Pasture-fed Livestock Association

REPORT AND REFLECTIONS

ON

THE SECOND MEETING OF THE SOIL HEALTH GROUP

Hill Barn, Fir Farm, Lower Swell, Gloucestershire
22 February 2017

SUMMARY

This document reports and reflects on the day spent at Hill Barn learning about, and reviewing, the potential proxy measures for monitoring soil health under pasture. More than 70 people gathered together, a mixture of scientists (techies) and farmers, who each shared their own experience with the others.

The opening sessions addressed (1) the factors that cause fluctuations in soil organic matter and embedded carbon at Wimpole Estate, (2) options for using proxy measures to monitor soil health and soil organic matter and (3) options for directly measuring soil carbon and organic matter. These were followed by three participatory workshops covering:

a) In the field – earthworm counts, water infiltration rate, penetrometer/compaction & pH

b) In the barn – the slake test, the Solvita (respiration) test, soil biology/food web, soil colour and the teabag test.

c) In the barn and field – above ground biodiversity and brix.

28 non-techies (of which 24 farmers) rated the tests in order of interest/relevance and whether as farmers they would be interested in testing them formally on their farms. 19 techies responded to the opportunity to recommend their favourite/most relevant tests. For both farmers and techies, earthworm counting and the slake test were the most popular by far. For farmers, perhaps surprisingly because of the lack of a clear relationship between it and soil carbon/OM/health, measuring biodiversity was popular.

The films, reports and web links should provide a pool of information around the topic. Some of this may be applicable immediately and other aspects may be of value once there has been time to absorb the information more fully. Details of the interests and contacts of those techies who responded to my request can be found at the end of the report. We plan to put together a simple trials programme that will endeavour to assess how these tests work in practice on the farm and how helpful they are in monitoring soil health under pasture. We will also continue to build our relationships with technical and research institutions that share our interests.

FOREWORD

22 February 2017 was a bright if blustery day at Fir Farm, high in the Cotswolds, when more than 70 of us came together to focus on how we could monitor the health of our soils under pasture. Roughly a third of those present might be described as "techies", with specialist knowledge in aspects of soils, ecology and water management. Roughly two thirds were farmers who were keen to learn from, and question, the techies and share their practical experience. Conscious that, in the words of Adam Horovitz (our poet in residence), the soil is *"the perfection of decay…a crucible for rebirth….the rooftop on another world"*, the focus of the day was to address the question: ***"How can we monitor the health of our soils under pasture?"***

We met in the grand Dutch barn, courtesy of Jane and Alan Parker, the same gloriously renovated barn that had recently hosted Joel Salatin from Polyface farm. We were able to spread out into the surrounding fields and investigate how to monitor the rate of water infiltrating into our soils, how to measure compaction and pH and survey the number and types of worms in the soil. We looked at how to measure respiration and observe the organisms making up the soil food web. We discussed the effect of biodiversity on the soil and the potential value of measuring brix. The agenda for the day is overleaf.

The institutions represented there include Rothamsted Research Station (North Wyke), The Centre for Ecology and Hydrology, The Centre for Agro-ecology, Water and Resilience, Natural England, AHDB's Great Soils Project and its emerging Soil Biology and Health Project, FWAG SW, the RASE's Innovation for Agriculture, The National Trust (Food and Farming), the Game and Wildlife Conservancy Trust, the Organic Research Centre, IBERS, Soil Advice, Earthcare Technical, Soil Bio-Lab and Gloucestershire Wildlife Trust.

We began the day with a moment of silence to remember Tim Green, of Village Farm, who had tragically died a few days earlier in a tractor accident. Following a short introduction, we heard presentations from Richard Morris, Jenni Dungait and Jeanette Whitaker and then split into three groups that participated in demonstrations and discussions led by the "techies" present. We recorded the formal sessions, and some of the demonstrations, on film and the links can be found on page 6.

The following pages are an attempt to summarise what happened on the day, what happens next and provide pointers to where supporting technical information can be found. We are grateful to all who came and contributed in different ways and particularly to:

- Jane and Alan Parker for providing the venue and for underwriting the event
- Paddy Hoare and his colleagues for organising the venue
- Niels Corfield for assistance in the detailed planning and delivery of the event
- Hannah Steenbergen of the Sustainable Food Trust for taking notes on the day
- The National Trust for contributing to the cost of the event
- Fiona Meadley for recording and editing the films.

We will continue to collate and interpret the outcomes of the day, encourage further collaboration between the "techies" present and both plan and implement a programme of on-farm trials to assess the value of the various proxy measures as indicators of soil health. We received good coverage in the Farmers' Guardian.

IS THERE A RISING PLATE METER FOR MEASURING AND MONITORING SOIL HEALTH UNDER PASTURE?

