ASDA

Soil health assessment guide

UNIVERSITY OF CAMBRIDGE
INSTITUTE FOR SUSTAINABILITY LEADERSHIP

NIAB

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Contents

Introduction	3
Importance of good soil management	4
What is soil?	5
Indicators of soil health	6
Sampling for soil health	7
Soil texture – the skeleton of the soil	9
Assessing soil texture	10
Soil structure and physical condition	11
Field measure – visual evaluation of soil structure (VESS)	12
Field measure – soil compactness	13
Field measure - earthworms	14
Soil sample analysis – organic matter	15
Soil sample analysis – soil pH	16
Soil sample analysis – soil nutrients	17
Case study	18
Further information	19

Designed and produced by NIAB in association with CISL and ASDA.

Introduction

To understand the soil environment and then manage it more effectively it is important to determine how well the soil is performing all of its functions and how those functions can be maintained. It is recognised that physical, chemical and biological aspects of the soil interact to determine overall soil health and therefore it is important to include measures of all these aspects. Some measures can be made directly in the field; other characteristics are measured by sending away samples for analysis, but it is important to take an integrated approach to assessment to get a good picture of soil health.

As a grower a key objective is to maximise crop production in the present whilst ensuring a sustainable future. To achieve this it is helpful to remember that nearly all soils processes are powered by living organisms and the aim of soil management is to maintain the soil environment and keep this soil-crop ecosystem running smoothly. Soil health is therefore the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans.

To help in this process NIAB has been working with University of Cambridge Institute for Sustainability Leadership (CISL) and ASDA to provide guidance on how assessments of soil health indicators can be made most effectively on-farm.

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Importance of good soil management

The importance of good soil management has gained recognition and priority amongst businesses in the food and farming supply chain including retailers.

Important soil functions related to crop production and environmental quality include:

- Retaining and cycling nutrients and supporting plant growth
- Sequestering carbon
- Allowing infiltration, and facilitate storage and filtration of water
- Suppressing pests, diseases, and weeds
- Detoxifying harmful chemicals
- Supporting the production of food, feed, fibre and fuel

When the soil is not functioning to its full capacity, sustainable productivity, environmental quality, and net farmer profits are jeopardised over the long term.

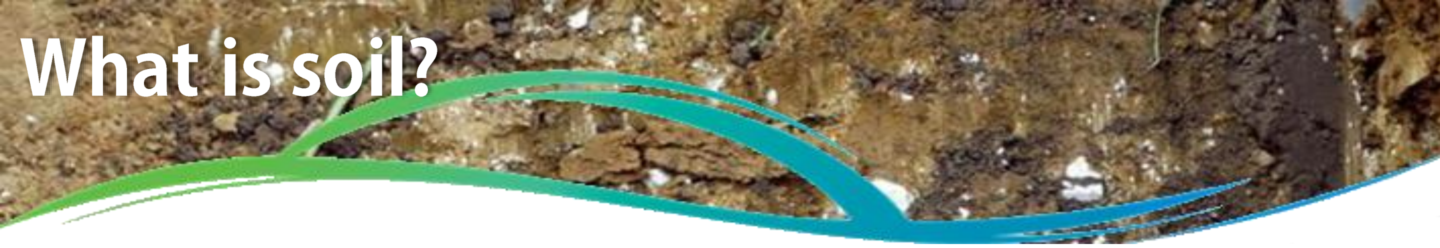
The economic benefits of maintaining and improving soil health include:

- Better plant growth, quality, and yield
- Reduced risk of yield loss during periods of environmental stress (e.g. heavy rain, drought, pest or disease outbreak)
- Better field access during wet periods
- Reduced fuel costs by requiring less tillage
- Reduced input costs by decreasing losses and improving use efficiency of fertiliser, pesticide, herbicide and irrigation applications

Why assess soil health?

- Increase awareness of soil health
- Understand constraints beyond nutrient deficiencies and excesses
- Target management practices to alleviate soil constraints
- Monitor soil improvement or degradation resulting from management practices
- Facilitate applied research – compare management practices to develop recommendations for farm and field specific soil health management planning
- Land valuation – facilitate the realisation of equity embodied in healthier soils
- Enable assessment of farming system risk

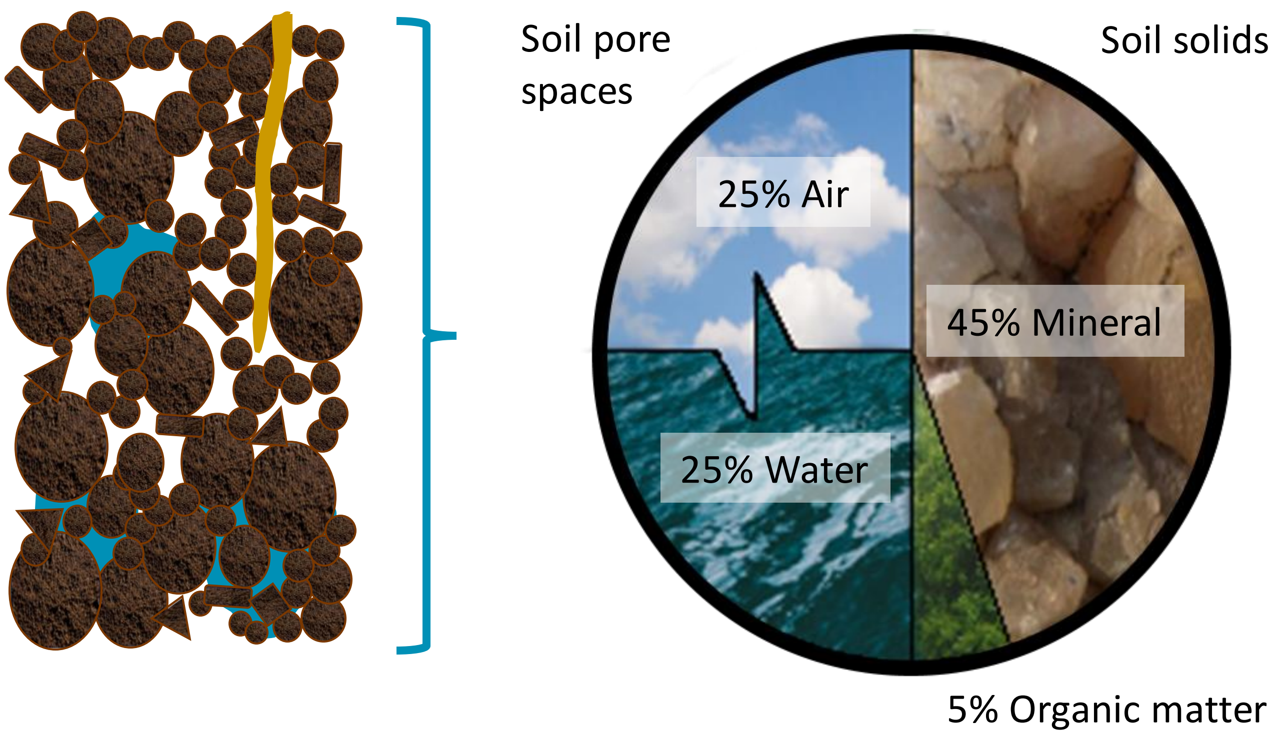
What is soil?



