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Soil Biology and Soil Health Partnership Project 8: Industry benchmarking

Identifying current understanding, knowledge gaps and confirming the key priority issues in understanding and management of soil biology and health

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1. Abstract

The agri-food industry has a huge breadth of experience and depth of understanding of the practical issues involved in the management of soils within a rotational context and their implications for crop yield and quality; the term soil health though not widely used, is one that is readily grasped by farmers. Farmers and growers are already separately implementing a range of innovative approaches to the management of soil health within crops and rotations, often combining a number of the strategies investigated in AHDB research projects and integrating new approaches that are adapted for site-specific use. This project is part of a suite of 11 integrated projects (Soil Biology and Soil Health Research Partnership) specifically aimed at addressing the AHDB and BBRO Soils Programme call - "Management for Soil Biology and Soil Health". The purpose of this project (Project 8; see Figure 1) is to identify the key industry drivers, the potential barriers to adoption and identify areas where rapid knowledge exchange of basic science and /or existing research findings will provide rapid benefits.

To achieve this AHDB invited farmers, growers, advisors and industry partners to join one of two industry workshops to shape the direction of this new research on soil health. The interactive workshops took place in Northumberland and Gloucestershire on 13th and 15th November 2017 respectively and the summary of the feedback received at the events was made available online in December 2017. A short online questionnaire was developed to follow up some of the questions raised and the summary of the feedback was made available on-line at the end of January 2018. In parallel, there was a process of consultation with academics and technical experts to share current work and emerging results and frameworks for analysis.

We were pleased with the interest from, and enthusiastic engagement of, the industry in these consultation processes. There is a wide range of innovation already in place on-farm and we will draw from it during Project 9 to enhance the understanding of mechanisms underpinning soil health, gained in the planned experiments and observations within long-term trials in Workpackage 2. Consultation supports the presentation of existing knowledge and new research information within a two-tier system with: a) basic background information in formats aimed at all farmers; b) links to more detailed information for farmers and advisors who want to go further. Initial outputs will focus on soil organic matter and the soil food web.

Together with the benchmarking of existing academic knowledge carried out in WP1 (Project 1), this project ensured that the partnership establishes strong co-operative relationships across the industry from the outset. Co-construction of knowledge in this way ensured that the research partnership is strongly founded on the actual, rather than researcher-perceived, needs of the industry and allowed an early challenge to the programme design and focus of all the experimental projects in WP2 and

the further co-design and research approaches in WP3. Continued industry engagement is a priority and updates will be provided via www.ahdb.org.uk/greatsoils as appropriate.

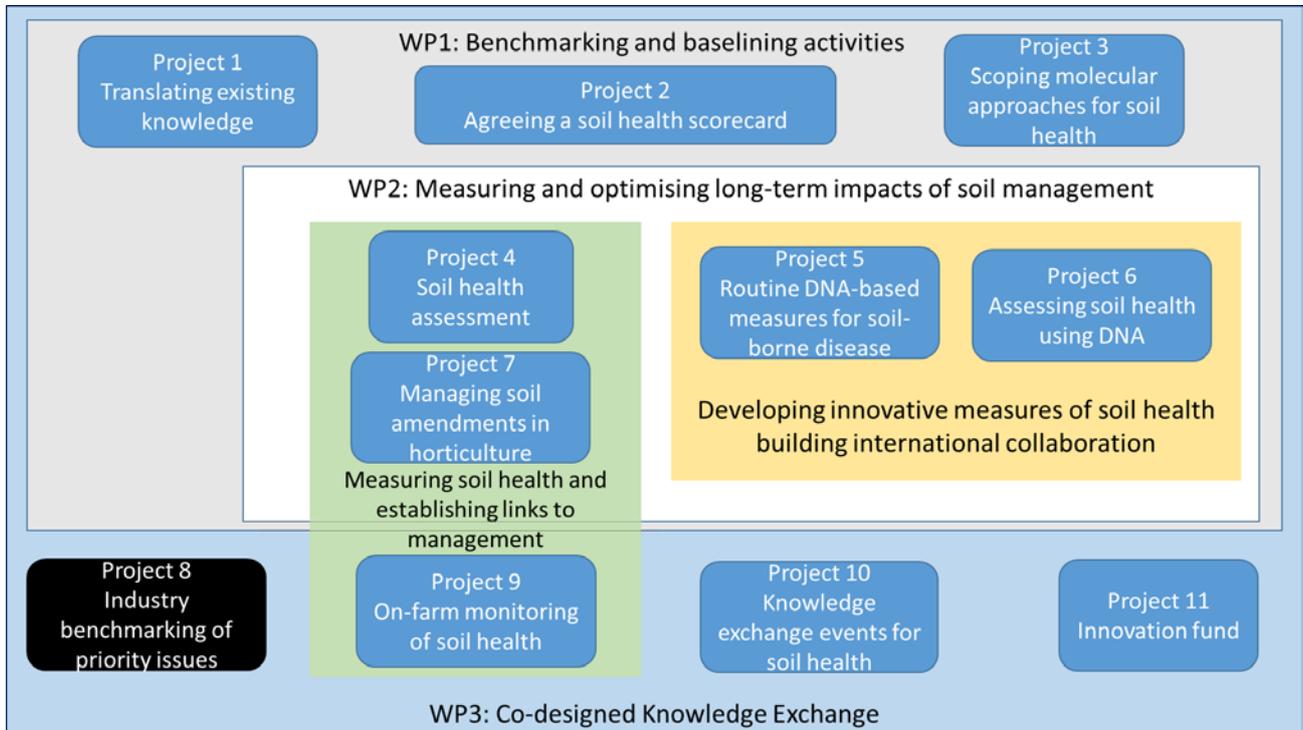


Figure 1: Diagram to show how project 8 (in black) fits into the organisation of the Soil Biology and Soil Health Partnership.

2. Background

In the UK levy-funded soil research for many years has focused on management of soil chemical status to remove constraints to crop and grassland productivity and to ensure optimisation of crop nutrient supply with regard to amount, timing and placement. More recently there has been an increased focus on soil physical condition and minimising crop constraint resulting from soil structural condition. Work delivered in AHDB Cereals & Oilseeds ongoing Soils research programme (2012-2016) has a focus on the development of practical and sustainable soil management practices including increasing understanding of how different types and quantities of organic matter influence soil structure and the effect of different cultivation techniques. AHDB Potatoes have a number of ongoing projects which have focused on changes in soil structure to identify constraints to crop production and the verification of soil quality and crop productivity indicators (e.g. R467 Soil platforms for potatoes). With regard to soil biology, the focus of levy-funded research has largely been on the management and minimisation of soil borne disease e.g. common scab, potato cyst nematode, take-all. In 2014-15, AHDB Dairy and AHDB Beef & Lamb funded a knowledge transfer project to provide farmer-facing information on soil health in grassland systems – now available under the GREATsoils programme as Healthy Grassland Soils. AHDB and the British Beet Research Organisation (BBRO) have an interest in developing research work to provide farmers and growers with guidance and better understanding of soil biology and soil health measures to improve management for soil health that supports crop and grassland productivity by optimisation of soil biological function and minimising the risks of soil-borne disease.

There is much known about the impacts of agricultural management on soil biology, crop growth, soil health, and levels of pests and diseases across temperate regions relevant to UK agriculture. This information needs to be packaged into a form that growers and their advisors can easily digest and utilise to improve productivity, cost management and resource use efficiency of their farms. However, by design, many research projects have specific and narrowly focused remits, often with limited acknowledgement of rotational impacts, and consequently implementation and impact at this scale, and within the context of the whole farm business, has been less well studied.

The agri-food industry has a huge breadth of experience and depth of understanding of the practical issues involved in the management of soils within a rotational context and their implications for crop yield and quality; the term 'soil health' though not widely used, is one that is readily grasped by farmers. Farmers and growers are already separately implementing a range of innovative approaches to the management of soil health within crops and rotations, often combining a number of the strategies investigated in AHDB research projects and integrating new approaches that are adapted for site-specific use. Therefore as one of the initiation projects of the Soil Biology and Soil Health Partnership, this project (WP3; Project 8) took a co-construction approach to the

benchmarking of current knowledge and experience and to confirm the key priority issues with regard to soil biology and health.

The purpose of this project is to identify the key industry drivers, the potential barriers to adoption and, together with the benchmarking of existing academic knowledge carried out in WP1 Project 1, to identify areas where rapid knowledge exchange of basic science and /or existing research findings will provide rapid benefits. This project also ensures that the partnership establishes strong co-operative relationships across the industry from the outset. Co-construction of knowledge in this way will ensure that the research partnership is strongly founded on the actual, rather than researcher-perceived, needs of the industry and will allow an early challenge to the programme design and focus of the research projects in WP2 and the further co-design and research approaches in WP3.

2.1. Project objectives

The industry benchmarking project (WP3; Project 8) delivered the following objectives:

- 1) Hold at least 2 one-day interactive co-construction workshops (15-40 attendees per workshop) from a wide cross-section of the agri-food industry and farming systems across the country to confirm research priorities, identify the key industry drivers, the potential barriers to adoption and identify areas where rapid knowledge exchange of basic science and /or existing research findings will provide rapid benefits.
- 2) Provide critical independent review of the descriptive model and associated farmer-friendly visual tool developed in WP1 Project 1 and make recommendations for change, if needed.
- 3) Elicit interest in participation in farmer-research innovation groups (for WP3, Project 9) that will link up a wide range of farms and farming systems across the country (encompassing a diverse range of climate, soil, rotations).
- 4) Collate the information from all the workshops as a key issues report to inform the development of the research projects in WP2 and the development of KE approaches (WP3).

3. Industry consultation

3.1. Industry workshops

AHDB invited farmers, growers, advisors and industry partners to join one of two industry workshops to shape the direction of new research on soil health. The interactive workshops took place in Northumberland and Gloucestershire on 13th and 15th November 2017 and were led by Dr Elizabeth

Stockdale (NIAB). There were *circa* 100 attendees from across all sectors and who were operating at a range of scales.

The aims of the workshops were to:

- Summarise the state-of-the-art from research in soil biology and health and ask for input on the best ways to share this information with the grower on the ground;
- Present a proposed “soil health scorecard” and seek feedback ahead of piloting through the farmer-research innovation groups;
- Listen to the questions of farmers and growers; identify challenges and opportunities that the programme should tackle in soil biology and soil health on-farm.

The overall presentation that was used to provide structure and information throughout the workshop is provided as Appendix 1. Throughout the workshop, attendees completed specific feedback sheets, which asked targeted questions and promoted discussion in small groups. Not all attendees completed the sheets and not all sheets were completed fully. In total, 75 sheets were collated and summary of the feedback received at the events is provided as Appendix 2. (For this report, the sections of the presentation are best considered in conjunction with the corresponding sections in the feedback document).

The opportunity within the Programme to participate more fully as part of farmer-research innovation groups (for WP3, Project 9), that will link up a wide range of farms and farming systems across the country (encompassing a diverse range of climate, soil, rotations), was highlighted to all participants.

3.2. Wider on-line consultation

A short on-line questionnaire was developed to follow up some of the questions raised at the workshops and to allow a wider group of farmer/ growers to contribute to the process. This was released at the beginning of December 2017 and was open for one month and received 110 responses. This is provided as Appendix 3.

The opportunity within the Programme to participate more fully as part of farmer-research innovation groups (for WP3, Project 9), that will link up a wide range of farms and farming systems across the country (encompassing a diverse range of climate, soil, rotations), was highlighted through the GREATsoils web pages on the AHDB website and an online form was developed for individuals and farmer groups to register interest. Fifty-six expressions of interest were received and discussion meetings are being held around the country (April – July 2018) with those who expressed interest; it is expected that 6-8 farmer-research innovation groups will be formed within the Programme and taken forward within WP3, Project 9.

3.3. Technical workshop

In parallel, there was a process of consultation with academics and technical experts to share current work, emerging results and the frameworks used for analysis. A Technical Workshop held on 31st October 2017 aimed to bring together those who are actively engaged in research / knowledge exchange in soil health in both academic and industry organisations to:

- Share information on current research projects and industry initiatives in the area of soil biology and soil health
- Provide a critical review of the state-of-the-art in soil biology and health summarised by the Programme team from published research;
- Provide feedback on the proposed “soil health scorecard” ahead of piloting through the farmer-research innovation groups within the Programme;
- Identify challenges and opportunities for joint working / new proposal development that the attendees could take forward in soil biology and soil health on-farm.

There were 35 attendees /apologees. The meeting began with an opportunity for all to share key information about the research projects and/or industry initiatives that they were involved within the area of soil health. These presentations were informal and confidential to the group, thus allowing more complete discussion of new/ongoing work than would otherwise have been possible. Working in groups, the attendees also sought to identify the links between projects / topics presented.

In the afternoon, the programme team briefly presented the findings of a critical review of the state-of-the-art in soil biology and health which has drawn from published research and also invited feedback on the proposed “soil health scorecard” ahead of piloting through the farmer-research innovation groups within the Programme. Participants annotated feedback sheets and the feedback was collated, integrated and summarised as appropriate.