TIME	EVENT	Delivered by
0915	Arrivals and coffee	
1000	Opening remarks	John Meadley
1015	Increasing and measuring organic matter at Wimpole Estate	Richard Morris
1035	Options for using proxy measures to monitor soil health	Jenni Dungait
1105	Choosing a method for measuring soil organic matter – and introducing the mySoil App	Jeanette Whitaker
1130	Tea break – taken on to…….	
1145	*The first practical session*	
1245	Lunch	
1330	The second practical session	
1430	The third practical session	
1530	Tea (and completion of feedback)	
1600	Summary of AHDB soil health &biology project Introduction to the research project Drawing together the threads to take forward the agreed priorities (summaries from groups) What happens next?	
1700	Depart	
Session 1	**General soil observations** – the spade test, soil sampling, infiltration rate and earthworms	
Session 2	**Above ground biodiversity**	
Session 3	**Soil structure and biological activity** – the Slake test, the Solvita test, the tea bag test and the soil food web	
ALLOCATION OF TIME		
	Networking and refreshments – 2 hours	26%
	Formal sessions - 2 hours 30 minutes	34%
	Practical/discussion sessions – 3 hours	40%

1.0 INTRODUCTION

At the first meeting of the PFLA Soil Group in September 2016, the vital importance of soil organic matter/carbon was reinforced whilst recognising the difficulties in measuring it with any accuracy - as well as the costs involved. The feeling that emerged was that we should endeavour to identify proxy measures that could reflect the soil organic matter content and more broadly the health of the soil – measures that are simple, inexpensive, quick and repeatable - and find ways of linking these with soil management practices that encourage the formation of organic matter in the soil. Farmer Ben Mead highlighted the vital role that the rising plate meter has played in increasing the productivity of grassland and suggested that we need an equivalent for monitoring soil health. Whilst I had interpreted this as meaning a tool to generally monitor soil health, from subsequent correspondence it became clear that Ben had also been asking whether a rising plate meter could be modified to measure the accumulated trodden pasture and manure left after a session of mob grazing and if that could be correlated with the amount of organic matter likely to be incorporated into the soil. For more on this see Annex 1. The full report of the first meeting is here.

Farmers want a healthy and functioning soil, which might be defined as one that:

- Is workable for much of the year, with the potential to extend the period of access for livestock and for cultivation.
- Supports a dynamic micro-biome that not only feeds plants but also assists in their defence against pests and diseases.
- Retains and releases moisture as required – valuable in drought and reducing flooding.
- Retains and releases nutrients as required – reducing the need for artificial fertilisers.

From a national perspective, such soils also generate a range of public goods/ecosystems services through:

- Reducing the requirement for energy-intensive and polluting artificial fertilisers, pesticides, herbicides and fungicides
- Removing CO_2 from the atmosphere and storing carbon
- Holding moisture that might otherwise result in floods – with related financial and human costs.

There is a range of practical measures that can contribute to the building of an organic matter-rich/healthy soil. These include:

- Soil surface management - keeping the soil covered at all times as far as possible
- Recognition of the potential impact of cultivation (particularly deep ploughing)
- The use of synergistic crop rotations and companion cropping
- The use of deep rooting, herb-rich pastures – either permanently or as leys
- The role that trees can play in Agroforestry and Silvo-pastoral systems; etc.

What are the options for farmers to measure the improvements in their soil that result from introducing OM-friendly practices – both with and without the need to take samples and have them analysed? Is there a preferred method based of sampling and laboratory analysis? Are there any simple proxy measures? Where and when are they taken? What is the relationship between the different measures taken and the health of the soil?

Our second meeting on 22 February at Fir Farm brought farmers together with specialists in various aspects of soil, soil-water and soil-plant relationships to consider these options. It provided an opportunity to consider the various options for monitoring soil health, for ideas and experience to be shared and for voices to be heard. As some of the techies did not know each other, opportunities also arose for future collaboration between them.

The question raised in the introduction was: "How can we monitor the blood pressure and pulse of the soil under pasture?".

Why pasture? *The world's soils hold roughly three times as much carbon as its atmosphere. With two thirds of both global and UK farmland under pasture, and with pasture playing a vital role in building soil structure and fertility, the way that pasture is managed will play a critical role in limiting climate change. This is something that is barely addressed in current national and international agricultural policy. At the level of the individual farm, pasture plays a vital role in building fertility, retaining moisture and capturing carbon – and providing nutritious feed for the millions of ruminants that provide us with meat and milk whilst manuring the land.*

Why blood pressure and pulse? *To my untutored eye, many of the traditional soil tests are essentially descriptive in nature, in some cases requiring expensive laboratory analysis, and reflect its physical and chemical nature rather than the life within it. Further, as can be seen in the table overleaf, different organisations recommend different tests and there is little consistency. For us humans, readings of blood pressure and pulse are, together, useful indicators of our respiratory and circulatory health. Abnormal readings suggest that something might be wrong or needs attention. Are there some simple tests that we can regularly and inexpensively apply to the soil to keep us in touch with its general health?*

We addressed this question through three talks followed by a series of workshops/demonstrations and discussions. At the end of the day, both the farmers and techies were asked to rate and prioritise the different techniques – see section 4.

The video recordings of the day can be found via the links below. We had a glitch with one of the tapes so in a couple of places live movement has been replaced by stills.

Introduction
Richard Morris
Jenni Dungait
Jeanette Whitaker
Demonstrations and workshops

Be sure to check that the films start at their beginning.