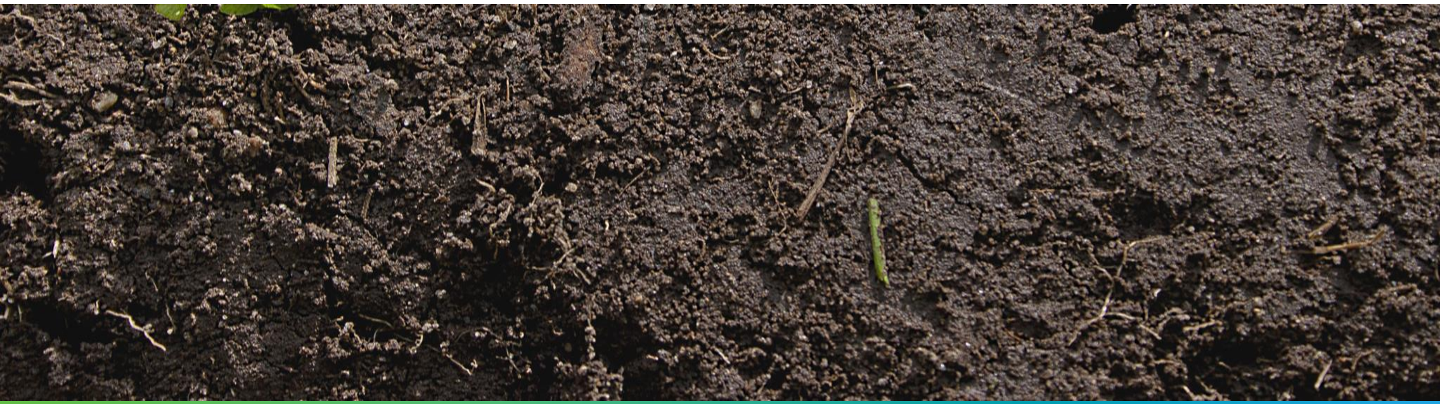
Soil is a mixture of minerals, dead and living organisms (organic materials), air, and water in varying proportions and these four ingredients interact with one another in amazing ways, making soil one of our planet's most dynamic and important natural resources.

A healthy soil is defined as one that has a resilient capacity to respond to (agricultural) intervention, such that it supports the provision of ecosystem services (e.g. clean air and water, abundant biodiversity) as well as optimising agricultural production.

Healthy soil is....



Knowing what soil is made of is only part of the story. The way the soil constituents are organised (structure) has a key influence on how they interact with one another to control soil processes.

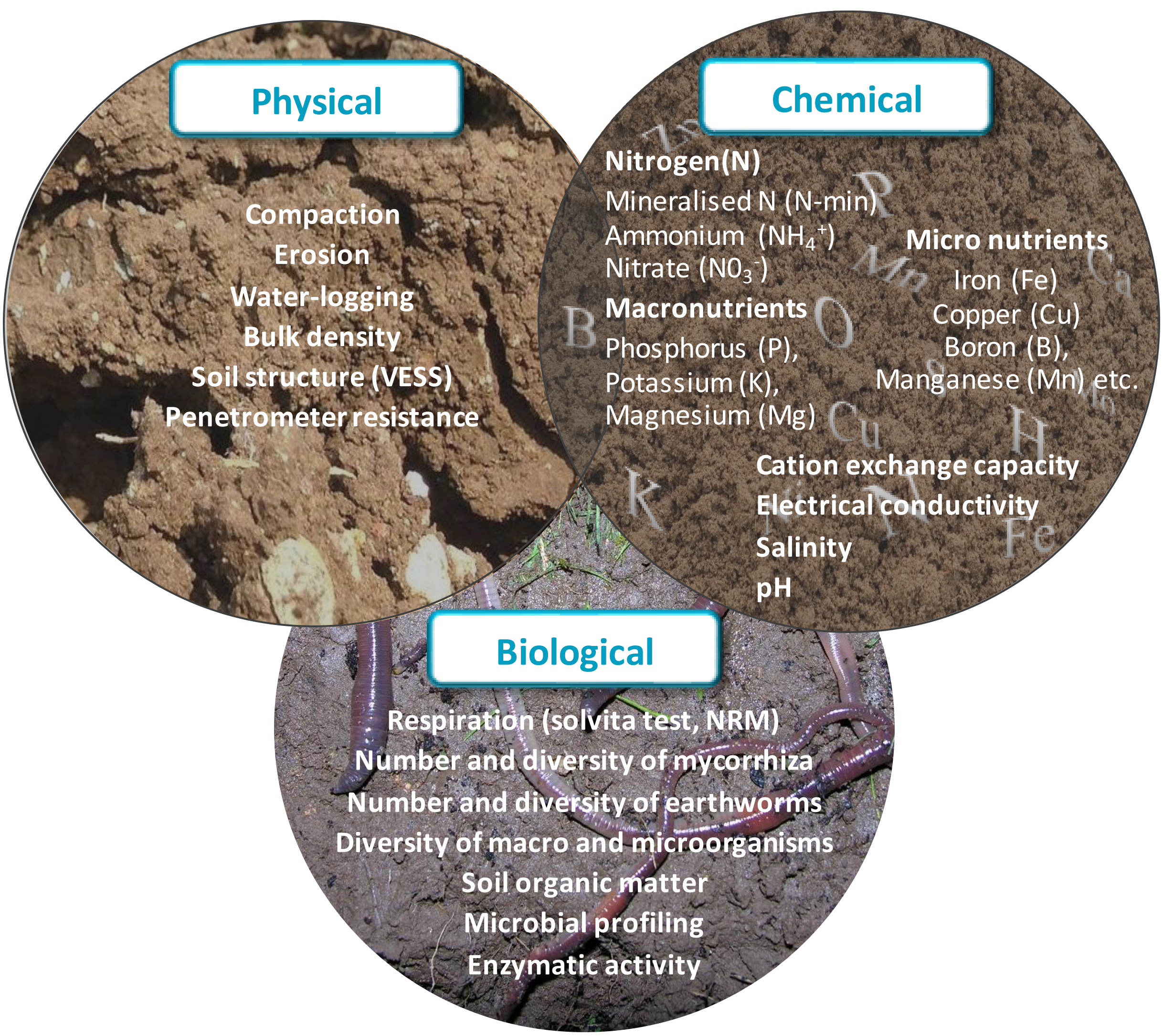


Indicators of soil health

There are many indicators available that provide clues about how well the soil can function. The indicators can have physical, chemical and biological properties or be indicators of overall function such as crop yield or amounts of soil erosion. But soil health cannot be determined by only measuring crop yield, water quality, or any other single outcome.

There are a whole range of measures that can be used. NIAB has screened possible indicators to identify a set of procedures that are relatively easy and cost effective to measure, clearly linked to changes in soil functions and are sensitive to variations in climate and management. These are not the only indicators available and NIAB recommend this set as a useful minimum baseline for soil health.

After measurements are collected, the data can be evaluated by looking for patterns and comparing results to measurements taken at a different time or in a field with the same soil type but different management approach.



