The Healthy Grassland Soils project was funded by the Agriculture and Horticulture Development Board through its Beef and Lamb and Dairy divisions. The work was conducted by SRUC, Newcastle University and ADAS. It was established to develop an industry recognised method to 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% 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% reduction in grass growth
- Restricted drainage
- Poor rooting
- Reduced nutrient uptake
- Increased weed burden
- Fewer working days
- Increased risk of runoff, 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 gives you 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 soil structure damage

- 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**

Dig out one spade-sized block of soil (depth approx. 30cm). Cut down on three sides and then 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 assessing 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 controlled 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 0.06mm and 0.002mm)
- 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 as the pore sizes are smaller.

Soil texture cannot be easily changed but it is important to understand.
## Effects of soil type

<table>
<thead>
<tr>
<th>Type</th>
<th>Drainage notes</th>
<th>Risk of compaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandy (light)</td>
<td>Freely drained and less organic material</td>
<td>Generally less prone 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</td>
</tr>
<tr>
<td>Silty/Loamy (medium)</td>
<td>Can be slow draining</td>
<td>Susceptible to compaction when wet</td>
</tr>
<tr>
<td>Clay (heavy)</td>
<td>Poor natural drainage, remains wet longer</td>
<td>High chance of soil compaction when wet, although naturally crack in dry and frost conditions, helping to alleviate compaction</td>
</tr>
<tr>
<td>Peaty soils</td>
<td>Often artificially drained, but peaty soils with clay subsoil can remain wet for long periods</td>
<td>Prone to compaction when wet and to irreversible drying and erosion when artificially drained</td>
</tr>
</tbody>
</table>
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 below to give 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
Is the moist soil predominantly rough and gritty?

Yes

Does soil mould to form an easily deformed ball and feel smooth and silky?

No

Is it difficult to roll into a ball?

Yes

Does soil feel smooth and as well as gritty?

No

Does soil stain the fingers?

Yes

Loamy Sand

No

Sand

No

Sandy Loam

Yes

Sandy Silt Loam

No

Silt Loam

Yes

Clay Loam

No

Sandy Clay Loam

Yes

Silty Clay Loam

No

Clay

Yes

Sandy Clay

No

Silty Clay
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
- 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 clumps).

- 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 **Moderate**; and 4 or 5 is **Poor** and requires management action.
- Record depth of limiting layer to assess 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.
Moderate

Poor
Score 1 – Crumbly

Structure quality – Aggregates readily crumble with fingers

Description

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

Soil structure
Soil aggregates

Small (<6mm), round

Management options
Re-assess if visible signs of damage in wet conditions or every two years.
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 entrance 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)

Soil structure

• Roots clustered in large pores, worm channels and cracks between aggregates
• May have sulphur smell (ie bad eggs)
Soil aggregates

Management options
Consider use of sward slitter or aerator (if poor soil structure at a depth of <10cm) or top-soiler or sward lifter (if poor soil structure deeper than 10cm). If sward is poor, consider ploughing and re-seeding.
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

Management options

Consider use of sward slitter or aerator (if poor soil structure at a depth of <10cm) or top-soiler or sward lifter (if poor soil structure deeper than 10cm). If sward is poor, consider ploughing and re-seeding.
**Decision tree**

**Poor (Score 4 or 5)**
Action needed to improve soil structure. What is the soil texture?

- **More than 50% sown species or productive grasses**
  - No: Plough & re-seed
  - Yes: **How deep is the compaction or ‘Limiting layer’?**
    - 0 to 10cm: Surface slitting
    - 10cm plus:
      - Yes: Clay soil
      - No: Sward lifting

- **Surface slitting**

- **Sward lift or mole plough**
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 if the aerator tears or lifts the soil surface by adding or removing weights.
- Use long, sharp and narrow blades to give greatest penetration and volume of the slot.
- Significant sward damage can result if the rotors are set at an 80 degree angle to the direction of travel, but can be sufficient to act as partial cultivation in an overseeding operation.
- Research has shown no benefit to using aerators in grassland soils with no compaction.
- Avoid using in very wet or dry soil conditions, too wet and the machine works too deeply and can 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 soil moisture conditions are correct to avoid damage.