4. Responses to issues raised through the consultation processes

In the following sections,

- The issues raised are given in normal text
 - *The response of the programme team is given in italics*

4.1. General

- We were pleased with the interest from, and enthusiastic engagement of, the industry in these consultation processes.
 - *Continued industry engagement is a priority and emerging findings and invitations to workshops etc will be shared through AHDB and the Programme partners.*

- The consultation confirmed that there is already a range of innovative practices used by farmers / growers deliberately targeting improvements in soil health and also that this innovation on-farm is often underpinned by detailed background observation and measurement to demonstrate the impacts of these changes. Changes have usually been implemented in an integrated way resulting in changes at farming systems level and hence many are at or beyond the scope of currently available detailed research-based understanding of the mechanisms involved.
 - *There is clearly scope to draw from the innovation already in place on-farm (Project 9) to enhance the understanding of mechanisms, which we will gain in the planned experiments and observations within long-term trials planned in Workpackage 2. We have already begun the recruitment process for the farmer-research innovation groups.*

4.2. Knowledge exchange for messages about soil biology and soil health

- The presentations made at the industry workshops that brought together the findings of the literature review on soil biology and its role in soil health provided information at about the right level to form the basis of introductory knowledge exchange for growers.
- Consultation confirmed the importance of using a mix of formats and approaches for knowledge exchange.
 - *During the Programme we will run workshops and farm walks, usually associated with the long-term trial sites and with farmer research innovation groups, to share information and discuss the emerging findings. We will also develop a range of materials about soil biology and soil health that are intended to outlast the Programme itself.*
- Consultation very strongly supported the use of an approach which presents existing knowledge and new research information within a two-tier system with:
 - a) Basic background information in formats aimed at all farmers
 - b) Links to more detailed information for farmers and advisors who want to go further.
 - *We will work with AHDB to develop a framework for existing KE materials and the information generated within the Programme (and other on-going work) that best organises and presents this information (on the GREATsoils website if appropriate) for all soil types and farming systems within a clear structure that is easily understood and from which materials can be easily accessed by growers.*
- Consultation did not identify any very strongly preferred formats for presentation of outputs / information.

- *We note the interest in the availability of regular updates / technical briefings and hence suggest that the development of a clear schedule for the development and provision of materials for use in this way via the GREATsoils website is part of the KE outputs for these Programmes and all future soils projects.*
 - *We note the interest in the development of an overall integrated reference source – UK Soils Guide – whether as textbook, Ebook or integrated on-line platform. By considering the overall integrating framework for Soil KE as outlined above, we would expect that by the end of the Programme, it will be possible to provide an integrated set of materials that taken together will largely provide this function. Further formatting and development into a textbook and/or Ebook format would require additional KE funding.*
 - *Alongside general introductory materials, we will provide specific and focused factsheets to describe the results of experiments and also a series of factsheets presenting detailed on-farm case studies.*
 - *We will work with the AHDB teams to prepare and make available targeted on-line videos for key topics / areas, especially, but not only, where experts and practitioners are already involved in the Programme workshops.*
- Consultation suggested that farmer engagement with KE materials and active uptake of changes to management practices would be increased where any KE platform included some interactivity and the capacity for farmers to contribute and discuss the implications / approaches in practice.
 - *AHDB should consider whether such interactivity can be built in to the GREATsoils website*
 - In the table following, we have considered the key questions and issues highlighted by growers at the industry workshops, together with the depth of information currently available following the literature review and the planned work within the Programme to determine how/ whether these issues fit within or outside the agreed scope of work.

	Ready for KE	Within SBSH Programme	Beyond SBSH programme
Knowing more about the soil and its function			
<ul style="list-style-type: none"> More education is needed 		Separate engagement with education and training providers to consider how materials can be developed / used to support learning.	
<ul style="list-style-type: none"> There is a need to explain to non-proactive farmers why they should do any of this 		Yes	
<ul style="list-style-type: none"> Is there a role for testing for specific bacteria or other micro-organisms? 	Simple messages ready to go	Yes, more detail to follow	
<ul style="list-style-type: none"> Does bacterial/ fungal ratio matter? 		With point above	Mainly outside scope
<ul style="list-style-type: none"> Can we have simple soil health indicators? 	Can already update guidance to support / encourage sampling and interpretation for a scorecard of <u>existing</u> indicators	Yes, more detail to follow	
<ul style="list-style-type: none"> Can we use the NRCS soil health test kit widely used in USA – how might it need adapting? 	In-field tests can be described with advice on limitations. Also see GREATSoils project work		
<ul style="list-style-type: none"> Can we use the Haney test? What value does this approach have? Does it need UK adaptation? 	Briefly considered in indicator review - no plan to give Which guide to existing tests		
<ul style="list-style-type: none"> Can we connect what goes on above ground to that below ground? Use of yield maps... 			Outside scope but can link to other AHDB work
<ul style="list-style-type: none"> How can we use remote sensing more effectively to guide soil management? 			Outside scope but can link to other AHDB work

	Ready for KE	Within SBSH Programme	Beyond SBSH programme
Farming systems management			
<ul style="list-style-type: none"> How can we cope without glyphosate? 			Yes
<ul style="list-style-type: none"> How can we support more adoption of mixed farming? 	Some simple messages on impacts from literature review	Expecting a farmer group in this topic area	
<ul style="list-style-type: none"> How can soil management help outdoor pigs and rotations with outdoor pigs? 			Outside scope but could add with Sector funded group
<ul style="list-style-type: none"> Can we show the value of different livestock groups within crop rotations 	Some simple messages on impacts from literature review		Mainly outside scope
<ul style="list-style-type: none"> Economics of changes in practice, both for the short term and over the course of a number of crop rotations, particularly where more than one grower is working in the same field/crop rotation and will only work the area of land for a proportion of the rotation. This is typically most important for lighter soil types where root cropping and irrigation feature. 		Economics will be considered in case studies. Multiple users across rotation noted as key issue to consider.	
Managing OM inputs			
<ul style="list-style-type: none"> Is there a simple OM test that can be used on farm? 	Yes, can draw from existing published work to give guidance on sampling, methods and interpretation		
<ul style="list-style-type: none"> How can we use soil mapping of organic matter? Does it work? 			New technology which supposedly gives remote sensed map is out of scope
<ul style="list-style-type: none"> Can advice about OM ranges from soil analysis be split / advice by textures –? 	Yes, can draw from existing work	Testing in projects	

	Ready for KE	Within SBSH Programme	Beyond SBSH programme
<ul style="list-style-type: none"> There isn't always OM available – how to find cost-effective sources? 			Socio-economic aspects are out of scope
<ul style="list-style-type: none"> Is there good / bad organic matter? 	Some simple messages on impacts from literature review	Yes, more detail to follow	
<ul style="list-style-type: none"> Is there a right type of OM to add – e.g. does adding the same amount of C as compost do something different than C as biochar/colloidal humus. 	Some simple messages on impacts from literature review	Yes, more detail to follow	
<ul style="list-style-type: none"> Checklist for different types of OM and the relevant value in terms of OM building or nutrient value. OM balance tool needs developing. 			Fully developed OM management checklist is out of scope; can link to other AHDB work
<ul style="list-style-type: none"> Is there an opportunity for support for improving carbon sequestration? 			Policy aspects are out of scope
Maintaining soil physical condition			
<ul style="list-style-type: none"> More information about drainage design, improving existing drainage systems 	Promote re-issued Drainage Guide		
<ul style="list-style-type: none"> Using guided systems (GPS) in grassland systems to protect soil structure / minimise compaction. 			Outside scope but can link to other AHDB work
<ul style="list-style-type: none"> What are the benefits of soil aeration in grassland re soil structure, drought tolerance and nitrogen efficiency? 	Some simple messages already in Healthy Grassland Soils work		Outside scope but can link to other AHDB work
<ul style="list-style-type: none"> What are the effects of good/poor drainage – can these be quantified to show the long-term value of drainage as a high cost investment? 		Yes, long-term trial will consider some of these effects	

	Ready for KE	Within SBSH Programme	Beyond SBSH programme
<ul style="list-style-type: none"> Investigate sources of soil contamination of watercourses, silting of drains / ditches. It's not just an in-field problem; we all see the damage done by vehicles of all sorts to roadside edges. 			Outside scope
Cover crops			
<ul style="list-style-type: none"> How do we measure the wider effect of different cover crops? What effect do cover crops with a nematicide effect have on other organisms? 	Existing recent AHDB Research Review plus on-going work	Expecting farmer groups will develop this topic area building on existing work	
<ul style="list-style-type: none"> Can cover crops really fix deep compaction? 			
<ul style="list-style-type: none"> How do we manage weeds better and include cover crops in the rotation at the same time? 			
<ul style="list-style-type: none"> Taking account of the costs in cover crops – seed, cultivation, slug pellets 			
<ul style="list-style-type: none"> Is grazing of cover crops positive, negative or neutral? 			
<ul style="list-style-type: none"> Can there be guidance on cover crops by soil type and cropping system? 			
<ul style="list-style-type: none"> Need to integrate consideration of slugs alongside other options e.g. cover crops 			
Managing other inputs			
<ul style="list-style-type: none"> What role does gypsum have? Is it about amounts of Ca / Mg in soil or ratios? 	Some simple messages from literature review		Outside scope but can link to other AHDB work
<ul style="list-style-type: none"> What role does Calcifert have vs lime? 			
<ul style="list-style-type: none"> Do sulphur inputs affect biology? 			

	Ready for KE	Within SBSH Programme	Beyond SBSH programme
<ul style="list-style-type: none"> Need to take all trace elements into account – as well as NPK inputs – advice on the impact on soil as well as crop nutrition. 			Outside scope but can link to other AHDB work
<ul style="list-style-type: none"> Is there a role for compost teas? 	Some simple messages on impacts from literature review; but more from GREATsoils project	Expecting farmer groups will develop this topic area building on existing work	
<ul style="list-style-type: none"> What role molasses? Is it an effective biostimulant and if so when to apply? 	Some simple messages on impacts from literature review		
<ul style="list-style-type: none"> Seaweed extract – to stimulate root growth 	Some simple messages on impacts from literature review		
<ul style="list-style-type: none"> Can we use very targeted amendments in potato crops to reduce impacts – injection? 			Outside scope but can link to other AHDB work
<ul style="list-style-type: none"> Are there guidelines for use of digestate especially from food wastes 	Some simple messages on impacts from literature review		
<ul style="list-style-type: none"> How can we use sewage sludge without pushing P indices too high? 	Some simple messages on impacts from literature review		
<ul style="list-style-type: none"> Graphs of soil index for a given nutrient vs crop yield would be very useful. "Maintaining an index of 2" is based on 50 year old data when "economic" crop production was entirely different. 			Outside scope but links to other AHDB work

- The literature review has been used to underpin the development of the soil health scorecard and the descriptive model for the impacts of management practices on soil health, crop yield & quality and environmental impacts. These outputs will be reviewed and updated (as needed) throughout the remainder of the programme.
 - *The development of a descriptive model was largely supported by the industry and technical workshops. Both made some useful recommendations with regard to how the information is presented (certainty of outcome) and the detail of presentation. We will focus on the development and presentation of the model as part of the two-tier approach, in particular to provide additional detail and capacity to interrogate the background data / relationships. The model will continue to be developed and also reviewed to ensure it is fit for use by growers throughout the programme.*

- *We are proposing that the 'legacy' KE outputs emerging from WP1 of the Programme and delivered during 2018 are focussed on:*
 - *Soil organic matter – sampling, measurement and thresholds*
 - *The soil foodweb – roles and interactions with soil functions*
 - *Principles for managing healthy soils – the triangle but with specific text identifying practices / impacts for heavy, medium, light soils and by grassland / cropping as a minimum*
 - *What is soil health? Introducing the need for integrated consideration and basic issues for sampling and integrating physical, chemical + biological*
 - *Healthy xxx Soils – providing an in-field soil structure card for a wider range of systems. Arable reformatted from SRUC and development for both intensive cropping and perennials (working with PF-Hort team).*
 - *Observing soil health in your own fields – links and materials on in-field testing*

- *This KE will be presented online through the GREATsoils website, as appropriate; the main focus will be on providing introductory KE outputs but in each case, links and additional more detailed materials will be provided.*
- *Interactivity and information posting /commenting will be considered in discussion with AHDB and piloted, if appropriate, together with KE on in-field observation of soil health.*
- *We will discuss the format and structure for presentation of the factsheets describing experiments and case studies with AHDB and these will be developed ready for reporting from 2019.*

4.3. Soil health scorecard

- The approach of presenting information as a soil health scorecard rather than as a single value for soil health was supported very strongly during consultation.
 - *There are already a number of industry approaches in place for reporting. We will continue to work closely with the industry so that we influence new developments and create some consensus whilst recognising that the site-specific interpretation of soil health data for growers is an area where there is a growing market operating.*
- The use of the traffic light approach alongside the values for different indicators to give a quick overview was supported strongly. Consultees reminded us that any colours used should allow the information to be readily understood by a person who is red-green colour blind.
- The use of a computer-based system showing the development of trends through time or patterns across the farm was considered useful and benchmarking of data (by soil type, farming system, region) was also considered to be potentially useful.
 - *We will continue to work alongside the SARIC project soilquality.org.uk to inform and develop benchmarking approaches and we will also input to the iRecord soil/ land project which is developing an app to support soil sampling linking data collected in field with the results of laboratory analysis.*
- Consultation has shown that there is a desire for farmer-friendly in-field tools to monitor soil health.
 - *Some soil health monitoring systems have focussed solely on in-field tools; others are based solely on lab. testing. The pilot scorecard measures includes in-field assessment of soil structure alongside lab. measures. We will also provide information on the wider range of in-field tests and their limitations. As discussed above this is also an opportunity to add to the interactivity of the KE.*
- At the industry workshops, we suggested an autumn sampling timing for the soil health scorecard, which would be deployed rotationally (*circa* 1 in 4 years). The feedback raised significant concerns about the workload implications (and hence the likelihood of adoption) and also the difficulty of ensuring a common state for sampling sites (crop, stubble, cultivated soil). In the online questionnaire we specifically asked about the fit of the sampling with workload. There was no clear consensus.
- Simultaneous sampling for all the scorecard measures is essential to make the proposal practicable, but requires compromise in the science as most of the measures will show some temporal variation. We would like to include assessment of earthworm populations as part

of the scorecard and hence the soils need to be moist (field capacity) and not too cold at sampling hence spring and autumn are preferred.

