Principles of soil management

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Contents

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Introduction

This science-based guide can aid with the management and maintenance of healthy soils. Until recently, the term ‘soil health’ has not been widely used. However, it has gained traction in the last few years by farmers, growers and the wider stakeholder community.

No single set of on-farm management practices can put soils in good health. Good soil husbandry requires a flexible approach that is likely to vary from field to field, and season to season.

The agricultural industry has a huge breadth of experience and depth of understanding of the practical issues involved in the management of soils within UK crop rotations. Recent research, including that funded by AHDB and the BBRO, has also advanced knowledge of sustainable soil management.

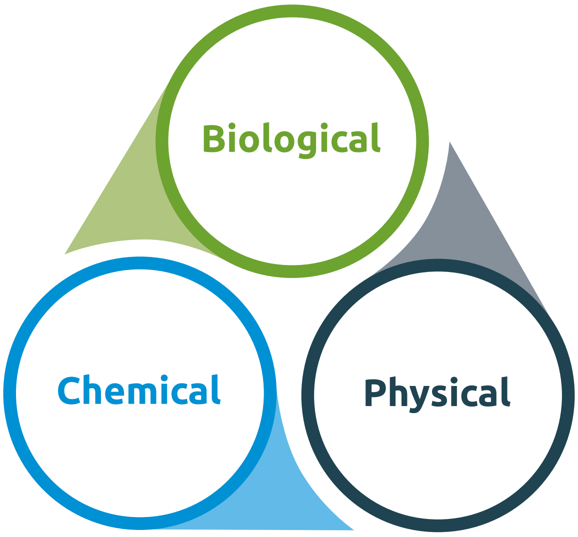
This publication brings together such information. It looks at what makes soil and how it is classified. It outlines soil-related issues and how they can be addressed. Finally, the guide highlights wider reference sources, most of which can be accessed via **ahdb.org.uk/soil-principles**

What is healthy soil?

The intricate web of relationships between physical, chemical and biological soil components underpins crop and livestock health and productivity. Protecting soil health is also critical to environmental sustainability, as soils:

- Exchange gases, such as carbon dioxide and nitrogen oxides, with the atmosphere
- Regulate the flow of water and rainfall in the water cycle
- Provide nutrients for plant growth, by breaking down organic matter and altering chemical fertilisers
- Transform and store organic materials, as part of the terrestrial carbon cycle
- Degrade contaminants applied through human activities or left by floods and aerial deposition

A healthy soil is able to sustain, in the long term, these important functions. In a healthy soil, the interactions between chemistry (pH, nutrients and contaminants), physics (soil structure and water balance) and biology (including earthworms, microbes and plant roots) are optimised for the conditions in that place.



Soil classification

Soils form over thousands of years (Figure 1) through local interactions of climate, geology, hydrology and management. Physical and chemical alteration (weathering) break down parent materials (solid rocks and drift deposits). Finally, biological cycles of growth and decay produce the critical extra ingredient: organic matter (OM). Each field has unique soils.

Underlying geology determines the soil parent material and its properties, including soil depth, stoniness, mineralogy and texture. Soil maps, therefore, often closely resemble geological maps.

Parent material is the main determinant of whether soils are likely to have a shortage or an abundance of particular nutrients – phosphorus (P), potassium (K) and magnesium (Mg) or trace elements.

For example, some clays release enough potassium to support moderate crop growth, without additional fertilisation. Potassium-releasing clays include: chalky boulder clay, Gault Clay, Kimmeridge Clay, Weald Clay, Oxford Clay, Blisworth Clay.

Note: Carboniferous clays do not release much potassium.

Find out more about the underlying geology in your area. The Geology of Britain viewer is free to use and has good supporting information. Access the maps via **ahdb.org.uk/soil-principles**