The slides can be found here.

There are three annexes. The first being from Ben Mead with his ideas about the rising plate meter, the second being from Ian Boyd with his thoughts on the day and the third provides information on most of the techies present.

TABLE 1. COMPARISON OF SOME DIFFERENT TESTS SUGGESTED FOR ASSESSING SOIL HEALTH						
Test	**USDA**	**AHDB**	**NRCS**	**Bullseye**	**FAO**	
Soil respiration/Solvita	■	■	■			
Infiltration	■	■	■		■	
Bulk density	■		■			
Electrical conductivity	■	■				
pH	■	■	■		■	
Available water capacity			■			
NO_3	■					
Aggregate stability	■	■	■		■	
Slake Test	■		■		■	
Earthworms	■	■	■		■	
Physical observations	■	■			■	
Water quality	■				■	
Soil structure and macropores			■		■	
Compaction/pans		■			■	
Organic matter		■	■		■	
Total organic carbon		■				
Tea bag test						
Brix						
Soil biology (general)		■				
Soil crusts			■		■	
Soil enzymes			■			
Soil food web		■				
% bare ground				■		
Erosion				■		
Plant pedastaling				■		
Litter amount				■		
Litter distribution				■		
Litter incorporation				■		
Dung breakdown/incorporation				■		
% desirable plants				■		
Age distribution of desirables				■		
Plant spp. diversity & functionality				■		
Living organisms				■		
Plant canopy				■		
Plant vigour				■		
Plant distribution				■		

TALK 1. Wimpole Estate study of effects that cause fluctuations in soil organic matter and embedded carbon.

The opening talk was given by, Richard Morris, at the time in transition between managing the National Trust's Wimpole Estate in Cambridgeshire and moving to manage Sheepdrove Farm in Berkshire. His talk focused on his experience of measuring soil organic matter and carbon in the soils of the estate, how it was measured and what can be done to rebuild soil organic matter. He reminded us that the quality of the (undisturbed) soil under your hedges is a pretty good indicator of the potential quality of the soil in the open field – the hedge test! Richard's talk is here. Below are some key points from the opening slides.

- The determination of organic matter in soil is technique-specific and there is no absolute, 'correct' answer.
- The organic matter content of a soil should always be defined in terms of the analytical method used, whether Walkley-Black or Loss on Ignition (LOI) - the usual techniques.
- Combustion may be an under- or over-estimate depending on what else is present.
- Most of the soil organic carbon is not inert but in a continuous dynamic state of accumulation and decomposition.
- There is a continuous exchange of carbon between the soil and the atmosphere, mostly as carbon dioxide $C0_2$ and methane CH_4.
- Grassland farmers could look at soil structure by digging small inspection pits along the lines of Visual Soil Analysis, designed by Graham Shepherd in New Zealand and outline by Vaderstad in UK. This also includes assessment of worm numbers and comparison of fields and hedges. For more information see here.

TALK 2. Options for using proxy measures to monitor soil health and soil organic matter.

The second talk was given by Jenni Dungait, who is also the chair of the 2017 6th International Symposium on Soil Organic Matter

She reminded us that soil health is NOT defined solely as soil organic matter content, the former relating more to functionality, and that:

- The Soil Health Indicators concept was developed to 'evaluate how well soil functions, since soil function often cannot be directly measured' (FAO).
- Soil health is impossible without a sustained supply of soil organic matter (SOM).
- Soil organic carbon (SOC) is a large part (about 60%) of SOM.
- SOM is mostly dead plant material in the process of decay from fresh plant material to CO_2 gas.
- The decay is caused by soil organisms eating the SOM.
- SOM decay is directly linked to many soil physical, chemical, and biological processes.
- We recognize the products of some of these processes as Soil Health Indicators.

Jenni is looking for indicators that are low tech, zero cost and can be interpreted in-field as she is working in areas of the world where there are no labs. Her talk highlighted the various physical (structure), chemical (colour) and biological (earthworms) indicators and strongly recommended that we use the Cornell Soil Health Assessment Training Manual - and check out Jay Fuhrer of NRCS at Menoken Farm in the US. Jenni's talk is here.

TALK 3. Soil organic matter and soil carbon. The third talk was given Jeanette Whitaker of the Centre for Ecology and Hydrology. She described:

- how carbon is cycled through the soil
- the results of a trial on bio-energy crops that demonstrated that, in general, they will increase soil carbon when starting with arable soils but reduce soil C if starting with grassland.
- how CEH is involved in measuring carbon under mob-grazed pasture in Canada
- the importance of soil OM not only for farmers but for society (ecosystems services)
- Why measuring soil C can be so complicated, the options for measuring it and that how you measure it depends upon what you want to know.

She reminded us that soil carbon levels change slowly and should be measured at intervals of 2 – 3 years. She closed with information around a few soil apps including:
mySoil (developed by CEH and BGS)
UKSO – the UK Soil Observatory
COSMOS-UK (a national network of soil moisture monitoring stations)
My Landcover (definitive, Landsat-based, 30 metre resolution land-cover database for UK)
SOCiT (a soil app for Scottish farmers)
SoilInfo (World soil information)

There are many different sources of information about describing soil and suggesting ways of testing aspects of its health. All of them differ but all have their value. Here are some of them. Links for the individual tests are provided in the relevant section below.

