SOIL ANALYSIS IN ORGANIC FARMING AND GROWING

FOREWORD

Soil fertility lies at the heart of organic farming, of course; the principle that "the health of soil, plant, animal and human are one and indivisible" (Balfour, 1943) is fundamental to what we are about. The way we manage soil has a direct impact on the health of plants and animals and the health of the people that consume them (Combs, 2005). Not only that, but the way we manage soil affects the consumption of finite resources, water pollution and greenhouse gases.

Organic farming aims to produce food of the highest quality, using the minimum of finite resources while enhancing the environment. It starts off with the concept of a biologically active, living soil, one where nutrients are made available from soil particles to the plant via its root hairs through the action of root acids and soil organisms such as mycorrhiza, nitrogen (N) fixed by legumes and nutrients recycled through the utilisation of the farm's own manures and other organic material. Any underlying nutrient deficiencies are addressed through the use of brought-in manures, green waste and mineral fertilisers, which are naturally occurring and generally non-soluble. It aspires to minimising waste of nutrients and operating a closed system, as far as possible.

What is striking, and why there is the need to address the matter, is the range and diversity of soil management practices amongst farmers and growers, amongst advisers and scientists. Some organic producers take the view that they have to work with what they've got and not bring in any nutrients. At the other extreme some are routinely using high levels of inputs of mineral and organic fertilisers, supposedly acceptable to organic standards. Some never analyse their soils – an inspector recently told me that only 10 or 20% of farms have regular soil analysis, and yet analysis is a Defra requirement of all farms. Some use comprehensive analysis costing £150 a time, others use basic pH, Phosphate (P), Potassium (K), Magnesium (Mg) analysis designed for conventional farming and others use various Soil Health and soil biology analysis. The problem is that none of these analytical techniques have been properly validated for organic farming, so it is no wonder that there is uncertainty.

Maybe we have to accept that there is no right or wrong and that there is a range of practices that conform to the fundamental principles of organic farming. We do need to recognise that organic farming results in a net off-take of all nutrients except nitrogen (N) and carbon (C) and that this off-take has to be supplied from soil reserves, which on some soils may be very great and able to supply indefinitely, while on others there may be a need for some externally sourced additions of mineral fertilisers, green compost or manures. That is until we find a safe way of returning human manure to the soil, where it belongs. I would like to emphasise at this stage that organic farming is not guilty of mining the soil, in an unsustainable way, as some have claimed.

Organic farming soil management contrasts with typical conventional soil management in that the latter generally works with limited soil information, takes little account of soil reserves or the effect of biological activity and each year adds enough fertiliser, in a soluble form to equate with the crop off-take. Many years of data from organic farms shows that with good organic management soil fertility is maintained despite much lower external inputs.

WHY DO SOIL ANALYSIS?

The most obvious reasons are a) to ensure that the soil is not too acid in order to optimise nutrient availability and b) to see that soil nutrients are not deficient for optimum crop health and productivity. Analysis should always be required prior to using any externally sourced organic or mineral inputs.

- Analysis can ensure that soil nutrient levels are adequate for the needs of soil organisms, such as Boron, which is needed by nitrogen fixing rhizobia.
- Soil analysis can be used to avoid excess levels that may be a pollution risk, such as excessive phosphate.
- Regular soil analysis can ensure that longterm trends are in the right direction and that the farming system is working well.
- Soil analysis can also ensure the quality of your product, e.g. it can ensure that the crop or milk that you are selling for human consumption has adequate trace element levels and avoid excess levels of toxic nitrates.
- Analysis can assess soil organic matter and soil type, which can inform soil nutrient and manure management.
- Some analysis can measure soil biology, such as mycorrhizae, which can inform soil management.

