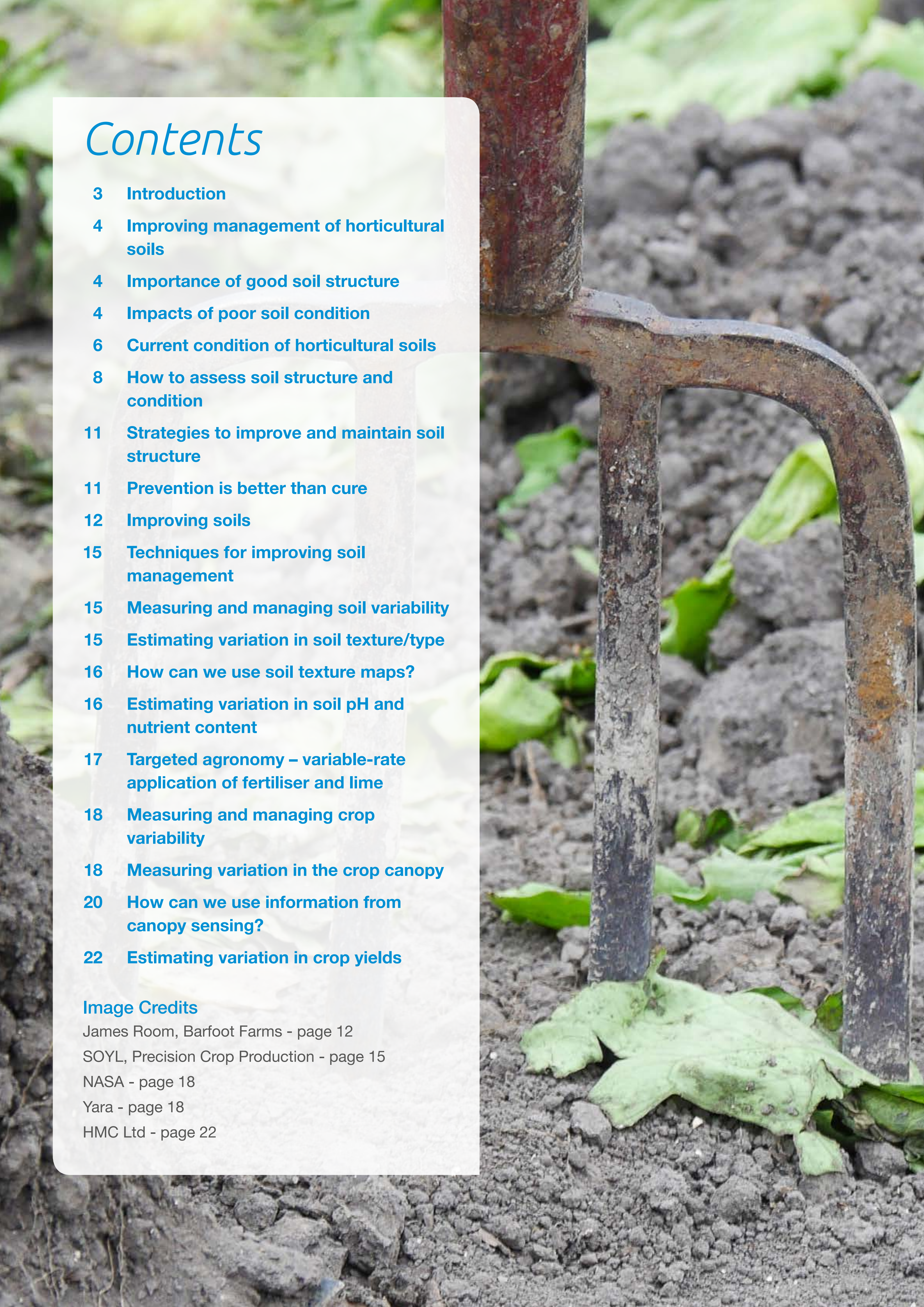
GREATSOILS

AHDB

Soil management for horticulture

HORTICULTURE



Contents

Image Credits

James Room, Barfoot Farms - page 12

SOYL, Precision Crop Production - page 15

NASA - page 18

Yara - page 18

HMC Ltd - page 22

Introduction

This soil management guide is a practical manual for growers and agronomists.

Pages 4–14 of the guide focus on soil assessment and management in horticultural cropping systems.

Good soil structure is vital for optimising water and nutrient-use efficiency and for sustaining profitable horticultural cropping systems (page 4). A recent survey of soil condition and soil management practices indicated signs of structural degradation in many soils under annual and perennial horticultural crops and found that soil cultivation practices are often not matched to soil condition (page 6).

This guide provides information on how to assess soil texture, structure and condition (page 8) and considers strategies to improve and maintain good soil structure. These include approaches for avoiding soil compaction where possible (eg lower tyre pressures, limiting wheel loads, avoiding cultivation when soils are wet and controlling traffic – page 11) as well as best practice for alleviating compaction, maintaining good drainage and enhancing organic matter to build productive soils that are more resistant to compaction and erosion, and more resilient during spells of dry and wet weather.

Pages 15–22 provide an overview of current commercially available precision farming techniques, which have the potential to improve soil and nutrient management in horticulture.

Precision farming involves measuring and responding to variability in soils and crops to optimise returns on inputs. Soil variability is one of the main factors determining differences in crop growth. Soil mapping can be used to identify boundaries between soil types and characterise field areas according to their soil pH or nutrient indices. Soil electrical conductivity (EC) scanning and satellite soil brightness imagery can be used to help identify soil variability (page 15).

Precision soil sampling is used to map pH and nutrient indices. A regular or grid-based soil sampling method typically takes samples from approximately equal-sized blocks within a field. Zone-based soil sampling uses existing knowledge of within-field soil variability to direct where samples are taken. Soil pH and nutrient maps can be used for variable-rate fertiliser and lime applications (page 17).

Canopy sensing and yield mapping can help assess crop variability. Canopy sensing uses data (eg from satellites, tractor-mounted sensors or drones) to measure reflectance from the crop surface. Canopy sensing can provide valuable information on the performance of the crop across the entire planted area (ie spatial) and also throughout the growing season (temporal) and can be used as the basis for variable rate nitrogen management (page 18).

Yield monitors provide information on the harvested crop and locate it using GPS coordinates to produce spatial yield maps. Variation in crop yield is a result of the combination of spatially-variable soil, environmental and crop factors. Yield maps can be used to identify the highest and lowest yielding areas of the field to target field investigations (Page 22).

The costs of adopting precision farming will vary depending on the technology but may include machinery/equipment costs, software licences, set-up time etc. It is important to assess the costs of adopting precision farming techniques against the potential benefits. Page 15 of this guide provides an overview of precision farming techniques focused on improving soil and nutrient management – how they work, how they can benefit growers and under what circumstances they are likely to be most effective and profitable.

This guide was developed as part of AHDB Horticulture project CP107c 'The application of precision farming technologies to drive sustainable intensification in horticulture cropping systems'. The work was carried out by ADAS and SRUC.

What are soil texture, soil structure and soil condition?

Soil texture – relates to the proportions of sand (coarse), silt (medium) and clay (fine) particles (ie particle size distribution) and soil organic matter content. Texture can be assessed by hand, and soils with more than 50% sand and less than 18% clay feel predominantly rough and gritty (sands, loamy sands and sandy loams); those with over 20% sand and under 35% clay feel predominantly smooth and silky (silt loams and silty clay loams); and those with more than 30% clay feel predominantly sticky, mould to form a strong ball and take a polish (sandy clays, clays and silty clays).

Organic (peaty) soils have an organic matter content greater than 20%.

Soil structure – is the overall relationship between solids and spaces and is determined by how the soil particles (sand, silt, clay and organic matter) are held together into aggregates (or structural units).

A well-structured topsoil has small, rounded aggregates associated with a dense, fibrous root structure and a range of pore shapes and sizes that form a continuous network, allowing good aeration, root proliferation (to access nutrients and water) and better drainage.

Compacted soils have restricted pore space and aggregates that are either large and angular, or absent (structureless or 'massive'). Any cracks and fissures tend to be horizontal rather than vertical, resulting in a 'platy' structure (like a stack of plates). Compacted soil layers are dense, restrict water movement and roots cannot proliferate, tending to run horizontally along the upper surface of the layer.

Soil condition – the overall assessment of the whole soil in terms of the nature of soil structure in different soil layers. Soil condition controls soil functions, the efficiency of nutrient and water use and the sustainability of production.

Soils in good condition are generally well-structured; moderate soil condition is characterised by larger and more angular aggregates and restricted pore space; and soils in poor condition are severely degraded with very large angular or platy aggregates and/or a very dense compacted layer.

Importance of good soil structure

Soil is the fundamental resource from which crops take up nutrients and water – two of the three building blocks of yield and quality (Figure 1).

Crop growth relies on good soil aeration (for respiration) and drainage and the efficient supply of nutrients and water.

Soil drainage (how quickly water drains from the land) is determined by soil texture and soil structure. Well-structured sandy and light silty soils (<18% clay) tend to drain more quickly than medium-textured soils (18–30% clay), and medium soils more rapidly than heavy soils (>30% clay). However, if the soil is compacted, drainage can be slow, irrespective of the soil texture.

