

Healthy grassland soils

AHDB



The Healthy grassland soils project was funded by the Agriculture and Horticulture Development Board through its Beef & Lamb and Dairy sectors. The work was conducted by SRUC, Newcastle University and ADAS. It was established to develop an industry-recognised method for assessing grassland soils and to provide guidance on soil biology.



Understanding soils is fundamental to profitable grassland farming. It is often thought that soils under grass are in good health, however, a recent Defra-funded survey of 300 grassland fields indicated that only 40 per cent of fields had good soil structure.

Soil compaction occurs when soil particles are compressed, reducing the spaces (pores) between them, which carry vital air and water through the soil. It has been estimated that soil compaction costs up to £250/ha/year.

Compaction can cause:

- 10–20 per cent reduction in grass growth
- Restricted drainage
- Poor rooting
- Reduced nutrient uptake
- Increased weed burden
- Fewer working days
- Increased risk of run-off, soil erosion and nutrient loss

To combat soil compaction, it is essential to routinely assess soil structure. This can be easily incorporated into the farm soil sampling programme.

This pocketbook provides information on assessing, maintaining and improving soil structure.

For more information, visit **healthygrasslandsoils.co.uk**

Step one: Surface assessment

Look at sward quality to identify potentially damaged areas that require further assessment. It is worth assessing a part of the field that is poor, as it will help prioritise fields for action.



Good

- Sward intact
- No poaching
- Few wheelings



Moderate

- Surface poached
- Wheelings in places
- More weed species



Poor

- Surface capping
- Soil exposed
- Severe poaching
- Poor sward quality

TIPS

- When starting out, it is useful to dig in an area where you know there may be a problem (eg a gateway) and get familiar with signs of damage to soil structure
- Sample when the topsoil is moist. If the soil is too dry or too wet, it is difficult to distinguish signs of poor soil structure
- Soil is too dry for assessment if the surface is extremely firm and there has been little rainfall over the previous few weeks
- Soil is too wet for assessment if a boot penetrates more than 5cm when walking

Step two: Soil extraction

To extract the soil block, cut down on three sides (width and depth – approximately 30cm). Lever the block out leaving one side undisturbed.

The undisturbed side can be used for assessment while still in the ground or another block of soil can be dug behind the undisturbed side so it can be removed and assessed.

Lay the soil block on a plastic sheet or tray.





Importance of soil type

It is worth identifying soil type at this stage as it can influence how the soil is assessed and aid management decisions.

Texture of the soil helps define the soil type and is determined by the percentage of three particle sizes that make up a particular soil:

- Sand (large particles – between 0.06mm and 2.0mm)
- Silt (smaller particles – between 0.002mm and 0.06mm)
- Clay (smallest particles – less than 0.002mm)

A soil with a greater sand content will drain more easily, as there are greater pore spaces between the particles, whereas a soil with a large clay content will drain more slowly because the pore sizes are smaller.

Soil texture cannot be easily changed but it is important to understand it.