- *We will continue to consider and review this question. For 2018, we have been successful in obtaining charity funding (JC Mann Trust, The Morley Agricultural Foundation) to deliver a short parallel study of the soil health indicator scorecard in a long-term rotation/ cultivations experiment (STAR). This will include a comparison of the scorecard measures made in spring and autumn in a sub-set of treatments.*

5. Conclusions

Together with the benchmarking of existing academic knowledge carried out in WP1 (Project 1), this project ensured that the partnership established strong co-operative relationships across the industry from the outset. Co-construction of knowledge in this way ensured that the research partnership is strongly founded on the actual, rather than researcher-perceived, needs of the industry and allowed an early challenge to the programme design and focus of all the experimental projects in WP2 and the further co-design and knowledge exchange approaches in WP3. The findings of the project as outlined above will inform the remainder of the programme.

The ongoing work will take place within the framework established by the Soil Biology and Soil Health Research and Knowledge Exchange Partnership and updates will be provided via www.ahdb.org.uk/greatsoils as appropriate.

Appendix 1 – Managing soil health workshop: presentation

GREATSOILS



Managing Soil Health Workshop

Soil Biology and Soil Health Partnership

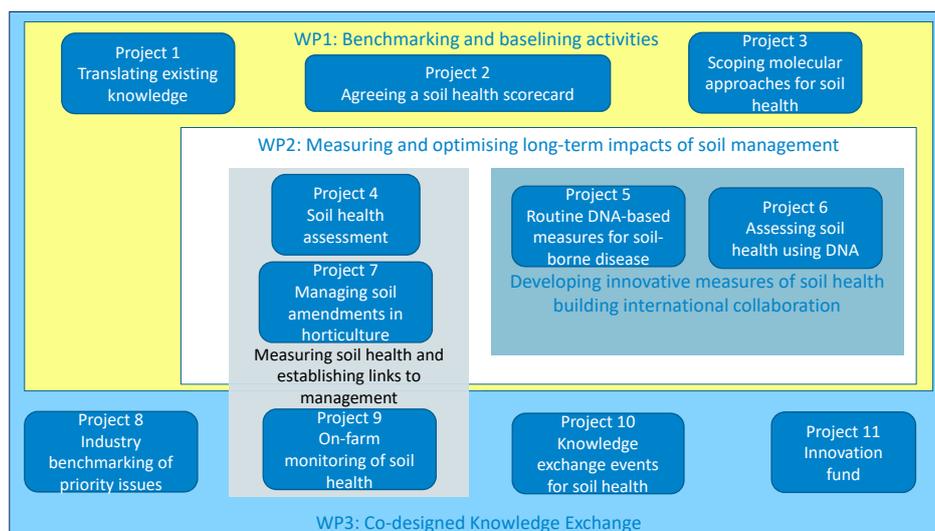
Research and Knowledge Exchange

GREATSOILS



What will the partnership do?

- Five years to deliver linked knowledge exchange and research on soil biology and soil health
- Improve on-farm understanding of soil health by sharing current academic and industry knowledge in usable formats
- Developing and validating indicators of soil biology and soil health in research trials and on-farm
- Building on work already carried out



GREATSOILS



Farmer innovation
developing locally
adapted practices



GREATSOILS



Knowledge exchange for
messages about soil biology

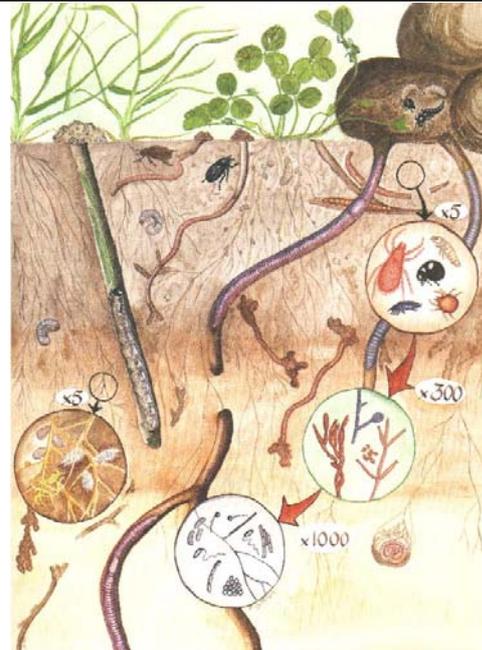
FARMING
Winter 2006



WORTH PRESERVING

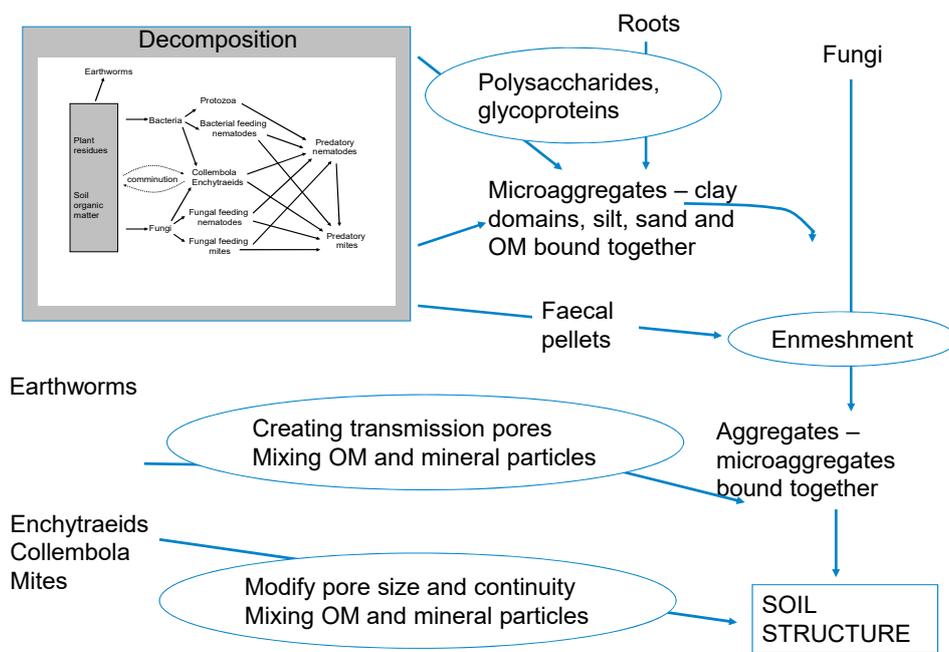
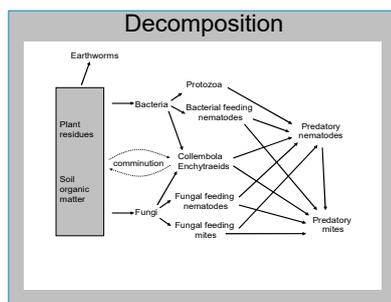
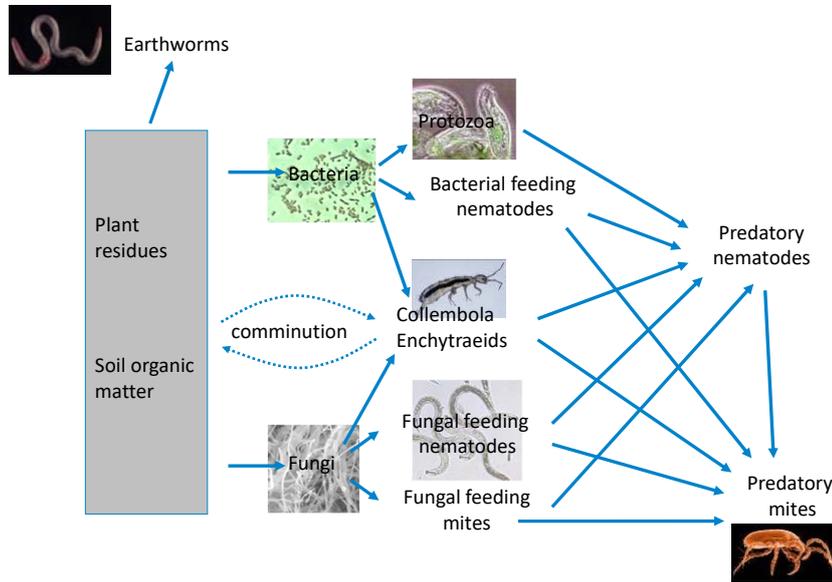
SOIL LIFE

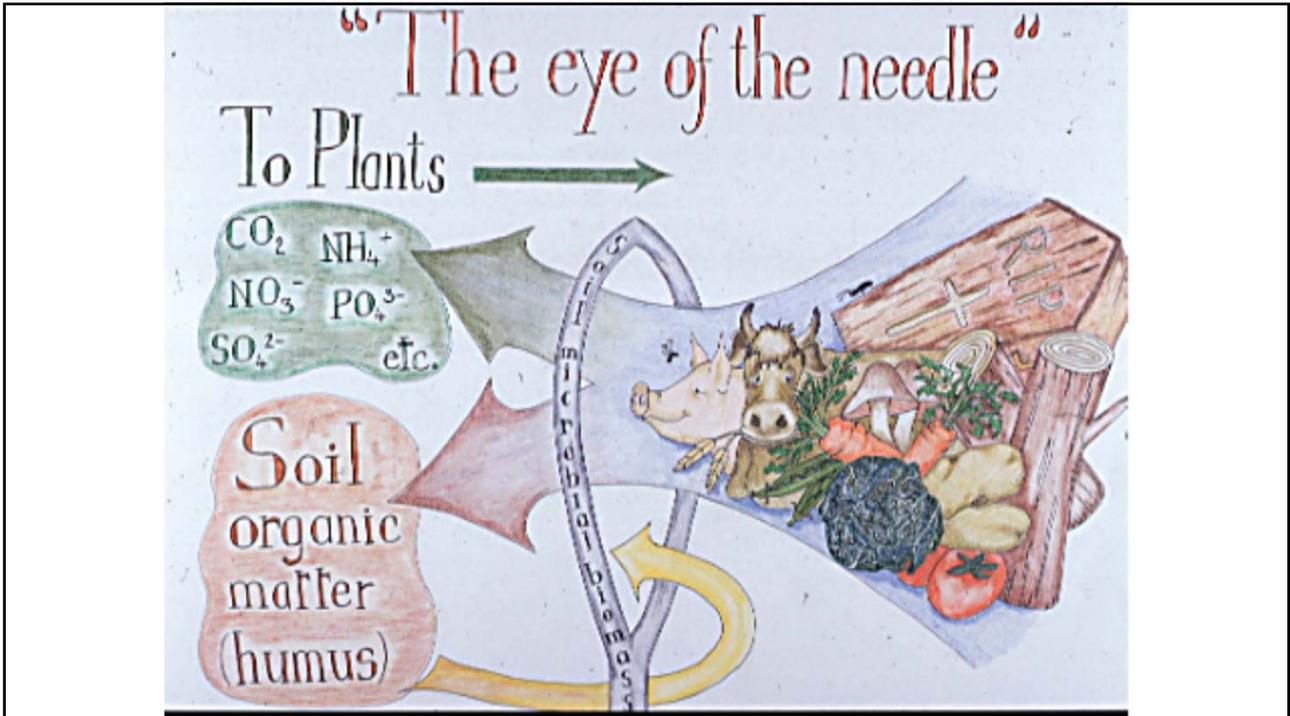
- There is lots of it
- Very species rich – still more to find and identify
- Hangs out in hot spots
- High proportion dormancy
- Specialists – but lots of shared roles



