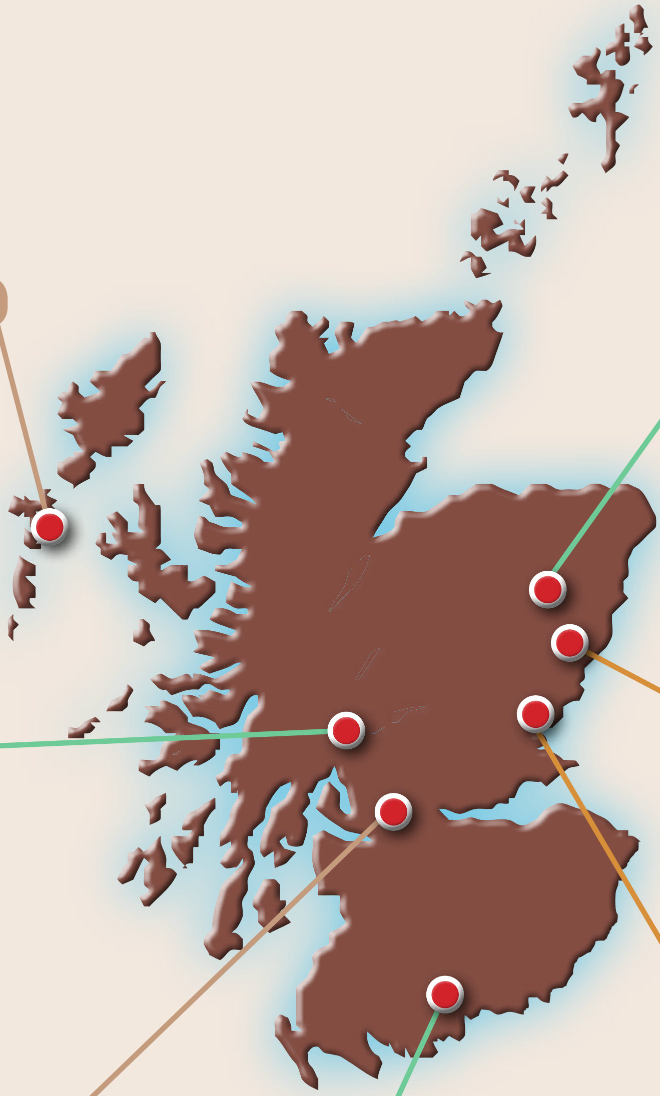
Valuing Your Soils

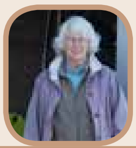
Practical guidance for Scottish farmers

What have other farmers done?

Read about common problems and actions in the case studies along with further information and useful websites.

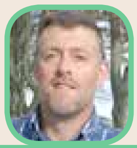
Mixed | **Grassland** | **Arable**





Kenary Croft

Mary Norton
Improving Organic Soils using Traditional and Modern Methods
(see Page 7)



Glensaugh

Donald Barrie
Integrating Farming and Forestry Protects Soils
(see Page 20)

Kirkton and Auchtertyre

Ewen Campbell
Combating Hill Farm Weeds and Managing Costs
(see Page 9)

Ardoch of Gallery

Willie Officer
Taking a Closer Look at Soils and Costings
(see Page 24)

Arnprior

Duncan McEwen
Rewards from Improved Soil Drainage and Nutrient Management
(see Page 17)

West Mains of Kinblethmont

Robert Ramsay
Controlled Traffic Farming
(see Page 28)

Crichton

Hugh McClymont
Good Dairy Farm Soil Management and Growing Maize as Additional Forage
(see Page 11)

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This document is a replacement brochure for the Farm Soils Plan and all costings information is valid at time of printing (May 2016).

Electronic versions can be downloaded at http://www.sruc.ac.uk/info/120603/farming_and_water_scotland

Valuing Your Soils

Practical guidance for Scottish farmers

Tips and ideas in this brochure can help you to **protect and improve farm soils** which could also **make your farm business more profitable**. The brochure includes:

- **Case studies** with real evidence of good practice and advice for current issues facing Scotland's farming community
- **Simple guidance** for taking action and valuing your farm soils
- **Ideas** on how you can **increase the efficiency, productivity and sustainability of your farm**

Practical field sheets in the back cover of this brochure:

- ✓ **Taking soil samples for testing**
- ✓ **Visual evaluation of soil structure (VESS)**
- ✓ **How to check for and alleviate soil compaction**
- ✓ **Checking soil drainage status**
- ✓ **Grassland rejuvenation**

Contents

1 Soils and income

Soil structure degradation narrows profit margins.

Simple assessments can be done on the soil in your fields that may cost at most an hour of your time and a few £10s for analysis but could help save £1000s in the longer term.

Likely financial returns of adopting good soil management

(based on SRUC, CREW and ADHB 2016 costings, suitability depends on soil conditions and farming systems)

Using a spade to dig pits for a quick soil inspection to identify soil structural problems – FREE (one hour of your time).

Soil testing for pH and nutrient status costs ~ £20 per sample.

Avoid problems associated with compacted or poorly drained soils such as reduced yields (~14-35%) and increased nutrient run-off losses (~ 40%). Alleviating compaction and improving drainage by sward lifting/subsoiling or mole ploughing can cost between £25/ha and £40/ha. Note that these operations must be done under suitable soil conditions.

If grassland soils are poor, grassland rejuvenation methods can cost between ~ £100/ha - £500/ha (see field sheet at the back of this booklet).

Soil aeration improves sward condition and quality and can extend the grazing season for dairy cows by 5-10 days, saving £1.50 - £1.90 per dairy cow per day.


© SEPA

Loss of crops due to poor drainage and flooding can result in financial losses of ~£1,112-£1,630/ha.

Well drained soils with good structure can support an increased growing season as the soils warm up quicker, this can save ~£2/cow/day.

Drainage operations can cost between £3,000-£5,000/ha but if the soil is compacted, surface water cannot readily get to the drains.

A good drainage system relies on good soil structure. Drains maintenance costs vary from £25-£45/hr for drain jetting with tractor and £35/hr for ditch cleaning.

Good drainage systems can last between 30 and 40 years.

Drainage improvements to a field can be very expensive (£20,000 plus) but can prevent waterlogging and poor harvest. Improving soil structure might be a better and less expensive option so it is essential to check for and alleviate compaction first.

A 500 m^3 temporary storage bund for protecting land prone to flooding can cost ~ £1,000.

Cover crops can increase organic matter and prevent soil erosion. They can reduce nitrogen (N) loss due to soil degradation by up to 30-40 kg/ha/year, i.e. savings of ~£30/ha on N fertiliser costs.

Cost of planting cover crops varies with seed choice. Seeds cost ~£30/ha upwards. Ploughing, seeds and sowing costs ~£100-180/ha).

Planting hedgerows and trees can improve soil quality and minimise soil erosion. Hedgerows cost ~£5.4/m. Tree establishment costs vary depending on species planted, number of trees planted, area of land to be planted and how the trees are protected. As a guide, consider a cost of £5,000/ha that will include maintenance for the first 5 years. Grants for planting reflect what woodland type is planted and vary from about £1040/ha to £6210/ha. Tree protection including fencing attract an additional grant.

Riparian buffer strips/fencing off stock to mitigate diffuse pollution – £4.50/m for stock fence, £50-£100/ha for seed.

For suitable soils, reduced tillage or no tillage could typically save £63 - £81/ha/year and protect soils from erosion and compaction especially if used with controlled traffic farming techniques.

Tramline disruption every 3 years can prevent long-term problems associated with waterlogging, soil erosion and surface run-off.

Opportunities for support and funding:

Scottish rural development programme
http://www.gov.scot/Topics/farmingrural/SRDP/SRDP20142020Schemes

Rural payments
www.ruralpayments.org

CREW Learning from community led flood risk management report
http://www.crew.ac.uk/publications/learning-community-led-flood-risk-managment

Forestry grants
http://scotland.forestry.gov.uk/supporting/grants-and-regulations/forestry-grants

Taking a look at your soils could be more profitable than you think

© Lorne Gill/SNH

Flooding can wash out ploughed fields

Further information:

Healthy Grassland Soils pocketbook – AHDB
http://beefandlamb.ahdb.org.uk/wp/wp-content/uploads/2015/12/Healthy-grassland-soils-pocketbook-021215-web.pdf

Soil Association report 'Seven ways to save Scotland's soils
http://www.soilassociation.org/scotland

Diffuse Pollution General Binding Rules (DP GBRs)
http://www.sepa.org.uk/regulations/water/diffuse-pollution/diffuse-pollution-in-the-rural-environment/

2 Know your soil type

What is soil texture?

Soils are made from the weathering of underlying rock or glacial/river deposits and take thousands of years to form.

The textures of the soils in a particular field won't change over time but can differ over a short distance, between fields, or sometimes within the same field. An understanding of the variations in soil texture is important as soil management can depend on texture.

Soil texture is defined by the proportion of three particle sizes; the small clay particles (less than 0.002 mm), silt (between 0.002 and 0.06 mm) and sand (between 0.06 and 2.0 mm).

More information is available in the Appendix Page 30.

Assessing your soil texture is easy

Soil texture can be easily estimated by hand.

Take a small handful of moist soil (add water gradually or spit on it to hold the soil together). Assess the feel of the soil and attempt to roll it into a ball and make it into a ribbon.

Compare your soils with the table below.

Texture	Colour/Feel	Ribbon length before it breaks
Organic (peaty)*	Dark, contains plant remains	Not possible to mould in to a ribbon
Sandy	Gritty and non-cohesive	Not possible to mould in to a ribbon
Loamy sand	Slightly cohesive	Not possible to mould in to a ribbon
Sandy loam	Gritty and cohesive	< 2.5 cm
Silt loam	Smooth	< 2.5 cm
Sandy clay loam	Gritty, cohesive, takes a polish when rubbed	2.5–5 cm
Silty clay loam	Extremely sticky, smooth, takes a polish when rubbed	2.5–5 cm
Clay loam	Moderately sticky, neither smooth nor gritty, takes a polish when rubbed	2.5-5 cm
Sandy clay	Gritty, very cohesive and sticky, takes a polish when rubbed	> 5 cm
Silty clay	Extremely cohesive, smooth, high degree of polish when rubbed	> 5 cm
Clayey soils	Extremely cohesive, neither gritty nor smooth, high degree of polish when rubbed	> 5 cm

**Organic soils are not included in the soil textural triangle classifications*

What can happen to soils with different soil textures?

Sand, Loamy sand, Sandy loam, Sandy silt loam (Light or sandy soils)

Light soils have a low clay content (< 18%) with a high sand, loam or silt content. They are usually well drained and will warm more quickly in the spring. They typically have a low organic matter content and are easier to cultivate but are susceptible to erosion and nutrient leaching.

Light sandy soil under oilseed rape

Loamy brown earth soil profile

Silt loam, Clay loam, Sandy clay loam and Silty clay loam (Medium or silty/loam soils)

These soils have a clay content between 18 and 35%, free draining but usually slower to drain and can still be susceptible to surface capping.

As the clay content increases there is a greater potential for structural damage with the chance of surface run-off and soil erosion.

Medium soils are good for intensive cropping systems if they are drained.

Silty soils and fine sandy soils are susceptible to surface capping after heavy rainfall. Surface crusts or caps make it harder for seedlings to emerge and can increase run-off.

Surfacing capping

Medium silty soil

Clay, Sandy clay and Silty clay (Heavy or clay soils)

These soils have a clay content greater than 35%, are mainly acidic and are generally poorly drained. They hold water and nutrients (calcium, ammonium and potash) well but can be waterlogged for part of the year.

Heavy soils also have a high risk of structural damage especially compaction and smearing (localised spreading and smoothing of soil by applied pressure such as slipping tractor wheels) as well as erosion of the soil from surface run-off. Surface smearing leads to restricted movement of water and roots, reducing crop productivity.

Organic (Peaty soils)

These soils have organic matter contents greater than 20%.

The majority of Scotland's soils are highly organic peaty soils which tend to be acidic and not very fertile, and have a high water content.