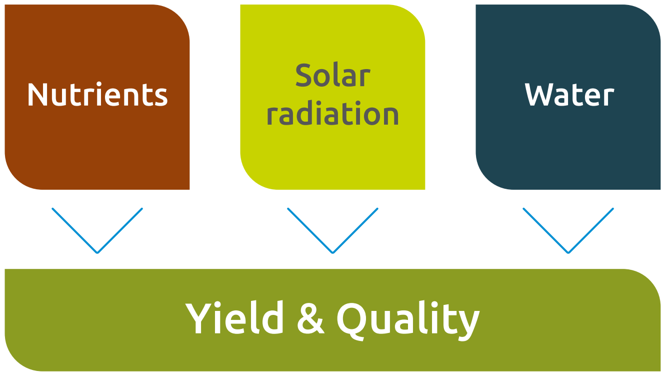


Figure 1. The building blocks of crop yield and quality

Impacts of poor soil condition

Soil compaction can impact on the efficiency and economics of production in a number of ways, resulting in:

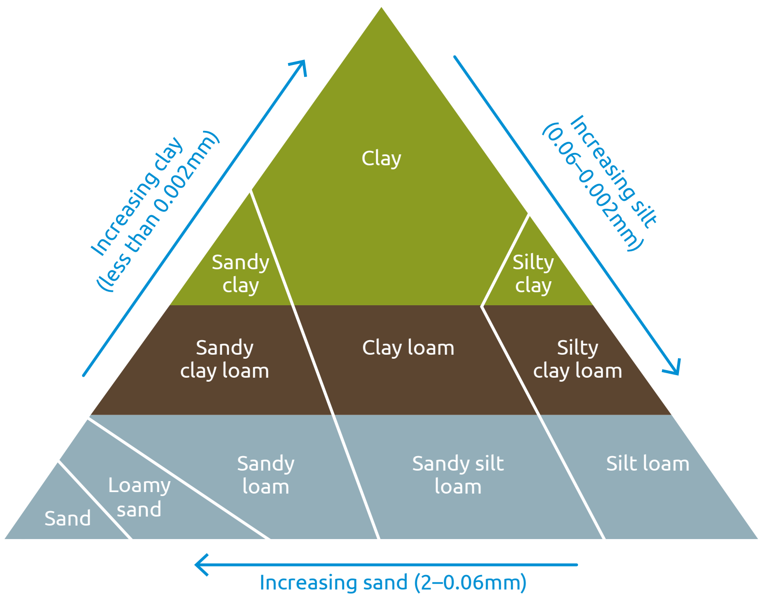
- Poor rooting and reduced crop yield and quality
- Less crop uniformity
- Poor drainage
- Reduced timeliness (fewer days when land can be worked by machinery)
- Increased fuel use: 50%+
- Higher weed/disease pressure
- Higher irrigation costs
  - Typical overall operating costs for a 25mm application are £85–£155/ha

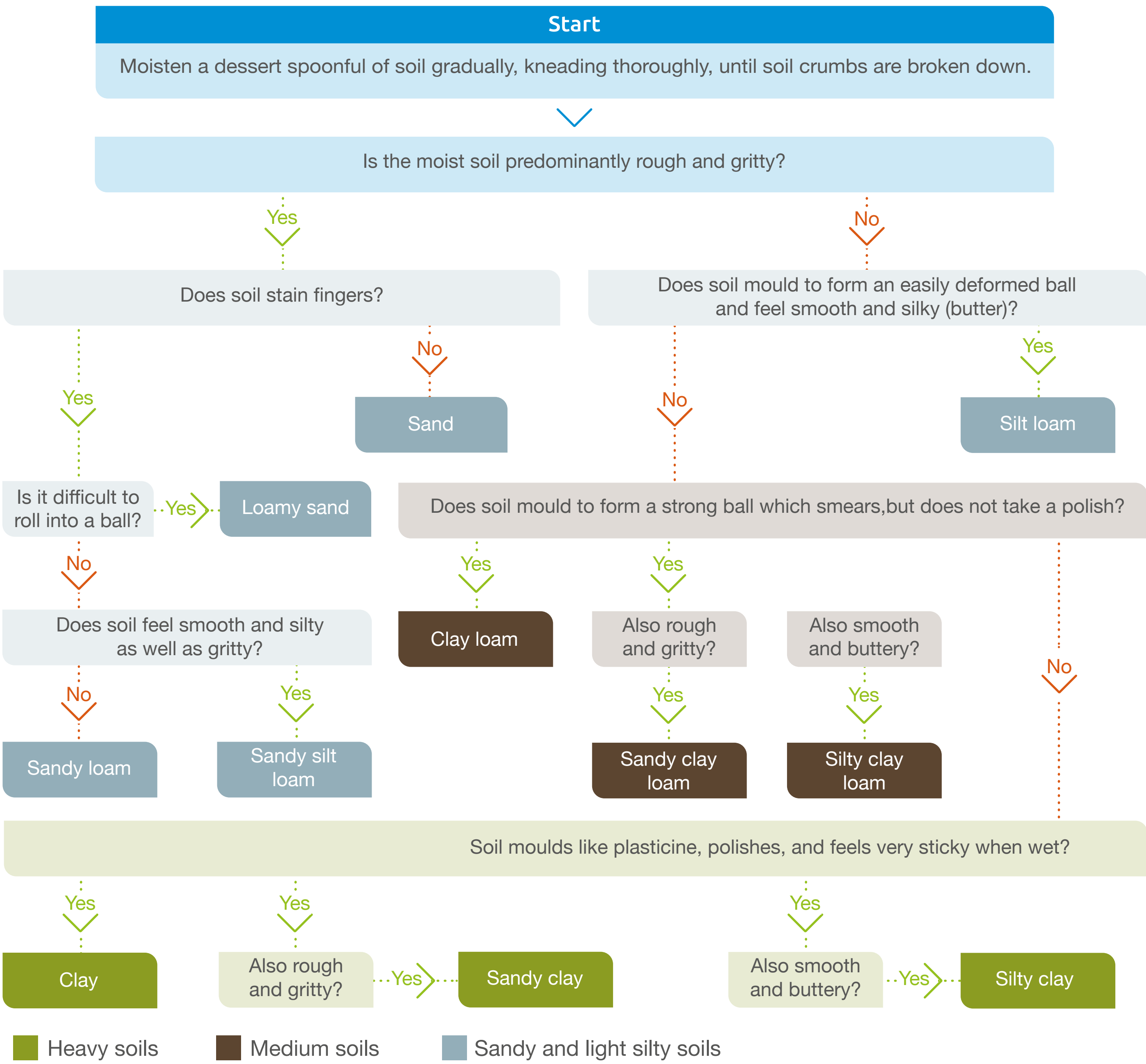
Soils that are compacted or cap easily are more vulnerable to erosion and surface run-off, which can result in soil loss, declining productivity and off-site impacts involving neighbours and local authorities.

Conversely, better structured soils are less prone to erosion and surface run-off, increase opportunities to access land (improved timeliness), reduce irrigation and tillage costs and can improve the uniformity and overall yield of commercial crops.

How to identify soil texture

1. Take a small block of soil that you can mould between your fingers and thumb.
2. Use extra water to work the soil (if necessary).
3. Follow the flow chart below to give a soil type.





Source: Controlling soil erosion (Defra, 2005)

Current condition of horticultural soils

In many horticulture systems, the pressures of establishment and harvesting schedules inevitably lead to some soil structural damage. The need to maintain continuity of product supply and meet demands for extended season requirements from retailers can lead to crops being harvested during unfavourable weather and soil conditions.

How are horticultural soils bearing up in the face of these production pressures?

In 2016, a survey of 75 fields covering a range of crop types (Table 1) identified soil compaction in 70% of annual crops and 60% of perennial crops. Annual crops were surveyed pre-planting and post-planting to assess the effectiveness of cultivations.

Based on visual assessment of topsoil structure, the majority of soils under annual and perennial cropping were in moderate condition and none were in poor condition (ie topsoil severely degraded). In general, cultivations prior to planting improved soil condition for the established crop. In some cases however (eg soil preparation for carrot and parsnip crops), the contrast in condition between pre-planting and post-planting indicated that soil structures were unstable (ie large aggregates broke down very readily), particularly on lighter textured soils that were low in organic matter.

The majority of soil cultivations were effective at removing compaction. However, in some cases, cultivation had no effect or resulted in further compaction through smearing (spreading of soil by sliding pressure when soil sticks to implements), puddling (dispersion of soil aggregates) or compression, when carried out in moist or wet field conditions.

Cultivating or travelling on wet soils or at the same depth over a number of years can result in the development of a tillage pan (a compacted layer) at or just below cultivation depth. Tillage pans often develop in the transition layer between the topsoil and upper subsoil.

A well-developed pan can significantly reduce productivity and the overall efficiency of production by restricting drainage and root growth. Around 60% of fields growing annual crops and 50% of fields with perennial crops had a well-developed tillage pan (Figure 2).

Deeper cultivations were not always matched to soil conditions or the need for subsoiling, with around 10% of fields deep-cultivated when there were no signs of compaction. Conversely, around 40% of fields that showed clear signs of a compaction were not deep-tilled.

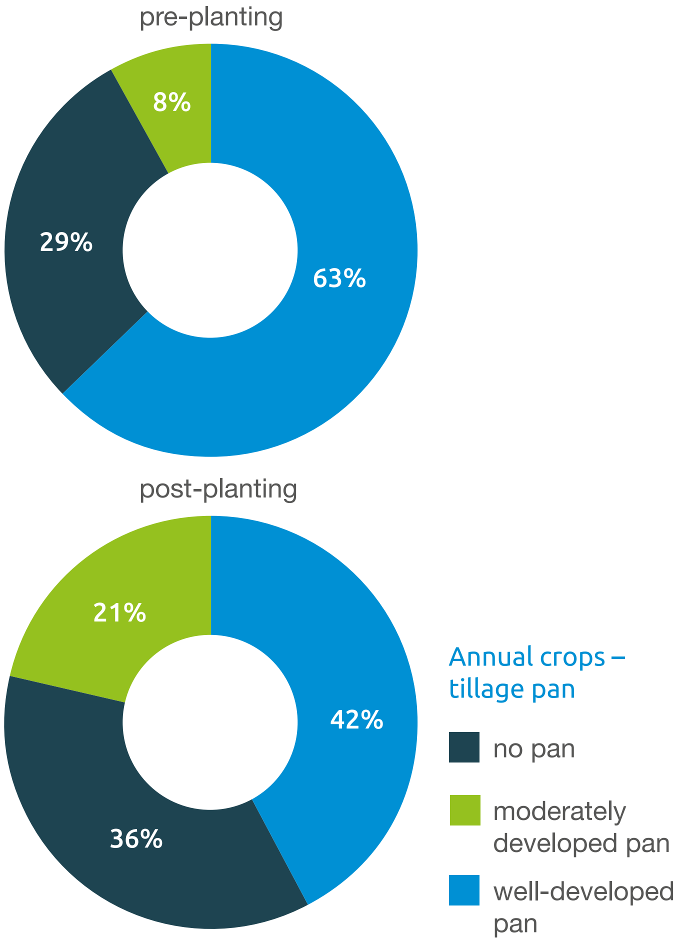


Figure 2. Over 70% of annually cropped fields had a tillage pan pre-planting and around 60% post-planting

Table 1. Soil structure survey stratification

Crop	Number of fields	Pre-planting	Post-planting
Brassicas	15	15	15
Carrots/ Parsnips	9	9	9
Onions	5	5	5
Leeks	5	5	5
Lettuce	10	10	10
Vining peas	3	3	3
Asparagus	6	2	4
Blackcurrants	6	2	4
Raspberries	4	1	3
Apples	6	2	4
Narcissus/cut flowers	6	2	4
Total	**75**	**56**	**66**

Figure 3. Soil block showing marked transition between upper layer with many pores, fissures and biological activity and heavily compacted lower layer

Earthworm numbers in the topsoil can be a useful indicator of soil condition and can vary from fewer than 100 individuals per m^2 (under 4 earthworms per 20cm x 20cm block) to more than 750 individuals per m^2 (over 30 per spadeful). Numbers generally depend on the degree of cultivation and the availability, nutritional quality and continuity of earthworm food supply.

