil' may have very different meanings. A simple definition of soil is: the material that plants grow in, and which provides them with physical support and nutrients. There are other more particular views of soil. To the engineer, soil is the finely divided and relatively loose 'rock' material at the Earth's surface (often called 'overburden' and considered an inconvenience because it has to be removed). The geologist calls this layer the 'regolith', and he frequently begins his investigations below it. The hydrologist looks on the soil as if it were a large 'sponge' storing water to supply streams and rivers. The farmer and gardener often think of the soil simply as the top few centimetres -- the depth of ploughing or cultivating for the farmer, and a spade or garden fork depth for the gardener. There is a tendency to disregard what is below this top layer.

Scientists who work with the soil examine it in very different ways. The soil surveyor in the field looks at a deep section of the soil in the hole he has just dug; the soil chemist takes a small soil sample and mixes it with chemicals to determine its chemical make up; and the soil microbiologist takes a very small soil sample and looks at the microbial life it contains.

Digging a hole – the soil profile

What many people see of the soil is simply the surface of the land. They may see a little more if the soil has been recently ploughed or cultivated, but generally people see only the topsoil. If you dig through the topsoil, down to the upper part of the underlying rock, you expose a cross section of the soil. This is called the **soil profile.**

A soil profile often has a number of distinct layers within it. These layers are known as **horizons.** It is possible to make many subdivisions and classifications of soil by using these horizons, but a simple threefold division, into **topsoil, subsoil** and **parent material,** is sufficient here (Fig. 1).

Topsoil, as the name suggests, is the material at the top of the soil profile. It is usually coloured dark brown or black. The topsoil may simply consist of rock material that has been chemically and physically broken down and changed, and well mixed with the decomposed remains of plants. There may also be a layer at the surface of fresh plant litter which has yet to be incorporated into the soil. The topsoil is that part of the soil most affected by the activities of living things. Most roots are found in this layer, together with abundant plant and animal life, from the larger animals such as moles and earthworms, to the microscopic bacteria and fungi.

Subsoil consists chiefly of altered rock fragments. It contains very little plant material, although live roots and some soil plant and animal life occur. Within the subsoil, mineral materials are actively broken down and altered, plant nutrients are released, and the size of the soil particles altered. Soil material which has been transported from the topsoil may accumulate here. Considerable reorganisation of soil material may also occur in the subsoil. This reorganisation may involve the binding together of soil particles to form aggregates, which can often be seen when the subsoil is exposed.

Parent material is the material from which the soil has developed, and generally consists of almost unaltered rock. The original nature of the rock is clearly seen. This zone of the soil is least affected by soil forming processes. The depth at which the parent material occurs depends very much upon the nature of the underlying rock (i.e. the ease with which it can be broken down and altered), as well as the length of time during which soil formation has been taking place.

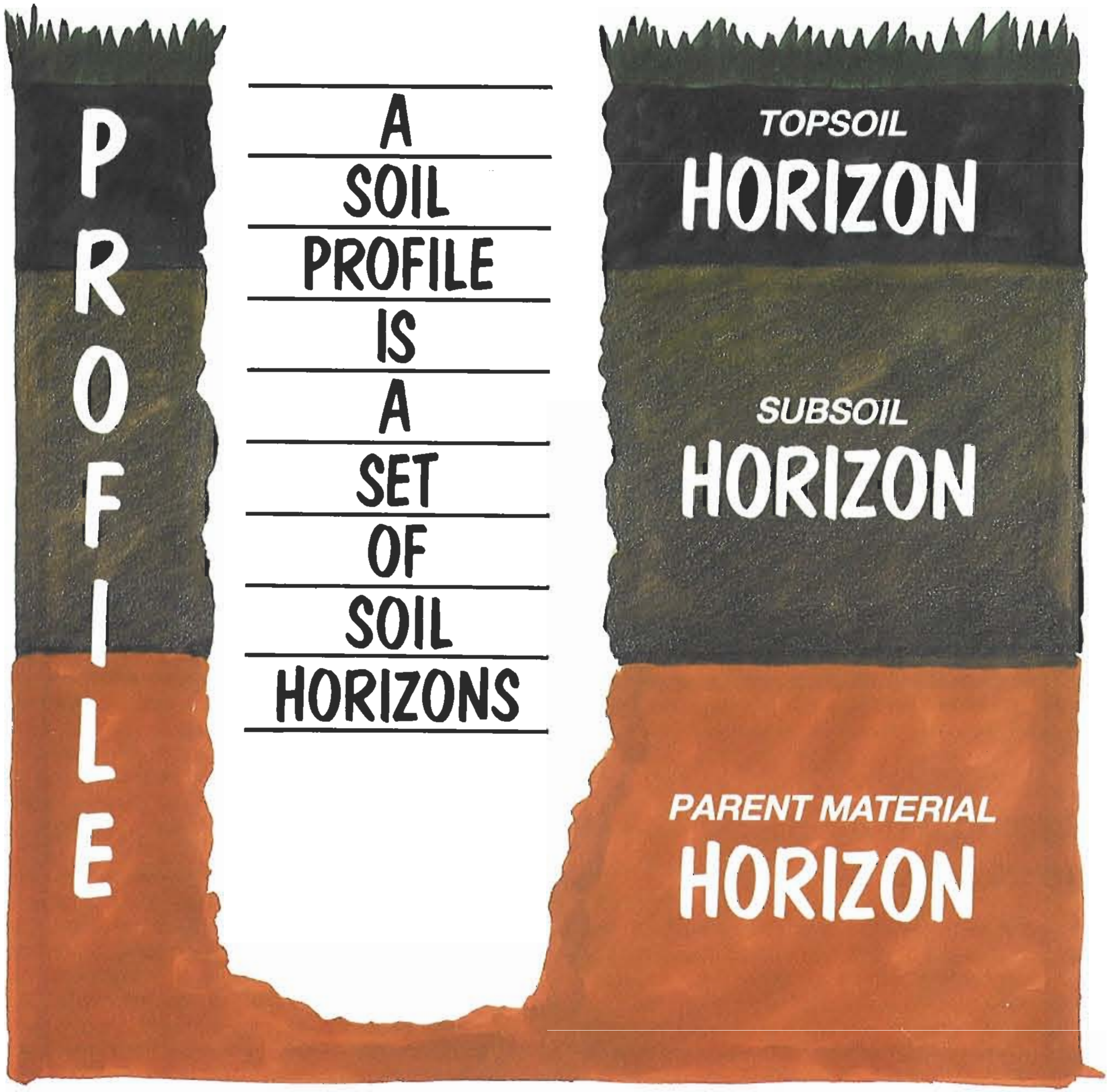
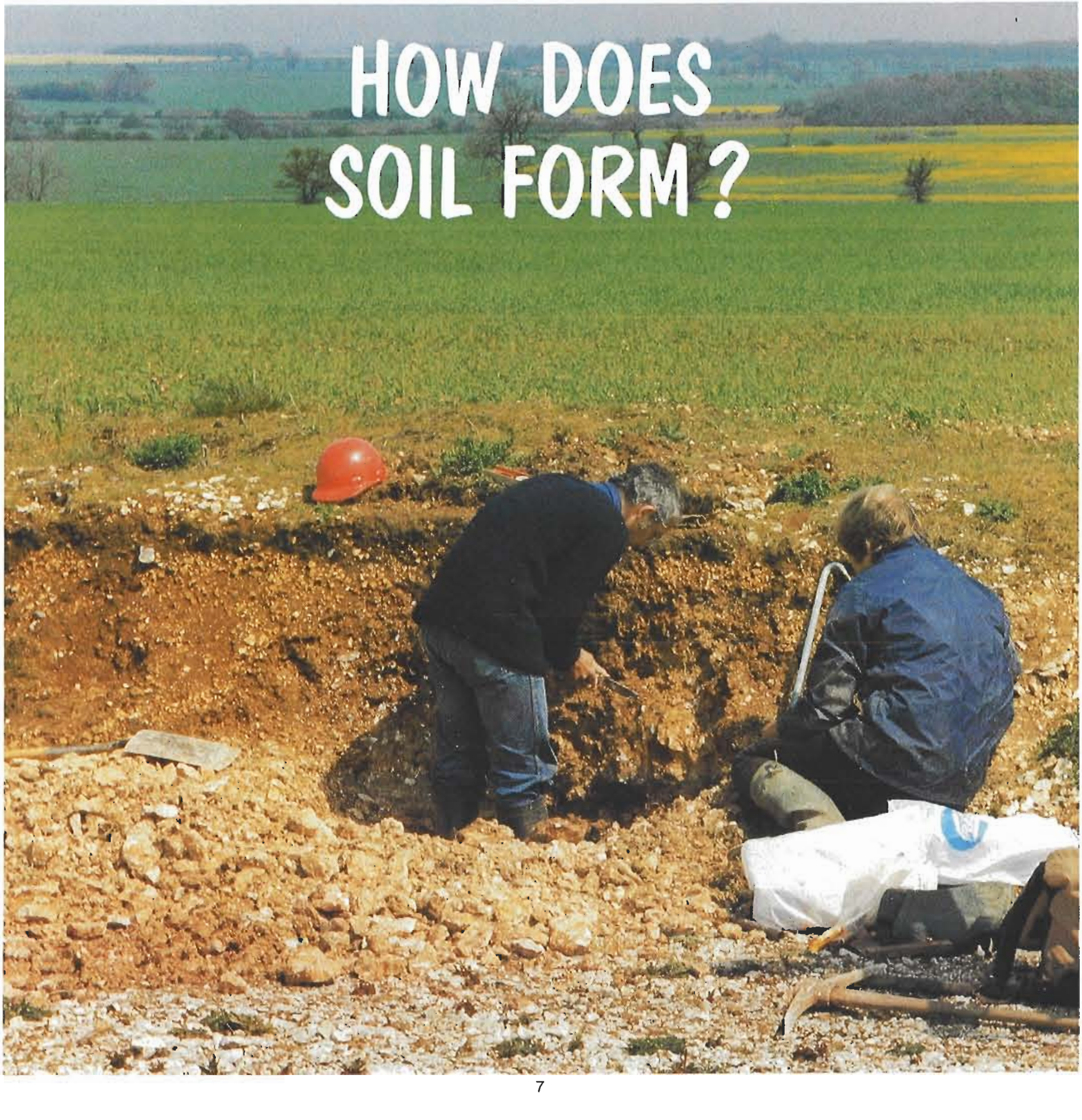


Fig. 1 . Soil profile – summary diagram.

HOW DOES SOIL FORM?



Many processes

An enormous range of very different soil profiles have been described (e.g. Figs. 2, 3). They are produced by many different soil processes operating at different rates and in different combinations. Despite the diversity of processes involved, it is possible to consider many of them under one broad heading: **percolation of water through the soil profile.**

Water is chiefly held within the soil profile in holes and cracks of varying sizes; some of very small diameter are full of water under most normal conditions, other larger holes and cracks become filled as water percolates through the soil after rainfall. This water is held within the holes and cracks and slowly taken up by plant roots. The largest holes and cracks are full of water only briefly as water begins to percolate through the soil after rainfall. They enable water to pass through the soil and drain away.

Water is the key to the development of soil and soil profiles. It has a role to play at every stage of the process.

When rock is weathered

When fresh rock is first exposed at the surface of the earth there is no soil. Soil is produced by the physical and chemical change of rock. The processes creating this change are known as **weathering,** and may be considered under two broad headings: **physical weathering** and **chemical weathering.**

Physical weathering involves the mechanical disintegration of rock; there is very little or no chemical change in the nature of the rock material. This physical breakdown takes place due to internal stresses, caused for example by the expansion and contraction of rock at extreme temperatures. At the high daytime temperatures reached in hot deserts, rock expands; as the temperature falls at night, rock contracts. If the cycle of high and low temperatures is repeated over long periods, the stresses produced by expansion and contraction may lead to the physical disintegration of the rock.

Water plays a significant role in the disintegration of rock in cold climates, as a result of freeze-thaw cycles. Ice occupies about 10% more volume than its liquid equivalent, so water freezing in a confined space will tend to force rock fragments apart. If freezing and thawing is repeated many times, the rock can be broken into fragments. Another form of mechanical breakdown associated with cold climates occurs beneath glaciers and ice sheets, where rock is ground down by the debris transported in the base of the ice. This action has been compared to that of sandpaper. The physical weathering associated with cold climates may have had an important role to play in the development of British soils. During the last Ice Age, Britain was subject to conditions under which these 'cold climate' physical weathering processes operated.

Chemical weathering involves changes in the chemical make up of the rock, chiefly due to the action of weak acids. A major product of chemical weathering is the group of minerals known as **clays;** these greatly affect the nature and properties of the resulting soil.

When life grows on and in the weathered rock

Weathering and soil development are hastened by the appearance of simple plants on the surface of the bare rock, or on weathered debris. These plants, which include lichens and mosses, are able to store the sun's radiant energy; lichens, for example, 'fix' atmospheric nitrogen and incorporate it as plant protein. When these plants die, they return a variety of organic materials to the surface of the weathered rock – this is

Fig. 2. Soil profile from South Thoresby, Lincolnshire.

TOPSOIL
A thin topsoil lies directly on calcareous parent material (this type of soil is called a **rendzina**). It is dark, contains a reasonable amount of organic matter, is friable and easily cultivated.

PARENT MATERIAL
This is deeply weathered, well drained Chalk rubble. It was affected by periglacial conditions during the last Ice Age, and has wind blown silt incorporated into it.

Soil profiles are illustrated at approximately one tenth natural size.

Fig. 3. Soil profile from Howden Reservoir, Derbyshire.