Peaty soil

Further information:

Soil texture classes in Nitrate Vulnerable Zones - interactive map http://www.soils-scotland.gov.uk/data/soil-texture

Find your soil type from http://www.soils-scotland.gov.uk/data/soils or **download the app at** http://sifss.hutton.ac.uk/ **to identify your field soils using your postcode**.

Case study: Improving Organic Soils using Traditional and Modern Methods

Mary Norton is the tenant of a 15 ha croft, Kenary, on Grimsay, North Uist in the Outer Hebrides. The black soil is more than 50% organic matter, wet and acid; rainfall is about 1250 mm/year. She currently keeps 2 registered Dexter cows and their calves, and makes winter keep of about 90 small bales of grass silage. She also grows a small amount of Shetland cabbage and other brassicas as a supplement. Mary is a member of the crofting group CEIA.

"Crofting is small-scale, and usually on land not suitable for high-input, high-horsepower farming. Most croft land used to be very productive and today still breeds some of the best livestock in Scotland. Old ways - with some modern knowledge and machinery - work best."

Mary Norton with CEIA's machinery

Grass silage field at Kenary

"In 2009, Kenary was a mess, overgrown with rushes and moss with the fences down, drains filled in, and stray sheep hammering it, like many others in the west of Scotland. Such croft land has been very under-used since the 1950s due to changes in payments, technology and advice. The first step was to flail-mow. The big surprise - if you mow, you get grass! That's the most important tip. On our blackland soil, we use shell sand, not lime which washes out quickly. Sand also helps with trafficability. Manure from winter stabling is composted for a year and spread on whatever field seems to need it most."

"I really dislike the term 'weed grasses' because in many places, such species are all that grow. Modern grass varieties are bred to need high-inputs, and are too feeble to compete here. I cut as early as I can which improves feed value, and have made silage from local fescues, bents and even Yorkshire fog, testing at DM 35, D 65, Protein 12.4, ME 10.1 without artificial fertilisers."

PROBLEM

DRYING OUT OVERGROWN FIELDS & PASTURE

ACTION

CLEAR DRAINS, FLAIL MOW & RAKE

"The trick is to select crops and stock that are suitable for the land, not try to change the land to suit demanding crops and animals. That's what the old guys would have done and that's what I am trying to do."

3 Soil - a living resource

Soil life

A teaspoonful of healthy soil contains billions of bacteria, kilometres of fungi and thousands of microscopic animals. Think of soil biology as the oil in an engine, without it the soil will not work.

Looking after and encouraging soil living organisms is an essential part of maintaining and improving sustainability of soil.

Earthworms are very useful as indicators of biological soil quality and improve the structure of the soil by burrowing and feeding.

The biological quality of the soil can be assessed at the same time as the soil structure using a spade test by breaking up the soil and counting the earthworms.

Earthworm

Organic matter

Soil organic matter is good for soil quality as it increases soil stability, drainage, fertility and encourages biodiversity.

In some situations tillage can reduce organic matter in surface soils because it breaks open soil aggregates and exposes previously protected organic matter which can then break down.

Organic matter is lost from a field as a result of continued cultivation when stubbles are not ploughed back into the soil or when organic manures are not returned.

Sandy soils with inherent low organic matter levels and soils subjected to excessive tillage (e.g. during stone separation for potatoes) are particularly susceptible to organic matter loss.

A healthy soil would normally have 5-10 earthworms in a 10 cm thick slice of soil to spade depth

Intensive tillage during potato cultivation increases the susceptibility of soils to organic matter loss and compaction

Actions for reducing loss of soil organic matter from your fields

- **To avoid loss of organic matter associated with erosion damage, use grass leys, cover crops and consider reduced tillage or no tillage**
- **Maintain regular inputs of good quality organic matter (plant residues/inputs, organic fertilisers) to prevent loss of organic matter and sustain fertility**
- **Apply manures to the land to help increase soil organic matter and maintain soil structure and nutrient status**

Soil organisms feed off organic matter, such as harvest residues, dead roots and added farm yard manure

Evidence case study: It is estimated that soil carbon in Scottish arable fields may be decreasing

Organic matter in soils can act as a carbon store, offsetting carbon dioxide emissions to the atmosphere which contribute to climate change. Scottish agricultural soils will be expected to have organic matter contents of 5 to 10% (equivalent to organic carbon contents of 3 to 6%) but recent assessments of topsoils from over 100 arable fields in Scotland indicated that half of the fields had organic matter contents < 5%.

Conserving or increasing carbon content in soils can be a win - win situation for crop health and climate change mitigation.

Further information:

www.farmingforabetterclimate.org

https://www.fginsight.com/vip/nuffield-scholar-seeks-best-soil-management-practices-7090;

http://www.gov.scot/Publications/Recent

Case study: Combating Hill Farm Weeds and Managing Costs

Ewen Campbell, SRUC Kirkton and Auchtertyre Hill Farms, West Highlands looks after 2,200 hectares, 1,300 sheep and 20 cattle.

Problems such as soil compaction, controlling rushes and bracken, poor sward quality on the moorland and poor retention of more productive grass species after reseeding inbye fields are common and can impact production by reducing grazing area. Sward lifting (typical cost £38/ha), liming to improve soil pH and control weeds (around £70/ha lime) and reseeding (£450 to £600/ha/year total cost - *see full reseeding costs in Appendix P35)* help to alleviate these problems.

Increases in production were best after slot seeding rather than ploughing then reseeding, and using lime to raise soil pH before applying rush control techniques.

"Look to your soil if you want to control rushes on your farm."

PROBLEM

SOIL COMPACTION, POOR SWARD QUALITY

ACTION

SWARD LIFTING, RESEEDING, LIME APPLICATION

Further information: www.sruc.ac.uk/kirkton

4 Soil structure

- Soil structure is the size, shape and hardness of the crumbs and lumps that make up the soil.
- Soil structural damage reduces soil quality, decreases crop yield and quality due to reduced plant growth.
- Poor structure increases production costs as more tillage and fertiliser are needed.

A well structured soil

Structure can be described using a simple spade test, called the Visual Evaluation of Soil Structure (VESS).

See pull out field sheet at the back of this brochure.

VESS assesses the soil structure based on the appearance, feel and smell of a block of soil dug out with a spade. Structure can range from score 1 (good) to score 5 (poor).

Clay soils usually have larger lumps than more sandy soils. Good quality soils contain a network of holes and cracks (pores) where the roots grow, soil organisms live and where water drains or is stored. The hardness or compaction of the soil influences how easily it can be cultivated and how readily roots can penetrate and absorb nutrients and water. The stability of soil is related to its resistance to erosion and compaction; the two main causes of structural damage.

VESS Score Sq1

A good soil structure has rounded aggregates that readily crumble in the fingers when moist, with many pores that allow easy root growth and passage of water throughout

VESS Score Sq5

A poor soil structure is almost always very compact with mostly large (> 10 cm) hard and sharp blocks. Porosity is very low and fissures tend to be horizontal and contain any roots. The soil can be grey or blue in colour with a sulphur smell (rotten eggs) indicating a lack of oxygen

Further information:

VESS information including training videos www.sruc.ac.uk/vess

Four quick steps to assess grassland soil structure http://beefandlamb.ahdb.org.uk/research/climate-change/climate-change-generic/grassland-soil-assessment-tool/

Case study: Good dairy farm soil management and growing maize as additional forage

Hugh McClymont is farm manager of the Crichton Royal Dairy Farm, Dumfries. He looks after 300 ha, with 150 ha of grass for grazing and silage, 150 ha of maize, beans and winter wheat for forage, 500 dairy cows and 350 young replacement cows.

Hugh has long been a fan of maize and a strong advocate for its use on Scottish farms. An increasing number of Scottish dairy farmers are now growing maize, once a crop only grown in warmer drier weather conditions. The maize is initially grown under protective plastic film and conserved as silage.

"Care is needed when growing maize as the bare soil left through the winter can lead to increased run-off of rainfall from the field taking farm soils and any nutrients attached with it. This can increase diffuse pollution if the run-off drains into water courses."

The harvesting of maize towards the end of the growing season when soils are starting to become wetter are ideal conditions for causing soil compaction. Any soil structural problems need to be addressed soon after harvest when there is still a chance of traffic movement across the field. Maize can be a challenging crop to grow in Scotland but the benefits are considerable with consistency of quality, high intake potential and relatively cheap starch-based energy on offer. Maize needs a long warm growing season so success cannot be guaranteed every year.

"Opening up the stubble after maize harvest is important. Wheel pressures have compacted the soils and the soils need to be opened up to maintain soil structure and to allow the next lot of rain to percolate through the soil, reducing the chance of surface water run-off and potential soil erosion. For best soil management practice, the optimal time to plough the fields is straight after harvest if soil and weather conditions are suitable."

PROBLEM

SOIL COMPACTION, EROSION AND RUN-OFF

ACTION

CONSIDER TIMING OF OPERATIONS. OPEN UP SOILS AFTER MAIZE HARVEST TO MAINTAIN STRUCTURE

Further information:

www.sruc.ac.uk/info/120197/research_farms/414/crichton_royal_farm

5 Assessing soil compaction and drainage

- The effects of poaching and compaction are clearly visible at the soil surface.
- Compaction causes waterlogging and increases surface run-off.
- Compaction is common in wet soils, loose soils and in soils with low organic matter content.
- Poaching and compaction will impact soil and crop quality and animal health.

Sward damage from extensive poaching by livestock

Compaction layers can occur at different depths. On top of or underneath uncompacted layers.

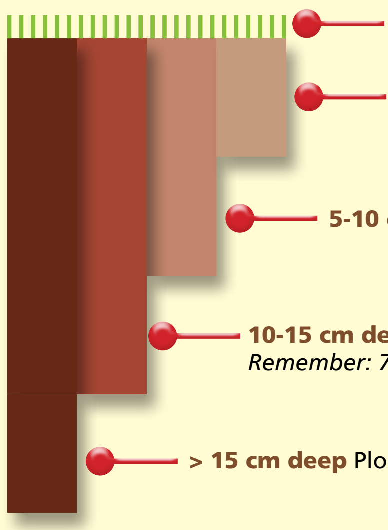
Moderate over good

Good over poor

See pull out field sheet at the back of this brochure.

Grazing, trafficking and use of heavy machinery when the soil is close to field capacity can lead to compaction problems on any type of soil.

Identifying likely causes of compaction. The depth of the compaction zone gives an indication of possible causes.



Surface level capping Capping on new reseeds

0-5 cm deep Sheep trampling at high stocking densities

5-10 cm deep Cattle pressure e.g. grazing in very wet conditions

10-15 cm deep Heavy machinery trafficking e.g. silage, muckspreading
Remember: 70% of the damage occurs on the first wheelings

> 15 cm deep Plough pan due to repeated cultivation

Practical steps for avoiding compaction

- The heavier the machine/livestock burden the deeper compaction penetrates into the soil.
- Reduce poaching and compaction by controlling grazing density.
- Avoid heavy grazing or driving over wet soils as this is when the soil is most vulnerable to compaction.
- At all times try to use the right size of tractor, axle weight and tyres for the job – remove unnecessary wheel weights and front loaders when doing light tasks - use lower pressure, larger tyres to spread the weight over a larger area.
- Deep subsoil compaction may be impossible to eradicate. Lower pressure tyres help avoid subsoil compaction.
- Keep to existing tramlines wherever possible even during harvest of silage or grain and straw. It is better to repeatedly run over one set of tracks than to traffic the field at random.
- Tramline disruption every 3 years can prevent long-term problems associated with waterlogging, soil erosion and surface run-off.
- Take action if you think compaction is reducing your yield or damaging your swards. In particularly vulnerable yet highly productive fields, consider using controlled traffic to reduce the overall coverage of the field (see Case Study on Page 28).

Tramline disruption can prevent waterlogging, soil erosion and surface run-off

Silage making

Localised trampling by livestock near feeding stations is difficult to avoid.

Consider alternatives to supplementary feeding and keep livestock away from sensitive habitats and water courses.

To assess the suitability of your fields for traffic/stocking and minimise the possibility of damage, soil or sward condition can be assessed using a simple 'squelch test'.

