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Helping UK farmers to choose, use, and interpret soil test results to inform soil management decisions for soil health

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Introduction

The importance of soil health is now well recognised. With warnings that the UK's soils have only 100 harvests left, and with flooding a growing problem, farmers are increasingly aware of the need to improve the physical, chemical, and biological health of their soils. At a policy level, the House of Commons Environmental Audit Committee advocates replacing the existing "damage limitation" approach to soil health with more pro-active requirements and incentives for landowners to restore and improve soil quality and organic matter.[1] Such trends are encouraging. However, there remains widespread uncertainty across the farming community as to how we should monitor and measure soil health. Better understanding is needed of how farmers should choose, use, interpret, and apply soil testing to inform on-farm management decisions.

Key words: Soil, soil health, soil quality, soil organic matter, soil testing, decision support

What is Soil "Health"?

Soil health has been defined as "the continued capacity of the soil to function as a vital living ecosystem that sustains plants, animals and humans" (Natural Resources Conservation Service – USDA-NRCS, 2012). It is a function of a soil's physical, chemical, and biological systems.

Physical systems

While little can be done about a soil's texture (sand, silt, clay), its physical properties/characteristics can be significantly enhanced by improving its structure. Well-structured soils have optimal water storage capacity and drainage characteristics to feed plants and enable microbes and nutrients to move around the soil profile. The movement of water through the profile also helps air to circulate, maintaining an aerobic environment in which plant roots and soil fauna can thrive.

Chemical systems

A healthy soil provides an adequate and available supply of the essential nutrients that plants need to grow and reproduce. This is largely a function of the level of organic matter (humus) in the soil. Negatively charged organic matter particles bind to positively charged nutrient cations (Na+, Mg+, K+), holding them in the soil until they are taken up by the plants (through cation exchange). In the absence of organic matter[1], many of these nutrients will be lost from the rooting zone after significant rainfall events.

[1]Or a high proportion of clay.

Biological systems

The biological component of soils comprises two elements: i) soil organic matter, which includes living plant roots and shoots, dead and decomposing plants and animals ('organic material'), and humus; and ii) soil organisms (e.g. bacteria, fungi, protozoa, nematodes, earthworms, etc.). Healthy soils contain a plentiful supply of both organic material to feed soil organisms and humus to create a stable habitat in which soil organisms can thrive. The role of soil microorganisms in creating glomalin, which is essential for binding soils together and maintaining soil structure, is also increasingly recognised as vital for soil health

All three systems – physical, chemical, and biological – are intricately and inextricably interlinked. For a soil to be "healthy", all three systems must therefore be functioning properly. For example, poor structure may result in soils becoming waterlogged, creating anaerobic conditions in which many 'beneficial' soil organisms cannot survive. This slows the breakdown of organic materials into humus, which in turn reduces the soil's ability to hold onto essential nutrient cations, to the detriment of plant growth and health. The loss of soil biology may also result in further loss of soil structure, a lower rate of nutrient cycling, and loss of some natural plant protection.

Soil Testing in the UK

Soil testing in the UK has, to date, largely been limited to identifying nutrient deficiencies and excesses. Thus, the most commonly used test – available at relatively low cost from a large number of commercial suppliers – is the standard soil index test (pH, P, K, Mg). Many farmers also undertake regular soil mineral Nitrogen (Soil MinN) tests and some undertake more comprehensive analysis of macro and micronutrients (including Albrecht ratios/base saturation analysis).[2]

This approach appeared effective during the golden years of the green revolution. Standard soil index testing used to inform the application of synthetic nutrients saw yields grow year on year. This picture has changed over recent decades, however, with many farmers experiencing yield plateaus (or worse), while input costs (synthetic nutrients, insecticides, herbicides, etc.) continue to rise and profits fall. At the same time pest, disease, and weed pressures have seemingly increased. The scourge of blackgrass taking its toll across Eastern England is just one example.

This is largely down to the loss of soil health over the past 60 years. Excessively focused on the chemical element of soils (the availability of plant nutrients), we have neglected the physical and (particularly) biological aspects of our soils. Meanwhile our over-reliance on chemical inputs, use of ever-heavier machinery, and depletion of soil organic matter have had dramatic consequences for the biological life and structure of our soils.

As our understanding of our soils has improved, so too should the way we monitor and manage them.

A good starting point would be a more holistic approach to soil testing; one that encompasses not only the chemical but also the physical and biological processes at work in our soils. That is, a system of measuring "soil health".