Sampling for soil health

A soil health assessment analysis is only as good as the observations and samples that have contributed to it.

Choosing representative sampling sites

As for all soil sampling, the area selected should be relatively uniform.

- Avoid headlands, gateways, unless you are specifically targeting them as a sampling site, and also avoid marked wheelings where possible.
- Ensure soil texture and cropping history show limited variation. There may be just one sample site per group of fields, or there may need to be several per field, where soil texture varies markedly.

Choose sites where the data will best inform farm practice in soil management.

You can use a yield map and soil scanning data (if available) to identify possible sample sites. Here sample sites have been selected within areas that have shown low (L), medium (M) and high (H) yields of winter wheat to investigate why these patterns are occurring.

Sampling timing

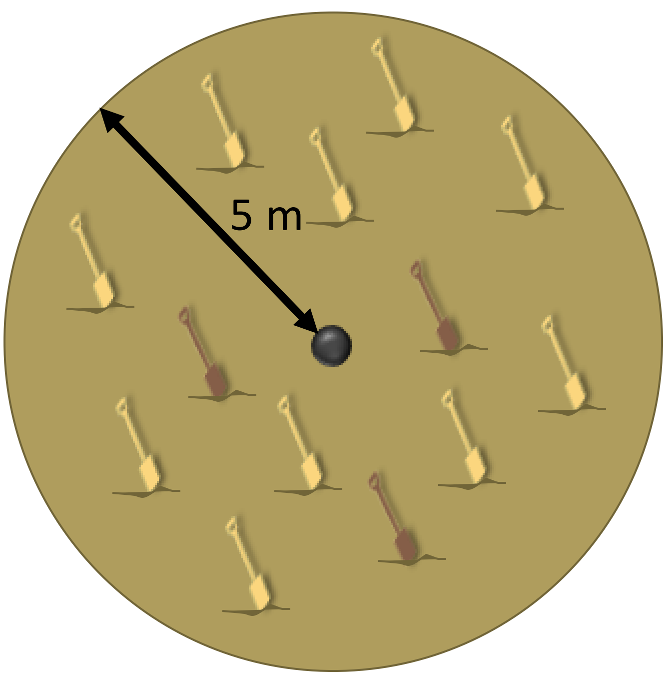
Soil observation and sampling should take place at a time when soil is moist and at least one month after any cultivations / moderate soil disturbance. Ideally the sample should not be taken within three months of application of organic inputs.

Regular sampling for soil health monitoring is expected to take place once per rotation and at the same point in the rotation to maximise comparability between samples. You should choose the point in the rotation to integrate soil health assessment which will allow you to fit in the assessment most effectively and then act on the results.

Sampling for soil health

- Locate the sampling site. The site is a circle of c. 5 m radius. You may want to record the centre point accurately so you can come back to it easily; many mobile phone apps can do this!
- You are combining measures of soil physical condition (VESS, penetrometer) and soil biology (earthworms) made at three locations with measures assessed on samples collected and sent to the laboratory for more detailed analysis.
- Each soil sample should be a composite of 10-15 sub-samples taken across the site using a random pattern. The distance between sub-samples should be at least 1.5 m.
- Penetrometer readings can also be taken which measures resistance in the soil in pounds per square inch (PSI) giving an indicator of soil compaction and therefore soil health.

Sampling site within field



Spade assessment of soil structure

Randomly located multiple cores (use numbers advised) consolidated into sample sent for analysis

Kit contents checklist:

- ✓ Spade
- ✓ Marker pen
- ✓ Plastic bags
- ✓ Sample containers
- ✓ Penetrometer

What to do.......

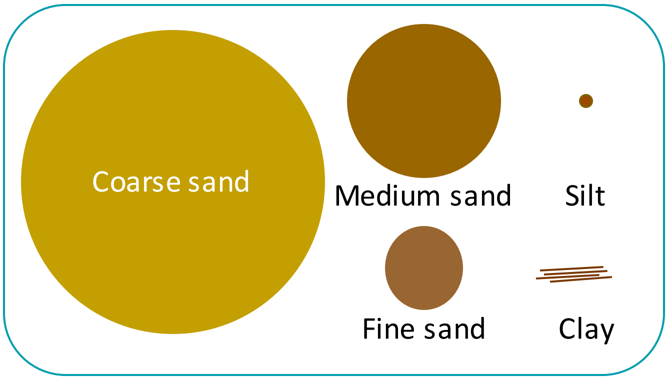
Steps for taking a soil sample at each location

1. Remove surface debris
2. Use a spade to dig a small hole about 20 cm deep.
3. From the side of the hole take a vertical, rectangular slice of soil 15 cm deep and about 5 cm thick.
4. Place the sub-sample into a clean plastic bag or container.
5. Repeat steps 1 to 4 for each site bulking the samples together.
6. Take a sample (about 300 g) and place into a clearly labelled sample bag. This is the soil sample for the field or part of field.
7. At each of the sub-sample locations, you could also collect soil hardness information with a penetrometer, if the soil is at / close to field capacity. Record the maximum hardness (in psi) from the 0 to 15 cm and at the 15 to 45 cm depth ranges.

Ideally use a laboratory for soil analysis that is a member of the Professional Agricultural Analysis Group (PAAG)

Soil texture – the skeleton of the soil

Relative size of soil particles

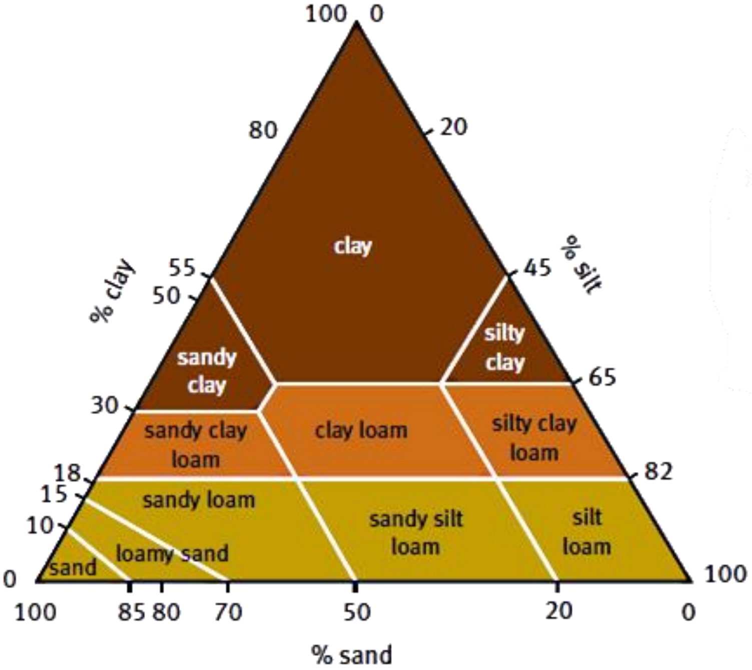


Soil texture can have a major effect on many other properties and is one of the fundamental characteristics of the soil. Soil texture is not a soil health indicator *per se*, but a knowledge of soil texture is needed to interpret most soil health indicators.

In most soils, the majority of the solids materials are minerals inherited from the soil parent material. Mineral particles are defined by their sizes (gravel, sand, silt and clay). They also differ in how they influence soil functioning beyond size-related effects.