USDA Soil Quality Test Kit Guide
USDA Natural Resources Conservation Service – monitoring soil health
Cornell Comprehensive Assessment of Soil Health
A Soil Owner's Manual – John Stika
AHDB Great Soils Project
AHDB Growing resilient, efficient and thriving soils
Environment Agency – Think Soils
SRUC Visual assessment of soil structure (VESS)
NRCS Soil Quality for Environmental Health
FAO Soil assessment
Soil carbon storage (Nature Education)
USDA Soil Biology Primer
Soil organic matter under mob grazing
Visual soils assessment guide – Vaderstad
SoilCare (testing soil-improving systems in Europe)
SoilCare Inc (US producers focused on soil health)

2.0 A REVIEW OF THE TESTS CONSIDERED ON THE DAY

A range of practical tests were demonstrated in the field and the barn with separate discussions being held around the role that biodiversity can play in assessing soil health.

SESSION 1. OUT IN THE FIELD

The first of the demonstration sessions was held out in the field in blustery and occasionally rainy weather. Practical demonstrations were given around several potential proxy measures. Links to how to do the tests are provided where appropriate and those provided by the USDA's Soil Quality Test Kit Guide can be found here – check the appropriate test.

1.1 Measuring the rate of water infiltration.

- Small holes the width of a spade were dug in an arable field, a grass field and along a hedgerow.
- Water was poured into the holes and the amount of time it took for the water to infiltrate was timed.
- In general, the quicker the water soaks into the ground the better the soil structure.
- The group felt that the pasture area was still quite compact, and we discussed different management practises for pasture and how they may influence water infiltration rates. In this instance, the prevalence of bare soil, and moss thereon, suggested longer rest periods would be useful to allow the grasses to dominate and tiller.
- There are various techniques for measuring water infiltration – what is important is being consistent the technique used so as to allow comparisons over time.
- For one approach see USDA-defined test number 3. Another approach can be seen here.

1.2 pH.

Most farmers are likely to know the pH of their soil, but there are several simple pieces of equipment that can be used. A summary of some of these (with reviews) can be found here and the conical Mudder pH soil tester (which was demonstrated during the soils day) can be found here – although there is little detailed information about it online. There is also a simple strip for testing soil pH in the earthworm kit and these can be purchased here, at around 10p per strip. Also see USDA test guide number 6.

1.3 Soil compaction.

This can be tested using one of various types of penetrometers – about which more here and here. There are other sources of information and supply. While expensive soil compaction tools exist, it is also possible to use a re-bar with a nib of weld on the end as an easy measure of soil compaction. By putting pressure on the bar and driving it into the ground and comparing this to another field or part of the field one can feel how compact the soil is depending on the ease with which it sinks in.

1.4 Earthworm counts

- Earthworms are a good biological indicator of SOC because they are a large and visible member of the soil food web that relies on good quality organic matter for nutrition.
- *Earthworms are an ideal "indicator species" that will give you a measure of soil health (a bit like salmon and trout as measures of water quality in rivers and streams). Their presence and abundance are an excellent barometer of good farming practice. The test is best used at certain times of the year when they are most active in the soil and perhaps not as good during dry periods of the year when they may burrow deep or go dormant*.
- Small squares of soil in the grass field were dug, the width of a spade. Mustard powder was mixed into the water to help to draw the worms to the surface.
- A worm species identification sheet made it possible to find out more about the worms.

AHDB has a useful guide on to how undertake such a survey, produced by Jackie Stroud (earthworm research fellow at Rothamsted) and she would be happy to provide further advice. If you are really interested in worms you can follow her on Twitter at @wormscience. She also recommended the comprehensive guide produced by Imperial College, which was used on the day. This provides a detailed guide on how to do an earthworm survey and how to recognise the different types of earthworms. It is highly recommended – see here and here and here. Replacement consumables such as mustard and vinegar can be found in your kitchen and the source of pH strips was given in section 1.2 Another project encouraging the monitoring of earthworms is called EarthwormWatch and is being promoted by Earthwatch and Garden Organic, based on a kit produced jointly by the Natural History Museum and the Royal Geographical Society. You can download the instructions and the guide here.

SESSION 2. IN THE BARN

The second of the demonstration sessions was given in the barn and covered:

- The Slake test
- The Solvita test
- The soil food web
- Soil colour
- The teabag test
- Brix (in the field)

2.1 The Slake test.

- This is a simple test that involves putting soil samples into a glass of water and seeing how quickly they fall apart or stay stuck together.
- Samples that have more organic matter hold together more.
- Soil samples need to be dried before doing the slake test
- To compare different soil samples a simple scoring system is needed - for example, what percentage falls apart over 10 seconds.
- Having visual images to compare against is also helpful
- How to undertake the slake test is demonstrated in the film of Jenni Dungait's presentation and can also be found here and another video is here – the latter also demonstrating an alternative approach to demonstrating the importance of water infiltration.