Why Measure Soil Health?

Measuring soil health offers a number of practical benefits for farmers.

Better understanding of yield constraints

Plant productivity is not only constrained by the availability (or excess) of nutrients, but also by biological and physical factors. Poor soil structure, for example, can hamper root development and the plant's ability to access available water and nutrients. So too, can the absence of beneficial

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[2]Arguably, the 'standard' index based tests do not constitute "soil" tests at all. Since they assess the level of plant available nutrients rather than the total and available level of nutrients in the soil itself, such tests would perhaps better be described as "nutrient tests" rather than "soil tests

fungi (mycorrhizae) in the soil. Applying synthetic nutrients to poorly structured, biological inactive soils is likely to achieve only a fraction of the desired yield response.

Less reliance on external inputs

A better understanding of soil health could also reduce the need for external inputs. Active soil biology is essential for releasing nutrients into the soil in plant available forms. For example, earthworm casts contain five times as much nitrogen, three to seven times as much phosphorus, eleven times as much potassium, and three times as much magnesium as undigested soil. Van Groenigen *et al*. (2014) reported that the presence of earthworms increased crop yield by 25%. The presence of active biology can therefore reduce the need to provide plants with synthetic nutrients. The presence of beneficial soil organisms also protects crops from pests. For example, certain nematodes have been shown to protect plants by attacking and consuming plant pathogens, including plant parasitic nematodes. Mycorrhizal fungi can provide a protective sheath around plant roots, protecting them against attack by non-beneficial or plant parasitic organisms. In these, and a plethora of other ways, maintaining active and healthy soil biology can help reduce the need for chemical methods of pest and disease control.

Cost savings

Reducing reliance on external inputs, whether fertilisers, pesticides, or herbicides, will inevitably deliver cost savings.

Better understanding of the impact of management practices

Monitoring soil health can help farmers to understand how different soil or crop management practices impact their soils. Just as farmers have in the past tested soil nutrient levels to inform nutrient management plans, measurements of soil biological activity and analyses of soil structure can be used to inform decisions about cultivations, chemical use, machinery choice, etc. At a national level, these results can be used to facilitate research into best practices for farm- or field-specific soil health management.

What and When to Test?

A wide range of potential indicators can be used to assess soil health. These include:-

Physical indicators

Texture; structure; bulk density; available water capacity; porosity; and surface/sub-surface hardness (penetrability). Many of these physical assessments can be carried out using simple, cheap equipment and methodologies; a basic spade is a good starting point. Assessments such as water infiltration tests, slake tests, bulk density and shatter tests, and the Visual Evaluation of Soil Structure (VESS) for Soil Health test[3], are simple and useful tests that can be performed on-farm.

Chemical indicators

Affordable chemical analyses are widely available from a whole host of different soil testing laboratories/suppliers across the UK. These include tests for pH; nitrogen; phosphorus; potassium; magnesium; manganese; copper; boron; sulphur; trace minerals; soil organic matter; soil organic carbon; cation exchange capacity; nitrate/ammonium availability; and base saturation.

Biological indicators

Biological indicators include microbial respiration rates; earthworm populations; total and active fungi, bacteria, nematodes, protozoa (flagellates, amoebae, ciliates); hyphal diameter; and potential soil nitrogen. However, cheap and simple measures of biological activity, such as earthworm counts, can also be carried out on-farm.

[3]Developed by Scotland's Rural College, see: http://www.sruc.ac.uk/info/120625/visual_evaluation_of_soil_structure.

Barriers to Change

Farmers in the UK increasingly recognise the need to improve soil health and the critical role that physical and biological processes play in achieving that goal. Nonetheless, the majority of farmers, agronomist and suppliers who undertake soil testing continue to test only the chemical aspects of their soils.

There are perhaps several reasons for this. First and foremost there is a *lack of information*. A review of existing decision support tools reveals that there is currently little, if any, meaningful guidance to help farmers maximise the value and impact of soil testing for soil health.[4] This information gap desperately needs to be plugged.

Second, farmers and agronomists/suppliers need guidance as to what they should be testing to monitor soil health. This will depend on the farm's long-term soil health objectives. Is the farmer looking to boost productivity, increase water holding capacity, improve nutrient cycling, or build structure? Improving water retention capacity, for example, depends on the level of soil organic matter. This, in turn, requires high numbers of bacteria to break down plant and animal residues and high numbers of soil fungi to convert this into long-term humic matter. A farmer aiming to improve water retention capacity therefore may have less interest in soil nutrient holding capacity, but may wish to understand how much, and what type, of biology is present and active in his soils.