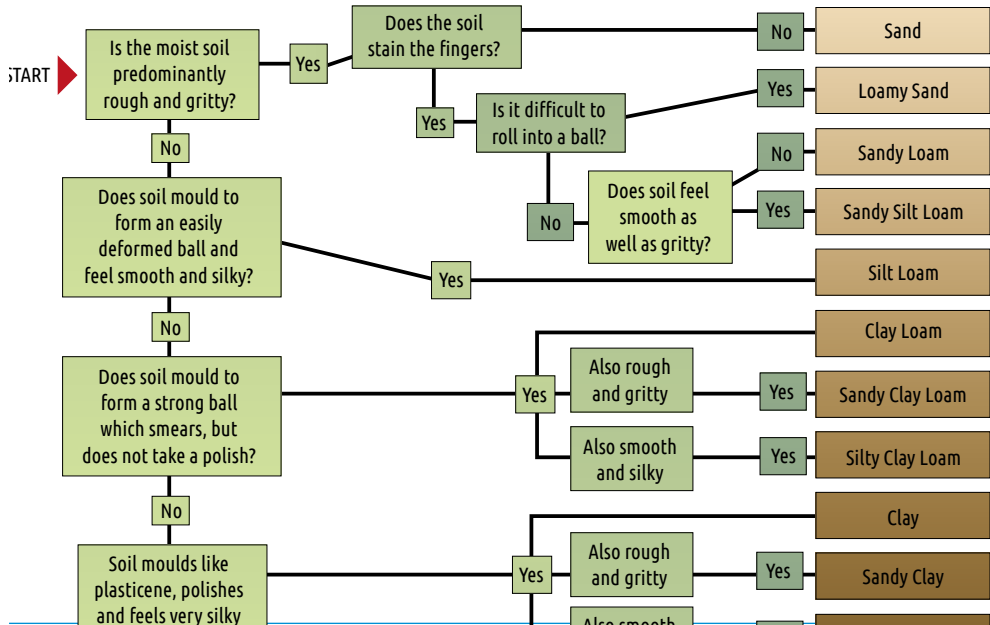
Effects of soil type

Type	Drainage notes	Risk of compaction
Sandy (light)	Freely drained and less organic material	Generally less prone to compaction due to better drainage. If compaction does occur, sandy soils are often slow to recover due to low organic matter, so mechanical intervention may be necessary
Silty/Loamy (medium)	Can be slow-draining	Susceptible to compaction when wet
Clay (heavy)	Poor natural drainage, remains wet longer	High chance of soil compaction when wet, although naturally cracks in dry and frosty conditions, helping to alleviate compaction
Peaty soils	Often artificially drained, but peaty soils with clay subsoil can remain wet for long periods	Prone to compaction when wet and to irreversible drying and erosion when artificially drained

How to identify soil texture

- 1 Dig out a small hole from the top 0–10cm of the grass sward
- 2 Take a handful of soil
- 3 Use extra water to work the soil (if necessary)
- 4 Follow the flow chart on page 11 to determine a soil type

The following diagram is taken from Controlling soil erosion: A manual for the assessment and management of agricultural land at risk of water erosion in lowland England. PB4093 © Crown copyright 2005



Step three: Soil assessment



Gently open the soil block like a book to break it up.

- If the structure is uniform – assess the block as a whole
- If there are two or more horizontal layers of differing structure, identify the layer with the poorest structure (the limiting layer)
- Carry out the rest of the assessment on this limiting layer

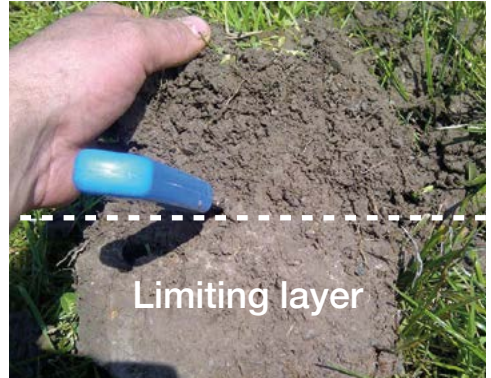
The limiting layer is defined as the layer within the soil profile that is limiting root penetration or water drainage.

The limiting layer is an area of more compacted soil, where the soil particles have been pushed together, leaving little space for water or air. The depth of the limiting layer will help identify its cause and determine its remedy.

Moderate over Good



Good over Poor



Step four: Soil scoring

Break up the soil with your hands into smaller structural units or aggregates (soil lumps).

- Assign a score by matching the soil to the descriptions and photos on pages 15–24
- A score of 1 or 2 is **Good**; a score of 3 is **Moderate**; 4 or 5 is **Poor** and requires management action
- Record depth of limiting layer to decide management options

The size and shape of the aggregates (lumps) are the key to soil structure assessment. If the soil is only breaking up into large (>10cm) and angular lumps, then action is needed.

Good



Moderate



Poor



Score 1 – Crumbly

Structure quality – Aggregates readily crumble with fingers

Description

- Good soil structure
- Highly porous
- Numerous, well-distributed roots
- Sweet, earthy smell
- Small, rounded aggregates

Soil structure



Soil aggregates



Small (< 6mm), rounded

Management options

Reassess every two years or if visible signs of damage appear in wet conditions.