Roll a handful of soil into a tube 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 always important to dig a hole after a pass of the aeration equipment to check it is having the desired effect and not caused 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 prior to use to the expected depth to check moisture content and friability (see photo on page 28)

Tines need to be working around 5cm (2 inches) 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 speeds depends on soil moisture, but should be sufficient to cause 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
It is not recommended in poorly drained soils with no drainage system present

Remember:
  • It is always important to dig a hole after a sward lifter pass to check it is having the desired effect and not caused damage
On-going 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 creates smooth-walled channels in the soil to allow water to flow away by dragging a solid rounded tube (the mole) through the soil to create a channel. 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.

- 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%, 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% are likely to collapse due to erosion of the channel walls.
See AHDB Drainage Guide for more information

Ploughing

- Ploughing and re-seeding may be the only option for severely compacted soils with a significant weed burden.
- Ploughing should be done when both the topsoil and subsoil is moist, but not too wet.
- Re-seeding allows new varieties and sward mixtures to be introduced and pH problems to be addressed as well as weeds controlled.
- Allows more organic material to be added to the soil.
- April and August are the best months to re-seed.
## Management cost benefits

<table>
<thead>
<tr>
<th>Action</th>
<th>Cost</th>
<th>Benefits</th>
<th>Likely returns – depends on the severity of compaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grass harrow to break surface capping</td>
<td>Low</td>
<td>Accelerate drying process in spring, reduce run-off, improve nutrient cycling</td>
<td>Small</td>
</tr>
<tr>
<td>Slit aeration</td>
<td>Low</td>
<td>Reduce soil moisture and bulk density in top 10cm</td>
<td>Medium</td>
</tr>
<tr>
<td>Sward lifting to break deeper compaction</td>
<td>Medium</td>
<td>Improved water movement through soil, encourage deeper rooting</td>
<td>Medium</td>
</tr>
</tbody>
</table>
### Sub-soiling or mole ploughing

| Medium | Accelerate movement of soil water to drains, reduce soil waterlogging and risks of damage | Medium |

### Cultivation and re-seeding 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:** <£150/ha
- **High:** >£250/ha
Cost benefit of aeration

Extending the grazing season for dairy cows.

Aeration can help extend the grazing season 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 ten days. This can typically result in savings of between £1.50-1.90 per dairy cow per day.

<table>
<thead>
<tr>
<th>Costs (£/cow/day)</th>
<th>Aeration</th>
<th>Housing</th>
<th>Feeding</th>
<th>Cost-benefit (£/cow/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aeration</td>
<td>0.44</td>
<td>1.30</td>
<td>1.06</td>
<td>1.92</td>
</tr>
<tr>
<td>Sward lifting</td>
<td>0.88</td>
<td></td>
<td></td>
<td>1.48</td>
</tr>
</tbody>
</table>

Table assumes: Cost of spike aeration (£35/ha), sward lifting (£70), TMR cost of £2.28/cow/day and a pasture + concentrate cost of £1.82/cow/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 care is particularly needed when the soil is moist.

Adapted from: Soil Husbandry by Tom Batey
The Surface Squelch test (SQ)

How much does a boot sink into the ground when walking on the surface of the grass sward? See diagram on page 39.

