Environment and Rural Affairs Monitoring & Modelling Programme (ERAMMP)

ERAMMP Report-103: Recommendations for farmer-led soil monitoring in Wales

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Abbreviations Used in this Report

C	Carbon
Ca	Calcium
CO_2	Carbon dioxide
e-DNA	Environmental-DNA
ERAMMP	Environment and Rural Affairs Monitoring and Modelling Programme
FAS	Farming Advisory Service
GHG	Greenhouse gas
GMEP	Glastir Monitoring and Evaluation Programme
K	Potassium
LOI	Loss on ignition
Mg	Magnesium
N	Nitrogen
NATMAP	National Soil Map of England and Wales
NMPT-GB	Nutrient Management Planning Tool-GB
NSI	National Soils Inventory
P	Phosphorus
PAAG	Professional Agricultural Analysis Group
S	Sulphur
SFS	Sustainable Farming Scheme
SFI	Sustainable Farming Incentive
SIC	Soil inorganic carbon
SMN	Soil mineral nitrogen
SNHS	Soil Nutrient Health Scheme
SNS	Soil nitrogen supply
SOC	Soil organic carbon
SOD	SOil funDamentals
SOM	Soil organic matter
SRUC	Scotland's Rural College
TGA	Thermogravimetric analyser
UA1	Universal Action 1: Soil Health
VESS	Visual assessment of soil structure

CONTENTS

1 Introduction

The Welsh Sustainable Farming Scheme (SFS) aims to support farmers to produce food sustainably while addressing, and not further contributing to, environmental challenges (Welsh Government, 2025a).

During the SFS consultation, it was proposed that, to comply with Universal Action 1: Soil Health (UA1), farmers should test at least 20% of their land that is classified as improved or has previously received, or is planned to receive, inputs (i.e., natural and artificial fertilisers or lime) per year, thus 100% of the farm would be tested within a 5-year cycle (Welsh Government, 2024). Improved grassland is that which has been modified by management to enhance agricultural productivity, often characterised by reseeding and the application of fertilisers (Welsh Government, 2017). To be classified as improved grassland, at least two of the following criteria should be met: 1) over 30% cover of ryegrass and white clover, 2) up to 8 species per m^2, 3) less than 10% cover of wildflowers and sedges (Defra, no date). Semi-improved grassland has also been modified by management, although is managed more for habitat benefits rather than enhanced agricultural productivity (Welsh Government, 2017). Semi-improved grassland usually has a higher species diversity than improved grassland and does not need to be monitored as part of UA1.

That said, in the latest advice on SFS Universal Actions, where Soil Health is now UA1, the following criteria are given: “This action involves soil testing of your agriculturally improved land which has previously received or may receive inputs (natural and artificial) or lime. This should be all pasture not classified as habitat as part of Universal Action 5: Habitat maintenance." Improved clarification of the land that should be included in UA1 would be beneficial in the final guidance for farmers.

The soil must be tested for potassium (K), phosphorus (P), magnesium (Mg), pH, and soil organic matter (SOM) content. It should be noted that assessing soil nitrogen supply (SNS) is not included, as this is already a requirement under The Water Resources (Control of Agricultural Pollution) (Wales) Regulations 2021 (Welsh Government, 2021). Following analysis, the results should be uploaded to RPW Online, with records also being retained on-farm. Soil sampling, analysis and testing is an essential component of effective nutrient management planning, as it provides farmers with an understanding of their soil nutrient status, meaning they can optimise fertiliser application and crop yield, and reduce their environmental impact.

The addition of SOM to the traditional nutrient and pH assessment recognises the importance of organic matter in many aspects of soil health, as well as the contribution of soil for carbon (C) sequestration and storage.

Welsh Government would like all farmers to have the same level of knowledge and understanding on the sampling process, to ensure that soil samples are taken accurately and that results are comparable.

The main aim of this report was to build an outline for farmer-led soil testing, detailing how this would fit into a national framework, and the logistics of doing so, and providing a summary of how the data could be used.

The specific tasks were to:

- Task-1: Review existing farmer-led soil testing options that could align with the monitoring program and indicate a favoured approach, which would match the needs of the SFS. Consider how this differs with the methods and purpose of national monitoring approaches.
- Task-2: Outline the on-farm processes and a testing framework, including: a step-by-step guide for farmers, time required, materials needed, the information provided by each measurement, and indicator thresholds if available.
- Task-3: List the soil analysis that would be required, including the costs and importance of doing so via an accredited laboratory.
- Task-4: Indicate how the data will be used and interpreted by farmers and the Welsh Government.
- Task-5: Provide recommendations, which would enable improved data integration between farmer-led soil testing data and national monitoring by the Environment and Rural Affairs Monitoring and Modelling Programme (ERAMMP) in Wales for a more complete picture of current soil health across Wales.

2 Task-1: Review of farmer-led soil testing options & national soil monitoring programmes

The aim of Task-1 was to review existing farmer-led soil testing options that could align with national soil monitoring programmes and indicate a favoured approach to match the needs of the SFS. There are a range of options available across Great Britain and Northern Ireland, although these vary due to differing overall purposes (e.g., farm/field baselining, soil monitoring, nutrient management planning). This section focuses on the existing method(s) used (i.e., ERAMMP National Field Survey) and lists potential alternative farmer-led soil testing options, along with commercial tools and contracted soil testing options, providing commentary on how they could be used in Wales. The section ends by indicating a favoured approach, to match the needs of the SFS, that will be expanded on in further sections.

2.1 Soil testing versus soil monitoring

Soil testing to support best practice by farm managers is fundamentally different to national soil monitoring with respect to its purpose, scale and overall scope.

National scale monitoring carried out by ERAMMP for Wales, as for many other countries across the UK and EU, is designed to capture how soil health on individual farms, conservation and peri-urban land aggregate up to national scale trends of soil health. Reporting categories are usually based on land use/habitat types (e.g., arable, woodland) as this is the fundamental basis of management decisions, which is the primary driver of soil health change. Increasingly, ERAMMP reports are moving away from providing mean values within these habitat classes to report on the number of sites that fall outside recommended thresholds for specific soil health indicators, as this provides greater understanding of the scale and distribution of soil health issues. The ERAMMP Report-105, for example, recently reported that 19% of improved grassland soils now exceed recommended target levels for P, most likely due to regular applications of organic manure and fertiliser that are not integrated with crop offtakes or soil need, and therefore increase the risk of P loss to rivers and groundwater (Emmett *et al.*, 2025). Ways of reporting for a wider range of soil properties have now been developed to provide greater resolution, and to identify which habitat and climate combinations have more soil health issues and whether these are increasing or decreasing over time (ERAMMP Report-94; Feeney *et al.*, 2025).

It is important to understand that this national monitoring approach cannot be used for sub-national reporting at the individual farm, catchment or regional level, as the population of samples, which provides the power for reporting, sits with the replicate samples taken within habitat, soil and climate categories across Wales as a whole. Furthermore, national monitoring is always carried out by independent professionals (e.g., UKCEH in the case of ERAMMP) due to the nature of the work being on a national scale. The scope of national reporting is also much broader than most soil testing schemes, and includes an array of soil physical, chemical and biological indicators, which would be beyond the technical and financial limitations of most on-farm soil testing ambitions.

In contrast to national monitoring, on-farm soil testing is designed to improve best practice at the field and sub-field scale. Traditionally, this has been focused on fertiliser and lime use to identify whether insufficient amounts are being applied, and therefore limiting optimum production, or whether too much is being applied and therefore wasting money and risking nutrient losses to air and water. In high value cropping systems, global positioning systems (GPS) attached to tractors can spatially control application rates within fields. For lower value systems, a whole field approach is usually taken. Advisors/consultants can be used to conduct this soil testing, but increasingly simplified approaches which enable farmers and farm managers to carry out the soil testing are being encouraged. Advice from commercial laboratories on how to interpret results are provided, but the use of accredited advisors to consider potential management options is usually considered beneficial. Increasingly, as in the SFS, and the Sustainable Farming Incentive (SFI) in England and other countries, testing for SOM is now also being encouraged alongside the more traditional nutrient and pH analysis. This is due to the clear link between SOM content and improved soil structure and stability, nutrient supply to crops, and soil C sequestration potential, helping to mitigate greenhouse gas (GHG) emissions from the agriculture sector. Management options often linked to improved SOM levels include reduced tillage, use of organic manures, cover crops, and more diverse rotations and swards.

2.2 Soil testing

2.2.1 Farmer-delivered soil testing

2.2.1.1 Wales

2.2.1.1.1 Farming Connect

Farming Connect is a Welsh Government funded Knowledge Transfer Programme (The Programme) and aims to provide support for agriculture in Wales through facilitated knowledge transfer (Welsh Government, 2025b). The Programme aims to provide independent advice, delivered in a professional manner, to support the development of a resilient land-based sector. The knowledge transfer and advisory services provided aim to improve the environmental performance and sustainability on farms in Wales.

Within Farming Connect, there are options for both farmer-delivered and contracted soil testing. Farmers have the option to take the soil samples themselves and use The Programme to cover the costs of the laboratory fees and interpretation of results at a range of intervention levels (C. Barrow, personal communication, 23/06/2025 and 15/09/2025). Alternatively, they can commission a Farming Connect approved advisor to deliver the whole service. Soil clinics have been fully funded in the past, while the technical interventions currently on offer provide 70% of the funding support, with the farmer having to pay the remaining 30% (C. Barrow, personal communication, 23/06/2025 and 15/09/2025). Another option are soil surgeries, which are fully funded and involve communication (either digital or via the telephone) with the farmer to help them interpret the soil results if they have been sampled outside The Programme (e.g., by suppliers).

Soil samples are typically analysed for standard nutrients (i.e., P, K, Mg and pH). Most farmers opt for this service to help reduce their fertiliser input costs. Some farmers wish to include nutrient supply from the application of organic materials and will commission a nutrient management plan to ensure they are making the best use of this resource, applying organic materials at the correct rate and time, to maximise crop available nutrients. This service is more expensive, however, as it requires more time to deliver and may include sampling of organic materials for their nutrient content.

Some farmers use GPS devices to conduct precision sampling; these farmers typically measure SOM and soil C content in addition to the standard nutrients as an additional indicator of soil health. These farmers often do this as part of a supply chain initiative, or for Farm Assurance within a supply chain. To interpret the results of soil analysis, Farming Connect offer FACTS-qualified advisory services to farmers.

The SENSUS app is part of a Farming Connect project investigating how technology can help farmers collect and interpret soils data on their farm (Davies *et al.*, no date). To use the app, farmers dig three soil pits to count earthworms and conduct a visual evaluation of soil structure (VESS) assessment. Geo-tagged photographs of these assessments are uploaded to the app, and the user can enter additional comments on topics such as compaction and rooting depth. Users can also store the results of soil and grass forage analysis in the app with geo-location tagging, which allows farmers to better map their soils across the farm, and will help demonstrate soil nutrient status, structure and biological activity.

The Programme, via Lantra, offers training courses and e-learning modules relating to all aspects of farm performance, including soils and soil health. The Wales Master Soils course, for example, is a workshop that teaches farmers how to complete an assessment of soil fertility, how to understand soil structure, soil type and secondary nutrients, and introduces nutrient management plans. Another example is the Sustainable Farming – Building and Maintaining Soil Fertility module, which helps farmers understand soil fertility and methods for practical soil management.

Farming Connect also offers a range of meetings and events which farmers can attend to enhance their knowledge of soils (L. Price, Farming Connect manager for Mentera, personal communication, 08/07/2025), and facilitates a mentoring scheme, where users can connect with mentors who have expertise in a range of relevant skills. Farmers can also apply for funding as part of the Management Exchange Scheme to broaden their knowledge on different ways of farming, through farm visits and learning dissemination events.

2.2.1.1.2 Other approaches

Several other approaches are available for soil analysis when samples are collected by farmers:

- Fertiliser companies: a range of fertiliser companies, such as Agrii, partner with independent laboratories to test soil for nutrient availability and other soil fertility factors (e.g., SOM, microbial biomass) and offer advisory services to help farmers interpret their results (Agrii, 2025).
- Farmer co-ops: there are a range of farmer co-ops that offer soil sampling and analysis advice, for example Wynnstay (Wynnstay Group, 2025).
- ADAS: offer independent soil surveys and advice to help farmers and land managers understand the health and nutrient content of their soils (ADAS, 2025). These soil assessments include: VESS, SOM sampling, earthworm counts, soil health testing, cultivation advice, and financial appraisals of management systems.

2.2.1.2 England

2.2.1.2.1 Sustainable Farming Incentive Guidance

As part of the Sustainable Farming Incentive (SFI) in England, action SAM1 (Assess soil, produce a soil management plan and test soil organic matter) encourages farmers to understand the condition of their soil by completing a written soil management plan (Rural Payments Agency, 2023). While no standard format is specified, farmers are required to "effectively plan how to increase the long-term health, productivity, and resilience" of their soil to complete their soil assessment and are directed to the Environment Agency's 'thinksoils' guidance (Environment Agency, 2008), NIAB Soil Health Assessment Guide (NIAB, 2020) and information from Championing the Farmed Environment (CFE, 2021). Farmers are instructed to conduct the assessments when the soil is not too dry or too wet, such as in spring or autumn. The SFI Guidance for SAM1 encourages farmers to assess soil structure to a depth of 30 cm and assess for soil biology by counting earthworms. Additional information is included on how to take SOM samples. Guidance is included on selecting a sampling area based on the size of the land parcel and management practices used, when to take samples depending on the soil conditions and management practices used, and how to take soil samples, with reference to the 'W' sampling technique, where the farmer walks a W shape across the field, taking 25 soil cores across the W to a depth of 15 cm. The guidance also details laboratories where the soil samples can be sent for analysis, and the analysis that should be requested. This information should then be recorded by the farmer in a soil management plan.

As part of action NUM1 (Assess nutrient management and produce a review report) farmers must arrange for a member of the BASIS Professional Register who is qualified under the Fertiliser Advisers Certification and Training Scheme (a 'FACTS qualified adviser') to visit their farm to help them produce a written nutrient management review report (Rural Payments Agency, 2023). The nutrient management review involves sampling and testing the soil in each field for pH, P, K and Mg, calculating the nutrient and pH requirements of the crop, calculating the nutrient supply from organic sources, and calculating the amount of manufactured fertiliser to apply to meet crop and soil requirements. It is suggested that soil sampling takes place every 3-5 years, ideally between September-March when the previous crop has been harvested.

2.2.1.3 Scotland

2.2.1.3.1 Scotland's Rural College Technical Notes

Scotland's Rural College (SRUC) provides farmers with resources on how to understand their soil structure, take soil samples, and check for soil compaction and drainage status to make decisions on whether actions are required to improve their soil (SRUC, 2016). The Valuing Your Soils guidance details the importance of good soil structure and provides information on soil texture, soil compaction, soil erosion, soil nutrient content and SOM, and the need to test these soil properties for good nutrient management, as well as how to interpret the results that are sent back from the laboratory. Practical guidance is provided on:

- How to assess soil texture: take a handful of moist soil (or wet if needed), assess feel of soil and roll into a ball/ribbon, compare with descriptions in table provided (i.e., colour, feel, length of ribbon before it breaks).
- How to take soil samples for testing: 'W' sampling technique, collect 15-20 soil samples along the W, sampling permanent grassland to 10 cm depth and arable land or short-term grassland to 20 cm, combine the samples to create a representative bulked sample to send to the laboratory. Sampling should be avoided within two years of lime application or within two months of applying fertiliser or manure. If fields are larger than 5 ha then these should be divided and sampled separately, sampling in unusual or unrepresentative areas of the field should be avoided.
- How to check for soil compaction: check depth and conduct a VESS assessment (see below).
- How to check soil drainage status: investigate soil structure in waterlogged areas.
- How to conduct a VESS: the VESS assessment sheets guide users on how to extract and examine a block of soil for its structure, and how to assign a score to each layer of differing structure based on the size and appearance of aggregates, visible porosity and roots, appearance after breaking up major aggregates, any distinguishing features, and the appearance of fragments *c.*1.5 cm diameter.