Squelch test assessment to avoid soil compaction damage

Dry Soil → **Wet Soil** → **Very Wet Soil**

SQ1	SQ2	SQ3	SQ4	SQ5	SQ6
Surface firm - No compression by foot	Surface loose - Boot pressure penetration up to 2 cm	Surface slightly soft - Boot pressure penetration up to 5 cm	Surface soft - Boot pressure up to 7 cm	Surface very soft and wet – surface water and boot imprint deeper than 7 – 10 cm	Water standing on the surface

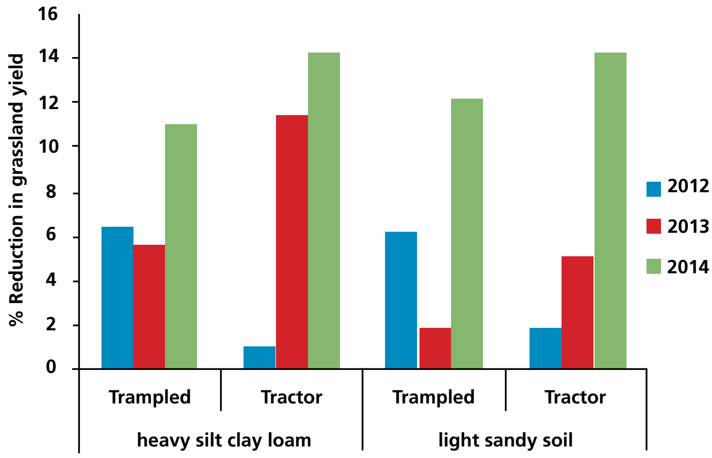
Suitable for stocking and traffic with a low chance of damage	**Grazing possible but risk of damage**	**Stock movement or traffic will result in soil compaction damage**

How much does a boot sink into the ground when walking on the surface of the soil/grass sward?

A squelchy clayey grassland soil with boot imprint around 3 cm deep

If you suspect that compaction is present:

- Check the extent of compaction using VESS – compact layers of score 4 and 5 need management to improve the structure
- A simple penetrometer can also be used, but always check with a spade and take care that 'compaction' below the topsoil is not due to naturally shallow topsoil or a naturally hard subsoil
- Compare assessments of soil structure in cultivated areas with those in non-cultivated areas such as field boundaries



Evidence of reductions in grass yields (up to 14% and estimated cost of £158/ha for sites studied) due to compaction from trampling and tractors

Platy compacted soil with VESS score of Sq5

A penetrometer can be used to estimate soil strength and identify the depth of soil compaction in fields

Compaction and impeded drainage have a large effect on crop productivity and are common causes of soil degradation

Compaction symptoms	Consequence
Reduction in soil porosity	Water, manure and fertiliser run off causing water pollution. Reduction in crop productivity due to increased run-off and losses of nitrogen from the soil (up to 40%).
Hard layers	Reduction in crop productivity due to poor rooting (roots cluster in earthworm burrows or in horizontal cracks). Fuel consumption for tillage is increased.
Sharp-edged clods	Reduction in crop uptake of moisture and nutrients and therefore crop productivity.
Reduction in water drainage (including increasing standing water on productive land)	Poor sward productivity and quality could result in animal health issues. Ideal habitat for mud snails that host liver fluke disease – increasing the risk of livestock infection. Crops become rotten, crops cannot be harvested, crops do not establish after sowing. Work window for tillage is decreased. Soils take longer to warm up, decreasing window of opportunity for crop growth and harvest; increases loss of nutrients.
Waterlogged soils	Reduction in the growing season for crops and the number of work days. Crops do not establish or grow, crops cannot be sown, land cannot be grazed or trafficked as a wet soil has a far greater chance of suffering from soil compaction. Reduced grazing days increases the cost of housing and feeding stock.

Poorly draining and waterlogged soils can hamper profitability and are bad for the climate. They can cause an increase in the loss of nitrogen from soils through nitrate run-off and emissions of the greenhouse gas nitrous oxide. Poorly draining soils can also release the greenhouse gas methane.

Further information: www.farmingforabetterclimate.org

Soil loosening to alleviate compaction

Compacted grassland soil

Machinery to loosen compaction damage depends on cropping and on the depth of the compaction. Loosen to below the depth of compaction to break up the compacted layer.

Machinery suitable for grasslands are:

- Aerators i.e. surface spikers or slitters working to 10 cm soil depth
- Sward lifters working between 20 and 35 cm soil depth
- Subsoilers (with and without wings) working between 35 and 50 cm soil depth

Sward lifters may be needed if shallow tillage is used over several seasons

For arable land, ploughing will remove most topsoil compaction but subsoilers may be needed for deeper compaction. Subsoiling can be particularly important for maize, soft fruits and potatoes.

"Consideration of soil moisture levels is needed to optimise subsoiling operations. Subsoiling a wet soil is a waste of money and can make the problem worse"

Ideally you should incorporate organic matter at the same time as subsoiling.

If soil drainage conditions are suitable, soils in field headlands, where heavy machinery turns, should be loosened in the autumn to allow the winter rainfall to drain before estabilishing a spring crop. Here, use a single leg subsoiler without wings to a depth BELOW the pan to get a "moling type" of soil disturbance (so the cracks are vertical). This helps to keep the soil much stronger than a generally loosened soil and more resistant to tractor and machine loads.

For sward lifters and subsoilers, make sure the base of the compacted layer is 3-4 cm above the critical working depth of the implement used.

Use a spade to check that loosening is effective!

Subsoiling alleviates deep soil compaction by breaking through the compaction layer

Improving soil drainage in arable and grassland farming

Good soil structure is important but will not resolve drainage problems in wet areas of the field if the water moving through the topsoil cannot drain away. Very heavy rainfall, changes in the water table and the occurrence of natural springs can also result in waterlogged land.

Suitable field drainage should reduce the amount of water flowing over the soil surface and thus the amount of erosion, preventing diffuse water pollution and silting of streams and rivers.

Well draining arable soil profile

See pull out field sheet at the back of this brochure.

Before a drainage scheme is started a thorough site and soil investigation is essential. Assess whether a suitably designed drainage scheme is necessary. In some situations management actions to improve soil conditions may be all that is required. Drainage of organic peaty soils should be avoided.

Smaller lateral drains that act as interceptors on sloping land should run across the slope. Use permeable infill in drains. Although it may be up to £3/m more expensive, it can prolong the drains' use and help connect to mole drains.

Ensure all out flows are kept clear and drainage ditches are cleared regularly (see GBRs website below). Fences around the ditches will ensure that the animals are protected from falling into ditches and outfalls.

Further information:

AHDB Drainage guide
http://www.ahdb.org.uk/Article.aspx?ID=304163

AHDB Improving soils for better returns report
www.ahdb.org.uk/projects/documents/Improvingsoilsforbetterreturns

SRUC farm management handbook
http://www.sruc.ac.uk/info/120376/farm_management_handbook

Diffuse Pollution General Binding Rules (DP GBRs)
http://www.sepa.org.uk/regulations/water/diffuse-pollution/diffuse-pollution-in-the-rural-environment/

SNH Guidance note 'Avoiding the need for supplementary feeding and minimising its impact on sensitive habitats' http://www.snh.gov.uk/land-and-sea/managing-the-land/farming-crofting/farming-wildlife/livestock-dairy/

Field Drainage Maintenance and Inspection

Poor field drain maintenance can lead to sediment build up at the drain outfall resulting in reduced flow and waterlogged soils

"Poor soil structure leads to poor drainage, so soils should be checked regularly. Sometimes farmers will spend ~ £20k on a new digger and allow soil to go down their drains, especially in cold and wet conditions. Thistle roots growing in ditches and clogging drains are also a major problem." (Ronald Dick, Drainage Contractor)

Field drainage systems

Field drains with green algae slime (left) and orange iron ocre slime deposits (right)

Case study: Rewards from Improved Soil Drainage and Nutrient Planning

Duncan McEwen (Arnprior Farm, West Stirlingshire) manages a mixed arable and livestock farm (330 ha). He has ~ 1000 ewes, 30 heifers and 80 ha arable cropping (including hybrid rye for anaerobic digester unit, spring barley, oats and beans).

Duncan only recently started to pay attention to the management of soil nutrients through soil testing. He has applied both conventional (£95/ha) and alternative (£103/ha) soil testing approaches for the last 3 years. Improved nutrient management planning has reduced fertiliser use by 25% and Duncan has seen forage yields increase by 24%, improved forage quality and lamb growth rates (15% increase, 0.8 kg higher live weight gain).

"Taking notice of the soil nutrient balance and soil structure is essential for getting decent yields. Short-term pain can provide long-term gain."

Busting compaction layers in suitable fields with a sward lifter helped to rejuvenate swards and improve soil drainage. Maintaining well drained soils may also help control occasional outbreaks of liver fluke. Many changes have been successfully introduced during Arnprior's time as a Quality Meat Scotland (QMS) Forth Monitor Farm. Swapping straw for dung with neighbouring farms provided a cost effective source of nutrients.

Heavy clay soil

"Heavy and saturated carse ground can be a huge challenge to successfully cultivate. You have to be patient and wait for soils to dry after prolonged heavy rain. Working heavy clay soils when they are very wet can seriously damage them."

"The biggest surprise was the adoption of rotational grazing which has reduced fertiliser usage. I was sceptical but I found that it maintained the quality of the grass and a better growth rate in the stock, especially the lambs and I've seen clover and ryegrass coming back into the swards."

PROBLEM

POOR SOIL DRAINAGE AND NUTRIENT USE EFFICIENCY

ACTION

SWARD REJUVENATION, SOIL TESTING AND ADOPTION OF ROTATIONAL GRAZING

Further information:

http://www.qmscotland.co.uk/news/earlier-calving-cards-forth-monitor-farm

6 Reducing soil erosion

Erosion is the loss of soil due to the action of water flowing over the land or by strong wind. It can also be caused by excessive cultivation. Loss of soil due to erosion is a growing problem in Scotland due to more extreme weather and to a progressive reduction in organic matter in some eastern areas.

Erosion breaks up the structure of exposed soil into its component particles that are then washed away or blown off. Erosion depletes soils of valuable nutrients and organic matter. The loss of soil reduces soil depth and increases 'droughtiness'. Transported soil material will cap the soil surface or accumulate in low lying areas so that water cannot enter the soil and so runs off. Surface water pollution and waterlogged fields can be the result. Light sandy and loamy sands are most vulnerable to wind erosion.

Sandy loam soils are more at risk of water erosion because they break down easily. Water erosion can occur due to surface capping, the presence of compacted layers or intermittent spring lines.

Wind erosion

Ploughing across field slopes can reduce erosion risk

Crops on vulnerable soils	Erosion risk	Erosion risk scenarios
Maize	High	Fine seedbeds
Potatoes		De-stoning practices
Turnips		Bare land after root crop harvesting
Winter wheat/barley		Outdoor pig rearing areas
Spring barley		Livestock feeding, watering, shelter and access points
Winter oil seed rape		Rough ploughed land
Spring oil seed rape		Cereal stubble
Grass	Low	Land with good crop/vegetation cover

Control is best achieved by good husbandry and adjusting agronomy, but awareness of the soil type, land forms and agricultural systems is needed. Minimising the period during which the soil is bare in the vulnerable winter and spring seasons is important. Consider these methods to control erosion:

- Clean and maintain interception ditches between field boundaries (*good practice that follows the Diffuse Pollution General Binding Rules)*
- Remove compact layers in vulnerable areas to avoid run-off
- Prepare seed-beds no finer than necessary to avoid capping
- Re-instate hedges and woodland wind-breaks
- Maintain soil organic matter
- On susceptible fields, avoid crops with later harvests such as maize or potatoes as these leave bare soil over winter. In any case, plough compacted harvested areas and leave the land open and rough (see Case Study on Page 11)
- Avoid winter cereals on particularly vulnerable fields
- On land to be spring-cropped, plough as late as possible to avoid leaving soil bare
- Consider the use of minimum tillage or no-tillage. These need to be true 'conservation tillage' measures with residues at the surface to protect the soil
- Reducing the amount of soil erosion will reduce the amount of material that may need to be dredged from downstream ditches

Field damaged by channel erosion

Bare soils are susceptible to erosion

Further information:

SRUC TN646: River floodplains and natural flood management

Cross Compliance - Good Agricultural and Environmental Conditions (GAEC)
http://www.gov.scot/Topics/farmingrural/Agriculture/grants/Schemes/Crosscompliancesection/ccompliance

- GAEC 4 (minimum soil coverage)
- GAEC 5 (minimum land management reflecting site specific conditions to limit erosion)
- GAEC 6 (maintenance of soil organic matter)

Diffuse Pollution General Binding Rules (DP GBRs)
http://www.sepa.org.uk/regulations/water/diffuse-pollution/diffuse-pollution-in-the-rural-environment/

Know the rules (DP GBRs)
http://www.sruc.ac.uk/homepage/680/know_the_rules

SEPA Controlled Activity Regulations practical guide
www.sepa.org.uk/media/34761/car_a_practical_guide.pdf

SEPA Natural Flood Management handbook
http://www.sepa.org.uk/media/163541/sepa-natural-flood-management-handbook.pdf

Planting trees can protect soils vulnerable to erosion

Woodlands can provide significant benefits on farms, including slowing down surface water run off and erosion, shelter, sport, wildlife habitat and providing a timber income (fuel wood or sawlogs if land is suitable).