Earthworm numbers were generally low in both annual and perennial crops, although numbers tended to be higher in fields with abundant crop residue and in apple orchards. For annual crops, 81% of sites pre-planting and 85% of sites post-planting had, on average, less than four earthworms per block of soil (ie less than 100 earthworms per m^2 – Figure 4). Frequent cultivations are likely to be an important factor in the relatively low number of earthworms observed at annual cropping sites. Some of the highest earthworm numbers (up to 350 earthworms per m^2) were recorded in fields growing a mustard cover crop.

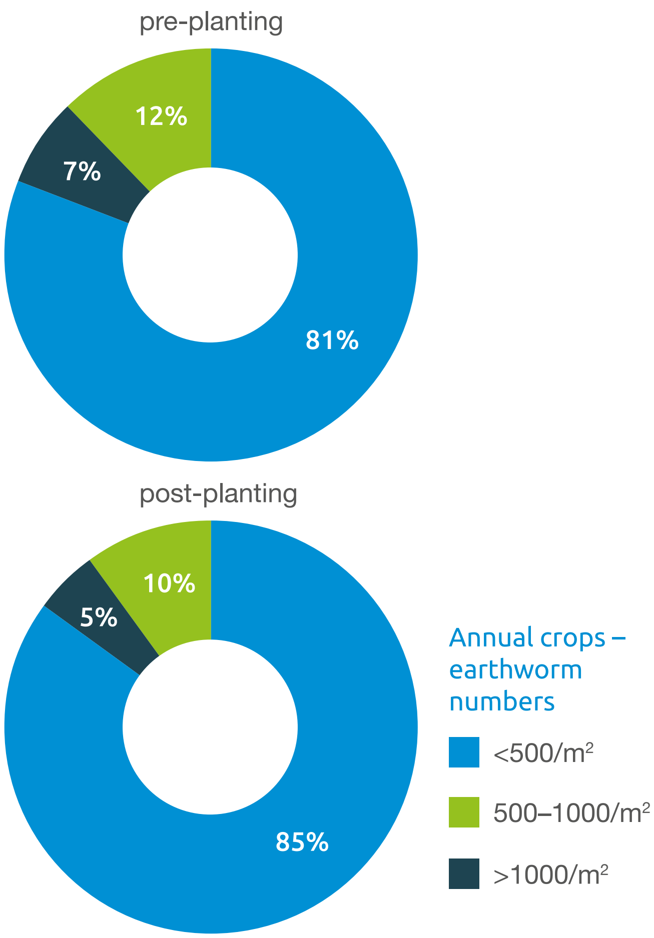


Figure 4. Earthworm numbers were low at the majority of annual cropping sites

How to assess soil structure and condition

An hour or so of your time and a few £s spent on soil analysis could save you £1,000s in the long run.

The soil structure survey identified a clear need to improve assessment and management of soil structure for greater efficiency and profitability of production. A third of annual crop growers and three-quarters of perennial crop growers were keen to learn more about visual assessment of soil structure to inform soil management decisions.

Growers can use their experience and knowledge of past field operations to assess whether soil compaction is likely to have occurred. Differences in crop growth within a field can also be useful to identify areas of compaction. Electrical conductivity (EC) scans (page 15) can distinguish differences in soil texture and can also pick out areas of topsoil or subsoil compaction and a penetrometer can be used to help determine the depth and extent of a compacted layer (Figures 5 and 6). However, using a spade or fork is the most reliable method for identifying the depth and nature of any soil structural problems.

Soils should be assessed when they are moist and soil aggregates are easy to break up by hand. If the soil is too wet, soil units may stick together and the spade or fork can smear the soil. If the soil is too dry, it can be difficult to dig and soil that has dried hard may be misinterpreted as being compacted. It is possible to assess the soil at any time of year, but doing so from late autumn (when drains are running on heavier land) to early spring (on a 'drying front') is usually better than mid-summer. Avoid assessing soils during prolonged spells of wet or dry weather.

Figure 5. A penetrometer can be used to help determine the depth and extent of a compacted layer

There are a number of methods and guides to help growers assess and score soils. The Think Soils guide uses terms and descriptions (from the Soil Survey Handbook) and photos to help growers assess their soil structure and provides management advice for different soil types.

Soil structural descriptions

The following paragraphs describe good and poor macroporosity and structure and are taken from the Think Soils manual: **ahdb.org.uk/thinksoils**

Macroporosity

Soil with good structure has abundant pores and fissures, allowing good drainage, aeration, root growth and biological activity. Soil with poor structure is where there are few pores (within soil structural units) and fissures (between the units).

Soil structure

Spherical structures are termed granular. Square shapes are called blocks. Flattened structural units are called plates.

Where blocks have mainly curved/rounded faces, they are termed subangular. Where faces are mostly flat, the blocks are termed angular.

Small blocks are called very fine when they are under 5mm, fine when they are 5–10mm and medium when they are 10–20mm. Large blocks are called coarse when they are 20–50mm and very coarse when they are over 50mm.

Soils with coarse and very coarse angular blocks, and those with plates, have poor drainage and aeration because blocks and plates can fit tightly together. Conversely, fine granules and fine subangular blocks allow good drainage and aeration.

Other soil assessment methods allow comparison between fields and to track changes over time (eg due to applying organic amendments to increase organic matter content, subsoiling to remove a pan or cover cropping to add roots). Some scoring methods require very little expertise to come up with a robust score of soil condition (eg VSA or Simply Sustainable Soils). Others need more experience before you can confidently assign a score to a soil or soil layer (eg VESS).

The Visual Soil Assessment (VSA) method from Landcare Research in New Zealand has been adapted for use in the UK by the Soil Management Initiative and Catchment Sensitive Farming and a 2016 version is published by Vaderstad.

landcareresearch.co.nz/publications/books/visual-ssxoil-assessment-field-guide/download-field-guide

smartagriplatform.com/resources/Pictures/Visual%20Soil%20Assessment%202016%20Edition.pdf

Both methods use a number of visual indicators such as structure and consistency, porosity, presence of a tillage pan and number of earthworms to score the soil and derive an overall ranking score for all visual indicators combined.

The Visual Evaluation of Soil Structure (VESS) focuses on assessing soil structure and porosity and the degree of layering in soils. This method involves the extraction of a soil block about the width and depth of a spade or fork and the pulling apart of the block by hand to assess ease of break up, visual appearance (size, shape and arrangement of soil structures, pores and roots), colour and smell.

The VESS enables users to assess the nature and depth of soil layers and to relate condition to the depth and nature of recent cultivations. This information helps with decisions on whether deeper soil cultivations are needed to remove a compacted layer and the most appropriate depth of cultivation.
sruc.ac.uk/info/120625/visual_evaluation_of_soil_structure

The most important step for any method focusing on visually assessing soil structure is the extraction of the soil block to be assessed. It is vital that when extracting the block, one of the vertical faces of the block is undisturbed, with roots, pores and soil structures intact. This is most effectively done by cutting down on three sides with a spade or fork and then levering the soil upwards to leave one face uncut as the undisturbed face. It may be easier to extract a first block before extracting a second adjacent block on which to carry out your assessment.

If you want to check for presence of a tillage pan, either dig a little deeper into the transition layer between the topsoil and subsoil when extracting the block or first dig out a block to just above topsoil depth and then extract a second block to include the transition layer.

Assessing the subsoil

SRUC has developed the SubVESS method for visually assessing subsoil: **sruc.ac.uk/downloads/file/3206/subvess_chart_nov_16**

The method uses similar indicators of structure and porosity to the VESS tool but is adapted for the specific nature and properties of subsoils, which tend to have lower organic matter content, larger structures, fewer roots and lower porosity compared with topsoils.

The SubVESS method can be used in combination with a penetrometer to give you a good indication of whether or not your subsoil is compacted.

Top Tips

Topsoil and transition layer condition

The two key questions you need to answer when assessing your soils are:

- **Is the topsoil well structured?**
- **Are there signs of a cultivation pan?**

Compaction in the subsoil is important and can affect the productivity of your land, but it is more difficult to assess and even more difficult to remove; most agricultural subsoilers work effectively to a depth of around 45cm (18 inches), ie they can remove a cultivation pan but cannot deal with more deeply seated compaction.

Figure 6. Root development in soil with good structure, left, and with compacted layer, right

Figure 7. Water seepage from above compacted soil layer

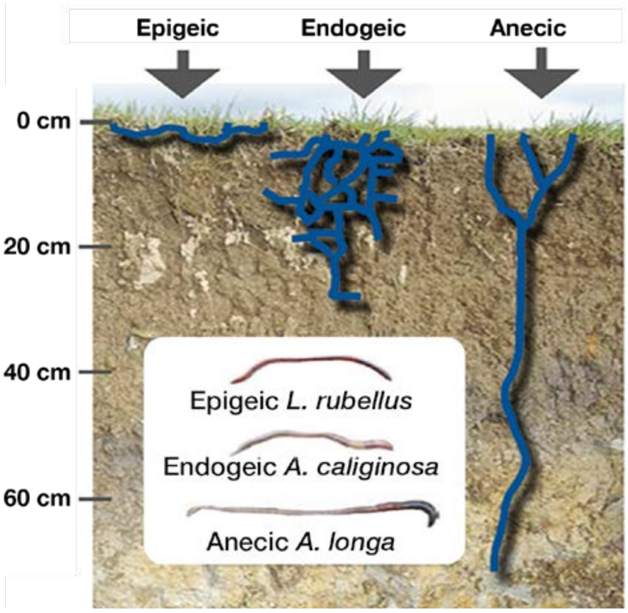
Use roots and soil drainage as indicators of good/poor structure

Roots are often the best indicators of soil compaction. Finer roots will run horizontally across the surface of a compacted layer and taproots similarly become pronged and run laterally if they cannot push through the soil.