2.2.1.3.2 FAS Technical Notes

The Scottish Farming Advisory Service (FAS) also publishes a range of technical notes to help farmers understand, among other things, fertiliser recommendations for crops and how nutrients can be managed on-farm. Technical Note TN656 “Soils information, texture and liming recommendations” (Sinclair *et al.*, 2014) provides guidance on how to assess soil texture in the field (Figure 2-1), although it does note the importance of laboratory analysis for an accurate assessment of sand, silt and clay content. In addition, hand texturing soil is a skill that can take time and practice to learn and potentially requires training to become proficient. The potential for risk associated with inaccurately texturing soil should therefore be considered, as this may affect nutrient management planning and potentially increase nutrient loss.

Technical Note TN668 Managing soil phosphorus (Sinclair *et al.*, 2015) highlights that soil P sampling should occur every 4-5 years, ideally immediately before potatoes, although no guidance is provided on how to take the soil sample. Technical Note TN710 Soil Analysis in the West Highlands and Islands (Sutherland, 2019) emphasises the importance of choosing the correct soil test for the soil type, due to the acidic nature of Scottish soils, providing insight on the difference between Morgan’s and Olsen’s tests, and how to interpret the results of laboratory analysis.

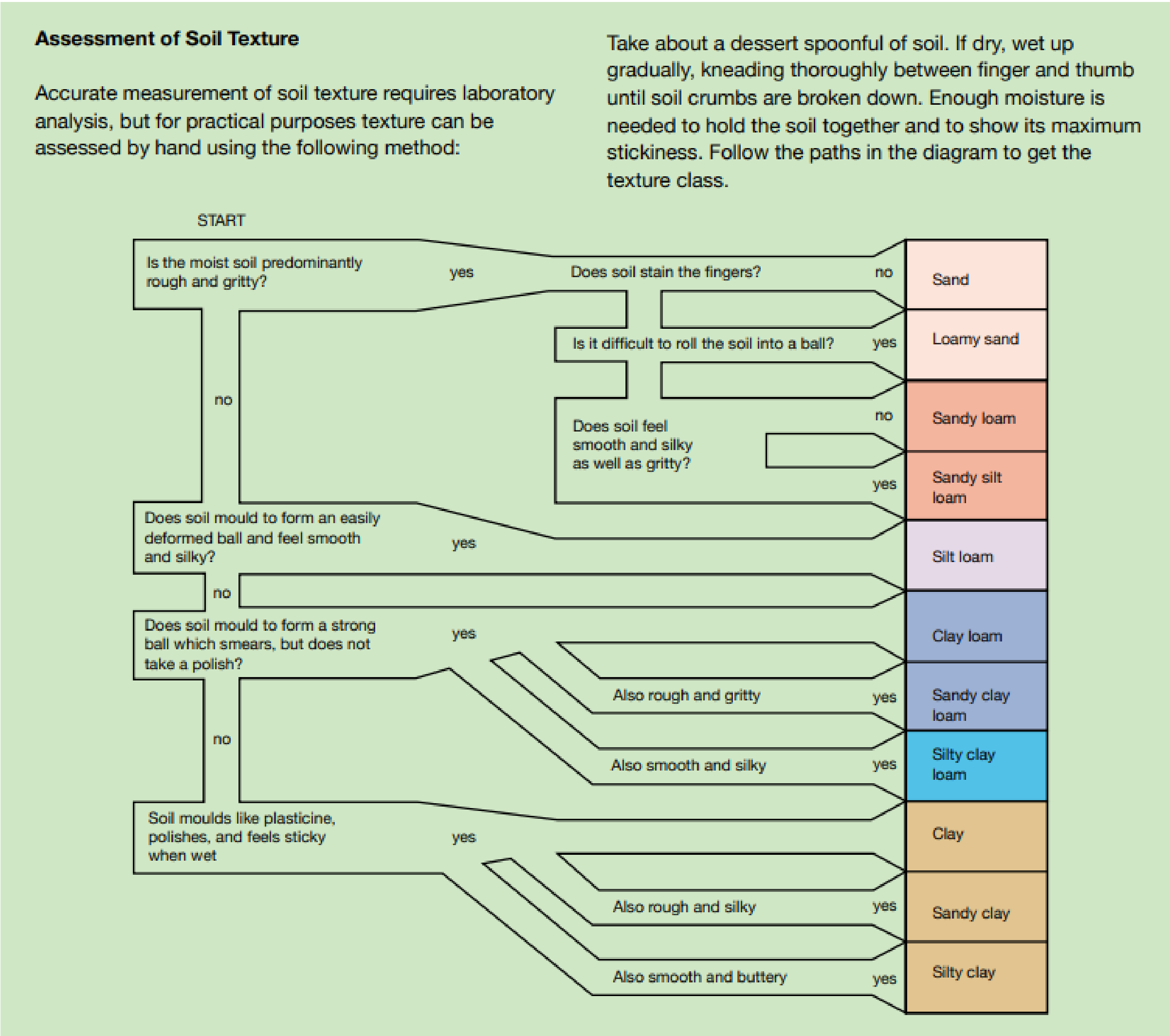

Figure 2-1 Soil texture assessment guide included in FAS Technical Note TN656. Source: FAS.

2.2.1.4 England, Wales & Northern Ireland

2.2.1.4.1 AHDB Nutrient Management Guide (RB209)

The AHDB Nutrient Management Guide (RB209) is a resource for farmers and agronomists and explains the value of nutrients and soil, and the importance of good nutrient management in relation to fertiliser use to achieve optimum economic yields and limit environmental impacts (AHDB, 2025a). It is supported by a technical review steering committee and provides robust agronomic advice for manging nutrients on improved agricultural land. RB209 Section 1 (Principles of nutrient management and fertiliser use) outlines the importance of understanding soil properties to make nutrient decisions. More specifically, soil texture is mentioned, with reference to the hand texturing method to approximate soil sand, silt and clay content, along with laboratory analysis, UKSO map viewer, and regional soil maps, as ways to assess soil variability (AHDB, 2023a). The soil texture of the whole soil profile (topsoil and subsoil) is important for understanding SNS. RB209 Section 3 (Grass and forage crops) includes guidance for soil sampling for pH, P, K and Mg, which can be used to understand whether any actions are required in relation to lowering, maintaining, or raising soil nutrient indices (AHDB, 2023b). The guidance on soil sampling can be summarised as follows:

- When: sample the soil in each field every 3-5 years, every three years if regularly cut; at the same point in the rotation and well before a sensitive crop; between September and February for long-term grass. Sampling not to be conducted within 6 months of lime or fertiliser application or within six weeks of the last organic manure application in autumn. Sampling should not be conducted for very dry soils.
- Where: avoid sampling where muck is stored or nearby unusual features. Sample in areas that are representative of the entire field. Sample areas of land that are non-representative of the field separately. Do not sample areas larger than 4 ha.
- How: use the W sampling technique, take 25 cores across the W to a depth of 7.5 cm in long-term grasslands or to 15 cm in arable fields and short-term grasslands.
- Analysis: bulk the samples and send to a laboratory for analysis. The information can then be used to assign a Soil Index to the field for each nutrient.

In addition to repeating the information above on soil sampling, RB209 Section 4 (Arable crops) includes guidance on assigning the soil type of a field into a category, and determining SNS to a crop, either using the Field Assessment Method (using soil type, previous crop and excess winter rainfall as the principal factors determining SNS) or the Measurement Method, which involves the measurement of soil mineral nitrogen (SMN) in autumn (medium, deep silty or deep clayey soils only), or spring (shallow and light sand soils) (AHDB, 2023c), and an estimation of the amount of N already taken up by a crop (at the time of SMN sampling) and supplied by the soil after SMN sampling through mineralisation (microbial activity releasing mineral N from SOM). The Measurement Method includes specific instructions on SMN sampling as follows:

- When: late winter or early spring before N is applied. Sampling not to be conducted within 2-3 months of fertiliser or manure application or within a month after sowing.
- Where: sample in areas that are representative of the entire field. Sample areas of land which are non-representative of the field separately.
- How: W sampling technique, take 10-15 cores across the W at depths of 0-30 cm, 30-60 cm and 60-90 cm in the spring, or at depth of 0-60cm in the autumn. Take additional samples if the field is over 10 ha.
- Analysis: bulk the samples and send to a laboratory for analysis of nitrate-N and ammonium-N. The samples should be kept cool at 2-4 °C.

Nutrient management guidance for grassland contrasts significantly with the guidance for arable crops and provides a range of nutrient supply recommendations depending on the amount of grass needed for each field and farming system. This is particularly important for grazing livestock farms in Wales where there is a large range in management intensity from high output dairy farms to low input extensively managed beef and sheep farms. The nutrient recommendations for grassland in RB209 should therefore be used as a starting point for farmers to consider their fertiliser use depending on their cutting and grazing practices. The context and aim of each individual farm should be considered when interpreting and following the guidance.

2.2.1.5 UK

2.2.1.5.1 AHDB Soil Health Scorecard

The AHDB Soil Health Scorecard is an Excel tool which benchmarks soil analysis results against typical ranges for comparable UK soil types and climate regions (AHDB, 2025b). The benchmarking system can be used to guide management decisions to improve soil health where required (i.e., monitor, review, or investigate). The soil health indicators used by the scorecard are soil structure, pH, extractable nutrients (i.e., P, K, Mg), earthworm count, and SOM. Prior to completing the scorecard, users are directed to the “Sampling protocol and benchmarking tables” document, which provides guidance on how to obtain the required data for input into the scorecard. Guidance for England and Wales (AHDB, 2022a) is provided separately to Scotland (AHDB, 2022b), due to the different benchmarks between the regions.

A high-level summary of the soil sampling protocols is below:

- When: conduct sampling every 3-5 years, ideally at the same point in the crop rotation, or once every five years in permanent or semi-permanent pasture. Soil samples should ideally be conducted in autumn when the soil is warm and moist, after harvest, and one month after cultivations or the application of organic inputs.
- Where: the farmer should determine their own sampling sites, although if fields are particularly large, or if soil texture is highly variable across a field, these fields should be split up into multiple sampling sites.
- How: within a 5 m radius of each sampling point, three structural assessments should be conducted, and multiple soil cores should be taken. For the structural assessments, conduct a visual assessment of soil structure using the VESS guidance document, inspecting three topsoil blocks at each sampling point, with photographs also taken. Earthworm counts can also be done at this time. The soil core samples should be bulked for each point and sent for laboratory analysis for pH, P, K, Mg, SOM, and microbial activity.
    - Users are directed to the AHDB webpage “Measuring soil nutrients, pH and organic matter” (AHDB, 2025c) for instructions on how to take a soil sample. This reiterates the guidance provided in RB209.

It should be noted that the AHDB Soil Health Scorecard is not applicable to all habitats, e.g., unimproved upland grazing systems, which are highly prevalent across the Welsh landscape. However, it is applicable to the improved grasslands targeted by UA1.

2.2.1.5.2 Environment Agency ‘thinksoils’ Guide

The ‘thinksoils’ guide produced by the Environment Agency is a practical guide to soil assessment, which can be used to recognise issues with runoff and erosion from agricultural land (Environment Agency, 2008). In addition to providing information on the factors that influence runoff and erosion, and what good and poor soil structure looks like for different types of soils, guidance is also given on how to examine soils in the field. This includes how to identify signs of erosion, runoff, compaction, poaching, and capping of the soil surface, and how to examine the topsoil structure:

- Preparing an area for examination: dig three square holes per field and examine specific areas of interest (i.e., those prone to runoff or compaction). Dig soil from one half of each square to a depth of 20 cm, leaving the other half of the square intact so the profile can be seen and soil structure examined.
- Soil structural examination: includes text and photo examples of how to identify distribution and size of pores and fissures, the shape, size and colour of structural units or peds, and the packing density of the soil.

Guidance on how to examine subsoil structure is also provided:

- Preparing an area for examination: continue to dig to a depth of 30-40 cm in the half of each square previously dug for topsoil examination. This should be done when the soil is moist. Remove a block of soil from the hole with a spade.
- Soil structural assessment: includes text and photo examples of how to identify pores and fissures, the size, shape and colour of peds, and the packing density of the soil.

2.2.1.5.3 UKCEH Countryside Survey Soil Health Webtool (SOil funDamentals)

The SOil funDamentals (SOD) tool was developed in 2022 with the aim of aiding farmers and land managers to monitor the health of their soil (UKCEH, 2025). The tool uses soil data (0-15 cm) from the UKCEH Countryside Survey to generate benchmarks for all common habitats, soil types and rainfall combinations in Great Britain, against which users can compare their soils. Four indicative metrics are currently provided to capture soil physical, chemical and biological conditions. Due to a lack of available data, saltmarsh and near-shore habitats, urban and man-made habitats, deep peat, and disturbed industrial soils are not yet available to be benchmarked as part of the tool. When using the tool, users are asked to select a habitat type, soil type and climate type (i.e., annual average rainfall). The tool classifies the soils of Great Britain into 8 soil types (i.e., light coarse-textured soils, medium loamy-textured soils, heavy clayey soils, shallow mineral soils, carbon-rich soils, river floodplain and coastal soils, deep peat, and disturbed industrial soils), and users are provided with a flow chart (Figure 2-2) to help understand their soil type if they are unsure. Following this, the typical and extreme values (i.e., the top and bottom 10% of the population) for SOM content, earthworm count, soil pH and soil bulk density are shown for the combination of habitat, soil and climate type that was selected by the user. Note that nutrients are not included in the tool as guidance for this was already available. The user can then enter their own data for these four variables to assess how they fit within the typical and extreme benchmarks provided (Figure 2-3). The following guidance is provided to guide farmers on how to measure their soil health (UKCEH, no date a):

- Walk a W-shaped sampling scheme across the breadth of the field, taking 25 samples across the W to a depth of 15 cm. At each sampling point, take cores of topsoil for SOM and pH analysis, and a core for bulk density. In addition, 10 samples should be taken across the W to count the number of earthworms.
- Soil samples should be bulked and sent to a laboratory for analysis.
- The guidance also recommends that sampling after fertiliser or manure additions is avoided, and that the autumn is a suitable sampling time.