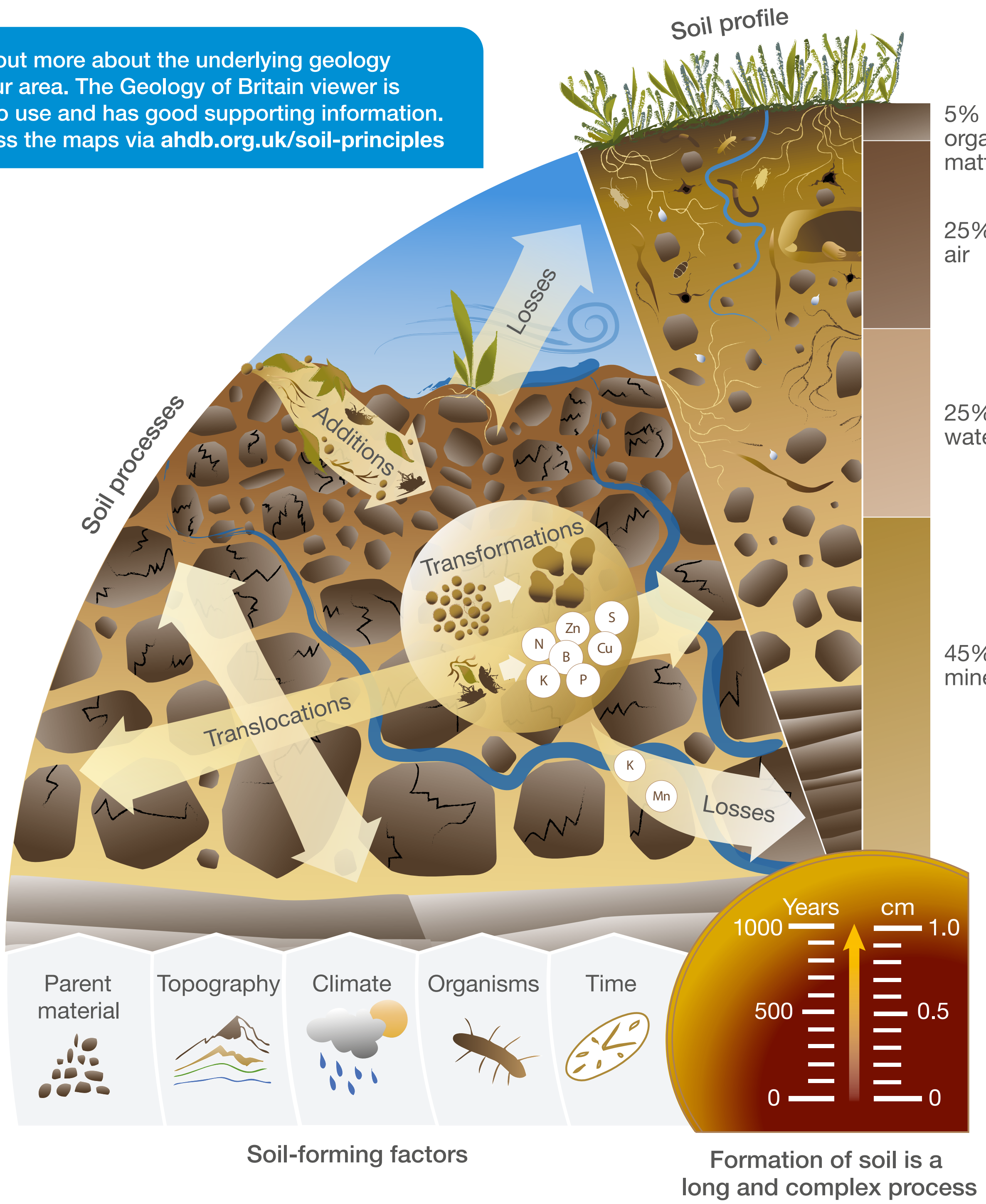


Figure 1. The formation of soil

Source: Adapted from FAO 2015 'How soil is formed' www.fao.org/resources/infographics/infographics-details/en/c/284480 (accessed 07 November 2019)

Soil types are classified in a hierarchy based on observations of soil properties from soil pits (up to 1.5 m deep). The number and arrangement of the layers that make up the soil (horizons) and their texture and colour are particularly important.

The largest classification units (equivalent to species for plants/animals) are the major groups. Most agricultural soils, except some upland soils, fall into one of the subgroups of well-drained brown earths. Usually, the iron compounds in agricultural soils give the horizons a reddish-brown colour. However, when deprived of oxygen, such as under waterlogged conditions, the compounds change to a grey or bluish colour in one or more characteristic gleyed layers. Rusty orange-red mottles can also form, where air enters around roots or on the surface of larger pores (Figure 2).

The smallest classification units are the soil series (equivalent to a crop variety or animal breed). Named after the places where they were first fully described, soils in any given series have similar texture, depth, and mineralogy. On many farms, there are usually about three to four soil series but the number can be far higher than this.

There are about 750 soil series in England and Wales. National soil maps group soils that often occur together into smaller ‘map units’. At present, there are about 300 ‘soil associations’ and about 30 ‘soilscapes’ in England and Wales (Scotland and Northern Ireland have a different classification system).

The basic soil types determine many of the inherent soil-related constraints (e.g. waterlogging and erosion risks, soil texture, depth and stoniness) reflected in the agricultural land use capability classification.

Figure 2. Soil profile showing characteristic horizons. This is a surface-water gley soil showing gleying as a result of waterlogging. The clay soil is relatively impermeable and, therefore, anaerobic conditions occur during excess rainfall

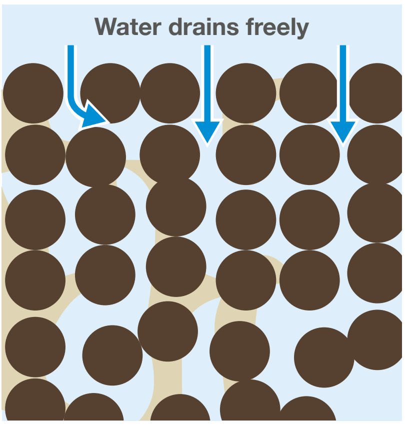
Soil composition

Texture

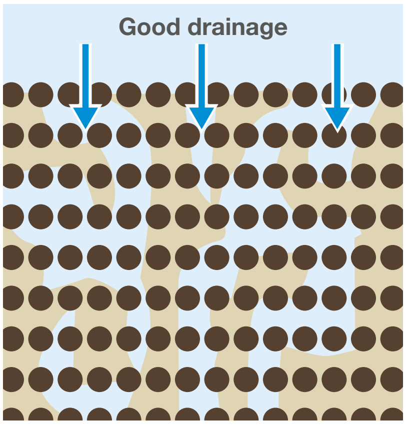
The amount of primary particles (sand, silt and clay) in soil defines its texture. Marked changes in texture can occur vertically within the soil profile. Texture determines how easy the soil is to work and can indicate how resilient the soil is to structural damage. Soil texture is also a major factor that controls how much water a soil can hold (water holding capacity) (Figure 3), how available it is to plants (available water capacity), how good it is at holding onto lime or other nutrients (buffer capacity) and how well roots can grow. It is not easy to change soil texture but management needs to adapt to it.

Soil texture is determined most accurately by laboratory analysis. However, it is possible to get an indication of the soil texture class by hand (Figure 4). Soils with more than 50% sand and less than 18% clay feel predominantly rough and gritty (sands, loamy sands and sandy loams). Those with a high proportion of silt particles and under 35% clay feel predominantly smooth and silky (silt loams and silty clay loams). Soils with more than 30% clay feel predominantly sticky, mould to form a strong ball and take a polish (sandy clays, clays and silty clays). Loams fall into the middle with a good mix of sand, silt and clay particles. Organic (peaty) soils have an organic matter content greater than 20% and are grouped according to the balance of sand and organic matter content.