TOPSOIL AND SUBSOIL
Very little soil has developed on this steeply sloping site. Organic material has accumulated at the surface and includes some undecomposed vegetation.

PARENT MATERIAL
This mixture of relatively unweathered pieces of rock is called 'head'. It was formed under periglacial conditions during the last Ice Age.

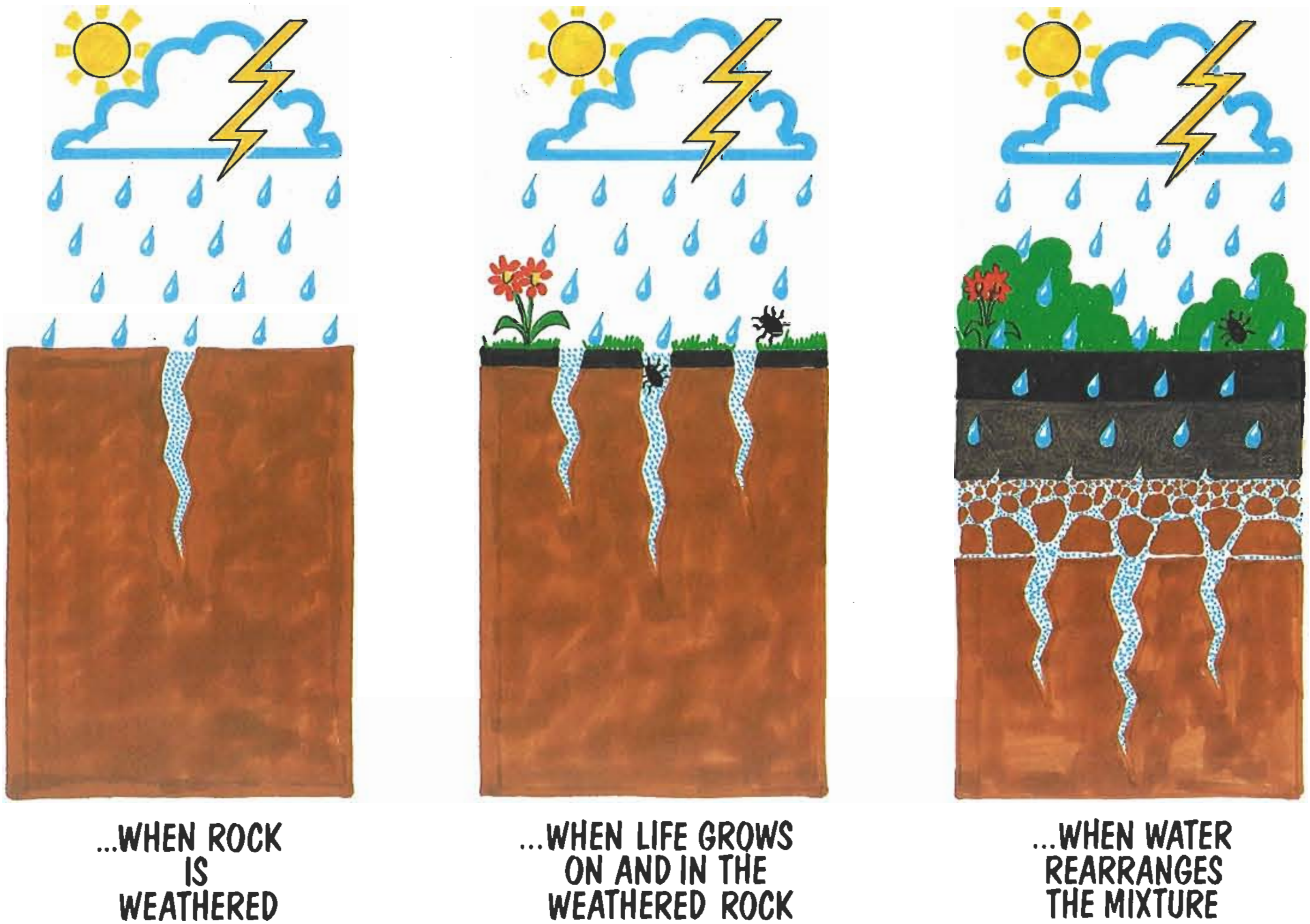


Fig. 4. Soil formation – summary diagram.

the first soil material. By returning organic material to the surface, these first colonisers of the rock provide both nourishment and a 'foothold' for a succession of plants and organisms – from lichens and mosses, through grasses and shrubs, and eventually to trees. This is the beginning of the organic cycle, which gives soil many of its distinctive characteristics. Its importance is not just in the addition of plant material to the soil; there is also a large population of soil organisms (including earthworms, centipedes, fungi and bacteria) which help break down material for incorporation with the weathered minerals. The biological activity of plants, in particular their roots penetrating into the underlying rock and forcing it apart, means that some physical processes of disintegration may also be described under the broad heading of **biological weathering.**

Soil is a dynamic component of the environment, and soil development is a continuous process, operating at various rates during the different stages. Soils are subject to more or less continuous weathering and erosion, and the eroded materials eventually form the parent material for future soil development. Conversely, rock hitherto buried beyond the reach of weathering processes, when exposed at the surface will also form the parent material of future soils.

When water rearranges the mixture

We have seen that water has a role to play in creating the material within which the soil may develop. It is also a major factor in bringing about the rearrangement of weathered material, producing the distinctive soil profiles referred to earlier. Rearrangement takes place chiefly via the transfer of material by water through the soil profile. Most transfers are vertical, upwards and downwards. Only when the soil is considered as part of a landscape do horizontal movements become an important consideration. Upward movement is mainly biological and results from the uptake of water and nutrients by plants. Downward movement of water, bearing materials in suspension or solution, is the key to how soil profiles develop. The amount and speed of water flow through the soil determines both the rate at which the products of weathering are removed and, in part, the nature of the resulting soil.

There are soils where the profile evidence for the transfer of soil constituents is clear. Such a soil is the **podzol** in Fig. 5. In their natural environment in Britain, podzols often occur under heather or coniferous woodland, on sandy, freely draining, parent materials. They have a very distinctive profile which can be divided into four broad zones from the surface downwards.

1. organic material at the surface
2. white or grey 'bleached' layer
3. black or dark-red layer
4. little altered parent material

The second and third zones must be considered together, for it is here that the effects of the downward transfer of soil material by water are clearly seen. The second zone consists chiefly of bleached sand grains (that is, sand grains from which the surface coatings have been removed). In contrast, the third zone often appears to consist of coated sand grains cemented together by black organic materials and/or red-brown iron rich materials. The fourth zone is the little altered parent material from which the soil has developed.

The soil forming process responsible for this type of profile involves the transfer, by percolating water, of iron, aluminium and organic matter from the second zone of its deposition in the third zone. This process produces one of the most visually distinctive soil profiles to be seen in Britain, but there are others involving the transfer of materials by percolating water which are often not so clearly visible.

Fig. 5. Soil profile from Clipstone Forest, Nottinghamshire.

TOPSOIL
Immediately below the near surface humus, a dark horizon contains a matt of grass roots. These roots do not generally penetrate the lighter 'bleached' horizon below. Rainwater, charged with organic compounds from the humus layer, has removed iron, aluminium, and organic matter from this bleached horizon.

SUBSOIL
Hard cemented layers at the top of the subsoil are formed by redeposition of the organic matter (dark layer), and the iron and aluminium (red-brown layer) originating from the overlying bleached horizon. Below these cemented layers, the brown sandy subsoil becomes paler with depth as less iron is deposited by percolating water.

The lower half of the subsoil shows clear stratification and little evidence of disturbance by plant roots. Stratification is enhanced by redder bands of clay washed down from higher up the profile.

No unaltered parent material is visible in this deep soil.

British soils a special case

As we have already seen, rock at the surface of the earth is subject to decay and disintegration, and eventually a soil develops in this material. This covering of weathered rock at the earth's surface is known as the **regolith.** In certain environments (e.g. parts of the tropics), the processes of rock weathering have proceeded unhindered for thousands and maybe millions of years. Under these circumstances, the regolith may be as much as 100m thick. Soils, of course, develop only in the upper part.

Once the rock material has been weathered, however, it may remain in place as a deep regolith, or it may be transported by water, wind or ice and deposited elsewhere. In some cases the transported material is destined to become part of a new generation of sedimentary rocks, through the action of geological processes over millions of years. When eventually exposed once again on the surface of the earth, these in turn weather to form a regolith. In other cases, the transported material will be subject to soil forming processes immediately.

This latter situation occurs in much of Britain, where soil development does not take place directly on the underlying solid rock, but on a carpet of materials of wide ranging composition and size, which has been weathered, transported and reweathered (Fig. 6). This is a direct result of the fact that, until about ten thousand years ago and for periods during the previous one million years, much of Britain was in the grip of an Ice Age and covered by ice sheets. Those areas which were not buried beneath the ice were greatly affected by the cold climate. During this time ice sheets carried away much of the previous soil cover and regolith, mixed it with material from other sources, and deposited the mixture as a covering (of variable thickness) over the landscape. In addition to this covering of **glacial drift,** thin layers (less than one metre thick) of wind blown silt and sand-size material often covered much of the landscape, particularly in southern and eastern Britain. Once these materials

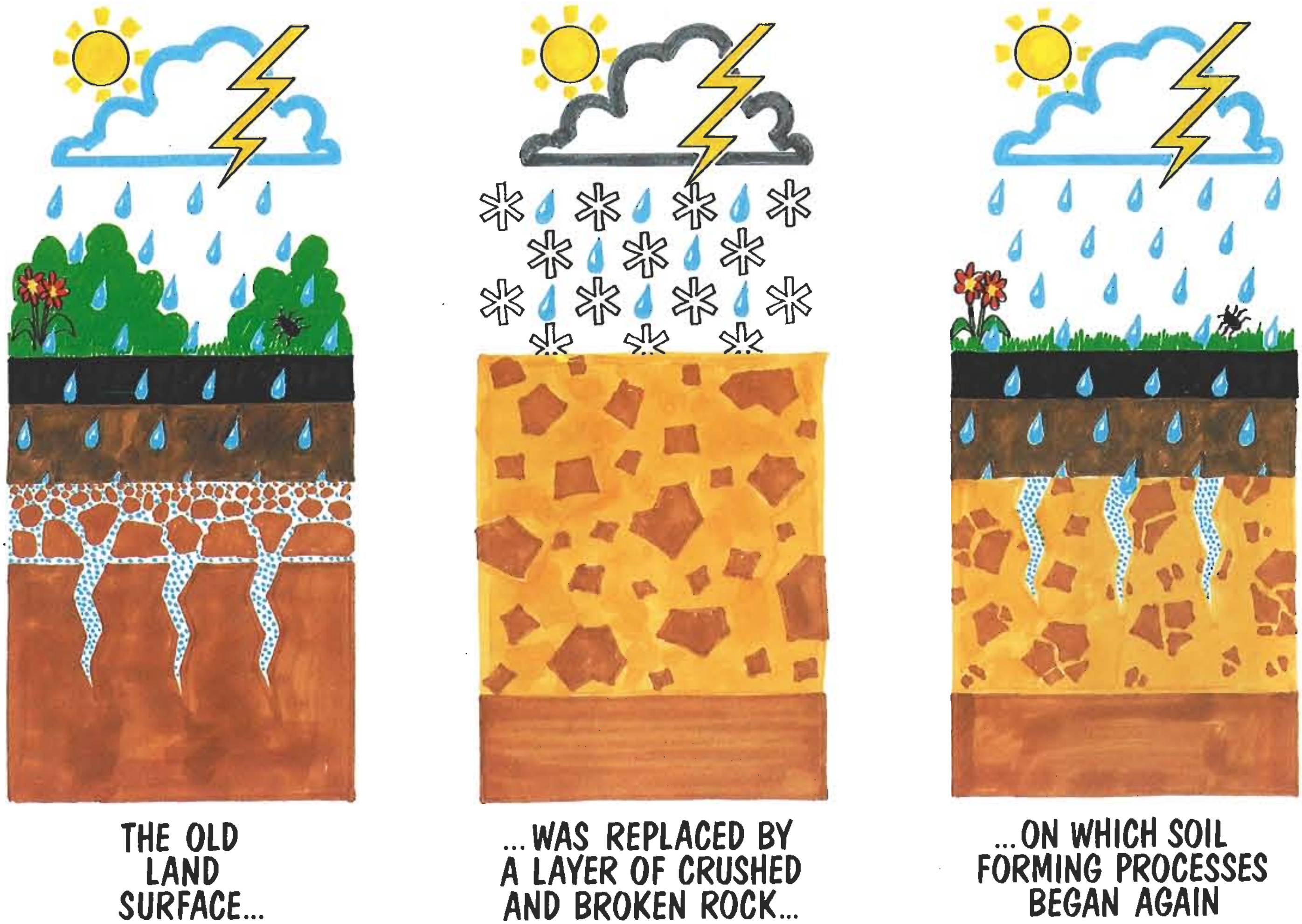
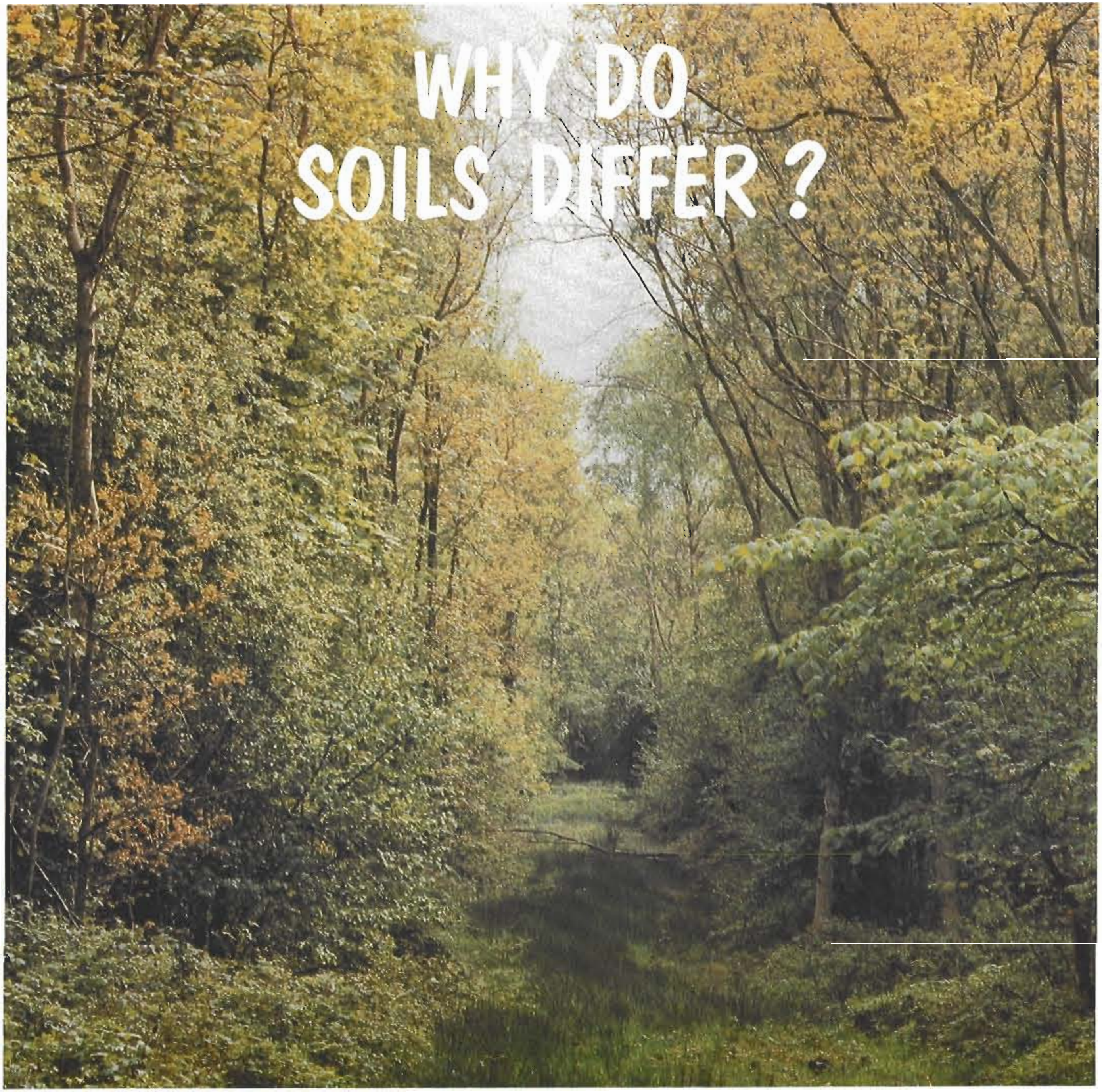