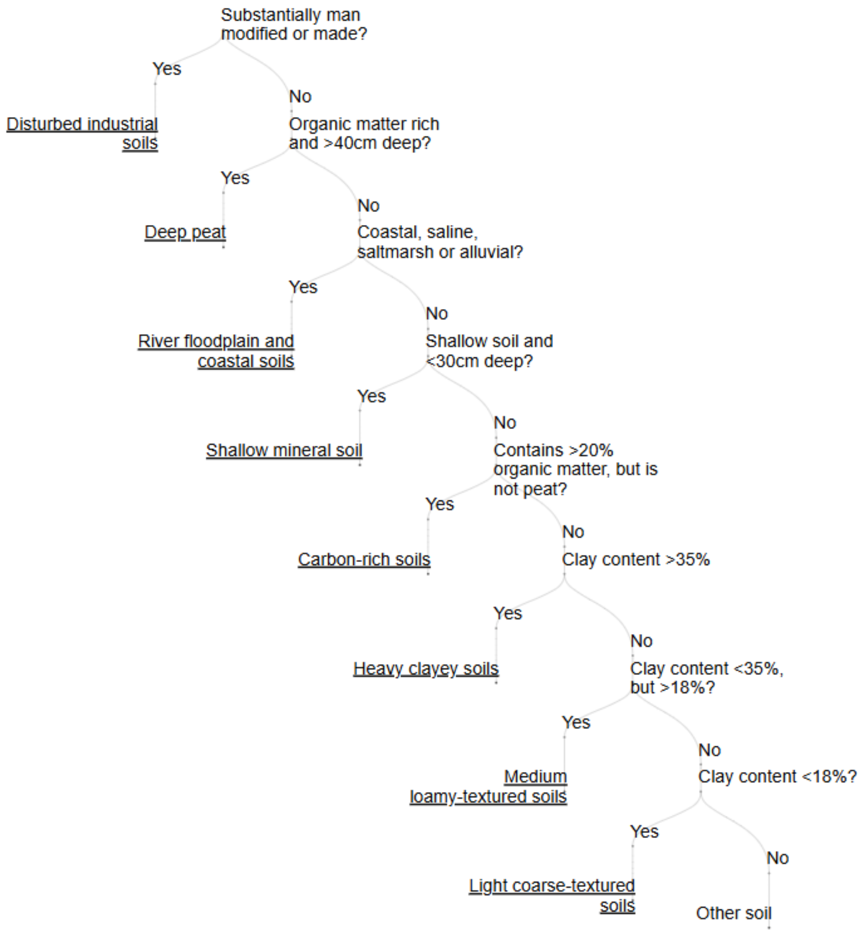

Figure 2-2 Soil type classification guide included in UKCEH SOil funDamentals tool. Source: UKCEH.

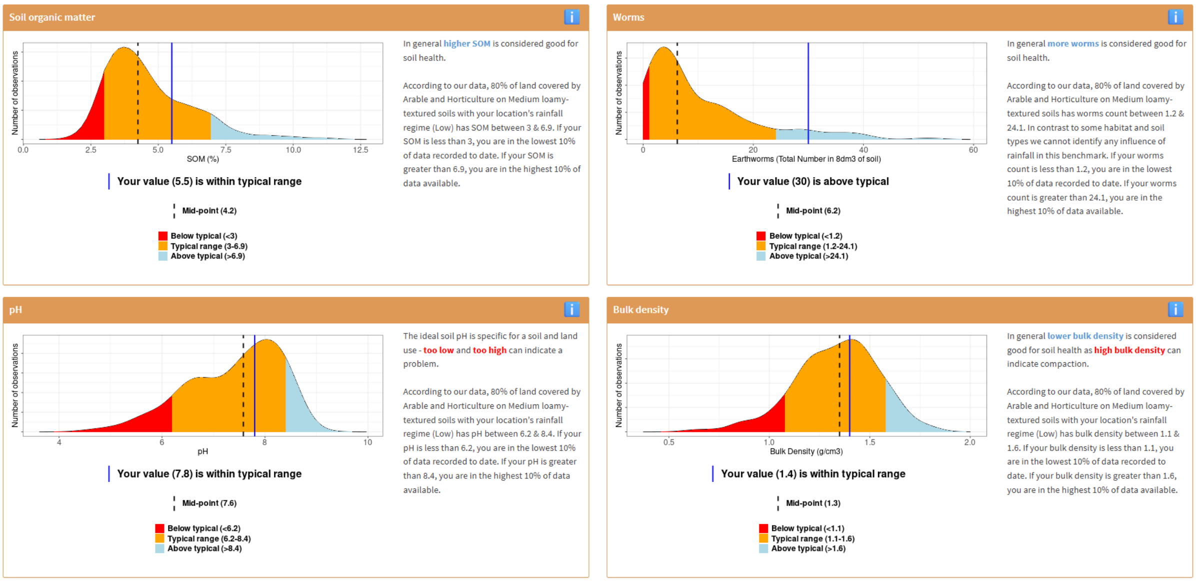

Figure 2-3 UKCEH SOil funDamentals results dashboard showing the user's value (blue line) benchmarked against typical and extreme values for Great Britain. Source: UKCEH.

2.2.1.6 Republic of Ireland

2.2.1.6.1 Teagasc Green Book

The Teagasc Green Book 'Major and Micro Nutrient Advice for Productive Agricultural Crops' (Teagasc, 2020) provides soil health and nutrient management advice for the agricultural industry in the Republic of Ireland, covering topics such as good agricultural practice, the importance of macro and micronutrients, and fertiliser recommendations for arable crops and grasslands. The Green Book includes a section on soil sampling, stating the importance of sampling every 3-5 years on which to base fertiliser recommendations, the equipment that is required, and advice on how to take soil samples as follows:

- Where: one sample should be representative of *c.*2-4 ha, so the field/farm may need to be divided up into smaller parcels for soil sampling. Separate samples should be taken from areas of differing topography, soil type, cropping history, and areas of consistently differing yields. Unusual areas such as ditches or manure storage areas should be avoided. Avoid sampling along lines of fertiliser and lime spreading operations.
- When: sample at least 3-6 months after the last application of P and K, and at least two years after the application of lime. Sample at the same time of year and avoid sampling under extreme weather conditions (e.g., extremely wet or dry soil).
- How: take 20 soil cores, bulk these, and send a subsample for analysis. Take a representative soil sample using the W sampling technique or sample using a grid pattern, taking at least 20 cores and bulking as above.
    - Note the texture code (1 = sand/gravel, 2 = loam, 3 = clay soil, 4 = peat) as this information is required for fertiliser or lime advice. Appendix 2 in the report provides advice on how to decide the texture category (Figure 2-4).

Table A2 - 1 Assessing the texture of soils (Diamond, 2001)

Criteria	Texture Sand/gravel	Loamy	Clayey	Peat
General	Predominantly rough and gritty, porous	Crumbly, neither smooth nor rough	Smooth and silky or buttery	Dark brown to black colour. Obviously of exclusively organic origin. Very low bulk density when dry.
Ease of moulding wet soil	Difficult to roll into a ball	Moulds into a ball which does not polish or feel sticky	Moulds like plasticine, polishes, and feels sticky	
Mineral soil particles	Large, individual particles visible	Medium-sized	Small, individual particles invisible	Absent
Water absorption capacity	Low (prone to moisture deficit in dry conditions)	Medium	High	Very high
Workability	Good in all weather conditions	Good in all weather conditions	Poor in wet conditions	

Figure 2-4 Soil texture assessment guide included in Teagasc Green Book. Source: Teagasc.

2.2.2 Commercial tools

There are several commercial tools available for farmers to use to benchmark their soils against other soils in the UK in locations of similar weather conditions and topography. These include Soilmentor (Vidacycle, 2020), Soil Benchmark (Soil Benchmark, 2025), Soil Test Pro (TapLogic, 2025), Soilsens (Proximal Soilsens, 2024), Soil Samples (Farmis, 2023), PES Technologies Soil Tester (PES Technologies, no date), and Soil Association Exchange (Soil Association Exchange, 2024a). These tools are available at a cost to the farmer to enable them to baseline soil chemical and biological properties across their farms, which can then be used in soil and nutrient management plans. Two of these approaches, Soilmentor and Soil Association Exchange, are described in more detail below.

2.2.2.1 Soilmentor

Soilmentor is an app and online platform produced by Vidacycle which allows farmers to map their farm by identifying field boundaries, record the results of soil tests and save photos of the field, and compare their results with UK benchmarks (Vidacycle, 2020). It is marketed at farmers and growers who wish to farm in a 'regenerative' way, providing the option to track how the selected soil indicators change over time as a result of implementing various 'regenerative' practices. The platform requires a subscription to use, ranging from £280 to £640 per year per farm. The soil tests (or indicators) that users can measure and benchmark, and a summary of the guidance on how to measure each of these and the importance of doing so, are as follows:

- Earthworm count
  - Why: the number of earthworms provides an indication of biological life in the soil, a higher earthworm count indicates improved soil health.
  - When: early autumn or late spring, avoid sampling during extreme weather conditions or within a few weeks after manure or compost application.
  - How (hand sort method): dig a hole of 20 x 20 x 20 cm and place the soil from the hole onto a plastic sheet, break up the soil and place any earthworms to the side, fill the hole back in with the soil. The number of earthworms can then be recorded in the app. Additionally, the earthworms can be separated into adults and juveniles, and the type of adult recorded if known. The earthworms should then be returned to the soil.
  - How (mustard extraction method): make up a mustard solution using 15 g English mustard powder and 1.5 l water and leave overnight. In the field, mark out a 0.25 m^2 quadrat and pour half of the mustard solution over, removing the earthworms as they emerge from the soil. Repeat with the remainder of the solution. The earthworms can then be identified as with the hand sort method and then returned to the soil.
- Soil insect score
  - Why: a low number or absence of insect pests indicates improved soil health.
  - When: this can be done at the same time as the earthworm count measurement.
  - How: when looking through the soil for earthworms, also count and take photos of insect pests in the soil and return the soil to the hole. The sample can then be scored from 0-2 according to the number of insect pests based on the Soilmentor scoring system.
- Rooting depth (80%)
  - Why: provides an indication of whether anything is limiting deep vertical root growth.
  - When: when vegetation is growing.
  - How: using a spade dig a section of soil under vegetation to approximately 20 cm or deeper if the roots are longer, measure and record the depth at which 80% of plant roots are concentrated.
- Nodulation of legumes
  - Why: the presence of nodules on legume roots indicates that N is being fixed.
  - When: in autumn or spring, avoid conducting the test after heavy rain or when soil is very dry. Sample when a legume crop is growing.
  - How: using a spade dig a small section of soil of 20 x 20 x 20 cm, wash away the soil from legume roots, observe any root nodules. If there are nodules, select four of the largest nodules, cut to check the colour and score from 0-2 based on the Soilmentor scoring system according to the legume type.
- Rhizosheaths
  - Why: the presence of rhizosheaths indicates biological/microbial activity in the rhizosphere, with more rhizosheaths indicating better soil structure.
  - When: can combine with other spade tests such as rooting depth (80%) or nodulation of legumes.

    - How: after digging a section of soil 20 x 20 x 20 cm, break soil away from roots and shake roots to remove loose soil, observe any light soil around the roots. If there is light soil around the roots, score from 0-2 based on the Soilmentor scoring system and upload a photo to the app.

- Percentage bare earth (basal cover)
    - Why: a greater proportion of ground exposed (i.e., not covered by litter or vegetation) indicates the soil is at a greater risk of erosion and drought.
    - When: only when plant matter is going into the ground, not when ground is covered by canopy/foliage.
    - How: from a starting sample point, walk in a straight line away from the sample point placing a stick into the ground every 60 cm, where the stick goes into the ground mark whether it hits bare soil, forbs, ground litter, grasses, or legumes. Continue until (ideally) 100 readings have been taken.
- Brix barometer
    - Why: provides a measure of the light refracting through dissolved solids and sugars in vegetation and weeds and indicates the health of the plant sample.
    - When: regularly throughout the year, can be done alongside percentage bare earth (ground cover) assessment.
    - How: moving along the first 10 m of the transect away from the sample point, collect a handful of plant material by tearing the vegetation, collect a measurement for crops brix and one weed brix in the Soilmentor app. Squeeze the plant material into a garlic crusher and squeeze the liquid onto the glass of the refractometer, close the refractometer and record the reading from its scale.
- Carbon stocks (top 30 cm)
    - Why: an indicator of how much C is being stored.
    - When: can monitor over time or at a single time.
    - How (soil organic carbon %): collect a 30 cm (depth) soil core at the sample location, repeat up to 20 times per sample location, bulk the samples and send for analysis.
    - How (bulk density): collect a 30 cm (depth) soil core at the sample location, send for analysis.
    - A range of suggested laboratories to send the soils to are included.
- Slake test
    - Why: indicates how well soil structure holds together in water, with a good soil structure indicating a healthier soil.
    - When: on a day when the soil is not waterlogged, avoid sampling after cultivation.
    - How: dig up an area of soil to 20 cm depth, break up the soil, collect a handful of soil. Indoors, select three 1-3 mm lumps of soil and leave to dry, arrange the dry soil into a sieve and immerse into water until the lip of the sieve is reached, observe the behaviour of the pieces of soil underwater for 5 minutes and score from 0-2 based on the Soilmentor scoring system.

- Infiltration
  - Why: indicates soil structure, a faster infiltration rate indicates a good soil structure with less chance of runoff occurring.
  - When: avoid sampling when soil is saturated from rainfall.
  - How: insert a cylinder/tube into the soil to 75 mm depth, firm soil on the inside of the tube, pour 450 ml of water into the cylinder/tube, record the length of time it takes for the water to disappear into the ground. Then repeat for a second time.

After users input their data, they are shown a dashboard which uses a traffic light benchmarking system to compare the score for each indicator measured on the farm with regenerative benchmarks of the same soil type.

2.2.2.2 Soil Association Exchange

The Soil Association Exchange provides both free and paid for services for farmers to support them in assessing the environmental impact of their farm business for a variety of purposes. The free service 'Exchange Explore' generates a simple report based on farmer-inputted data. Paid for 'plans' are also available, giving users access to an online platform, baseline sampling, and farm consultancy visits. The complete service assesses 40 metrics linked to soil health, biodiversity, water, animal welfare, C and 'people & society', with the full protocol available online (Soil Association Exchange, 2024b).

The following soil health metrics are measured: soil texture, C:N ratio (0-30 cm), pH (0-15 cm), bulk density (0-30 cm), VESS, earthworm count (20 x 20 x 20 cm pit), SOM content and soil organic C stocks (to 30 cm depth). These metrics are benchmarked against industry standards (where available) and other farms on the platform. Soil organic matter is determined using the Dumas methodology and benchmarked against all farms on the platform and farms with a similar rainfall, land cover and soil texture.

Almost 2,000 farmers have accessed the service, with *c.*1,000 requesting the full baseline environmental audit (A Cole, project manager, pers. comm).

2.2.3 Summary of farmer-led soil testing approaches

Table 2-1 summarises the farmer-led soil testing approaches, including positives and negatives of the options.

Table 2-1 Summary of farmer-led soil testing approaches.