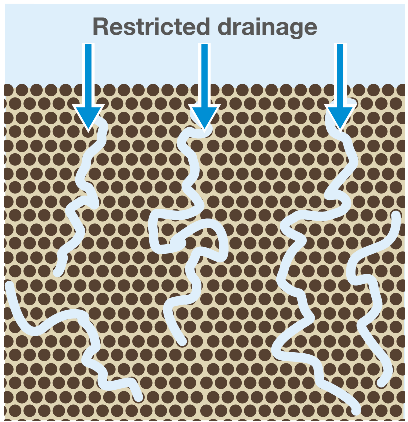
Sand
Largest soil particle at 0.06–2 mm

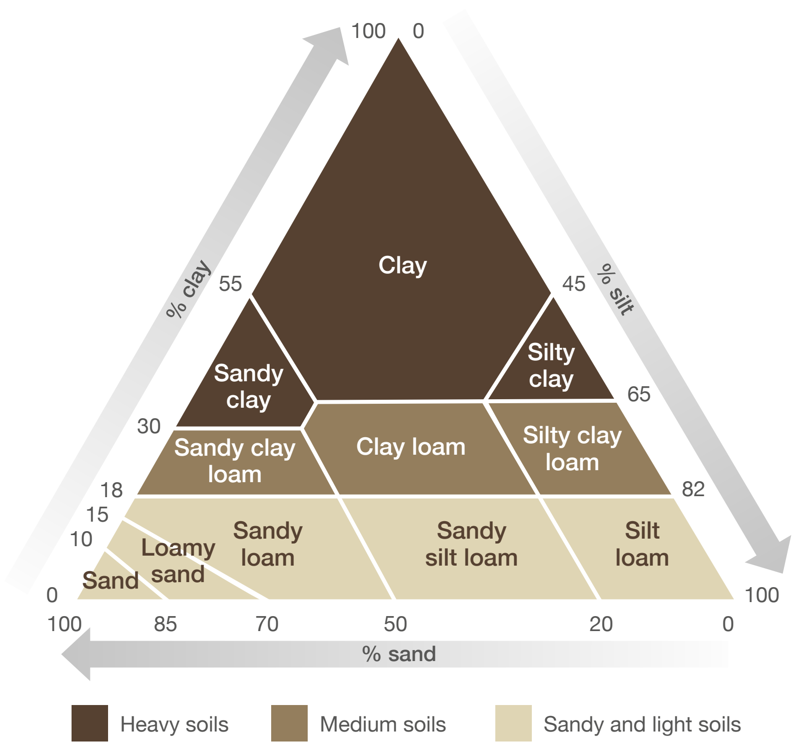


Silt
Smaller than sand but bigger than clay at 0.002–0.06 mm



Clay
Smallest particle at less than 0.002 mm





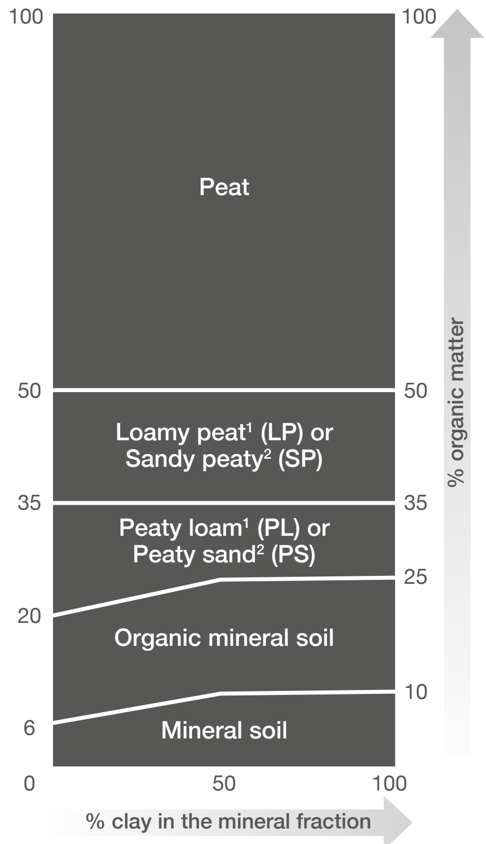


Figure 4a. Classification of mineral soils into soil texture classes

[1] Less than 50% sand in the mineral fraction
[2] 50% sand or more in the mineral fraction

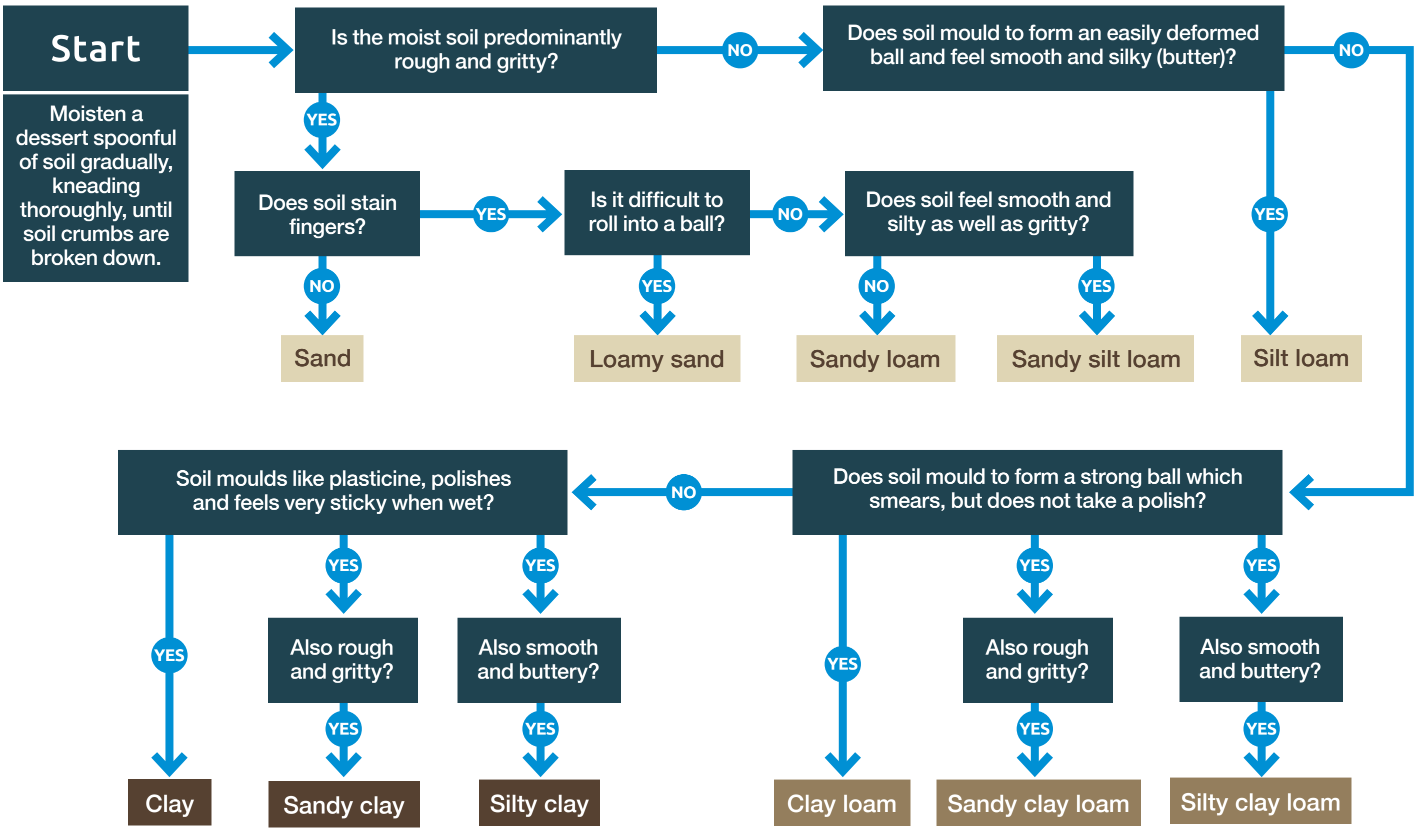


Figure 4b. Classification of mineral soils into soil texture classes

Cation exchange capacity

Cation exchange capacity (CEC) reflects the ability of a soil to hold positively charged cations (including important nutrients). Easily exchanged with other cations, these adsorbed cations are plant-available. High CEC soils hold onto cations more effectively. Soils with a low CEC are more likely to acidify quickly and to develop deficiencies in K, Mg and other cations.