Score 2 – Intact

Structure quality – Aggregates easily break apart

Description

- Good soil structure
- Porous
- Good root distribution
- Earthy smell
- Some indication of larger aggregates

Soil structure



Soil aggregates



Rounded (10mm)

Management options

Consider infrastructure changes (eg back-fencing, multiple field entrances or tracks) to minimise traffic in marginal weather conditions. Reassess annually.

Score 3 – Firm

Structure quality – Most aggregates break down

Description

- Adequate soil structure
- Larger aggregates, some angular
- Moderate root distribution
- No strong smell
- Less visible pores

Soil structure



Soil aggregates



Mostly rounded, some angular (> 10mm)



Management options

Reassess in six months and consider aeration options if no improvement.

Score 4 – Compact

Structure quality – Effort needed to break down aggregates

Description

- Large, angular aggregates (> 5cm across) with low pore numbers
- Some red/orange mottling may be present (sign of poor drainage)
- Roots clustered in large pores, worm channels and cracks between aggregates
- May have sulphur smell (ie bad eggs)

Soil structure



Soil aggregates



Larger (> 5cm), angular

Management options

If soil structure is poor at a depth of less than 10cm, use a sward slitter or aerator.
If soil structure is poor at a depth of 10cm or more, use a sward lifter or top-soiler.
If the sward is poor, consider ploughing or reseeding.

Score 5 – Very compact

Structure quality – Aggregates compact, difficult to pull apart and are platy

Description

- Very large, angular aggregates (> 10cm), with very few pores
- Any roots seen mainly at the surface or clustered down large pores or cracks
- May have grey colour with red/orange mottling (sign of poor drainage)
- May have strong sulphur smell (ie bad eggs)

Soil structure



Soil aggregates

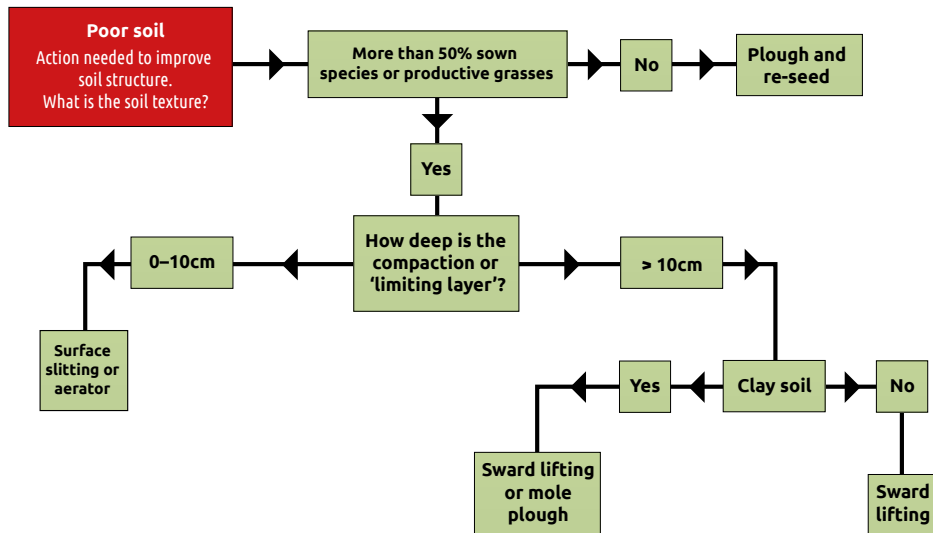


Large (> 10cm), angular

Management options

If soil structure is poor at a depth of less than 10cm, use a sward slitter or aerator.
If soil structure is poor at a depth of 10cm or more, use a sward lifter or top-soiler.
If the sward is poor, consider ploughing or reseeding.

Decision tree for scores 4 and 5



Management options for scores 4 and 5



Surface slitting

Surface slitters or aerators are tractor-mounted, ground-driven machines with sets of blades fitted concentrically on a horizontal shaft.