2.2 The Solvita test (or the CO_2 burst test).

Martin Wood demonstrated the Solvita test– also shown in the workshop film.

- This is a new test developed in the USA
- It measures the level of CO_2 release in the soil as an indicator of biological activity, as soil organisms inhale oxygen and release carbon dioxide.
- A fresh soil sample is sealed in a jar, to which is added a test paddle that has a panel of gel impregnated with an indicator solution (like a breathalyser test). The soil is left at room temperature for 24 hours.
- The paddles come with a colour reader that interprets the CO_2 concentration.
- It can be used for measuring the effects of different management methods.
- It is also a useful proxy indicator of likely available and release of plant nutrients within the soil.

The paddle is not cheap (£20). However, since the process is reversible it is possible to use the paddle several times before it needs to be replaced. The paddles (and jars) can be purchased from Earthcare Technical, the link for which also provides another demonstration video. Although video this refers to compost, the kit can also be used for soil. Martin explained that, because of the much higher level of biological activity under pasture, the test needs some further calibration for accurate use under pasture.

2.3 Soil biology and the soil food web.

Simon Parfey demonstrated some of the opportunities for analysing the soil food web, using direct observation to make counts of micro-organisms using a light microscope. He noted that it takes much time and training to develop the skill set to ensure consistency and, although the assays are quite simple (in scientific terms), they take a great deal of time to perform in the entirety when compared to other, more standard soil tests.

There are, however, other and simpler ways that interested people can check their soil and composts for bacteria, fungi, nematodes and protozoa using a microscope and some basic training - the qualitative assessment.

- *When the soil starts to warm up in the spring the organisms become active.*
- *Take a soil sample and apply water, then put it on a slide with a cover slip.*
- *Look for organisms swimming around*
- *It is important to pick a time that is repeatable, e.g. same time of year, time of day.*

The full SFW analysis requires a series of extractions from a sample of soil. From this is made a series of cultures and the microorganisms are stained with special dyes to make them more readily identifiable. The counts are considered in the context of the moisture content of soil, season and plant type that the sample relates to. This provides further understanding and guidance of not just the dynamics within the biomass (including total and active populations of bacteria and fungi) but also the relationship and ratios between the different organism types. This information can be used to inform a management programme to encourage balanced conditions. An example of such an analysis is shown overleaf – for which the cost is £150 per field (consolidated samples taken using the W system).

Simon would be happy to organise some microscope training for the PFLA members in the future and can look at ways to make this most cost effective and useful. A course is currently being planned for May-June time. Further details of these services can be found here.

2.4 **Soil colour.** Compare dried top soil with dried sub soil (below rooting layer). Under pasture, the top soil should have more soil organic matter and be darker. Understanding soil colour is a topic in itself. There is an introduction to soil colour here and an introduction to the Munsell Manual of soil colour is here.

2.5 **The Spade Test**

Farmers should always carry a spade with them in their tractor so that they can assess their soil while in the field. In carrying out a spade test, information about earthworms is also gained and materials for the slake test can be obtained. The spade test doesn't produce quantitative data, but the qualitative nature of the process is invaluable for gaining an understanding of one's soil. For more information see here.

SoilBioLab
Specialists in soil testing

Soil Microbiology

Organism Biomass						
Analysis	Units	Result	Guideline	Low	Optimal	High
Moisture content	%	22	15 - 55			
Active Bacteria	µg/g	21.9	20 - 45			
Total Bacteria	µg/g	755	150 - 300			
Active Fungi	µg/g	42.4	20 - 45			
Total Fungi	µg/g	115	150 - 300			
Hyphal Diameter	µm	2.9	>2.5			

Organism Ratios					
Analysis	Result	Guideline	Low	Optimal	High
Active/Total Bacteria	0.03	0.15 - 0.20			
Active/Total Fungi	0.37	0.15 - 0.20			
Active Fungi/Active Bacteria	1.94	1 - 2			
Total Fungi/Total Bacteria	0.15	1 - 2			

Protozoa						
Analysis	Units	Result	Guideline	Low	Optimal	High
Flagellates	No/g	7377	>5000			
Amoebae	No/g	2744	>5000			
Ciliates	No/g	59	50 - 100			

Nematodes						
Analysis	Units	Result	Guideline	Low	Optimal	High
Total Nematodes	No/g	6	10 - 20			
Nematode types	Fungal feeders: 63%; Bacterial feeders: 31%; Juveniles: 6%.					

Mycorrhizal Colonisation						
Analysis	Units	Result	Guideline	Low	Optimal	High
Ectomycorrhizae	%	-	10 - 50			
Endomycorrhizae	%	5	10 - 50			

Potential Nitrogen in Soil			
Nitrogen (N)	kg/ha	56 - 84	Potentially cycled for a period of 3-6 months

*Please note that this value is related to the microbiological activity and is not a chemical measure of nitrogen.