Research has shown that on some soil types where trees have been planted, the infiltration rates of surface water are more than 60 x better than on adjacent land.

Agroforestry at Glensaugh (see case study overleaf)

Re-instating hedgerows can help protect soil from erosion and enhance biodiversity

Case study: Integrating Farming and Forestry Protects Soils

Donald Barrie, manager of the hill farm of Glensaugh, south Aberdeenshire. 1,000 hectares, 900 ewes, 50 suckler cows and 100 red deer hinds.

Glensaugh has 57 ha of woodland, around half of which has been planted since 2010. Recent planting of oaks has provided a long term buffer to contain nutrient run-off.

Glensaugh also has 7 ha of agroforestry. **Agroforestry is the integration of farming and forestry on an area of land. It takes many forms and includes shelterbelts, rows of trees on a field margin, individual field trees, hedges and woodlands open to grazing.** The original agroforestry trial assessed the performance of a silvopastoral grazing system using different densities of Scots pine, hybrid larch and sycamore. The lower densities of larch were removed early on leaving the three species at 400 stems/ha and sycamore alone at 100 stems/ha. The trees were not thinned and now leave little grazing, but create an excellent sheltered environment in which to winter livestock. The larch now needs to be thinned and fuel wood will be produced.

Tree shelter across the farm encourages better pasture growth. Rotational grassland areas are reseeded with perennial ryegrass and white clover mixtures every 7-10 years to provide grazing, silage for winter feeding and aftermath grazing for finishing lambs.

Quad bikes instead of tractors are used as much as possible to avoid soil compaction and forage rape is only grown on fields with low risks of erosion.

"You must balance risks with rewards and consider your long and short-term aims. Agroforestry at Glensaugh helps to control soil erosion and run-off, protecting soil structure and vulnerable water courses."

PROBLEM

SOIL EROSION AND RUN-OFF

ACTION

PLANTING TREES

Further information

www.hutton.ac.uk/about/facilities/glensaugh

Other Scottish agroforestry case studies - http://www.snh.gov.uk/land-and-sea/managing-the-land/farming-crofting/lupg/

7 Understanding and managing soil pH and nutrients

Why do I need to test my soil?

Soil testing is an essential nutrient management tool that allows you to assess fertiliser requirements for optimal crop growth.

Scottish soils are typically rich in organic matter and naturally acidic (low pH) with low levels of key plant nutrients such as phosphorus (P), potassium or potash (K) and nitrogen (N). They are usually high in magnesium (Mg) except for some of the more sandy soils.

Where fertilisers supplement the natural fertility of the soil, it requires testing every 4-5 years in order to be both effective and efficient.

The standard soil index system for soil nutrient testing is pH-centred and is based on the concept of maintaining sufficient nutrient levels. It is simple and low cost.

Alternative soil testing approaches are also available and incorporate analyses of soil organic matter, active humus and trace nutrients in addition to pH and major nutrients. These approaches have not been tested as thoroughly as conventional methods.

See pull out field sheet at the back of this brochure.

Nutrient status

P, K and Mg

Standard soil tests assess plant available P, K and Mg. Plant available means the amount of nutrients that crops can actually use; this is always much smaller than the total amount that is stored in the soil. Soils have the ability to regulate (store and release) plant nutrients, a function that depends on the soil texture, its chemistry and local climate.

Soil analysis does not predict crop uptake of P, K or Mg: these depend on crop type, its yield potential, its potential rooting depth and other factors such as the weather.

Understanding your soil is an important part of effective nutrient management. Speak to your agricultural consultant to get nutrient management advice for your soils to ensure that nutrients are being used efficiently and economically (See Evidence Case Study results and a summary of functions of N, sulphur and micronutrients in Appendix Page 30).

Most crops (excluding root vegetables that require a slow steady nutrient supply) will not respond to applied P in the year of application. Unless your soils have low P status, you are usually fertilising next year's crop.

Interpreting Soil Analysis

The results of soil nutrient tests are expressed in mg/l of available P, K, or Mg. To simplify interpretation of these results they are grouped into Soil Nutrient Status as shown in **Table A**. Descriptive scales are used in Scotland and RB209 Index scales are used in England and Wales.

It is important to know the method of soil analysis used before interpreting results, as different methods extract different amounts of P, K and Mg. The SAC Modified Morgan's method is recommended for soils in Scotland because of their characteristic pH and chemical composition. The method suggested in RB209 for England and Wales is different - see **Table A** for a comparison of results between these two systems.

The optimum soil nutrient status for P, K and Mg is Moderate (M) in Scotland for most crops. The M status is divided into a M+ and M- for specific crop types to ensure cost effective management in the year of production but your soil should already be close to or "on target" in order for this to be effective.

Bringing a soil that has a Low or Very Low status for key nutrients up to the target Moderate status can take several years. Once your soil is "on target" the goal is to maintain this by replacing what your crop removes annually.

A soil that is above target (High or Very High) for either P or K is unprofitable and is an environmental risk (prone to nutrient run-off and leaching). A soil that is on target for both P and K is therefore a valuable farm asset.

Table A: Comparison of Scottish (SAC) and equivalent English and Welsh (RB209) Index soil nutrient status scales for P, K and Mg concentrations (mg/l)

SAC soil nutrient status	P concentration (mg/l)	K concentration (mg/l)	Mg concentration (mg/l)	Equivalent RB209 Index soil nutrient status
Very low (VL)	0-1.7	0-39	0-19	0
Low (L)	1.8-4.4	40-75	20-60	1
Moderate – (M-)	4.5-9.4	76-140	61-200	2-*
Moderate + (M+)	9.5-13.4	141-200	61-200	2+*
High (H)	13.5-30	201-400	201-1000	3
Very High (VH)	>30	>400	>1000	>3

***Division of class 2 into 2- and 2+ doesn't apply to Mg**

Example of SAC crop specific optimum soil nutrient targets

	P	K	Mg
Grass with high clover	9 mg/l – Middle of moderate status	108 mg/l – lower half of moderate	Moderate Status – (61 – 200 mg/l)
All other grass management	6 mg/l – lower end of moderate status		
Cereals and oilseed rape	Moderate	Lower half of Moderate	Moderate

Soil pH

Soil pH impacts the plant availability of the P and K fertilisers you apply and has a role in determining N use efficiency. For more information see Appendix Page 31.

Soil pH is a measure of acidity and alkalinity. The natural pH of a soil depends on the material from which it was developed. Scottish soils range from about pH 4 (very acid), when most crops will fail, to about pH 8 for soils naturally rich in calcium or magnesium carbonate.

At soil pH < 5.6 in mineral soils in Scotland, soluble aluminium inhibits cereal root growth and reduces yield. Organic soils contain less aluminium and for this reason can be maintained at lower pH values than for mineral soils for any given crop.

Soils tend to acidify due to natural processes (e.g. rainfall, crop growth and leaching in drainage water) and some farming practices (e.g. use of some nitrogen fertilisers). Acidifying processes can cause soil pH to fall quite quickly, particularly in sandy soils, and regular pH checks every 4 to 5 years are required.

The pH of mineral soils should be maintained at about pH 6.3 for arable crops and a minimum of pH 5.8 for lowland grassland. Aim lower with a target of pH 5.3 to 5.5 on peat soils (see **Table B**).

For each field, the amount of lime to apply will depend on the current soil pH, texture, organic matter and the optimum pH needed. Clay and organic soils need more lime than sandy soils to increase pH by one unit. A lime recommendation is usually for a 20 cm depth of cultivated soil and 7 cm for grassland soil.

Liming materials should be purchased on the basis of the price relative to the neutralising value and fineness of the products on offer. The finer the grinding of the product the more rapid the rate at which neutralisation occurs.

Testing soil pH

Table B: Impacts of pH on crops and recommended targets

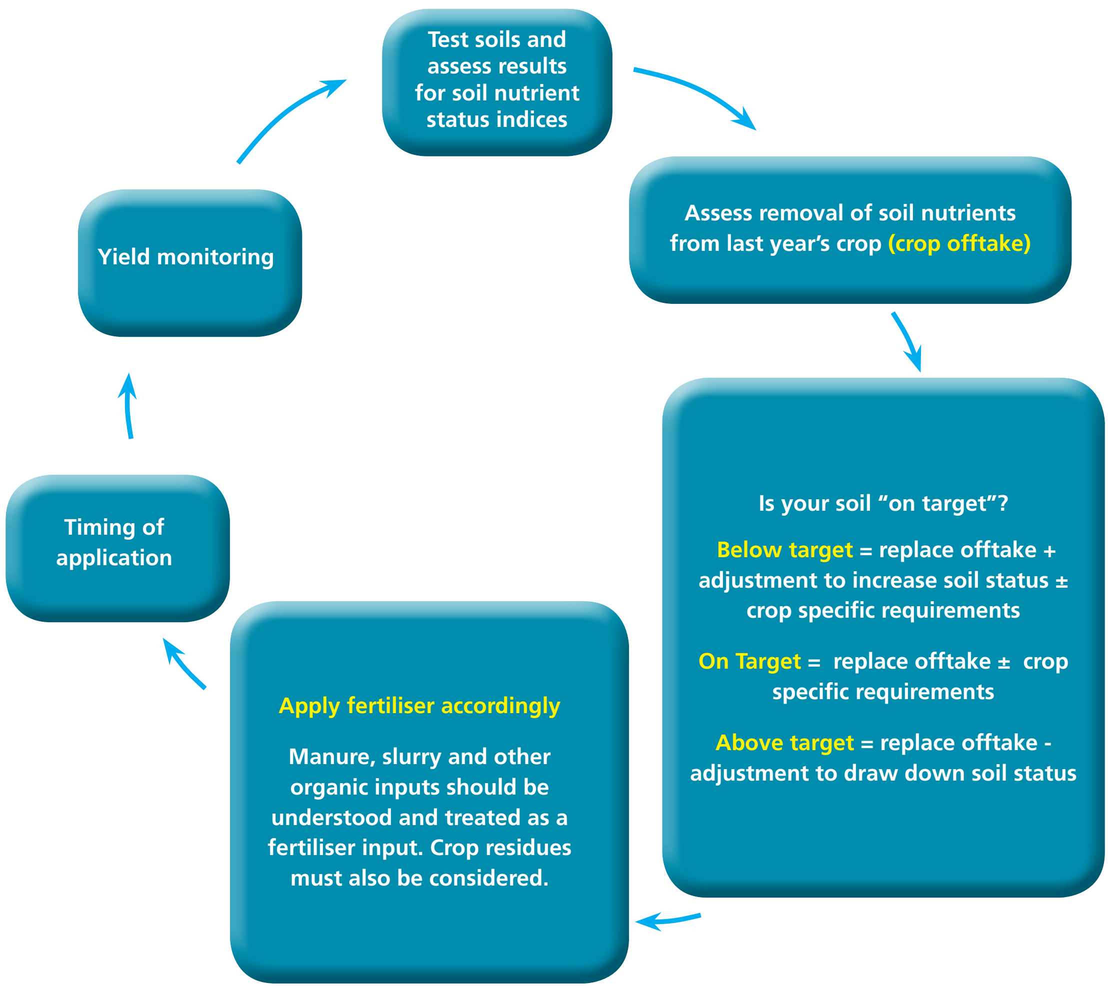
Soil pH ranges	Impact	Notes
4 – 5.3	Very Acidic soil where most crops will fail due to poor nutrient availability and/or presence of soluble forms of aluminium which inhibit plant growth.	Fertiliser use at this pH is not cost effective.
5.3 – 5.5	Acid soil with much reduced nutrient availability and continued impact of soluble aluminium in mineral soils. Arable crops, including forage, grown within this pH range will have reduced yield and quality.	This is the recommended pH range for peaty soils under grass. Increasing the pH of peaty soils beyond 5.8 is unlikely to be cost effective.
5.5 – 5.8	Acid soils with very low nutrient use efficiency. Crop yield will be consistently lower and fertiliser use efficiency reduced.	Many of Scotland's mineral grassland soils are being managed within this pH range. For arable crops grown on organic soils the pH target should be 5.7 – 5.8.
5.8 - 6	Acid soils with reduced nutrient use efficiency for arable crops but close to target for grass.	The target for mineral grassland soils in Scotland is pH 6.
6 – 6.2	The optimum pH range for most crops apart from arable and rotational grass on clay and silty soils where the target is 6.3.	At this range there is optimum nutrient availability.

