Soil Analysis and Management

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Introduction

Soil analysis provides information which can be used to improve soil fertility through management. The extent to which soil fertility can be improved depends on the inherent properties of the site – soil texture[1], mineralogy, slope and climate. Soil structure[2] is also key to plant performance as it affects the ability of plant roots to access available nutrients.

In this Technical Leaflet we explore some of the basic facts drawn from research and practical experience about soil analysis with a view to making the best use of available information. It is worth remembering that plant tissue analysis can also be useful, especially for trace elements.

Soil analysis is important in organic farming for nutrient management planning (e.g. rotational plans, making best use of manures, fertiliser application), to prevent long-term nutritional and health problems (crop and livestock), prevention of pollution and for derogations for use of restricted inputs.

- A one-off soil analysis simply provides a snapshot of nutrient availability at a particular time.
- Soil analysis should be repeated at regular intervals to identify trends in nutrient availability and adjust nutrient management accordingly.
- The soil analysis itself is only the first step. Specialist interpretation and recommendations are equally important.
- Soil analysis should be interpreted in rotational context. Large quantities of nutrients can be exported when selling a single crop, e.g. potash in potatoes.
- Interpretation should take account of the local conditions and crop; it may not be cost effective to set the same targets for lowland as for upland sites.
- Use annual soil analysis from one or two representative fields alongside nutrient budgets to track soil fertility changes over time.

This Technical Leaflet is one of a series commissioned and prepared by the Institute of Organic Training & Advice (IOTA) as part of its Defra-funded PACARes (Providing Access, Collation and Analysis of Defra Research in the organic sector) project. The PACARes project aims to improve awareness and uptake of organic research by farmers. For more information go to www.organicadvice.org.uk/pacares.htm

The Leaflets aim to provide a summary of the key practical recommendations for organic farming, drawing on the findings of research including IOTA's own Research Reviews commissioned for the PACARes project. Other Leaflets in the series include: Composting, Dairy Cow Nutrition, Financial Management for Organic Farms, Nutrient Budgeting and Organic Beef and Sheep Nutrition.

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How to take a representative soil sample

The expression "Rubbish in = Rubbish out" applies to soil samples! Unless each sample is representative of an area of relatively uniform soil then analysis is not worth paying for!

- Each field should be sampled at least once per rotation. The start of the fertility building phase is a good time. It may also be useful to get a soil analysis when you introduce a new crop or enterprise or if crops are under performing or showing signs of deficiencies.
- If fields are known to have areas of different soils that you might consider managing differently (e.g. different grazing intensity, different manure rates) then you should consider sampling them separately.
- Sample at the same time each year, outside the growing season. There is no ideal time, but ideally only compare results from samples taken at the same time.
- Sample a few fields every year to spread costs.

Soil sampling

Where to sample

A field is not always the best unit for a soil sample. You might need to split it if it contains very different soil types. Walk across the field and use your knowledge, soil maps and evidence such as changes in drainage or vegetation to decide.

How deep?

Aim to sample to plough depth or to 15cm in grassland.

Sampling pattern

It is traditional to walk across the field in the shape of a 'W' taking a sample every few paces.

Collecting the sample:

Use a trowel or auger to collect at least 10 to 15 soil samples from each sampling unit and mix them in a bucket. Take a subsample and send to the lab in a clearly labelled, sealed, clean plastic bag.

- Keep a chart or a notebook of changes in each field over time. Record information for each sampling time, otherwise you will forget when you come to look over the results (note any particular problems or successes with the previous crop, recent weather, etc).

pH

pH is a measure of the acidity of the soil and is used to predict lime requirements. It is important because it affects the availability of nutrients through both chemical and biological processes (See Figure 1, opposite page). Different crops are also tolerant of different levels of acidity, e.g. oats will yield well at a lower pH than other cereals.

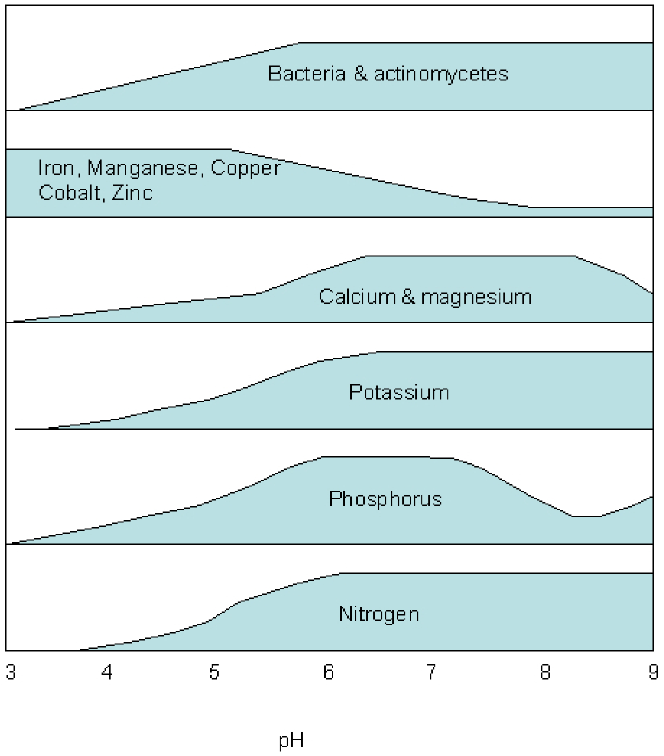
Recommended levels are normally 6.0 in grass/ clover and 6.5 for continuous arable. These are target levels and regular analysis should be used to check that the liming strategy you are using is able to maintain pH in its ideal range.