There is then the question of when it is best to test. While seasonal effects are important for soil physics and chemistry, they arguably have more impact on soil biology. It may therefore be best to test for soil health in spring and autumn when biology is more active, a relationship that is not widely recognised by farmers, agronomists, or suppliers.

Once a decision has been taken as to what and when to test, there is then the question of which method to use. For example, the amount of organic matter can be estimated using either the Loss on Ignition, Walkley-Black, or DUMAS combustion methods. Each is based on its own assumptions and the results obtained vary accordingly. Where different methods are used, this needs to be taken into account in interpreting the results.

Finally, better guidance is required on how to interpret soil test results. In addition to different methodologies, different labs use different reporting systems. For example, while some use parts per million (ppm) others only give relative sufficiency levels (very high, high, medium, low, very low). This can make it difficult to compare results from different labs. Soil test results must moreover be interpreted in light of a particular farm's soil type, topography, weather, crops, rotation, and cultivations, a daunting task without appropriate guidance.

A further barrier to the uptake of soil health testing is the perceived cost. While a standard pH, P, K, Mg analysis can be obtained relatively inexpensively, biological testing remains relatively costly (due to the labour intensive nature of the analysis). However, in addition to sophisticated laboratory tests, there are also a number of simple, and cheap, on-farm tests that can be used to gauge soil health. These offer a valuable alternative, particularly for biological testing, for which laboratory testing remains relatively expensive. For example, researchers at the University of Reading are currently developing a range of simple, in-field tests to measure soil biological activity.[5] Earthworm numbers, for instance, can be surveyed by sorting through a 20 cm × 20 cm × 20 cm cube of soil, with deep-burrowing earthworms extracted by pouring a mustard solution into the hole. Estimates of the rate of organic matter decomposition can be obtained by burying tea bags in the soil and weighing the loss of mass over time. The faster the tea inside the bag decomposes, the more active the soil biology and the healthier the soil. More work is required to develop and disseminate such simple techniques.

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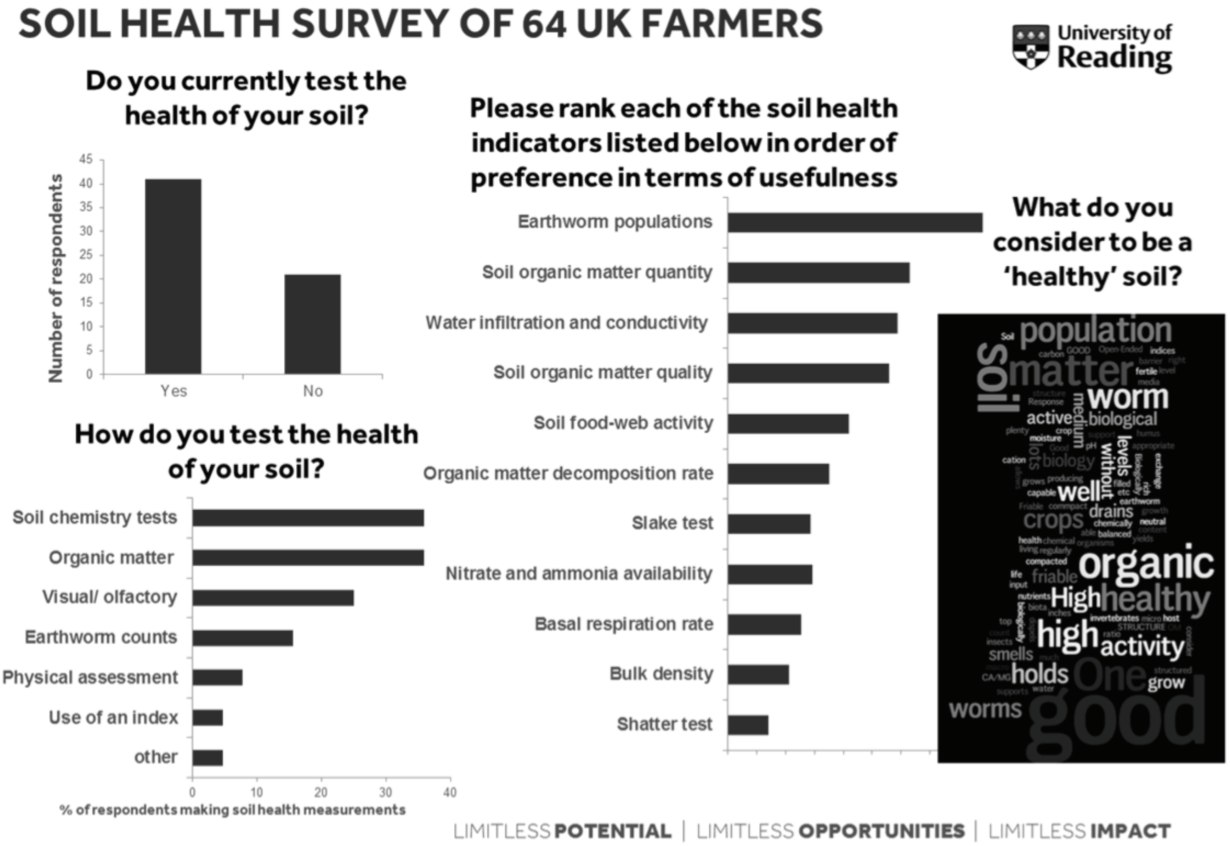
[4]Where farmers delegate the testing to agronomists and suppliers, suppliers and agronomists must also understand the importance of monitoring soil health and the options available for doing so.