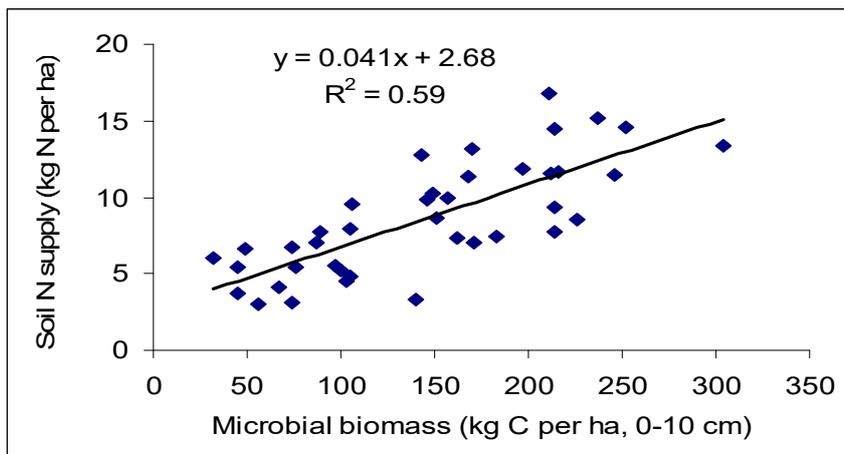
Source: Molloy, L. (1988) Soils in the New Zealand Landscape

Decomposition – transforming the sun’s energy a joint venture for the food web





Generally with greater microbial biomass,
there is more soil nutrient supply



Data from Western Australian Wheatbelt, Prof. Dan Murphy

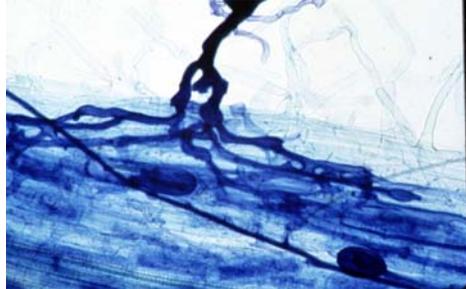
Roots plus soil micro-organisms

N fixing bacteria - rhizobia



- Bacteria-plant symbiosis
- Efficiency reduces when N available in soil
- Host specific

Arbuscular mycorrhizal fungi



- Fungal-plant mutual parasitism
- Increases plant water & nutrient esp. P, Zn uptake
- Stabilising soil structure

Don't forget that plant roots aren't just passive straws

- Changing soil pH in the rhizosphere
- Excreting chelates (often organic acids – lactate, citrate) into the rhizosphere
- Releasing hydrolytic enzymes which breakdown soil organic matter

All these mechanisms can give access to slowly available soil reserves of nutrients

Lupin roots

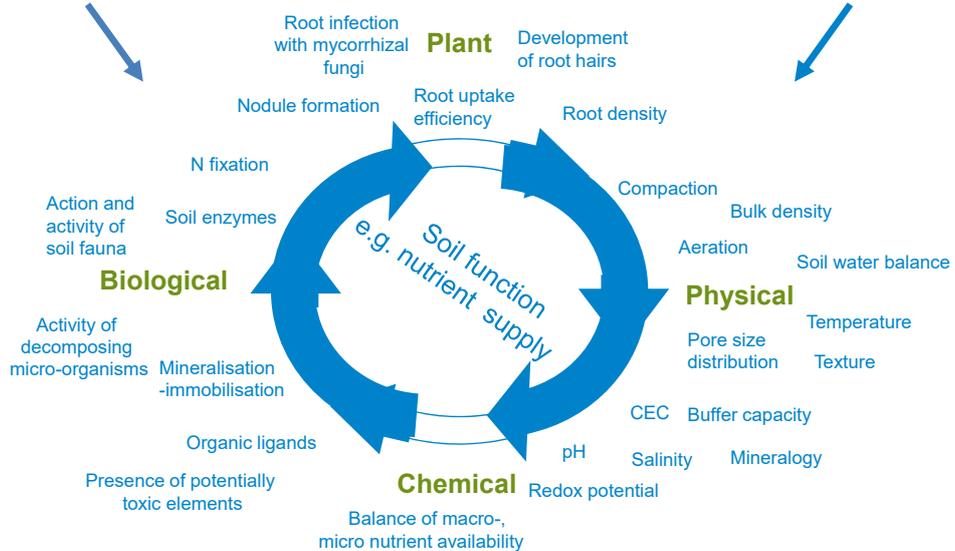
Yellow: pH < 6.5

Red: pH > 6.5



CLIMATE
Temperature, rainfall, evaporation
Where impact is mediated by
both amount and seasonality

NUTRIENT INPUTS
Fertiliser, manure, deposition etc
where availability is mediated
by many of the same factors



So what does science know?

At scale of farming systems, the scientists' understanding of impacts on soil quality is incomplete and, where it does exist, fairly sketchy.

But increasing evidence that the increased OM inputs (diversity) and reduced tillage act together to promote increased biological activity.

There is some indication that resilience to extreme events may be increased as a result.

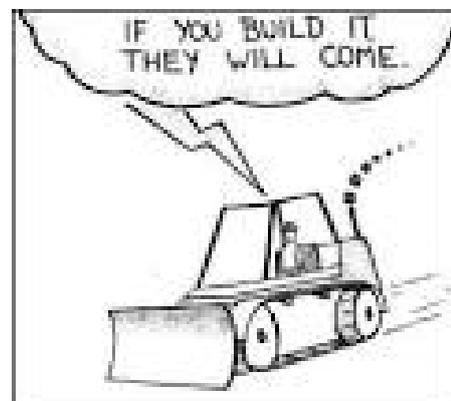
Increasing OM inputs to maintain good baseline activity increases resilience to tillage disturbance (even potatoes).



So how can I help
the soil life help me?

System-oriented approaches

- Increase OM inputs
- Increase plant diversity
- Reduce tillage intensity



In arable systems

- Tillage intensity appears to have great effect
- Organic matter additions (including crop residues) are also very important
- Optimum soil management for individual species is different and dependent on key species traits
- Soil type (especially texture) is a key influencing factor

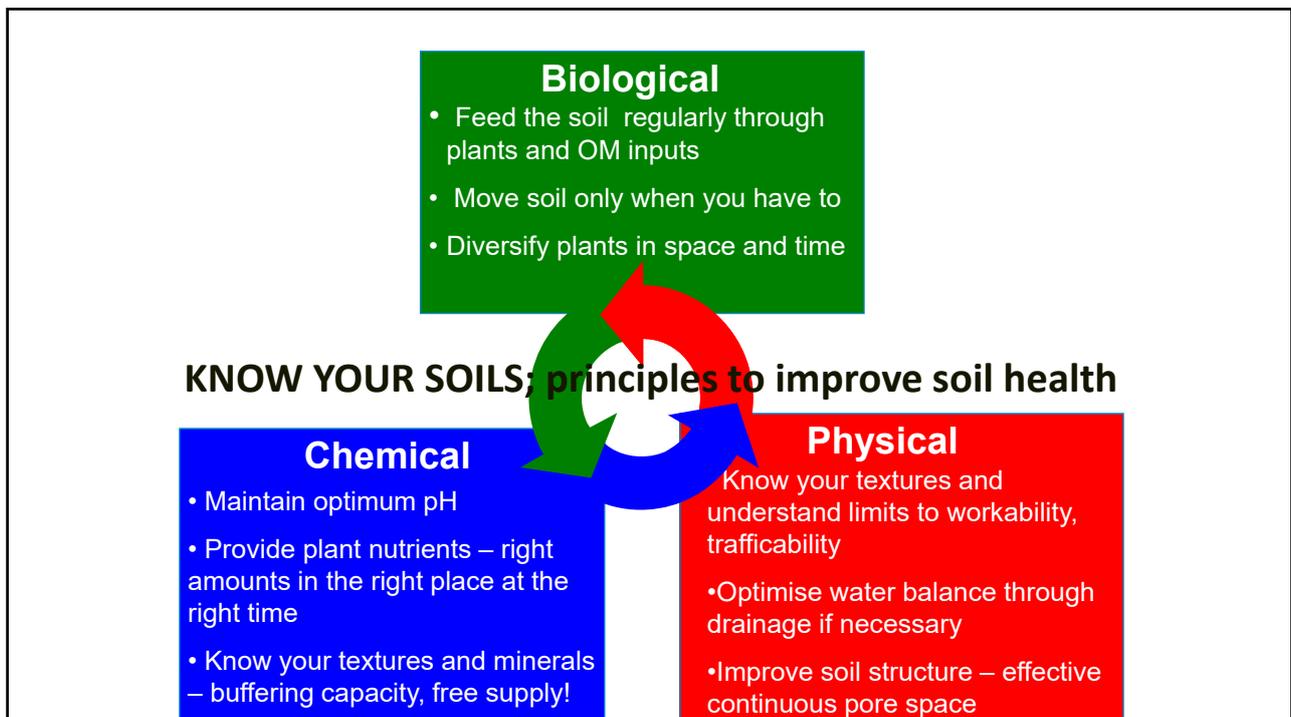
In livestock systems

- Stocking density appears to have a large impact (compaction, silage)
- Organic matter additions are also important but mixed methods for on-farm manure handling - reduced direct use of slurry and increased composting have positive impact
- Diversification of crop rotations with grass/clover leys and mixed whole-crop silage
- Mixed species swards for grazing and conservation
- Soil type (especially texture) is a key influencing factor

More detail ...
Natural England Commissioned Report 100

Available online

STOCKDALE, E.A. & WATSON, C.A. 2012. *Managing soil biota to deliver ecosystem services*. Natural England Commissioned Reports, Number 100.



What's the best way to provide information for growers to use?

- Paper leaflets
- On-line
- Webinars, presentation at your computer (live once – then accessible later)
- Video clips
- Case studies
- A mix of things (but what are your priorities?)

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Soil Health Scorecard

Why measure soil quality?

Think of it in terms of:

An MOT for your soil OR a check up at the doctors

- Working towards
 - (i) rolling out soil quality testing
 - (ii) 'what if' model for knowledge exchange

Why measure soil quality?

Think of it in terms of:

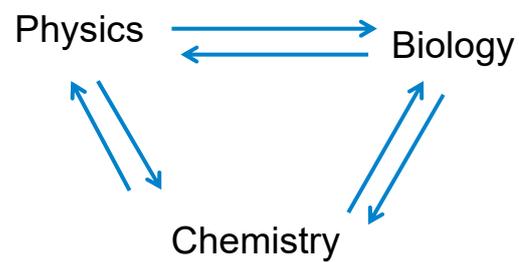
An MOT for your soil OR a check up at the doctors

- Working towards
 - (i) rolling out soil quality testing
 - (ii) 'what if' model for knowledge exchange

First questions

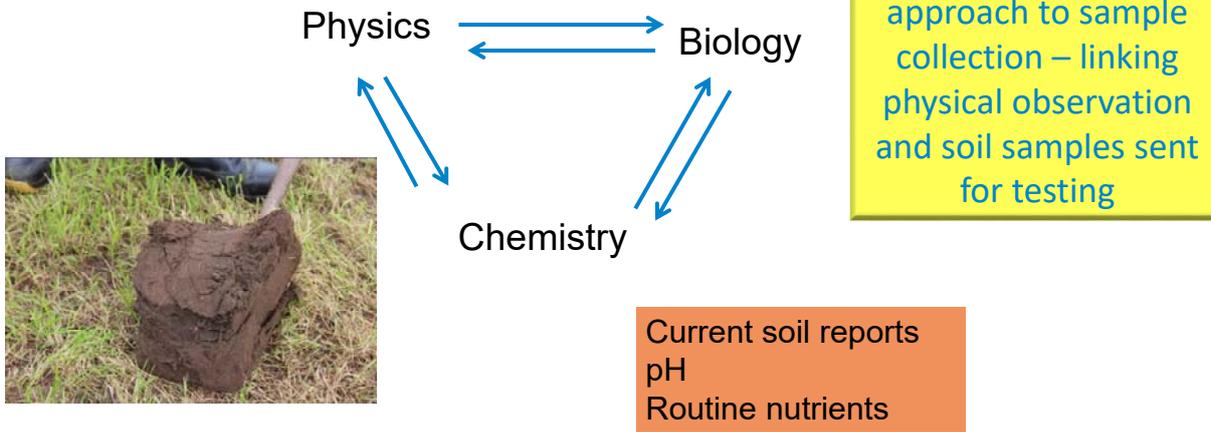
- What is the state of my soil?
- Depends on
 - Soil type
 - What you do with it
- How do I tell?
 - Need indicators as can't measure everything

Components of soil quality



Current soil reports
pH
Routine nutrients

Components of soil quality



Testing and developing measures of soil quality

Existing indicators included	pH Routine nutrients Bulk Density Penetrometer resistance
Less common indicators evaluated and framework for interpretation developed	Visual assessment of soil structure (VESS) Soil organic matter / loss on ignition (LOI) Respiration and Solvita test (NRM) Earthworms
New indicators developed and tested	Total N Microbial biomass carbon (MBC) Potentially mineralisable nitrogen (PMN) DNA measures of pathogens and soil health Nematodes Microarthropods

Rolling out soil quality testing Scorecard threshold values

Based on proposals for soilquality.org.uk (based on the Australian model - <http://www.soilquality.org.au/>) to enable utilisation of a wider database for benchmarking and ultimately advice.