	Approach	Positives	Negatives
Wales	Farming Connect	Provides farmers with knowledge on soil health Funding opportunities via grants/subsidies Guidance on soil sampling	Requires time investment for training courses and modules Not guaranteed funding Analysis and advisory costs
	Other approaches	Provides farmers with soil results	Associated analysis costs
England	SFI Guidance	Directed to guidance on how and where to sample	Cost of FACTS-qualified advisor to complete nutrient management plan

Scotland	SRUC Technical Notes	Directed to guidance on how and where to sample	Does not provide guidance on soil sampling
	FAS Technical Notes	Directed to guidance on how and where to sample Guidance on P analysis (specific to Scottish soils)	Hand texturing can be inaccurate if not skilled/practiced – may affect nutrient management planning and nutrient loss
England, Wales & Northern Ireland	AHDB Nutrient Management Guide (RB209)	Provides information on nutrient management Provides guidance on how, where and when to sample	Hand texturing can be inaccurate if not skilled/practiced – may affect nutrient management planning and nutrient loss
UK	AHDB Soil Health Scorecard	Benchmarking system is easy to understand Provides guidance on how and where to sample	Not applicable to all habitats (i.e., unimproved upland grazing systems which are prevalent across Wales) Soil analysis (and associated costs) required before using tool
	Environment Agency ‘thinksoils’ Guide	Useful for identifying soil structural features	Does not provide guidance on soil sampling
	UKCEH SOil funDamentals tool	Benchmarking system is easy to understand Provides guidance on how and when to sample	Not all habitats are included in the tool Soil analysis (and associated costs) required before using tool Does not include nutrients
	Commercial tools	Provides guidance on how, where and when to sample	Cost to the farmer Hand texturing can be inaccurate if not skilled/practiced – may affect nutrient management planning and nutrient loss Farmers may be concerned about data protection Sampling guidance can be inconsistent between services
	Soil Association Exchange	Assesses a range of soil health metrics Offers benchmarking	Some elements are available at a cost to the farmer
Republic of Ireland	Teagasc Green Book	Provides guidance on how, where and when to sample	Hand texturing can be inaccurate if not skilled/practiced – may affect nutrient management planning and nutrient loss

2.2.4 Contracted soil testing

2.2.4.1 Wales: Farming Connect

One-to-one advisory service

Farming Connect offers an advisory service under the technical limitation to help farmers sample and understand the results of their soil testing. All advisors involved in this service are FACTS-qualified, and the advisory service is partially (70%) funded by Farming Connect, with the farmer covering the remainder of the cost. The total cost of the service varies depending on the number of fields sampled, and whether the analysis is for standard soils or towards the production of a nutrient management plan (C. Barrow, personal communication, 23/06/2025). Some farmers are also now opting to sample for SOM.

Soil clinics

Earlier within The Programme, free (i.e., fully funded) soils clinics were available. These were restricted to four samples per farm and are no longer part of the service.

Soil surgeries

One-to-one surgeries are 1-hour subsidised sessions where farmers/farming businesses can talk to an expert advisor on a range of topics, including soil health, the interpretation of soil analysis results, soil management practices, and the development of a nutrient management plan (L. Price, personal communication, 08/07/2025). These are either delivered online or by telephone.

Business Action Groups

Advice is also offered in the form of Business Action Groups, where multiple farmers/businesses can join to receive advice as a group. The interpretation of soil results must form part of a business efficiency drive and typically consider larger matters such as overall soil health and the productive performance of the land.

Sustainable Farming Scheme

Farmers who carry out soil sampling in autumn/winter 2025, on their productive land, and who will be entering into an SFS scheme, are able to use these soil results as evidence. Farmers can include this as part of the 20% annual requirement. Farmers sampling in spring 2026, however, will not be able to have soil sampling on productive SFS land conducted through Farming Connect, as they will be paid to do this as part of the SFS scheme. These soil samples will be required to include SOM.

Other knowledge transfer

Farming Connect hosts the 'Welsh Soil Project' demonstration network; 17 farms (both red meat and dairy) participate in the network, which has involved the completion of a soil C audit and an assessment of soil microbial diversity. Farming Connect also works with farmers on trials and smaller projects, such as the Digital Soil Nutrient Mapping trial (Farming Connect, 2018); this involved the use of precision technology for variable rate fertiliser application to better target inputs where they were needed in the field. Funding is available for projects such as this, and for farmers who want to analyse their soils either individually or as part of a group application.

2.2.4.2 Northern Ireland: AFBI Soil Nutrient Health Scheme

In 2022, AFBI launched the Soil Nutrient Health Scheme (SNHS), a £37 million DAERA-funded scheme with the aim of sampling all agricultural fields in Northern Ireland by 2026 (AFBI, no date). The aim of the project was to provide farmers with information on the nutrient status of their soils, runoff risk maps for nutrient losses to water, estimates of C storage and aboveground biomass, and training on the interpretation of nutrient data, with the intention of aiding farmers to optimise nutrient applications, increase farm profits and achieve the targets of Northern Ireland's Nutrient Action Programme. Farmers opt in to the scheme (to get access to agri-environment scheme funding), although they are not asked to take soil samples themselves, with external providers conducting the sampling. The results of the soil analysis include soil pH, extractable P, K, Mg, calcium (Ca), sulphur (S), SOM, and crop-specific fertiliser and lime recommendations. The training on the interpretation of the soil analysis results, provided as one-to-one advice and in workshops, involves understanding nutrient management, the role of soil C, and the completion of a nutrient management plan.

2.2.4.3 UK: AHDB Environmental Baselining Pilot

The AHDB Environmental Baselining Pilot is a UK-wide project started in 2024, which aims to provide farmers with an understanding of their farm's environmental performance by determining the amount of net C stored within their farm's soil, hedges and trees (AHDB, 2025d). The first phase of measurements involves LiDAR scanning to estimate above-ground C stocks on 170 farms (i.e., in hedges and trees) and will be followed by measurements of soil C and nutrients, and a full carbon audit. As is the case for AFBI's SNHS, farmers are not asked to take soil samples themselves, with contractors carrying out sampling.

2.2.4.4 Summary of contracted soil testing approaches

Table 2-2 summarises the contracted soil testing approaches, including positives and negatives of the options.

Table 2-2 Summary of contracted soil testing approaches.

	Approach	Positives	Negatives
Wales	Farming Connect	Advisory services to help farmers understand their soil and nutrient management Opportunities to apply for funding Farmers save time not conducting the sampling	Not guaranteed funding Cost of advisory services
Northern Ireland	AFBI Soil Nutrient Health Scheme	Farmers save time not conducting the sampling	Farmers must opt in to the scheme Potential risks of exceeding laboratory capacity Farmers may be concerned about data protection
UK	AHDB Environmental Baselining Pilot	Farmers save time not conducting the sampling	Farmers may be concerned about data protection

2.3 National soil monitoring (including the latest 10-year trend for soil health in Wales)

An overview of all current national soil monitoring across the four nations was captured at a workshop run by the Sustainable Soil Association and UKCEH funded by the UKRI Land Use for Net Zero, Nature and People project in February 2024. A database was completed by all soil monitoring delivery bodies for the four nations, capturing the design, sampling and measurement details of their national monitoring programmes. A full report, slideshow and the database can be found online (LUNZ Hub, 2024).

The following two sections include details of the two national soil monitoring programmes that cover Wales and the UK, with the final section (2.3.3 Soil maps) discussing available soil maps for the UK.

2.3.1 Wales

2.3.1.1 ERAMMP National Field Survey

The ERAMMP National Field Survey builds on the work of the Glastir Monitoring and Evaluation Programme (GMEP) and UKCEH's Countryside Survey. The GMEP ran from 2013 to 2016 and involved surveying 300 1 km^2 areas across Wales for evidence on climate change mitigation and trends in soil quality, water quality, biodiversity, woodland management, and access to landscape and historic features (Emmett *et al.*, 2017). These were all topics targeted by the Glastir scheme, which involved the Welsh Government paying for environmental goods and services. The ERAMMP builds on the GMEP by re-sampling the same 300 1 km^2 areas across Wales to capture evidence on habitats, soil, headwater streams and ponds, plants, birds, pollinating insects, landscape quality, access and historic features (Emmett *et al.*, 2025).

The methods used in the ERAMMP survey align with those previously used in the GMEP scheme and those used in the UKCEH Countryside Survey. The soil sampling methodology is detailed in ERAMMP Document-51: Field-Survey Handbook (Procedures) Soil Sampling (Robinson *et al.*, 2023). Briefly, soil cores are taken to 15 cm depth from 5 randomly located points across each 1 km^2 plot. At each point, three cores are taken – one for chemistry and physical analysis, one for biological analysis, and one for archiving. The soil samples are analysed for pH, SOM, organic C, N, P, bulk density, moisture content, porosity, and peat depth where appropriate (UKCEH, no date b). These locations are revisited for repeat sampling during each survey.

Most recently, soil erosion measurements have been added to the soil health assessment included in ERAMMP. The methodology is detailed in ERAMMP Document-71: Field-Survey Handbook (Procedures) Soil Erosion and Damage Recording 2021 (Robinson *et al.*, 2021). Soil erosion is assessed at 240 of the 1 km^2 areas using aerial photography, with the field survey then validating the images taken by recording soil erosion features in the field for 130 of the 1km^2 areas. At each location, field surveyors confirm either the presence or absence of features identified by the aerial photography, record what they are, and photograph the features. A comprehensive list of the features to be identified is included in the document, with examples including poaching by livestock, machinery damage, footpath damage, scree, sheet erosion, muddy outwash, and peat hags where appropriate.

ERAMMP recently reported on national trends and outcomes of the Glastir scheme following the most recent re-survey cycle carried out between 2013-16 and 2021-23, including those related to soil health (Emmett *et al.*, 2025). The findings for agricultural soil can be summarised as follows:

- Arable soils showed a decrease of 8% in topsoil C concentration.
- Bulk density increased by 6% in arable soils (indicative of increased compaction), 10% in improved grassland and 12% in semi-improved grassland. Overall bulk density increased by 8% across Wales.
- Topsoil P increased by 15% in improved grassland, with the number of sites exceeding the leaching threshold increasing threefold (equivalent to 19% of sites now exceeding the recommended levels of leaching risk to rivers). Arable soils showed an increase of 18% in topsoil P, equivalent to a twofold increase in the number of sites exceeding recommended levels (11% of sites now exceed recommended levels).

- Arable soils showed a 10% reduction in average N levels, although these remained within recommended guidance levels for production.
- 72% of improved grassland sites fell below the minimum soil acidity levels when productivity may be reduced. This statistic has not changed over the last 10 years.
- The area of arable land and improved grassland decreased by 5% (-49,000 ha), primarily due to increased urban (+28,200 ha) and woodland (+23,600 ha) areas.
- The agri-environment scheme Glastir had minimal beneficial effect on soil health in agriculture soils over the last 10 years.
- 3% (526 ha) of agricultural peatland had been restored (i.e., rewetted, scrub removal).
- A new baseline assessment suggested 4% of Wales experiences some form of soil erosion and disturbance.
- Baseline data were gathered for bacteria, fungi and other soil taxa using an environmental-DNA approach (George *et al.*, 2019). Dried and frozen soil samples have been archived for future assessments including change to soil biodiversity levels and levels of contaminants and control chemicals.

Overall, these results indicate early warning of a potential decline in soil health on agricultural land.

2.3.2 UK

2.3.2.1 UKCEH Countryside Survey

The UKCEH Countryside Survey, which began in 1978, is the longest integrated national monitoring programme of the countryside for Great Britain. The results provide a unique insight into how plants, soil, woodlands and small water bodies have changed over time. The data from the Countryside Survey serves as an audit of the natural resources of the countryside and are a great source of data for researchers and the general public. They are used for numerous purposes including fundamental research, the UK National Ecosystem Assessment (Defra, 2022), the UK Natural Capital Accounts (Office for National Statistics, 2024), agri-environment reporting, validating the UKCEH Land Cover Map (UKCEH, no date c) and soil health reporting. Northern Ireland recently commissioned some elements of the Countryside Survey, including soil testing, so the programme now is UK-wide.

The overall objective of the soil health work in the UKCEH Countryside Survey is to understand the state and change of UK topsoil (0-15 cm). It is recognised that sampling to greater depth would be beneficial, however the funding has not been available. The methods used provide evidence of the state and change to physical, chemical and biological properties of soil, which together help track soil health status. This approach to national soil monitoring is now being encouraged across Europe as part of the EU Mission ‘A Soil Deal for Europe’ (European Commission, no date a) with a very similar approach being taken by the EU LUCAS soil monitoring programme (European Commission, no date b). It is also the basis in design and methodology for soil monitoring carried out by ERAMMP within its National Field Survey.

Soil health status and change have been reported in 1978, 1998 and 2007, and the programme has now adopted a cycle of reporting every five years. The latest report is due in 2026, although early results, including evidence at a Great Britain level, indicate that soil C levels are increasing, contrasting with the previous 40 years of reports of a decline in soil C (Bentley *et al.*, 2025). It is important to note that this trend is not observed for Wales, where a continued decline was reported by ERAMMP (see Section 2.3.1); this is the first time a clear difference in soil health trends have been reported between the four nations.

2.3.3 Soil maps

2.3.3.1 NATMAP

The National Soil Map of England and Wales (NATMAP) is a group of online vector datasets created from over 200 years of soil sampling (Cranfield University, 2025a). It comprises a total of 11 datasets, all of which are available to purchase and download:

- NATMAP vector: shows the distribution of the 297 soil associations across England and Wales, costs £500 per 1000 km^2.
- NATMAP Soilscapes: shows the distribution of the 27 Soilscapes across England and Wales, more generalised than NATMAP vector, costs £250 per 1000 km^2.
- NATMAP 1000: a version of NATMAP vector displayed in a 1 km^2 gridded vector, less detailed than NATMAP vector but provides a general understanding of the distribution of soils within a region, costs £150 per 1000 km^2.
- NATMAP 5000: a version of NATMAP vector displayed in a 5 km^2 gridded vector, less detailed than NATMAP vector and NATMAP 1000 but provides a general understanding of the distribution of soils within a region, costs £900 for the data for all England and Wales.
- NATMAP WRB: shows the distribution of the soil classifications in England and Wales according to the World Reference Base (WRB) classification system of 2006, costs £400 per 1000 km^2.
- NATMAP HOST: shows the distribution of the 29 classes of the Hydrology of Soil Types (HOST) - the range of soil hydrological responses typical across England and Wales, costs £250 per 1000 km^2.
- NATMAP topsoil texture: shows the distribution of 21 distinct classes of topsoil texture across England and Wales, costs £250 per 1000 km^2.
- NATMAP subsoil texture: shows the distribution of 22 distinct classes of subsoil texture across England and Wales, costs £250 per 1000 km^2.
- NATMAP wetness: shows the distribution of six classes of typical soil wetness regimes/classes across England and Wales, useful for the assessment of Agricultural Land Classification and Areas Facing Natural Constraints (previously Less Favoured Areas), costs £250 per 1000 km^2.
- NATMAP available water: shows crop-adjusted available water capacity for the soils across England and Wales for four crop rooting models (grassland, cereals, potatoes and sugar beet), useful for the assessment of Agricultural Land Classification, costs £250 per 1000 km^2.
- NATMAP carbon: three layers showing carbon stock for the soils across England and Wales at 3 depths (0-30 cm, 30-100 cm, 100-150 cm) with 1 layer per depth, £250 per 1000 km^2.

The NATMAP layers are commonly used by consultancies, governments, research organisations and water companies. NATMAP is unlikely to be used by many farmers due to the cost barrier and the skills required to use the vector datasets in mapping software.