Soil pH can vary considerably within fields, especially if there is a range of soil textures. GPS sampling (typical cost £25/ha) for soil pH at 4 samples/ha, each sample containing a number of cores bulked together, and variable lime application can be a cost-effective option.

Money can be saved by more efficient nutrient budgeting, especially linked to pH levels

Efficient nutrient management is the process of ensuring the right amount of nutrients are present at the right time across the entire rotation and growing season.

Key steps in an effective nutrient budget



Further information:

Specific soil nutrient targets and fertiliser requirements for your crop are provided in SRUC technical notes
http://www.sruc.ac.uk/downloads/120451/crop_technical_notes
and from PLANET Scotland
http://www.planet4farmers.co.uk/

AHDB RB209 Fertiliser Manual
http://www.ahdb.org.uk/projects/CropNutrition.aspx

Soil Nutrient network
http://www.farmingandwaterscotland.org/farmingwaterscot/info/7/soil_and_nutrients

Know the Rules guides
http://www.farmingandwaterscotland.org/farmingwaterscot/info/2/know_the_rules

Cattle slurry is a rich source of nutrients and if used correctly can be worth £273/ha to the average dairy farmer

Case study: Taking a Closer Look at Soils and Costings

Willie Officer. Ardoch of Gallery near Montrose, Angus. 131 ha arable land growing winter wheat, spring barley, oilseed rape and seed potatoes. The business has recently diversified into daffodils, with 8 ha in bulbs and a significant investment in new storage facilities.

"It's important that farmers look at their soils. I try to assess soil structure twice within each crop rotation."

Daffodil field soil ridges

"You need to look after costings. Target each crop and their end market as appropriate. There is no need to over apply mineral fertiliser if soil nutrient testing indicates that you don't need to. The same principle applies to spreading lime to control pH. The price of fertiliser will directly change the figure but it is fair to say there is certainly room to save a few pounds per ha which all helps in the current commodity pricing. I estimate that I have saved around 15% on the fertiliser bill."

PROBLEM

SOIL NUTRIENTS ABOVE TARGET

ACTION

ASSESSMENTS OF SOIL pH, NUTRIENT STATUS AND STRUCTURE

Further information:

www.sruc.ac.uk/info/120200/climate_change_focus_farms/1506/ardoch_of_gallery_angus

8 Increasing organic matter and reducing erosion using cover crops

Cover crops (winter soil cover or catch crops) can increase soil organic matter, protect soils from erosion, improve soil structure and potentially reduce fertiliser costs.

Cover crops can be grown successfully in most parts of Scotland if they are established early. Cover crop mixtures can be designed to alleviate particular problems. Identify the soil problem that you want to alleviate and then select appropriate mixtures for your farm.

More farmers are using seed mixtures designed to protect the soil and use available nutrients between harvest and sowing. Well established cover crops can retain and release nutrients to follow-on crops. Some cover crop mixtures offer additional benefits of weed and nematode control.

A cover crop is sown between crops, especially if the soil would be left bare over the winter, to prevent surface erosion (wind blow and/or water run-off) and help to retain organic material and nutrients in the soil.

Ploughing in N-fixing cover crops such as clovers can provide 50 – 250 kg N/ha to the following crop and have other benefits such as weed suppression and soil structural improvement that can benefit the entire rotation.

Deep rooting radish can be used to loosen soils

Fertility building grass and N-fixing clover ley

Cover crops can also help improve water quality through reducing diffuse pollution risks.

One of the ways cover crops benefit soil is by increasing soil organic matter and encouraging earthworm activity, which in turn improves soil structure. Cover crops can also benefit bird species by providing food and cover for seed-eating birds (e.g. grey partridges) or increased availability of insects.

Radish, rye, phacelia and vetch cover crop mixture

Further information

Soil association
http://www.soilassociation.org/whatisorganic/organicfarming

Farming for a Better Climate
www.sruc.ac.uk/downloads/download/1108/carbon_footprinting_and_locking_in_carbon_on_the_farm

National Farmers Union
http://www.nfuonline.com/about-us/our-offices/north-east/campaign-for-the-farmed-environment/cover-crops-are-a-useful-tool/

9 Is reduced tillage or no tillage suitable for your soils?

Reduced tillage is a method of sowing crops without ploughing the soil.

Reduced tillage and no tillage can cut costs **(typical savings of £61 - £83/ha/year),** protect soils from erosion and compaction, improve soil quality and allow timely establishment of winter crops.

To maximise these benefits it is important to reduce the depth of tillage compared to ploughing.

Reduced tillage is not suitable for all soils and farming systems (see flowchart on Page 27). Seek advice from trained advisors before making the decision to change cultivation practices.

Reduced tillage is often used on an opportunistic basis within the crop cycle taking weather and soil conditions into consideration.

Minimum tillage can protect and enhance soil structure

Direct drilled crop

Straw residues protect soils from erosion and improve water infiltration. Direct drilled crop with (left) and without (right) straw residues

Under the wrong conditions, direct drilling can cause soil compaction (left) and poor crop emergence (right)

The application of controlled traffic systems to preserve structure and topsoil drainage status may enable use of no-tillage or direct drilling, very shallow reduced tillage or use of reduced tillage on heavier soils. No-tillage or very shallow reduced tillage can also help reduce erosion and pollution run-off to nearby water courses.

Could reduced or no tillage work for you? Identify possibilities using this flowchart

Assess the experience of others in your area and gather knowledge from consultants and colleagues.

Check that suitable equipment is available.

▼

Are field conditions suitable? Reduced tillage works best on well-drained soil with good stable structure. Heavy clay soils are best avoided. Fields with higher than average levels of grass weeds or crop residues may need to be avoided.

▼

Is the crop suitable? The most suitable crops are winter cereals especially winter wheat after potatoes, winter wheat after winter oilseed rape, winter oilseed rape after winter barley and winter wheat after peas.

▼

Use the correct machine wisely. Try to minimise the amount of soil moved. Cultivate only deep enough to bury most residues and loosen any shallow pans. Mix and invert the soil to a maximum of 15-20 cm with tines working down to 30 cm, dependent on conditions. Ensure that tines are only having a loosening effect. Avoid working after periods of heavy rainfall and use low ground pressure tyre options.

Further information

SRUC Technical Note 553 on Minimum Tillage:
http://www.sruc.ac.uk/downloads/120451/crop_technical_notes

CTF Europe:
http://www.controlledtrafficfarming.com/Home/Default.aspx

Case study: Controlled Traffic Farming

Robert Ramsay. West Mains of Kinblethmont in Angus husbands 750 hectares arable land growing winter wheat, spring and winter barley, oilseed rape, plus both ware and seed potatoes. By monitoring yield variability under different tillage techniques, Robert identified that even light trafficking was having a measurable impact on crop yields.

Controlled traffic farming was seen as an opportunity to protect farm soils and improve yields.

Using set tracks identified by GPS, controlled traffic farming keeps vehicles in the same pre-set areas of the field. This keeps machinery and trafficking off the majority of the ground, protecting farm soils from compaction and damage and reducing yield penalties due to poor soil conditions.

"Following the switch to controlled traffic farming, we have seen a definite improvement in soil structure; for example both the water holding capacity and the speed of water percolation has improved. Aside from added yield benefits, the move to controlled traffic farming has saved around 40% of fuel and time when establishing a crop compared to the old plough and till system."

PROBLEM

TRAFFICKING REDUCING THE SOIL'S POTENTIAL

ACTION

SWITCH TO CONTROLLED TRAFFIC FARMING

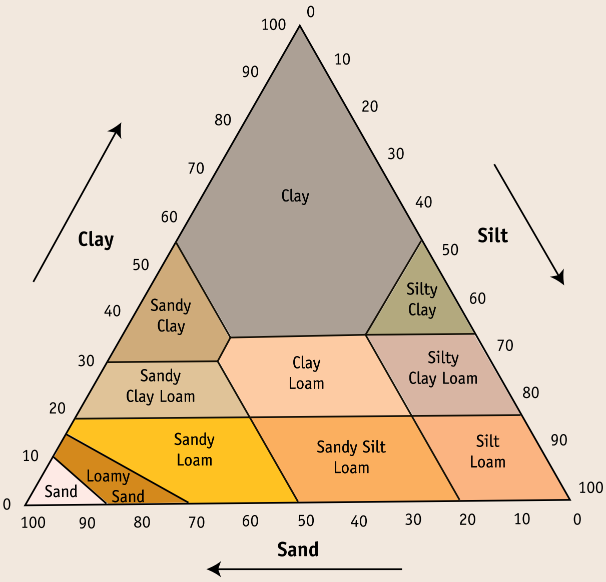
Further information:

www.farmingforabetterclimate.org

10 Managing farm soils - checklist

- Dig a pit and take a look at your soils
- If the crop looks poor, look at the soil structure, colour and worm populations
- Take soil samples if necessary to test pH, nutrients and organic matter content
- Soil chemical changes can be gradual so try to monitor regularly
- A well managed soil with ideal pH conditions and good structure makes it easier for plant roots to access nutrients, increasing nutrient recovery by 20% when compared to a compacted soil
- If soil is lost due to erosion or compaction under extreme weather events, change the cropping to conserve the soil
- Improve the 'green credentials' of your farm by using cover crops or minimum tillage to reduce pollution risk, lock up organic matter and support wildlife
- Try to minimise compaction (and fuel costs) by using the smallest tractor and correct tyres for the job and minimising wheelings
- A healthy soil really can improve farm profits
- Love your soil!