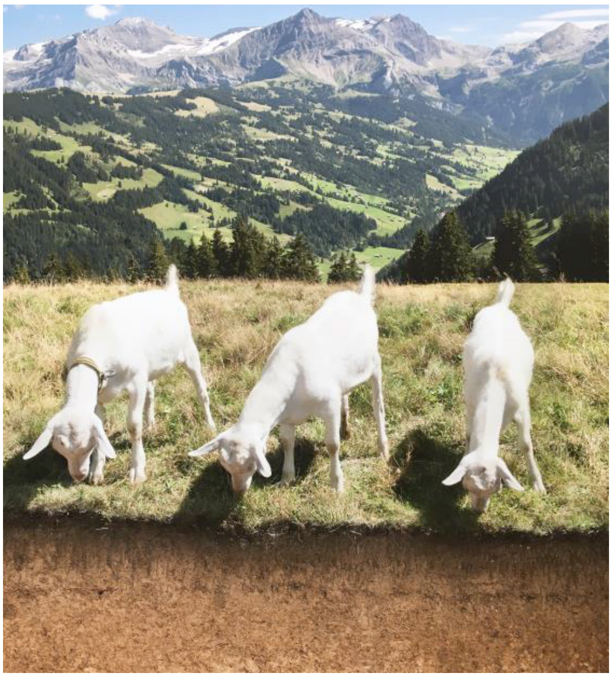


Photo: Agroscope 1

WHICH ANALYSIS SERVICE SHOULD I USE?

Standard pH, P, K, Mg analysis

Cheap (£8 – 12) and the most widely used by organic farmers, this analysis reliably measures pH. However, it only measures plant-available K and Mg. The majority of P in the soil is bound up to some extent, particularly on clays and P analysis only indicates some of the available P, but not that in organic forms or that which is locked up and may become available with high levels of biological activity. Standard soil analysis and the interpretation offered by most labs has severe limitations:

- The methods and interpretation have been developed for use in conventional farming where short-term nutrient availability is the primary concern and yields are higher than expected in organic farming.
- There is no account taken of nutrient reserves, this is a particular problem for P assessment; the availability and dynamic movement of P between reserve, intermediate and available forms cannot be assessed.
- There is no consideration of total soil organic matter or of the type of organic matter.
- There is no assessment of soil biology or meeting the needs of the soil bacteria and fungi.
- There is no account taken of the soil type and potential long-term nutrient release.

In order to make better use of the prevailing pH, P, K Mg analysis soil specialists working at SRUC, Newcastle University and Organic Research Centre have proposed that soil index targets for P, K and Mg should be one index point lower for organic farming than the target for conventional e.g. soils growing organic wheat should have an index target of 1 for P and K, compared to Index 2 in conventional farming. Table 1.

	Conventional	Organic	
Grassland	2-	1	
Arable crops	2-	1	
Veg crops	2+	1+/2-	Crop yield dependant

Table 1: RB209 (Conventional) Target Soil Index for K, with proposed revision for organic.

This reflects the higher levels of biological activity and lower yields achieved under organic farming and the expected lower nutrient requirements and offtakes, but ensures that no one macro-element is limiting. pH targets remain the same. Reference the IOTA Research Review: Laboratory mineral soil analysis and soil mineral management in organic farming. https://tinyurl.com/IOTA-RR-N

While there is currently no research validating these revised Index targets this Standard Analysis is the most widely used by organic farmers and does provide some useful basic information.

Standard Analysis services often provide the option of analysing for organic matter and a range of trace elements at a total cost of around £35.

The use of other information, including soil type from reference data e.g. Soils Guide. Cranfield University 2017 www.landis.org.uk and soil type analysis (clay, silt, sand determination), soil organic matter, soil trace elements, plant tissue analysis, nutrient budgeting and soil structure assessment can be very valuable in the interpretation and recommendations.

Soil Health analysis

Soil Health analysis is an attempt at a comprehensive assessment of the soil's physical, chemical and biological characteristics; recently developed services such as that offered by NRM (£45) in the UK includes pH, P, K, Mg, texture and organic matter and an assessment of soil biological activity using the Solvita carbon dioxide burst (respiration) test. Services offered in the US by Cornell University provide additional trace element analysis and a more detailed assessment of soil biology using the Active Carbon test (potassium permanganate) and Soil Protein test, two tests that appear to be particularly useful. The test offered by NRM provides an overall health score from 0-6 based on the various parameters measured but is heavily influenced by the respiration rate, with small adjustments made for the chemical and physical factors. The respiration test is a crude measure of soil microbiology and gives no information about the microbial population's diversity or functions. Earthworm counts and a visual assessment of soil structure should be used in conjunction with the health score to give a more accurate overall impression of soil health.