CEC is highly influenced by soil texture. The CEC of sand and silt in most soils is negligible. As clay is negatively charged, CEC increases with the amount of clay. CEC also depends on the type of clay, as well as soil pH and the amount of organic matter. Well-broken down soil organic matter (often known as humus) has a high CEC. As a result of the differences in active surface area (linked to CEC), the natural levels of organic matter held in a sandy soil are much lower than in a soil with more clay. This is because of the ways in which clay helps to stabilise organic matter in soil. A good level of organic matter for a sandy soil is considered too low in a clay soil.

Organic matter

Soil organic matter (OM) is the term used for all living or once-living materials in the soil. It adds to soil fertility and enhances the physical, chemical and biological properties of soil. It is critical to soil health, although the precise contribution of OM to soil function remains poorly understood. However, there is growing evidence to show that the 'active' OM fraction (up to 10% of the total soil OM) is more important to soil physical properties than total soil OM. The active fraction consists mainly of recent additions of crop residues and organic manures. Under arable cropping, annual returns of crop residues to the soil are the major source of these active substances. Long-term arable soil contains less organic matter than grasslands because of the high returns of OM from root turnover in grasslands. Increasing the total soil OM content in soils is difficult. Changes occur slowly and, hence, may be difficult to detect, except with repeated analysis over the long-term (5–10 years).

Soil OM has a range of benefits for the physical, chemical and biological properties of the soil. Together, these benefits improve a soil's ability to recover following adverse events (e.g. extreme weather and pollution). Soil OM:

- Improves soil structure, making it more friable and improving workability/trafficability. Benefits include a greater window for mechanical operations, faster forward speeds, less implement wear, reduced need for subsoiling and greater window for mechanical operations
- Improves infiltration, water holding capacity and drainage
- Reduces the risk of capping, compaction and erosion
- Enhances drought resistance
- Adds to cation exchange capacity when well broken down (humus)

- Contains and supplies nutrients (N, P, S) and adsorbs and stores other nutrients (e.g. K, Ca, Mg, Cu, Zn)
- Buffers pH during decomposition and stabilisation
- Acts as a long-term store for carbon added via the plant-soil system and organic matter applications
- Provides a food source for soil biota (life)

Figure 5. Well-structured clay loam soil in an arable rotation with organic matter distributed throughout the topsoil

Structure

Soil structure is the architecture of the soil. It is usually described by the size, shape and stability of units (called aggregates, crumbs, blocks or peds) in which the particles (sand, silt, clay and organic matter) of the soil are held together. The pore space (gaps) between these aggregates are the most important part of the structure, as these control the balance of oxygen and water available to plant roots and soil organisms. Bigger (transmission) pores, in which water moves easily, are more than 150 µm in diameter (just thicker than a human hair). In topsoil, these pores are usually filled with air. Plant roots can extract water from pores as small as 0.2 µm (smaller than a bacterial cell). All pores can be blocked, disrupted or diverted, due to natural processes and tillage operations.

Topsoil structure

A well-structured topsoil has small, rounded aggregates and a range of pore shapes and sizes that form a continuous network (Figure 6). This allows good aeration, root proliferation (to access nutrients and water) and better drainage. Good plant growth requires aggregates of 1–10 mm that remain stable when wetted.

Plant roots and some soil organisms (sometimes called 'ecosystem engineers') move through the soil and change its structure (e.g. by moving soil particles and extracting water). In UK agricultural soils, earthworms are important engineers. Because rooting has a major role in structure formation, cover crops or leys can help maintain or improve soil structure within the rooting zone.

Biological interactions have a central role in the formation and stabilisation of soil structure, together with a range of physical effects (drying-wetting) and the formation of chemical bonds in some soils. Organic matter, clay and, in some soils, calcium and iron compounds can bind larger particles together. The strength of the bonds determines the stability of the soil and its potential to withstand wind and water erosion.

Figure 6. Examples of well-structured topsoil in grassland and arable systems

Subsoil structure

A well-structured subsoil has vertically orientated, often continuous, pores and fissures that are formed by physical shrink-swell processes and maintained by root and earthworm action. Between these pores, the soil forms column-like structures. In clay subsoils, these may be single prismatic aggregates (Figure 7). These columns give the overall soil profile strength. Strong soils are more resilient and can better resist damage by compaction. Cultivations and restructuring operations need care to avoid weakening any natural column strength.

Figure 7. Clay subsoil showing vertical fissuring

Some soils, with clay or clay-loam textures, 'self-structure'. Such soils have specific clay minerals present that absorb moisture and swell and, when moisture is released, shrink. This occurs with smectite and vermiculite clays. With regular inputs of organic matter, self-structuring is enhanced, especially in calcareous soils.

Benefits of good soil structure

One of the main benefits of good soil structure is that it increases the duration of the cultivation window. It also minimises tillage costs – in terms of tractor hours, number of passes, and size of tractor and implements required.

Soil workability changes markedly with moisture content. Critical moisture contents vary with soil texture and this property is best determined by hand. When conditions are optimum for tillage, soils are friable. As soils get wetter, they become softer and more easily deformed. Eventually, they can reach a condition known as the plastic state (i.e. acts like plasticine). If a handful of moist soil can mould into a ball or a cylinder, the soil is in the plastic state. In this state, soil is highly sensitive to compaction by livestock, traffic and tillage. It is important to take account of moisture content and consistence (resistance of samples to deformation or breaking) throughout the soil profile. As soil wets or dries, various soil layers can have markedly different moisture contents. This can lead to unintended compaction in the subsoil. When any layer is close to or above (i.e. wetter than) its plastic limit, significant structural damage can occur. Compaction causes a reduction in air spaces between soil particles. Overall, poorly structured soils (Figure 8) reduce water infiltration and can lead to erosion, and surface ponding and crusting.