They can remove surface layer (0–10cm) compaction, increase surface aeration, improve water/slurry infiltration rates and help mineralise nitrogen from soil organic matter.

The amount of soil disturbance will depend on forward speed, soil type, soil moisture level at the time of operation and angle of blades.

As the working depth is relatively shallow, suitable soil conditions can change comparatively quickly throughout the grass growing season and optimum results are achieved over a relatively narrow range of soil moisture levels.

Using slit aerators

- ✓ Use wide-working widths to treat a larger area relative to the tractor wheels
- ✓ Travel slowly (1–2km/h) to ensure adequate penetration
- ✓ Adjust the depth of penetration by adding or removing weights if the aerator tears or lifts the soil surface
- ✓ Use long, sharp and narrow blades to give greatest penetration and slot volume
- ✗ Significant sward damage can result if the rotors are set at an 80° angle to the direction of travel, but can be sufficient to act as partial cultivation in an overseeding operation
- ✗ Research has shown there is no benefit to using aerators in grassland soils that are not compacted
- ✗ Avoid using in very wet or dry soil conditions. Too wet and the machine will work too deeply and could cause surface damage and smearing, too dry and the machine will not penetrate sufficiently

Soil working conditions

If choosing to aerate soil, it is important to make sure moisture conditions are correct to avoid damage.

Working
conditions
too wet



Suitable
working
conditions

Roll a handful of soil into a 'sausage'. If the soil gives a moist smooth surface, then it is too wet to work (above left). If the soil starts to crack, then it is suitable for slitting or sward lifting (above right). This works best for medium to heavy soils.

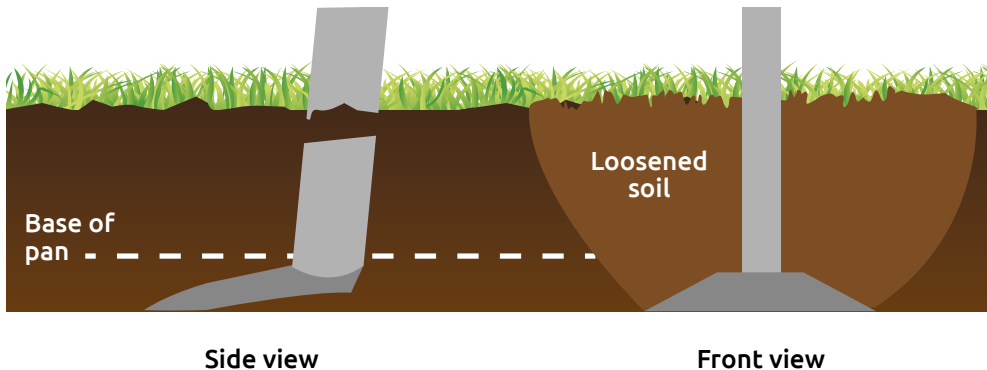
Remember:

It is important to dig a hole after a pass of the aeration equipment to check it is having the desired effect, rather than causing damage.

Sward lifting

Sward lifters (also called top-soilers) are tractor-mounted, ground-driven machines with two or three legs that are pulled through the soil.

They can remove compaction at depths of 10–35cm, improve water infiltration rates and help mineralise nitrogen from organic matter.



- ✓ Dig holes to the expected depth before you start, to check moisture content and texture (see photo on page 29)
- ✓ Tines need to be working around 5cm below the base of the compacted layer
- ✓ Work above the 'critical working depth' of the implement used – around six times the tine width
- ✓ Leading discs should be aligned with tine legs to avoid excessive sward tear
- ✓ Tine wings should have a low rake angle to minimise surface damage
- ✓ The ideal forward speed depends on soil moisture, but should be sufficient to allow lift over the advancing tine without causing turf to 'flip' over the packer roller
- ✓ Sward lifting should be carried out in the autumn when grass growth is declining