The relative proportions of sand, silt and clay determine a soils texture and textural class.

Soil pyramid for determining soil textural class



- Sandy and light silty soils
- Medium soils
- Heavy soils

Sandy and light silty soil	0-18% clay
Medium soil	19-35% clay
Heavy soil	>35% clay
Shallow soil over chalk/ limestone	<30 cm depth
Peaty soil	>20% organic matter

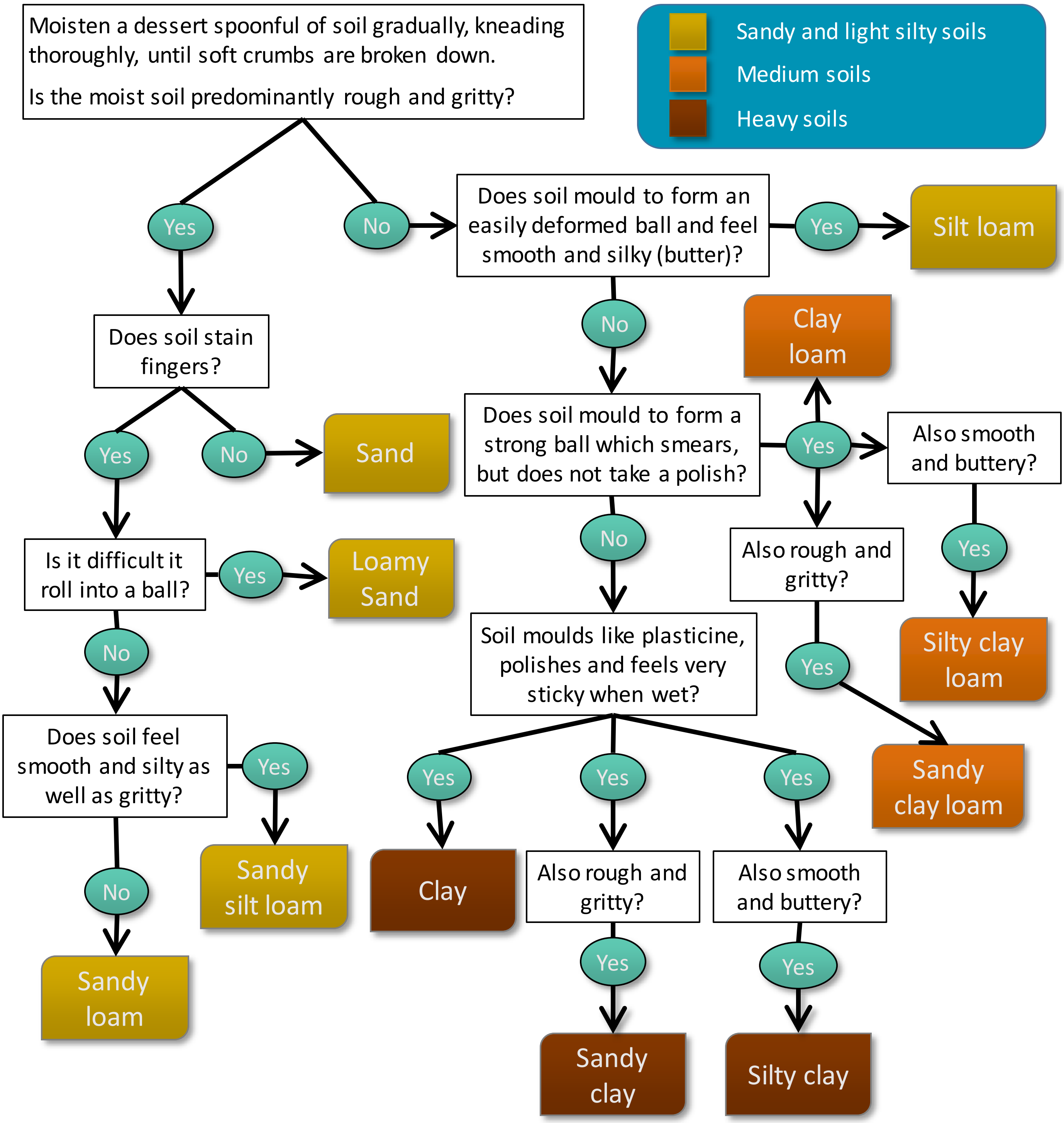
Impact of clay on soil chemical properties

The amount of clay can greatly influence the ability of the soil to hold and exchange nutrients, and store organic matter. Clays have a lot of surface area (because they are very small and layered particles) and the surfaces are negatively charged, so that positively charged nutrient ions can 'stick' to them. This ability of soil particles to hold onto nutrient ions and exchange them with the soil water, or soil solution, is referred to as the soil's cation exchange capacity (CEC).

Assessing soil texture

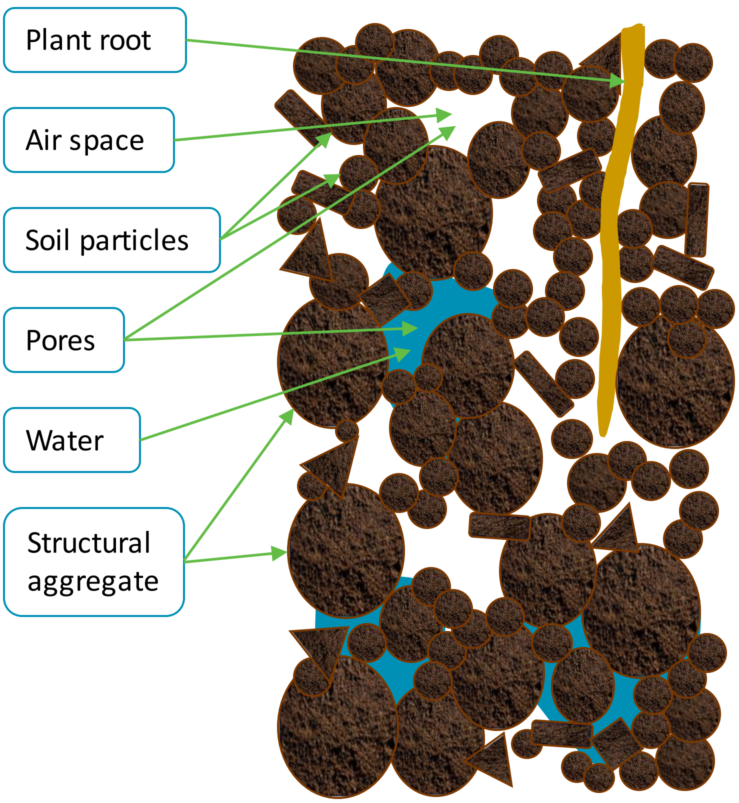
What to do......

Soil texture can be determined by taking about a dessert spoonful of soil in your hand and working between your fingers and thumb to break down any clumps or aggregates, removing any obvious stones and plant debris. If the sample is too dry you will need to wet it gradually with water until it is wet enough to hold together and determine if the sample is sticky. Then work through the flow diagram below to determine your soil type.



