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Soil Health scorecard approach
Sampling protocol and benchmarking tables

Scotland

Version 1.0

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1. Background

The Soil Health scorecard approach has been developed in partnership with farmers and agronomists across the UK as part of the Soil Biology and Soil Health (SBSH) Partnership funded by the AHDB and BBRO.

Soil observations and samples are collected on farm for a number of distinct purposes, for example to check the performance of fertilisation/liming strategies, plan new fertiliser applications, or determine timeliness for cultivations. This approach to routine measurement of soil health is intended to fit within those approaches but not necessarily to replace them all. On any farm, there are likely to be further but complementary approaches to soil characterisation e.g. grid sampling of soil P/K for precision fertiliser management; or scouting to determine the most effective tillage method and depth.

The Soil Health scorecard aims to capture the interactions between physics, chemistry and biology that underpin soil health in a concise and practical format for the user and also to provide useful information to inform management. The aim is to provide a set of measures and an interpretation framework that can:

i) provide a routine soil health check (every 3-5 years, ideally at the same point in a crop rotation),
ii) identify areas where more focus or further detailed sampling may be needed, and
iii) support farmers and agronomists when they are evaluating changes in farming systems or management practices.

Soil texture is a fundamental property that is not changed by management and is, therefore, not appropriate as an indicator to monitor changes in soil health. However, an underpinning knowledge of soil texture is needed to benchmark the values obtained for the indicators appropriately. For example, the natural levels of organic matter that can be held in a sandy soil are inherently much lower than in a heavier clay soil because of the ways in which clay particles can stick to and stabilise organic matter in soil. It is important to take both soil texture and climate into account when assessing organic matter levels in soil. For benchmarking within the Soil Health scorecard, the simplest grouping of topsoils by texture, as used in Cross Compliance, is used.

Climate can be estimated from a knowledge of site location. Here, UK region is used in the benchmarking process. In addition, straightforward descriptions of land use and topsoil characteristics for sites are chosen from simple pre-defined lists. This information can be used to set up categories that allow users to compare data from similar sites and with benchmarks.

Rotational cropping		**Topsoil (key characteristic)**
Cropping – combinable crops		*Light (sandy and light silty)*
Cropping – rotation including late harvested crops		*Medium (clay loams)*
Cropping – rotation including leys		*Heavy (clays)*
Cropping – field-scale vegetables		*Organic*
Grassland – intensively managed		
Grassland – permanent pasture		*Calcareous (Y/N)*

2. Soil sampling and field records

The Soil Health Scorecard combines physical observations of topsoil in the field with the results from analysis of soil samples sent for testing. Some of the data may already be collected for other purposes, however, it is recommended that the information and samples for the Soil Health scorecard are collected at the same time and in the same place.

Regular sampling for soil health monitoring is expected to take place once per rotation (or about every 5 years in permanent and semi-permanent pasture), at the same time of year and the same point in the rotation to maximise comparability between samples. The SBSH Partnership concluded that _data collection in the autumn as the soil wets up_ is most appropriate. The date of sampling is less important than the fact that the soil is both moist and warm. It is possible to sample when it is drizzling, but if there has been heavy rain it is best to let drainage occur for at least 2 days before sampling. Farmers will determine the best point in their rotation to integrate soil health sampling. Many of the arable farmers who evaluated the approach, as part of the SBSH Partnership, have chosen to sample after a first cereal.

Soil observation and sampling should take place at a time that is:

- after harvest,
- after the topsoil has wetted up in the autumn, and
- ideally, at least 1 month after any cultivations / moderate soil disturbance and/or application of organic inputs, such as manures/composts.

This timing may mean that rotational sampling for soil health does not easily fit at all points of the rotation. In some rotations, this may mean sampling in an actively growing cover crop or after drilling of the next main crop.

The farmer is best placed to determine their own representative sampling sites (within which soil texture and cropping show limited variation) and where these sites can provide useful data to monitor soil health and inform farm practice in soil management. Farmers should sub-divide fields as needed into similar zones and that, where appropriate, each zone is sampled. _There may be just one sample site per group of fields, or there may need to be several per field, where soil texture varies markedly._

Where sites are set up with the intention of using them to measure trends through time, then a detailed characterisation of the site, including subsoils, would provide more detailed information on the inherent limitations e.g. drainage, or micronutrient availability. As for all soil sampling, the area selected should be relatively uniform. Avoid headlands, gateways, and feeder locations unless they are specifically being targeted as a sampling site, and also avoid marked wheelings where possible.