Soil Health analysis is primarily used for a spot check on the overall health of the soil, it is not intended to replace the routine analysis which is used for more regular checking on nutrients and shorter term need for soil amendments.

Base Cation Saturation Ratio (Albrecht)

The Base Cation Saturation Ratio (BCSR) analysis was developed in the 1930s and is widely used in the USA, but relatively little used in the UK and Europe.

The method places great emphasis on the development of soil biological activity and improving the availability of nutrients. Underpinning the BCSR approach is the idea that it is not just a matter of ensuring sufficient levels (or Index) of soil nutrients but that the correct ratio or balance of nutrients is essential for proper plant nutrition. Notably the proportions of the cations Calcium (Ca), Magnesium (Mg), Potassium (K), Sodium (Na) and Hydrogen (H) are considered important, and the following percentages are given as the optimum: 60 -80% Ca, 10 – 20% Mg and 3 – 5% K, 1% Na, 10 – 15% H. Figure 1. Desired cation ratios. The base saturation expresses the percentage of potential CEC occupied by these cations. It is important to say that soil type and the underlying geology must be considered and may render this ratios approach less relevant given for example that soils over chalk will always have a very high Ca and will be impossible to alter ratios. So much of this particular analysis is in the interpretation and the cation ratios may not always be deemed so important. The additional information provided on a wider array of nutrients as well as trying to 'know your soils' better and the focus on biological activity are positive aspects of this approach, however remember that those who offer the service and interpretation, may also have products to sell.

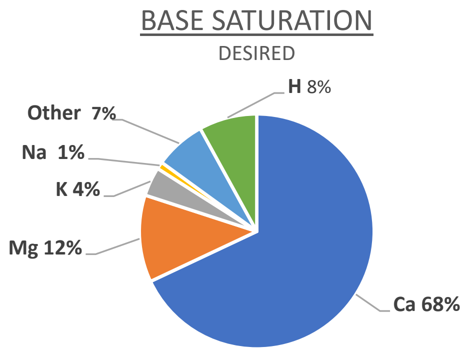


Figure 1:Desired cation ratios

The BCSR analysis usually includes the following, although there are differences between laboratories:

Organic Matter, available Phosphorus (in 2 or 3 extracts: Bicarbonate P, P1 Weak Bray and P2 Strong Bray), available Potassium, Magnesium, Calcium and Hydrogen, soil pH, Buffer Index, Cation Exchange Capacity, percentage base saturation of the cations, Sodium (Na), Nitrate Nitrogen, Sulphur (S), Zinc (Zn), Manganese (Mn), Iron (Fe), Copper (Cu) and Boron (B).

Additional services include soil type (sand, silt and clay fractions).

The interpretation of the BCSR analysis is complex and usually needs specialist expertise. The aim of the BCSR approach is to ensure optimum nutrient supply to crops by using management practices and fertiliser inputs that stimulate biological activity, enhance soil structure and improve the availability of soil nutrients. Much greater emphasis is placed on trace elements than is typical with both conventional and organic farming in the UK and elsewhere, not just to meet the crop's mineral needs but also to support the soil organisms needs for optimum biological activity; particular emphasis is placed on boron which is needed for calcium uptake, sugar translocation and rhizobia activity, manganese for photosynthesis and zinc for enzymes. However surprisingly selenium does not get a mention, even though it is essential for farm stock and perhaps soil organisms as well.

Adequate sulphur, calcium, zinc and particularly potassium are considered essential to cope with dry conditions and adequate potassium for winter hardiness.