Soil structure and physical condition

Texture is the ratio of the three soil particle types (sand, silt, clay). Soil structure describes the relationship between solids (soil particles and organic matter) and spaces and is determined by how the soil particles are held together into aggregates (structural units). These units are bound together by physical chemical and biological processes. The physical characteristics of soil allow water and air to infiltrate, roots to explore, and biota to thrive.



Most pores in a sandy soil are large (but generally still smaller than 2 mm) whilst the pores in a clay soil are small (generally less than 0.002 mm).

Soils with a higher clay content have a higher proportion of small pores and so have a greater ability to retain nutrients and are also able to stabilise organic matter.

Pores in the soil are important in governing water and air movement which affects water infiltration, permeability, water storage, aeration, nutrient leaching, and denitrification.

Soil organisms and plant roots live and function in pore spaces.

Poorer compacted soil layers, caused by cultivations and wheel traffic, are dense with little air flow. This restricts water movement and inhibits root growth so the growing crop is unable to access nutrients and water efficiently.

Good crop growth relies on a structure that provides:

- Good soil aeration (for respiration)
- Drainage
- Efficient supply of nutrients and water.
- pH balance preventing leaching of nutrients and contamination of water courses
- Movement of sodium as excess clogs soil pores trapping water
- Decomposing organic matter
- Fine roots and fungal hyphae to stabilise aggregates

Soil structure can be improved by adding soil amendments to increase organic matter and improve the soil ecosystem, making clay more porous and sand more water retentive

FIELD MEASURE
Visual Evaluation of Soil Structure (VESS)

When to do an assessment

Sample when the soil is moist – if the soil is too dry or too wet it can be difficult to distinguish signs of poor structure. Spring or autumn are usually the best times of the year.

Don't just do it once

Compare samples from the soil health sampling site with areas where you expect good structure (uniform crop growth) and from areas where you expect poor structure (wheeled areas or areas near gates) to allow you to see structural differences.

Download a copy of the VESS score chart from sruc.ac.uk

Kit contents checklist:

- ✓ Spade
- ✓ Plastic tray or mat
- ✓ Tape measure or ruler
- ✓ VESS score chart
- ✓ Penetrometer

What to do…….

1. Dig out a spadeful of soil to a depth of about 25 to 30 cm.
   - If the soil is freshly dug or recently tilled, simply push the spade vertically into the soil and dig out a spadeful.
   - In soils with a hard surface or in crop, cut out a spade-sized block of soil down to approximately 25-30 cm. Cut down on three sides and then lever the block out leaving one side undisturbed.
2. Gently open the undisturbed side of the block like a book and start to break it up.
   - If the block breaks up easily into small fragments then the structure is likely to be good.
   - If the block is hard to break up and is held together by roots, pull the roots apart to expose the soil fragments.
3. Break up the block to determine if there are any distinct layers of differing structure. If the block is uniform assess as a whole, if there are two such layers, then score separately.
4. Measure the depth and thickness of any distinct layers
5. Break up the soil with your hands into aggregates and give a score by matching what you see to the VESS chart, available from the link on the left.

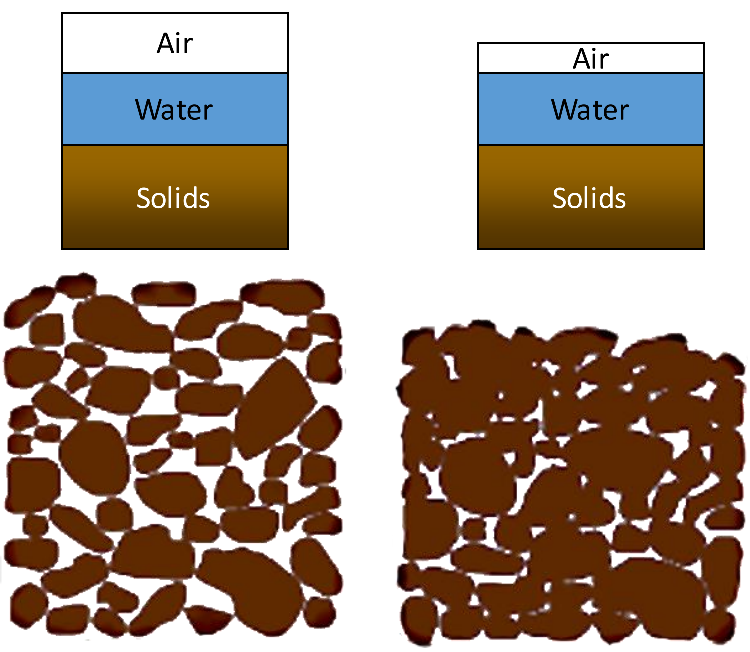
FIELD MEASURE
Soil compactness

Field penetration resistance is an indicator of the soil compaction status. Compaction occurs when large pores are packed closer together through tillage or traffic with heavy equipment, particularly on wet soils.

It is measured in the field using a penetrometer pushed through the soil profile at two depth increments (surface 0 – 15 cm and subsurface 15 – 45 cm).

The level of soil moisture can greatly affect the ease the probe penetrates the soil, and therefore the measured values. It is recommended that penetration readings be taken when the soil is friable and near field capacity. If soil conditions are not ideal, it is important to note conditions at the time so that proper interpretation of the reading can be made.

Effects of compaction on soil structure



High	Soil volume	Low
Low	Bulk density	High
More and larger	Pore space	Fewer and smaller
Low	Soil strength	High

Kit contents checklist:

✓ Penetrometer

What to do.......

1. Apply slow even pressure so the penetrometer advances into the soil at a rate less than 4 cm per second.
2. Record the highest pressure reading measured for each of the two depths
3. If you detect a hard layer, make a note of the depth – this is important for future management decisions.
4. Repeat the process at each of the sub-sampling station (see soil sampling for chemical analysis)

Root growth decreases linearly with increasing penetration resistance, until stopping above 300 psi

Growth of mycorrhizal fungal hyphae and mobility of other beneficial soil organisms may be severely restricted in compacted soils

Compaction reduces crop growth, increases weed pressure and makes crops more susceptible to pathogens

FIELD MEASURE
Earthworms

Why are earthworms important?

Earthworms:

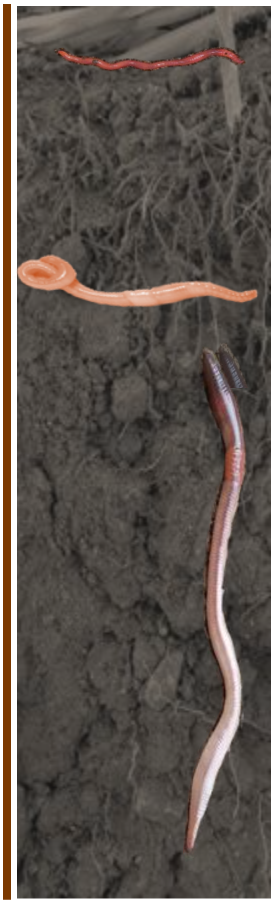
- Help break down organic matter
- Mix materials in the soil profile
- Alleviate compaction
- Help form soil aggregates
- Develop soil pores and channels which help drainage aeration and root growth.

Why count earthworms?

Earthworms are excellent indicators of soil health as they tend to be both easily visible and sensitive to management being affected by changes in pH, waterlogging, compaction, tillage, crop rotation and organic matter management.