[5]Tom Sizmur, "Soil Health Survey Results", available at:
https://sites.google.com/site/tomsizmur/home/news/soilhealthsurveyresults (accessed 11 January 2017).

A Need for Better Decision Support Tools?

Little recent work has been undertaken on understanding how farmers choose, use, and interpret soil test results to inform soil management decisions for soil health. Recent work by Dr Tom Sizmur at Reading University surveyed a limited group of 64 UK farmers on how they test for soil health. A summary of the results is provided in Fig. 1.



Source: Tom Sizmur, University of Reading, available at: https://sites.google.com/site/tomsizmur/home/news/soilhealthsurveyresults (accessed 11 January 2017).

Fig. 1. Summary of the results of a soil health survey conducted by Tom Sizmur, University of Reading.

The results from the limited survey show that soil testing for chemical/nutrient components and soil organic matter is still the predominant method of testing. However, when asked to rank indicators of soil health, many identified indicators such as earthworm populations, soil organic matter quality, infiltration rates, and soil food web activity. Few, if any, of these are currently routinely measured by farmers or agronomists. This suggests that the wrong indicators are currently being used for to assess soil health.

With this in mind, Innovation for Agriculture is currently surveying a large cross section of English farmers and agronomists on how they measure the health of their soils. This is being undertaken though a 2017 survey of workshop attendees, seminar delegates, agronomist groups, suppliers, and members of the Royal Agricultural Society of England (RASE). The survey will also be available online. The aim is to understand better farmers' soil testing objectives, what tests are used and when, how testing services are selected, who undertakes the testing, and how the results are interpreted and used to inform farm management decisions. The survey will also aim to identify the problems that have been encountered and the sort of guidance that would help farmers/agronomists to maximise the value and impact of soil testing.

Using the survey information, the goal of the research is to develop improved guidance and/or decision support tools that will encourage farmers to move towards a more holistic approach to soil testing, to better define their soil testing objectives, and to select the appropriate laboratory or in-field approach to meet those goals. Farmers should then be better placed to take farm management decisions that promote soil health.

The survey is being undertaken during 2017, with the results to be reported and published in the farming press in late autumn 2017. A copy of the survey is presented in Fig. 2 overleaf and can be completed on line at: http://www.innovationforagriculture.org.uk/soilhealthsurvey2017. Innovation for Agriculture would be pleased to receive completed soil health surveys (paper or completed on-line) from anyone involved in soil testing, including farmers, agronomists, suppliers etc.

Reference

Van Groenigen J W, Lubbers I M, Vos H M J, Brown G G, De Deyn G B, Van Groenigen K J. 2014. Earthworms increase plant production: a meta-analysis. *Scientific Reports* **4**:6365, DOI: 10.1038/srep06365.

Fig. 2. Innovation for Agriculture 2017 Soil Health Survey.

How do you test your soils?

INNOVATION for AGRICULTURE

This short survey is intended to help us understand how farmers and land managers currently test their soils and use the results to inform day-to-day management decisions.

The results of the survey will be used by Innovation for Agriculture and its academic partners to develop decision support tools to help farmers and land managers interpret their soil test results.

The survey should take no more than 10 minutes to complete. It does NOT require any measurement data.