Drainage in winter is another good indicator. Soils will often 'sit wet' above a compacted layer, making the saturated layer susceptible to further compaction. This layer may be duller in colour and, if associated with incorporated residues, may smell of bad eggs. Once a block of soil has been extracted for assessment, soil water may even trickle into the pit from above a compacted layer.

Earthworm lifestyles

There are three main earthworm lifestyles in the soil:



- Surface-dwelling (epigeic) worms that feed on leaf litter and other organic material on the surface; these are common in woodlands but rarely found in agricultural soils
- Shallow-burrowing (endogeic) worms live in the soil and feed on organic matter there. They make vertical and horizontal burrows in the topsoil
- Deep-burrowing (anecic) worms come to the soil surface in the evening and gather organic material into permanent burrows deeper down the soil profile. These worms leave casts on the soil surface

Count earthworms

Earthworms are useful indicators of soil condition and deep-burrowing (anecic) species provide channels to drain water and help roots access deeper into the subsoil. Earthworms also feed on soil organic matter, crop residues and leaf litter and are vital to the turnover of organic matter and the mixing of organic and mineral components of the soil.

Counting earthworms can provide a quick and easy way of assessing soil condition. The best time to count earthworm populations is early to mid-spring or after the soil has wetted up in autumn.

A series of measurements taken in a number of fields, or over a number of years or crop rotations, can give an indication of long-term trends in soil condition.

Dig out 10 cubes of soil 20cm x 20cm and approximately 20cm deep across the field, and hand-sort the blocks for worms.

Worm numbers are affected by a range of factors, including soil type, weather and land management. However, a soil in good condition will typically contain 10–15 worms per soil block.

Further information:

- An AHDB method for counting and assessing earthworm numbers is available at **ahdb.org.uk/greatsoils**
- A guide to earthworm identification is available at **www.opalexplorenature.org/earthwormguide**

Use the look, feel and smell of the soil

Crumb and granular structures crumble in your hands, are associated with abundant fine roots, are normally dark brown in colour, have abundant pores and smell earthy.

Compacted soil is firm or hard to break up by hand, normally paler in colour, has few roots, is dominated by horizontal cracks/fissures and platy structures, and has few visible pores.

Use a knife or trowel

Create an undisturbed face to your soil pit (shallow or deep) and push or twist a knife or trowel into the vertical face at various points down the profile and relate the degree of resistance to soil structure, porosity, rooting, drainage and colour.

Strategies to improve and maintain soil structure

Successful soil management should avoid or limit soil structural damage and alleviate compaction when it occurs. Any soil management strategy should include methods to improve soil condition and resilience as well as those to repair damage.

Poor soil structure and compacted layers usually result from overloading, cultivating or lifting wet soils that are not strong enough to hold the weight of machinery. In medium and clay soils, this results in deformation through smearing and puddling. In sandy and light silty soils, compression increases soil density and dispersion from cultivation, or raindrop impact causes slumping.

Generally, soils that are low in soil organic matter are more susceptible to soil compaction and structural deterioration.

Prevention is better than cure

Good soil structure is best maintained by avoiding soil compaction in the first place, where possible.

Tyre pressure, wheel loads and controlling traffic – many growers are now using low ground pressure (LGP) tyres to reduce ground contact pressure. These include very high flexion (VF), increased flexion (IF) and variable-pressure tyres with on-board Central Tyre Inflation Systems (CTIS). VF tyres can run in the field and on the road at a uniform low tyre pressure of less than 1.0 bar. These and other LGP tyres increase the tyre footprint (or contact) area, which can improve traction and fuel economy and reduce the degree of topsoil compaction. VF tyres can also reduce the width of the impacted area through increasing lengthways contact and potentially eliminating the need for dual wheels.

Keeping applied pressure low – less than 0.7 bar – will allow most roots to grow enough for crops to alleviate compression caused in dry to moist conditions. However, in wet conditions, even LGP tyres will cause wheel slippage and associated compression and smearing, leading to compaction that will inhibit crop growth.

The use of tracks, particularly on harvest machinery, can reduce the depth of compaction (compared with tyres alone), although shallow compaction can still be significant.

The weight of machinery and when and how it is used are important factors to consider. Restricting loading of soils to the smallest possible area will limit the extent of deep-seated soil compaction and associated impacts on productivity and efficiency. This is the principle of controlled traffic, which works towards confining compaction to the least possible area of permanent traffic lanes. In its simplest form, it involves greater discipline in use of routeways and tramlines.

True controlled traffic farming (CTF) requires modifications to machinery so that all machines are on the same track gauge (Barfoot case study). However, where contractors are used or modifying harvest machinery is particularly difficult, an alternative is seasonal CTF (SCTF), whereby the majority of equipment runs on common tracks and working widths up to harvest. Within SCTF systems, the compaction effects of harvest traffic have to be managed with tillage in the crop growth zone.

Without guidance systems, a form of manual CTF can be adopted whereby the driver steers machinery along the same tracks each year and 'A–B' lines are marked in the hedge or fence line. With Real Time Kinematic (RTK) guidance, it is possible to achieve pass-to-pass and static accuracies of ±1–2cm, guaranteeing that CTF lanes can be followed year-on-year. Pass-to-pass accuracy of ±2cm, and an absolute or repeatable positioning of ±4cm, is also now achievable using correction from a geostationary satellite orbiting over the equator, which does not require a modem or radio.

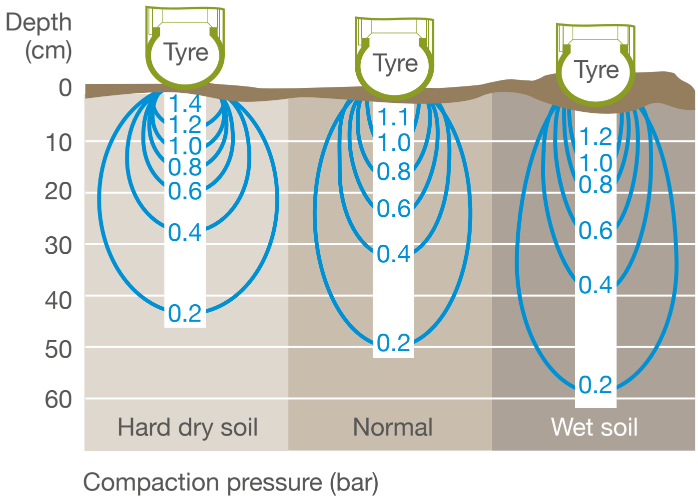
Appropriate soil conditions – even under CTF systems, cultivating in wet conditions is likely to damage soils. It is therefore important to consider the soil moisture content (ie the soil physical state or consistency) at the depth of cultivation. When soil can be moulded into a 'worm' with a moist smooth surface, it is in a plastic state and is too wet to work without causing damage. If the soil starts to crack on rolling, it is in a friable state and in a suitable condition for cultivation.

If in doubt, use this worm test to check the physical state of the soil at cultivation depth.

How to limit compaction by machinery

Following heavy rainfall, if possible keep off fields for 24-48 hours as wet soil is extremely vulnerable to compaction damage.

- Consider the '8–8 rule': under wet conditions, the depth of compaction beyond 30cm depth increases by 8cm for each 1 tonne increase in wheel load (above 1 tonne) and by 8cm for each doubling of the tyre inflation pressure (above 1 bar)
- Reduce machine size and total axle loads, as wheel loads greater than 3.5 tonnes can cause serious, permanent, deep-seated compaction, even with large low-pressure tyres
  - The greater the weight of the vehicle, the deeper the potential compaction
  - The greater the tyre pressure, the greater the degree of compaction in the topsoil and upper subsoil

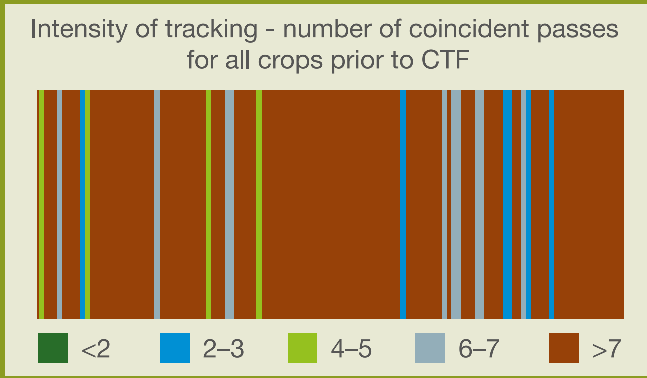


(Adapted from Soehne, 1958)

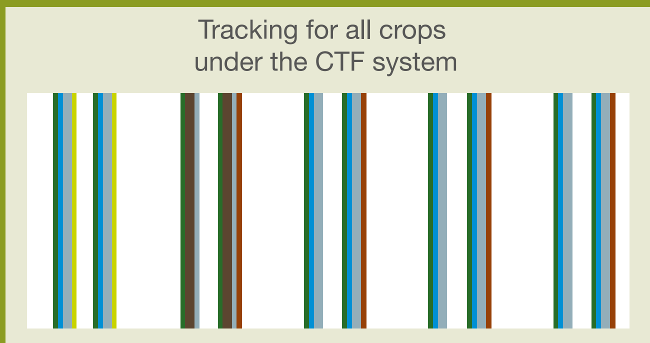
Barfoot Farms CTF

- **Farm:** Barfoot Farms Ltd, Hampshire and West Sussex
- **Rotation:** sweetcorn, pumpkins, tenderstem broccoli, courgettes, asparagus and beans
- **Soil types:** Medium (silt and clay loams)
- Barfoot's soil management strategy includes CTF, reduced tillage and the use of cover crops

- Detailed technical information was collated for all the machinery before and after CTF adoption, including track gauges (distance between wheels on an axle) and implemented working widths
- This data was then used to establish a sequence of field operations for both the conventional and CTF systems

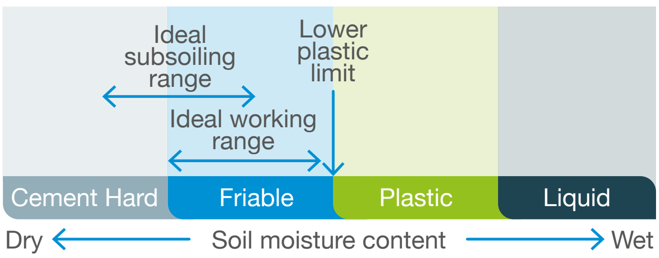


- Adoption of CTF at Barfoot Farms has resulted in a 63% reduction in tracking
- Maximising the area that is not wheeled should allow good soil structural conditions to develop in the growing bed, with associated improvements in crop yield and soil drainage



Soil physical state (consistency)

Consistency = the strength with which soil materials are held together (in clay soils, it increases with moisture content up to the plastic limit, then decreases rapidly as soils become saturated)



When soil is above the lower plastic limit:

- Soil can be rolled/moulded into a 'worm' or ring without cracking/crumbling
- Soil aggregates are unable to reform after compression from machinery/cultivation (moisture and air is expelled) and so compaction/panning can result
- Avoid cultivating/travelling on soil to prevent compaction and poor crop development

Improving soils

Where soils are compacted, they can be improved by increasing organic matter content. This can be done over several years by applying bulky organic materials, or over a longer period by using cover crops, green manures and grass leys. However, if there are clear signs of compaction (eg a well-developed tillage pan), appropriate cultivations will be necessary before the plants can do their work, ie a combination of 'metal' and roots.