- ✘ Do not use on sward heights over 6cm to reduce the risk of sward damage
- ✘ Do not use sward lifters unless there are clear signs of soil compaction and the moisture content is suitable
 - Using sward lifters in wet conditions can increase soil damage through smearing and wheel slip
 - Using sward lifters in dry conditions is likely to lead to the formation of large clods, sward tearing and excessive surface heave, giving an uneven surface finish
- ✘ Avoid using in poorly drained soils with no drainage system present

Remember:

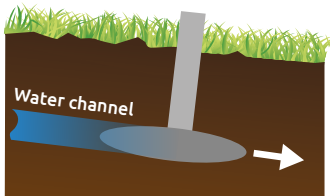
It is important to dig a hole after a sward lifter has passed in order to check it is having the desired effect, rather than causing damage.

Ongoing management

- Recently loosened soil is very sensitive to re-compaction
 - It is important to allow the newly loosened structure to be stabilised by root activity and natural soil processes
 - Sandy subsoils can be very unstable with mechanical loosening at depth, resulting in a complete loss of structure and surface slumping
- Cut or graze the site immediately before treatment
 - Avoid grazing after loosening and conserve rather than graze in the first spring after treatment
 - If late growth needs utilising, use sheep rather than cattle to minimise re-compaction damage

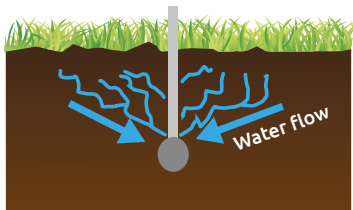
Mole ploughing

A mole plough drags a solid, rounded tube (the mole) through the soil to create smooth-walled channels, allowing water to flow away. These channels need to be connected to existing, gravel-filled drainage channels. As gravity is needed for the water flow, channels must be placed such that the slope of a field can be used.



**Work down the gradient
to allow water to flow**

- In poorly drained, slowly permeable clay soils, mole ploughing is not effective without associated field drainage systems
- Where the soil is relatively stone-free and clay content is greater than 30 per cent, mole drains should be created across existing drains every 5–10 years
- Mole drains are best formed in moist soils that are drying out



- The aim is to have mole drains running at a depth of 45–50cm and 1.5–1.8m apart
- Moles with a gradient in excess of 10 per cent are likely to collapse due to erosion of the channel walls

For further information, see **AHDB Field drainage guide** available on the AHDB website.

Ploughing

- Ploughing and reseeding may be the only option for severely compacted soils with a significant weed burden
- Ploughing should be done when both the topsoil and subsoil are moist but not too wet
- Reseeding allows new varieties and sward mixtures to be introduced, pH problems to be addressed and weeds controlled
- Ploughing allows more organic material to be added to the soil
- April and August are the best months to reseed

Management cost benefits

Action	Cost	Benefits	Likely returns (depends on the severity of compaction)
Grass harrow to break surface capping	Low	Accelerate drying process in spring, reduce run-off, improve nutrient cycling	Small
Surface slitting or aeration	Low	Reduce soil moisture and bulk density in top 10cm	Medium
Sward lifting to break deeper compaction	Medium	Improved water movement through soil, encourage deeper rooting	Medium

Action	Cost	Benefits	Likely returns (depends on the severity of compaction)
Sub-soiling or mole ploughing	Medium	Accelerate movement of soil water to drains, reduce soil waterlogging and risks of damage	Medium
Cultivation and reseeding to break deep compaction and plough pan	High	Opportunity to create a well-structured topsoil without limiting layers	Large

Indicative costs:

Low: < £50/ha

Medium: < £100/ha

High: > £150/ha

Cost benefit of aeration

Aeration can help extend the grazing season for dairy cows by reducing water retention in the soil. The extent of this will vary from farm to farm depending on soil type and amount of compaction. However, typically, it can increase the grazing season by between five and 10 days. The cost benefit of this can result in savings between £1.50 and £1.92 per dairy cow, per day.