11 Tools to help you



Soil textural triangle showing the proportions of the three main particles in different soil textures

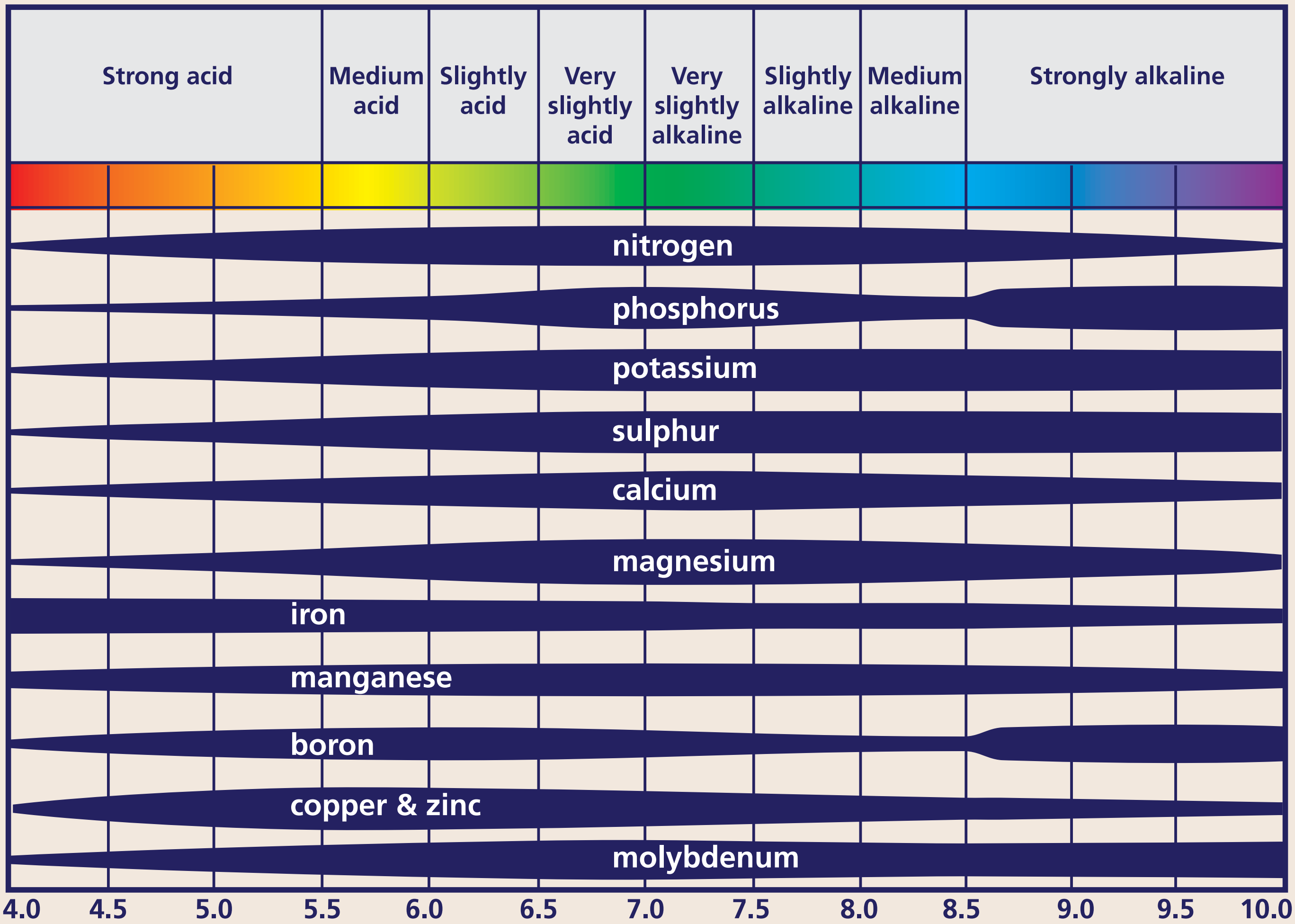
Soil texture is defined by the proportion of three types of particle; the small clay particles (less than 0.002mm), silt (between 0.002 and 0.06 mm) and sand (between 0.06 and 2.0 mm).

The soil textural triangle uses the proportions of these three particles to describe the soil texture of mineral soils in the field. *Organic (peaty) soils are not included.*

Functions of nitrogen, sulphur and micronutrients

Nitrogen (N)	Plant available N is naturally scarce and its availability is central to profitable crop production. Unlike other nutrients soil testing is not used to determine nitrogen requirements. Rates and timing are based on crop type, establishment practices and yield requirements. Advisory rates for N use assume that the soil is "on target" for pH and other key plant nutrients.
Sulphur (S)	Sulphur is an essential plant nutrient and deposition from air pollution resulting from industrial activities has historically been sufficient to meet crop demand in Scotland. As deposition from air pollution has declined due to controls on emissions to the atmosphere, S deficiencies are likely in crops. Sands, shallow soils or sandy loams with low organic matter content are most prone to deficiencies. Organic fertilisers are a good source of S and mineral fertilisers often contain some forms but its inclusion in a well balanced budget is becoming increasingly important.
Micro nutrients	There are a range of other essential soil derived nutrients (boron (B), copper (Cu), cobalt (Co), iron (Fe), manganese (Mn), molybdenum (Mo) and zinc (Zn)) that are required in small amounts (micro nutrients) to ensure good crop or animal health. Soil and plant testing can help identify a deficiency but of more use is an understanding of your soil and its risk of having such deficiencies based on its texture and chemistry. Soil specific risk maps for Co and Cu deficiencies have been created (see http://www.sruc.ac.uk/downloads/120451/crop_technical_notes)

Soil pH and nutrient availability



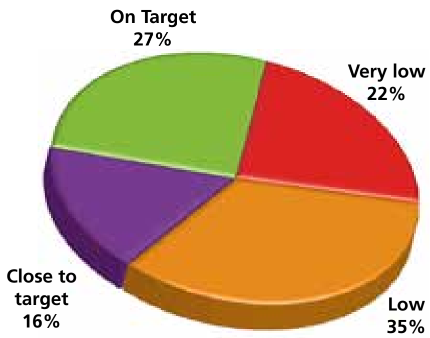
PLANET Scotland is a computer based soil nutrient management system that can help you manage your nutrients and make best use of slurries and other farm residues along with mineral fertilisers. It can help improve nutrient management efficiency. It is available freely as a downloadable form http://www.planet4farmers.co.uk/

PLANET NUTRIENT MANAGEMENT

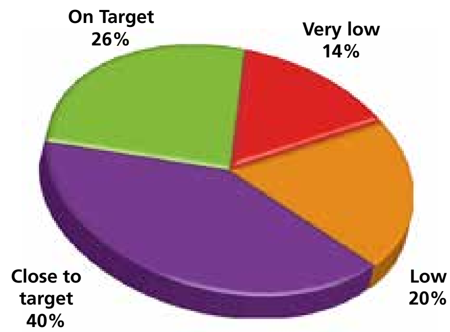
Evidence Case Study: Recent Assessments of Scottish Agricultural Soil pH and Nutrient Status

Soil samples from over 1000 fields from grassland (Ayrshire, Water of Coyle) and arable land (Perth, East Pow) were collected and tested. Findings are summarised below.

Grassland soil pH



Arable soil pH

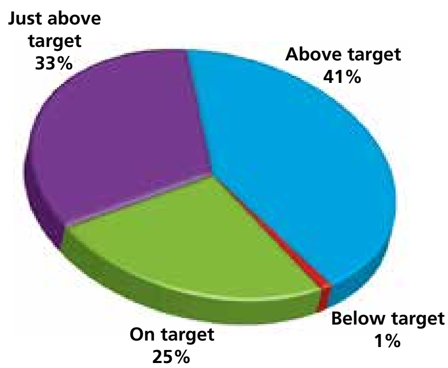


Consequence

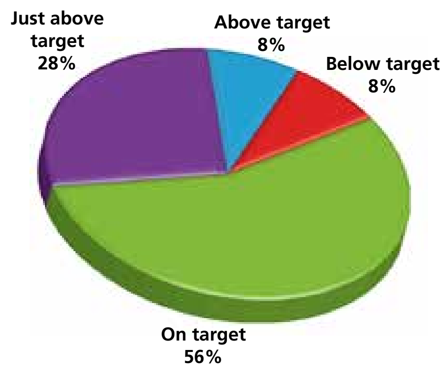
The majority of soils are being managed below optimal pH status.

Applied fertilisers are being used less efficiently causing reduced crop production and a potential risk to the environment

Grassland soil K

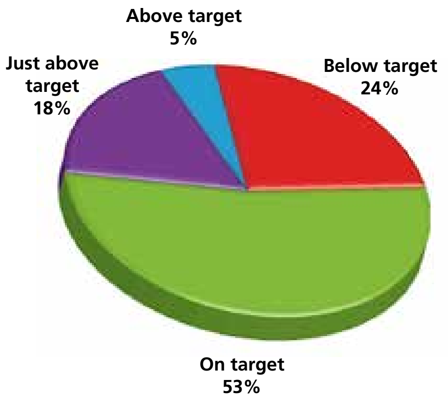


Arable soil K

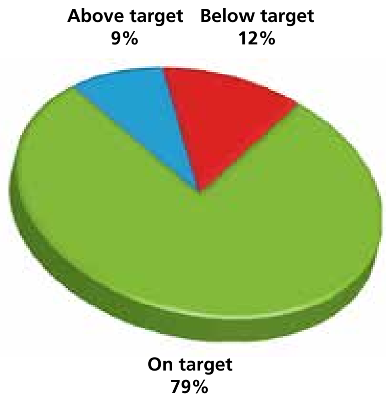


Farmers that are at or above target could save around £43/ha by making better use of soil K reserves

Grassland soil P



Arable soil P



Farmers that are at or above target could save around £12/ha by making better use of soil P reserves

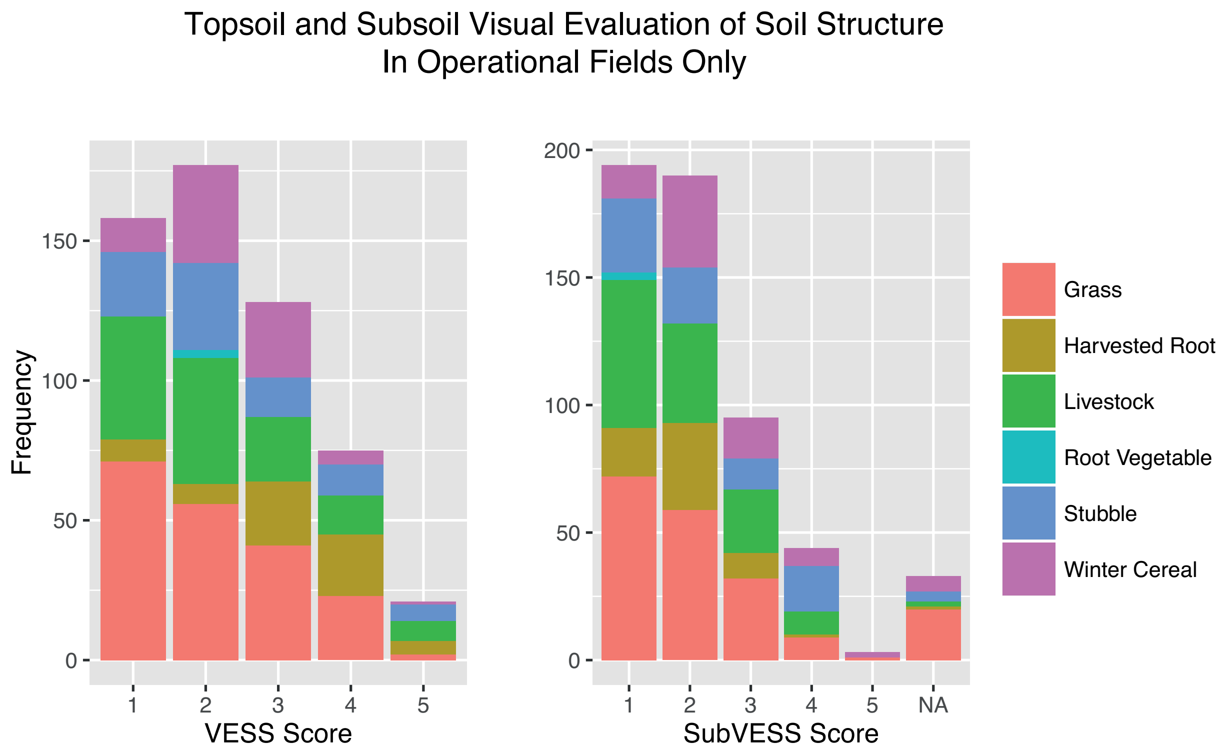
Arable soil P levels required maintenance rather than any increase or decrease. Restrict future P inputs to equal annual crop offtake

This project was commissioned by SEPA

Evidence Case Study: The Effect of Soil Structure and Field Drainage on Water Quality and Flood Risk

Scotland generally has good agricultural soils. However evidence suggests that some land management practices are damaging soil structure which in turn affects crop yields, how efficiently fertilisers are used and also the transport and storage of water.