The centre point of each sampling site should be recorded. In the SBSH Partnership both mapping pins and “What 3 Words” locations were used by farmers to record site locations. The sampling site is then considered to be the area within 5 m in all directions of that centre point i.e. a rough circle of 10 m in diameter (Figure 1). It is likely to be representative of a larger area.

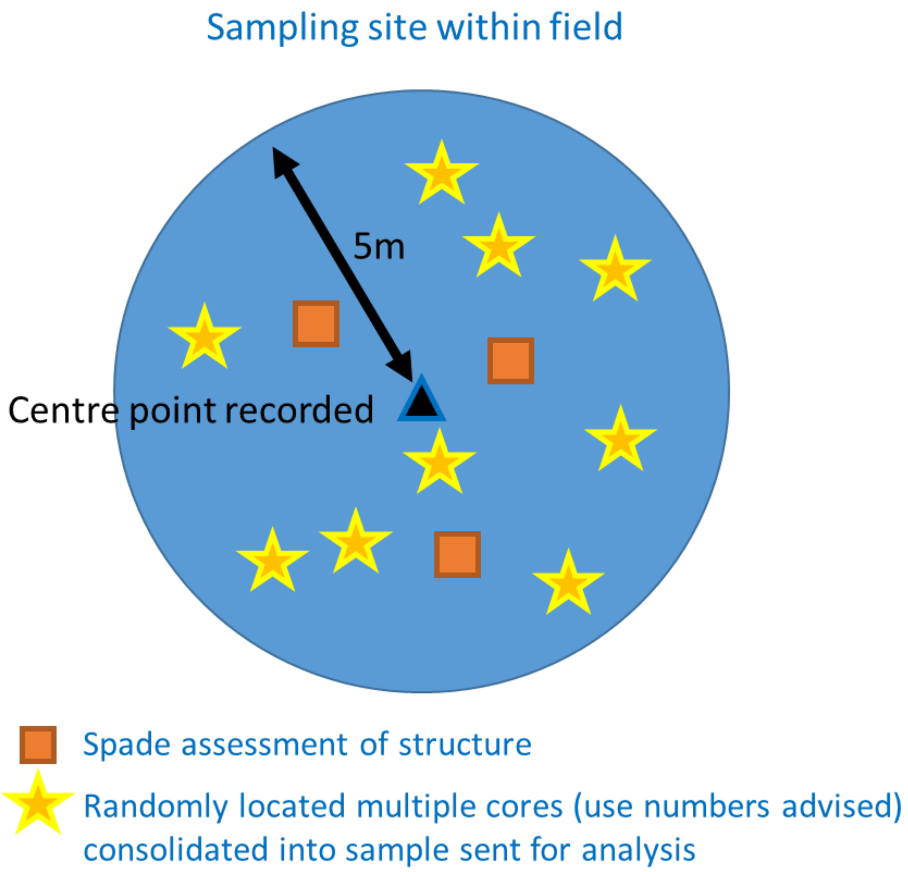

Figure 1: Schematic representation of a sampling site for the soil health scorecard approach

The process of indicator selection and evaluation is described in full in the Soil Biology and Soil Health Partnership Project reports. As discussed in those reports, a number of other indicators can be used on-farm such as the slake test (for assessing aggregate stability) or infiltration measures and tests for direct measurement of decomposition (such as the T-bag test or "Soil my undies" approach). However, whilst these are useful measures to compare side by side at the same site, they are difficult to benchmark and to use to compare sites or seasons. Penetrometer data can give excellent insight when scouting for soil structural issues. There is a range of other laboratory analyses that can be used to increase knowledge of the soil character e.g., the micronutrient profile or to provide more detail e.g. indicators of soil organic matter quality. Some of these approaches can be useful as part of more detailed sampling where potential problems have been identified by the scorecard.