Nitrogen (N)

The layers of mineral soil exploited by plant roots generally contain between 5,000 and 15,000kg N ha^{-1}. The simplest estimate of total soil nitrogen is from organic matter content (see below).

- Most of the N in soils is in organic forms which are not plant available.
- Organic N is released in plant available inorganic forms (nitrate and ammonium) by microbially–mediated processes of mineralisation.
- Around 1-2% of the total N in soil is in inorganic forms at any time. Pools of (plant available) inorganic N fluctuate on a daily basis depending on temperature and moisture so measurements of these pools are not very helpful to organic farmers.
- Available nitrogen which is not taken up by plants is subject to losses through leaching and to the atmosphere as the greenhouse gas, N_2O.
- Available N levels in soil interact with other nutrients. If available N is limited, plants may not be able to take enough phosphorus or potassium (potash).

Figure 1: *Effect of pH on nutrient availability. Redrawn from* *http://www.routledge.com/textbooks/0415232945/resources/resources.html*



Phosphorus (P)

The total P content of soil varies greatly, ranging from around 500 to 2,500kg ha^{-1}. The total level of native P in soil is low compared to other plant nutrients. Between 15-70% of soil P is present in strongly adsorbed or insoluble inorganic forms with the remainder present in organic forms (White, 1995). Very little available P is found in the soil solution at any one time. Providing adequate levels of P for plant growth depends on both chemical and biological pools of soil P.

- Standard analytical techniques only measure chemical pools and therefore cannot give a complete picture of P available for plant growth. In organic systems the biological P pools are likely to be particularly important.

- In arable soils about 3% of P is in the soil microbial biomass, this can be up to 24% in grassland soils (Brookes *et al.*, 1984)

- There are numerous analytical techniques which rely on chemical extraction of P pools of different solubilities. These include the standard advisory techniques which vary across Britain (Olsen-P in England and Wales and Modified Morgans reagent in Scotland). The index values are described differently as shown in Table 1 (on page 5).

- The Defra funded project OF0114 concluded that the more complex Balzer-P analysis which uses three different extractants may give a better long-term picture of P availability in organic farming. However, it is more expensive and not widely used.

- A target soil index of 2 (on the Olsen based scale) is recommended by Defra for arable, forage and grassland and index 3 for vegetables (Anon., 2000). However, it is possible that in organic systems soils with an index of 1 may supply adequate P. This is because of the importance of the biological pools and processes in supplying P and the regular inputs of organic and relatively insoluble P sources, e.g. rock P, which do not significantly enrich the available P pool but can contribute P over the long term. In other words, there is no right answer to P levels in organic farming but avoid downward trends.

Potassium (K)

Large reserves of K are present in many soils, varying from 1000 to 75,000kg ha^{-1} (Cresser *et al.*, 1993). Potassium exists in four different forms in soils: solution, exchangeable, fixed and structural (native/mineral/matrix). Only K ions in soil solution and exchangeable K are plant available, this amounts to around 2% of total K.

The rate at which plants take up K is generally much greater than the rate at which it is released into plant available forms. So, depending on the size of the starting pool of exchangeable K, deficit situations can appear very rapidly.

As with P there are a number of chemical methods available to estimate soil K available to plants.

- K availability to plants is controlled mainly by chemical processes in the soil.

- Standard advisory soil analysis uses exchangeable K to estimate plant available K.

- The Defra funded project OF0114 showed that available K using standard advisory techniques gave a good indication of the plant available K in soils farmed organically. The project also showed that crops respond to increasing available K and continued cropping causes a decline in the pool of available K in soil.

- For arable and grassland production, the target soil K level recommended by Defra for optimum production is usually 120-180mg K l^{-1} (Index 2-) and 181-240 mg K l^{-1} (Index 2+) for vegetable crops (Anon., 2000). Research results suggest that a K index of 1 may be adequate for satisfactory organic production due to the less intensive nature of production under organic agriculture, the supply of nutrients from soil reserves and organic manures. Again, there is no right answer to K levels in organic farming but avoid downward trends.

Soil biological properties

The interactions of soil organic matter (OM) and soil organisms are critical for food and fibre production particularly with regard to nitrogen fixation, transmission and prevention of soil-borne crop disease, interactions with plant roots, decomposition of organic substrates and the transformation of nitrogen (N), phosphorus (P) and sulphur (S) through direct and indirect microbial action. 80-90% of all soil processes result from the interaction of soil organisms and OM. Soil OM is the main food resource for soil organisms as most rely on decomposition of the complex organic materials which comprise the soil OM to obtain energy. Maintaining soil OM levels is also critical for maintaining soil structure. Different soil OM pools have different functions. It is the fresh or active pools that are really important, but unfortunately there is not an easy way yet of measuring these!