Fig. 6. Soil formation on glacial drift – summary diagram.

were exposed, soil forming processes again began to reorganise them into the distinctive zones of topsoil and subsoil.

In those areas not covered directly by ice, but nevertheless affected by the cold conditions, much of the soil was moved down the valley sides and deposited in the valley floors. This local reorganisation of material meant that soil development in the valley floors occurred in thick deposits, while on the valley slopes soils developed on freshly exposed parent materials, or in materials which formed the subsoil of the previous soil cover.

Because of these associated processes of deposition and local reworking, much of the material within which our present soils are developing occurs as thin coverings of glacial drift over relatively unaltered rock.


WHY DO
SOILS DIFFER ?

Soil forming factors

Soil is only one part of the natural environment, and it interacts with other components. The wide variety of possible interactions is responsible for the large number of soil types found. In considering which components of the environment exert a major influence on the nature and distribution of soils, it is possible to isolate four major factors:

1. **parent material**
2. **climate**
3. **terrain**
4. **plants**

It is important to take account of how long these interactions have been taking place, hence **time** may be considered as a fifth factor.

Parent material

Parent material strongly influences the soil and its properties, particularly during the early stages of soil development. For example, the weathering of a coarse sandstone parent material produces a well-drained, coarse sandy soil. In contrast, a shale parent material generally weathers to give a fine textured soil, which may allow water to flow through it only very slowly.

A distinctive influence is that associated with a parent material like chalk or limestone (predominantly calcium carbonate and therefore easily soluble). When it is weathered, what remains is often only a very small mass, and consequently the soils are often shallow with an organic topsoil directly overlying weathered parent material (Fig. 2).

Climate

Climate is another important factor to consider in relation to soil formation. On a world scale there are broad climatic regions, and it has become traditional to distinguish complementary soil and vegetation regions which often extend latitudinally across the globe. On a smaller scale, climate remains of fundamental importance, and even in Britain soil variations occur because of differences in temperature and rainfall. At this level, the major climatic influence on soil development is probably rainfall. Rainfall is the major source of soil water and, as we have seen, the presence of water and its percolation through the soil is essential for soil to be formed. In a soil which allows rapid percolation, a high annual rainfall produces a substantial throughput of water, and hence a substantial potential for moving material from one part of the soil to another. Much of this water drains freely out of the soil and through the material below, taking with it dissolved or suspended material. This process is termed **leaching.** Climate also has a marked influence on soils developed in materials of low permeability. When rainfall is large, such soils are likely to become waterlogged.

It is possible to group the climatic effect on soil development in Britain under two broad geographical regions:

1. **North and west Britain.** Soils either have high rates of water percolation, which promote leaching, or are waterlogged for a large part of the year.
2. **South and east Britain.** Water percolation is less and waterlogged soils are less common.

Terrain

Terrain influences soil development in a rather complex way, reflecting both the varying conditions of drainage and waterflow within the landscape, and the patterns of erosion and deposition. Taking an idealised landform developing on one uniform parent material,

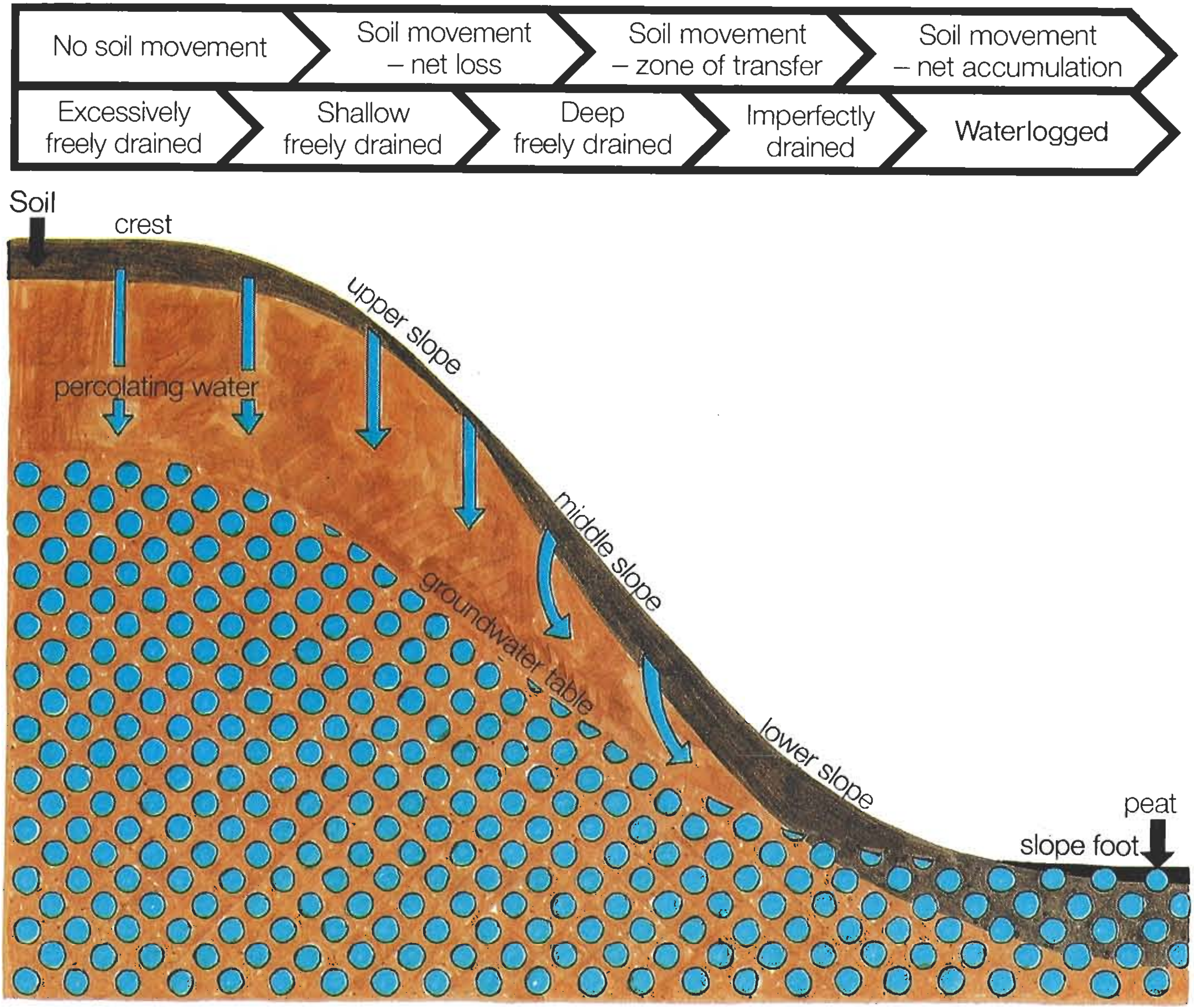


Fig. 7. Variation of soil with terrain.

the sequence of soils across that landscape reflects the varying conditions of soil moisture and drainage at each site (Fig. 7).

On the flat crest, the soil is well above the water table so water percolates rapidly to give a soil which is **excessively freely drained.** Moving downslope from the crest, over the upper slope convexity, the water table moves closer to the surface, but drainage is enhanced by lateral flow, either over or through the soil; these soils are typically **freely drained.** This convex part of the slope may also be subject to soil erosion, and consequently the soils may be shallow. Further downhill, on the middle and lower slopes, the soil is again influenced by both vertical and lateral movements of water; but this is an area where material eroded from upslope accumulates, so the soils are deeper and freely drained. At the slope foot, the water table is likely to be close to the surface, and there is little gradient to promote lateral flow; vertical percolation becomes restricted and the soil may be waterlogged for part or all of its depth. Valley soils are often deep because of the accumulation of eroded material, and they can often be **waterlogged**. In some circumstances the flat valley floor soil may be sufficiently wet to lead to the formation of peat.

Plants

Plants have a twofold influence on soil development: they take up and cycle plant nutrients, and they add organic material to the soil surface.

Time

Time is often difficult to establish as an independent influence on soil development. Nevertheless, the time during which the foregoing factors have been interacting to produce soils will be reflected in the nature of the soils developed. It is often suggested that the influence of parent material is greatest during the earliest stages of soil development, but that with time climate may become dominant. Since most soils in Britain have developed since the end of the last Ice Age (about 10,000 years ago), it is important to ask how well developed are they, and how might they change in the future?

HOW DO SOILS DIFFER ?

Given the complex interactions between the soil forming factors, it is not surprising that such an enormous range of soils exist in Britain. Within this range, it is possible to make a fundamental division between **well drained soils** and **waterlogged soils**.

Well drained soils

Rainfall arriving at the surface of a well drained soil percolates rapidly through it, and often carries soluble soil constituents which may be transferred from one part of the soil to another, or completely removed. If the process of removal has been operating for long enough, the soil is described as leached. The rate at which a leached condition is attained will depend on the nature of the parent material; in sandy soils it may occur rapidly.

The podzol in Fig. 5 is a well drained soil, developing on a sandy parent material under coniferous woodland. Within the upper part of the profile a distinctive grey 'bleached' horizon is clearly visible. A black layer underneath is followed by a dark brown layer – evidence for rapid percolation of water through the profile, and leaching. Organic matter and iron is removed from the bleached layer and deposited in the two layers beneath: organic matter in the top layer and iron below. It is interesting to note that the material is not uniform sand, but has bands of clay within it.

Waterlogged soils

Many soils are affected by waterlogging periodically and for varying lengths of time. The cause of waterlogging may be a high ground water table, slow percolation of rainfall through the soil, or both. The characteristic features of waterlogged soils are predominantly grey and bluish-grey colours in the zone of permanent waterlogging, and a patchwork of grey and bluish-grey colours together with orange or yellow colours (this patterning is known as **mottling**) in the zone where waterlogging occurs for part of the year, or for short periods throughout the year.

The most extensive waterlogged or seasonally waterlogged soils are **gley** soils. Soils affected by a high ground water table are **ground water gley soils** (e.g. Fig. 8), those with slow or inhibited percolation of rainfall through the soil are **surface water gley soils** (e.g. Fig. 9).