There are three different groups of earthworm

0 cm



20 cm

Epigeic species: surface dwellers living in the leaf litter. They are brownish red in colour and small, generally 2 to 6 cm long

Endogeic species: shallow burrowing species living in horizontal burrows in the topsoil (between 5 to 40 cm deep). These worms are pale in colour, can be up to 18 cm long

Anectic species: vertical burrowing species that can be found up to 4m below the soil surface. Adults are usually between 15 and 45 cm long and are a reddish- brown colour with darker heads

Kit contents checklist:

- ✓ Spade
- ✓ Large tray or mat
- ✓ Container or pot for temporarily storing earthworms
- ✓ Bottle of water

What to do…….

Steps for counting earthworms at each location

1. Dig a soil pit (20 cm x 20 cm x 20 cm) and place soil in the large tray or on a mat. You can use the VESS block or one collected alongside.
2. Sort through the soil by hand putting each whole earthworm into the pot
3. Make a note of:
    1. Total number of earthworms in the sample
    2. The number of adults and juveniles
    3. The number of each type of adult worm present
4. Return all of the earthworms to the pit
5. Repeat steps 1 to 4 for at least three pits. For a detailed study of earthworms at least 10 pits are needed

What to look for

Adult earthworms differ from juveniles in that they have a saddle…..

Further information can be found on the AHDB how to count earthworms leaflet

SOIL SAMPLE ANALYSIS
Organic matter

Organic matter:

- Plays a vital role in soil structure, improving soil aeration, water retention and drainage
- Consists of both living and dead plant and animal tissue providing a fertile and healthy environment for the development of healthy plants
- Has many negative charges which improves the cation exchange capacity of the soil. This enables the soil to hold on to nutrients which makes available to the crop and prevents them from leaching deep into the subsoil

Organic matter content is often provided by soil analysis laboratories along with major and minor nutrient contents and is a measure of carbon-containing material.

Physical benefits

- Enhances aggregate stability, improving water infiltration and soil aeration, reducing runoff
- Improves water holding capacity
- Reduces the stickiness of clay soils making them easier to till
- Reduces surface crusting, facilitating seedbed preparation

Chemical benefits

- Increases soil CEC or its ability to hold onto and supply essential nutrients such as calcium, magnesium and potassium
- Improves buffering capacity, the ability of a soil to resist pH change
- Accelerates decomposition of soil minerals, making the nutrients in the minerals available for plant uptake

Biological benefits

- Provides food for the living organisms in the soil
- Enhances soil microbial biodiversity and activity that can help in the suppression of diseases and pests
- Enhances pore space through the actions of soil microorganisms. Helping to increase infiltration and reduce runoff

The organic matter content of agricultural topsoil is usually in the range of 1–6%

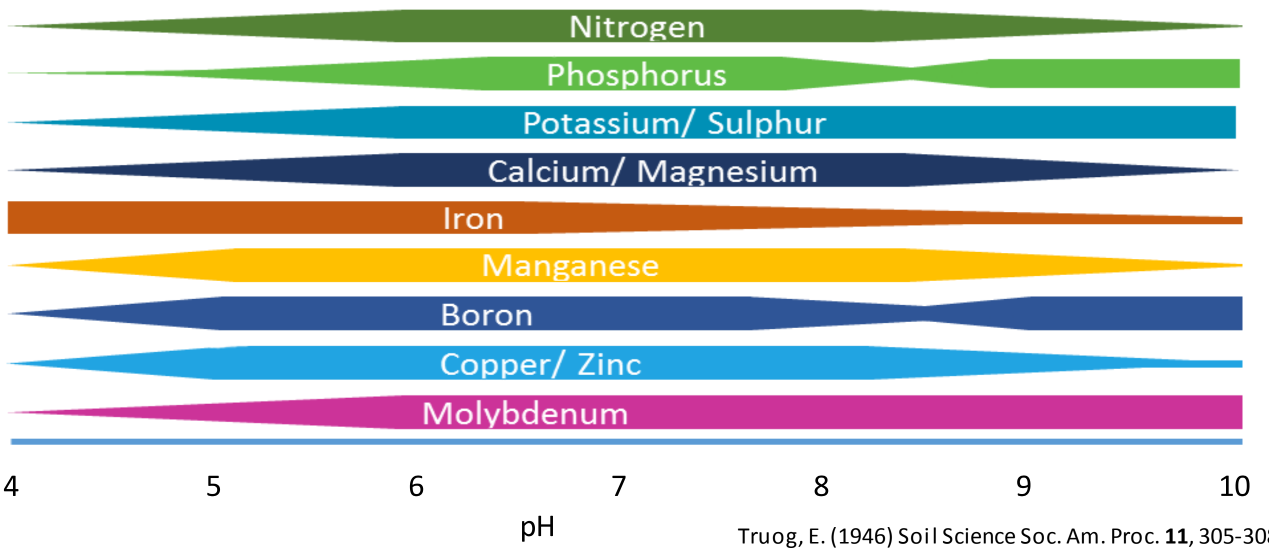
Organic matter contains a large amount of carbon-based compounds. The largest component of organic matter is dead matter. In soils, dead matter makes up roughly 85% of the organic matter.

Organic matter includes dead matter, living microbes, and living parts of plants (e.g. roots).

Compounds like sugars, starches, and proteins are relatively easy to break down, and do not take as much time. Fungi and bacteria in the soil can break down these compounds making the energy they provide readily available. However, some compounds like cellulose can take much longer to be broken down, on the order of 10 to 1,000 years.

SOIL SAMPLE ANALYSIS
Soil pH

Soil pH is a measure of how acidic the soil is and is an important indicator of soil health. It affects crop yields, crop suitability, plant nutrient availability and soil micro-organism activity which influence key soil processes.

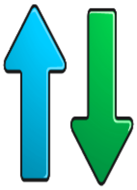


Truog, E. (1946) Soil Science Soc. Am. Proc. **11**, 305-308

The availability of some plant nutrients is greatly affected by soil pH. The "ideal" soil pH is close to neutral, and neutral soils are considered to fall within a range from a slightly acidic pH of 6.5 to slightly alkaline pH of 7.5. Most plant nutrients are optimally available to plants within this pH range, and is generally very compatible to plant root growth.

The pH scale goes from 0 to 14 (with a neutral pH represented by 7.0). Most agricultural soils have pH values between 5.5 and 7.5

If pH is too high, nutrients such as phosphorus, iron, manganese, copper and boron become unavailable to the crop.



If the pH is too low, calcium, magnesium, phosphorus, potassium and molybdenum become unavailable to the crop

The pH scale is logarithmic; a pH of 5 is ten times more acidic than a pH of 6 and 100 times more than pH7

A soil pH that is too high or too low may also cause a decline in microbial activity, decrease in crop yield, and a deterioration of soil health.

Soils with high clay and organic matter content are more able to resist a drop or rise in pH (have a greater buffering capacity) than sandy soils

Soil pH can be managed by measures such as applying the proper amount of nitrogen fertiliser, liming, and cropping practices that improve soil organic matter and overall soil health.