Figure 8. Examples of poorly structured soils. Sandy loam soil showing compaction (large platy aggregates) after late harvest of potatoes in wet conditions (top). Clay soil showing compaction (dense layer with evidence of waterlogging) following overstocking in wet conditions (bottom)

Water

Soil constantly wets and dries, in response to numerous factors (Figure 9), such as rainfall, evaporation and plant transpiration.

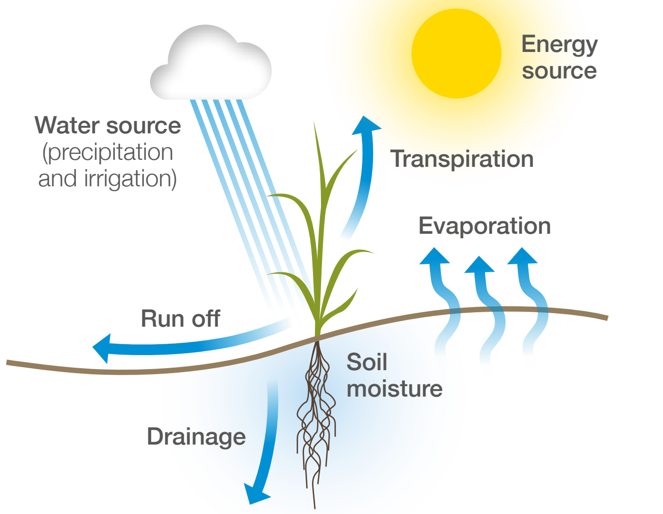


Figure 9. Soil water balance: the main soil water flows and stores

Soil is rarely at the same moisture state across all its layers. Moisture state is highly influenced by soil texture. For example, water moves relatively slowly through clay soils, clay layers and compacted layers. Infiltration rate is the speed at which water enters through the soil surface. Hydraulic conductivity describes how easily water moves through any soil layer. Soil permeability (pore size, fissures and compaction) and moisture content affect conductivity. Cracks and macropores allow rapid infiltration and movement between layers. Smaller pores take longer to fill and movement of water into these pores relies on capillary forces, as well as gravity.

The pore network is most likely to collapse at the soil surface. Wet aggregates are weak and easily broken by raindrops. Soil particles become detached and block the coarser surface pores, markedly reducing infiltration rates, a process known as soil capping (Figure 10).

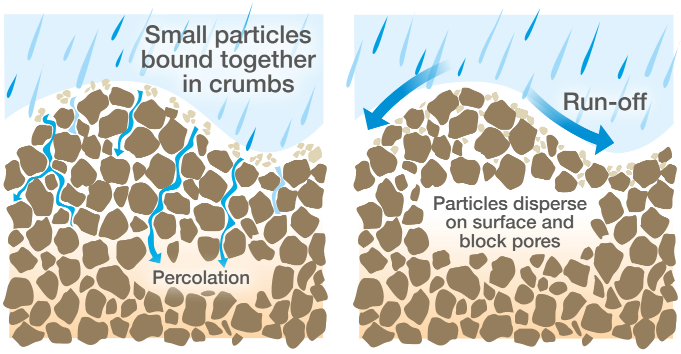
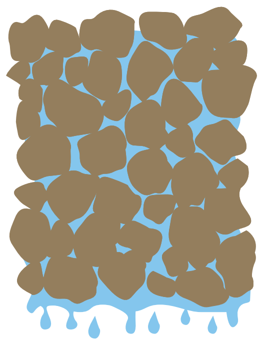


Figure 10. Water infiltration, percolation and soil capping

Drainage rates are a combination of infiltration and hydraulic conductivity. In most soils, the subsoil drainage rate controls drainage across the whole profile. Water moves from wet areas to dry areas by capillary action. As this does not depend on gravity, water can move upwards, sideways and downwards. Smaller pores hold water with more force. This is why water moves more slowly in the very small pores associated with clay soils. Generally, soils with larger pores, such as sands, drain more quickly and retain less water. However, if water running through the profile encounters a layer of coarse material, it often stops until the soil above it becomes nearly saturated. This is because the water cannot enter the sand layer until the large pores can pull water into it. A soil that becomes sandier with depth holds more water than its texture suggests.

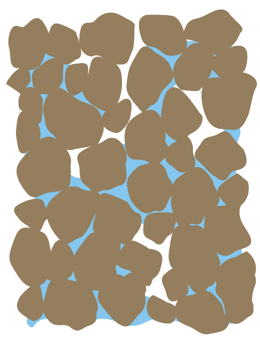


Saturation

All pores filled with water (i.e. no air in the soil). Gravitational water is lost.

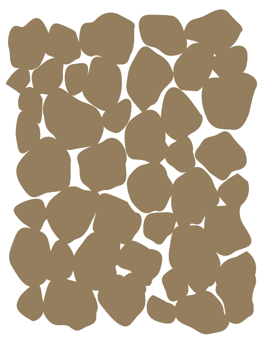
Soil moisture deficit

Occurs when more water is removed by evaporation and plant transpiration (evapotranspiration) than is added through rainfall and irrigation. When there is a soil moisture deficit, soil will dry out. Soil moisture deficits are common in the UK in spring and summer. This is the key soil measure used in irrigation scheduling.



Field capacity

Reached following heavy rain, when a soil has drained for about 48 hours, air has re-entered the soil and no more water is lost through gravitational drainage. Soils are usually at field capacity or wetter during winter.



Permanent wilting point

Soil dries progressively until only the smallest pores contain water. Roots are unable to draw on this water, causing leaves to wilt. Plants may recover at night but, when damage is permanent, the soil has dried to the permanent wilting point. Some soil types (especially clays) still contain up to 20% water at the permanent wilting point. It is uncommon for a soil to reach permanent wilting point in the UK.

Figure 11. Impacts of soil water status on drainage and water availability for plants

Water availability

The water in a soil between the moisture content at field capacity and that at permanent wilting point is available to crops – known as the available water capacity (AWC). Total soil pore space does not vary significantly between sandy and clay soils – but the type of pores present changes markedly. This affects both the AWC and water movement. Improving soil structure, for example, by increasing soil organic matter content, can markedly improve the AWC.