Soil texture

Soil is made up of a range of mineral particles, in some cases intimately mixed with organic particles. These mineral particles are of a wide range of sizes, but are normally divided into three broad groups called **sand** (2mm to 0.06mm diameter), **silt** (0.06mm to 0.002mm diameter) and **clay** (less than 0.002mm diameter). The feel of the soil when handled depends to a great extent on the relative proportions of sand, slit and clay. The feel of the soil is generally described as **soil texture.**

Sandy soils feel **gritty;** the coarser particles can be clearly seen and look like sandpaper. A moistened **silty soil** feels smooth and rather **soapy.** A **clayey soil** has a large proportion of clay size particles and feels **sticky.** These three categories – sandy, silty and clayey – are just the broad textural classes. Finer subdivisions are made to take account of soils with different mixtures of sand, silt and clay. For example, a soil described as having a **sandy clay loam** texture will have approximately 57% sand, 18% silt and 25% clay.

Soil texture refers only to how soils *feel* to the touch. Soils of the same texture may *look* very different. Alternatively soils may look very similar but have

Fig. 8. Soil profile from Cossington, Leicestershire.

Topsoil, subsoil and parent material are difficult to distinguish. The entire profile is developed in alluvium, deposited on the flood plain of the River Soar. The generally grey colouration indicates waterlogging throughout the profile, caused by a ground water table which reaches almost to the soil surface for much of the year (rising above the surface during winter floods).

An ancient soil is visible as a faint dark band near the bottom of the profile. This became buried by more recent alluvium in which the modern soil developed.

Fig. 9. Soil profile from Countesthorpe, Leicestershire.

TOPSOIL.
Double digging of this allotment soil has produced a deep topsoil. Gardeners have added lime, ash and domestic waste as fertilizers.

SUBSOIL.
The top of this sandy clay is slightly coarse in texture, fining downwards into a zone with columnar structure (affected by wetting and drying in summer).

PARENT MATERIAL.
The colours of this weathered Boulder Clay suggest waterlogging for some considerable time in winter.

Fig. 10. Soil profile from Ashby-de-la-Zouch, Leicestershire.

TOPSOIL
The sharply defined lower boundary reflects the depth of ploughing before this land was quite recently converted to pasture.

SUBSOIL
Columnar structures are clearly defined. Waterlogging for part of the year is suggested by the greyish colour of structure faces, in an otherwise red subsoil.

PARENT MATERIAL
Red and green Triassic marl.

Fig. 11. Soil profile from Castle Donington, Leicestershire.

TOPSOIL
The gradational lower boundary indicates that this land has not been under the plough for a long time, if ever. It has a good crumb structure with fine root growth.

SUBSOIL
Large blocky structures are prominent.

PARENT MATERIAL
Some weathered rock (red and green Triassic marl) appears near the bottom of the profile.

quite different textures. The two soils illustrated in Figs. 10 and 11 are from Ashby-de-la-Zouch and Castle Donington, both in Leicestershire. Both soils are currently under grass and look similar in colour. Colour is however only one of the properties used to distinguish between different soils, and if we examine the two Leicestershire soils further we can recognise clear differences. The soil from Castle Donington has a finer texture and is less well drained than that from Ashby. Thus we have two soils which at first glance look broadly similar, but on closer examination differences between them become clear. These differences affect the soil properties and probably the way the soil is best used.

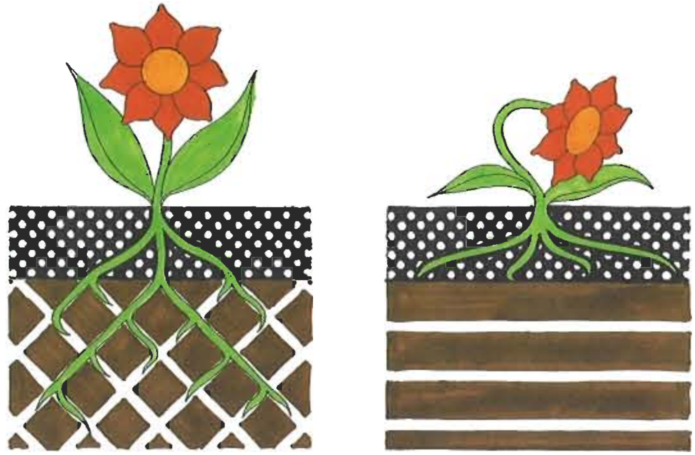


Fig. 12. Blocky and platy soil structures.

Soil structure

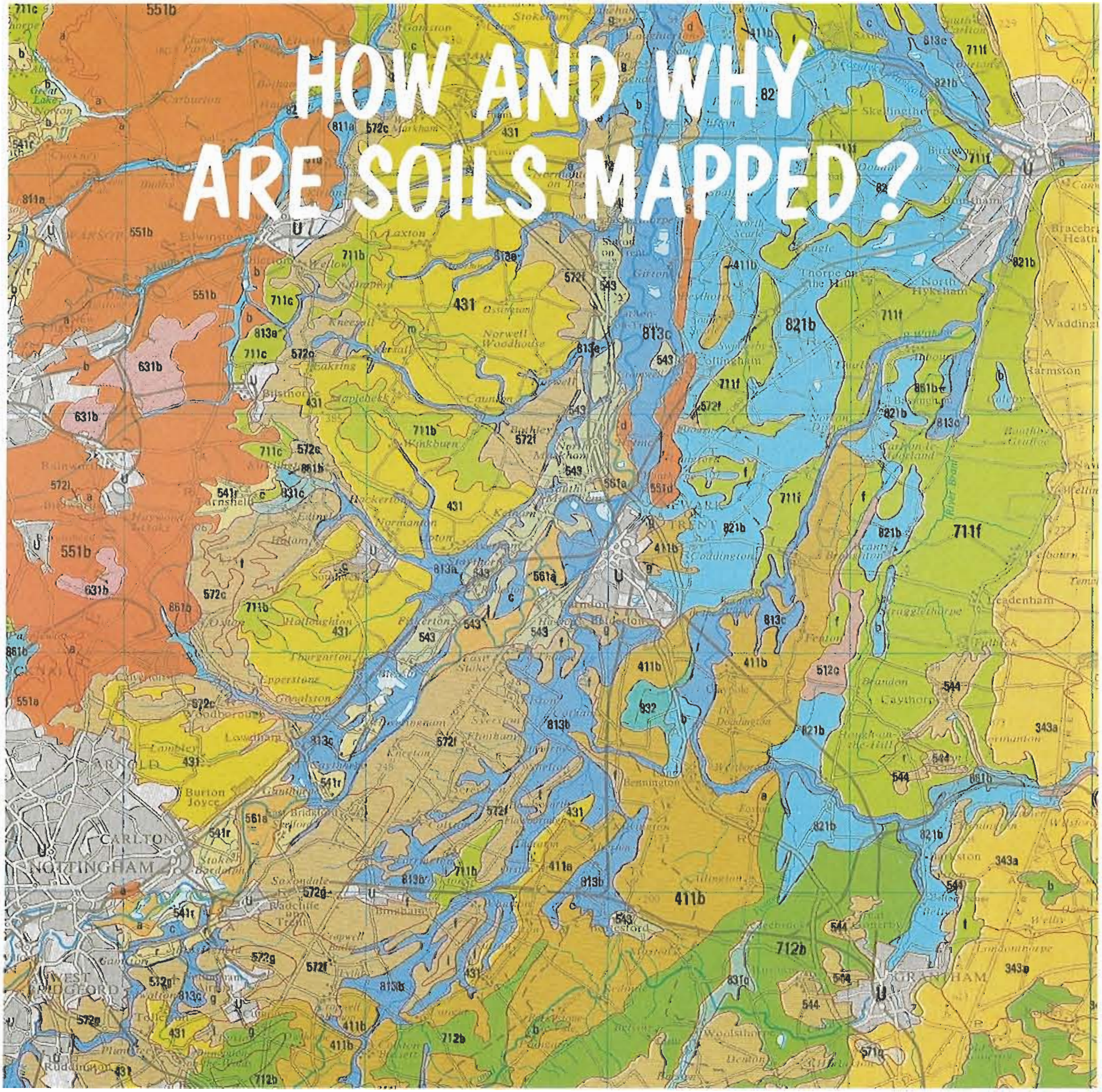
The components of soil do not usually occur as separate sand, silt or clay particles, but are normally 'stuck' together and organised into **aggregates,** when the soil is described as having **structure.** This organisation was mentioned earlier as one of the processes associated with soil development; it is a most important soil property. Where there is no organisation into aggregates, the soil is described as **structureless.**

There are many types of soil structure. Some are produced by the actions of the farmer or gardener when he artificially breaks up the soil. These are very irregular in shape and called **clods** or **fragments.** Naturally occurring soil structures have different shapes and sizes, ranging from near ball-like structures of a few millimetres in diameter (**granular** or **crumby** structure), through to large, vertical, pillar-like structures (**columnar** or **prismatic** structure) which may be more than 20cm long. Structure helps to determine how successful a soil will be in supporting good plant growth and allowing water to percolate.

Blocky structures result when the soil particles are aggregated into irregular cube-like shapes. This arrangement, with blocky structures of different sizes, provides a loose packed soil with large connected holes down through the subsoil. Soil water percolates freely and plant roots grow easily into the subsoil to take up water and plant nutrients (Fig. 12). Under these conditions crop growth should be good.

In contrast, **platy** structures result when the soil particles are aggregated into plate-like forms, arranged horizontally. These structures are often very compact with few vertical holes or cracks. They restrict the free percolation of water from topsoil to subsoil and, under moist conditions, may produce waterlogging within the topsoil and restrict plant growth. Plant growth is further restricted when roots are unable to penetrate platy structures to the soil below, thereby denying the plant access to water and nutrients within the subsoil (Fig. 12). In normal British summers, the water provided by the topsoil may be insufficient to satisfy the needs of plants, which may wilt and die. Platy structures occur naturally within the soil, but they are also produced by the farmer ploughing or the gardener digging the soil at the wrong time, when the soil is wet.

HOW AND WHY ARE SOILS MAPPED?



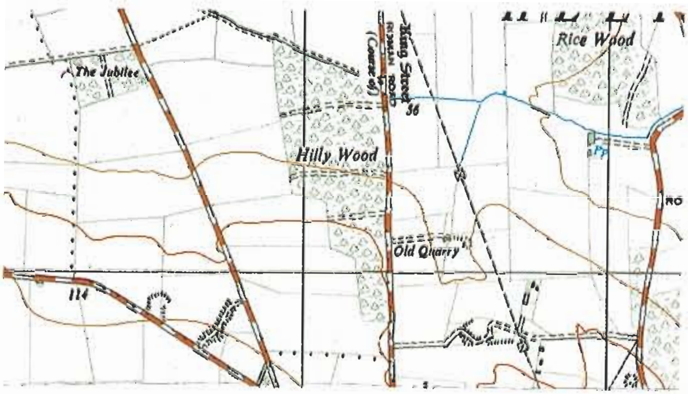
Soil surveying

Complex interactions between the soil forming factors described earlier explain why soils are often different at different places in the landscape. The distribution of different soils helps us to understand how these factors have interacted, and which soil development processes have operated. The **soil surveyor** studies the soil in the field and produces maps which represent the pattern of soils he finds. Such a map is just the final product of a full and detailed investigation of the soil and land use in the area under study.

Before the soil surveyor even begins to look at soils in the field, he gathers together as much information as he can from a wide variety of sources. In Britain this information gathering includes examination of Ordnance Survey maps (at a range of scales) and maps of the geology of the area produced by the British Geological Survey. The surveyor also looks at any agricultural records for the area. As a further guide, general aerial photographs are used to obtain an up to date 'bird's eye' view of the area, from which changes that have occurred since the Ordnance Survey maps were produced can be identified (Fig. 13).

Armed with all this information, the surveyor has a good background knowledge from which to plan a detailed survey. This normally begins with a short reconnaissance survey to identify some of the soils found in the area and confirm soil-environment relationships. For the detailed survey, the surveyor uses large scale maps and air photographs, together with field equipment such as a soil auger and a spade.

Soils at a large number of sites are examined in a systematic way. The location of sites is determined by the surveyor's pre-survey investigations, the identification of patterns on large scale air photographs, the knowledge gained during the survey, and experience from previous surveys in similar areas. The observations are often made predominantly with the aid of a soil auger (Fig. 14), when the surveyor records horizons, depths, texture, colour and other readily observable properties on a data recording sheet. On a



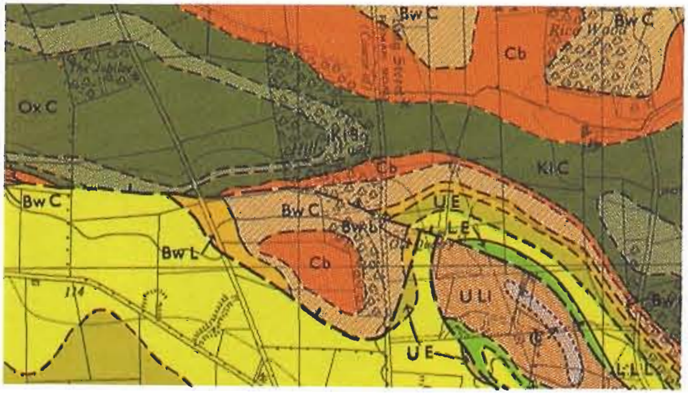


Fig. 13. Soil surveyors collate information from many sources.
Top: Ordnance Survey map.
Centre: British Geological Survey map.
Bottom: aerial photograph.

Fig. 14. Soil surveyor using an auger to sample the soil.

number of occasions the surveyor digs a pit, the description of which is fuller than those for auger borings, and from which samples are taken for laboratory analysis. Once the field work is complete, the surveyor puts all his information together and produces a map showing soil distribution (Fig. 15). The final published map may be accompanied by a book which gives descriptions of the soils, and lists the results of laboratory analysis.