Field drainage – On soils with clay, slowly permeable subsoils, even with the best topsoil structure, it is vital to install and maintain field drains to sustain efficient production.

If there is any break in the chain from the soil surface to field ditches, the land will stand wet for long periods, particularly over winter and, on sloping land, significant surface run-off and erosion can occur.

Further information:

AHDB Field drainage guide **ahdb.org.uk/greatsoils**

Well-targeted cultivations

If you suspect that there is a compact layer in the upper subsoil and are considering improving it by subsoiling, then it is important to confirm this by digging a hole and assessing the soil (see 'How to assess soil structure and condition').

- Do NOT subsoil unless you have identified clear signs of compaction
- Subsoiling soils that are in good condition is likely to do more harm than good!

Suitable conditions – Subsoiling should only be carried out when the soil at working depth is in a dry and friable condition so that it will shatter rather than smear. Examine soils early in the operation to ensure effective shattering is occurring.

Both the soil surface and the compacted layer should be dry to avoid soil structural damage.

Choice of equipment – Winged subsoilers shatter the soil much more effectively than conventional subsoilers. They require higher draught force but can disturb a volume of soil two to three times greater than a conventional subsoiler, resulting in more effective disturbance.

The use of leading tines can result in an increased volume of soil disturbed without increasing draught.

Depth – It is best practice to use a depth wheel or rear packer roller to maintain a constant tine depth. Aim for tines to be about 25–50mm below the base of the compacted layer, up to a maximum depth of approximately 450mm below ground level.

Maximum depth may be limited by shallow field drains, rock or the critical depth of the tine (related to tine width and soil conditions). Normal drain depth is around 70–90cm below the soil surface.

Do not cultivate any deeper than you have to, because:

- Doubling the tine working depth can quadruple the draught force requirement
- Increasing the working depth by 5cm (two inches) can easily double the fuel requirement

Working deeper than you need to not only produces undesired soil disturbance but also causes an unnecessarily large increase in the draught requirement, which increases wear and tear, fuel consumption and wheel slip, which will cause smearing and further soil structural damage.

Spacing between tines – many subsoiler manufacturers now have fixed tine spacings on their subsoilers. However, it is important to use the following tine spacing where possible.

- Conventional subsoiler: up to 1.5 times the tine depth
- Winged subsoiler: up to 2 times the tine depth
- With leading shallow tines: up to 2.5 times the tine depth

After a trial run, dig down and examine the result. Adjust spacings, where possible, to achieve the desired degree of soil disturbance.

Avoiding re-compaction – Recently loosened soils are very sensitive to re-compaction. Avoid running over land that has already been subsoiled. AHDB Pork have some excellent videos on subsoiling here: **pork.ahdb.org.uk/subsoiling**

Improving organic matter content

Maintaining or enhancing soil organic matter can be achieved most effectively by applying bulky organic manures (eg green compost or farmyard manure) on a regular basis. An application of green compost supplying 250kg/ha total nitrogen (N) will add about 4.5 tonnes/ha of organic matter (Table 2).

Table 2. Organic materials are a good source of organic matter

Organic material	Dry matter	Application rate (t/ha)[1]	Organic matter applied (t/ha)
Cattle FYM	25%	42	5.5
Broiler litter	60%	8	2.5
Green compost	60%	33	4.5
Green/Food Compost	60%	22	5.0

[1] using typical nitrogen content values, the application rates are within the Nitrate Vulnerable Zone (NVZ) *organic manures field limit* of 250kg total N per ha in any twelve-month period.

In Nitrate Vulnerable Zones (NVZs), PAS100 certified green or green/food compost can be applied at a double rate of up to 500kg total N/ha every 2 years (ie in any two-year period) as a mulch or worked into the ground.

If you are applying PAS100 certified green or green/food compost as a mulch in an orchard (growing fruit of the genera *Malus*, *Prunus* or *Pyrus*), you can apply up to 1,000kg total N/ha every 4 years (ie in any four-year period).

In low organic matter content soils, adding organic materials can potentially lead to better drainage, more resilient soil, more efficient irrigation, higher crop yields and better crop quality.

Composts typically have a higher lignin content, which is more resistant to microbial breakdown, than farmyard manures and therefore tend to increase organic matter content more quickly (relative to the same amount of organic matter added). Farmyard manures tend to contain more fresh organic matter and are better at stimulating biological activity and increasing microbial biomass.

Before using any organic materials, first check for compliance with your crop assurance scheme.

Don't forget to allow for the nutrient content of organic manures.

Further information:

Nutrient Management Guide (RB209)
ahdb.org.uk/rb209

Digestate and compost good practice guidance
www.wrap.org.uk/content/digestate-and-compost-good-practice-guidance

Grass leys and cover crops

Growing any crop when the land would otherwise have been left bare is likely to improve soil structure within a year or so (compared with not growing a crop) and over longer time scales (10–20 years) increase organic matter content.

Grass leys provide vegetation cover throughout the year that will store carbon in leaves and roots whenever the crop is actively growing. In addition, a grass ley will develop a dense root system and a 'thatch' layer consisting of stems, decomposing leaf material and roots. The use of deeper-rooting herbs and legumes may also allow organic matter to be stored deeper in the topsoil and upper subsoil. The inclusion of grass leys in the rotation can help improve soil structure and increase organic matter content. They are also good for biodiversity and can support natural predators of crop pests.

Cover crops provide winter cover to reduce weed pressure and minimise erosion, surface run-off and nitrate leaching. There are potential benefits for soil structure, water-holding capacity and porosity, but a green manure or cover crop will not improve soil structure where soils are in poor condition (ie they have a well-developed tillage pan).

Cover crops can be used as part of a long-term strategy to improve soil quality and provide other agronomic benefits; for example, cover crops may help to perturb certain pest and disease cycles or be used as part of wider weed management strategies.

Cover crops can also provide wider habitat value and give rise to options for livestock and supplementary feeding opportunities for wildlife.

They are commonly used in vegetable rotations as overwinter catch crops and for fertility building.

Crops that are quick to establish, such as cereal rye, ryegrass and vetches, provide direct competition to weeds. Other crops such as rye, buckwheat and mustards are being investigated for their weed germination inhibiting effects, but for mustard (and radishes and turnips) think about potential rotational conflicts, eg clubroot, where vegetable brassicas or oilseed rape are grown in the rotation.

Overwintered cover crops should usually be established by mid-September to provide good ground cover and reduce nitrate leaching losses (by taking up N in early autumn), although establishment conditions will vary according to soil type and season.

An overwintered cover crop is more likely to supply nitrogen to the following crop (up to around 30–40kg N/ha for long-season crops) if it is destroyed earlier in the year, when the crop is still relatively green and 'fresh'. Crops that are destroyed later with more stem and a deeper, denser root system are more likely to increase soil organic matter.

A well-developed green manure can return between 1 and 3t/ha of organic matter compared with 4–5t/ha for a typical application of organic manure. However, more carbon is likely to be retained in the soil from organic manures (particularly compost) than from green manures.

Cover crops (green manures) can be used in Ecological Focus Areas under the Basic Payment Scheme 2018 or as a Countryside Stewardship option.

Further information:

AHDB cover crop information sheets
cereals.ahdb.org.uk/covered

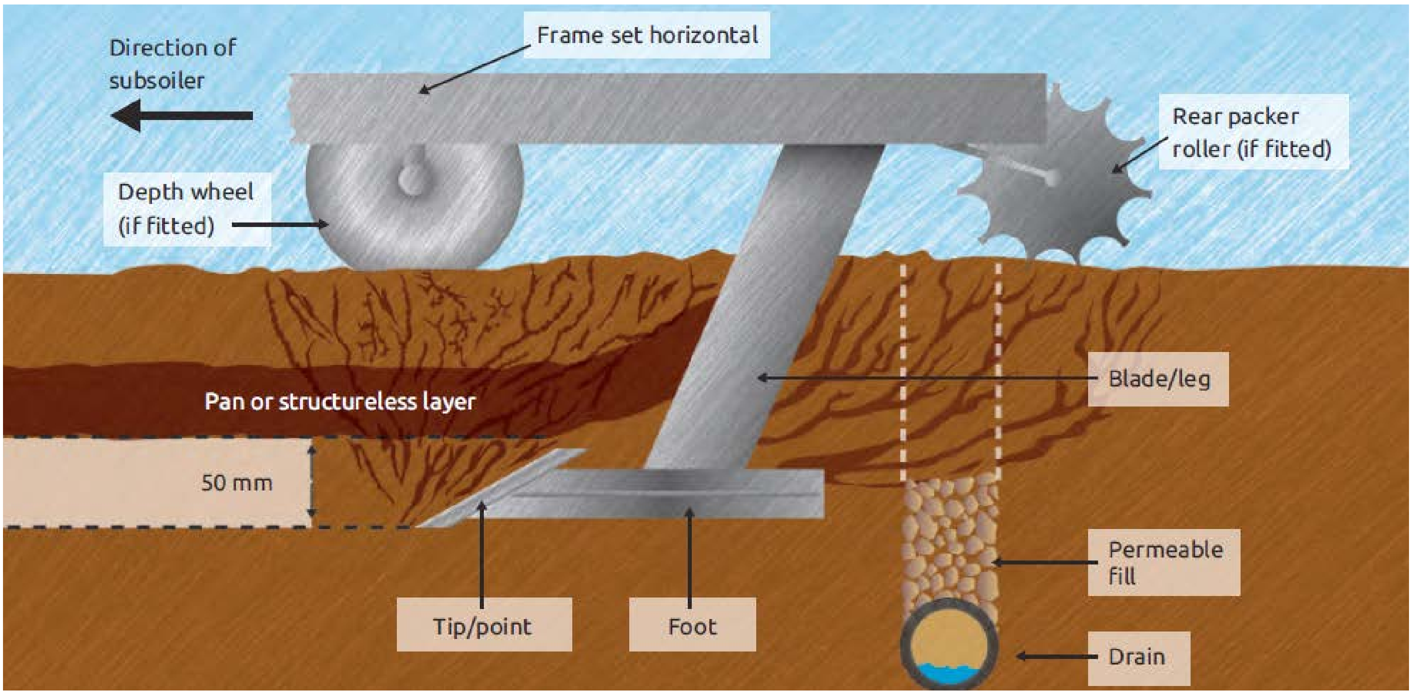


Figure 8. How a subsoiler works

Measuring and managing soil variability

Consistency of crop size and quality are key issues for growers. However, within-field variability in crop growth is usually apparent in most fields. Soil variability is one of the main factors determining differences in crop growth. Variations in soil texture leading to differences in moisture-holding capacity, organic matter content, nutrient content, drainage, compaction and soil depth will all be reflected in crop performance.