The Soil Health scorecard uses field recorded data for topsoil structure (the most-limiting layer score for visual assessment of soil structure (VESS)) together with earthworm numbers (and an observation of species diversity in grassland systems) together with a mixed representative soil sample sent away for analysis of pH and routine nutrients and soil organic matter (SOM) content. The SBSH Partnership also evaluated the use of some commercially available indicators of microbial activity.

	Soil health scorecard indicators		
Comparison categories	Physical	Chemical	Biological
Region (rainfall class)	Visual assessment of soil structure (VESS) most limiting layer	pH	Earthworm count
Rotational cropping		P	SOM
Topsoil character		K	(Microbial activity)
		Mg	

Field measure	Measured in a soil sample

3. Benchmarking

The framework used for communication of information about indicator values to farmers / growers is based on the soilquality.org.uk framework developed and tested initially as part of a Sustainable Agriculture Research and Innovation Club funded project (2016-2019). Results for each of the soil health test indicators are presented as an analytical value together with a 'traffic light', whereby a result in green indicates a typical or optimum result. Amber and red categories indicate the need for further examination (perhaps by more detailed sampling) and, in many instances, management intervention to maintain or improve soil condition. The traffic light system represents either a comparison to a 'norm' e.g. for soil organic matter or earthworms, or is linked to a directly measured negative effect e.g. pH, nutrients.

The benchmarks have been developed for use in cropping systems and lowland grassland. The benchmarks presented here are not applicable to peats / organic soils i.e. those with >20% organic matter to more than 50 cm deep in Scotland. A different set of benchmarks would also be required for upland grass / semi-natural systems.

The traffic light system proposed for communication alongside indicator values

INVESTIGATE	Notes are given together with the traffic light result
REVIEW	
CONTINUE ROTATIONAL MONITORING	

3.1. Visual Assessment of Soil Structure - VESS

Visual Assessment of Soil Structure should be accompanied by a visual assessment of soil surface condition and an inspection of the local area for signs of soil erosion and/or rapid run-off. The ThinkSoils manual gives a really useful introduction to soil structure for soils of different types.

Observations characterising each class

Surface condition	**Cropping**	**Grassland**
Good	• Soil surface covered by vegetation and/or residues • No standing water • No deep wheelings	• Sward intact • No poaching • Few wheelings
Moderate	• Areas of surface water • Poor vegetation growth or soil surface cover	• Surface poached • Wheelings in places • More weed species
Poor	• Surface capping • Poor growth • Deep wheelings present	• Surface capping • Soil exposed • Severe poaching • Poor sward quality

The SRUC VESS (arable) and Healthy Grassland Soil methodology is recommended; these are slightly different methods for arable and grassland but have a matched 1-5 scoring system. This is a simple in-field assessment approach which requires a spade and a scoresheet for comparison. The lowest score (Sq1) is given to the least compact and most porous condition, and the highest score (Sq5) to a very compact condition with very large and often platy aggregates with very low visible porosity.

Ideally the soil should be moist to 30 cm but not saturated; hence it is possible to do these assessments on a damp/rainy day – but not at the end of a run of rainy days.

At least 3 topsoil blocks should be inspected for each sample site. A score (between 1 and 5) is recorded for an extracted block of soil. Different layers showing different structures may be observed to 25 cm. Different structures may also be seen in each of the three topsoil pits. However, the score recorded for the Soil Health scorecard is a typical score of the most limiting layer for the site. It is also useful to record the depth at which the limiting layer occurs and to add further notes e.g. *surface very good tilth (1) overlies more blocky structure (2) at 10 cm; one pit had some larger blocky aggregates at 15 cm*.

A representative block should be photographed to give a more detailed record; the block should ideally be on a white background and with an appropriate scale (e.g. ruled measure, spade blade).

Visual assessment of soil structure

Traffic light	Ranges	
Monitor	1 or 2	CONTINUE ROTATIONAL MONITORING Good soil structure. Friable / crumbly. Small round aggregates. Make a comparison with an area known to be poor (e.g. gateway) and likely to be good (e.g. hedge bottom). Consider including an assessment of subsoil. Assess regularly and especially where it has been necessary to traffic or cultivate the soil in wet conditions.
Review	3	REVIEW Adequate soil structure. Firm. Larger aggregates, some angular, but most aggregates break down. Make a comparison with an area that is known to be poor (e.g. gateway) and likely to be good (e.g. hedge bottom), include consideration of subsoil. Assess regularly and especially where it has been necessary to traffic or cultivate the soil in wet conditions.
Investigate	4 or 5	INVESTIGATE Poor soil structure. Compact or very compact with impacts on rooting observed. Serious compaction or runoff must be dealt with quickly. Major arable compaction problems are more commonly tackled as part of the cultivation operations for the next crop. Check subsoil layers, alleviating compaction in surface layers may be of limited value if subsoil has suffered compaction damage. It is essential that all operations to address poor structure are done under the right soil conditions. Working soil in wet conditions will usually make the problem worse.