Thank you for your help.

1. Do you currently test the soils on your farm?

☐ Yes ☐ No

2. Who selects what soil testing should be done on your farm?

☐ Farmer/Farm Manager ☐ Agronomist

☐ Consultant ☐ Other - please specify: ________

3. How often do you test the soils on your farm?

☐ Yearly ☐ Every 1-3 years

☐ Every 3-5 years ☐ Every 5+ years

☐ Other - please specify: ________________

4. Why do you test your soils? (Tick all that apply)

__ Crop nutrition __ Fertiliser rates

__ Lime requirements __ Soil structure

__ Soil biology __ Impact of fertilisers /pesticides on soil

5. Do you currently undertake soil mapping/zoning on your farm?

☐ Yes ☐ No

6. How do you schedule soil testing on your farm?

☐ Rotationally ☐ Field by field

☐ By crop ☐ Randomly

☐ Someone else plans it (e.g. agronomist) ☐ Other - please specify: ________

7. Who takes the soil samples on your farm?

☐ Farmer/Farm Manager ☐ Agronomist

☐ Consultant ☐ Other - please specify: ________

8. Where do you find out about suppliers of soil testing services?

☐ Advertisements / trade press ☐ Agronomist

☐ Consultant ☐ Input suppliers

☐ Other - please specify: _________________

9. Which organisation/company do you currently use to test soil samples from your farm?

____

10. Why did you choose this supplier?

☐ Location ☐ Service

☐ Results format/ advice provided ☐ Same as I have always used

☐ Price ☐ Other - please specify:________

11. How did you decide which soil tests to run?

☐ Advice of soil test supplier ☐ Price

☐ Advice of agronomist/ Consultant ☐ Same as I have always used

☐ Other – please specify: __________________

12. Who currently interprets your soil test results?

☐ Farmer/Farm Manager ☐ Soil Testing Lab

☐ Agronomist/ Consultant ☐ Other - please specify:_________

13. How do you currently use soil test results to inform management decisions?

☐ To inform use of mineral fertilisers

☐ To inform use of organic fertilisers

☐ To inform use of pesticides/fungicides

☐ To inform cropping decisions

☐ To inform cultivation methods

☐ Other - please specify: ____________________

14. Do you currently assess soil structure on your farm?

☐ Yes ☐ No

15. If yes, how?

☐ Spade ☐ Penetrometer

☐ Visual ☐ Bulk density

☐ Shatter test ☐ Other - please specify: __________

16. Do you currently assess soil chemistry (N, P, K, etc) on your farm?

☐ Yes ☐ No

17. If so, which of the following do you commonly test?

☐ pH ☐ N ☐ P ☐ K ☐ Mg ☐ Mn

☐ Cu ☐ B ☐ S ☐ SOM ☐ SOC ☐ CEC

☐ Trace minerals ☐ Nitrate/NH_3 availability

☐ Base saturation ☐ Texture

18. Do you test water infiltration rates of your soil?

☐ Yes ☐ No

19. If yes, how do you test this?

☐ Ring infiltrometer ☐ Tensiometer

☐ Other - please specify: _________________

20. Have you undertaken any soil biological assessments?

☐ Yes ☐ No

21. If yes, which?

☐ Respiration tests ☐ Earthworms

☐ Fungi ☐ Bacteria

☐ Nematodes ☐ Mycorrhizae

☐ Other - please specify: ____________________

22. Where do you get your information on soil health?

☐ Press ☐ Internet

☐ Agronomist/Consultant ☐ Input suppliers

☐ Conferences ☐ Levy bodies

☐ On-farm meetings /discussion groups ☐ Universities/ research institutes

☐ Other - please specify: ____________________

ABOUT YOUR FARM

23. How many hectares do you farm?

☐ 0-50 hectares ☐ 100-250 hectares

☐ 50-100 hectares ☐ 250+ hectares

24. What % of your farm is used for: (%)

Permanent grassland	___
Rotational leys	___
Arable	___
Horticulture	___
Other (please specify__________)	___

25. What is the ownership structure of your farm?

☐ Owner occupied

☐ Tenancy - AHA

☐ Tenancy – FBT

☐ Contract farming arrangement

☐ Other - please specify:

____

26. If you would like to receive a copy of the survey results, please provide your contact details:

Name:__________________________________

Email:__________________________________

Address:________________________________

____

Postcode:_______________________________

Your personal information will not be shared with anyone outside of Innovation for Agriculture.

Thank you for your help.