Increasing organic matter content of the soil can improve soil buffering capacity to limit changes in pH.

SOIL SAMPLE ANALYSIS
Soil nutrients

Crops do not grow properly if nutrients are not present at the right time of the season, in sufficient quantities and in balance with one another. When plants do not grow well they are more susceptible to disease, loss of yield, and poor crop quality which leads to reduced economic returns.

Excessive nutrient application may also create problems that lead to poor plant growth or to environmental degradation. These concerns have resulted in more emphasis on better management of N and P as their excessive use contributes to surface and groundwater degradation and to greenhouse gas emissions.

Soil nutrient analyses are based solely on chemical extraction and are used to recommend the type and quantity of nutrients to add through amendments, as well as whether soil pH needs to be adjusted for improved nutrient availability.

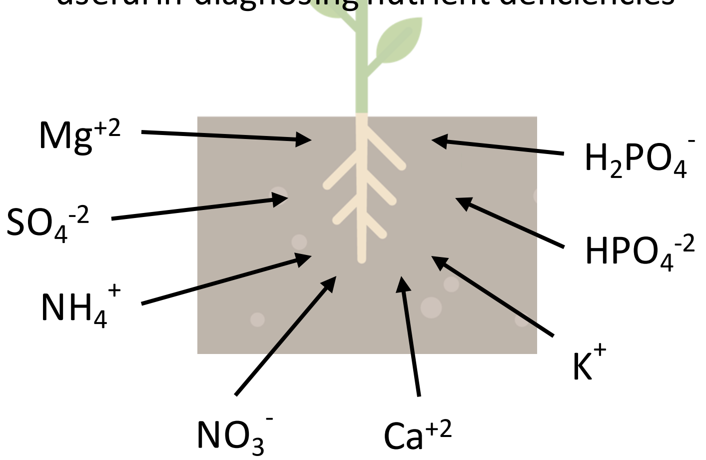
Alongside measuring soil acidity (pH) the standard soil analysis undertaken by a laboratory estimates the plant-available concentrations of the major nutrients, phosphorus (P), potassium (K) and magnesium (Mg).

Uptake of plant nutrients

» Each nutrient is taken up in an "ionic" or charged form

» Knowing the form the plant absorbs nutrients helps understanding what controls the cycling and movement in the soil

» Understanding nutrient and mobility are useful in diagnosing nutrient deficiencies



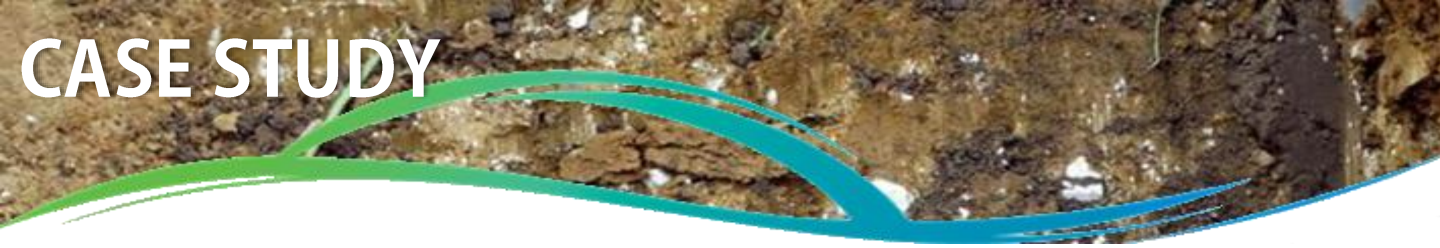
Plant nutrients are essential for crop development if:

- The plant cannot complete its life-cycle without it
- The function cannot be replaced by another chemical
- Directly involved in growth and reproduction

Macronutrients are elements which plants require in relatively large amounts
Micronutrients are those plants require in much smaller amounts

Plants require ten different macronutrients (calcium, carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, chlorine, sulphur and magnesium) and six micronutrients (iron, manganese, zinc, copper, boron and molybdenum)

Soil analysis in the laboratory uses chemical extractants to provide an estimate of the amount of available under field conditions



How using cover crops and reducing inversion tillage improved the soil and increased productivity

Challenges:

- Reduce losses of top soil due to wind erosion
- Improve soil biology and minimise loss of nutrition

Motivation for change:

- Loss of top soil year on year due to wind erosion
- Promoting, balancing and feeding soil biology & improving the soil available nutrition
- Belief that long term use of cover crops can reduce the amount of artificial fertilisers used

Actions taken:

- Treated each field separately on the basis of the outcomes of soil analysis
- Started planning rotation timings between crops, working out what we could establish and grow
- Cover crops drilled between every crop - a 'no bare soil policy'- even if the gap is only weeks not months
- Attended events to better understand what species to use in the cover crop, and for what benefit – not just for the soil but for the next crop
- Stopped the blanket policy of cultivate everything, reducing the amount of land that is ploughed each year, a mindset change for the whole team