Where soil variability is substantial, and can be managed at practical scales, applying different management regimes *within* the field, eg for fertiliser or lime application or cultivations, may be worthwhile. Soil mapping can be used to identify boundaries between soil types and characterise field areas according to their soil pH or nutrient indices. Increasing numbers of growers are mapping soil variability as the first step towards understanding and managing soil and crop variability.

Estimating variation in soil texture/type

Understanding the underlying spatial variation in soil physical characteristics (soil type, slope and drainage) is an important first step. Soil electrical conductivity (EC) scanning and soil brightness imagery from satellites can be used to help identify and assess soil variability as a basis for creating different soil management zones within a field.

Soil electrical conductivity (EC) or Electromagnetic induction (EMI) surveys

Soil EC is a measure of the soil's ability to conduct an electric current and is used to identify differences in soil texture, moisture and organic matter content. There are two main types of sensor:

- Soil EC scanners make contact with the soil and measure variation in electrical conductivity across the field (Figure 9). This method typically uses two or three pairs of coulters mounted on a toolbar; one pair provides an electric current into the soil (transmitting electrodes) and the other coulters (receiving electrodes) measure the voltage drop between them
- Non-contact electromagnetic induction (EMI) sensors are held above the soil when scanning (Figure 9). This method uses the principle of electromagnetic induction to derive the apparent electrical conductivity of the soil (ECa); these sensors have a transmitter and receiver coil at opposite ends of the unit and a sensor in the device measures the resulting electromagnetic field that the current induces. The strength of this secondary electromagnetic field is proportional to the soil EC

Although EC and EMI scanners use different methods for measuring soil EC, research has shown that both provide comparable information on soil variability.

The main factors affecting soil EC are texture, moisture and organic matter content and bulk density. In the majority of fields, soil texture is the main cause of soil EC variation. Clay soils with high particle-to-particle contact and high moisture-holding capacity are highly conductive. Sandy soils with limited particle-to-particle contact and low moisture-holding capacity are poor conductors. Soil moisture content may affect the measured EC values but will not affect the pattern of variability – a soil EC map will consistently identify areas of different soil texture regardless of the soil moisture content at the time of measurement. Studies have demonstrated that fields mapped several times during the year at differing soil moisture contents had different EC values but consistently identified the same pattern of variation in soil texture.

Figure 9. Soil electrical conductivity (EC) scanner

EC and EMI surveys are conducted when there is no crop cover (typically during the autumn/winter period between crops). For 'contact' EC sensors, it is important to ensure good soil-to-coulter contact, so scans are usually carried out following harvest, prior to cultivations. The instruments are pulled across the field by a tractor or truck at bout widths typically between 12–24m.


Figure 10. Soil electromagnetic inductance (EMI) scanner

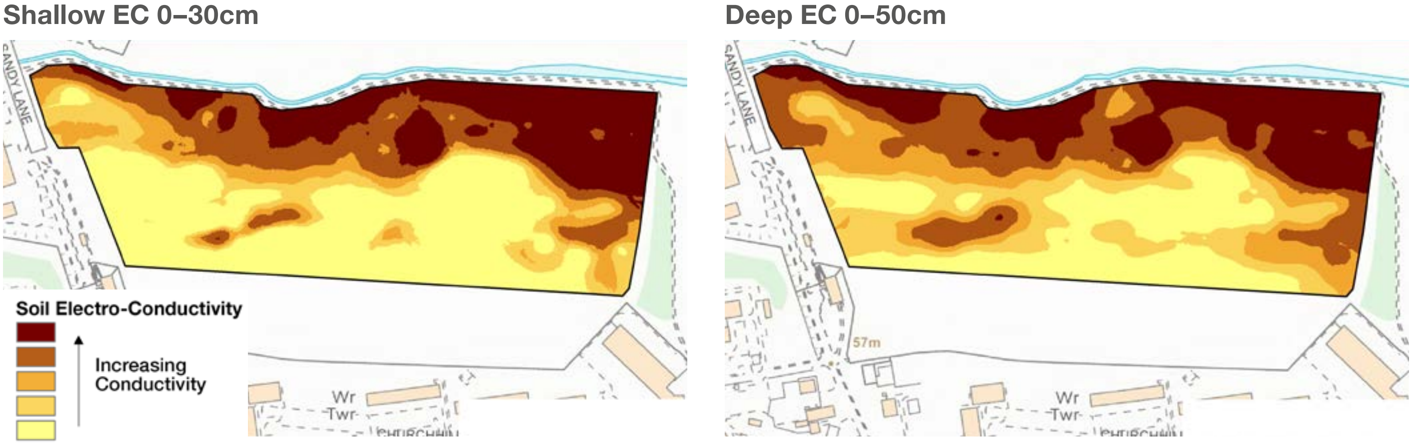


Figure 11. Soil EC map showing variation in soil texture at different soil depths

The information is combined with GPS data to produce a soil EC map. Soil EC measurements should not be taken when the soil is frozen.

Some EC and EMI scanners will measure conductivity for two depths simultaneously, providing EC maps for a shallow and deep vertical cross section (Figure 11). Growers should use the shallow EC measurements for directing soil sampling, and the deep EC measurements for comparing soil EC and crop yield maps or as a basis for variable-rate seeding, as crops are affected by soil properties to rooting depth.

Soil brightness satellite maps

Soil brightness is a measure of how intensively the surface layer of bare soil reflects incoming sunlight and is affected by factors such as soil moisture, organic matter content and texture. Soil brightness maps are derived from optical satellite imagery and are usually cheaper than soil EC/EMI surveys as the satellite images are collected remotely. Maps are obtained by analysing single satellite images, with the resulting brightness bandings standardised across the holding. Since values obtained are relative rather than absolute, it is not appropriate to compare results between farms or from images captured on different dates, since soil moisture and other temporally and spatially variable conditions will impact on soil reflectance.

Figure 12. Soil brightness map

In order to assess soil brightness, the satellite image has to be of bare soil. Consequently, measurements are typically taken before crop establishment. Each image will show a slightly different colour range based on the method of cultivation, time of data acquisition, soil moisture and stubble interference. Soil brightness maps can be used to help identify boundaries between soil types or conditions which, on further analysis, may justify different management regimes.

How can we use soil texture maps?

Soil survey, EC maps and brightness maps can be used to identify in-field management zones with similar soil properties which can be combined for soil sampling and cultivation/fertiliser management. Several precision farming companies will define soil management zones for growers based on soil EC or soil brightness maps.

Estimating variation in soil pH and nutrient content

EC and brightness maps can provide information about spatial variability in soil properties. However, in order to quantify spatial variability in soil nutrients, it is necessary to take samples for laboratory analysis. The AHDB Nutrient Management Guide recommends soil sampling each field for pH, P, K and Mg every 3–5 years. Traditional soil sampling, where a single composite soil sample is taken from a field (usually made up of 25 cores taken from walking a 'W' pattern across the field), will provide average soil pH and nutrient indices for the field. This is the cheapest option. However, single bulked samples can conceal significant variation in soil pH and nutrient indices.

Many precision farming and agronomy companies now offer a soil sampling and mapping service where multiple soil samples are taken and the results used to create a field map of soil pH and nutrient indices. There are two main approaches to precision soil sampling:

Regular or grid-based soil sampling

A regular sampling approach typically divides a field into approximately equal-sized blocks. Samples are taken either from the centre point of each block (point sampling) or a representative sample is collected from the whole block (by sampling in a 'W' pattern across the block).

Where a representative sample is taken from each block, the soil nutrient map produced shows the boundaries of each block.

Where a sample is taken from the central point of each block, the sample is a composite of about 16 cores taken in a small radius around the pre-designated point. The location of each sampling point is GPS-logged and this information is used to create a contoured map of soil pH and nutrients. The map is derived using data interpolation to estimate values between the measured points. The interpolation method uses values at each sample point to determine boundaries between mapping units and does not take any account of soil type variations. GPS referencing means repeat samples can be taken at the same point, enabling monitoring of changes in soil pH and nutrient content over time.

Case study – Avenue field, F.B. Parrish & Son, Bedfordshire

- The 10ha Avenue field varies from sandy loam to medium clay loam and has been used as a case study to demonstrate the options available to growers for soil mapping, including soil EC mapping and soil nutrient mapping. Soil samples were taken in November 2016 to enable comparison of the effect of soil sampling intensity and method (a regular grid-based, compared to a zone-based, approach) on the pH and nutrient maps produced.
- A single composite soil sample was taken from the field in a 'W' pattern (25 soil cores). This soil sample showed that the field average was pH 6.1, P Index 3, K Index 2- and Mg Index 2.
- More intensive grid sampling showed within-field variation in soil pH of 5.3–7.1, P Index 2–4, K Index 1–4 and Mg Index 2–4.
- The soils on this farm are developed from glacial and river outwash deposits, resulting in significant variability in soil types. Having recognised the significant within-field soil variability, the farmer has had all fields in his holding EC-mapped. The resulting EC maps were used in combination with existing knowledge of soil and crop variability to define soil management zones within each field. These zones are sampled separately for soil pH, P, K and Mg every 4 years. The farm uses the soil pH and nutrient maps for variable-rate lime and fertiliser applications. The soil EC maps are also used as the basis for variable-rate drilling the farm's arable crops.