The development of structure in subsoil is driven dominantly by physical processes and is mainly determined by the inherent characteristics of any soil, especially texture and stoniness. However agricultural management can transform the structure of the sub-soil e.g. through deep tillage and compaction. Risks of compaction are also affected by local hydrology which interacts with soil properties to determine the soil wetness class (good, moderate, poorly drained). Poor topsoil structure is often linked to poor subsoil structure and hence further evaluation of sites with poor surface condition (Review or Investigate groupings) should include an assessment of subsoil, together with a comparison with an adjacent unmanaged area to distinguish natural consolidation from processes resulting from land use practice.

Scientists at SRUC have developed a method to assess subsoil structure numerically (subVESS). For this assessment, a mechanical digger is needed to dig a trench > 60 cm wide, 1 m deep (where underlying parent material permits) and not less than 2 m in length. The final flowchart for subVESS is available.

Some farmers and advisors are also using in-field assessment of infiltration rates and aggregate stability. These can give good site comparisons when conducted on the same day, for example to support a field demonstration day, but are not robust enough for widespread comparison and benchmarking between sites or between seasons. Simple farmer accessible methods are reported by the USA Natural Resource Conservation Service:

Aggregate stability

Infiltration

3.2. pH

This is the routine pH measurement (1:5 soil:water). The groupings and traffic lights have been set with reference to the categories used by the Professional Agricultural Analysis Group (PAAG) and production-based information – Nutrient Management Guide RB209. FAS Technical Note TN656 provides additional detail.

Separate tables are given for Cropping and Grassland.

pH - Cropping

Traffic light	Ranges	
Investigate	≤ 5.49	INVESTIGATE Potential problems with aluminum toxicity Liming is usually required every 3-5 years to maintain pH, it will need to be done more frequently on lighter land. Where large changes in pH are required, a long-term liming programme may be needed.
Review	5.5-6.49	REVIEW Ensure there is a robust liming plan in place on non-calcareous soils to maintain pH
Monitor	6.5-7.49	CONTINUE ROTATIONAL MONITORING On non-calcareous soils, ensure that the lime rates used in the liming plan are not over-correcting. It may be better to use lower rates more often and maintain pH at 7 unless if there are very sensitive crops (such as oilseed rape, sugar beet, peas) in the rotation.
Review	≥ 7.5	REVIEW Potential nutrient interaction issues Monitor crops for trace element deficiencies; foliar feeds will be more effective than soil applications in high pH soils

pH - Grassland

Traffic light	Ranges	
Investigate	≤ 5.49	INVESTIGATE Where biodiverse acid grasslands are not the management aim, liming is usually required every 3-5 years to maintain pH, it will need to be done more frequently on lighter land. Where large changes in pH are required, a long-term liming programme may be needed.
Review	5.5-5.99	REVIEW Ensure that there is a robust liming plan in place on non-calcareous soils to maintain pH
Monitor	6.0-6.49 6.5–7.49	Liming may be needed for reseeds CONTINUE ROTATIONAL MONITORING Ensure that there is a robust liming plan in place on non-calcareous soils to maintain pH
Review	≥ 7.5	REVIEW Potential nutrient interaction issues Where high pH soils are used for livestock production, trace mineral deficiencies including cobalt, manganese, zinc and copper are aggravated as a result of the high pH soils. Hay (or silage) may have high Ca content and lower than desirable Mg or K contents and a high calcium to phosphorus ratio of the forage which can have negative impacts on livestock performance. These issues cannot be managed in the soil and should be addressed through careful planned grazing, with dietary supplementation as needed.