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
  - Greater the weight of the vehicle and greater the tyre pressure the deeper the potential compaction

<table>
<thead>
<tr>
<th>Tyre size: 11-28</th>
<th>Load: 1650lbs</th>
<th>Inflation pressure: 12PSI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard dry soil</td>
<td>Normal</td>
<td>Wet soil</td>
</tr>
<tr>
<td>0</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>18</td>
<td>18</td>
<td>18</td>
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<td>15</td>
<td>16</td>
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<td>12</td>
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<td>6</td>
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<tr>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>24</td>
<td>24</td>
<td>24</td>
</tr>
</tbody>
</table>
- Reduce the pressure to the ground, with larger tyres, lower inflation pressures to spread the weight over a larger area
- Consider established wheelings or reduced traffic systems
- Avoid over using entrances, use a separate exit if possible
Soil test

- Ensure there is a recent soil test for the fields of interest – as it may not be structure that is limiting yields or quality
  - Note the locations of the sampling points in the “W” when collecting sample of soil across the field for analysis
  - Assess a few of the sampling points for soil structure at the same time

Example recommendations

<table>
<thead>
<tr>
<th>Field name/ Ref/Soil type</th>
<th>Last crop/ Next crop</th>
<th>P</th>
<th>K</th>
<th>Mg</th>
<th>Lime</th>
</tr>
</thead>
<tbody>
<tr>
<td>GLEBE FIELD/ 12641/12/Heavy</td>
<td>P Pasture/ P Pasture</td>
<td>40</td>
<td>24</td>
<td>0</td>
<td>2.4</td>
</tr>
<tr>
<td></td>
<td>Units/Acre</td>
<td>50</td>
<td>30</td>
<td>0</td>
<td>6.0</td>
</tr>
<tr>
<td></td>
<td>Kg/Ha</td>
<td></td>
<td></td>
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</tbody>
</table>
From the example above, Glebe Field needs lime and some P and K (see the recommendation table on page 43). For more information look at Fertiliser Manual (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 remedy for this problem

• Where the soil is relatively stone free and clay content is greater than 30%, mole drains should be created across existing permeable drains every 5-10 years

More info: Land Drainage - A farmer’s practical guide to draining grassland in Ireland from Teagasc or AHDB drainage guide.
Biological improvements

Biological activity within the soil can help improve the 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 (e.g., nitrogen, phosphorus, sulphur)
- Providing habitat for organisms living in the soil
- Has a buffering capacity where nutrients (especially cations) can be held in soil
- Enhancing the water holding capacity of soil
- Moderating changes in soil temperature
Because of all these roles, it also adds resilience (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 tillage soils. Although increasing soil organic matter is a long-term process, it can be aided by:

- Adding slurry and farm yard manure
- Using deeper rooting plants
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 are vital to the turnover of organic matter in the soil and the mixing of organic and mineral components of the soil as they feed on soil organic matter and leaf litter.

As they move through the soil they create big pores which can help rooting and the movement of water in the channels they create.

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 time 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 that feed on leaf litter and other organic material on the surface. These are common in woodlands but rarely found in agricultural soils.

- Shallow (Endogeic) burrowers live in the soil and feed on organic matter there. 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.
There is no right number of earthworms

A series of measurements taken 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 the worms.

Adult worms can be identified using a good field guide. Use the link to the Opal website to access a good 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.

www.opalexplorenature.org/earthwormguide
Summary

• Assess soil structure when soils are moist (when possible in autumn or spring) on a seasonal basis

• Remember to soil test, as nutrient levels may limit yields rather than structural problems

• Between 50 and 80% 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

• More 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 sward lifters unless there are clear signs of compaction and moisture content is suitable
  – Set the working depth to 5cm below the zone of compaction
  – Spacing between the sward lifter legs should be at least 1.5 times the working depth (2 x the working depth for winged tines), but wider if greater stability is needed post-loosening

• Check soil aeration equipment is working before doing the whole field

• 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 if sward needs to be grazed
# Field records

<table>
<thead>
<tr>
<th>Date</th>
<th>Field name</th>
<th>Current management</th>
<th>Surface assessment (% as poor)</th>
<th>Depth and thickness of limiting layer (cm)</th>
<th>Score (1-5)</th>
<th>Actions</th>
</tr>
</thead>
<tbody>
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