2.6 The Teabag test

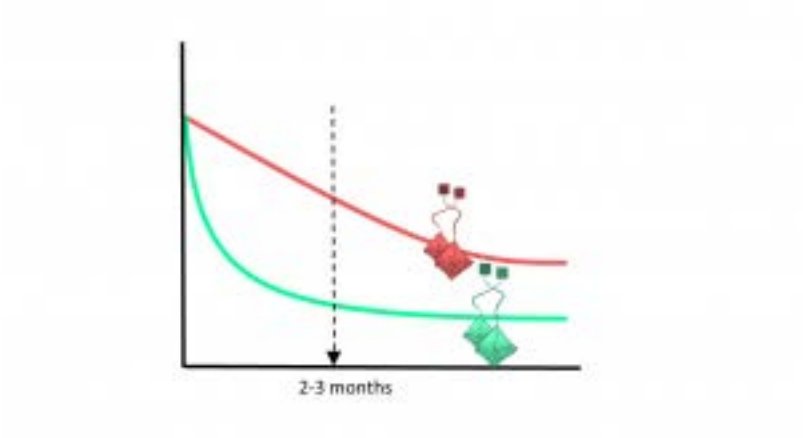
The teabag test measures the rate of decomposition of two different types of teabag over time and is a useful indicator of the level of biological activity. In brief:

- Buy specific types of Lipton teabags of black tea and Rooibos tea and bury them in the soil for three months.
- The two types of tea will decompose at different rates and will serve as indicators of
- Weigh the dried teabags and compare the difference - the more biological activity the faster they will decompose. The black tea should decompose much faster.

More details can be found here and here and below.

Methods to study decomposition – using the tea bag test[1]

To measure decay rates of dead plant material (litter), you need to put a certain amount of litter in a plastic mesh bag. The holes in the mesh will allow microorganisms to enter and consume the litter, but the plastic bag will prevent the litter from being lost. To measure the decay of the plant material in the bag you need to put this bag in the soil. The weight loss of the material after a certain amount of time will show you how fast the decay is at the location where you buried the bag. In the TBI-method we do not make such litterbags ourselves. We buy them in the store: tea bags. Green tea and Rooibos tea leaves are plant material, and will therefore decay like other organic material. The TBI method measures decay of plant material by using two types of tea bags (Green and Rooibos) as standard plant litter (Keuskamp et al., 2013) in plastic mesh bags. Tea bags are placed in the soil and weight loss is determined after three months. Tea is not only used as a standard litter. From the weight loss of Rooibos and Green tea we obtain two parameters that are indicative of two different phases of the decay curve. Usually, decay is initially rather fast when all the material that is easy to decay is consumed. Second, the weight loss curve over time levels off, when decay is much slower as only the more recalcitrant material is left. We call this latter phase stabilization.



With the decay of easy to decompose green tea (green line, Figure 1) one can determine how much of the material is stabilized (*S*). Rooibos tea decays much slower (red line, Figure 1) and after three months, it is still in the first phase of decay. Thereby, the weight loss of Rooibos tea after three months gives us a measure for the initial decay rate (*k*). With the TBI method it becomes easy to compare sites in an easy and standardized way and test climatic forcing on decay with a high resolution. The project aims:

1 To create a global soil map of decay rates.
2 To test relations between environment and decay on a global scale.

It can be used to:

- Test the effect of climate in large climate gradients
- Test experimental treatment effects
- Educate students on soil processes

2.7 Brix

[1] Source: http://www.teatime4science.org/about/background-relevance/

Brix is a measure of the dissolved solids and sugars in a plant and is an indicator of nutrient density. You can get up to speed about the value of brix in monitoring pasture quality here.

By using a garlic press, a drop of grass juice is squeezed onto a refractometer which provides a reading that reflects nutrient density. The higher the reading the better the result is. It is best to measure it the same time every day (as readings will tend to get higher during the day). A basic refractometer costs just £20.

Other links that will inform about brix can be found below:

http://practicalfarmers.org/blog/2012/12/18/mob-grazing-with-neil-dennis/
http://practicalfarmers.org/blog/2013/07/30/trip-to-sunnybrae-farm-mob-grazing/
https://www.youtube.com/watch?v=IB5pq6owxN0
https://www.youtube.com/watch?v=xLEVspCz6H8
https://www.youtube.com/watch?v=sMlis7iktjM

SESSION 3: BIODIVERSITY ABOVE AND BELOW GROUND

My interest in the potential for above-ground biodiversity being a potential indicator of soil health was stimulated by this article by William Stiles of Aberystwyth University. We were fortunate that Will, Rob Havard (Natural England lead adviser and PFLA certified farmer) and Paul Muto (Senior Agronomist at Natural England) could join us to lead the discussion around the issue. Whilst above-ground plant biodiversity may not be an accurate proxy measure of soil health, it could be a useful indicator for those who are interested in monitoring. An extract from Will's article is in the box below.

Biodiversity experiments have shown that rates of productivity and species richness are positively related. When comparing sets of sown grassland plots with different amounts of species, yield has been demonstrated to be higher in species rich grasslands than in species poor, and that this effect remained consistent in the long term (8 years). In one study comparing productivity in grassland managed either as high-diversity (of plants) low-input (of fertiliser) or as high-input low-diversity, yield was observed to increase as a result of higher plant diversity, which served to offset any yield gains from fertiliser input, resulting in similar yields from either system. Low plant diversity in this study may not necessarily relate to low diversity fields such as in intensive UK grassland systems, which contain few, but highly productive, species. Nevertheless, in principle at least, increasing species richness in grasslands could be an alternative management strategy for effective grassland production, which offers reduced environmental impact and production costs.