Knowing the water content of the soil alone is not enough, as the soil texture and structure affects pore sizes and their connectivity (Figure 12). For example, if the soil is at 29% water content:

- Very sandy soils are wetter than field capacity and drainage will occur
- Clay loam soils are in an ideal condition for plant growth
- Heavy clay soils could be at permanent wilting point

In the UK, light limitation of the growth and yield of grass and many combinable crops is more common than water limitation, except for short periods. Water requirements increase with growth duration (e.g. winter cereals use more water, overall, than spring cereals) and photosynthesis. Therefore, high-yielding crops increase the risk of water limitation. Irrigation of potatoes and many vegetable crops is common in the UK, as crop water demand can often exceed the natural supply.

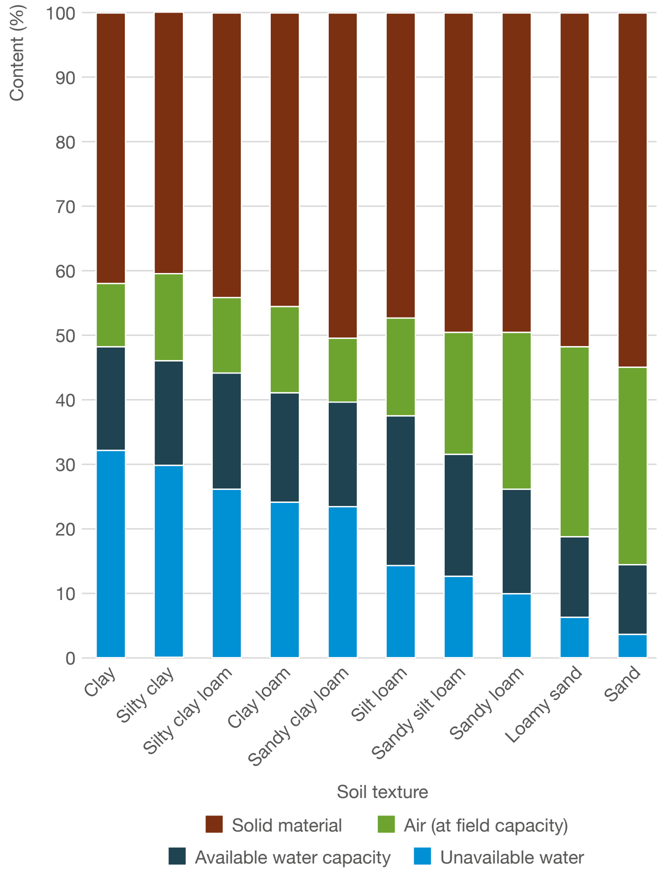


Figure 12. Soil texture affects the available water capacity (AWC)

Source: Data supplied by Mark Stalham, NIAB-CUF

Principles to improve soil health

Well-maintained soils provide good structure, water retention and nutrient availability. The physical, chemical and biological properties of soil interact to deliver these functions. The physical structure of soils (air/water balance) and the chemical environment (pH/nutrient levels) provide the habitats for biological components (e.g. roots and soil organisms) to interact within the soil matrix.

Although soils and management practices vary from farm to farm and field to field, there are some general principles that underpin all farming systems that have healthy soils (Figure 13). These aim to keep chemical, physical and biological properties in balance. Balanced soils reduce requirements for mechanical intervention. An understanding of soil health can also inform decisions, when any cultivation or restructuring operation is required.

Biological

- Feed the soil regularly, through plants and organic inputs
- Move soil only when necessary
- Diversify plants in space and time

Chemical

- Maintain optimum pH
- Apply nutrients (right amounts, in the right place, at the right time)
- Know soil textures and minerals (buffer capacity)

Physical

- Know soil textures and understand limits to workability and trafficability
- Optimise water balance, through drainage (if necessary)
- Minimise compaction and improve soil structure

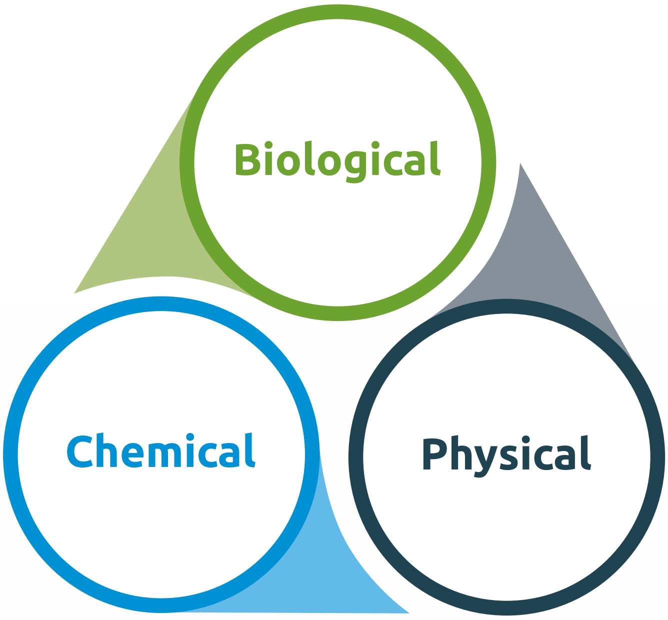


Figure 13. Know your soils: common principles to improve soil health

Biological

Soil organic matter (OM) is all living or once-living materials in the soil. A key biological component, OM provides a direct source of energy/food for many soil organisms. It is the fuel in the soil food web. Decomposition of OM increases nutrient cycling and improves the structure of soils.

Crops provide a valuable source of OM, and regular additions of OM (with diversity in OM types), combined with reduced tillage, can help restore soil health. Increased resistance and resilience of soil functions, such as nutrient and water supply, appear to be associated with diverse rotations with no-till periods (e.g. ley-arable rotations) in particular.

The tillage system influences the periods where roots are active and soil is covered by plants or residues. The system also changes the distribution of OM in the soil. For example, reduced tillage intensity is associated with increased fungal biomass. This includes arbuscular mycorrhizal fungi that colonise roots and increase crop access to phosphorus and water.

As reduced tillage stabilises habitats, it benefits many soil organisms. Reducing the occurrence or frequency of disruptive tillage is also associated with increases in soil biological activity, with earthworm populations a good indicator of these changes. Targeted use of OM can also offset some of the negative effects associated with intensive tillage.