The most common commercially used sampling intensity for grid-point sampling uses a 100m grid to produce one sample per hectare. If significant within-field soil variability is anticipated, it may be worthwhile increasing the sampling intensity; numbers of samples taken will determine the level of detail in the maps produced. The limiting factor is normally cost – the more samples that are taken, the more detailed the soil map is likely to be.

Zone-based soil sampling

Zone-based or *targeted* soil sampling uses existing knowledge of within-field soil variability to direct where samples are taken. Field soil management zones can be created using information on soil or crop variability which is likely to impact on or reflect soil pH or nutrient content, such as:

- Soil EC maps
- Satellite soil brightness maps
- Yield maps identifying consistently high- or low-yielding areas of a field
- Field boundary maps – where different parts of the field have different cropping histories

Once the soil management zones are defined, each is sampled separately (as a single composite sample representative of the zone). The soil pH and nutrient maps produced reflect the boundaries between the soil zones.

Zone sampling seeks to improve fertility management through managing cropping areas by soil type and uses patterns and boundaries evident from previous soil surveys or yield maps to define zones. However, grid sampling may identify 'hot spots' of soil fertility or pH (often related to field management history) that cannot be observed using (bulked) zone sampling, and GPS-located grid sampling is better at detecting change over time. Grid sampling is typically more expensive than zone sampling as a greater number of samples are usually taken.

Targeted agronomy – variable-rate application of fertiliser and lime

The results from precision soil sampling can be converted into a prescription map for variable-rate fertiliser or lime application. A prescription map is an electronic data file used to control variable-rate fertiliser spreaders.

Variable-rate fertiliser-application maps are typically based on RB209 fertiliser recommendations for different soil indices and lime recommendations for different soil pH values.

Potential advantages of variable-rate fertiliser or lime include:

- Cost savings in fertiliser or lime from not overapplying to areas of higher soil nutrient index or pH
- Potential for increased yields where lower index areas would otherwise have been under-fertilised/limed
- Reduction of in-field variability of soil pH and nutrients over the long term

Measuring and managing crop variability

Measuring variation in the crop canopy

Canopy-sensing technologies measure reflectance of visible light or infrared radiation from the crop surface. Differences in these measurements across a crop can be presented as a vegetation index – these can be calculated in many different ways, but the most well-known is the normalised difference vegetation index (NDVI). Since reflectance from the crop is determined by the size and vigour of its canopy, vegetation indices correlate with crop biomass and crop nitrogen uptake. There are a range of different platforms and methods for collecting crop-canopy information.

Platforms for collecting crop-canopy-reflectance information

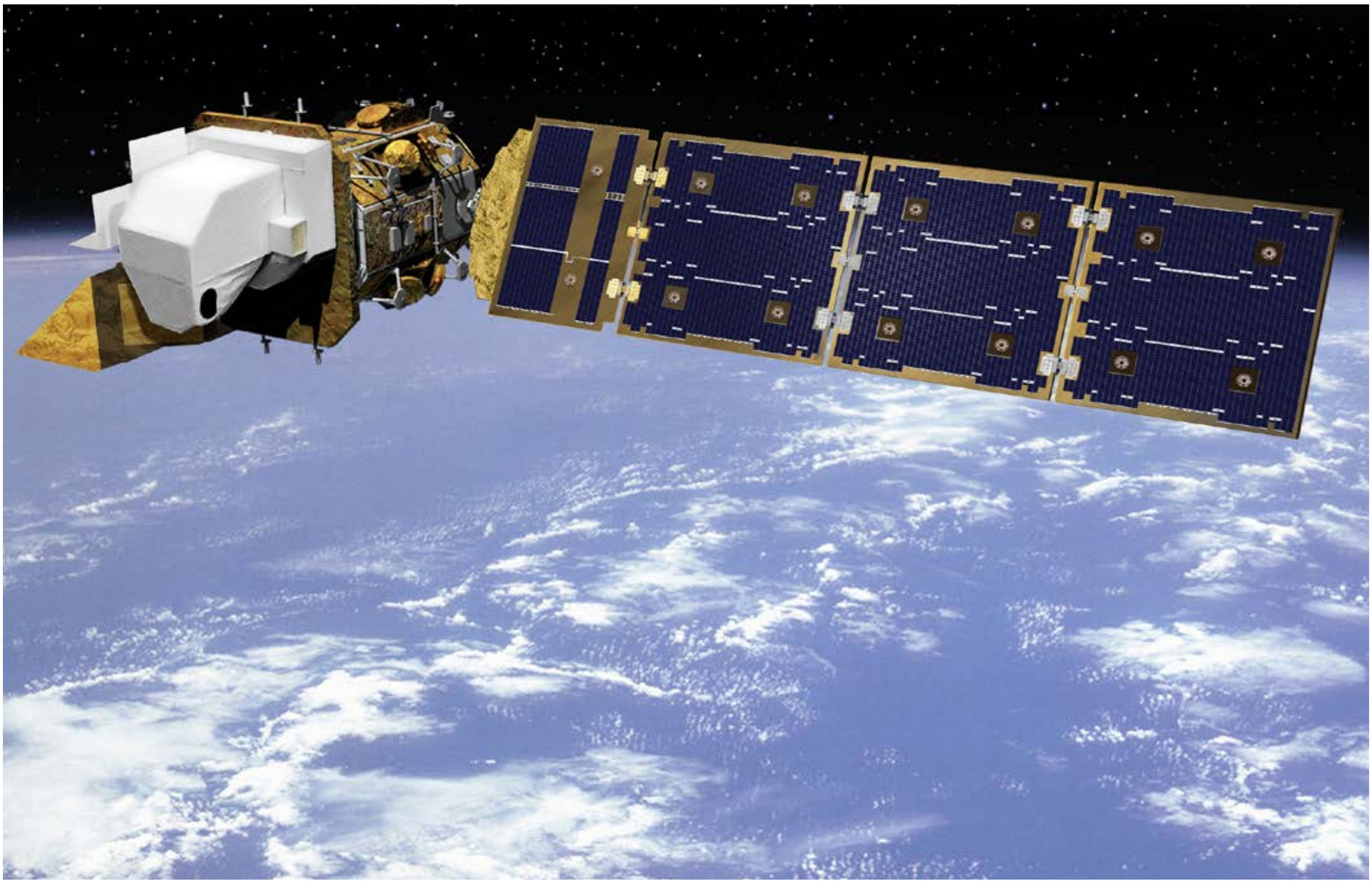
Satellite-based crop sensing

1. Satellite imagery is collected remotely and is relatively cheap compared to other methods of canopy sensing
2. Free imagery is available at medium resolution (10–30m) from ESA's Sentinel 2 and NASA's Landsat 8. Higher resolutions (5m–50cm) are commercially available
3. It is important to consider the timeliness of acquiring satellite imagery. Most precision farming companies acquire satellite imagery to coincide with the main arable growth season (January to June) and will aim to get growers at least two 'good' images per month (depending on cloud cover).

UAV with multispectral camera

Unmanned aerial vehicles (UAVs) or drones

- Can provide high-resolution imagery (up to 2cm resolution)
- High-resolution imagery allows plant counts/plant sizing
- High cost compared to other methods of canopy sensing
- The use of drones is strictly controlled by the Civil Aviation Authority (CAA). Farmers using their own drones to collect cropping information on their own farm are classed as commercial users and need to be licenced by the CAA



Landsat 8

Cab-mounted Yara N-Sensor controlling fertiliser spreading rate in real time

Tractor-mounted sensors

- Crop sensors are mounted on the tractor, typically on the cab or mounted at the front of the vehicle
- For example, Yara N-Sensor and Fritzmeier ISARIA
- Provides the flexibility to collect canopy information during routine field management operations

Handheld crop meters

- Quick and easy method of comparing crop canopy at a limited number of points within and between parts of different fields
- It is not possible to provide crop-canopy information for whole fields using handheld meters
- For example, RapidScan or OptRx handheld sensors. Yara N-Sensors and Fritzmeier ISARIA Sensors are available as handheld units

Handheld crop sensor

How can we use information from canopy sensing?

Identify underperforming areas of crop

Canopy sensing can provide valuable information on crop variability and can be used to target crop walking, eg to identify areas damaged by pests or disease.

Variable-rate nitrogen applications

Canopy sensing can be used as a basis for variable-rate nitrogen applications. Areas with well-developed, foliage will have different nitrogen requirements to thinner areas of the crop, and canopy reflectance can be used to vary the nitrogen rate across a field, usually seeking to improve uniformity by applying more nitrogen to weaker areas of the crop and reducing applications to dense canopies.

High-resolution imagery for plant counts/sizing

High-resolution imagery from drones or manned aircraft can be used to count and size crops (eg brassicas and lettuces), to predict supply and schedule harvest.