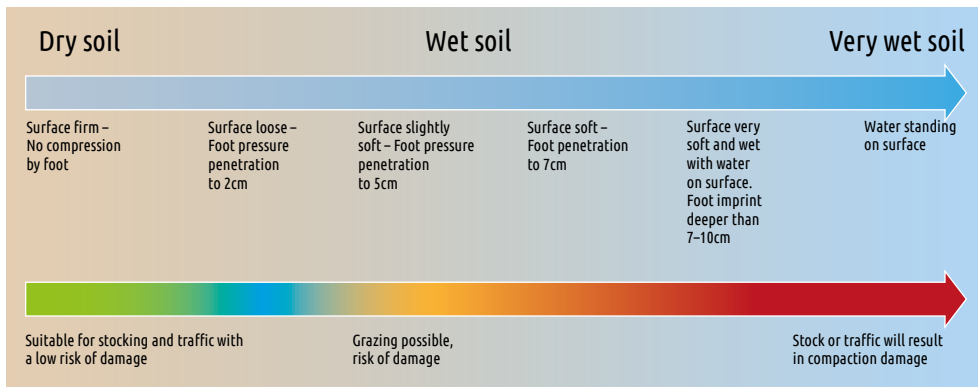
		Cost (£/cow/day)	Cost benefit of aeration vs. housing and feeding (£/cow/day)
Housing and feeding		£2.36 (£1.30 for housing and £1.06 for feeding)	
Extended grazing from aeration	Surface slitting	£0.44	£1.92
	Sward lifting	£0.88	£1.48

Assumptions: Cost of spike aeration (£35/ha), sward lifting (£70/ha), total mixed ration (TMR) cost of £2.28/cow per day and a pasture + concentrate cost of £1.82/cow per day.



Prevention is better than cure

For soils that have been scored as 1, 2 or 3, no immediate action involving machinery is required. However, it is important to prevent damage whenever possible. The wetter a soil becomes, the greater the potential for trampling by animals or damage by traffic, so extra care is needed when soil is moist.



Assess your fields by walking on them (adapted from Soil Husbandry by Tom Batey).

How to prevent compaction by livestock

- Keep livestock off wet fields after heavy rainfall
 - Grazing very wet fields results in poaching, damaging the upper layer of the soil and reducing sward density
 - Higher stocking densities can result in increased soil compaction
- Increase grazing rotations, particularly in wet conditions
- Strip graze with a back fence
- Ensure a good network of farm tracks and multiple gateways
- Site drinkers and feeders to avoid compaction. Move temporary drinkers and feeders regularly

How to prevent compaction by farm machinery

- If possible, keep off wet fields, especially 48 hours after heavy rainfall
- Reduce machine size and total axle loads, as loads greater than 3.5 tonnes can cause serious and permanent compaction
 - The greater the weight of the vehicle and tyre pressure, the deeper the potential compaction
 - If the soil is wet, the risk of compaction moves deeper into the soil profile
- For slurry-based systems, consider separation to ensure nutrients can be spread with less weight being carried
- If driving across a field, aim to focus traffic to the smallest possible area to minimise the amount of the field that may need remedial action
- Reduce the pressure to the ground with larger tyres and lower inflation pressures to spread the weight over a larger area; consult manufacturers' guidelines
- Consider established wheelings or reduced traffic systems
- Avoid overusing entrances and have a separate exit route if possible



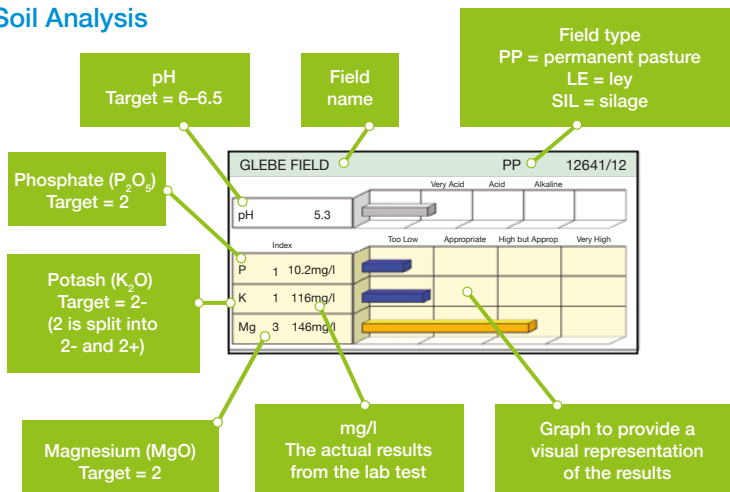
Soil test

- Ensure a recent soil test is available for the fields of interest as it may not be structure that is limiting yields or quality
 - Note locations of sampling points. Use a ‘W’ pattern across the field when collecting samples of soil for analysis
 - Assess a few of the sampling points for soil structure at the same time