Increases in yield with higher species richness have been attributed to the influence of resource partitioning, both above and below ground, which is where different growth forms allow for better usage of resources such as light or nutrients. This can allow plants to utilise resources that a neighbouring species is unable to capture (such as when plants with different root depths utilise nutrients at different levels in the soil profile) reducing the impact of competition. This is referred to as niche complementarity, where there are positive interactions amongst species by virtue of having numerous different plant species from a wide range of life histories. In addition, the architecture of more complex plant communities, again both above and below ground, can also allow for greater density of vegetation as a consequence of the different growth forms being able to live in more close proximity.

Effects of soil carbon: Increasing plant species richness can increase the density of vegetation below ground through the mechanism detailed above. Carbon, in the form of organic matter, is introduced to soil via the growth of plant roots and from root exudates. Fertiliser application can increase plant growth which can increase soil organic matter input through this mechanism, but fertiliser input can also increase the activity of microbial organisms, which can speed up rates of decomposition leading to carbon loss. Recent research has demonstrated that intensive grassland management has reduced soil carbon stocks at sites across England and that this effect is observable, and considerable, at much greater depths than previously recognised. In a study considering grasslands across a range of management intensities (from traditional, low intensity management with little fertiliser input and high plant diversity, to more intensive management, with high fertiliser inputs (>100 kg nitrogen per hectare per year) and few, high productive species), soils under low intensity management with high species diversity were shown to have significantly higher carbon content than those managed intensively.

More on a biodiversity-friendly grazing system can be found here. However, In the current absence of any measurable links between above-ground biodiversity and soil health, we will limit ourselves here to feedback from Rob, Will and Paul together with a summary of thoughts.

Following the event, Rob wrote to me as follows:

Above ground biodiversity as a measure of soil health. There is very little scientific evidence for this relationship, which does not mean that there is not a relationship. There can be times when a healthy nutrient cycling soil is not the most bio-diverse above ground. Particularly when we look specifically at plant diversity of semi-natural grasslands. For me the biggest indicator is what I will call the ecosystem diversity. Some very species rich grasslands can be fairly weak in their provision of habitat for small mammals, birds etc., etc.. I think management also comes into play here because an ecosystem is not just a collection of species on paper but also of their behaviours and interactions. Good conservation/farming management is essentially built around re-creating natural processes - be that recreating herds of wild herbivores or canopy breaks in woodland management. I wonder if a better measure (or an additional one) might be the presence or absence of ecosystem processes.

While we cannot infer a direct link between diversity and soil health (yet) we can record bio-diversity. For example, if we know the composition of the herbal ley then we know the plant diversity - I think native grasslands will be harder to measure for farmers not used to identifying grasses and plants but there is no reason that a researcher should not do this.

I suggest for bird-life we could link up with the RSPB volunteer/farmer alliance project. It would also be valuable to have dung beetle/ground beetle/invert surveys done but this again will need to be carried out by a competent surveyor.

I wonder if we could do a simple survey that records…how many kinds of birds, how many kinds of invertebrate, plants, mammals etc.? Again, the difficulty is having a statistically robust measure of biodiversity with farmer input. I have harvest mice in my tall grass pastures and I'm sure many others do since they are under-recorded, but you would be hard pressed to find them unless you know what you are looking for and are willing to spend the time looking.

However we measure the bio-diversity, it will at the very least give us a comparison and the opportunity to see if there is a positive correlation. Another possibility might be to go to sites where we already have good data on biodiversity and measure soil health on these sites.

Will Stiles wrote as follows:

To the best of my knowledge there is no existing system for determining soil health based on above ground biodiversity (presumably for many reasons, not least the enormous variability in natural systems/soil types etc.).

However, there are a couple of ways this might be possible. Studies which have connected productivity and biodiversity have determined that the presence of forbs (rather than, say, legumes) is a governing factor. It is plausible therefore that the role of some species groups is key to function. Thus, there is the potential for a suite of indicator species in species-rich pasture that may infer something with regard to soil characteristics – which could be interpreted as health or otherwise. If possible, that could be an extremely simple and practical way of interpreting soil processes/status, requiring minimal disturbance and effort. I would need to look into this further to ascertain if this is a real, testable, scenario for research, but I feel this could be an area worthy of further investigation.

Directly linking plant diversity and soil C I think would be difficult. You could establish a simple design to consider soil C (total C would be best following the Dumas combustion technique, but determining SOC/SOM with loss on ignition would do) under varying levels of pasture species richness, to try and indentify a relationship. But I think this approach would be problematic as other factors, such as nutrient input, would also have strong influences on both species richness and soil C, and are perhaps more likely to be the controlling mechanisms – and of course, this is also likely to invoke a chicken/egg argument. Do the plants influence the soil or vice versa?

I would certainly be keen to consider the former concept further with you if this sounds like something that would interest the PFLA.