2.3.3.2 LandIS Soilscapes Viewer

The LandIS Soilscapes Viewer is a free, online, interactive map showing the coverage of the 27 Soilscapes across England and Wales, produced by Cranfield University (Cranfield University, 2025b) (Figure 2-5). The map also provides information on soil texture, the distribution of the Soilscape(s) across England and Wales, drainage, fertility, habitats, C content, cropping, and water/drainage. It should be noted that the boundaries of the Soilscapes are based on the interpolation of widely spaced survey points (usually much < 1 per 100 ha), and therefore there is the potential for the boundaries to be inaccurate. The Soilscapes viewer is a simplified version of NATMAP and was produced with the aim of more effectively communicating the variation in soil type across England and Wales.

As the LandIS Soilscapes Viewer is a more accessible version of NATMAP, both regarding the cost (the service is free) and the user-friendly interface, farmers are more likely to use this service to understand the soil texture(s) of their fields. The Soilscapes Viewer could be used by farmers to help inform their sampling strategy (i.e., when assessing how to divide fields if there are multiple soil types present). However, due to the small scale of the mapping (usually much < 1 sample per 1000 ha), the accuracy of the soil units and the location of boundaries between units should be considered.

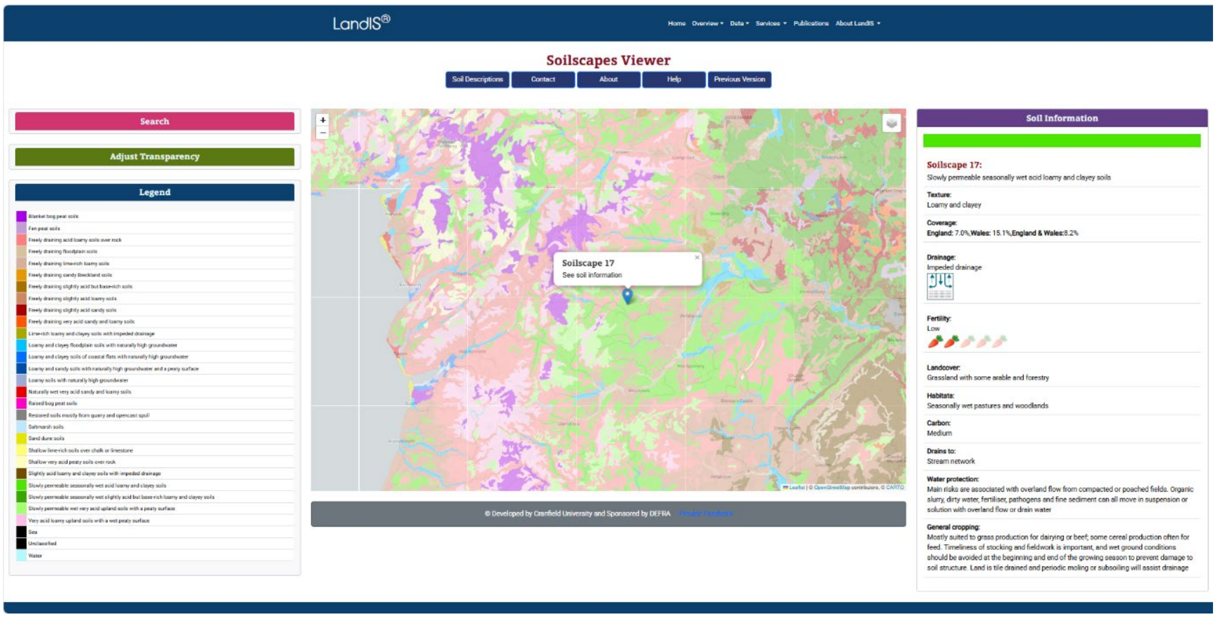

Figure 2-5 LandIS Soilscapes Viewer.

2.3.3.3 National Soils Inventory

The National Soils Inventory (NSI) is part of the services offered by LandIS/Cranfield University and is a set of point data that covers England and Wales on a 5 km grid (Cranfield University, 2025c). The data was collected between 1980-1990 and the data is used both as a general information source and in modelling software to assess trends over time. Like NATMAP, the NSI data is available to purchase:

- NSI Site: shows general land features (land use, slope, slope form, human influence on the landscape, rock outcrops, altitude, aspect, erosion features, deposition features, rock type) across England and Wales, costs £10 per data point or £3,500 for the entire dataset (6,127 data points across England and Wales).
- NSI Profile: describes the soil profile of each NSI data point, includes detailed information including soil texture, and mottle size and colour, costs £15 per data point or £6,250 for the entire dataset.
- NSI Topsoil83: shows topsoil data measured in 1983, contains information on elemental concentrations and soil pH, costs £30 per data point and £12,300 for the entire dataset.
- NSI Topsoil95: shows topsoil data measured in 1995, contains information on elemental concentrations and soil pH, costs £30 per data point and £12,300 for the entire dataset.

- NSI Textures: provides a detailed description of topsoil texture based on laboratory analysis, details grain size fraction and percentage of soil per fraction, costs £15 per data point or £6,240 for the entire dataset.
- NSI Features: provides data useful for soil modelling, including depth from the surface to various layers, and risks posed to the location by erosion and flooding, costs £24 per data point or £9,550 for the entire dataset.

Much like NATMAP, it is unlikely that this service would be used by farmers to understand their soil types due to the associated costs and mapping software/skills required.

2.3.3.4 UKSO Soil Observatory

The UK Soil Observatory map viewer is a free, online, interactive map containing over 100 map layers for the user to select (BGS, 2025). The layers include information on soil C content, moisture, texture, chemistry and geophysics at various scales/resolutions, and are derived from sources including BGS, UKCEH and NSI. Farmers may use the following soil textures layers to understand the variation in soil texture across their fields, which may help in determining sampling locations. However, the layers are prone to the same scale inaccuracies as other free mapping services such as the LandIS Soilscapes Viewer:

- Soil texture (simple) (1:50k): generalised soil texture groupings shown for England, Wales and Scotland, data based on Defra Cross Compliance Guidance for Soil Management 2006, G-BASE samples and expert judgement.
- Soil texture (1:50k): simplified texture classifications across England, Wales and Scotland, data sourced from BGS.
- Soil texture (1:50k) (points): reports soil texture as five simplified classes across Nottingham-Humberside and East Anglian G-Base soil survey areas, data sourced from BGS, Rothamsted Research and Nottingham University.

2.4 Soil health metrics

The following sections describe and discuss some of the candidate soil metrics for inclusion in soil testing for UA1 and the laboratory methods used to analyse them.

2.4.1.1 Soil organic matter

Soil organic matter and SOC are often confused and mistakenly used interchangeably. While SOC is a component of organic matter, it is not the same as SOM which also includes other elements such as hydrogen, oxygen, N, as well as fresh (living) and decomposed (dead) plant and animal material (FAO, 2019). The 'living' fraction includes plant roots and micro-organisms and the larger 'dead' fraction comprises root and leaf litter, manures, water soluble organic compounds and humus. Moreover, SOC can also be confused with soil total C, which is composed of both organic (C derived from the decomposition of plants and animals – i.e., SOC) and soil inorganic C (SIC – derived from underlying geology, most commonly in the form of carbonates).

Soil organic matter can be measured directly by loss on ignition (LOI), which measures the difference in soil mass before and after ignition at high temperatures (typically 350-500 °C), with the difference equating to the amount of SOM present in the soil sample. An important assumption is that the mass difference is only due to combustion of SOM and not due to loss of water from clay minerals (dihydroxylation) or the oxidation of carbonates (Wang *et al.*, 2012). This does not tend to happen if combustion temperatures are kept below 450 °C (Pribyl, 2010). Traditionally a muffle furnace is used for LOI determination, however, more recently a number of laboratories have moved to using a Thermogravimetric Analyser (TGA). This gradually heats a soil sample, first from 25 °C to 105 °C for 3 hours, then to 375 °C for 15 hours. The mass lost between 105 °C and 375 °C equates to the SOM as LOI. Samples are not removed from the TGA throughout the process for weighing thereby preventing water resorption. The samples can be heated further in the TGA to 1000 °C for the determination of total C (Lebron *et al.*, 2024).

The proportion of SOM (measured by LOI) that is SOC typically ranges between 43-58% (FAO, 2019); SOC can be indirectly estimated from LOI measurements of SOM with a standard conversion factor of 0.58 being most commonly used (Van Bemmelen, 1891). Some studies suggest that the value of 0.58 may lead to an over-estimation of SOC content (e.g., Jensen *et al.*, 2018). The Countryside Survey uses a conversion factor of 0.55, which was derived from measurements of both LOI and SOC in the 1998 and 2007 surveys, and is therefore most relevant for soils in Great Britain (Emmett *et al.*, 2010), and more recently confirmed by Bentley *et al.* (2025) in the 2020 survey. However, if SOC content is required, it should be measured directly.

Soil organic C can be measured directly using dry combustion (Dumas method), using an elemental analyser and temperatures in excess of 1000 °C (Wallace *et al.*, 2011). The procedure takes place in pure oxygen to ensure complete combustion to produce carbon dioxide (CO_2) which is then quantified by gas chromatography (FAO, 2019). Inorganic carbonates are first removed by acidification to avoid them being incorrectly assigned to the SOC pool. As with LOI, SOM can be indirectly estimated from direct measurements of SOC using the reciprocal of the conversion factor, typically 1.724 (Van Bemmelen, 1891).

The choice of analytical technique for measuring SOM or SOC depends, in part, on the intended use of the metric. Soil organic matter is widely recognised as a key indicator of soil health, providing a food source and habitat for the soil biological community, driving soil nutrient cycling, and is a central component of soil aggregation and the maintenance of soil structure and water relations. It is also an important C store and a key component of the global C budget, with changes in soil C having big implications for the mitigation or intensification of climate change. Monitoring changes in SOM concentrations (using LOI) is therefore useful for tracking changes in soil health, whilst measurement of SOC stocks (using the Dumas method) is required for C budgeting or footprinting purposes. The calculation of SOC stocks also requires the measurement of soil bulk density (g/cm^3), stone content and sampling depth (FAO, 2020). The move to a thermogravimetric method for national scale monitoring of SOM and soil C provides significantly more information on different soil C fractions, but has required significant work to enable a link back to legacy data. This method is now used by both ERAMMP and the England Ecosystem Survey (part of the Natural Capital and Ecosystem Assessment – NCEA – in England). Changes in methods are generally avoided unless, as in this case, the benefits outweigh the risks.

There has been considerable effort in attempting to establish critical thresholds of SOM to assist farmers and landowners in interpreting laboratory analysis results to understand whether they have a good or adequate level of organic matter within their soils or whether soil functions are impaired due to a low SOM content (e.g., Defra, 2000; Defra, 2004). The consensus is that there is no single threshold value below which SOM impairs soil functioning (Loveland and Webb, 2003), but rather it depends on a number of factors, most notably soil type (clay content) and rainfall, with a range of 'typical' values by soil type and rainfall region providing the best means to interpret SOM results (Verheijen *et al.*, 2005). Both the AHDB Soil Health Scorecard and UKCEH SOD tool follow this approach to setting benchmarks (Section 2.2).

There have also been efforts to better constrain the expectations of soil C sequestration to offset agricultural GHG emissions which have been exaggerated by some. An ERAMMP briefing note (Emmett *et al.*, 2023) was produced on this topic.

The Wellbeing of Wales National Indicator 13: Concentration of carbon and organic matter in soil aligns with goals 1 (A prosperous Wales), 2 (A resilient Wales) and 7 (A globally responsible Wales) (Welsh Government, 2022). The most recent data from the ERAMMP National Field Survey shows that the concentration of C and SOM is stable, being measured at 80.4 g C/kg between 2021-2023 (Welsh Government, 2022) and will continue to be monitored as part of the National Indicators. This national metric indicator however does obfuscate losses for example in arable soils as they represent a small percentage of the national picture.

2.4.1.2 Soil analysis methods

There is potential for variability in the results of soil analysis to be reported depending on the testing methods and equipment used by the laboratory. Soil organic matter, for example, can be measured by LOI or Dumas. The Dumas method is generally considered more accurate; however, it is more expensive, and so LOI is more commonly used. In addition, P can be extracted from soils using multiple methods and therefore different chemical extractants will be used. The Olsen P method uses sodium bicarbonate, whereas other methods, such as Bray-1, use acidic solutions to perform the extraction. Furthermore, differences in the preparation of soil samples for analysis, such as the drying time and temperature, grinding and sieving size, filtration, and extraction time, can also affect the results.

It is therefore important to use accredited laboratories for soil analysis, to ensure the analysis has been performed to the required standards, meaning that results will be reliable and accurate. It is just as important to be consistent in which method a laboratory has used if trends over time are to reflect real change rather than methodological effects.

Considering the requirement for all farmers in Wales to undertake testing of at least 20% of their land per year, many samples will be produced for analysis on an annual basis. It is therefore crucial to consider the capacity of the chosen laboratory/ies to undertake the required analysis, ensuring that samples can be processed and analysed within a sensible timeframe.

2.5 Favoured approach and suitability for Wales

Considering the aim for farmers to have a good understanding of their soil for accurate nutrient management planning, and for all farmers to have the same level of knowledge on the sampling process, ensuring that the samples are taken in a consistent manner, the favoured approach centres on the soil sampling methods detailed in The Nutrient Management Guide (RB209), with aspects of other, similar, methodologies incorporated where appropriate.

It is proposed that farmers use the ‘W’ sampling technique to collect soil samples, taking at least 5 cores along each line of the W, providing a total of at least 20 soil samples per sampling unit which can then be bulked for analysis. Samples from arable land and temporary grassland should be taken to a depth of 0-15 cm, and from long-term grassland to a depth of 0-7.5 cm. These depths are based on the sampling recommendations given in the Nutrient Management Guide (RB209) (ADHB, 2023a-c) and reflect the differences in the stratification of nutrient concentrations within the topsoil between the two land uses; the nutrients in long-term grassland soils are more concentrated in the top 7.5 cm of the soil, and so sampling to a greater depth (e.g., 0-15 cm) would ‘dilute’ the nutrient values given by the analysis, and could therefore lead to phosphate and potash fertiliser recommendations that are higher than required. The samples should be sent to an accredited laboratory for analysis of soil pH; extractable P, K and Mg; and SOM (e.g. by LOI).

This simple methodology would be suitable for Wales, and a further description of the recommended approach and logistics associated with the protocol are specified in subsequent chapters.

3 Task-2 and Task-3: Recommended soil testing approach and soil analysis

The aim of farmer-led soil testing is for farmers to gain a good understanding of their soil condition for efficient nutrient management planning. To do this effectively, farmers need clear instructions on how to conduct soil sampling. They also need the necessary knowledge or qualified support to interpret the results. In accordance with the SFS Universal Action 1: Soil Health, farmers are required to test a proportion of their farmland, meaning that the sampling process must be easy to follow and without complication.

Soil testing should align with best practice, with samples taken in a consistent manner, to ensure that results are accurate and comparable between fields and between farms. It is required that soil samples are analysed for pH, P, K, Mg and SOM. Guidance is also included on how farmers can conduct optional sampling for soil physical and biological properties, which will further enhance the understanding of the soil health on their farm.