The traffic light system represents:

RED (High risk, need to investigate urgently)
AMBER (Moderate risk, need to investigate further)
GREEN (Low risk, continue to monitor)

What might a scorecard look like ...

ACME SOIL ANALYSIS COMPANY

Report for Mr A. Farmer

(who has a grassland field that needs some lime, has had a fair bit of P added and is compacted)

pH	AMBER
P	AMBER
K	GREEN
Mg	GREEN
Potentially Mineralisable Nitrogen	GREEN
Loss on Ignition	GREEN
VESS	RED
Earthworms	GREEN
DNA measures	GREEN

Would be followed with links to or hard copy of background information on the parameters measured, especially if red or amber.

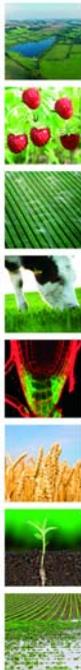
Backed up by details...

Scotland – Extractable P (Modified Morgan's)

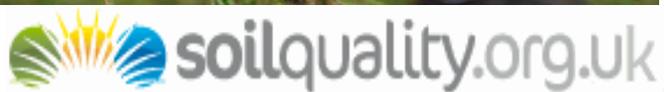
Bar chart classes	Traffic light colour	Description of this class (e.g. toxic)
0-1.7	Red	VL – risk to production
1.8-4.4	Yellow	L – potential risk to production
4.5-9.4	Green	M-
9.5-13.4	Green	M+
13.5-30.0	Yellow	H – potential risk to environment
> 30.0	Red	VH – risk to environment

Links to information sheets, websites, apps, hardcopy options

SARIC - SUSTAINABLE AGRICULTURE RESEARCH & INNOVATION CLUB

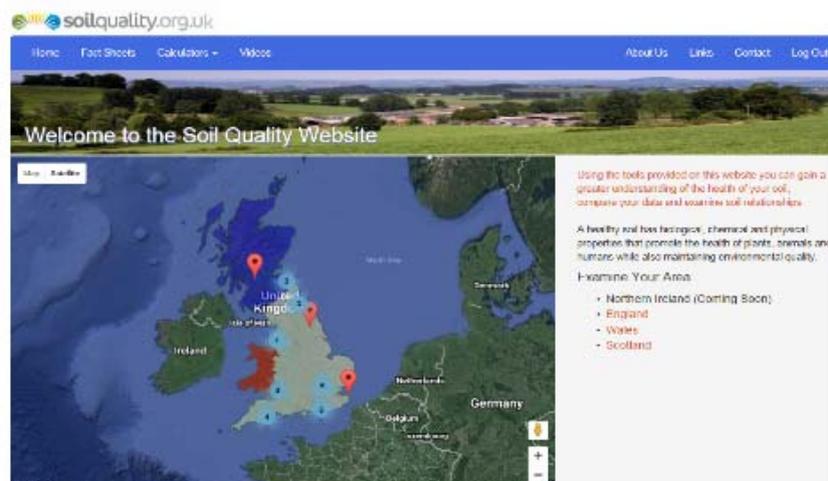


Making more of the results



Potential for benchmarking

- As in the current SRUC 'agricalc' where you can see your carbon footprint in relation to others
- You will be able to see how your soils perform against comparable soils and over time
- Benchmarking will improve the more data is entered



Great Southern Albany Sand Plain - pH (CaCl₂) - 0 - 10 cm

Australia / Western Australia / Great Southern

Overview **Examine** Compare Relate



Year	Soil Texture	Rainfall	Management Group	Land Use	Sample Size
All	All	All	Albany Sand Plain	All	261
All	All	All	Albany Sand Plain	Cropped	51
All	All	All	Albany Sand Plain	Permanent Pasture	106

Graph Additional DataSets

Year:

Soil Texture:

Rainfall: All Cropped Permanent Pasture Crop + Pasture Bushland

Management Group:

Land use:

Choose a Soil Quality indicator from one of the three tabs below to examine grouped data.

Biological

Chemical

pH (CaCl₂)

- 0 - 10 cm
- 10 - 20 cm
- 20 - 30 cm

Water Repellency

- 0 - 10 cm
- 10 - 20 cm
- 20 - 30 cm

Electrical Conductivity (ECe)

- 0 - 10 cm
- 10 - 20 cm
- 20 - 30 cm

Nitrogen Stock

- 0 - 30 cm

Cation Exchange Capacity

- 0 - 10cm

Physical

Fact Sheets related to pH (CaCl₂) - 0 - 10 cm

- [Making Sense of Chemical Indicators](#)
- [Managing Soil Acidity - WA](#)
- [Soil Acidity](#)

Cradle Coast Compare Your Data

Australia / Tasmania / Cradle Coast

Overview **Examine** **Compare** Relate

Site Report - Bulk Density - 0 - 10 cm

[Return to Site Report](#)

State
Tasmania
Region
Cradle Coast
Paddock ID
TASO164

Management Group
Unavailable
Soil Texture
Loam
Land Use
Crop + Pasture
Rainfall
< 800mm

How To Compare Data

The circle on the graph represents your value from soil test results. This sits next to a plot showing the entire spread of that groups' data. The line in the centre is the average value of the all the data, and the box surrounding represents the middle 50% of the sample sites in this dataset. The upper and lower "tails" reflect the range for the top and bottom 25% of the sample sites in this data set.

Choose a Soil Quality indicator from one of the three tabs below to compare grouped data.

Biological

Chemical

Physical

Clay Content

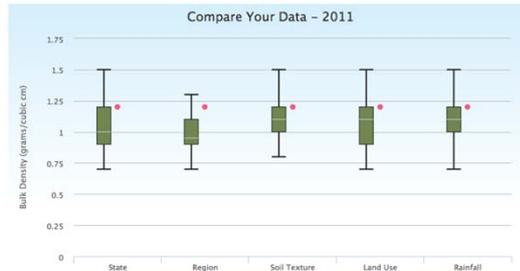
- 0 - 10 cm

Bulk Density

- 0 - 10 cm
- 10 - 20 cm
- 20 - 30 cm

Gravel Content

- 0 - 10 cm
- 10 - 20 cm
- 20 - 30 cm



Questions – the soil scorecard

- What are you already measuring? Why?
- Would a health check (once per rotational cycle) be useful?
- Is the idea of a scorecard (rather than a single soil health measure) useful?
- Are traffic lights a good way of summarising?
- Would the ability to relate values regionally and/or over time be useful?

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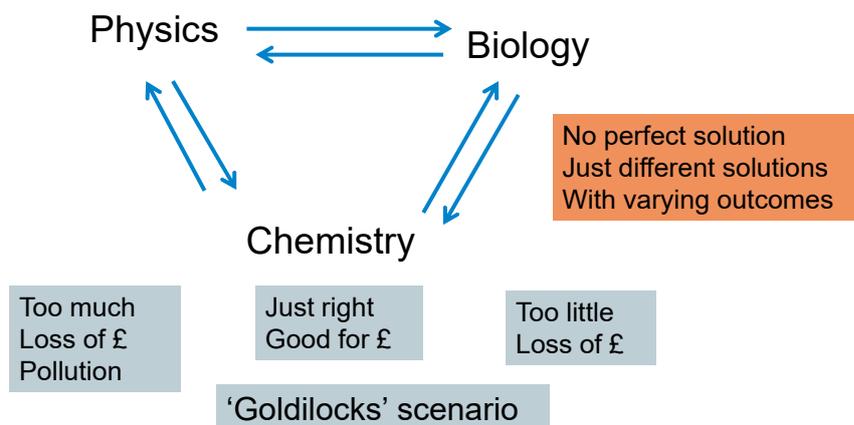
AHDB

Descriptive model and visual tool

'what if' model for knowledge exchange

- To get across the interactions that go towards soil quality
- To present some basic scenarios for management change
- Lead you to other sources of information

Interactions within soil quality



Background information – effects of general management options

DRIVER		Reduced Tillage
	Earthworms	+
	Microbial biomass	+
	+ve Enzyme activity	+
Biology	Biodiversity	+
	Natural enemies	+
EFFECTS	Slugs	+
	-ve Weeds	+
	Diseases	+
	+ve Soil Organic Matter	+
	Nutrient Loss	-
Chemistry	-ve Herbicide Use	+
	Pesticide Loss	
	Nutrient Immobilisation	
Physics	Soil Structure	+/-
	Trafficiability	+
	Water infiltration	+
	Yield	-
Margin	Short Term	-
	Long Term	+

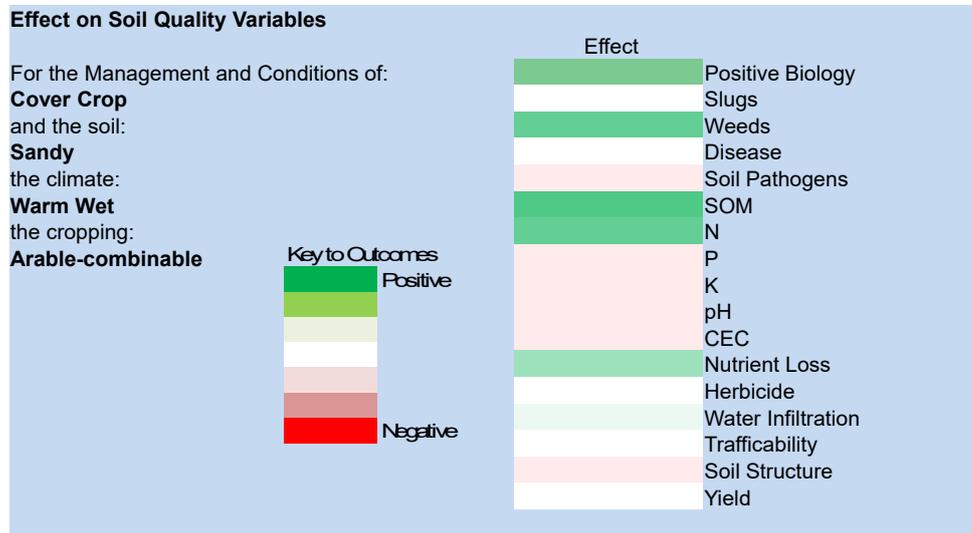
Similar tables for:
 No-till
 Cover crops
 High N amendment
 High C amendment

Knowledge introduction – visual tool

- Rationale is to visualise those complex interactions
- To give rapid overview of the general responses to expect

Knowledge introduction – visual tool

I'd like to know about the effects of changing management to.....



Questions – the visual tool

- Is this a useful way of giving information on the interactions between management actions and soil quality?
- What changes are needed to make it more useful?
- Throughout the programme we will be working to develop the presentation of the model to make it easier to use.
It is likely to be an online tool... are there any examples of successful tools (from any field) you think we should look at to guide us.

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www.ahdb.org.uk/greatsoils



**'Inspiring our farmers, growers
and industry to succeed in a
rapidly changing world'**

Appendix 2 – Managing soil health workshop: feedback from attendees

Feedback from attendees

Background

AHDB invited farmers, growers, advisors and industry partners to join one of two industry workshops to shape the direction of new research on soil health. The interactive workshops took place in Northumberland and Gloucestershire on 13th and 15th November 2017 and were led by Dr Elizabeth Stockdale (NIAB) who is leading the new Soil Biology and Soil Health Research and Knowledge Exchange Partnership. There were c. 100 attendees from across the sectors and who were operating at a range of scales.

Between 2017 and 2021, the Soil Biology and Soil Health Partnership will bring together the best research and the most effective practical approaches to soil management on-farm.

The aim of the workshops was to:

- Summarise the state-of-the-art from research in soil biology and health and ask for input on the best ways to share this information with the grower on the ground;
- Present a proposed “soil health scorecard” and seek feedback ahead of piloting through the farmer-research innovation groups;
- Listen to the questions of farmers and growers; identify challenges and opportunities that the programme should tackle in soil biology and soil health on-farm.

The following information is collated from the feedback sheets completed by the attendees. Not all attendees completed the sheets and not all sheets were completed fully. In total 75 sheets are collated here.

The introductory presentations are provided as a separate pdf document and their use to introduce the sections of the workshop are indicated with each section as appropriate.

Introduction to the programme

Catalogue of practices already in place to improve soil health on farm

Attendees shared information about the current range of practices that they were already employing on farm to improve soil health. I have listed these below in no particular order but with some attempt at providing rough grouping.