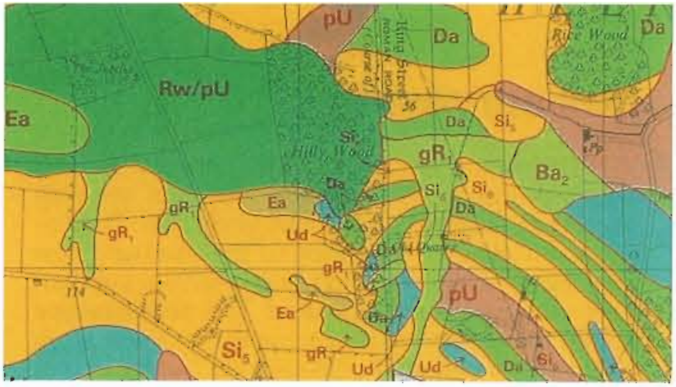


Fig. 15. The final soil map, on which colours are used to portray different soil types.

Soil maps and their uses

The Soil Survey of England and Wales produces soil maps at a range of scales. Most recently, six maps which together cover the whole of England and Wales have been published at the 1:250000 scale (approximately 4 miles to the inch). Each has a **key** which lists the soils found on the map, and a separate legend and booklet extends this information.

The soil map is an inventory of the soil – any nation's most valuable natural resource. Soil maps have a wide variety of users including farmers, town and country planners, conservationists, foresters, land agents, hydrologists and teachers. Many use soil maps to identify soil types. Others require not simply the basic soil data, but other information derived from the soil survey. This information may be closely related to that collected and presented during a routine soil survey. For example, maps have been produced which indicate land drainage requirements, giving guidance both as to the likelihood that artificial drainage will need to be installed, and to the most applicable type of drainage scheme. Other surveys have investigated soil suitability for particular crops or farming operations.


NATURAL
HISTORY

The teeming hordes

Soil contains a multitude of living organisms, some visible, others microscopic and invisible to the naked eye. These organisms form a complex food web within the soil; one group consumes plant litter, another group consumes the by-products of the first group, while a third group preys on the first two.

The number and variety of organisms within the soil is surprising. For example, a small spoonful of dry garden soil (1 to 2g weight) may contain about twice as many soil bacteria as there are people in the world! There can be well over five tons of bacteria per hectare of soil. Soil fungi may be equally numerous. Both these micro-organisms help to break down the fresh organic litter at the surface into **humus.** Figures for the larger soil organisms can be equally remarkable: for example, in a typical lowland pasture the weight of cows on the soil surface will be considerably less than the combined weight of the earthworms below the soil surface!

If we consider the visible (to the naked eye, or with low magnification) organisms within the soil, an immediate surprise to most people is their variety, e.g. moles, earthworms and other smaller worms, millipedes and centipedes, slugs and snails, insects (particularly springtails) and mites. Each has a role to play in breaking down and incorporating plant material into the soil, and making nutrients available for plant growth. The energy involved in all the transfers and transformations is enormous, far in excess of the energy provided by the plants grown at the surface and consumed by humans. Within the soil there is great variation in the distribution of soil organisms with depth but, whilst earthworms and the larger organisms may be found deep into the subsoil, the great májority of visible organisms remain close to the surface. As well as this vertical variation within the soil there are also marked contrasts between different soils. For example, the table below gives some population figures at two contrasting sites: the topsoil of a shallow soil (**rendzina**) developed over chalk in Lincolnshire, and the humus layer and topsoil of a podzol soil developed over a sandy parent material in Nottinghamshire.

	Rendzina	Podzol	
	Topsoil mean number of animals per core*	Humus layer mean number of animals per core*	Topsoil mean number of animals per core*
Mites	4.3	13.4	1.25
Springtails	9.8	1.9	0.5
Centipedes etc.	0.2	0.8	0.37
Worms	0.04	0.16	0.12
Insects	0.7	0.41	0.25
Total Soil Animals	15.04	16.75	2.50

*Varying numbers of cores were taken per horizon. Core cylinder size was 5.08 cm. diameter × 15.24 cm. (2 × 6in). Volume of soil per core was 308.9 cc (18.8 cubic in)

Mites are the major component of the population within both podzol horizons, but there are considerably more in the humus layer. Note the marked reduction in all five categories of organism between the surface humus layer and the topsoil of the podzol.

Next time you sit on the grass, or pick up a piece of soil, remember that you are touching an active microcosm, teeming with life!

Difficult choices

Soil is of fundamental importance to the development of man and the society in which he lives. In the western world it has often been said that we tend to undervalue our soil and misuse it. This opinion is perhaps a biased one, for it looks at soil chiefly in the context of man as an agriculturalist, while soil has a much wider range of uses. For example, it may be used as a base for building and as a grass growing medium for recreational use.

The question of alternative uses of the soil becomes a more pressing problem as our population increases and spreads outwards from the present urban centres. As urban settlements expand they tend to do so on to land that was previously used for producing food. Much of the present planning legislation in Britain is concerned with attempting to control this encroachment. There are often tremendous pressures to allow further urban expansion into the rural area and, as a consequence, to reduce the land upon which we are able to grow food. One remedy against this loss is to extend agricultural land into areas occupied by natural or near natural plant communities. This has been done at the margins of many moorlands in southern Britain, in the Chalk downlands, and in some of the wetland areas where there is pressure to allow land drainage – with the consequent loss of scarce natural habitats.

There are clearly a number of difficult choices to be made. Making these choices involves balancing widely different costs and benefits, some of which are difficult to quantify. It is nevertheless necessary that planning decisions are considered in a full knowledge of these conflicts. Having made the initial choice, it may be even more difficult to weigh up the possible impact of the decision on the environment. Taking a small scale example, how do you balance the decision to clear and drain a piece of rough land, if on the one hand it leads to a substantial increase in the production of an important crop, whilst on the other it destroys a finely balanced natural community of plants and animals? What costs do you allocate for the loss of the latter to offset the benefits from the increase in agricultural production? This is typical of many of the decisions facing those who manage the land.

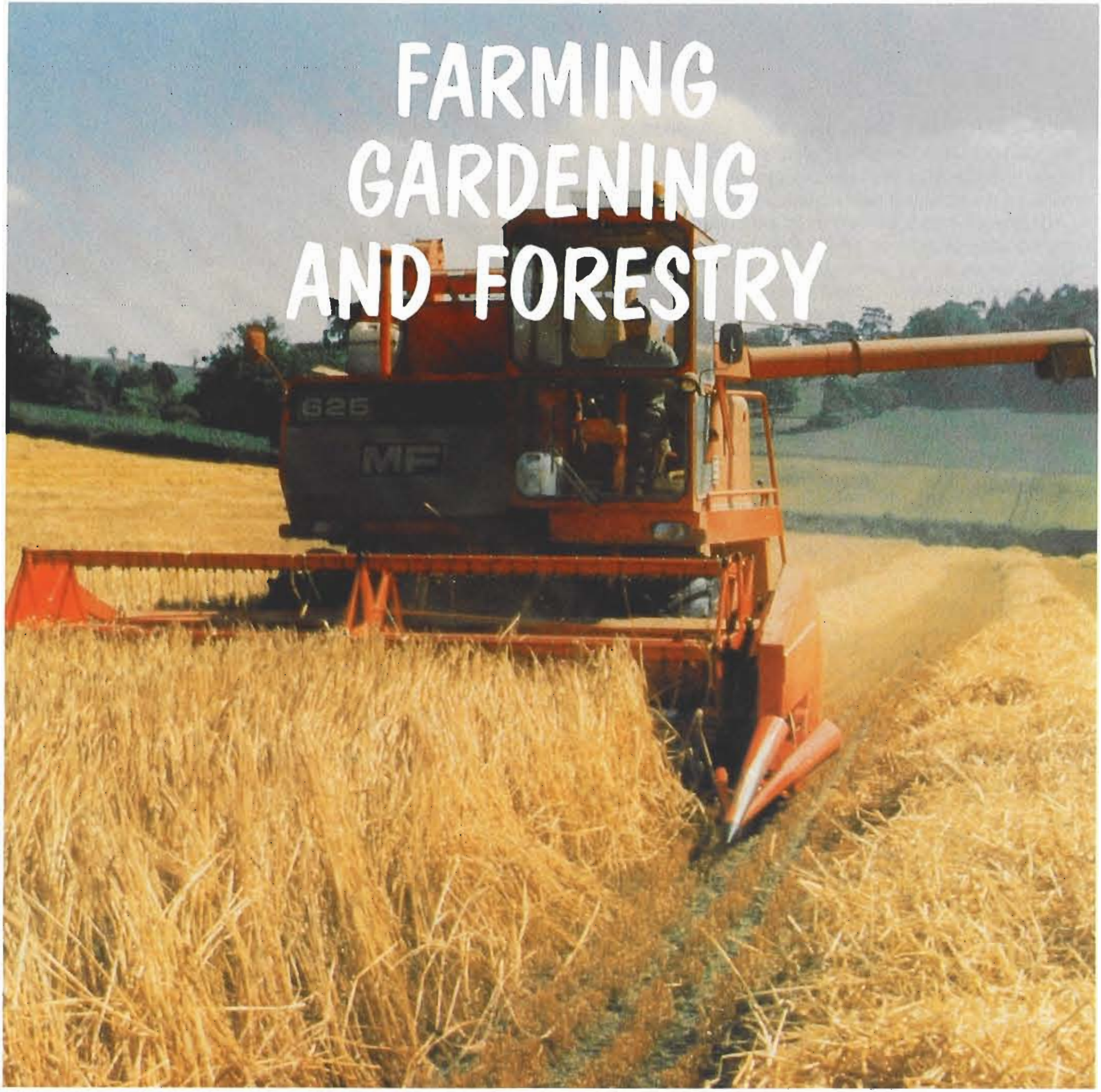
Farmers face the contentious choice as to whether the straw and stubble of a cereal crop should be ploughed back into the soil and broken down slowly by natural processes, or whether it should be burnt (Fig. 16). Burning is often strongly supported by farmers because of its apparent efficiency within the overall farming operation, but should the decision to burn or not be influenced by the public outcry about the smoke, debris and environmental damage which sometimes results? Perhaps the choice could be made easier by supporting research to examine ways of increasing the rate of breakdown of straw and stubble when ploughed in, thus making burning a less attractive proposition.

Fig. 16. Stubble – to plough in or to burn?

Another choice concerns afforestation. The grower can plant a single species of soft-wood coniferous tree, or alternatively a mixed system of hardwood deciduous trees. In making a decision, the benefits of a soft-wood monoculture (more rapid growth and ease of management) must be balanced against the benefits of a mixed deciduous woodland (most of which relate to the amenity value of the woodland). The latter is generally considered to be visually more acceptable, and is certainly ecologically more diverse.

These are just a few examples of the choices facing land users. Decisions are often made more difficult because the comparative costs and benefits are not easily measured in the same units, or are difficult to quantify. For example, how do you measure ecological diversity so that it can be included in an overall balance sheet?

FARMING GARDENING AND FORESTRY



Soil for growing plants

Soils vary markedly from place to place. This is often shown by the ability of plants to thrive in one soil, whereas in a nearby soil they grow only with difficulty. The key to successful farming and gardening is the provision of a soil environment suitable for plant growth. Once such an environment exists, the cultivator must maintain it and not do anything to seriously destroy its favourable properties. A good fertile soil must not only provide the nutrients necessary for plant growth, but also have a suitable structure and adequate water regime. The soil therefore must supply sufficient water at the correct time, must be well aerated (and consequently not waterlogged for long periods), and must allow plant roots to penetrate and exploit the full soil volume. Fig. 17 shows a soil with all of these properties, from the National Agricultural Centre at Stoneleigh, Warwickshire.

Why fertilize soil? – plant nutrients

In natural ecosystems like woodland or grassland, there is often a very efficient nutrient cycle. Nutrients are absorbed by living plants and, in time, returned to the soil as dead plant litter. At the surface, soil organisms decompose the litter, thereby releasing some of the nutrients which can then be taken up again by growing plants. In some situations like the tropical rain forests, this cycling is almost a closed system, but in general there is some loss of nutrients during the cycle – by removal in percolating water and other means. This loss may be made up by the natural addition of further nutrients, released by weathering from the soil profile or the parent rock. If there is no supply of materials to be weathered, the nutrient status of the natural ecosystem declines.

Farmers and gardeners are concerned with sup-

Fig. 17. Soil profile from the National Agricultural Centre, Stoneleigh, Warwickshire.

TOPSOIL
This has been slightly compacted by cultivating at the wrong time, when too wet. Notice the more stony layer, near the lower boundary, which restricts rooting by plants.

SUBSOIL
This course loam becomes more sandy with depth. Worm channels are picked out by their darker colour. The 'swirling' patterns, more prominent in the lower half of the profile, were produced under periglacial conditions during the last Ice Age. Roots can easily penetrate to great depths through this well aerated subsoil.

PARENT MATERIAL
Although not reached in this profile, a true parent material of glacial drift occurs at depth.

plying sufficient nutrients to sustain good plant growth, yet they harvest their plants, so breaking the nutrient recycling found in a natural ecosystem. They must replace these nutrients. In the past this was done by allowing the soil to lie fallow (uncultivated) to recover, but this is now not very common in 'developed' countries. Instead nutrients are applied to the soil surface, in the form of organic manures and composts, or inorganic fertilizers.

The organic applications made by the gardener are very often **composts**. Composts consist chiefly of organic garden and household waste which has been allowed to decompose in a heap or compost bin. Decomposition is enhanced by mixing organic materials, and in some cases by adding nutrients (like nitrogen) to enhance biological activity in the heap, thereby increasing the rate of breakdown of organic matter. Well rotted compost is not only a valuable source of plant food, it may also improve the soil's physical properties.