Enhancing the soil biological activity is a priority for BCSR management. Recommendations are made to optimise that by a variety of techniques; mechanical aeration or subsoiling to improve soil structure, incorporating large amounts of green manures, adding a low rate (e.g. 3 tonne/ha) of well made compost, ensuring adequate trace elements (particularly boron, zinc and calcium), microbial inoculants and seed treatments, providing energy to the organisms in the form of molasses, use of humates and avoiding damaging practices, such as excessive cultivations or fertilisers (chlorides) or pesticides. This emphasis on biological activity makes the approach attractive to organic and agroecological farmers; we are all agreed about the importance of mycorrhiza in extending the root system and mobilising and accessing nutrients.

The most notable feature from a farmer's perspective is that those who follow the BCSR recommendations use a much higher range and level of fertiliser inputs on a routine basis than is typical of organic farms in the UK. Most advisers advisers working with BCSR analysis advocate regular use of humates – mined carboniferous material which is supplying trace elements and stimulating biological activity, as well as use of other fertilisers, either as a one off or annually. In the US these include Chilean nitrate (prohibited in organic farming in the UK), micro-ground rock dusts, potassium sulphate, monoammonium phosphate (MAP), potassium magnesium sulphate (K Mag), rock phosphate, calcium sulphate (Gypsum), poultry manure and cane molasses, which is used to supply carbon – stimulating soil biological activity and increasing nutrient availability. All these are permitted under NOP organic standards in the USA, though not necessarily in the EU. This is in stark contrast to most organic farms in the UK who are not using the range and level of inputs advocated by the BCSR method. One is left wondering; if this is really organic farming?

The question remains: is it worth it? Costing around £135 per sample, time and cost in interpretation and management and often involving substantial expenditure on inputs there needs to be a clear benefit in terms of crop yield and crop quality. As with other soil analysis and management methods the research has not been done; there are a number of trials underway in the USA, Switzerland and the UK but most have not yet been written up. The evidence to date is that the system does have at least some positive effect on crop yield and quality, soil biological activity and structure. However, the only trial results that have been written up show that under conventional arable farming the costs in management time do not outweigh the benefits in reduced input costs, at least in the short term.

Mycorrhizae population analysis

This is offered by some laboratories including PlantWorks Ltd. In the UK http://www.rootgrow.co.uk/landing . Simon Cowell, UK Soil Farmer of Year 2018, uses mycorrhizae analysis to help monitor the health of his soils in a conventional non-till arable system where he can influence biological activity with the use of high quality home made compost and lucerne in the rotation. He analyses throughout the season and across years to establish trends in root colonisation as mycorrhizae play such an import role in soil mineral and water transfer and disease protection and provide a useful indictor of overall soil biological activity. The analysis is considerably cheaper than undertaking a full soil biology analysis and appears to be useful. However, colonisation varies across soil types, crops and time of year so a consistent approach to sampling should be taken and may be most use for establishing the direction of travel e.g. whether colonisation is going up or down.

Plant Tissue analysis

The value of plant tissue analysis is well established; it tells you what actually gets from the soil into the plant, and therefore what's truly "plant available". Although in my experience rarely used by organic farmers in the UK, it is an invaluable diagnostic tool helping to understand why a plant is not performing well despite good soil analysis results. It can help verify plant deficiency symptoms, identify if there is a nutrient lock up and assess the nutrient value of forage for livestock. There are many laboratories offering the service in the UK, that includes N, P, K, Ca, Mg, Na, S, Mn, Cu, Zn, Fe, B, Molybdenum (Mo) and an Animal Health analysis, which also includes selenium (Se). Although there are limitations, the required levels are not precise and nutrient needs may be transient, the analysis is however reliable and the interpretation of the results backed up with a great deal of research which indicates general deficiency and sufficiency levels.

Recently Sap Analysis is beginning to be more widely used. As its name implies it is the leaf sap that is analysed, in the laboratory processing the plant is not dried, as it is with tissue analysis, the advantage being that it assesses the nutrients that are available to the plant at that time, whereas tissue analysis includes the many nutrients that are complexed in the cell walls and are therefore not necessarily available to the growing parts of the plant. It is particularly useful as an aid to proactive fertiliser and foliar spray use as it tells what is about to happen. If higher crop quality and disease prevention can be achieved by early intervention following Sap Analysis this could be very worthwhile for high value fruit and vegetable crops.