3.3. Routine nutrients (P, K, Mg)

The groupings and traffic lights have been set with reference to the categories used by the Professional Agricultural Analysis Group (PAAG) and production-based information – FAS Technical notes TN668, TN715, TN716, TN717 and TN718. The Technical Notes should be consulted to assess the P and K sorption status of the soils in different regions of Scotland and the bands may change slightly.

Extractable P

The environmental risk from soil movement as sediment, especially for P is also taken into account. Therefore, there is a red traffic light at high P.

Extractable P (Modified Morgan's) mg/L

Traffic light	Ranges	
Investigate	0 - 1.7	INVESTIGATE Very Low. P should be applied in fertiliser / organic materials to help meet crop need and build the soil reserve. The best crop response may be seen where P is applied in early spring together with nitrogen.
Review	1.8 - 4.4	REVIEW Low. P should be applied in fertiliser / organic materials to help meet crop need and build the soil reserve. The best crop response may be seen where P is applied in early spring together with nitrogen.
Monitor	4.5 – 13.4	CONTINUE ROTATIONAL MONITORING M- to M+. A clear rotational P management plan is needed to maintain the soil reserve without compromising productivity or increasing environmental risk
Review	13.5 - 30.0	REVIEW High. A clear rotational P management plan is needed to sustainably maintain the soil reserve whilst reducing the environmental risk
Investigate	>30	INVESTIGATE Very High. Potential risk to the environment. A clear rotational P management plan is needed to sustainably run-down the soil reserve without compromising productivity

Extractable K

While target maintenance indices are different for sands (i.e. Low), this is still a level that is considered a potential risk to production and hence amber for presentation. There is no recognised environmental risk of high K levels.

Extractable K (Modified Morgan's) mg/L

Traffic light	Ranges	
Investigate	0 - 39	INVESTIGATE Very Low. K should be applied in fertiliser / organic materials to help meet crop need and build the soil reserve. Care is needed where K fertiliser is applied for grassland to avoid the risks of luxury uptake of K under cutting and inducing hypomagnesaemia (low Mg) under grazing.
Review	40 - 75	REVIEW Low. K should be applied in fertiliser / organic materials to help meet crop need and build the soil reserve. Care is needed where K fertiliser is applied for grassland to avoid the risks of luxury uptake of K under cutting and inducing hypomagnesaemia (low Mg) under grazing.
Monitor	76 - 200	CONTINUE ROTATIONAL MONITORING M- to M+. A clear rotational K management plan is needed to maintain the soil reserve without compromising productivity.
Monitor	>200	CONTINUE ROTATIONAL MONITORING H and higher. A clear rotational K management plan should reduce and sustainably maintain the soil reserve without compromising productivity. Care is particularly needed to maintain Mg where K levels are high to avoid the risks of inducing hypomagnesaemia (low Mg) under grazing.

Extractable Mg

Groupings and traffic lights also take account of the impact of high Mg levels in terms of nutrient interactions in medium/heavy soils, which are the only soil type in which such high values are expected to occur.

Extractable Mg (Modified Morgan's) mg/L

Traffic light	Ranges	
Investigate	0-19	INVESTIGATE Very Low. Where soil acidity also needs to be corrected, applying magnesian limestone is the best way to maintain soil Mg at a satisfactory level. An application of 5 t/ha of magnesian limestone will add at least 450 kg Mg /ha, and this Mg will become plant-available over many years. Where the Mg status is low but additional lime is not required, a range of alternative sources of Mg are available. Foliar Mg can also be applied where plant deficiency symptoms are seen.
Review	20-60	REVIEW Low. Where soil acidity also needs to be corrected, applying magnesian limestone is the best way to maintain soil Mg at a satisfactory level. An application of 5 t/ha of magnesian limestone will add at least 450 kg Mg /ha, and this Mg will become plant-available over many years. Where the Mg status is low but additional lime is not required, a range of alternative sources of Mg are available. Foliar Mg can also be applied where plant deficiency symptoms are seen.
Monitor	61-1000	CONTINUE ROTATIONAL MONITORING M- to High. A clear rotational Mg management plan will allow the soil reserve to be maintained without compromising productivity.
Review	> 1000	REVIEW Very High. High soil Mg concentrations do not damage crop growth directly, but may affect plant availability of other cations such as potassium or calcium. A clear rotational Mg management plan will allow the soil reserve to be reduced, and then maintained without compromising productivity. Careful planned grazing and dietary supplementation may be need in grassland on high Mg soils. If liming is necessary, consider the sources of lime available and, where feasible, select a low Mg lime. High Mg levels may reduce aggregate stability in some clay soils, if Na levels are also high and Ca levels are low.