Rotations that lack diversity, especially monocultures, simplify the soil food web. Such rotations can also build up pest, disease and weed problems. In arable and horticultural systems, diversification and/or the integration of green manures, cover crops and leys into crop rotations also has positive benefits for soil biota. Increases in plant diversity, whether in space or time, often lead to greater species richness of soil biota, through more diverse litter, exudates, rooting patterns and plant associations. Management of the farmed landscape, rather than fields per se, is also important. For example, field margins and hedges provide an important reservoir of a wide range of soil organisms.

Chemical

Parent material controls the texture and the types of minerals present in the soil. Texture determines the soil's ability to hold onto lime or other nutrients (buffer capacity). Some nutrients, especially trace elements, are from the parent material, whereas others may be missing completely. It is important to know the soil's chemical make-up to optimise inputs.

Maintain soil pH at the optimum level. The optimum level depends on the crop. However, under pH 5.5, soil biological activity tends to slow down and root growth and function become inhibited. The pH also affects other soil properties, such as nutrient availability.

The application of lime is the main way to raise soil pH. Reducing soil pH over naturally alkaline parent materials (chalk and limestone) is not often practiced at the field scale. However, relatively high pH soils affect nutrient availability, especially the reduction of phosphorus and many micronutrients.

To make the most of organic materials and balance the benefits of fertiliser use against the costs, both economic and environmental, use the AHDB Nutrient management guide (RB209).

Physical

Topsoil and subsoil textures largely determine the limits to workability and trafficability. Well-structured soils have a better balance of air and water. These benefit root growth and promote an active soil ecosystem. Such soils are more resilient to waterlogging and can increase the number of grazing days and machinery workdays.

Tillage and compaction disrupt the connectivity of pores and water films in the soil, changing the air/water balance. Careful management of grazing and/or timely operations can help a continuous pore network develop, from the soil surface to the subsoil. If soil is in a plastic state in the top 40 cm, then traffic should be minimised. Where installed and maintained, drainage can help naturally wet or slowly permeable soils stay below the plastic limit for longer.

Changes in tillage, especially use of non-inversion techniques and targeted reduction in compaction risk, alter soil surface conditions, especially overwinter, and help reduce run-off and associated sediment loss.

Sandy soils

Biological

Know: Low capacity to hold organic matter

Act: Add organic matter regularly to maintain biological activity

Act: Use composted organic matter to improve soil structure and stability

Act: Move to ley-arable rotations in very sandy soils, where possible

Chemical

Know: Low cation exchange capacity

Act: Lime little and often to maintain pH

Act: Manage nutrients to match supply and demand

Physical

Know: Drought risk is significant

Act: Avoid trafficking wet subsoil

Act: Install and maintain drainage, where groundwater is high

Medium soils

Biological

Know: Slow to change organic matter content

Act: Add organic matter regularly to maintain biological activity

Act: Monitor organic matter levels, at least every five years

Act: Add diversity to the crop rotation, while maintaining seasonal flexibility

Chemical

Know: Some capacity to buffer changes in pH and nutrients

Act: Monitor pH, P and K regularly

Act: Manage nutrients to match supply and demand

Physical

Know: Assess soil structure to know its workability and trafficability limits

Act: Optimise timeliness of operations to minimise damage

Act: Install and maintain drainage

Heavy (clay) soils

Biological

Know: Naturally high in organic matter

Act: Add organic matter regularly to maintain biological activity

Act: Use composted organic matter to improve soil structure and stability

Act: Move to ley-arable rotations, where possible

Chemical

Know: High cation exchange capacity and some clay soils have good reserves of K

Act: Develop good rotational strategies to manage lime, P and K

Act: Optimise seedbed quality to maximise nutrient use efficiency

Physical

Know: Waterlogging can be a major issue, especially in soils without active roots

Act: Optimise timeliness of operations to minimise damage

Act: Install and maintain drainage

Soil-related problems

Capping

Observed

- Seen where heavy rain or irrigation falls onto bare soil. More common in sandy and silty soils, and where organic matter is low

Symptoms

- Crust or cap (1–10 mm thick) that can be peeled back from the soil surface with a knife
- Reduced infiltration rate, as surface-connected pores become blocked
- Crust may act as an impenetrable barrier to seedlings

Solutions

- On susceptible soils, avoid seedbed preparation and planting ahead of bad weather
- Use a mulch of crop residues or compost
- For long-term improvement, add organic materials (especially well-composted additions) regularly to improve soil aggregate stability

Figure 14. Surface capping of soil

Compaction by livestock

Observed

- Seen where livestock have grazed on wet fields. Medium and heavy soils are most susceptible to compaction. Sandy soils are, generally, less prone

Figure 15. Cattle and farm traffic can cause structural damage to the soil, especially in wet conditions

Symptoms

- Large angular/platy aggregates (over 5 cm across) with low porosity in the topsoil
- Some red/orange mottling may be present (sign of poor drainage)
- Roots clustered in large pores, worm channels and cracks between aggregates
- Poached, damaged upper layer of the soil and reduced sward density

Solutions

- Keep livestock off wet fields after heavy rainfall
- Increase the length of grazing rotations, particularly in wet conditions
- Ensure a good network of farm tracks and multiple gateways
- Locate drinkers and feeders to avoid compaction. Move temporary drinkers and feeders regularly
- Surface slitters/aerators can remove surface layer (0–10 cm) compaction and increase surface aeration

Compaction from machinery

Observed

- Seen where there has been traffic on wet soils. All soil textures can show damage from compaction. The greater the weight of the vehicle and tyre pressure, the deeper the potential compaction

Symptoms

- Very large angular or platy aggregates and/or a very dense compacted layer
- Concentration of roots indicates hard-to-penetrate layers or blocks of soil. A soil pan may be present, if roots grow horizontally or do not penetrate to any depth. Severe panning may show as a web of roots on the upper surface of the pan with only a few penetrating below
- Rapid changes in water content within the soil, with wet and dry zones adjacent, also may indicate compaction

Solutions

- Sward lifters/subsoilers can remove compaction in sub-surface layers (over 10 cm) and help with restructuring
- Avoid driving on soils where any layer(s) in the top 40 cm are above their plastic limit
- Reduce the pressure to the ground, with larger tyres and lower inflation pressures
- Reduce machine size and total axle loads, wherever possible
- Consider established wheelings or reduced traffic systems
- Avoid over-using entrances; use a separate exit, if possible