VESS and SubVESS were used successfully to measure the state of soil structure in over 850 locations on commercial farms in winter 2015/2016. It was encouraging to find within operational fields good soil structure was found for about 60% of topsoils (VESS ≤ 2) and 73% of subsoils (SubVESS ≤ 2). However, severe soil structural degradation in 17% of topsoils (VESS ≥ 4) and 9% of subsoils (SubVESS ≥ 4) was found. In general, central parts of fields under agricultural production had poorer soil structure than areas receiving less traffic on their boundaries such as buffer strips. There is clearly great scope to improve soil structure on Scotland's farmland.

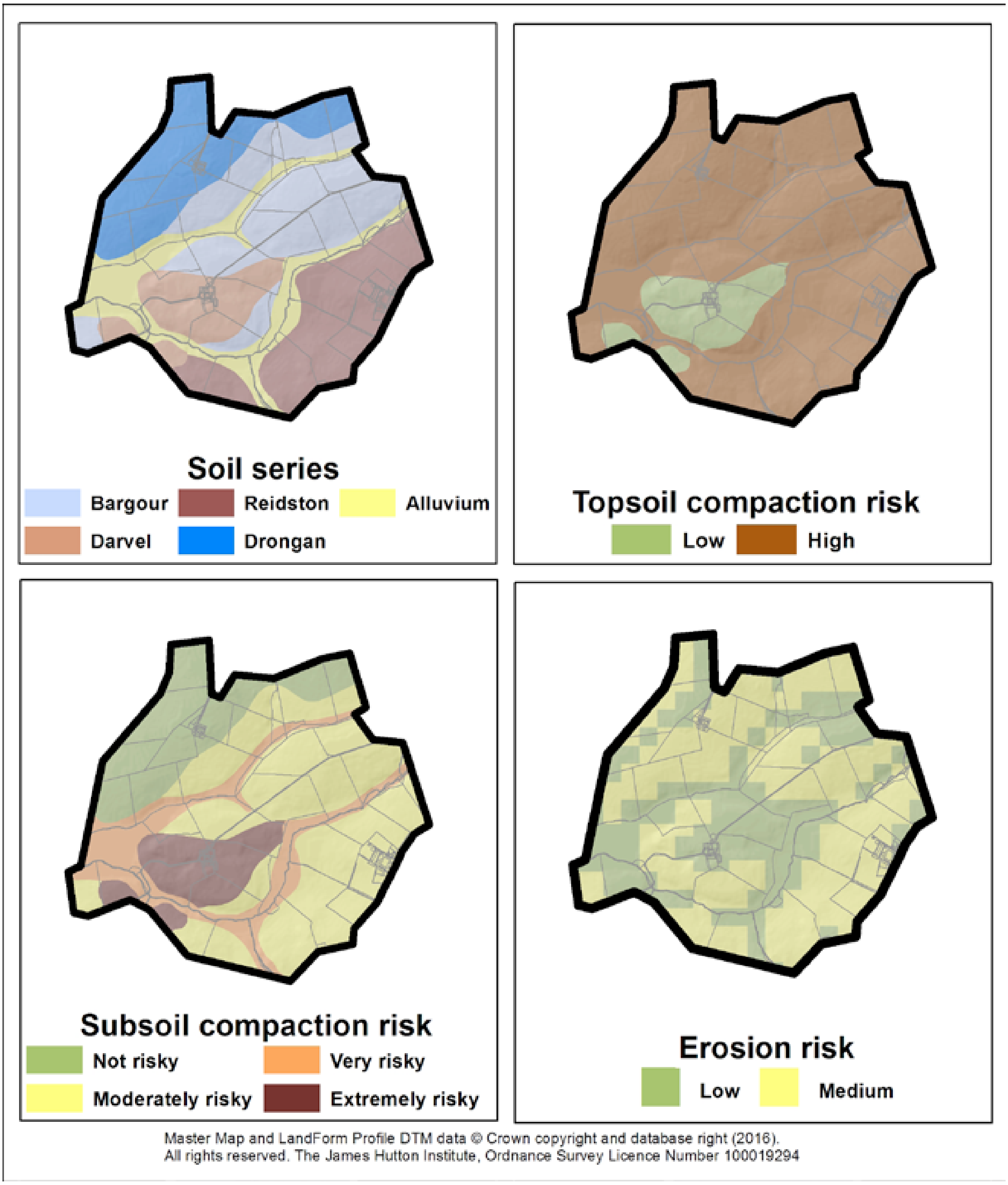


This project was commissioned by CREW at the request of SEPA

Evidence Case Study: Mapping areas at risk of damaging water quality

Field scale (1:25 000) soil risk maps will be available for much of the cultivated land in Scotland. The maps can be used to identify areas most at risk of water and nutrient run-off, soil erosion, compaction by machinery and nutrient leaching.

Maps will help target mitigation strategies to areas of land most likely to contribute to diffuse water pollution and a decline in water quality and so can help inform discussions between regulators and land managers. For further information see http://www.soils-scotland.gov.uk/data/derived.



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Kirkton and Auchtertyre Reseeding Costs (Materials and Contractor Costs[1])

	Cost (£/ha)			
Kirkton Trials Field 2013	Non-inversion Till 2013 - Grass Reseed	Ploughed 2013 - Grass Reseed	Ploughed 2013 - Forage Crop	Non-inversion Till 2013 - Forage Crop
Glyphosate (Clinic Ace)	£27	£27	£27	£27
Herbicide spraying[2]	SRUC farm equipment and staff time			
Ploughing[2]		£200	£200	
Harrowing & rolling[2]		£175	£175	
Grass/clover seed mix ('Kirkton Custom')	£188	£188		
Broadcasting grass/clover seed (seed barrow)[2]		£75		
Direct drilling of grass/clover seed[2]	£74			
Rape/stubble turnip seed mix (£3.75/kg)[3]			£50	£50
Broadcasting rape/turnip seed (seed barrow)			£75	
Direct drilling of rape/turnip				£74
Fertiliser (20:10:10 at £173.30/t spread at 185kg/ha)	£32	£32	£32	£32
Spreading fertiliser	SRUC farm equipment and staff time			
Big bale silage - cut, bale, wrap and stack	£198	£198		
Fertiliser (20:10:10 at £173.30/t spread at 173.9 kg/ha)	£30	£30		
Spreading fertiliser	SRUC farm equipment and staff time			
Total Cost/ha	**£549**	**£925**	**£559**	**£183**
Auchtertyre Reseed Field 2012	Non-inversion - Grass Reseed	Ploughed - Grass Reseed	Ploughed - Forage Crop	Non-inversion - Forage Crop
Glyphosate (Clinic Ace)	£19	£19	£19	£19
Herbicide spraying[2]	£36	£36	£36	£36
Ploughing[2]		£115	£115	
Harrowing & rolling[2]		£198	£198	
Fertiliser (15:15:15 at £236.94/t spread at 170 kg/ha)	£40	£40	£40	£40
Spreading fertiliser[2]	£44	£44	£44	£44
Grass/clover seed mix (£4.30/kg at a recommended sowing rate of 37kg/ha)	£159	£159		
Broadcasting grass/clover seed (seed barrow)[2]		£73		
Direct drilling of grass/clover seed[2]	£87			
Rape/stubble turnip seed mix (£3.75/kg)[3]			£37	£27
Broadcasting rape/turnip seed (seed barrow)[2]			£73	
Direct drilling of rape/turnip[2]				£87
Fertiliser (24:12:00 at £319/t spread at 200 kg/ha)	£64	£64	£64	£64
Spreading fertiliser	£10	£10	£10	£10
Total Cost/ha	**£459**[4]	**£758**	**£636**	**£327**[5]

[1] Contractor costs include travel time and fuel.

[2] When the field operations were restricted to the plots the costs per ha were inevitably high due to the relatively high contractor travel time and fuel costs involved.

[3] The non-inversion forage crop required less seed for direct drilling – only 75% of the conventional.

[4] The non-inversion till grass reseed costs were 60.5% of the conventional grass reseed costs in 2012.

[5] The non-inversion till forage crop costs were 51.4% of the conventional forage crop costs in 2012.

Valuing Your Soils

Practical guidance for Scottish farmers

This guidance was written by Joanna Cloy, Rebecca Audsley, Paul Hargreaves, Bruce Ball, Bill Crooks and Bryan Griffiths, SRUC.
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Photograph: Chris Hoskins www.expressionsofscotland.com

Valuing Your Soils

Practical guidance for Scottish farmers

Field Sheets

Valuing Your Soils
Practical guidance for Scottish farmers

Field Sheet

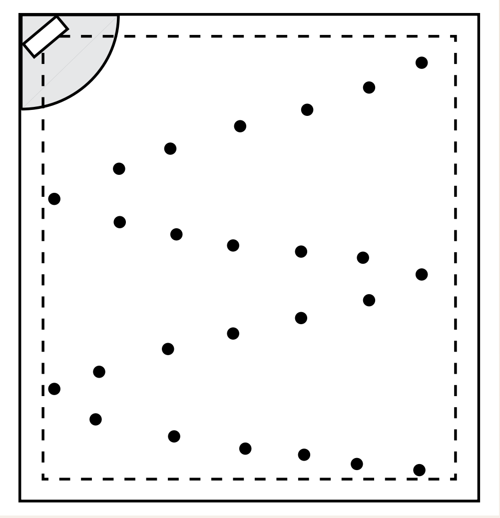
Taking soil samples for testing

What you need

- **A spade or soil corer/auger**
- **A bucket (collecting and mixing soil samples)**
- **Clean plastic sealable bags and waterproof marker**

How

- Walk across the field along a 'W' transect with your spade or auger. Collect around 15-20 soil samples from points along the transect to cover the area of the field
- Permanent grassland should be sampled to 10 cm depth and arable land (including short-term rotation grass) to plough depth 20 cm



- When using a spade, remove a slice of soil about 2.5 cm wide to sample depth and collect in a clean bucket. Further slices should be taken in the same way from different parts of the field until about 20 have been collected
- When an auger is used, it should be twisted into the soil to sampling depth and pulled out. All soil adhering to it should be carefully transferred to the bucket
- Write the field name, farm name and address on the sampling bag before it is filled and sent for testing. The sample should be thoroughly mixed in the bucket before taking a representative handful of soil to fill the bag. Large stones, roots and plant materials should not be placed in the bag

When

Soil samples can be collected at any time of the year, but avoid sampling within two years of applying lime or within two months of applying a compound fertiliser, organic manure or more than 50 kg/ha nitrogen.

Where

Large fields should ideally be divided into < 5 ha units and sampled separately. Samples should also be taken from areas which were manured differently or have different soil types or topography. Avoid headlands, near gates, areas where lime or manure have previously been dumped and areas where livestock congregate.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Use a soil corer or spade to take a sample

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Field Sheet

How to check for and alleviate soil compaction

It is important to assess the depth and severity of soil compaction before starting any remediation so the correct equipment can be used.

If you suspect that compaction is present then check the depth and extent by using VESS – compact layers of score 4 and 5 need more immediate management.

A simple penetrometer can also be used, but take care that 'compaction' below the topsoil is not due to a naturally shallow topsoil or a naturally hard subsoil. Compare the severity of the compaction with measurements from non-cultivated areas or at field boundaries.

There are a number of mechanical ways to improve soil structure if it has been damaged.

Grassland soil structure can be difficult to improve once damaged. Severe compaction can be costly. A grass reseed can cost over £500/ha.

Arable soils can be easier to remedy as ploughing after the crop has been lifted will introduce structure back into the ploughed layer of the soil. However, if compaction has occurred below the plough depth then a subsoiler should be used after ploughing. Use winged subsoilers to ensure an even lift when subsoiling a large arable area.

"Subsoiling a wet soil is a waste of money and can make the problem worse"

In grasslands, methods that minimise surface damage are used. These fall into three main groups:

- Aerators i.e. surface spikers or slitters working typically at a soil depth of 0 to 15 cm
- Sward lifters working between 15 and 35 cm soil depth
- Subsoilers working between 35 and 50 cm soil depth

Surface slitting using a sward slitter or aerator can remove surface layer (0-15 cm) compaction, increase surface aeration and improve water/slurry infiltration rates.