Extractable Ca levels - guidance

Ca is needed by plants for growth and is held as a cation on the soil exchange complex. In calcareous soils, Ca is also readily dissolved from parent material such as chalk, limestone and carbonate-rich clays. Typically, available Ca will fall in the range 1000-2500 ppm (mg Ca / kg). Ca levels in UK soils rarely limit growth as low Ca soils are also often acidic and hence liming materials containing Ca are routinely added. Where Ca is <1000 ppm, even if pH is not limiting, a response may be seen to added Ca. Very high levels of available Ca, often associated with high pH, do not damage crop growth directly, but may affect the plant availability of other cations such as potassium or magnesium. Low levels of Ca in clay soils, where Na levels are also high, may reduce aggregate stability in some clay soils.

3.4. Soil Organic Matter

There are a number of approaches to measure soil organic matter (SOM) – all are robust enough to detect trends through time and can be used for soil health benchmarking. The most common method used to estimate the amount of organic matter present in a soil sample is by measuring the weight lost by an oven-dried (105°C) soil sample when it is heated to 400°C; this is known as “loss on ignition”, essentially the organic matter is burnt off. In other laboratories, and for research purposes, the organic carbon content of the soil is measured (after removing any mineral carbonate) by dry combustion and elemental analysis; the amount of carbon measured can be converted into an estimate of organic matter (and vice versa). Where the aim is to detect changes over time, it is important that the same method is used each time, as variations in the results from the same sample can result from the use of different temperatures, duration of heating and pre-treatments during laboratory analyses.

Where carbon benchmarking for carbon stocks is required, then intact soil samples of a known volume are needed so that bulk density and stoniness can also be determined accurately. The Soil Health scorecard does not meet the requirements for assessing the soil carbon stock (t/ha). However, the benchmarking approach can help to identify sites where the SOM content is much lower than the expected equilibrium value for that soil texture/ climate combination and hence where changes in practice could be targeted to increase soil carbon storage. The measurement of SOM and soil organic carbon is an area where new methods are emerging to describe the quality of the SOM (and the different types of OM present) alongside assessment of the total amount. Where soil clay content is known accurately, then examining the specific ratio of soil organic carbon to clay content (carbon:clay ratio) can give extra information. However, in practice, it is difficult to get good measures of clay content – laboratory measures using laser diffraction are not well cross-calibrated at present and there are very large errors that can occur with chalk soils. Hence at this stage the recommendation is to use SOM content (as a %) for the Soil Health scorecard. The more detailed methods could be used where more specialist investigation was used to follow up the scorecard.

The SBSH Partnership has worked with existing datasets (especially Defra projects SP0306 and SP0310). For Scotland, the James Hutton Institute (JHI) Soil Information System database has been used. By drawing on a specific location for a sampling site, the Soil Information System identifies the main expected soil series. Hence the SOM thresholds can be related to this detailed and extensive database, providing data that are relevant for each particular soil type and location. The database gives the main soil series and ranges of SOM measured by loss on ignition (LOI) for each soil series in the form of a box and whisker plot (Figure 2), from which the thresholds can be generated.