Welsh Government have included soil testing as a Universal Action in the SFS (UA1) to support more sustainable and efficient food production, help mitigate and adapt to climate change and improve environmental outcomes. It is hoped this will be achieved through better fertiliser, lime, tillage and rotational practices once farm managers better understand the current state and trend of their soil health. The climate change and environmental outcomes are clearly articulated in the Agriculture (Wales) Act 2023 as the 4 Sustainable Land Management Objectives: air quality, water quality, ecosystem health, and carbon capture. Whilst not explicitly stated, it should be noted that soil health, including soil nutrient status and SOM, underpins all of these, in addition to sustainable and resilient food production.

3.1 Framework

3.1.1 Step by step guidance

Step by step guidance on the recommended soil testing approach is included below.

3.1.2 Advice on selecting sampling units

Before starting sampling, it is important to decide the areas on the farm to be sampled. Each farm should sample 20% of their fields (which are improved or have/will receive inputs) per year, so that all the fields are sampled within a 5-year period.

Improved grassland is that which has been modified by management to enhance agricultural productivity, often characterised by reseeding and the use of lime and/or fertilisers (Welsh Government, 2017). Improved grassland should meet at least two of the following criteria: 1) over 30% cover of ryegrass and white clover, 2) up to 8 species per m^2, 3) less than 10% cover of wildflowers and sedges (Defra, no date). Semi-improved grassland has also been modified by management, although is managed more for habitat benefits rather than enhanced agricultural productivity (Welsh Government, 2017). Semi-improved grassland usually has a higher species diversity than improved grassland and does not need to be monitored as part of UA1.

It is important that the samples taken are representative of the field or sampling unit. If the whole field is managed in the same way, the soil type/texture does not vary, and the field is of a size of 10 ha or smaller, the whole field can be sampled as a single sampling unit and a simple division of fields across the farm is sufficient to spread the work over a 5-year cycle. If the field is managed homogeneously and the soil type/texture does not vary, but the field is larger than 10 ha, then at least two sampling units should be designated.

If there is variation in soil type or texture across a field, divide up the field into similar units by management and/or soil type (Figure 3-1). This is important as contrasting soil types have different physico-chemical properties and can often benefit from being managed differently both in terms of grazing period/cultivation and the amount of lime or fertiliser to apply. Differences in soil type are most easily determined by the farmer or an adviser in the field. Most farmers will be aware of soil type differences within a field, reflected in differences in crop/grass growth, how well the land drains (i.e. 'wetness') or how easy the soil is to cultivate. For new fields, soil type differences can be determined through a combination of walking the field to observe changes in slope, grass/growth and wetness/droughtiness; and using a spade and hand texturing (Figure 2-1) in contrasting parts of a field to estimate topsoil texture. Alternatively, technologies such as electrical conductivity (EC) and electromagnetic induction (EMI) scanning can be used to determine boundaries between soil types plus soil analysis or hand texturing to determine the soil types. Many advisers have hand texturing skills and less experienced farmers can develop the skill on their own land. Hand texturing may not be as accurate as lab analysis but should give a good approximation of the soil type and is sufficient to decide whether to split a field into different sampling/management units.

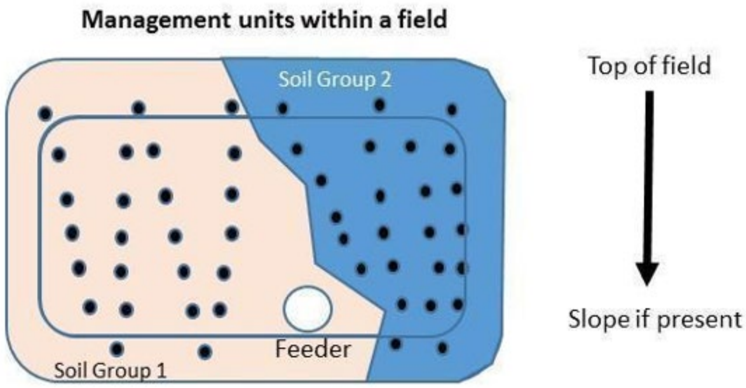

Figure 3-1 Guidance for a 'W' sampling design where a field has 2 management units. Source: Smith et al. (2022).

Within a field, if there is no variation in soil type, the field may be sampled as one sampling unit (providing it is smaller than 10 ha); if the field is larger than 10 ha then at least two sampling units should be designated. If there are different management practices occurring within a field, consider splitting the field up into different soil management zones/sampling units.

Avoid sampling within 6 months of a lime or fertiliser application (except nitrogen) or 6 weeks of the last organic manure application. In addition, it is generally recommended that soil sampling is conducted in the autumn, when the soil is not too wet or dry. Finally, avoid sampling areas of clear disturbance, for example near to gates, feeding areas, hedges, trees, and boundaries (Figure 3-2) to ensure that results are representative of the field.

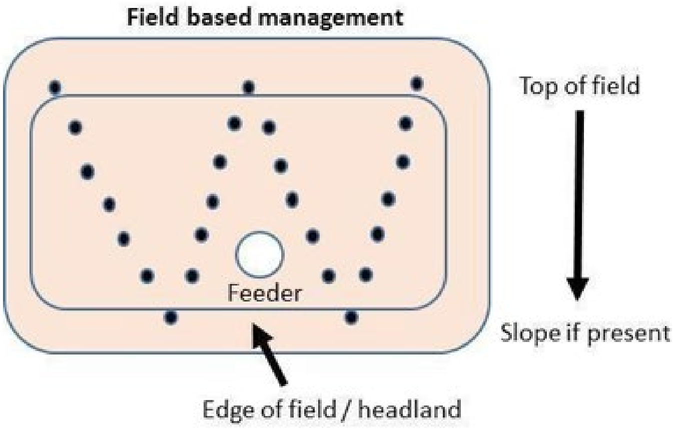

Figure 3-2 Guidance for a 'W' sampling design considering areas of disturbance. Source: Smith et al. (2022).

3.1.3 Materials needed

- Closed soil auger/corer (a screw or open auger could be used although these are less accurate when sampling grassland soil as they under-sample the organic-rich top layer)
    - These can be purchased online or in some hardware stores for around £60-£120
    - Prior to conducting the assessment, mark the corer at 7.5 cm or 15 cm depending on the land use type and required sampling depth (see Section 3.1.4 point 2 for required depth). Standardising and being as accurate as possible with depth are very important as soil properties can change significantly with depth.
- Ruler
- Bags for soil samples to be sent to laboratory with labels
- Permanent marker pen
- Smart phone or GPS device

3.1.4 Sampling protocol

For each sampling unit identified, conduct soil sampling according to the steps below. Guidance on selecting sampling units is provided in the next section.

1. Walk a W shape across the sampling unit.
2. Aim to take at least 5 samples evenly spaced across each line of the W – this will mean there are at least 20 samples for the whole sampling unit. At each sampling point, take a soil sample using the closed auger and collect the soil in the bag. Sample to 15 cm depth if in an arable field or short-term grassland, or 7.5 cm depth if in long-term grassland. Before adding each sample to the sample bag, remove any plant litter or large roots.
3. Shake the (sealed) bag of soil to homogenise the samples. Most labs will require ~400 g of moist soil for the analysis of P, K, Mg, pH and SOM (e.g. by LOI). Label the bag using a permanent marker with the sample name, your name, and the farm name and date.
4. Send the bag(s) to the laboratory for analysis with the necessary paperwork repeating again the farm name, sample names/codes (written on the sample bags), geolocation using GPS or phone if taken, sampling date, depth of sample and analysis required (P, K, Mg, pH, SOM) – see Section 3.1.7 for how to do this.
    a. Note that certain laboratories may send specific packaging (such as boxes) in which to send your sample for analysis.

3.1.5 Other data to record

In addition to soil sampling, it is beneficial to record supplementary data about the location, including soil texture and field management history for the sampling unit (i.e., previous crop, current crop, manure or fertiliser applications, etc.). Certain laboratories may request this information as standard if they send through a sample submission form.

For each sampling unit, record this information in the data submission form (see Section 10.1). You can also enter the results of the soil analysis once reported by the laboratory. It is important that units are indicated where appropriate.

3.1.6 Expected time required

It is estimated that walking the W across a field or soil management zone, taking the required minimum of 20 soil samples and bulking these will take between 20-25 minutes.

Optional measurements, including assessing soil structure (i.e., VESS assessment), counting earthworms and assessing erosion and disturbance features would take an additional 25-30 minutes per location.

3.1.7 Sample storage and dispatch

If you are unable to send the soil sample(s) to the laboratory immediately after sampling, the bagged soil can be stored in a fridge for up to 1 week. The samples should be dispatched to the laboratory within 1 week of sampling.

To arrange dispatching the sample(s) to the laboratory, use the sample submission form on the laboratory's website. You should include details of the farm name, sampling unit name, geolocation using a GPS or phone if taken, the analysis required (P, K, Mg, pH, SOM) and your contact details. Print out the sample submission form and place in a cool box (labelled with the farm address) with the bagged soil sample(s). Seal the cool box with tape. Following this, arrange a courier. This may be possible to do on the laboratory's website, or you can use a courier website to arrange sending the soil sample to the laboratory.

3.1.8 Use of accredited laboratories

It is important that all soil samples from your farm are sent to the same accredited laboratory and that the same methodologies are used (e.g., SOM by LOI) for each sampling cycle. This is crucial for ensuring that all samples from the same farm are treated and analysed identically and thus are comparable.

There are a range of laboratories which offer soil testing in the UK, although it is recommended that accredited laboratories are used to conduct soil analysis as these provide assurance that the results are accurate and reliable. The Professional Agricultural Analysis Group (PAAG) certifies laboratories which meet required quality standards; the AHDB website (AHDB, 2025f) lists a range of PAAG-certified laboratories where soil samples can be sent for analysis and provides details of companies that will both undertake the soil sampling and conduct the laboratory analysis. Examples of PAAG-certified laboratories are NRM Laboratories, Hill Court Farm Research and Lancrop Laboratories, although other PAAG-certified laboratories are available (AHDB, 2025f).

3.1.9 Costs of analysis

3.1.9.1 Time

Walking the W across each soil sampling zone, taking the required minimum 20 soil samples and bulking these is estimated to take 20-25 minutes. Organising the samples and associated documentation to send to the laboratory is estimated to take around 15-20 minutes. The amount of time required for a farmer to send the samples will depend on their locality to a post office; note that some laboratories will arrange for couriers to collect bagged/boxed samples from the farm.

The time required for a farmer to complete one years' worth of sampling (i.e., 20% of the farm) will depend on the number of sampling units identified across the farm.

3.1.9.2 Cost per sample

An analysis of pH, P, K, Mg and SOM conducted by an accredited laboratory typically costs between £24 and £40 per soil sample (AHDB, 2025f). If a farmer wishes to have their soil analysed for particle size analysis (i.e., the proportions of sand, silt and clay), this is likely to cost around £50, although this analysis would not be included as part of the scheme.

3.1.9.3 Cost per typical holding

The total cost of soil analysis for one farm per year will depend on the number of sampling units. To estimate the cost of soil analysis for one farm per year, multiply the number of sampling units (e.g., the number of samples to be sent to the laboratory) by £24-£40. You should also consider labour costs to take the samples and send these to the laboratory.

For example, a farm which has 10 fields of 5 ha, each with 2 soil types, would require two of these fields to be sampled per year (20% of the farm area). This would equate to four soil samples, a total time of 1 hour 20 minutes to undertake this sampling, and a rough analysis cost of between £96 and £160 per year.

3.1.9.4 Cost for advice and interpretation of results

The cost of consulting a FACTS-qualified advisor/agronomist to help interpret the soil nutrient and SOM analysis results will typically cost between £75 and £125.

3.1.10 Interpretation of analysis results

The analysis results from the laboratory will be sent to you via email. You will receive one set of analytical results per bulked soil sample (i.e., per sampling unit). The following information will be reported, and the typical range for each soil attribute is provided in Table 3-1.

Table 3-1 Typical ranges for soil analysis results including units and indices for soils in Wales. Note that these are typical ranges and there is potential for values to be higher/lower than this.

	Units	Soil indices	Typical range
Phosphorus (P)	mg/l	0-5	Index 1-3
Potassium (K)	mg/l	0-5	Index 1-3
Magnesium (Mg)	mg/l	0-5	Index 1-3
pH	N/A		5.5-8.0
Soil organic matter (SOM)*	% or g/kg		1-6 %

*See also Section 4-1 for more information on proposed thresholds for SOM.

The analysis results received from the laboratory should be entered into the data submission form for each sampling unit and uploaded to RPW Online.

3.1.11 Indicator thresholds

The Nutrient Management Guide (RB209) provides target soil pH, extractable P, K and Mg levels for all the main agricultural land uses in Wales (AHDB, 2025a). These recommendations can be considered within the context of each farm in relation to the aim and agro-climatic conditions (e.g., soil type and climate) of the farm and the extent to which the recommendations for optimum production are applicable. The targets for nutrients and pH were developed over the past 80 years and have been corroborated by regular reviews and revisions of the recommendations (e.g., Roques *et al.*, 2016). The Nutrient Management Guide (RB209) is also the industry standard against which agricultural advisors in England and Wales are assessed to achieve and retain FACTS-qualified status. The target indices have also informed the thresholds used in the AHDB Soil Health Scorecard (see Table 3-2 for pH thresholds and Table 3-3 for nutrient thresholds). However, RB209 is not a static recommendation system and will continue to be informed by new scientific evidence, data, indicator systems and other potential developments, such as changes in policy, in the future. The addition SOM benchmarks in the AHDB scorecard recognises the lack of any consensus on a threshold linked to function and uses a population approach (Table 3-4).

Table 3-2 Threshold values for soil pH for cropping and grassland according to the AHDB Soil Health Scorecard.

Land use	Status	Range
Cropping	Investigate	≤ 5.49
	Review	5.5 - 6.49 OR ≥ 7.5
Grassland	Investigate	≤ 5.49
	Review	5.5 - 5.99 OR ≥ 7.5

Table 3-3 Threshold values for soil nutrient content according to the AHDB Soil Health Scorecard. Note that there is no separation by land use.

Nutrient	Status	Range
Extractable P (Olsen) mg/L	Investigate	≤ 9 (Index 0) OR ≥ 71 (> Index 4)
	Review	10 - 15 (Index 1) OR 46 – 70 (Index 4)
Extractable K mg/L	Investigate	≤ 60 (Index 0)
	Review	61 – 120 (Index 1)
Extractable Mg mg/L	Investigate	≤ 25 (Index 0)
	Review	26 - 50 (Index 1) OR ≥ 351 (> Index 5)

Table 3-4 Threshold value for SOM (%) according to the AHDB Soil Health Scorecard for NW and SW NW England and all Wales (defined as high rainfall areas). These are based on typical values for a range of data sources not function.

Land Use & Soil Group	Status	Range
Cropping		
Light	Investigate	≤1.3
	Review	1.4 - 3.7
Medium	Investigate	≤2.5
	Review	2.6 – 5.0
Heavy	Investigate	≤ 3.6
	Review	3.7 – 6.2
Grassland (lowland)		
	Investigate	≤ 2.1

Light	Review	2.2 - 4.9
Medium	Investigate	≤3.4
	Review	3.5 – 6.4
Heavy	Investigate	≤4.6
	Review	4.7 – 7.6

The use of these thresholds has a different purpose than the use of thresholds at a national scale as they focus on improving management practices at the field-scale, whereas the national indicators seek to provide an aggregated trend of ongoing trends on a larger scale and relate to habitat protection as well as optimising production. It should also be noted that impact indicators such as these are different to activity indicators, the latter providing an earlier insight into the uptake of actions which are intended to result in the intended outcomes captured by impact indicators.