Example recommendations

Field name/ Ref/Soil type	Last crop/ Next crop		Phosphate (P)	Potash (K)	Magnesium (Mg)		Lime
GLEBE FIELD/ 12641/12/ Heavy	Permanent pasture/ Permanent pasture	Units/ Acre	40	24	0	t/acre	2.4
		kg/ha	50	30	0	t/ha	6.0

Example Soil Analysis



From the example above, Glebe field needs lime and some phosphate and potash (see the recommendation table on page 44). For more information, see the Nutrient management guide (RB209).

The importance of maintaining field drainage

Good soil structure is important but will not resolve wet areas of the field if the water moving through the topsoil cannot drain away:

- In the wetter winter months, investigate wet patches and areas of the field with standing water
- Check farm plans for existing field drainage
- Maintain existing drainage, including outlets and drainage channels
- Ensure field drain outfalls are not buried in silt or continuously submerged – ideally the outfall should be 15cm above normal winter water level
- Regularly check field drain outlets, especially in late winter and early spring when they should be running freely following rainfall of at least 5mm in one day
- Clear any blocked or slow-running drain outfalls

- Look for signs of reddish-orange slime in outlet pipes, which can block the drainage systems and needs to be flushed out by jetting – there is not a permanent solution for this problem
- Where the soil is relatively stone-free and clay content is greater than 30 per cent, mole drains should be created across existing permeable drains every 5–10 years

For more information, consult **Land Drainage – A farmer’s practical guide to draining grassland in Ireland**, from Teagasc, or **AHDB Field drainage guide**.



Biological improvements

Biological activity within the soil can help improve soil structure and be an indicator of soil health.

Soil organic matter

Soil organic matter has an important role in a number of key soil functions by:

- Providing energy for biological processes
- Binding soil particles into aggregates to improve soil structural stability
- Storing key nutrients (eg nitrogen, phosphorus, sulphur)
- Providing habitat for organisms living in the soil
- Acting as a buffer where nutrients (especially cations) can be held in soil
- Enhancing the water-holding capacity of soil
- Moderating changes in soil temperature

Due to these roles, organic matter also adds resilience to soils (the ability of soil to return to its initial state after a disturbance, for example after tillage).

Grassland soils tend to have higher levels of organic matter than arable soils. Although increasing soil organic matter is a long-term process, it can be aided by:

- Adding slurry and farmyard manure, or other organic manures
- Using deeper-rooting plants, such as white and red clover or lucerne



Plant roots

Plant roots can aid soil structure by:

- Extracting water
- Rearranging soil particles
- Providing a habitat for soil organisms including symbiotic bacteria, mycorrhizal fungi, root pathogens and herbivores, which can help build soil aggregates
- Adding organic matter to the soil

Keeping the soil covered with a crop for as long as possible helps increase soil organic matter content and reduces erosion and surface water run-off. Vegetation cushions the soil on top, while the plant roots maintain soil structure underneath.

Some crops with deeper tap roots can grow through compacted soil, leaving channels for drainage. For example, red clover, lucerne, chicory and fodder burnet have deep tap roots that can potentially improve soil structure and drainage. These species can be included in more vulnerable areas even if oversown every few years.

The nutrient levels and pH of the soil need to be maintained to ensure good root activity.



Earthworms

Earthworms feed on soil organic matter and leaf litter, making them vital to the turnover of organic matter and the mixing of organic and mineral components within the soil.