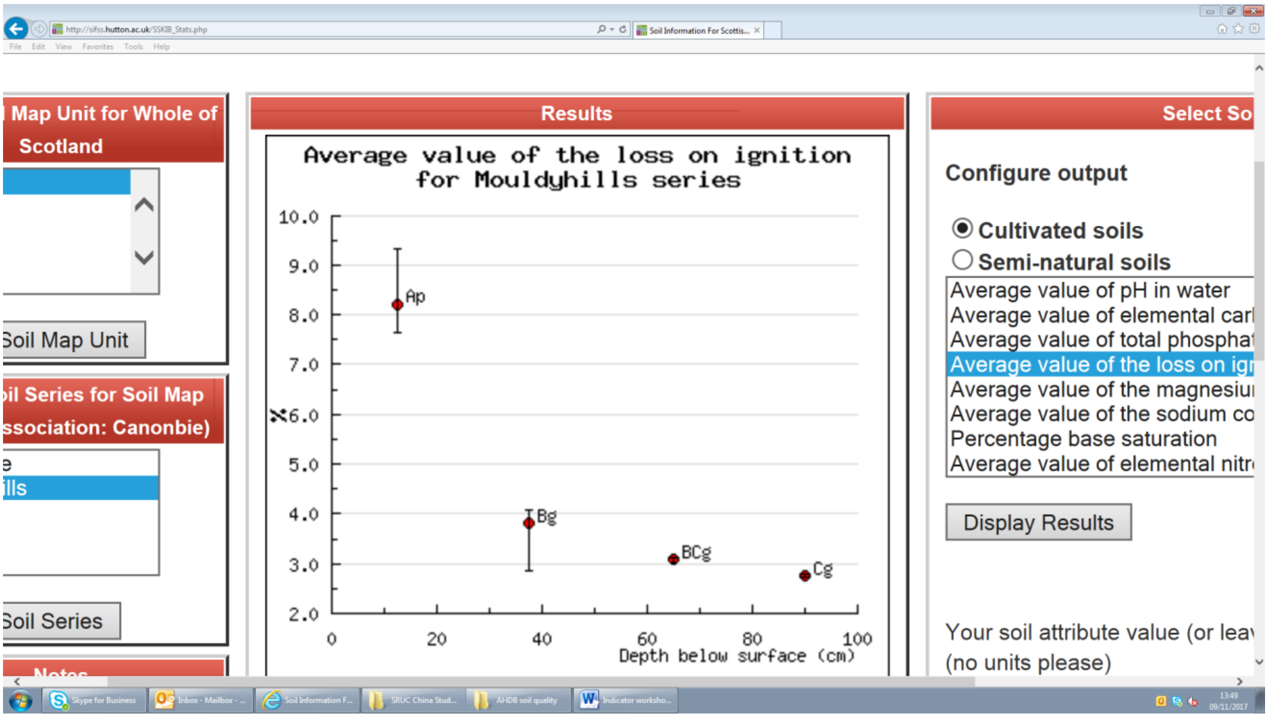

Figure 2. Example output from the JHI Soil Information System for Mouldyhills series soil, where the cultivated layer of soil has a median % loss on ignition (LOI) of 8.2% and a lower quartile of 7.6%

For each soil series, where data exists, the soil organic matter thresholds would be allocated as below.

Soil Organic Matter (Scotland)
(Based on the James Hutton Institute Soil Information System database)

Traffic light	Loss on ignition (LOI) class for particular soil series	
Investigate	Less than lower quartile	INVESTIGATE Poor; may be associated with intensive cropping rotations with few organic matter inputs. In general, the simple rule is: add more organic materials, build more soil organic matter. Changes in SOM as a result of changes in practice can take a long time to detect. Consider whether crop residues can be returned and what sources of organic materials can be accessed.
Review	Between lower quartile and median	REVIEW Moderate; may be associated with intensive cropping rotations with few organic matter inputs. In general, the simple rule is: add more organic materials, build more soil organic matter. Changes in SOM as a result of changes in practice can take a long time to detect. Consider whether crop residues can be returned and what sources of organic materials can be accessed.
Monitor	Greater than median	CONTINUE ROTATIONAL MONITORING Good; likely to be associated with crop residue returns and other regular organic matter inputs e.g. through cover cropping or compost. Changes in SOM as a result of changes in practice can take a long time to detect. There is no clear evidence for a critical value of SOM. Ensuring there are regular additions of organic matter to 'feed' the soil is more important than achieving any particular measured value.

3.5. Earthworms

The earthworm indicator combines information about earthworm numbers and the number of species seen when a 20 x 20 x 20 cm soil block is assessed in the field. The earthworm count is usually done alongside the VESS assessment in the same block of soil. Earthworm numbers can be highly variable as a result of weather conditions and soil moisture, with lower numbers recorded when soils are dry or very wet.

Although recent meta-analyses have indicated that there are variations in earthworm abundance with soil texture, the data collected across UK farms as part of the SBSH Partnership showed no differences between the texture groups. Therefore, benchmarks are only provided separately for cropping and grassland systems. However, extremes of soil texture can be important in determining the earthworm community structure and population size.