On a farm it is not possible to build huge compost heaps, and in many cases farm waste is ploughed directly into the soil where it decays naturally. The commonest organic additive used by farmers is animal waste, or **farmyard manure** (FYM), as a slurry or mixed with straw (Fig. 18). It is a most important source of nutrients for some agricultural systems. The amount of FYM available is however not sufficient to satisfy the nutrient demands of most farmers and gardeners. The shortfall is made up by **inorganic fertilizers**. These are often looked on with suspicion but many fertilizers are little more than naturally occurring rock materials, treated to make them release nutrients more readily. Others are the product of complex manufacturing processes. Manufacturers have developed the ability to vary the proportions of the three major components of most fertilizers: N (nitrogen), P (phosphorus) and K (potassium). An enormous variety of NPK 'cocktails' are now available. Fertilizers can also remedy deficiencies in other nutrients, and may consist of only one component rather than a 'cocktail'.

Fig. 18. Spreading farmyard manure.

Foliar, or leaf sprays provide a quickly assimilated plant food, of most importance to gardeners. This is expensive and time consuming, but can be done with considerable effect when a particular nutrient deficiency is recognised in a plant.

Farmers and gardeners can decide which nutrients to apply in two ways. They may wait until a deficiency shows in their plants, and attempt to remedy it. Alternatively they can analyse the soil and determine its **nutrient status**. With this information, and knowing the likely nutrient demands of their crop, it is possible to make fertilizer recommendations. Given an initial nutrient status and information about subsequent additions of nutrients and cropping practice, it is also possible to predict the necessity for further applications. Correct timing of the application can minimise any loss of fertilizer caused by rainwater washing it out of the soil.

Soil compaction

The ability of the soil to support crop growth is not simply based on nutrient status. It is also necessary

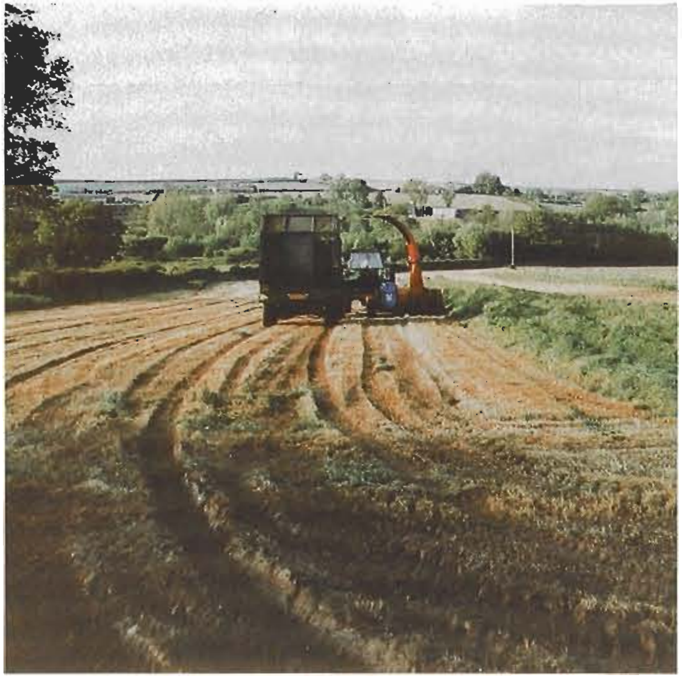


Fig. 19. Deep ruts caused by working the soil with heavy machinery when conditions are too wet. Compacted soil is the result.

for the soil to have good physical properties, to allow water and air to flow through it and encourage root penetration. This is often achieved by cultivating the soil to a considerable depth. In the garden soil from Countesthorpe, Leicestershire shown in Fig. 9, the gardener has been 'double-digging' to provide a soil with an open structure down to approximately twice the normal depth of cultivation. This is clearly shown by the very deep layer darkened by organic matter at the surface, which is two spade depths deep. Double digging provides a deep zone of relatively 'open' soil with a large number of holes for easy water percolation and root penetration (particularly important at this site because the soil is a surface water gley).

When this open structure is lost for some reason, the soil is said to be compacted. Soil compaction is a very widespread problem which arises because most

Fig. 20. A subsoiling plough at work, breaking up compacted layers below the topsoil.

soils have a much reduced strength when wet. If wet soil is cultivated by heavy machinery (Fig. 19), or in the garden by a fully grown man walking on it, the soil may become compacted. Once compacted, air and water cannot flow through the soil and root development is restricted. The compacted zone therefore must be physically broken up, often a difficult and time consuming task. In the garden double digging can be employed, while on the farm the compacted layer is broken by 'subsoiling' (very deep ploughing; see Fig. 20).

The key to the prevention of soil compaction is timing cultivation so that the right conditions prevail. If the soil is wet for a large part of the year, it may be necessary to drain the soil artificially.

Why drain land?

Most of Britain enjoys a moist maritime climate, so that for much of the winter there is a steady supply of moisture to the soil surface. This is reflected in most soils by moisture content, in which there is often a marked contrast between summer and winter. In many

Fig. 21. Waterlogging excludes air from the soil - roots drown and plants die.

Fig. 22. 'Herringbone' pattern of a newly laid drainage system, as seen from the air.

locations the soil is waterlogged to within 60cm of the surface for part of the year. In extreme cases there may be water at the soil surface and even lying on the soil. Waterlogging greatly affects plant growth (Fig. 21) and, if heavy farm machinery is used, promotes soil compaction. 60% or more of the soils in lowland Britain are affected to some degree by poor drainage, and consequently this is potentially a serious limitation to soil use.

The solution to these problems is to improve drainage. One simple improvement involves clearing the ditches at field boundaries or, if no such ditches exist, to dig them (ensuring that the ditches drain to an outfall). The ditches provide a low point to which soil water can drain. Tile or pipe drains laid beneath the field surface supplement ditch drainage: narrow trenches are dug (60–100cm deep) in which pipes are laid (together with a porous material), then the soil is replaced. How the individual lines of drains connect together and drain into a field side ditch is well seen from the air (Fig. 22). This pattern is often described as 'herringbone'. The most efficient spacing of the drains varies with both soil material and the nature of the drainage problem.

The effects of drainage on plant growth are shown in Fig. 23. A high water level within the soil severely restricts plant growth; good drainage lowers the level, thereby encouraging better growth.

Soil erosion

Until recently, soil erosion has not generally been considered a problem in Britain. Nevertheless, while it may not be as dramatic as that which occurs, for

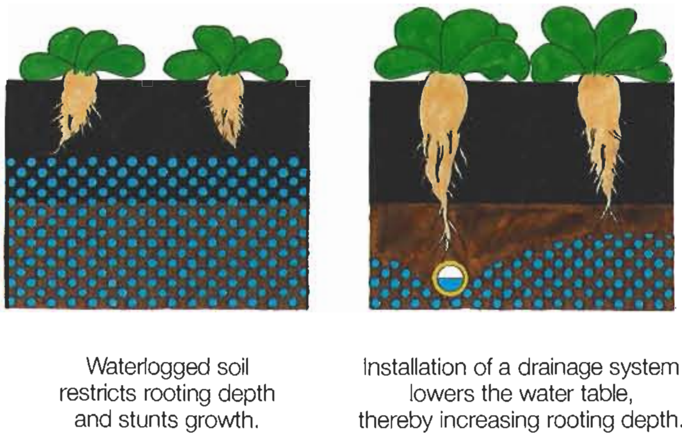


Fig. 23. Drainage improves crop growth.

example, in parts of the tropics, erosion certainly poses a potentially serious threat to many British soils, particularly those that are shallow. Any real increase in soil erosion in Britain may be partly caused by changes in farming practice. Some observers, however, have suggested that there has been no real increase in erosion, only that our awareness of it as a potential problem has grown. The truth probably lies midway between these two viewpoints.

Soil erosion happens in two ways: by water washing material down a slope, and by wind blowing it away. Erosion by water creates small rills down plough furrows or along seed drilling lines. More seriously, deep gullies may be eroded down to the underlying parent material (Fig. 24). The eroded material is deposited (up to a depth of several metres) at the bottom of slopes. This material can bury crops and, because it is structureless and weak, severely hinders the movement of farm vehicles. No single factor produces water erosion, but it is apparent in Britain that certain modern farming activities greatly influence its likelihood (Fig. 25).

Wind also causes soil erosion. This can be very dramatic, with 'blows' of soil across the countryside.

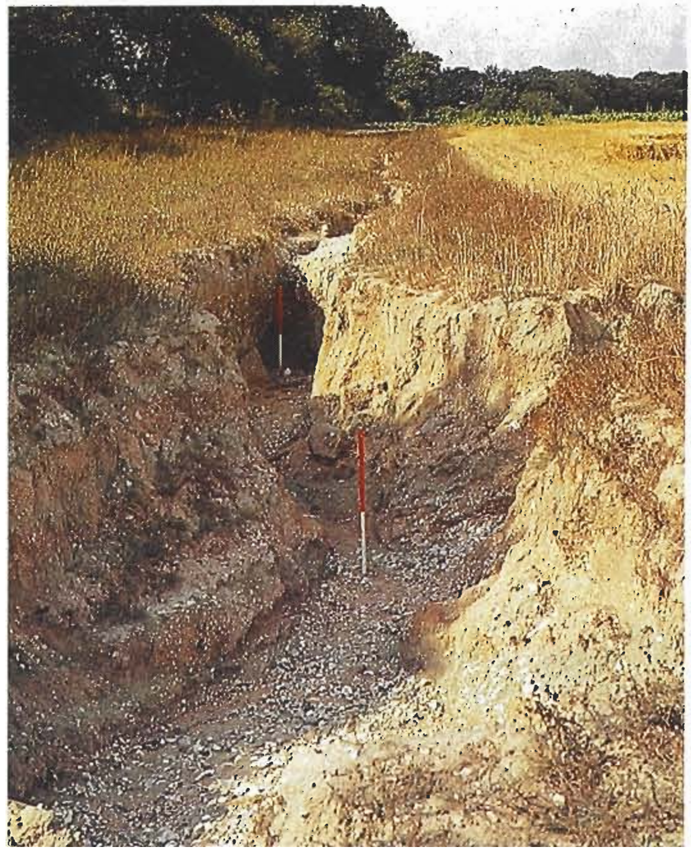


Fig. 24. Deep gulley erosion in a Norfolk field.

The material may be carried a few hundred metres or a few kilometres, and is deposited in ditches and behind hedgerows (Fig. 26). Farmers reduce the likelihood of wind erosion in two ways: either by interrupting the wind flow with hedgerows or similar wind breaks, or by attempting to change the surface soil characteristics. For example, the mixing of marl with soil has been widely employed in eastern England to reduce soil erosion.

Soil erosion is not a recent problem. In much of southern and eastern Britain there is a thin veneer of wind blown material, of glacial origin, at the surface or intermixed with other soil materials.

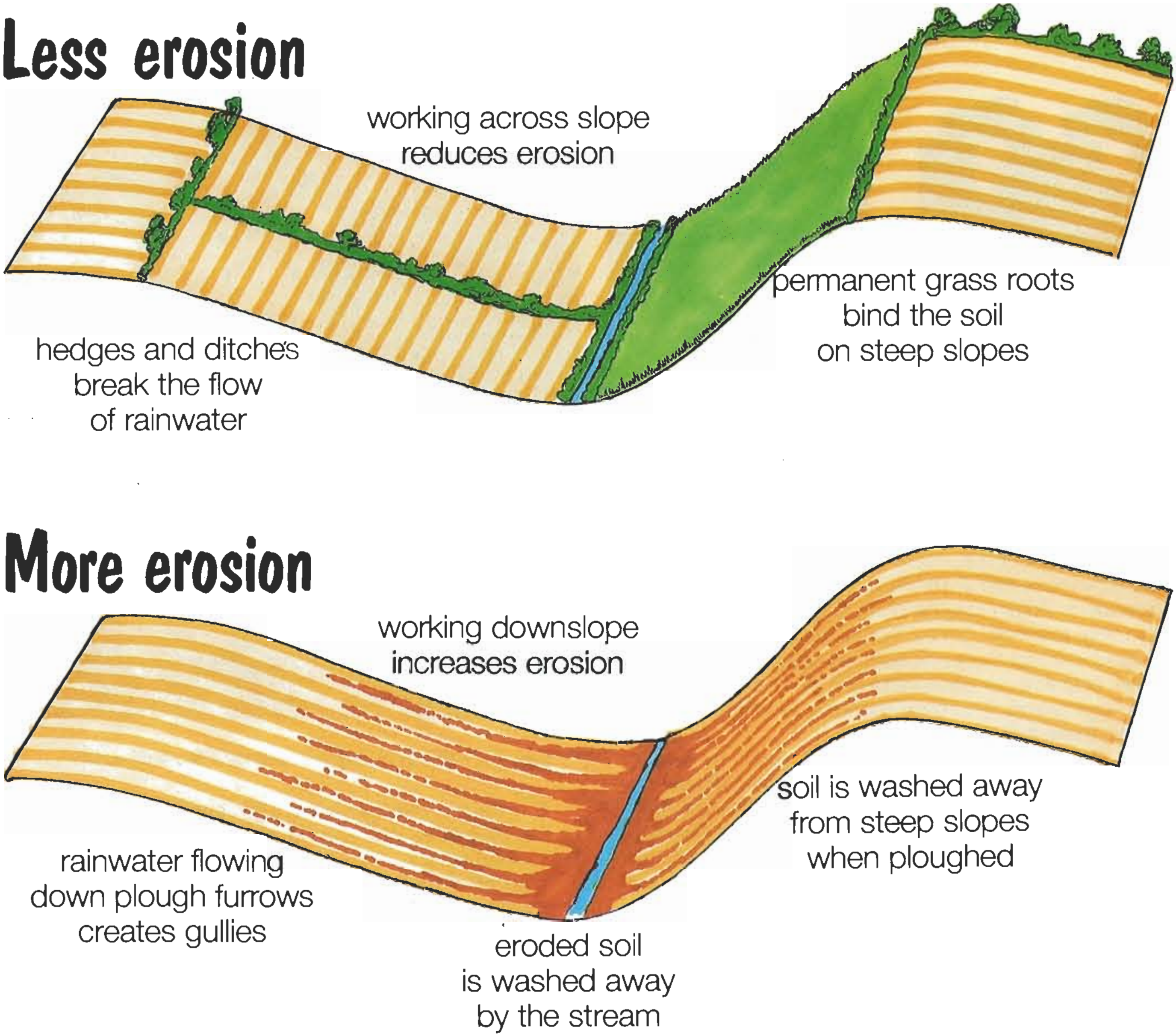


Fig. 25. Farming practice influences soil erosion by water in a variety of ways.