- There are a number of routine analytical methods for soil OM including combustion and chemical oxidation methods. Currently dry combustion at temperatures >900˚C is considered to give the most reliable determination of total soil carbon, as long as correction for carbonate (inorganic carbon from the soil parent material) is carried out. You usually get the results as percentage soil organic matter.

- Determination of the size of the soil microbial biomass as a single entity is possible; fumigation-extraction methods are robust and routinely used in monitoring. This methodology allows estimation of the amount of carbon, nitrogen, sulphur or phosphorus associated with the soil microbial biomass. These methods are not yet routinely available to farmers.

- Measurements of soil organisms and/or other biological parameters are not routinely taken in the UK or elsewhere in Europe. There is currently little research evidence to support the routine use of soil biology analysis.

- Within the next decade or so methods are likely to become available which will tell us not only about soil biodiversity but also about the function of different parts of the soil community.

Integrative soil analysis techniques

It is important for farmers to decide what works best on their farm and gives optimal value for money. Anecdotally, organic farmers use different soil analysis techniques to non-organic farmers. A small survey carried out as part of the IOTA PacaRes Laboratory mineral soil analysis Review suggests that this may not be the case.

Some alternative methods are used in the UK, most commonly:

- The Balzer system (Balzer and Balzer-Graf, 1984; Balzer, 2000) was developed specifically for organic farming. It used to be available in the UK from the Elm Farm Research Centre but they no longer provide this service. The soil is assessed using 14 separate tests which include pH, humus, humus type, P (extraction procedures described above), K, Mg and trace elements. The aim of the system is to provide a holistic view encompassing biological, chemical and physical parameters.

- The Base Cation Saturation Ratio or “Albrecht” technique (Kinsey and Walters, 1999) is also advocated to provide a soil analysis in tune with soil ecology. This analysis is available from a number of UK laboratories/soil service companies. Recent literature suggests that there is little scientific evidence supporting the claims that adopting its recommendations improves nutrient availability in UK soils (Johnston, 2006; Kopittke and Menzies, 2007).

- Precision farming is a concept that relies on the existence of in-field variability. It uses technologies such as global positioning (GPS), sensors, satellites or aerial images and information management tools (GIS) to assess and understand variations in soil properties. Soils are sampled and analysed and digital maps provided to the farmer. This allows targeted use of inputs to correct nutrient deficiencies or acidity. While this is primarily used in conventional farming for fertiliser application, it is now also being used increasingly in organic farming.

What lab should I use?

- It is important to use an analytical technique suited to your soil type! Standard methods differ in England and Scotland because soil type generally differs. See Table 1.
- Use the same analytical technique, and preferably the same lab, year on year to ensure consistency.
- Choose a service that gives an interpretation of the analysis that is relevant to organic production.

Table 1: *Relationship between Defra and SAC scales. (From PDA Leaflet "Soil Analysis: Key to nutrient management planning"). Please note the responses are described for conventional agriculture.*

		Yield response to added nutrient by	
Defra Index	**SAC description**	**Vegetable crops**	**Arable crops & grass**
0	Very low	Highly likely	Highly likely
1	Low	Highly likely	Probable
2	Moderate	Likely	Unlikely
3	High	Possible	Nil
4	High	Unlikely	Nil
5	High	Nil	Nil

Other important tools

- Plant analysis can be a useful integrative measure of nutrient availability. It is also very valuable for trace elements.
- If you suspect an animal health problem related to trace elements (deficiency or excess) then it is important to work with your vet. This may include soil analysis, although this should not be considered in isolation.
- Your own knowledge; keep notes about soil conditions in different fields. Remember that physical problems like compaction can adversely influence plant growth and nutrient uptake.
- Soil type maps can provide useful information with respect to identifying likely trace element and potassium deficiency.
- A guide to nutrient budgeting is available on the IOTA website (See useful information sources at the end of the document). Nutrient budgets should be used together with soil analysis for nutrient management planning.

Notes

[1] **Soil texture:** A description of the proportion of sand, silt and clay in a soil e.g. sandy clay loam. (See for example Soil Survey for England and Wales, 1974).

[2] **Soil structure:** A description of the 3-dimensional arrangement of particles, aggregates and spaces in soil.

References

IOTA PACARes Research Reviews (Defra project OF0347, 2007) downloadable from http://www.organicadvice.org.uk/reviews.htm

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Useful sources of further information

- PACARes Research Review on Nutrient Budgeting: www.organicadvice.org.uk/reviews.htm
- International open-access archive for research papers on organic agriculture www.orgprints.org
- Visual soil structure quality assessment www.sac.ac.uk/mainrep/pdfs/soilstructure
- Natural England Soil Texture Information Note TIN037: http://www.organicadvice.org.uk/member/technical.htm (member access only)
- The Farm Soils Plan (Scotland) download: www.sac.ac.uk/mainrep/pdfs/farmsoilsplandec.pdf

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