Knowing more about the soil and its function

- Soil analysis and acting on it
- Full soil analysis (Albrecht) on heavy soils for tree crops
- Plant tissue analysis
- Not getting too hung up on analysis but looking regularly at soil itself alongside analysis results
- Counting worms

Increasing OM inputs and their diversity

- Increasing OM%
- Incorporating more straw – ideally just gently in upper horizons
- Avoiding empty stubbles/bare soil overwinter - ensuring there are active roots for 12 months of the year.
- Managing volunteers (beans, cereals) & weeds to give cover post-harvest
- Autumn cover crops in arable and mixed rotations between harvest and spring crops – tillage radish, fodder radish, white/brown mustard, Italian rye grass, black oats, stubble turnips, canary grass
- Need to be careful with species choice – awareness of whole rotation implications
- Cover crops between spring crops in the rotation – phacelia, radish, rye, mixtures
- Summer cover crops (e.g. vetch) from early summer to late summer between harvest and a winter crop
- Cover cropping in perennial and tree crops
- Sheep-grazing of cover crops
- Undersowing
- Clover understorey in OSR
- Crop rotation incorporating rotation of cultivation types / depths
- Adding spring beans and spring oats to widen rotations
- Changing crops grown – avoiding late-harvested crops which have more soil damage
- Putting livestock back into arable systems
- Adding species to leys to create herbal leys (benefit for livestock and soil)
- Soil amendments in arable systems – composts, greenwaste, mushroom compost, anaerobic digestate, biosolids, chicken manures, biochar
- Mixed use of muck and slurry within the grassland systems – targeting use to field need
- Good straw for muck arrangements
- Muck onto OSR ground

Improving physical condition

- Looking at soil before working it (spade)
- Improved tyres and working practice to reduce compaction
- Leaving headland until last always to allow solid ground for turning
- Subsoiling
- Targeted aeration / subsoiling in grassland
- Minimum tillage approaches (10 cm or less)
- Non-inversion tillage
- Zero tillage – conservation agriculture
- Not travelling in winter/wet
- Not working soil when it is in less than ideal condition
- Flexibility in cultivation approaches – timing, depth +
- Rotational ploughing – no more than 1 year in 5
- Controlled traffic farming – arable and grassland
- Sheep wintering sites set up (including silage bales) with hand-moveable feed barriers when soil is trafficable so that no traffic is needed in the winter
- Checking drains and making sure they are running
- Improving drainage where needed
- Doing less

Managing inputs

- Targeted liming
- Using Ca lime on high Mg soils
- Use of Ca additions to lighten soil
- Developing specific wastes for the systems – targeted composting of wastes with inoculation of bacteria
- Using stimulants for biological activity e.g. molasses
- Variable rate lime, P& K (analysis and application)
- Using liquid fertiliser to improve accuracy
- Increased accuracy and control in muck /slurry spreading (usually by working with contractors with better kit)
- Targeted use of anaerobic digestate
- Using glyphosate appropriate with the correct timings whether pre- or post-harvest
- Using livestock (e.g. outdoor pigs) but need to be careful with soil type / management

Key questions that should be worked on during the lifetime of the Programme?

Following the discussion of their current practices in small groups, attendees discussed the key questions /topic areas that they would like to see covered within the Programme. Again, I have listed these below in no particular order but with some attempt at providing rough grouping.

Knowing more about the soil and its function

- More education is needed
- There is a need to explain to non-proactive farmers why they should do any of this
- Is there a role for testing for specific bacteria or other micro-organisms?
- Does bacterial/ fungal ratio matter?

- Can we have simple soil health indicators?
- Can we connect what goes on above ground to that below ground? Use of yield maps...
- How can we use remote sensing more effectively to guide soil management?

Farming systems management

- How can we cope without glyphosate?
- How can we support more adoption of mixed farming?
- How can soil management help outdoor pigs and rotations with outdoor pigs?
- Can we show the value of different livestock groups within crop rotations

Managing OM inputs

- Is there a simple OM test that can be used on farm?
- How can we use soil mapping of organic matter? Does it work?
- Can advice about OM ranges from soil analysis be split / advice by textures –?
- There isn't always OM available – how to find cost-effective sources?
- Is there good / bad organic matter?
- Is there a right type of OM to add – e.g. does adding the same amount of C as compost do something different than C as biochar/colloidal humus.
- When building up organic matter we need a checklist / recommendation for different types of OM and the relevant value in terms of OM building or nutrient value. Also need to understand how much OM we are removing in a rotation in order to understand better how much we need to put back in
- Is there an opportunity for support for improving carbon sequestration?

Cover crops

- How do we measure the wider effect of different cover crops? What effect do cover crops with a nematicide effect have on other organisms?
- Can cover crops really fix deep compaction?
- How do we manage weeds better and include cover crops in the rotation at the same time?
- Taking account of the costs in cover crops – seed, cultivation, slug pellets
- Is grazing of cover crops positive, negative or neutral?
- Can there be guidance on cover crops by soil type and cropping system?
- Need to integrate consideration of slugs alongside other options e.g. cover crops

Maintaining soil physical condition

- More information about drainage design, improving existing drainage systems
- Using guided systems (GPS) in grassland systems to protect soil structure / minimise compaction.

Managing other inputs

- What role does gypsum have? Is it about amounts of Ca / Mg in soil or ratios?
- What role does Calcifert have vs lime?
- Do sulphur inputs affect biology?
- Need to take all trace elements into account – as well as NPK inputs – advice on the impact on soil as well as crop nutrition.
- Is there a role for compost teas?

- What role molasses? Is it an effective biostimulant and if so when to apply?
- Seaweed extract – to stimulate root growth
- Can we use v. targeted amendments in potato crops to reduce impacts – injection?
- Are there guidelines for use of digestate especially from food wastes
- How can we use sewage sludge without pushing P indices too high?

Knowledge exchange for messages about soil biology

The first 6-9 months of the programme were used to collate the existing background research available to inform our understanding of soil biology and health. The full research review report will be available at the start of 2018 but a summary of the *key findings on soil biology* were presented.

Was the summary of information presented on soil biology useful for you?

Yes, taught me new things	44
Yes, but I knew most of it already	26
No, as I know most of it already	3
No, of no interest	1

Was the summary of information presented at the right level to use to develop introductory materials for farmers/growers?

Yes, good introductory level	68
No, too difficult to follow – simpler background needed	4
No, too simple – more detail needed	1

- The presentation tied together the familiar with the new and ensured there are some practical messages
- Some of the information was too academic to be useful on farm; some too simple for practical use – this is not yet developed enough to turn immediately into knowledge exchange materials
- In a presentation for farmers, you need more relevant bullet points on the slides to summarise the messages
- It is useful to provide handouts to allow presentations to be followed more easily if you want the information to be retained.
- Make sure the information is presented in bite-size chunks

What are the best ways to provide information for growers to use?

Following the presentation, small groups also discussed the best ways to provide information to growers; all recognised that a mix of approaches was needed. These are listed below:

- Leaflets (can be held as pdf summary on the AHDB website)
- Charts, Tables
- Graphs
- Decision support flow charts
- Process diagrams with links to further resources
- On-line based resources
- Accessible information about experiments
- Case studies and practical demonstrations of value
- Wide range of practical case studies in a variety of soil types in differing systems – be clear that one size doesn't fit all.
- Short on-line videos (easy to access via Youtube) – look at Philip Wright AHDB videos on soil structure
- Webinar but ensure they are very well-structured

- Show organisms under microscopes etc
- Online calculators /assessment tools
- Give information about how to investigate problem areas – step by step
- Workshops
- Support farmer innovation; don't just target the average
- On-farm visits with holes
- Demonstrations in practice through monitor farms
- Need more monitor farms need to keep it local (with 45 minute drive) - but challenge is getting farmers to provide farms /fields to do trials and monitor
- Local discussion groups – building on what's there e.g. grazing groups
- Regional study groups with round-table discussion
- Soil mentors – recognised and valued practitioners sharing locally
- Include examples which show where this don't work / have negative effects
- Allow follow up discussion of examples (facilitated) – this allows depth of practical experience to be combined
- Independent articles for magazines
- Social media interaction
- Twitter – short messages and links directly to articles etc
- Email
- Regular technical briefing – topical updates
- Books – long-term value to give the foundations for understanding

Other key points were made about the need and focus of a knowledge exchange programme:

- We need better and wider information targeted at advisors as well as farmers/growers
- Information for agronomists needs to show that the actions taken can improve profitability
- Look for key messages each time
 1. What are the benefits of good soil health?
 2. Can these benefits be demonstrated?
 3. How can they be realised in practice?
- Information about compliance and environmental impacts are of secondary interest to farmers
- Interactivity and capacity to contribute is important to engagement
- Not just internet-based, rural broadband is often awful!
- Wherever you can, link in to other knowledge exchange opportunities e.g. use existing Monitor farms
- Materials need to be regional and by farming system
- It is hard to demonstrate relevance to an individual
- It needs to be solution-based information
- Try and draw out key messages – e.g. try this on a clay ...
- Give information but ensure you link into strategies for improvement and priorities...
- Must relate to real time need in their environment
- Can we develop a two tier system of info
 1. very basic info for the worst soils
 2. advanced info for soils looking to get the extra 10%

Key current topics that are currently important to farmers:

- Cultivations, Rotations, Soil nutrition, OM improvement

Soil Health Scorecard

The Programme team has begun to develop a prototype soil health scorecard and the initial proposals were presented: *soil health scorecard*.

What is already measured on -farm?

What	Why	Sampling approach	Number
pH/P/K/ Mg	To guide fertiliser input	Field-scale some whole, some in part. W sampling	48
pH/P/K/ Mg	To improve use of fertiliser /lime (variable rate)	Grid sampling	9
Broader nutrient range inc trace elements	To guide fertiliser input for specialist crops or where problems (beet, maize, OSR)	Field-scale some whole, some in part. W sampling	13
Cation exchange, base saturation, (trace elements, especially in livestock systems)	To better understand soils to underpin management principles	By soil type and farmer zoning.	7
Soil organic matter	To show state of (arable) soils and help understand soil biology / function	W sampling with nutrient tests	19
Microbial activity – Solvita test	To indicate value of microbial cycling to nutrient supply	W sampling to match nutrient testing	3
Earthworms	To see if there has been an impact of practice (e.g. use of anaerobic digestate)	Spade and mustard test	6
Drainage / compaction (VESS, penetrometer)	Any issues that need attention	Spade, by soil type	18
Visual assessment but also stone content, subsoil character and soil depth	Zoning soil and to help understand water dynamics and impacts on crop growth	Purposive / targeted holes	5
Soil mineral N (0-90 cm)	To understand nutrient availability especially after complex inputs / NVZ regulations	Representative sample	7
Tissue testing	To make focussed in season nutrient applications	Plant - representative	4
PMN (topsoil)	To understand N supply		1
Heavy metals	Needed for compliance	Representative sample	2
Input nutrients	To allow adjustment to other management especially purchased organic materials	Representative sample	1
Soil food web	As part of investigation into problem areas	By soil zones or high / low performing areas	1
Workability	Before cultivations	Low lying or most vulnerable areas of the field	1
Electrical conductivity	To give texture map to guide variable seed rate	Surface scanning	5
Potato cyst nematode			1
Club root			1

Other comments:

- Compare to yield maps, species diversity in leys
- One farmer reported a strong relationship between yield and soil OM mapping – same response wasn't seen in soil zoning by texture or P/K.
- We need better information on how to interpret a soil test

Would a soil health check – to be used once per rotational cycle be useful?

Yes	30
Yes probably	31
No probably not	6
No of no interest	1

- Cost needs to be low enough
- Should fit alongside routine testing – not an added extra
- Not for every field every year

We are proposing a soil health scorecard (like a school report) does this seem to be a useful approach?

Yes	32
Yes probably	33
No probably not	3
No of no interest	
It depends!	

- Will Britton (USA) has an extended soil health approach – Solvita plus
- I like the approach but it does depend on measuring the right things – do we know this for biology and will the programme take us far enough
- Getting the right graphic is important or it will not create engagement – a problem with current soil test reports
- It is import that whatever is developed is developed for longevity

We are proposing a traffic light approach to benchmark the measured values (together with the values themselves) does this seem to be a useful approach?

Yes	25
Yes probably	31
No probably not	8
No of no interest	
It depends!	4

- I am concerned that a traffic light system dumbs down this complex area and reduces the responsibility of the land manager to measure, manage and take action
- Samples that fall close to the boundary – may give false worry /reassurance
- Needs to be clear if values are too high / too low (not red for both)
- Could you use different colours for too high / too low ?
- Don't forget about red/ green colourblindness
- Similar approach to that for calories in foods?
- The Index system is widely understood by most – build on that – don't just replace it.
- Why not adopt a 1-9 scale as per the varieties recommended / descriptive lists – this is understood and established

- Can you use fuel dial approach for presentation?
- But every soil is different so only with care
- Many have difficulty reading a soil sample report – this would help and identify good levels
- Might be helpful to pick up links
- Is this approach too simplistic?
- Give simple overview then detailed answer at end on the problems posed and solutions

We are proposing to provide a way of comparing on-farm data to a wider set of values grouped by soils, land-use and/or regions. Does this seem a useful approach?