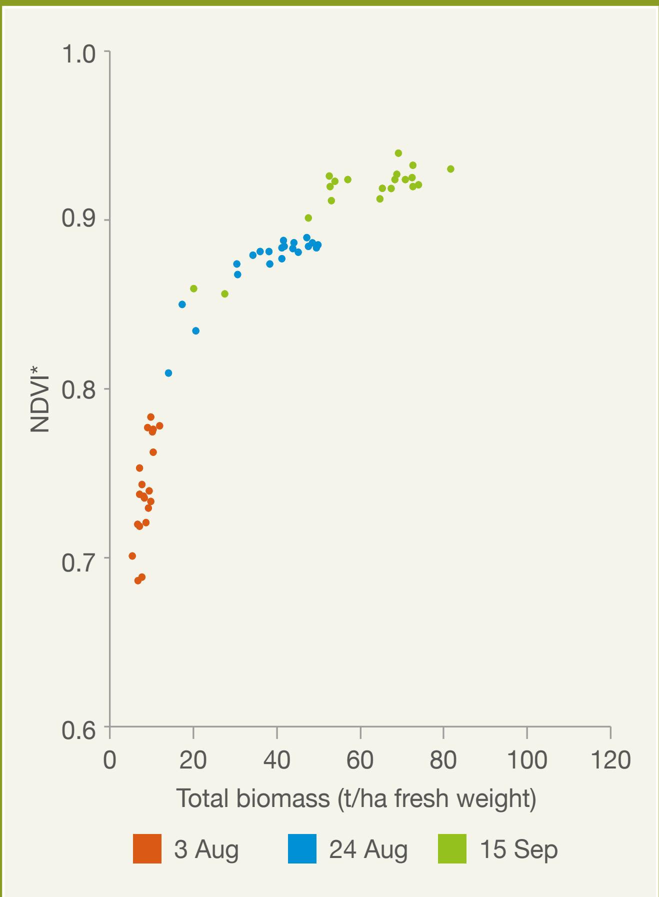
Variable-rate nitrogen management in horticultural crops

- The principles of variable-rate nitrogen management are applicable across a range of horticultural crops
- Variable nitrogen rate is most likely to be beneficial in crops that have a high nitrogen requirement and where the majority of the nitrogen is applied to the growing crop (rather than at planting), for example longer season brassica crops
- Canopy information is collected from the crop early in the season and used as a basis for varying later nitrogen application rates
- The operator has to set the field average nitrogen rate and minimum and maximum nitrogen rates
- Tractor-mounted sensors can be used to vary the nitrogen application rate ‘on the go’. Satellite or UAV imagery must be processed to provide a prescription nitrogen map

Tractor-mounted Fritzmeier ISARIA crop sensor assessing nitrogen requirements of Savoy cabbage

Case study – variable-rate nitrogen application to Savoy cabbage

- In 2016, variable-rate nitrogen management was demonstrated in a Savoy cabbage crop on a sandy loam soil in Nottinghamshire
- Three nitrogen-response experiments (7 rates from 0kg to 360kg N/ha) were set up in different areas of the field to see whether there was any evidence of within-field variation at the optimum nitrogen rate
- Crop-canopy measurements from the nitrogen-response plots showed a close relationship with biomass and nitrogen uptake (Figure 13a), demonstrating that canopy sensing can be used as a basis to vary nitrogen applications. Where soil nitrogen supply varies across the field and nitrogen is the main limiting factor for yield and quality, variable-rate nitrogen management has the potential to increase crop yields and reduce yield variability



*NDVI = Normalised Difference Vegetation Index (a measure of the crop canopy)

Figure 13a. Relationship between crop canopy measurements and increase in total biomas during the growing season

- Statistical analysis of nitrogen-response data from the three experiments indicated that, in this case, nitrogen response was similar across the field (Figure 13b)

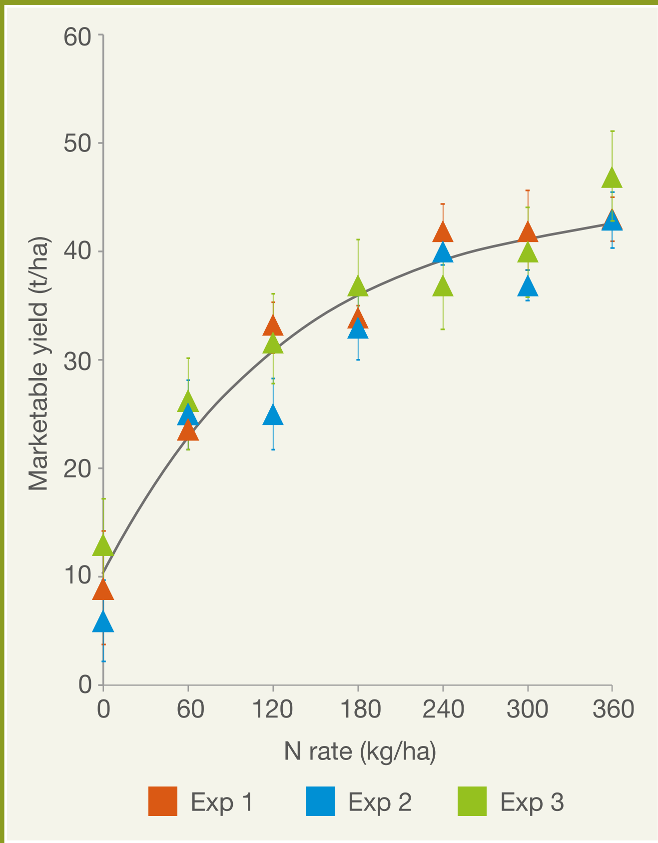


Figure 13b. Marketable yield response to N fertiliser

- In a tramline comparison, a uniform nitrogen application of 240kg N/ha applied in three splits was grown alongside a variable-rate treatment in which the first and third nitrogen applications were applied at the uniform rate but the second application was varied from 60–140kg N/ha (ie the farm standard of 100 ±40kg)
- Comparison of marketable head weights and total marketable yields from the uniform and variable-rate nitrogen tramline comparisons did not provide any evidence that varying the nitrogen rate increased total marketable yield or produced a more consistent crop
- Variable-rate nitrogen management will only be of benefit if nitrogen is the main factor causing variability in the crop canopy. At this site, the nitrogen-response experiments showed that the crop response to nitrogen was similar across the length of the field and the tramline comparisons did not show a yield benefit from variable-rate nitrogen management. It is likely that variability in the crop canopy here was due to other soil or crop factors (ie not only due to nitrogen)

Estimating variation in crop yields

Yield monitors can be used to collect information on the harvested crop and combined with GPS data to produce spatial yield maps. The magnitude of such variation in yield can be used to assess the potential benefits of implementing variable-rate management and to identify which fields are most likely to respond profitably.

Using yield maps from combinable crops

Most combine harvesters are now fitted with yield monitors and it is therefore relatively easy to produce yield maps for arable crops and, where these are grown in rotation with horticultural crops, it may be possible to use combine yield maps to improve management of all of the crops grown in the rotation.

Ideally, at least three years of yield maps should be combined to identify any long-term, consistent yield patterns, and these can be used to identify the most and least productive areas of the field and provide a basis for investigating problem areas. If crop growth is restricted due to problems such as poor drainage, soil compaction or low soil pH, corrective action will benefit all crops grown in the rotation.

Yield maps can be used alone or in combination with other spatial data (eg soil EC maps) to help define field-management zones, to target soil sampling and for the potential for variable management (see section ‘Measuring and managing soil variability’).

Mapping yields of horticultural crops

For high-value horticultural crops, yield variation across a field can highlight significant spatial variation in crop profitability.

Yield monitoring of root crops can be achieved using load cells under the web or conveyor belt to weigh the crop. This type of system is commercially available in the UK and can be retrofitted to most harvesters to monitor yields of root crops.

Other bespoke systems of yield monitoring may be developed between individual growers and precision farming companies/machine manufacturers. For example, recently, HMC peas have developed a yield-mapping system for vining peas.

Managing and processing yield map data

Removing data errors

Remove errors so the yield map represents yield as accurately as possible

Sources of errors in yield monitor data include:

- Unknown width of crop entering the combine header
- Start- and end-pass delays as the combine moves into and out of the crop
- Grain-flow delays representing the time lag through the threshing mechanism, which offsets the yield position along the route of the combine
- Grain losses from the combine, or surging grain through the combine transport system

In horticultural crops, the source of measurement errors will vary depending on the yield monitoring equipment, for example:

- Zero-yield measurements where the harvester stops to change trailers, or where the collection tank is emptied
- Stones or mud going over the conveyor with the harvesting of root crops

Many data management software packages offered by the precision farming companies and commercial farm management software include the facility to remove measurement errors

Combine multiple years of yield maps

- If possible, combine multiple years of yield data into an averaged or normalised yield map to help identify recurring yield patterns that are not affected by annual variations in growing conditions (although this approach can be confounded by consistent patterns seen in dry years differing from those observed in wetter years)
- Precision farming companies and commercial farm management software are able to process multiple years of yield data
- Where yield maps are available from horticultural and combinable crops grown together in the rotation, compare yield maps from the different crops and only consider combining if the yield patterns exhibited are broadly similar. If yield patterns differ between crops, it is important to understand the yield-limiting factors and it may be more appropriate to combine yield maps from single crops only

Case study – yield-mapping vining peas

- **Holbeach Marsh Co-operative (HMC) is a co-operative of around 30 member growers who produce vining peas for freezing**
- **HMC have developed a bespoke yield-mapping system to fit the PMC harvesters and started yield mapping vining peas in 2016**
- **Load cells were retrofitted to the harvesters’ collection tanks and linked to GPS to enable production of yield maps**
- **HMC are also collecting crop canopy information and hope to be able to combine this with yield maps to refine their projections of harvest date and harvest volume**

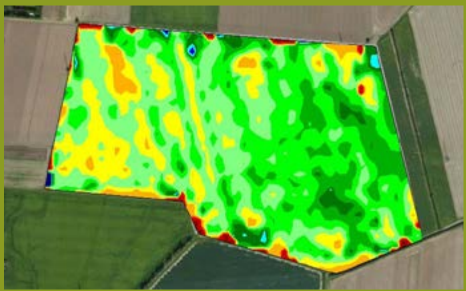


Figure 14. Harvesting vining peas

Further reading

Final Project Report CP 107c: Soils Programme: Precision farming technologies to drive sustainable intensification in horticulture cropping systems

This guide is based on the results of this project - for further information see **horticulture.ahdb.org.uk/project/soils-programme-precision-farming-technologies-drive-sustainable-intensification**

Soil management

AHDB provides a range of practical information on improving soil management for growers and advisors. Whether you need an introduction to soil biology or a detailed guide to improving field drainage, AHDB has information and guidance to support you.

Information on soil management for grassland, pig producers, arable and horticultural crops is available at **ahdb.org.uk/greatsoils**

Nutrient management

The Nutrient Management Guide (RB209) makes planning straightforward and accurate. The guide is available to download at **ahdb.org.uk/rb209**. You can also download the guide as an app for Apple and Android devices.

Get to grips with precision farming

AHDB has published a ‘Plain English’ glossary that defines precision farming terms in an accessible ‘A–Z’ format. The glossary is available at **cereals.ahdb.org.uk/precision**

AHDB Horticulture also published a Precision Farming Workbook – Does it pay? The workbook is available on the AHDB Horticulture website at **horticulture.ahdb.org.uk**

Produced for you by:

AHDB Horticulture
Stoneleigh Park
Kenilworth
Warwickshire
CV8 2TL

T 024 7669 2051
E comms@ahdb.org.uk
W horticulture.ahdb.org.uk
@AHDB_Hort

If you no longer wish to receive this information, please email us on **comms@ahdb.org.uk**