One option to create a new national indicator system is the proposed new Soil Health Alert Indicator (ERAMMP Report-94; Feeney *et al.* 2023; 2025) which is subject to further consultation as part of the Welsh Government funded “Sustainable Land Management Impact Indicators and Targets commission”, also being delivered by ERAMMP. To date, no decision has been made on whether to adopt the new indicator in Wales and / or an adjusted version of the indicator. The approach follows the principles of the approach of the EU Soil Observatory that can be found online (EUSO, no date a; no date b).

The proposed new national indicator proposes again uses a threshold approach for a selection of soil indicators within a range of habitat types, including arable and improved grassland required for UA1. For Wales, the thresholds used have been derived by the soil science community over the last 10-20 years based on an established relationship to a soil function which is known to be beneficial or essential for either efficient production and/or habitat support. However, thresholds are available for all soil measurements in which case, an approach has been proposed, which mirrors the approach used by the AHDB Scorecard where thresholds or benchmarks are set relative to ‘typical’ values collated from a variety of data sources. For Wales, the data source used is the nationally representative set of measurements reported by the ERAMMP National Field Survey. In the EU, whilst a threshold approach is again used, the threshold for SOM is set at the distance from the maximum reported from the LUCAS soil monitoring programme by more than 60%. This threshold is based on soil C estimated as lost from EU soils (De Rosa *et al.*, 2024). For Wales, the lowest 20% of recorded values for each indicator and for each land use, soil and climate combination is identified as the threshold range where functional thresholds are not available. A ‘one out/ all out’ approach as used in the Water Framework Directive is then proposed with targets set for reducing the percent of soils which do not meet a threshold for one indicator or more. In time, the area of land moving into the 'acceptable’ range could be included in an assessment to provide a more positive indicator.

Such an approach has been criticised as it is statistically based and is not inherently linked to a soil’s potential to support a range of functions (Hollis *et al.*, 2025), but see the response by Feeney et al. (2025). As a way to avoid this issue and in the absence of actual any national soil health change data, the approach in England uses an expert-based Bayesian Belief Network approach (Hannam et al. 2025) with an intention in time to populate this network with actual data. As part of this work, a review of current approaches to capture the complexity of soil health indicators is available which is not repeated here (Harris et al. 2023). Here in Wales, we have both an active national soil monitoring programme with change data which can be further augmented with farmer-led data going forward (see Section 5.1) which is why a data-led approach has been proposed.

4 Task-4: Data use

4.1 Use of data by farmers to inform nutrient management decisions

The SFS provides support for Welsh farmers based on the implementation of actions on their improved agricultural land. The scheme is supported by industry and actions are underpinned by scientific research and sound agronomic principles. UA1 requires farmers to test 20% of their improved agricultural land per year, which will subsequently require interpretation to understand and improve nutrient management practices where possible. Guidance on the interpretation of soil analysis results should be sought in the form of FACTS-qualified advice and should include discussion around the costs and benefits of specific actions, considering the principles set out in The Nutrient Management Guide (RB209) with regards to the specific aims of the farm.

Some examples of how the soil analysis results could be used to help inform farmers' nutrient management decisions are included below:

Example 1: *Soil extractable P is measured above the target soil index*. Olsen P is at 35 mg/l (Index 3) on improved grassland, indicating that soil P levels have been built up over the years with inputs from fertiliser and organic manure applications exceeding grass offtakes. When soil P levels are higher than required, the risk of P loss to water courses, primarily via surface wash of soil particles, is increased. In this situation, not applying phosphate fertiliser and avoiding frequent applications of livestock manure will allow for a gradual decline in soil P status to the target level. This results in a cost saving for the farmer and reduces the risks to the water environment.

Example 2: *Soil pH is below the optimum level*. Soil pH is measured at 5.4 on improved grassland, indicating strong acidity, which is likely to be affecting the ability of the grass sward to efficiently utilise applied nutrients. This would potentially reduce the amount of N taken up by the grass, reduce yields and increase the amount of N lost to water through nitrate leaching and to the air as nitrous oxide (a potent GHG). The farmer is also not getting full value from any nitrogen (N) applied. Soil pH can be raised to optimum levels by applying a liming material, such as ground limestone or ground chalk. While this would incur an initial cost to the farmer for the liming product, its application would raise the soil pH to target levels, resulting in improved soil structure, better sward quality, more efficient use of all major nutrients, increased grass yields and less N would be lost to the environment.

Example 3: *Soil organic matter is below typical levels.* According to the AHDB Soil Health Scorecard, SOM values for arable soils of ≤ 1.3 (light soil), ≤ 2.5 (medium soil) and ≤3.6% (heavy soil) would warrant investigation in high rainfall areas such as northwest and southwest England and Wales, whilst values between 1.4 and 3.7 (light soil), 2.6 and 5.0 (medium soil), and 3.7 and 6.2 (heavy soil) would warrant review as they are indicative of below typical values. This is similar to the 5% SOM value proposed in the proposed national Soil Health Alert indicator for arable soils which represents the bottom 20% of values observed in the ERAMMP national topsoil survey. For lowland grassland, the equivalent values are ≤ 2.1 (light soil), ≤ 3.4 (medium soil) and ≤ 4.6% (heavy soil) which would warrant investigation whilst between 2.2 and 4.9 (light soil), 3.5 and 6.4 (medium soil), and 4.7 and 7.6 (heavy soil) would warrant review. This compares to the value of 7% proposed in the proposed national Soil Health Alert Indicator. Clearly there is good comparability between the two approaches. The consequences of low SOM are potentially lower moisture retention and nutrient availability and poor soil structure resulting in reduced root growth. Increasing diversity of crops and sward species, introduction of leys and legumes, reduced tillage and increased use of organic manures and mulches may all improve SOM content.

In time, farmers will be able to enter their data (both soil analysis results and information on farm management practices) into the Defra Nutrient Management Planning Tool (NMPT-GB) which is currently in development. The tool provides a platform to access recommendations in the Nutrient Management Guide (RB209) in a more accessible way and may encourage more farmers to adopt a nutrient management plan. It should be noted that the tool does not provide any additional guidance to what is already included in RB209 but presents the recommendations in a more accessible and direct way to the user. By using a recognised nutrient management tool (such as NMPT-GB), users would also be compliant with the Water Resources (Control of Agricultural Pollution) (Wales) Regulations (CoAP). As mentioned, it is important for farmers to use a recognised recommendations system to guide their nutrient management. However, the context and aims of the farm should be considered and accounted for when determining what is suitable.

5 Task-5: Recommendations

5.1 Integration of farmer-led data with national (Wales) soil health monitoring

Major advances in data science including machine learning and AI have created methods for the integration of unstructured farmer-led (i.e., citizen science) data with structured national data. This has been tested for biodiversity data and demonstrated to be practical. See Ahmad Suhaimi *et al.* (2021), Simmonds *et al.* (2020), Jarvis *et al.* (2022, 2023 and 2025), and Seaton *et al.* (2024) for examples of this.

However, there are several caveats to this:

i) One limitation is the use of different sampling depths for improved grassland in different schemes: 7.5 cm for farmer-led fertiliser testing in long term grassland and 15 cm for national monitoring. The consequence of this is that a shallower sampling depth, although aligned with agronomic and Soil Health Scorecard advice, may give higher values for soil pH, nutrient status and SOM than in national monitoring schemes. One recommendation of this project is to set up a study to explore the relationship between soil analysis results using contrasting sampling depths to develop a simple transfer function for translating results from a 7.5 cm sampling depth to a 15 cm sampling depth and vice versa.

ii) It should be noted that the integration of unstructured citizen science/self-assessment data and structured national monitoring data is not always beneficial. Rather, a separate analysis followed by a comparison can be a more useful method for identifying differences relating to different spatial structures and data quality.

iii) Some farmers and land managers may raise concerns about data sharing, access and use. However, it should be highlighted that if data protection law is followed, as set out in the General Data Protection Regulations (GDPR), there is minimal risk of private data being shared with external parties. RPW will process any data collected to support only the National Monitoring Programme. The results will not be used for any other purpose other than the National Monitoring Programme and will not be used to identify individual farms. It is recommended that this information be provided to farmers at the time of receiving guidance on soil sampling.

Overall, there are many advantages of comparing the results from the unstructured farmer-led monitoring with the structured data from the national monitoring programme, not least due to the more numerous sample numbers from the farmer-led monitoring, even if data quality may need to be explored and the distribution of samples will not be nationally representative. Data science approaches are available which allow for these two elements to be considered, to enable the strengths of both approaches to be exploited.

5.2 Extension of metrics to include optional and collaborative schemes

In addition to the specified soil health metrics that farmers will be required to test for (soil pH, P, K, Mg and SOM), there could be further benefits to including additional soil physical and biological testing. This could potentially include soil structure (i.e., VESS); erosion and disturbance features (e.g., poaching, small slips); and soil biology (i.e., earthworm counts, environmental-DNA (e-DNA)). However, for e-DNA the cost of laboratory analysis will be an important consideration. Some of the additional tests (erosion and disturbance features and e-DNA) are already included in the ERAMMP National Field Survey.

5.2.1 Soil physical testing

The VESS approach can provide a visual evaluation and scoring of soil structure and porosity in the topsoil and upper subsoil and is linked to management options. It aligns to some extent with bulk density measurements, providing an indication of soil porosity and the degree of soil compaction (AHDB, 2025e), and has been included as an optional measure in the proposed sampling protocol (Section 3). Good soil structure is important for providing soil aeration, water drainage and nutrient supply to crops, ensuring good vegetation growth. Furthermore, measuring soil structure can help farmers understand the resilience of their soils to future climate change and associated threats. A VESS assessment forms an important part of nutrient management planning, as it indicates whether soil structure needs to be improved for optimum nutrient management.

Bulk density can provide very useful data in national monitoring schemes. However, measuring bulk density requires additional equipment to a composite soil sample collected for laboratory analysis (e.g., a mallet, kopecki rings, ring covers), is time consuming (particularly in soils with stones), and requires multiple samples to obtain a meaningful value for a single soil layer. In addition, the values obtained can be misleading if the bulk density ring is not carefully extracted from the soil.

The presence of erosion, compaction and disturbance features (e.g., poaching, small slips) indicate the physical degradation of soil structure and potential loss of soil. An assessment of soil disturbance is crucial for understanding the ability of soil to function effectively and can allow for the implementation of targeted management practices to improve soil condition.

5.2.2 Soil biological diversity and biological testing

Earthworms are vital for healthy soils due to their crucial role in nutrient cycling and aggregate formation. Earthworm counts are, therefore, a good indicator of soil health, with earthworm abundance relating to the amount of biological activity occurring in the soil (Agri-TechE, 2025). Earthworms have been included as an optional measure in the proposed sampling protocol (Section 3).

The measurement of e-DNA provides a more integrated and complete approach to detect the wide range of taxa currently present in the soil, including bacteria, archaea, fungi, protists, plants, and animals (Epelde *et al.*, 2025). However, to date the data has been difficult to interpret as, for example, bacterial diversity is greatest in our most disturbed and improved soils (i.e., arable soils). Environmental-DNA is typically analysed using a metabarcoding approach and is conducted by a laboratory. Despite the use of e-DNA analysis on soil samples becoming more commonplace, this analysis is the most expensive of all the soil health indicators considered above. The AHDB Soil Biology & Soil Health (SBSH) partnership note the high costs of measurement per sample, and, as e-DNA techniques are still emerging and being developed, these metrics are still difficult to interpret and thus they currently do not support the use of soil metabarcoding/e-DNA for soil health monitoring on-farm (SBSH, 2022).

National soil e-DNA biodiversity data for Wales, derived from the GMEP/ERAMMP national monitoring programme, described the complex and fascinating variation in underlying factors that determine the diversity of different soil microbial and animal taxa (George *et al.*, 2019). It is hoped that the UK Environmental Observation Framework (UKEOF) or a similar group will convene a soil e-DNA working group to agree on a small set of reportable eDNA metrics relating to soil function (e.g., mycorrhizal presence, pathogens, fungi abundance) which can be included in soil health assessment in the future.

It should be noted that the EU is also in the process of developing a single approach to assessing soil biological diversity with the following metrics and methods offered as potential indicators for a 'loss of soil biodiversity' in Annex 1 of the Proposal for a Directive on Soil Monitoring and Resilience (Soil Monitoring Law) (2023) (European Commission, 2023):

- Soil basal respiration (mm^3 O_2 g^{-1} hr^{-1}) in dry soil
- Metabarcoding of bacteria, fungi, protists and animals
- Abundance and diversity of nematodes
- Microbial biomass
- Abundance and diversity of earthworms (in cropland)
- Invasive alien species and plant pests

5.2.3 Materials and methods

These measurements can be taken in addition to the required soil health measurements.

5.2.3.1 Assessing soil structure and earthworms

Materials

- Spade
- Plastic sheet or tray
- Knife
- VESS assessment card
- Paper and pen
- Bottle of water

Methods

For each sampling unit identified, an assessment of soil structure and disturbance, and earthworm count can be conducted if desired. If choosing to complete these measurements, they should be completed at three points in each sampling unit.

Within each sampling unit, study the ground surface and note the percentage cover of soil disturbance features. These features could include but may not be limited to: rill erosion, gully erosion, signs of wind erosion, wheel ruts, runoff, compaction, poaching, surface capping, and small slips. Guidance on examining the soil for signs of disturbance can be found in the 'thinksoils' guide (Environment Agency, 2008), which can be downloaded for free online.

Soil structure is assessed using the VESS protocol, which is available on the AHDB website (see Section 10.2). Print a copy of this to take into the field.

Earthworms can be assessed following the '30 min worms' method (see Section 10.3) developed by UK Soils (UK Soils, no date). Print a copy of this to take into the field. After conducting the VESS assessment, hand sort through the soil on the plastic sheet/tray for 5 minutes and place any earthworms to the side. Record the number of earthworms and categorise into adults and juveniles if possible. Return the earthworms and fill in the hole with the soil.

5.2.3.2 Environmental-DNA

Materials

- Trowel
- Sample bag
- Marker pen
- Cool box and ice packs

Methods

Take a subsample of the bulked soil collected for the sampling unit for nutrient analysis (the amount of soil required will be specified by the chosen laboratory). Place in a separate sample bag and label with location details. Place the sample bags in a cool box with ice packs for transport to the laboratory.

It is critical that samples for e-DNA analysis are sent to the laboratory as soon as possible, as the sample has the potential to degrade very quickly. It should be noted that there are no recognised or accredited laboratories for e-DNA analysis at present.

6 Barriers to uptake and potential risks

6.1 Barriers to uptake

There are a range of potential barriers which may hinder the uptake of the scheme by farmers. The time required to conduct the sampling, for example, may be considerable for those with large farms, potentially spending several days to complete soil sampling for 20% of the farm. Additional time will be needed for sample dispatch and for the interpretation of the results with an agronomist or advisor (for farmers who are not FACTS-qualified). Furthermore, the costs associated with sampling, dispatch, laboratory analysis and agronomist/advisor fees (if not already paid for) may deter some farmers and land managers from participating in the scheme.