Yes	29
Yes probably	30
No probably not	8
No of no interest	
It depends!	2

- Make sure farmers can compare simply year on year on their own farms
- This will be key to identifying real trends and untangling noise from data
- Isn't there too much variation on farms for this to work
- Yes but need to be careful as there will be a wide range of attributes between similar farms
- But will this just identify a common trait/ problem that we already know about
- Avoid "wisdom of the masses" approach
- To be useful this will rely on having lots of data within the system

Overall the sampling for the Soil Health approach will measure all the indicators simultaneously – we are suggesting an autumn timing for sampling, does this seem sensible.

Yes	22
Yes probably	28
No probably not	7
No of no interest	1
It depends!	2

- The timing of the test is not so important as the fact that it is done the same time each time it is taken so that values can be compared
- The mechanics of this might be difficult to implement
- Autumn workload is high – will this slot in – not sure it will; but recognise that this would allow time to address issues
- Not always practical in autumn – all fields not stubble at the same time or for very long.
- It has to fit in with the farm type and system so different systems might have different sampling ... but then need to be careful about comparing
- Would conflict with organic manure application
- What about where there are standing crops in the autumn
- Is spring better? Does a crop vs stubble come out very differently
- Will values change if measured in stubble vs cover crop?
- For some crops, extra tests might be needed e.g. B for OSR
- Soil biology changes by season (growth stage, time, temp etc) so autumn might be an issue; spring better as responses to plant growth seen, autumn more related to residues

- How can it be useful given the seasonal and weather variations – won't it be a lot of effort for unreliable information
- Some measures will change during the year, is autumn the best time to show need?
- If the aim is to monitor rather than provide a guide to rectify problems, then spring might be better
- The logistics of this are tricky – some of these things are likely to be measured by the farmer, some by an agronomist, some in-field, some sent away.
- 4 year sampling interval feels about right
- This may give a simplistic view of soil – given it is such a variable substance can it really be summarised in this way?
- Information only as good as sampling – how to ensure consistency of sampling?
- It is important to ensure that there will be enough resources in place to sample, analyse and interpret the results if this is successful
- Is the aim to have an industry standard scorecard ?
- Will the results from different labs or service providers be comparable?
- What is to stop a commercial service provider saying that their test is better than the AHDB standard tests?
- Make sure the scorecard leads people on to investigate options/ recommendations
- Regional benchmarking is good but it is important to understand who will own and manage the data
- Healthcard in general is a good idea But must be cheap enough to do regularly and possibly by zone etc
- Could it become a requirement for Red Tractor certification

Other comments

- The term soil health needs to both defined and then contextualised for different soils, crops and husbandry systems
- Not clear what the soil health card is for
- We want indicators that can be seen in the field e.g. worm counts
- None of the indicators proposed seem to address drainage – not needed, present and working, present and needing work!
- Slope also important to determine run-off and water erosion risk
- Healthy soil smells different – can we use “smell” with a gas chromatograph to diagnose?
- Can we fit with the simple demonstration measures e.g. #soilmyundies
- Would be good to have a flow diagram/checklist – if this then ... especially for follow up steps of investigation into problems identified
- Farmers need support to help identify and put the basics right, then to move on to more detail
- Can we link satellite/remote sensing to these measures and bring together – at least provide guidance for those beginning to use such data about how it can be used together with soil info. or to guide sampling
- Ensure there is thought given to the link to variable rate technology
- The relevance of the tests for yield and returns must be able to be shown.

- Would be good to have a region-based database where farmers can record actions taken and results to gain a wider real results base, benchmark against one another, linked to regional meetings and crop/land walks
- Look at Soil pH testing leaflet – there seems to be some confusion – p3; if lab says 5.7 we shouldn't have to ask what method and find it is actually 6.3?

Descriptive model and visual tool

The Programme team has begun to develop a descriptive model to bring together the information about soil biology and health and to present it visually and the initial proposals were presented.

Is the approach we are taking to develop a descriptive model useful?

Yes	17
Yes probably	36
No probably not	10
No of no interest	1
It depends!	

- Keep going this is the right direction, though not there yet.
- Keep close control over any macros / coding – try and keep them transparent, but not able to be changed by a user.
- The relationships may need to be modified through time, so build in capacity to update.
- Build on field history cropping/cultivation/field performance
- Could you use post-code to link to info on likely soil type, rainfall etc as PLANET does
- Need to balance the amount of detail required at field level and hence amount of input required vs output quality
- Field records of management and inputs would need to build up over time to begin to give useful answers
- Needs to be simple and quick – no-one has the time for lengthy things to complete any more.
- The more visual the better
- Build on flow-charts
- Is there any way to build in the financial implications?
- The version you showed us is much too simplistic – want to be able to investigate the complex causes and effects and impacts on different scenarios
- Please don't oversimplify the complex subject – leave room to understand the variability and interactions
- Seems too general to be applicable to an individual farm
- Need to be specific – species choice and species mix of cover crops; impact of plant protection products on soil biology
- Try and make sure it is not crop specific but useful for the full range of minor crops too
- Needs a bigger matrix to allow the combined effects of a range of practices to be investigated e.g. ploughing with cover cropping is likely to give a different range of outcomes to conservation tillage and cover cropping
- Being able to investigate the combined effects of several different management practices would be useful – though we are aware that the answer become less certain.
- Needs to include the innovative practices as well as the established ones
- Focusing the presentation on management actions may result in choices which together may confound each other. It will be difficult to present multiple interactions – but two-way will be useful
- It would be good for the report to draw out a conclusion or at least a loose recommendation

- Makes sure it builds to give useful interpretation at farmer level
- Needs to be useful by day-to-day farmer
- Looking for practical and specific not general – so details on which cover crops suit which soil, practical steps to decide how to improve your OM levels
- Be careful not to be judgemental and try and ensure it links up to on the ground experience.
- Give realistic principles and lead on to changes that can be implemented
- Scenario based approaches are useful but this would make it a soil health guide rather than a description of soil health.
- Cost and benefit indicated even if not able to be quantified directly
- Must link to the soil health report and support interpretation or use values as inputs
- Would be good if it was able to take the issues raised by the healthcard, compare this with known problems / issues and then make recommendations for improvements.
- Can we reverse the process you have shown i.e. enter your aims for what you want to improve, then asked a series of questions about your system and it would generate possible approaches with pros and cons of each. Economic issues could be incorporated.
- Can the tool help to diagnose why different outcomes occurred – e.g. why cover crop worked in this field but not that?
- There will always be demands from farmers for specific soil health, however, a single system will be unlikely to provide this information
- Can you give simple overview and also additional information to drill down into
- If it is too advanced it will leave the beginner behind and not increase understanding and support change; if it is too simple it will dissuade the enlightened farmers – can it somehow be a two tier system?
- Two levels ? simple descriptions vs more complex scenario or investigation tool?
- Ease of access, is phone app to be available
- Is this a lot of effort to produce something that won't get a lot of use?
- Feel that making small changes in isolation will have limited benefit. The main changes come from a holistic approach at whole farm system level; changing one thing can have negative impacts else where.
- Medium to long-term impacts so need to be clear that these may not be seen in the short-term
- Communicate about resilience to extremes – not always direct impacts
- Need to support farmers to look after their own soil – but communicate the importance of good drainage, good rotation and correct pH
- Should AHDB be becoming an extension service – our focus should be on research in this area

Are there any examples of effective online tools we should take account of, if we take the on-line tool forward?

- Not online but psychometric tests; outlines the trends in the results of indicators/measures to form a general recommendation of qualitative results; this is engaging for the user...
- Career options where you answer a few questions and then it gives you some options that might suit you to apply
- Some agronomy companies have on-line tools for clients to store field/farm data

- Learn from VSA NZ approach – but this needs better adaptation for UK, especially for less common soil types e.g warp soils
- See Slurry-Max project and the work they have done to assess the ease of use work done of nutrient planning software for farms
- PLANET software works well

Appendix 3 – Online questionnaire: feedback

On-line questionnaire

Background

Between 2017 and 2021, the Soil Biology and Soil Health Partnership will bring together the best research and the most effective practical approaches to soil management on-farm. In autumn 2017 AHDB invited farmers, growers, advisors and industry partners to join one of two industry workshops to shape the direction of new research on soil health. The interactive workshops took place in Northumberland and Gloucestershire on 13th and 15th November 2017 and the summary of the feedback received at the events was made available on-line in December 2017.

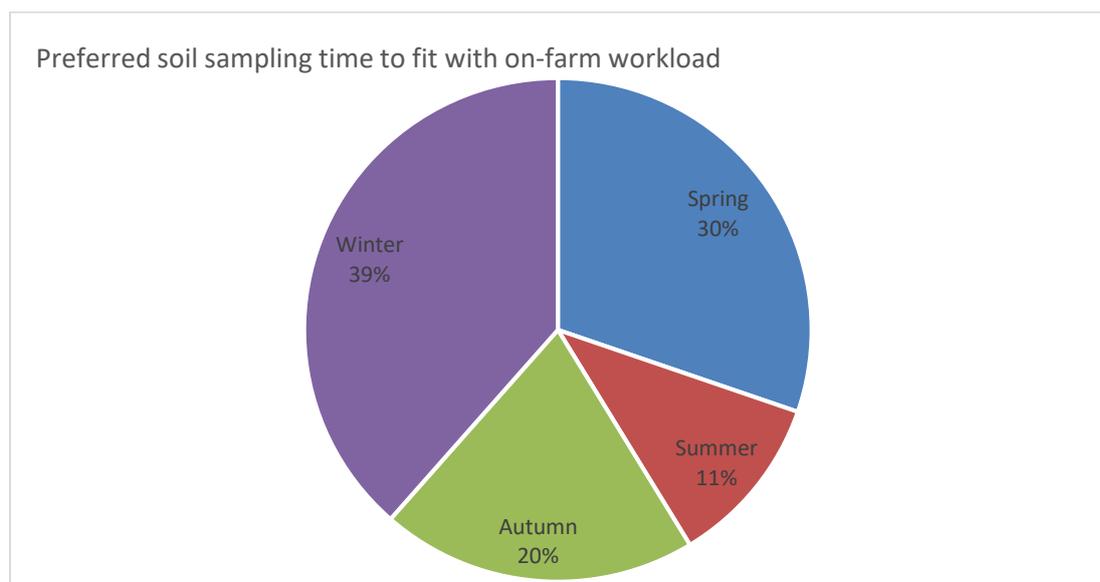
A short on-line questionnaire was developed to follow up some of the questions raised. This was open on-line for 4 weeks and received 110 responses.

The following document provides a summary of the responses received

Sampling for soil health

90% of the attendees at the consultation workshops indicated that a soil health test deployed in each field/zone every 4 years (or once in the rotation) would be useful. To allow the data to be benchmarked, samples will need to be collected at the same time of year each year and across farming systems.

Responders to the questionnaire selected the season in which they felt that such sampling would best fit into the workload on-farm in practice. There is no clear consensus.



A number of additional / explanatory comments were also provided. I have listed these below in no particular order but with some attempt at providing rough grouping.

Winter

- Within a predominantly field veg and potato growing business, winter would be the time when soil sampling and analysis would normally be carried out, within this type of production a large proportion of the land would be on an annual rental basis so may be better to engage the host farmer in managing and decision making.
- Winter but note that we will be at risk of poor / wet soil conditions stopping the testing / monitoring
- Winter would suit workload on farm best, however this may be too close to some applications of fertiliser, which may affect results.
- In winter there is less work load plus ground is softer, and water is not limited for biological activity to occur. You should speak with companies like SOYL who can add this standardised test to their sampling list.
- Depends on what is needed for the test, but from a workload perspective, winter may be the best
- Which is the best time for an assessment? that should determine the season. Winter is the easiest time but I suspect that summer may give better results.

Spring

- Spring was considered years ago by ADAS soil scientists to be near 'optimum time' to assess crop & soil condition with a spade, to plan cultivation decisions etc, ahead of the following crop - however not so easy these days with 'all the pressures' that Spring brings regards available 'manpower & time'.
- Soils need to be moist but biologically active. Spring best for sampling and fields likely to be visited most often already so could be fitted with crop walking
- February/ early March
- Early spring before any fertiliser applications
- Spring - before sowing and/or any application of fertiliser
- Early spring once soil temp are on the rise. The winter may also be suitable but soils could be frozen etc.
- In early spring just before the first nitrogen application (where there is one) will give the best measure of soil condition at the start of the growing season and fit in best with farming systems.
- Spring gives the opportunity to make some immediate potentially yield improving changes and also gives time to allow planning for post harvest inputs/remediation. Spring or Autumn are the best times to see measurable info, winter generally too cold and less activity, summer can be too dry
- Farm workload would go against the autumn, weather conditions probably not favourable in winter or summer. If not doing in the spring, the summer would be a the second choice
- Spring best but it depends on how many samples needed per field. All fields will have growing crops in by late spring.
- Mid April just after all the spring crops have been drilled.