Farm facts

Farm name: Cambridge Farm Growers Ltd

Grower: Charles Shropshire

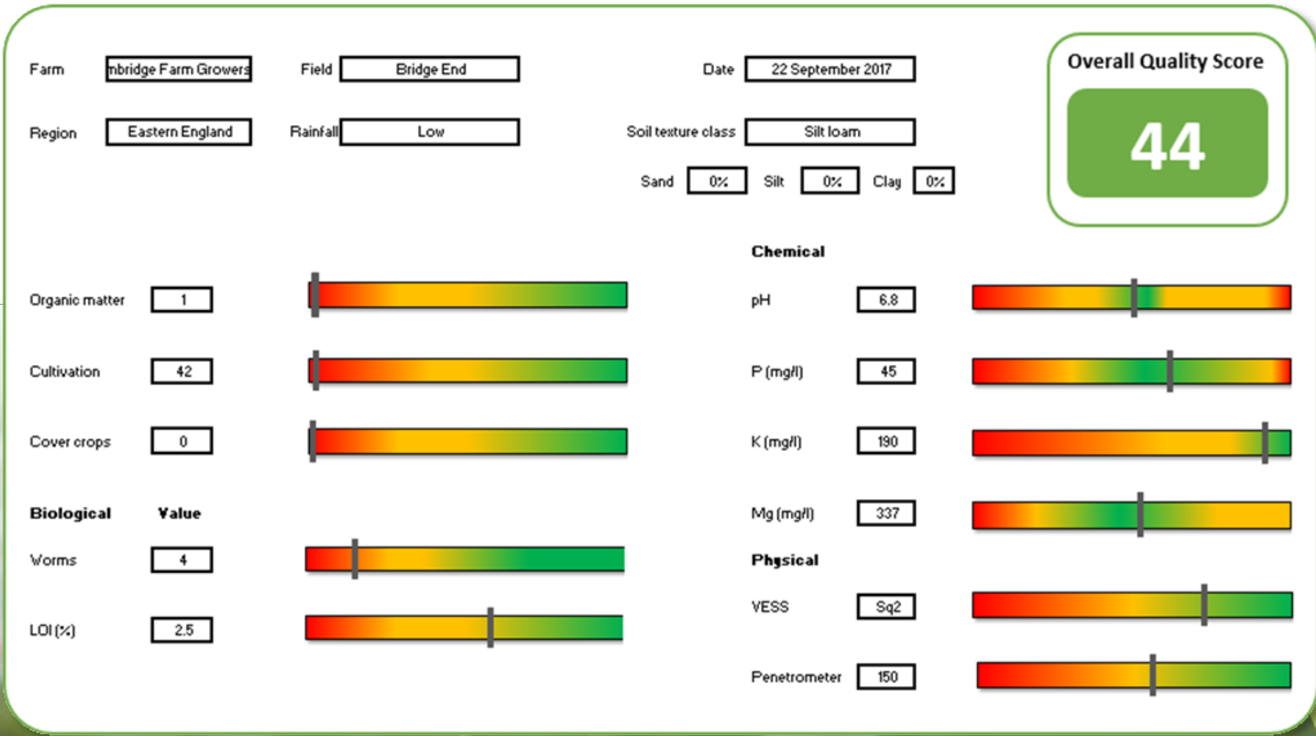
Ha: 4000ha

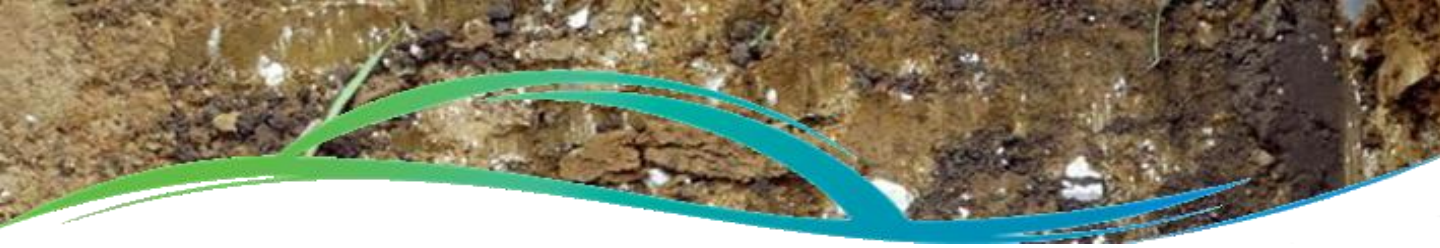
Rotation: Lettuce, Wheat, Maize, Celery/ Beetroot, Maize, Wheat, Onions/ Potato

Location: Cambridgeshire

"We see cover cropping as a 'need to do' not a 'nice to do'. Soil is such an important part of our farm and we need to invest in its restoration and regeneration.

We have had to start viewing cover crops as cash crops as they add significant financial benefit to the farms longevity"





Outcomes

CFGL have been using a programme of cover crops and reduced tillage for 2 years, starting small to understand the operation that is required and the costs involved. Since then they have been assessing soil health to monitor the improvement to their soil but the benefits to crop quality and yields have been testimony to the programme they have followed.

Since starting we have seen:

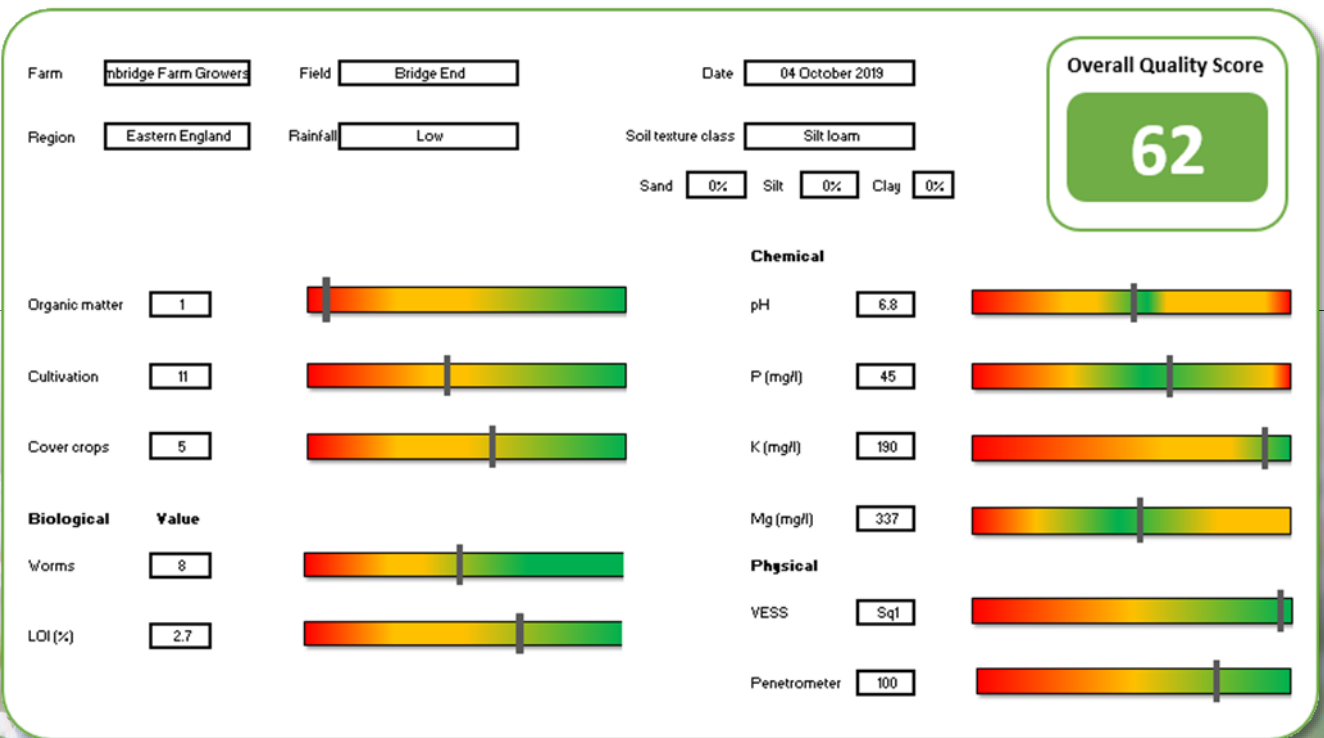
A reduction in soil loss from wind erosion across our fields, which is fantastic

- An improvement in the friability of the soil
- Better establishment of arable crops
- A clear increase in the number of earthworms at all stages of maturity
- That even after costing in the production of cover crops, there is a reduction in cultivation costs, as well as reduction in the carbon footprint

We are pleased with the outcome of the programme as we were told it can take more than five years to see significant changes in soil characteristics and we are already seeing improvements

They have also learnt that:

- Timing is important. Cover crops drilled too late will struggle to establish and this must be factored in when choosing what cover crop to grow and the ability to irrigate if needed.
- It is important to research what species to use in the seed mixes and undertake both small and large trials to monitor the benefits as some species will help unlock vital nutrients in the soil, others will encourage mycorrhizal fungi keeping the soil alive – especially over winter.



Further information:

AHDB: Great soils

AHDB: Testing soil health

Visual Evaluation of Soil Structure

Earthworm identification guide

Think soils

Soil texture calculator

Video: LEAF The importance of soil at Greenseed

Simply sustainable soils

FAO: Soil assessment

IPL INTERNATIONAL PROCUREMENT & LOGISTICS

ASDA

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