6.2 Potential issues and risks

Encouraging farmers to conduct soil testing will be associated with various risks, due to the independent nature of the testing, the inability to perform quality control on the sampling, and issues surrounding funding and data usage.

These risks include, but are not limited to:

- Concerns from farmers about raising the expectations of public funding to improve soil health if the soil testing reveals soil health is below recommended thresholds.
- Data on soil health may also impact on land values if the data is known to exist and used for integration with national assessments. Disclosure may therefore be requested.
- Fear of enforcement action if soil health metrics are above/below threshold levels – e.g., a potential penalty if P index is too high or erosion extent exceeds cross compliance requirements.
- Samples being non-representative of the field – e.g., farmers may target areas of the field which they know will have 'better' soil health, such as under hedgerows, rather than areas of the field that are representative of the wider area.
- Elevated risk of water pollution (particularly into field margins, ponds, and wetlands) as some farmers may increase their fertiliser application to land where production levels are below optimal. However, this only poses a risk if fertiliser application is inaccurate and codes of practice are not followed (e.g., if nutrients are added where/when there is no requirement from the crop/soil).
- The number of samples sent for analysis exceeding laboratory capacity. In Wales, there are various estimates of the area of arable and improved grassland depending how this is defined and measured. Estimates from Earth Observation (i.e. the UKCEH Land Cover Map) identified there to be 853,000 ha of 'improved' grassland and 84,000 ha of arable in 2021. These values excludes semi-improved, semi-natural and acid grassland This would lead to a total of 937,000 ha of land to be sampled over a 5-year period - 20% of this land i.e., the amount to be sampled per year – which would equate to *c.*19,000 samples sent for analysis on an annual basis. The WG Agriculture and Horticulture Survey estimated the area of cropland to have been 107,800ha in 2024 and 1,275,633 ha of 'permanent and new grassland' (i.e. excluding rough grazing and 'other land') in 2024 i.e. a total of 1,383,433 or an additional 48% of land area and number of samples. It is not clear however how much of this land would be considered as 'improved' grassland and therefore included in the sampling programme. Whatever the final value, there could clearly be a very large number of samples requiring analysis and it is crucial to establish whether there is capacity for this number of samples to be analysed by the commercial laboratories. It is therefore recommended that Welsh Government contact laboratories directly to formally advise them that an estimate of ≥ 19,000 Welsh soil samples will be sent for analysis on an annual basis.

- The number of samples requiring interpretation exceeding advisor capacity. There are *c.*3,000 FACTS-qualified advisors in the UK, with some of these being based in Wales. However, the exact number of these advisors based in Wales who specialise in grassland soil health is unknown.

7 Funding for improved soil health

Recent findings from the ERAMMP National Field Survey identified various emerging soil health issues in agricultural soils across Wales (Emmett *et al.*, 2025). These were reported to the recent Senedd Soil Health in Agriculture Inquiry as outlined in Section 2.3.1. Overall, the results suggested a situation that is one of concern for soil health in agriculture, as many indicators indicated a decline in soil health. Furthermore, the Welsh Soils Policy Statement 2025 sets out three objectives to ensure the protection and sustainable management of soils in Wales, which must be achieved for soils to effectively deliver the services we rely on and to prevent future degradation of our soils:

1. Increase information on Welsh soils
2. Encourage sharing of information on soils
3. Protect, maintain and enhance soils, soil functions and services

The following question therefore arises: where should the funding come from to restore soil health in Wales where it is currently poor, as many negative impacts of soil degradation are experienced away from the farm (e.g., rapid runoff of rainwater increasing flood peaks due to compaction; C release from soil accelerating climate change; nutrient loss from soil causing eutrophication of water courses)?

Currently, cross compliance does not prevent such issues occurring. Meanwhile, on-farm improvement in soil health is likely to improve resilience of production (e.g., more SOM increases water availability for crops during droughts), which will be of benefit to farmers (e.g., Schjønning *et al.*, 2018), although scientific evidence of a direct link between SOM levels and yield in Wales is limited. Many farmers may therefore not be persuaded to undertake the investment required. On the other hand, a ‘bounce’ back in yield is now being reported by some farmers adopting ‘regenerative’ soil management practices (British Ecological Society, 2025). Across the UK, the number of farmers undertaking these ‘regenerative’ practices is increasing. However, reliable figures on the exact numbers are unavailable. The question therefore remains: is the improvement of soil health the responsibility of the farmer, government, business, or a combination of these stakeholders?

Wales is not alone in asking the question of where the funding to improve soil health should come from. The EU estimates soil degradation is costing €74 billion annually for the EU (European Commission, 2023) and is moving rapidly to identify new business models and investment opportunities to support the restoration of soils and uptake of more sustainable practices.

One established funding option is the C credit market. However, this has been met with concerns linked to ‘greenwashing’ and the fact that the EU considers soil C to be only a temporary store. Furthermore, some companies have indicated that they consider soil C only as a temporary, or initial, entry point to more broad-based action(s) to improve soil health. One perceived benefit is embedding actions in value chains, hoping to increase profit by demonstrating more sustainable practices. This includes some food and drink, processing and retail companies who are requiring producers to demonstrate more ‘sustainable’ management approaches. Some companies are also willing to invest in improved soil health as they believe it will increase resilience to global warming and supply chain security. In addition, some insurance companies who deal with the farming industry are starting to take an interest in this area. Local funding opportunities may also be available through targeted initiatives, such as community wind farms for soil health, but these are still untested.

8 Conclusions and recommendations for further work

The Welsh SFS aims to have farmers test at least 20% of their improved land per year for soil pH, P, K, Mg and SOM, with the aim of sampling 100% of their improved land on a 5-year cycle (although there is an option for a break in soil testing in the second year in the scheme to ensure that farmers have time to interpret and act upon their first set of results). It is estimated that this will result in ≥ 19,000 soil samples being submitted to the laboratory for analysis per year. This report aimed to build an outline for farmer-led soil testing, detailing how this would fit into a national framework, the logistics required, and how the data could be used.

8.1 Recommendations for farmer-led soil monitoring in Wales

Following a review of the existing approaches, the recommendations for farmer-led soil monitoring in Wales are as follows:

- The soil testing approach recommended here is based on the simple 'W' sampling technique to obtain a bulked soil sample which is representative of a farmer's sampling or soil management units. Guidance is provided on how to select sampling units based on land use and soil type.
- It is recommended that Welsh Government contact laboratories directly to formally advise them of the estimated number of soil samples to be submitted for analysis on an annual basis to ensure there is sufficient capacity.
- Following receipt of the soil analysis results from an accredited laboratory, it is suggested that farmers consult a FACTS-qualified advisor and The Nutrient Management Guide (RB209) (or NMPT-GB in the future) to help interpret their results and consider altering their nutrient management and liming plan if required. Clear access to accredited advisors should not limit the value of this soil testing for practical application and improvement in the field.
- Provision of training to farmers to help interpret their soil analysis results, particularly SOM, and what this means regarding future farm management practices (i.e., tillage, choice of following crop(s)).
    - The required soil sampling is expected to take 20 minutes per sampling unit, and soil analysis costs to be £24-40 per soil sample plus time for sample collection, sending to the laboratory and collation of paperwork.
- The proposed framework aligns with the goals of Welsh Government and SFS to inform better fertiliser practice and improve on-farm nutrient management.
- Potential barriers to uptake of the scheme are predominantly in the form of time and monetary cost associated with soil sampling and analysis.
- Perceived risks associated with the scheme could include potential non-representative sampling, funding concerns, data ownership, data privacy and fear of penalties where soil metrics are outside recommended ranges.

8.2 Recommendations for further work

The following recommendations for further work are suggested:

- Support for the assessment and improvement of new soil health alert indicator thresholds based on the relationship between soil properties and soil functions, and Wales ERAMMP data including greater resolution for different soil types.

- Work to enable integration of data from soils sampled at different depths (7.5 cm and 15 cm) in permanent grassland between farmer-led assessment and national monitoring.
- Action by communication experts to ensure the advice provided here is fully tested, attractive and understandable by the intended end-users (e.g., farmers, farm managers and staff).
- Additional soil health metrics (VESS, soil disturbance features, earthworm counts, and e-DNA) are considered for the future, although it is highlighted that e-DNA analysis is currently costly and results are difficult to interpret and benchmark at the present time.
- An assessment of the number of FACTS-qualified advisors who are knowledgeable of the main farming systems in Wales and active in the territory.
    - What further training needs are required to support the advisors of the future?
    - To what extent are current initiatives meeting this need (e.g., the Horizon Europe Climate Smart Advisors project, 2023-2030)?

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10 Appendices

10.1 Data submission form exemplar for RPW

Use the data submission form below to enter information for your sampling unit. Please use one data submission form for each sampling unit. Enter information in the white boxes only. Information on P, K, Mg, pH and SOM can be found on the soil analysis results sheet from the laboratory.

	Data to input	**Units**
Farm name		
Field name		
Land use type		
Geo-location (e.g. What3Words)	*Enter What3Words or coordinates*	
Soil type (if known)		
Sampling date		
Sampling depth		cm
Previous crop		
Current crop		
Manure additions within last 3 years?	*Yes/No*	
Fertiliser additions within last 3 years?	*Yes/No*	
P	*Enter laboratory result*	mg/l
K	*Enter laboratory result*	mg/l
Mg	*Enter laboratory result*	mg/l
pH	*Enter laboratory result*	
SOM	*Enter laboratory result*	%
VESS score (optional)	*Write VESS score (1-5)*	
Erosion and disturbance features (optional)	*Write list of erosion and disturbance features identified and % ground cover of each*	
Earthworm count (optional)	*Write number of total earthworms* *Write number of adults and juveniles if possible*	
Environmental-DNA (optional)	*Enter laboratory results*	
Notes		

10.2 VESS methodology (AHDB)

Print the VESS assessment sheets (AHDB, 2024) below to take into the field for use when assessing soil structure.

AHDB

How to assess soil structure

A visual examination of soil structure (VESS)

Soils should be assessed when they are moist and soil aggregates are easier to break up by hand. Avoid assessing soils during prolonged spells of wet or dry weather. Wait at least one month after cultivations.

Step 1: surface assessment

Assess the cover (grass sward, crop or residue) to identify moderate or poor areas that require further assessment.

Good

- Good cover
- No standing water
- No poaching and/or deep wheelings

Moderate

- Poor cover (or with more weed species in grassland)
- Some standing water
- Some poaching and/or deep wheelings

Poor

- Very poor cover and growth/sward quality
- Standing water and/or surface capping
- Severe poaching and/or deep wheelings

Step 2: soil block extraction

- Cut out three sides of a square block (about 30 cm deep) – leave an undisturbed side
- Lever out and lay the block on a plastic sheet or tray – undisturbed side up
- If the soil block falls apart easily, dig out a second block (and place it next to the first)

Top tip

Dig in 'good' (e.g. hedge bottom) and 'bad' (e.g. a gateway or tramline) areas to get familiar with soil structure.

Step 3: soil assessment

Gently open the soil block by hand (like a book) to look for layers.

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

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

Using one hand, break up larger soil aggregates to assess their strength. Consider their shape, porosity and roots.

Step 4: soil scoring

Assign a score using the descriptions and photos overleaf.

Step 5: management

Consider management options based on the soil structure score. Then reassess:

- After a change in management practice
- After grazing/trafficking on wet ground
- Routinely every two years on grassland
- Routinely after each rotation on arable land

Further information

See **ahdb.org.uk/GREATsoils** for more information (including management options).

This factsheet is based on the VESS method of soil structure assessment – **sruc.ac.uk/vess**

Use this ruler to measure the depth of any limiting layer (cm). 5 10 15 20 25

Score	Soil structure	Soil aggregates	Description	Management
Score 1: GOOD Crumbly (aggregates readily crumble with fingers).			Good soil structure, highly porous. Small, rounded, crumb-like aggregates (<6 mm). Numerous, well-distributed roots down to spade depth. Sweet, earthy smell.	No management changes needed, continue routine monitoring.
Score 2: GOOD Intact (aggregates easily break apart with one hand).			Good soil structure, mostly porous. Larger rounded aggregates (2 mm to 7 cm). Numerous, well-distributed roots down to spade depth. Sweet, earthy smell.	No management changes needed. Reassess annually on grassland. Continue rotational monitoring on arable land.
Score 3: MODERATE Firm (most aggregates break apart with one hand).			Adequate soil structure, less visible pores. Rounded aggregates, with some angular (2 mm to 10 cm). Fewer roots distributed within soil aggregates. No noticeable smell.	Minimise traffic on wet ground. Infrastructure changes in grassland can help, e.g. back-fencing, multiple field entrances or tracks. Consider cultivation depth on arable land in autumn.
Score 4: POOR Compact (effort needed to break apart aggregates with one hand).			Poor soil structure, very few pores. Mostly large angular aggregates (>10 cm). Reduced rooting, clustered in large pores, earthworm channels and cracks between aggregates. Red/orange mottling may be present (sign of poor drainage). May have 'bad egg' smell.	Minimise traffic on wet ground. Check subsoil layers for compaction. Consider targeted cultivations under the right soil conditions. On grassland, consider using a sward slitter or aerator (<10 cm depth) and a sward lifter/top-soiler (10 to 30 cm depth). If the sward is poor, consider ploughing or reseeding. On arable land, consider improved drainage and diversifying crop rotations, especially the inclusion of no-till periods (e.g. ley-arable rotations).
Score 5: POOR Very compact (aggregates difficult to break apart with two hands).			Poor soil structure, very few pores. Very large angular or platy aggregates (>10 cm). Few roots, if any, restricted to the surface, down large pores, following earthworm channels or cracks. May be grey/blue in colour, or with orange mottling (sign of poor drainage). Strong 'bad egg' smell.	Minimise traffic on wet ground. Check subsoil layers for compaction. Consider targeted cultivations under the right soil conditions. On grassland, consider using a sward slitter or aerator (<10 cm depth) and a sward lifter/top-soiler (10 to 30 cm depth). If the sward is poor, consider ploughing or reseeding. On arable land, consider improved drainage and diversifying crop rotations, especially the inclusion of no-till periods (e.g. ley-arable rotations).

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10.3 ‘30 min worms’ methodology (UK Soils)

Print the ‘30 min worms’ method (UK Soils, no date) below to take into the field for use when assessing earthworms.

Method

Safety information: This is an outdoor activity, digging holes can be strenuous, cover open wounds before handling soils, and wash your hands after the assessment.

Equipment

Spade & ruler *Mat* *Pot for worms* *Bottle water* *Record keeping*

Procedure

5 soil pits per field using standard W shape field sampling

1) At each soil pit spot, check the soil surface for the presence of middens (key shown) and tick/cross on the results sheet

2) Dig out a 20 cm x 20 cm x 20 cm soil pit and place soil on mat (30 sec). 20 cm = 8 inches)

3) Hand-sort soil (5-minutes), placing each whole earthworm into the pot. Note if pencil size vertical burrows are present and tick/cross on the results sheet

4) Count the total number (adults and juveniles) of earthworms and note down

5) Select the adult earthworms (usually only a few) and return juveniles to soil pit. Only adults have a saddle - the reproductive ring near the head. *Top tip: a saddle can be more obvious on the underside of the earthworm.*

6) Count the number of each type of adult earthworm (key shown) and note down. *Top tip: take a photo for your records.*

7) Return worms to the soil pit and back fill with soil

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