Fig. 26. Wind eroded soil material blocking a field ditch in the Vale of York.

Forestry

So far much of the emphasis has been directed to man as a cultivator of arable crops. Trees are also an important crop, and knowledge of the soil and soil conditions is as important to the forester as it is to the farmer – both encounter similar soil problems. This can be illustrated by looking at three soil conditions which cause shallow rooting in trees (Fig. 27), and a tendency therefore for them to be blown over by strong winds (**windthrow**).

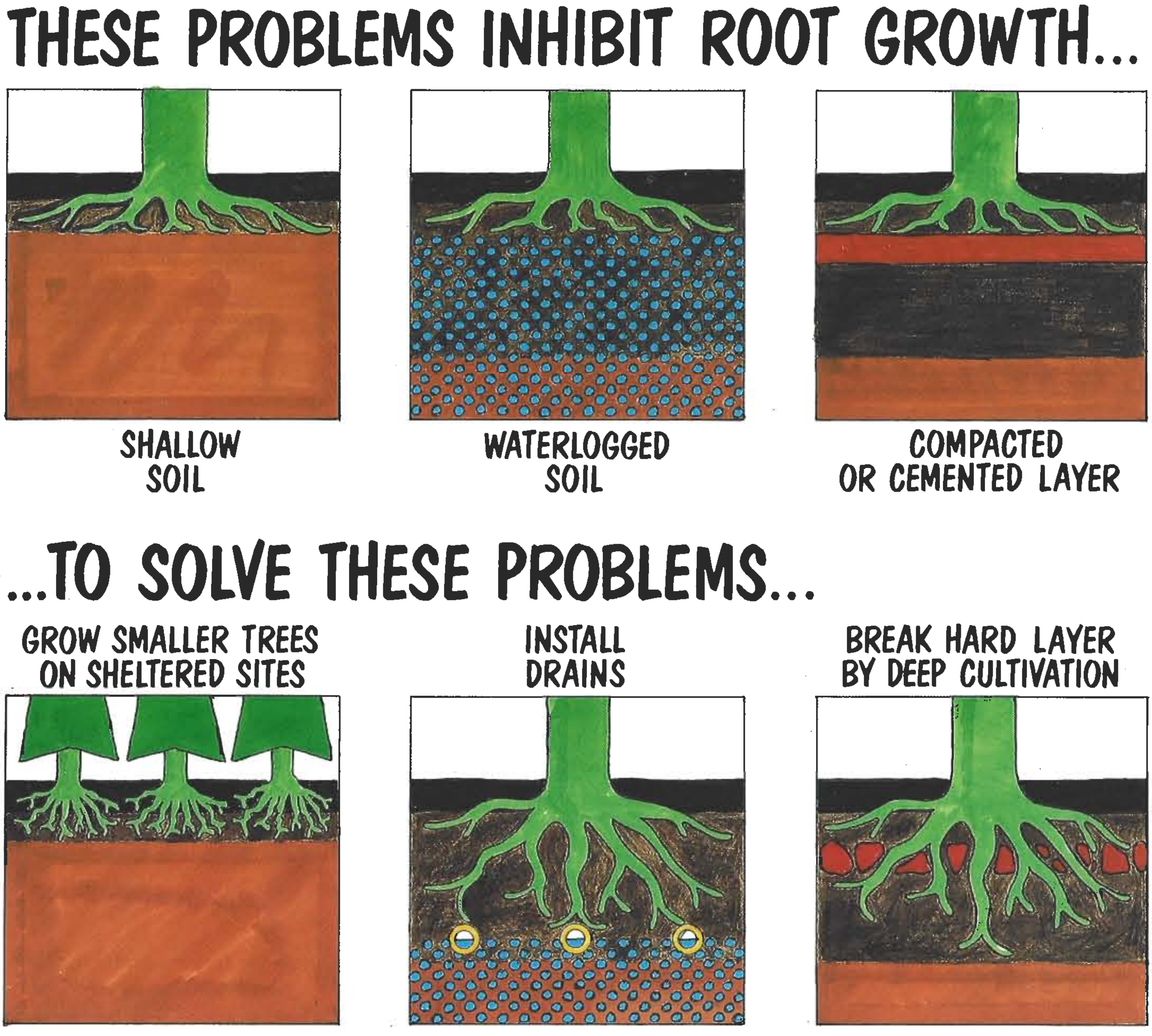


Fig. 27. Windthrow – its causes and some solutions.

LAND RESTORATION

Why restore land?

The rate and duration of soil formation is controlled by the complex interaction of soil forming factors. One major factor, often rather surprisingly omitted from the consideration of soil development, is man. We have had a dramatic effect on soil development and distribution. Man is readily thought of as an agriculturalist or urban developer, but we also affect the soil by extracting minerals from beneath it. Where materials are extracted from a considerable depth, waste products are often piled in large heaps at the surface. Major extractors like the National Coal Board have made considerable efforts to find ways of accelerating the rate of soil development and the establishment of stable plant communities on the spoil heaps.

A far more fundamental change in the soil occurs where the extracted material is only a few metres below the surface. This is how coal is mined in parts of Britain (for example, in Northumberland and South Wales), and also how much of our sand and gravel is extracted (for example, in the Thames Valley). Extraction starts by removing the **overburden** of topsoil, subsoil, regolith and unweathered rock. What happens to the overburden depends upon the projected use of the site after extraction has been completed. This is another of the many choices facing the user of land. In some cases the excavated hole may be filled with water and used for recreation. Here the developer must dispose of the overburden in the best possible way, perhaps by selling the topsoil to developers and using other material as infill elsewhere. Alternatively the site may be returned to a condition similar to that which prevailed before extraction. Such **restoration**, if it is to be successful, requires a full understanding of the soil and its plant and animal communities – the **soil ecosystem.** If the topsoil and subsoil are separated during the initial stripping of the overburden, their subsequent restoration will be an easier task.

Fig. 28. National Coal Board opencast site in Northumberland, during extraction of coal, and after restoration to agriculture.

Fig. 29. Mounds of topsoil act as a sight and sound screen around the edge of an active site.

Fig. 30. Breaking up the surface of the infill material (prior to restoration of subsoil and topsoil) to improve drainage.

How it is done

A National Coal Board opencast mine in Northumberland illustrates the techniques involved (Fig. 28). Both topsoil and subsoil are carefully stripped and stored. The mounds of topsoil and subsoil can be used as sound and visual barriers for the subsequent excavation programme (Fig. 29). During excavations the soil mounds remain untouched but they must be properly stored to prevent both the breakdown of soil structure and the washing away of nutrients. In some projects the material to be extracted is exposed in stages, and as one site is being worked another is being restored.

The first stage of restoration is to fill the hole, and what is used depends upon availability. It may be previously excavated overburden, or even household refuse. The infill is allowed to settle and its surface is broken up in stages (Fig. 30), before laying the subsoil and finally the topsoil. Great care must be taken to restore the site when conditions are right: for example, if conditions are very wet all the care taken in storing the soil material may be undone, with the restored surface or subsurface layers becoming compacted (preventing easy percolation of water, and restricting plant growth).

Once replaced, the soil takes time to 'recover' and to achieve a balance with the plant and animal life within and around it (Fig. 31). How long this takes is difficult to estimate, but often the success of soil restoration is not judged until five to ten years have elapsed. Restoration normally involves the laying of artificial

Fig. 31. Soil profile from a recently restored National Coal Board opencast site near Mansfield, Nottinghamshire.

TOPSOIL
Recently replaced topsoil with a distinct lower boundary and a compacted lower half.

INFILL MATERIAL
Rock waste from the quarrying operation, largely sandstone and shale. This is not a true parent material because the topsoil above was replaced artificially. Time will create a more natural looking profile.

Fig. 32. Crops on a restored National Coal Board opencast site.

drains and seeding the area with grass or cereal seed. Seeding by aeroplane or helicopter avoids the necessity of running heavy machinery over the soil surface, thereby preventing problems of compaction.

Successfully restored land can be used to satisfy a wide variety of demands by the community, including housing, farming, recreation and forestry (Fig. 32).

ARCHAEOLOGY

by Charles French (Fenland Archaeological Associates)

Soil the preserver

Man and the environment leave a lasting impression on the soil. Information about past climate, vegetation and animals is buried in the soil, as are objects made or used by man (**artefacts**) that were discarded or lost (pottery, flint, stone and metal tools, coins, and the remains of meals). A study of these objects provides evidence of vanished cultures. We will take as an example the area around the village of Maxey in Cambridgeshire where archaeologists have proved occupation by man for at least the last 5000 years.

Settlements leave other tell-tale traces, like buried drainage ditches representing field boundaries. There are also holes and channels that are clues to the shape and construction of buildings, and pits used for storage. In time these hollows became disused, filled with rubbish, and were covered by soil. These features can be revealed by careful excavation, and are recognised today because of the differing appearance of the soil in them. At Maxey, rectangular garden plots and paddocks have been discovered which were in use during the Romano-British period (1800 years ago).

The soil may also contain fragments of past plant and animal life (**ecofacts**), like pieces of wood and charcoal, seeds, pollen, snail shells, bone and the hard parts of insects. These provide evidence for past farming activities and contemporary ecosystems. There is evidence at Maxey for both limited agriculture and forest clearance before the Neolithic period (before 4500 years ago).

Whether or not objects decay in the soil depends on soil conditions, in particular on the amount of water in the soil throughout the time they remain buried. Waterlogged soils preserve all kinds of artefacts and ecofacts. They survive because waterlogged soils contain very little dissolved oxygen, which is essential to the soil organisms responsibe for decay. In a well drained soil many of these remains rot. In a dry soil, even shell and bone can be broken down if conditions are sufficiently acid. The sieved material from a Neolithic enclosure ditch near Maxey contained pollen,

Fig. 33. Soil profile from Maxey, Cambridgeshire.

TOPSOIL
A well drained, fine loam with reasonably blocky structure.

SUBSOIL
This is not easily distinguished from the topsoil, except by a decrease in organic matter content, and a coarsening in texture down to the parent material.

PARENT MATERIAL
This sand and gravel was deposited by the River Welland during the last Ice Age. Many of the rock fragments are derived from local limestones of Jurassic age.

seeds and carbonised grain which survived in the boggy soil.

Study of the soil's structure may reveal evidence of past erosion, accumulation or stability. Very often ancient soil layers remain undisturbed below later features. These layers are termed buried soils and at Maxey they have been discovered beneath undisturbed Neolithic burial mounds. This **buried soil** shows periods of vegetation clearance, erosion and disturbance, and some practice of agriculture. The Welland valley as a whole shows a relative increase in silt deposition during Romano-British to medieval times, suggesting increased land clearance and agriculture.

Searching the soil

Careful and systematic sieving of soil excavated from archaeological sites is essential to retain very small artefacts and ecofacts. For example, sieved soil from an Iron Age round-house enclosure ditch might contain broken pottery, flint tools, animal or even human bones, snail shells, seeds, nuts and carbonised grain. From such finds, the ditch's age, when it went out of use, the types of pottery used, what tools were available, which animals were kept, and the varieties of food collected, cultivated and eaten, can all be suggested. From the plant and animal remains, the ecology of the area can be reconstructed, at least in part.

The remains of snail shells, insect skeletons, seeds and pollen are particularly valuable clues which enable us to say what the overall environment was like and how it has changed. Snail and insect remains are good guides to past climate because temperature is often a critical factor which controls where these creatures live. Certain species of insects and snails are only recovered from deposits laid down during colder periods of the last Ice Age. At that time, Britain's climate resembled the Arctic tundra of today. Other species preferred the warmer temperatures which occasionally prevailed between periods when ice advanced southwards. These species enable the archaeologist to build up a picture of past climatic change.

Pollen grains and seed remains indicate which plant species constituted the natural vegetation. They also tell us whether arable or grazing agriculture was practised. Pollen may be deposited from a wide area and preserved in peat bogs and lake sediments; seeds and pollen from the local area may fall into waterlogged soils and ditch deposits. A Neolithic enclosure ditch near Maxey contains pollen that indicates a surrounding marsh with open water in a generally open environment, but with deciduous forest nearby on higher ground. (The same area today is open dry land under intensive arable cultivation). Seeds and carbonised grain are similarly preserved in the ditch; these may eventually provide further evidence of natural and cultivated plants. Sometimes the presence or absence of certain parts of cultivated grain suggests how it was processed; for example, whether or not it was brought to the site already threshed.