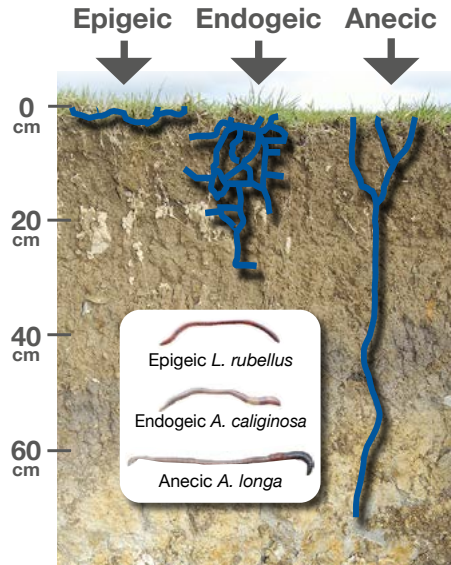
As they move through the soil, they create large pores that can help rooting and the movement of water.

Earthworms are generally most active during spring and autumn but, if living in burrows, can be found within the soil at any time of the year. The best period to observe or count earthworm populations is early to mid-spring or after the soil has wetted up in autumn.



There are three main earthworm lifestyles in the soil:

- Surface-dwelling (Epigeic) worms feed on leaf litter and other organic material on the surface. They are common in woodlands and rarely found in agricultural soils
- Shallow (Endogeic) burrowers live in the soil and feed on organic matter within. They make horizontal burrows in the topsoil
- Deep (Anecic) burrowers come to the soil surface in the evening and gather organic material into permanent burrows deeper down the soil profile. These worms leave casts on the soil surface



Earthworms

Taking measurements in a number of fields or over a number of years or crop rotations can give an indication of the biological health of the soil. When assessing soil structure or digging a soil pit, do not forget to look out for worms and the signs of their activity (casts and burrows).

Counting worms

Dig out five blocks of soil, 20x20cm and approximately 30cm deep, across the field. These need to be hand-sorted for worms (see below). Make sure the fields are assessed for worms at the same time of year.

Adult worms can be identified using a good field guide. Visit the Opal website (www.opalexplornature.org/earthwormguide) to access a guide for grassland in the UK.

Worm numbers are affected by a range of factors including soil type, weather and land management. However, a healthy soil will often have 10–15 worms per soil block.



Summary

- Assess soil structure when soils are moist (if possible in autumn or spring), on a seasonal basis
- Remember to test soil, as nutrient levels rather than structural problems may limit yields
- Between 50 and 80 per cent of damage is caused by the first pass of machinery on wet ground
 - where possible, avoid trafficking, grazing or cultivating land when soils are wet
- Higher sward density provides greater protection against soil compaction damage
- Compaction is caused by more animals in one area. Areas around drinking troughs and feeders are likely to become compacted in wet conditions
- Use low ground pressure tyres to reduce the impact of heavy machinery
- Check and maintain drainage
- Concentrate on problem areas of the field
- Consider mechanical loosening if the soil scores 4 or 5 and match the management to the compaction depth

- Do not use surface slitters, aerators or sward lifters unless there are clear signs of compaction and moisture content is suitable
 - For sward lifters set the working depth to 5cm below the zone of compaction
 - For sward lifters spacing between the legs should be at least 1.5 times the working depth (twice the working depth for winged tines), but wider if greater stability is needed post-loosening
- Check the equipment is working before doing the whole field by digging holes
- Soil is more susceptible to damage after slitting and sward lifting
 - Allow at least six weeks before grazing or machinery use. It is important to avoid grazing a loosened sward in the autumn. Sheep will cause less damage if sward needs to be grazed

Field records

Date	Field name	Current management	Surface assessment (% as poor)	Depth and thickness of limiting layer (cm)	Score (1–5)	Actions

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Produced for you by:

AHDB

Middlemarch Business Park
Siskin Parkway East
Coventry
CV3 4PE

T 024 7669 2051

E comms@ahdb.org.uk

W ahdb.org.uk

 @TheAHDB

If you no longer wish to receive this information, please email us on comms@ahdb.org.uk

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