- Surely a simple soil health assessment should be carried out each May - a lot can change in 4 years e.g. autumn 2012.
- Spring, but on heavy Gault clay there would be challenges when wet
- Access is a problem Late spring may be best

Autumn

- After harvest
- Post harvest collection.
- From stubbles
- Autumn – more bare soil so easier.
- I think it would be best in autumn while soils are being worked after harvest, but before any manure or fertiliser are added. In summer soils are too dry and crop in the way In winter soils too wet In spring very busy and fertiliser being applied will be different on each farm
- Late autumn
- We have used British Sugar's soil sampling service who carry out the tests and sampling themselves - combined with this would be best, but if needed to carry out sampling myself, the autumn would be best.

Summer

- Needs to be done in summer when the soil is warm and there is maximum biological activity.
- In arable crop before harvest. All nutrients for crop used. Ground carrying capacity good. Use tramlines; CTF; mid front axle sample borer and collection tin; GPS "stake" sample spots; use these next time for a better cf..

Wider issues / comments

- Any season; but what is the best time to get better results
- More important to do it at the same point in the rotation and at the same time of year on each block in the rotation. Also need to spread the workload for sampling and analysis. Try to give several options but sampling best done when soil has wetted up so winter and spring would be preferred.
- The main issue is soil standardisation. Clearly a nutrient such as phosphate reaches equilibrium only slowly and readings will change where moisture or crop growth differs. Bacteria and mycorrhizal fungi growth is not constant throughout the year and depends on root exudate.
- Making sure no products applied or minimum time from application for testing to remove immediate short-term impacts
- Soils need to be neither hard and dry or at field capacity for best assessment. Maybe shoulders of autumn and spring so the soil will be in a better condition to assess?
- I would think microbe diversity would alter with crop and season. Surely what crop has been in field will influence soil health. ie root density and mass etc
- Develop a field test that can be done by farmers and advisors i.e. CO₂ measurement, or soil composition.

Knowledge exchange for messages about soil biology and soil health

Over 60% of the attendees at the consultation workshops were not fully satisfied with the information they currently access on soils and their management. It was suggested that the Partnership should present existing knowledge and new research information as a two-tier system of information with:

- a.) Basic background information in formats aimed at all farmers
- b.) Links to advanced information for farmers and advisors who want to go further.

89% of the responses to the on-line questionnaire agreed with this proposal.

A number of additional / explanatory comments were also provided . Again I have listed these below in no particular order but with some attempt at providing rough grouping.

- It is important to give technical information that is accessible at all levels.
- Please don't overload us with information - we receive too much already!
- Make sure it's relevant & interesting
- Every farm is different - try to avoid prescriptions
- Only having basic information may lead to incorrect interpretation so to be useful to all farmers a degree of training may be necessary.
- Don't think you need to spend much time presenting basic info like P,K, pH indices. That has been readily available to anyone interested for years.
- Too much basic information is available, which leaves a void for marketing and sales to fill. We need easy access to research level soil ecology/biology, which will help us all work together to refine practical approaches to soil management.
- Basic means stuff farmers can do themselves and understand thereby taking ownership. Currently there is far too much aimed at science and not enough practical - spade, smell, feel & worms. Benchmark using soil under hedge / in fence line
- The links to advanced information should be made as attractive as possible, as some farmers may not see the potential benefits in gathering further information.
-depends on the definition of "advanced"?
- Produce a roadmap that gives simple steps to help maintain soil health (point a) and more details in (point b) for those wishing to have an integrated ecological system
- Make sure you give a full picture. Currently there is no mention of the benefits to wildlife from growing a cover crop or the increase in numbers of insects. Mostly it is worms that get the attention not the fungi and other soil biology.
- It depends on the growers and advisors actual understanding of biological terms. Having done a degree in agricultural botany which included three years of studying soils, structure, . etc, I think it would help to have some biological knowledge as well as understanding calculus for understanding soil strengths.
- Campaign for the Farmed Environment workshops in the summer attracted minimal interest from the farming target audience. More than just information is needed to reach the bottom 30% of farmers improved rather than a few large prestigious estates who will or are doing this already
- Soil analysis information is very useful if it is done regularly at the same time of year and the same person agronomist or farmer over the long term. The health check data I have done on a field or two is expensive. And it is not yet clear what this really means and how you use it.

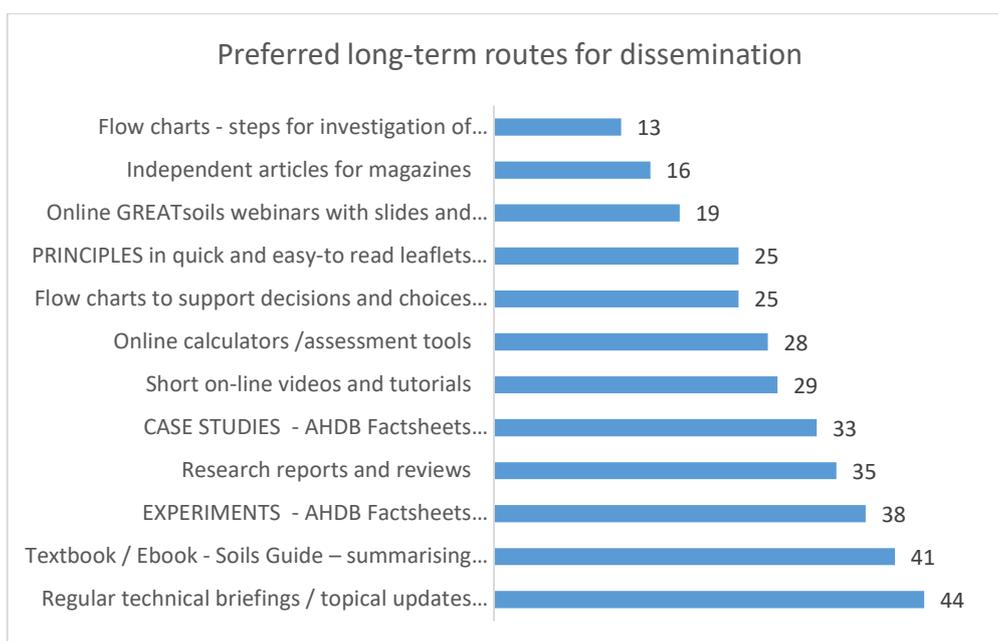
- Soil type is very important; hence any information on soil health needs to be clearly linked to soil type.
- There is a huge difference between soils where getting rid of excess water is a problem (high clay content or peaty soils) and soils where moisture retention and irrigation are key factors. The importance of this should be recognised.
- Is it possible to have detailed online maps of soil types?
- There are already a number of companies offering soil scanning, conductivity tests, sand, silt and clay maps. This needs going through as some information given contradicts other info.
- More detailed information will be required if you are to use Precision Applications / Variable rates
- RB209 is unsatisfactory and there is no evidence that soil mapping supplies a return on investment - only that new boundaries are created resulting in over and under application.
- Often it will be relevant to clearly separate research on soil biology between Arable and Grass (and other farming systems)

What are the best ways to provide information for growers to use?

Within the Programme, there will be regular workshops and farm walks to share information and discuss the emerging findings. We will also develop materials to share information about soil biology and soil health that are intended to outlast the Programme itself.

At the industry workshops, small groups discussed the best ways to provide information to growers; all recognised that a mix of approaches was needed. A range of different resources are possible and we expect to produce a mix of different materials during the project and present them on-line via the AHDB GREATsoils webpage and as printed materials, where appropriate.

When completing the questionnaire, responders selected the three formats for the long-term outputs from the Programme, which they felt would be most appropriate. There is no clear consensus.



Other comments

Responders were given the opportunity to comment about any aspect of soil biology or soil health and in particular to provide guidance to the research team planning the details of the research and knowledge exchange programme.

A number of additional points were made; these are listed below in no particular order but with some grouping of topics.

- AHDB should be working with the advanced farmers and advisors to help prove new technology and assist farmers who are lagging behind to catch up. A bit like the bench marking currently being done.
- I think there is too much time/money spent by research replicating/duplicating work where answers are already known and lots of different organisations doing commercial work under a science banner. Be targeted in what you do and focus on what isn't being done elsewhere.
- Remember who the target audience are - levy payers (farmers) and deliver what they actually need to make better informed decisions. Not what you think they need!
- The science doesn't always seem to keep up with the on-farm practice when it comes to soil health. Practices that farmers see working for them in the field are hard to get peer-reviewed evidence for, partly because they are system changes rather than changes to just one thing.
- Keep it relevant, farmer-focused and practical.
- Fit in as many types of management and soil types as possible
- How are you going to measure your effect on practice?
- Work closely with innovators. Be open minded
- Draw from the experience/knowledge from well-respected persons in this area e.g. in the industry (independent or commercial) as well as academics
- Get out and look at what the innovators around the world are doing, implement that on monitor farms, then get the UK results out to UK farmers.
- Building on long-term practical studies is important. For example, the 10 year NIAB Rotations & Culti Study says a lot re dispelling Myths as well as providing a foundation of facts on the impacts of UK Farming Systems.
- More imagination and more sophisticated stats. Better use of GPS/GIS analysis techniques.
- Be prepared for the long haul
- The subject is extensive. Make sure you set boundaries and work within them. Set expectations for research and practice in this area e.g. a standard soil texture analysis before you begin anything in a field.
- Make sure you keep a focus on yield and quality
- Make the links between soils and nutrition transfer to crops and ultimately food.
- We want to use more practical tests to assess and quantify/measure soil biology, be that microscopes, burying pants or whatever so that this can be assessed
- Remember - the more complex and demanding the testing / monitoring - the less it is likely to be completed!
- Ensure the total independence of this work
- Mindful not to be tunnel-vision by ag-chem sponsors when setting the project parameters. The focus should be bottom up, farmer-driven

- Farmer funding (AHDB/NIAB etc) should be used to commission research projects and fund PhD studentships that do not have a commercial interest and therefore will not receive backing from business/industry as there is nothing to sell at the end of it e.g. Studies into mycorrhiza - fertiliser companies won't invest as they will potentially lose sales, and there is no saleable product at the end of the study however the information gained could save and benefit farmers immensely
- Ensure there are a range of engagement opportunities and routes with easy to access outputs.
- Wherever you can, provide key speakers to commercial and AHDB conferences
- Concentrate on producing directly relevant information that farmers can realistically put into practice
- Make the science of soils and research available to farmers, in a way that can be practically implemented on farm. The farmers' level of knowledge will improve and how they can then implement the research on a farm level.
- Ensure that something useful practical and applicable is produced.
- Not all farmers have big acres and access to "new " tackle. We have to make do with what we have plus small fields, make sure the approaches and recommendations can be applied for us too.
- Try to avoid fuzzy answers, it is hard to work through a system of improvement on farm where guidance is filled with statements like 'depends on soil type or weather'. Please go into detail about these different scenarios. People who want to advance in this area will go to the trouble of reading it.
- Fix communication; make it easy to find out. I still do not get contacted about our local monitor farm. I have to make an effort to find out
- To aid interaction with farmers, as much information regarding the programme should be heavily advertised online, through social media and all associated websites. As a young farmer myself, this is one of my most favourable platforms to gather information and hear about new research being done throughout the industry.

Specific topics/ questions

- In this part of the world (Oxfordshire) we're trying to manage unsustainable rotations, largely due to the loss of 'Grazing Livestock', as a result declining OM% levels besides trying to farm bigger areas & everything that brings with it.
- The most useful thing to me would be graphs of soil index for a given nutrient vs crop yield. "Maintaining an index of 2" is based on 50 year old data when "economic" crop production was entirely different.
- Take note of the NRCS soil health test kit widely used by NRCS farm advisers in USA
- The Haney test in the USA is being used by an increasing number of farmers and advisers for decision. But there is a lot of criticism of it by the universities. Not sure what the answer is to this but it would be good to have some scientific review of different soil health tests such as Haney in a UK context.
- There is evidence that high organic matter and microbial activity reduces the effectiveness of residual herbicides so the negative consequences must be recognised.
- What are the benefits of soil aeration in grassland re soil structure, drought tolerance and nitrogen efficiency?
- With grass we need to make sure it is palatable as well as plenty of it.
- What are the effects of good/poor drainage – can these be quantified to show the long-term value of drainage as a high cost investment?

- To connect soil management to water management, please see if it is possible to investigate sources of soil contamination of watercourses, silting of drains / ditches. This is clearly a problem at this time (midwinter) but it's not just an in-field problem; we all see the damage done by vehicles of all sorts to roadside edges.
- This is a very important area but work must be economically practical.
- Please consider the economics of changes in practice, both for the short term and over the course of a number of crop rotations, particularly where more than one grower is working in the same field/crop rotation and will only work the area of land for a proportion of the rotation. This is typically most important for lighter soil types where root cropping and irrigation feature.
- Some sites may prove to be better in forestry! Guidance on land suitability for crops may be useful but shouldn't be prescriptive.