Then as now objects were accidentally or deliberately discarded by people inhabiting the area. Domestic rubbish was thrown on to manure heaps which were then spread on the land. Settlements may have become completely buried, but modern ploughing brings this debris of the past to the surface. Ploughed soil may in fact contain objects from all times including nails, bricks, tiles, glass and plastic discarded recently. Systematic searches of ploughed land maximises the chance of discovering this kind of archaeological evidence.

Fig. 34. 'Fossil waterscape' of ancient stream channels, superimposed on today's field pattern in the Fens of East Anglia. Such features become visible from the air because of differences in soil colour.

Patterns from the past

Aerial photography is a vital aid for archaeologists. It reveals different soil colours and crop patterns of growth which are not clearly visible from the ground. These **soil marks** and **crop marks** often indicate geological or archaeological features beneath the surface. The results of glacial or water action are revealed. Fig. 34 shows a 'fossil waterscape' of stream channels which show up as differences in soil colour superimposed on the modern field patterns of fenland Cambridgeshire. The soil which has infilled pits or ditches can often be more damp and have more organic material than that surrounding it. This makes such pit or ditch features a darker colour than the area around them. Crop marks, however, show up because of differential crop growth over upstanding and hollowed out archaeological features (Fig. 35). For example, a crop growing in the relatively shallow soil covering a buried stone wall will be stunted and ripen earlier than the crop around it. On the other hand, the crop over an organically rich, damp, infilled ditch will grow taller and mature later than the adjacent plants (Fig. 36). In practice, the situation is often more complicated than this because of interactions between the crop plants, soil types, and possible drought periods.

Soil and crop marks are a valuable guide to the otherwise concealed evidence of man's exploitation of the landscape. These features are particularly common on the terrace gravels of Britain, for example in the upper Thames and lower Welland valleys. Their absence, however, does not necessarily signify the absence of buried archaeology, only that it may be more deeply buried under an accumulation of river borne deposits.

The soil is important to the archaeologist because it contains a record of almost all aspects of past human activity. Man's impression on the soil may be visible or invisible to the unaided eye, but it is detectable despite varying conditions of preservation and the fact that soil continues to change and develop through time.

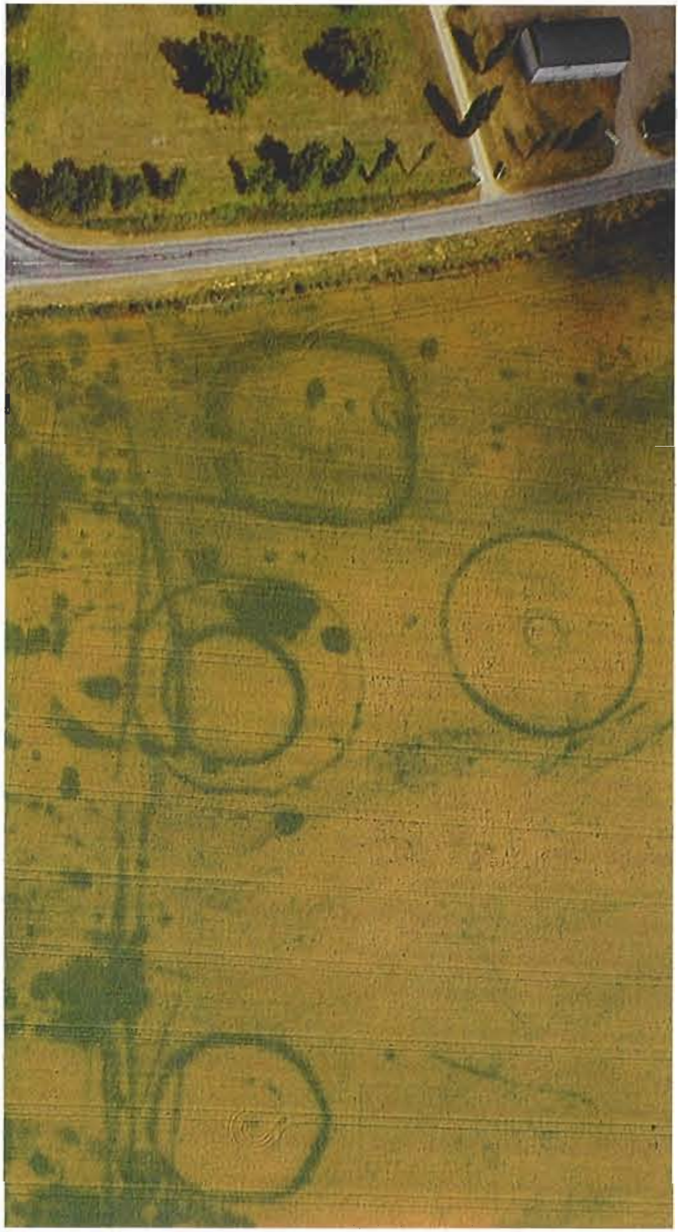


Fig. 35. Crop marks pick out an ancient settlement in a field near Maxey, Cambridgeshire.

CROP COLOURS REVEAL...

BURIED MASONRY

thin soil

shortage of moisture

stunted crop growth

quick ripening

BURIED DITCH

thick soil

no shortage of moisture

good crop growth

slow ripening

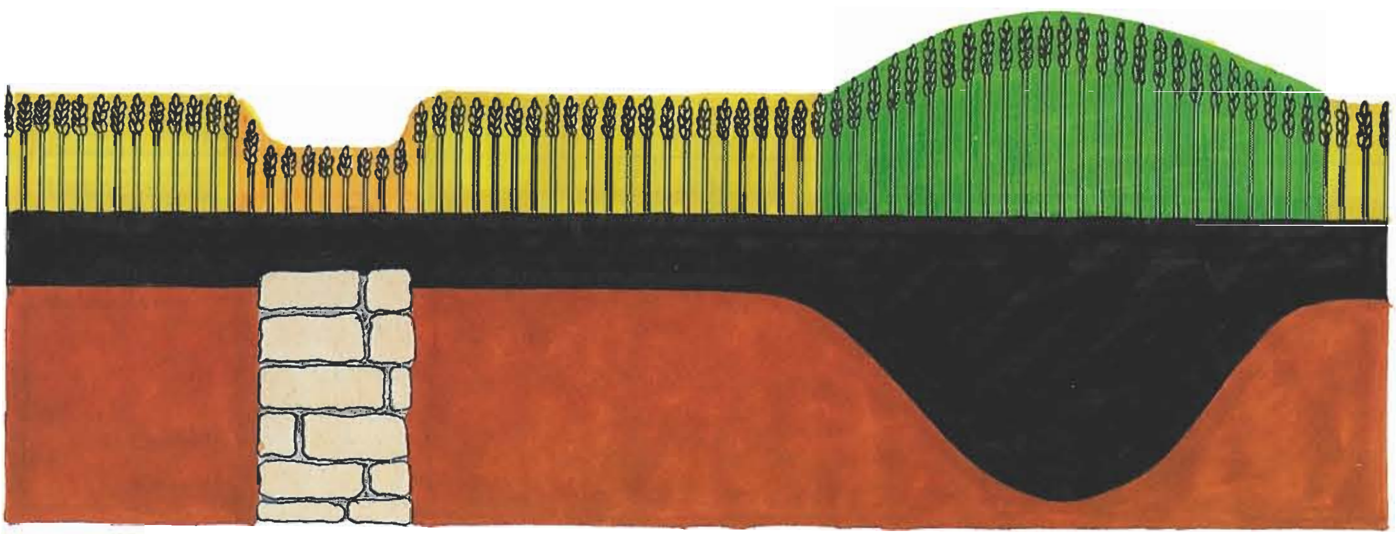
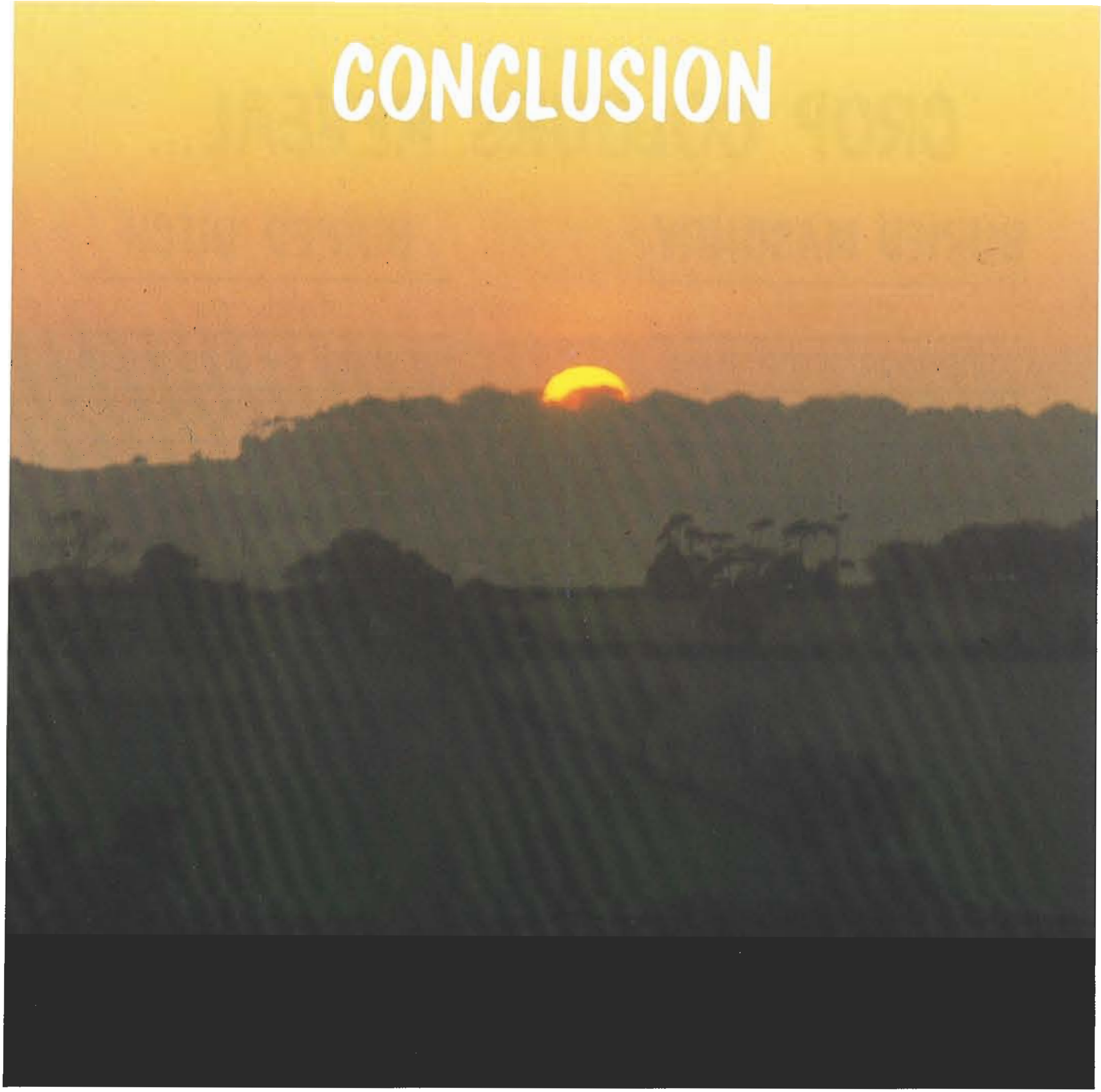


Fig. 36. Buried features, like walls and ditches, affect crop growth.

CONCLUSION



Throughout this book, the fine balance that exists between the soil and its environment has been stressed. In Britain there is considerable evidence of this balance, with a wide range of soils reflecting the often intricate interactions of environmental factors. In a land as densely populated as Britain it is not surprising that man's activities have to date been a major influence on soil development, and it seems this influence will continue and maybe increase in degree. In your own locality it may be possible to examine the changes in soil type which occur across the landscape as one of the natural soil forming factors changes. Look at the different soils as you go down a hillslope or as you pass from grassland to woodland. These soil differences often reflect soil-environment interactions which have taken place, with only minor alterations, for hundreds or thousands of years. It is almost impossible however not to see the impact of man's activities on the landscape, be it for agriculture, forestry, urban development or recreation.

Many soil users ignore this fine balance between soil and the environment, and often seem to consider the soil as a static, indestructible commodity. All around us there is evidence that this is not so. Taking the soil for granted is one of man's greatest mistakes. It is all too easy to destroy in a very short time a resource which has developed over thousands of years. Soil is one of Britain's most valuable natural resources and must be properly protected today for our own use, and for the use of future generations.

FURTHER READING

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Hanwell, J. D. and Newson, M. D. 1973. *Techniques in physical geography.* Macmillan.

Newson, M. D. and Hanwell, J. D. 1982. *Systematic physical geography.* Macmillan Education.

The Soil Survey of England and Wales and the Soil Survey of Scotland produce soil maps and accompanying texts, at a variety of map scales. Enquiries about soils may be sent to The Secretary, British Society of Soil Science, University of Reading.

DOWN TO EARTH

by Stephen Nortcliff

with a Foreword by David Bellamy

DOWN TO EARTH is a basic introduction to soils. The book describes in non-specialist language what soil is, how it forms, how and why it is classified and mapped, and how soil is used and affected by mankind.

DOWN TO EARTH has been written for the general reader who wishes to discover more about our most precious natural resource. It will be found useful by school and college students of geography, geology, biology, environmental studies, agriculture, horticulture, forestry, soil science and related courses.

DOWN TO EARTH complements a travelling exhibition of the same name, produced by Leicestershire Museums, Art Galleries and Records Service in conjunction with the Soil Survey of England and Wales.

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