CHOOSING AN ANALYSIS TO SUIT THE FARM

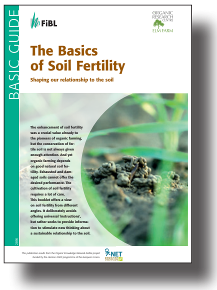
The management system. The individual farmer should choose an analysis and soil management system that suits their situation. A high management, high external input approach is unlikely to be cost effective in an upland pasture situation with low returns from beef and sheep enterprises, but it might be appropriate for a lowland vegetable cropping or fruit farm where profitability is closely linked to crop yield and quality.

1. **Initial analysis.** Initially a new field needs a comprehensive analysis, which should include pH, P, K, Mg, S plus organic matter and trace elements Na, Fe, Cu, Zn, and Bo. In addition Co, I and Se should be included if these are known to be low in the region.
2. **Routine analysis.** Ongoing Routine analysis at least once every rotation can be met by a Standard Analysis including pH, P, K and Mg (plus S for arable crops) prior to cropping. Interpretation and mineral fertiliser recommendations must take account of the lower offtakes and improved nutrient availability under a biological system.
3. **Long term monitoring.** Long term monitoring of the same two or three fields every year, to show trends over time, is invaluable. It could use one of a number of methods.
    - Standard analysis plus S is the minimum. Include Active Carbon if possible, organic matter if not.
    - Comprehensive Analysis would provide useful information on trace elements, which would be important where they may be deficient.
    - Soil Health Analysis would provide much more information on the overall health of the soil, particularly if it included trace elements, protein and Active Carbon, as with the Cornell Soil Health Analysis.
4. **Investigating problem fields or areas:** Additional trace element, N min and plant tissue analysis is very useful to help resolve problems and identify constraints to yield or crop quality.
5. **Fine-tuning.**
    - Root mycorrhizae are a good indicator of soil biology and offer a cost-effective means of monitoring. With frequent, long term analysis it is possible to build up a knowledge of mycorrhizae on your farm and develop methods of improving populations.
    - If you are growing high value vegetable crops or run a profitable cropping or dairy business there is potential to use the BCSR analysis and management. Higher value fruit and vegetable crops may warrant frequent analysis and more proactive management. Experience in using the analysis on your farm needs to be built up.
    - Sap analysis appears to offer good potential in vegetable and fruit crops for monitoring actual plant nutrient levels and responding quickly to any deficiencies and reducing pest and disease susceptibility.
    - Weekly soil N min analysis may be useful in maintaining growth and quality in vegetable crops.

FURTHER INFORMATION

The Organic Research Centre has led on the development of soil analysis and management for organic farming in the UK, at one time offering an analysis service for organic farming, something which is now sorely missed. ORC now has had three soil related projects; TILMAN-ORG, GREAT Soils and the Soil EIP project which is investigating the efficacy of different soil analysis and management strategies.

- Information: on the research projects is available at https://tinyurl.com/ORC-soils-crops
- IOTA Technical Leaflets on Soil analysis, Compost use and Phosphate management https://tinyurl.com/IOTA-leaflets
- Joint ORC/FiBL publication The Basics of Soil Fertility http://tinyurl.com/ORC-FiBL-soil



Analysis is only an aid to good organic soil nutrient management, the absolute priorities are to ensure good soil structure and drainage, develop a diverse rotation with sufficient legumes, avoid excessive tillage and support a thriving biological activity by feeding the soil organisms with large quantities of organic matter from fertility building leys, green manures and compost. In short, a systems based approach to soil management. Dig, walk, look, smell and grow!

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REFERENCE

Combs Jr GF (2005) Geological impacts on nutrition. In Essentials of Medical Geology, eds. Selinus O. (Amsterdam: Elsevier, 2005) 161-177.

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The European Agricultural Fund for Rural Development
Europe investing in rural areas