Squelchy clayey grassland soil with boot imprint around 3 cm deep

A penetrometer can be used to identify the depth of soil compaction in fields

Sward lifter

Compacted grassland soil

Sward lifters can shatter the soil from depths of 15-35 cm and improve water infiltration and nutrient uptake rates. The tines should be just below the lower compaction band (approximately 2 – 3 cm); if they are set to run through the compaction then this will just increase the problem. Each sward lifter will have a **critical depth** for use, this is generally 6 times the depth of the horizontal part of the tines. Soil moisture content is also very important: if the ground is too dry it will be difficult to pull through the soil, if too wet, channels will be formed with smearing and cutting of the sward.

Always get a spade and assess the soil after one run across the field with a slitter or a sward lifter to ensure the correct result is being achieved.

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Field Sheet

Checking soil drainage status

Drainage 10 point check list:

1. **Investigate wet or waterlogged areas of field to assess soil structure**
2. **Remove soil compaction or compaction layer to help drainage**
3. **Check farm plans to see if a field drainage system exists**
4. **Check outflows and drains are clear, jet if necessary**
5. **Keep drainage ditches clear of silt and the water level at least 15 cm below the level of the outflow**
6. **Only use mole drains if soils contain more than 30% clay**
7. **Make sure any new drainage system is suited to the soil type and conditions**
8. **Lateral drains should always run across the slope**
9. **Backfilling drains with a permeable material helps maintain their use and allows connection to mole drains**
10. **Ensure the correct drainage pipe diameter and material is used**

© SEPA

For regularly waterlogged fields or waterlogged areas within a field, some simple investigations can be done before spending money on an expensive drainage system.

- Check the field for areas of poor drainage and standing pools of water after the rest of the field has dried. Weed species such as rushes can indicate the wettest areas of a field, as well as reduction in yield of crops.
- Investigate the reasons behind the poor drainage: Is it an area of the field that has received a great deal of traffic i.e. around field entrances? Is it an area around animal feeding or water troughs that shows poor sward cover? These are both indication of a soil structure problem from compaction and simply digging a hole with a spade could reveal the depth of compaction, where the compacted layer is located and the type of management needed.

- In the wetter winter months, investigate wet patches and areas of the field with standing water. Check farm plans for existing field drainage and the outlets from these drains. Maintain existing drainage, including outlets and drainage channels. Ensuring field drain outfalls are not buried in silt or continuously submerged should maximise the flow of water. Ideally outfall should be 15 cm above normal winter water level.

- Regularly check field drain outlets especially in late winter and early spring when they should be running freely; this should be more obvious following rainfall of at least 5 mm in one day. Clear any blocked or slow running drain outfalls.

- Look for signs of reddish-orange slime or ochre in outlet pipes which can block the drainage systems; this needs to be flushed out by jetting. (There is no permanent remedy for this problem but pine bark can help control ochre formation).

- 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. Avoid creating mole drains on too steep a slope (i.e. over 10% gradient) as the movement of the water will erode the drainage channel. If the flow is too shallow the water will not flow along the drains and can cause erosion that blocks the drain. Mole drains are generally spaced 1.5 to 1.8 m apart and at a depth of 0.45 - 0.5 m.

- If installing a new drainage system, ensure the drains are installed deep enough not to be damaged by the cropping management.

- Running a drain too close to a tree rooting zone or < 1.5 m from a hedge should be avoided as the roots can grow into permeable drains and cause blockages.

Grassland rejuvenation

When it comes to putting life back into pastures, rejuvenation of existing swards by over-seeding with a harrow and/or drill (£100-£200/ha) could prove a cost effective method, especially when compared to a full ploughed re-seed (over £500/ha for a complete reseed, includes costs of ploughing and reseeding).

Given the right establishment of grass mixtures, you should expect well managed leys to be highly productive – delivering plenty of grazing as well as being able to secure valuable silage cuts. However, even the best managed medium- and long-term leys will deteriorate over time, and within 5 years it is not unusual to find the percentage of the original sown species has been reduced by as much as 50%.

Grassland production is largely dictated by the level of ryegrass and clover in the sward. 30% clover cover in the sward will contribute 150 kg N/ha during the growing season. Ryegrass has a D value (digestibility of the dry matter) of around 78% whereas weed grasses such as bents and fescues will have a D value of ~ 58%. Each unit of D is equivalent to 40 g liveweight gain/head/day. 15% of weed grasses will be established at the same time as a re-seed and by year 5, will dominate the sward.

General good sward

Purple base of perennial ryegrass

Grass drilling equipment

Specialist grass drill

Grassland rejuvenation checklist*

*Does not apply to grassland under conservation management

Step 1

Sample and test the soil to ensure pH and nutrient status is correct. Remedial action should be taken as per recommendations.

Step 2

Assess soil structure. Take remedial action if compaction layers are detected. If deeper subsoil structure or drainage issues are suspected use a digger to excavate a full soil profile.

Step 3

Assess the balance of ryegrass/weed grasses in the sward. The higher the proportion of weed grasses, the more benefit will be gained from rejuvenation.

Step 4

Decide on the most appropriate type of rejuvenation

• If the sward composition is poor:

Option 1) RAPID REJUVENATION- Replace sward by ploughing (ideally use minimum tillage) and reseeding.

OR

Option 2) SLOW REJUVENATION- Improved management (e.g. oversowing, use of lime, better use of nitrogen, improved grazing management).

• If the sward composition is good but there is no clover present:

Renovate by oversowing with clover in July

• If the sward composition is good but the sward is thin:

Renovate by strip seeding or oversowing

• If the sward composition is good but improved spring growth is desired:

Renovate by oversowing with early varieties

Visual Evaluation of Soil Structure

Soil structure affects root penetration, water availability to plants and soil aeration. This simple, quick test assesses soil structure based on the appearance and feel of a block of soil dug out with a spade.
The scale of the test ranges from Sq1, good structure, to Sq5, poor structure.

Equipment:
Garden spade approx. 20 cm wide, 22-25 cm long.
Optional: light-coloured plastic sheet, sack or tray ~50 x 80 cm, small knife, digital camera.

When to sample:
Any time of year, but preferably when the soil is moist. If the soil is too dry or too wet it is difficult to obtain a representative sample.
Roots are best seen in an established crop or for some months after harvest.

Where to sample:
Select an area of uniform crop or soil colour or an area where you suspect there may be a problem. Within this area, plan a grid to look at the soil at 10, preferably more, spots. On small experimental plots, it may be necessary to restrict the number to 3 or 5 per plot.

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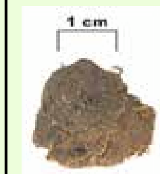
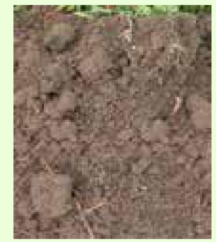
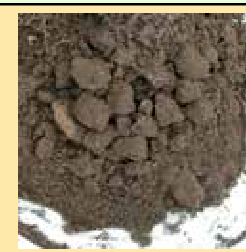
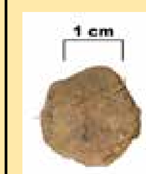
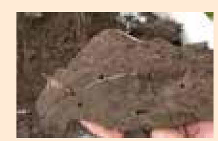
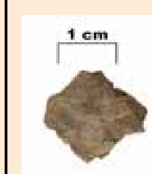
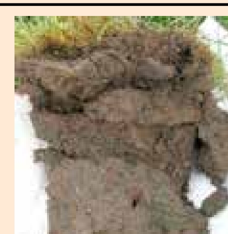
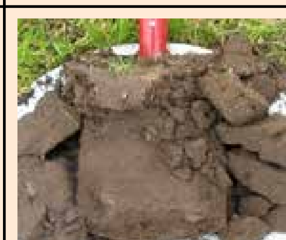
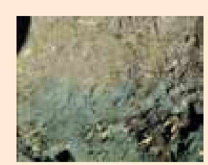
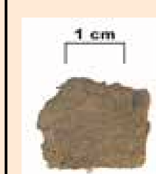
Method of assessment:

Step	Option	Procedure
Block extraction and examination		
1. Extract soil block	Loose soil	Remove a block of soil ~15 cm thick directly to the full depth of the spade and place spade plus soil onto the sheet, tray or the ground
	Firm soil	Dig out a hole slightly wider and deeper than the spade leaving one side of the hole undisturbed. On the undisturbed side, cut down each side of the block with the spade and remove the block as above.
2. Examine soil block	Uniform structure	Remove any compacted soil or debris from around the block
	Two or more horizontal layers of differing structure	Estimate the depth of each layer and prepare to assign scores to each separately.
Block break-up		
3. Break up block (take a photograph - optional)		Measure block length and look for layers. Gently manipulate the block using both hands to reveal any cohesive layers or clumps of aggregates. If possible separate the soil into natural aggregates and man-made clods. Clods are large, hard, cohesive and rounded aggregates.
4. Break up of major aggregates to confirm score		Break larger pieces apart and fragment it until a piece of aggregate of 1.5 - 2.0 cm. Look to their shape, porosity, roots and easily of break up. Clods can be broken into non-porous aggregates with angular corners and are indicative of poor structure and higher score.
Soil scoring		
5. Assign score		Match the soil to the pictures category by category to determine which fits best.
6. Confirm score from:		Factors increasing score:
	Block extraction	Difficulty in extracting the soil block
	Aggregate shape and size	Larger, more angular, less porous, presence of large worm holes
	Roots	Clustering, thickening and deflections
	Anaerobism	Pockets or layers of grey soil, smelling of sulphur and presence of ferrous ions
	Aggregate fragmentaion	Break up larger aggregates ~ 1.5 – 2.0 cm of diameter fragments to reveal their type
7.Calculate block scores for two or more layers of differing structure		Multiply the score of each layer by its thickness and divide the product by the overall depth, e.g. for a 25 cm block with 10 cm depth of loose soil (Sq1) over a more compact (Sq3) layer at 10-25 cm depth, the block score is (1 x 10)/25 + (3 x 15)/25 = Sq 2.2.

Scoring: Scores may fit between Sq categories if they have the properties of both.
Scores of 1-3 are usually acceptable whereas scores of 4 or 5 require a change of management.

16 Oct 2012

Structure quality	Size and appearance of aggregates	Visible porosity and Roots	Appearance after break-up: various soils	Appearance after break-up: same soil different tillage	Distinguishing feature	Appearance and description of natural or reduced fragment of ~ 1.5 cm diameter
Sq1 **Friable** Aggregates readily crumble with fingers	Mostly < 6 mm after crumbling	Highly porous Roots throughout the soil			 Fine aggregates	 The action of breaking the block is enough to reveal them. Large aggregates are composed of smaller ones, held by roots.
Sq2 **Intact** Aggregates easy to break with one hand	A mixture of porous, rounded aggregates from 2mm - 7 cm. No clods present	Most aggregates are porous Roots throughout the soil			 High aggregate porosity	 Aggregates when obtained are rounded, very fragile, crumble very easily and are highly porous.
Sq3 **Firm** Most aggregates break with one hand	A mixture of porous aggregates from 2mm -10 cm; less than 30% are <1 cm. Some angular, non-porous aggregates (clods) may be present	Macropores and cracks present. Porosity and roots both within aggregates.			 Low aggregate porosity	 Aggregate fragments are fairly easy to obtain. They have few visible pores and are rounded. Roots usually grow through the aggregates.
Sq4 **Compact** Requires considerable effort to break aggregates with one hand	Mostly large > 10 cm and sub-angular non-porous; horizontal/platy also possible; less than 30% are <7 cm	Few macropores and cracks All roots are clustered in macropores and around aggregates			 Distinct macropores	 Aggregate fragments are easy to obtain when soil is wet, in cube shapes which are very sharp-edged and show cracks internally.
Sq5 **Very compact** Difficult to break up	Mostly large > 10 cm, very few < 7 cm, angular and non-porous	Very low porosity. Macropores may be present. May contain anaerobic zones. Few roots, if any, and restricted to cracks			 Grey-blue colour	 Aggregate fragments are easy to obtain when soil is wet, although considerable force may be needed. No pores or cracks are visible usually.