Figure 16. Transporting heavy loads in wet conditions can result in deep compaction

Run-off and water erosion

Observed

- Seen where rainfall exceeds the soil's infiltration rate. It is particularly common where there is little crop cover or the soil is compacted
- Surface run-off usually occurs during heavy storms or following prolonged rainfall
- Can occur on all soil types but especially on sandy and chalky soils on moderate-to-steep slopes

Figure 17. Surface run-off can wash soil onto adjacent field tracks or roads

Symptoms

- Overland flow seen after rainfall, which washes soil particles from the field. This results in muddy run-off in the field, on adjacent roads or in watercourses
- Ponding may occur in depressions in the field and lead to waterlogging
- Extreme run-off can result in rilling or deeper gullying in the field

Solutions

- Identify paths for run-off
- Create buffer zones (e.g. permanent strips of grass or rough vegetation) to slow down run-off and promote infiltration
- Plant hedges or build new ditches to restrict and control run-off
- Maintain a good structure in the soil surface with continuous pores to depth so that water can infiltrate
- Avoid fine seedbeds, especially in light soils
- Maintain soil cover, wherever possible
- Cultivate across the slope, wherever possible, but be aware of complex slope patterns that may channel run-off

Slumping

Observed

- Seen where heavy rain or irrigation water falls onto a bare seedbed. More common in sandy and silty soils, where organic matter is low, and in soils with high concentrations of sodium, relative to other cations

Symptoms

- Water disperses weakly developed soil aggregates throughout the cultivated layer
- Soil becomes structureless. If this dries, it can lead to a massive hard-set layer
- If a hard-set layer forms, this has few cracks and greatly reduced pore space. This layer is associated with poor infiltration, low water holding capacity and a high soil strength

Solutions

- On susceptible soils, check the forecast carefully and avoid seedbed preparation and planting ahead of any bad weather
- Do not over-cultivate
- On lighter-textured soils, increase soil organic matter, maintain surface cover and reduce soil trafficking
- On soils with high sodium, add lime or gypsum to help improve soil structure

Wind erosion

Observed

- Seen where dry seedbeds, in light sandy and peaty soils, are unprotected by cover (e.g. mulch or stubble)

Symptoms

- Sand deposits on roads
- Airborne dust clouds. The finest particles (organic matter and clay) can travel great distances

Solutions

- If planting is delayed, leave seedbeds in a wet or cloddy state, or with ridges perpendicular to the prevailing wind direction
- Grow rows of trees or hedges to provide protection for soil. Grow crops on the sheltered side
- Use cover crops to minimise the presence of bare soil
- For long-term improvement, add organic materials (especially well-composted additions) regularly to improve soil aggregate stability

Figure 18. Heavy rainfall can cause weakly developed soil aggregates to disperse

Soil assessments

Assess soil structure, texture and suitability regularly, especially if a change to soil management is planned. Soil assessment methods cover physical, chemical and/or biological indicators, and range from simple to more complex.

All assessments require a robust soil sampling strategy. Take samples at least once per rotation and at the same point in the rotation. This maximises comparability between samples. Ideally, divide fields into similar (relatively uniform) zones and take representative samples from each one. To identify zones, note soil and crop variations when cultivating, field walking, spraying and fertilising, combining (especially if yield mapping) and soil scanning (e.g. conductivity).

Consider testing physical, chemical and biological indicators at the same time. As a minimum, combine visual evaluation of soil structure (VESS) and earthworm counts with sampling for pH, nutrient status and organic matter.

Physical condition

Observations of the soil surface, the soil profile and rooting patterns are the best way to get information about structure. For comparison, dig holes in 'good' and 'bad' areas of a field.

- Soils in good condition are generally well structured
- Soils in moderate condition have larger and more angular aggregates, and restricted pore space
- Soils in poor condition are severely degraded with very large angular or platy aggregates and/or a very dense compacted layer

Figure 19. Assessment of soil physical condition

For a visual guide to good and poor soil condition in a range of soil types, see the thinksoils manual at ahdb.org.uk/soil-principles

Examine each layer of soil. When digging soils of similar texture and moisture content, variation in resistance can help pinpoint poor structure. The position, quantity and vigour of roots in the soil can also highlight issues. Concentrated areas of roots indicate hard-to-penetrate layers (e.g. soil pans) or blocks of soil. Soil pans are more likely in gateways and headlands. The dryness of zones in the soil may also shed light on root activity.

A hardened layer can form in the subsoil where quantities of calcium carbonate, silica or iron, manganese and aluminium compounds cause particles to bind together tightly in a discrete layer. Such layers are often associated with a fluctuating water table. Identify areas of damaged/poor soil structure (e.g. areas prone to surface capping, slumping, waterlogging, compaction or drought).

Visual Evaluation of Soil Structure (VESS) is a straightforward and quick way to test soil structure in three simple steps – soil removal, soil assessment and soil scoring. The soil quality score produced can help highlight where soil structure needs to be improved. Ideally, assess each distinct soil layer separately and target the worst performing, 'limiting' layer first.

Chemical condition

Sample areas of land known to differ in some important respects (e.g. soil type, previous cropping and applications of manure, fertiliser or lime) separately. To minimise the impact of local variation (e.g. the presence of old fertiliser granules), mix samples (at least 25) collected in the field in a clean receptacle (e.g. bag or bucket). Send a well-mixed subsample away for analysis. Where sampling is robust, results can determine the need for variable rate nutrient application. It is usually safe to use soil analysis results for phosphorus, potassium and magnesium as a basis for fertiliser recommendations for up to four years from the date of sampling.

Biological condition

Earthworms are useful indicators of soil condition. Deep-burrowing (anecic) species provide channels to drain water and help roots grow deeper into the subsoil. Earthworms also feed on soil organic matter, crop residues and leaf litter. They are vital to the turnover of organic matter and the mixing of organic and mineral components of the soil. Earthworm counts provide a quick and easy way to assess soil condition. The best time to count earthworm populations is early in the spring, or after soil has wetted up in autumn. Counts from several fields over a number of years or crop rotations can indicate long-term trends in soil condition. New methods to assess soil biological activity by laboratory analysis are available but need careful consideration and interpretation.

Further information

Other publications from AHDB

- **Field drainage guide**
- **Arable soil management guide**
- **How to record soil health (with the soil health scorecard)**
- **How to count earthworms**
- **How to assess soil structure (VESS)**
- **Nutrient management guide (RB209)**

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