Earthworm species are often distinguished by size and colour, as well as other morphological features. When counting earthworms, it is possible to separate juveniles from adults and also to identify the eco-type of the worm [surface-dweller (epigeic), topsoil-dweller (endogeic), deep burrower (anecic)]. Considering the earthworm ecotypes (and species) present and the balance between juveniles and adults can be useful to give more information about the factors affecting earthworm populations. For the Soil Health scorecard, the total number of earthworms present in a soil block is the main indicator.

Earthworms – Cropping

Traffic light	Number per 20x20x20 cm spadeful	
Investigate	≤3	INVESTIGATE Depleted. Crop rotations characterised by high tillage intensity and low inputs of organic matter through roots, residues and organic manures are often associated with low earthworm numbers. Reducing tillage intensity and increasing organic matter inputs wherever possible will benefit soil biology and is likely to be reflected in increased earthworm numbers.
Review	4-8	REVIEW Intermediate. Deep burrowing earthworms are most strongly affected by tillage practice with low populations in crop rotations with regular ploughing and intensive cultivations for seed-bed preparation e.g. for potatoes. Considering the earthworm species present and the balance between juveniles and adults can be useful to give more information about the factors affecting earthworm populations.
Monitor	≥9	CONTINUE ROTATIONAL MONITORING Typical. There is no right number. In cropping systems, no or non-inversion tillage coupled with regular inputs of organic matter can lead to large and diverse earthworm populations. Considering the earthworm species present and the balance between juveniles and adults can be useful to give more information about the factors affecting earthworm populations

Earthworms - Grassland

Traffic light	Number per 20x20x20 cm spadeful	
Investigate	≤9 or predominantly one species	INVESTIGATE Depleted. Acid wet grasslands, especially those which are waterlogged for a significant part of the year, are often associated with low earthworm numbers. Often the main factors affecting earthworm numbers and diversity need to be addressed through physical (drainage) or chemical (liming) interventions. These changes are also likely to benefit grassland productivity as well as soil biology and are likely to be reflected in increased earthworm numbers.
Review	10-19	REVIEW Intermediate. High rate applications of slurry or digestate are often associated with the short-term disturbance of earthworm populations. Considering the earthworm species present and the balance between juveniles and adults can be useful to give more information about the factors affecting earthworm populations
Monitor	≥20 with good range of eco-types	CONTINUE ROTATIONAL MONITORING Typical. There is no right number. In grasslands neutral and moist, but well-aerated, soils with diverse swards are often associated with large and diverse earthworm populations Considering the earthworm species present and the balance between juveniles and adults can be useful to give more information about the factors affecting earthworm populations

3.6. Microbial activity

The size and activity of soil microbial biomass is considered to be a key indicator of soil biological health. Two alternative methods can be used to infer the size and activity of the microbial community: (i) potentially mineralisable nitrogen (PMN) which measures the amount of N readily decomposed under controlled (anaerobic) conditions, and (ii) CO_2-C burst which measures the amount of C released as CO_2 when a dried soil is rewetted. These processes are both dependent on the size and activity of the soil microbial biomass. The methods are currently delivered by commercial laboratories in the UK. The interpretation frameworks (or guideline values) developed in the United States were reviewed during the SBSH project using UK data to derive guideline values (given below) that are more relevant for UK agro-climatic conditions.

Potentially Mineralisable Nitrogen – all rotational land uses

Traffic light	mg/kg	
Investigate	<27	INVESTIGATE Very low
Review	28-40	REVIEW Low (below average)
Monitor	>40	CONTINUE ROTATIONAL MONITORING Typical

CO_2-C burst – *Cropping*

Traffic light	mg/kg	
Investigate	< 100	INVESTIGATE Low activity
Review	100-135	REVIEW Moderate activity
Monitor	>135	CONTINUE ROTATIONAL MONITORING Good activity (above average)

CO_2-C burst – *Grassland*

Traffic light	mg/kg	
Investigate	< 130	INVESTIGATE Low activity
Review	130-180	REVIEW Moderate activity
Monitor	>180	CONTINUE ROTATIONAL MONITORING Good activity (above average)