Paul Muto wrote as follows

The belief that above-ground biodiversity is a potential indicator of soil health is somewhat problematic, as there are many situations where plant species-richness may actually be highest on thin or poorly developed soils (due largely to lack of competition from productive grasses). One can make the argument, however, that multi-species swards outperform single species forages due to more efficient resource utilisation. It is perhaps better to aim for a diversity of functional groups within a grassland rather than sheer numbers of species. A functional group can be a plant family or a collection of species with similar plant architecture that plays a specific function within a grassland ecosystem. Examples of functional groups are legumes (nitrogen fixation), productive tall grasses, grazing-adapted grasses, deep-rooted forbs (deep soil nutrient access, productivity during drought), medicinal forbs, hemi-parasitic plants, etc. All of these have a role to play in productive and sustainable grassland management which, in turn, has implications for soil health. I believe that above-ground biodiversity is a laudable aim for grassland management, but there may not be absolute, clear-cut links with soil C sequestration or soil health. Nonetheless, there are clear gains to be had in improving arable soils through temporary, multi-species grass leys, particularly if key plant functional groups are present (highly productive grasses, legumes and deep-rooted forbs).

Determining a benchmark for what constitutes sustainable grassland management practices will continue to be an evolving science, particularly around the question of the suitability of synthetic nitrogen inputs. Above-ground biodiversity will certainly continue to be a key measurement in grassland monitoring, but its exact role in soil health is still somewhat debatable.

These observations are encouraging and it is almost certain that work around this topic is going on elsewhere – if we can only find it. Claire Horrocks told us, in passing, that she is working on the effect of different grass species (including high sugar grasses) on what happens in the soil.

Hannah noted the following on the topic.

- Good biodiversity is not always the best indicator of good soil health, but biodiversity can be a functional tool for improving soil health.
- Rather than absolute numbers, it is better to look at functional groups, for example, productive grasses, nitrogen fixers, broadleaved plants, beneficial for animal health, deep rooting species
- A high carbon soil is likely to encourage biodiversity. Soils propped up by NPK are less likely to.
- A lot of grasslands are leaning towards monoculture, but are very productive when measured in terms of dry matter. How to find a balance?
- Good pasture diversity can work well for finishing livestock providing they are moved regularly – the cattle will self-select the best forage from the plant.
- Yield can increase in response to biodiversity (as per William Stile's article), which suggests that productivity can take place in harmony with nature.
- There was some good discussion on the NE stewardship options and their suitability for improving biodiversity and soil health.
- We should not think of biodiversity just in terms of plant species but the whole ecosystem - birds, mammals, soil bacteria and so on.
- An important way to assess biodiversity is to observe: focus on what you see while moving fences in holistic planned grazing. Look before and after. Makes notes on which flower species and relate to grazing chart. Look at germination. Focus on red clover and bird's-foot-trefoil and other common flowering plants e.g. ox-eye daisy, sorrel, plantain.
- It is also helpful to monitor the number of nesting birds such as skylarks, meadow pipits. Their chicks are insectivorous which is a good indicator of soil health.

  Not directly concerned with biodiversity in this context but here's a link to the Wildlife and Farming: conservation on lowland farms hand book by Dr Ruth Feber, from WildCru/University of Oxford.
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4. WHICH OF THE TESTS PROVED MOST POPULAR?

We asked both the farmers and the techies to rate the various tests.

4.1 Views of the farmers present

28 people responded to the questionnaire/survey, of which 24 are farmers. They were asked two key questions:

Question 1. How do you rate the various tests in order of priority – with (1) being top priority and (5) being the lowest priority? Nine of the tests were included. In the table below you can see how many people rated the tests (i.e. considered them worthy of being rated) and the average score for each test, adjusted for the level of priority. These figures would not stand any kind of statistical test – they are simply the total score for each test divided by the number of people who rated it. The lower the score, the higher the rating. But they give an indication of the level of interest.

Question 2. If you were included in a field trials programme to evaluate these tests, which ones would you wish to test on your farm?

The table below shows:

- How many people rated each test (i.e. felt it was worth commenting on)
- What was the weighted priority (the lowest number indicating the highest priorit)
- How many people would like to include the test in a field trials programme on their farm.

TABLE 2. How were the various tests were rated by the participants?

	How many people rated this test?	Weighted average	Would include it in a trials programme
Earthworm counts	27	1.41	17
Slake test	27	1.44	17
Food web	16	2.06	10
Infiltration rate	22	2.23	13
Fauna biodiversity	19	2.37	12
Flora biodiversity	19	2.53	14
Teabag test	15	2.47	9
Solvita respiration	16	2.69	10
Brix	18	3.17	12

4.2 Views of the techies present

In a subsequent exercise the techies present were asked to nominate which tests they would encourage farmers to use – including those covered in the event and any others that they felt would be helpful. 19 people responded. The list of test options is much longer but there are some similarities. In both cases the earthworm test and the slake test top the list.

TABLE 3. RATING OF TESTS BY THE TECHIES PRESENT

Test/indicator	Number recommending it
Earthworms	11
Slake test	8
% organic matter	6
Visual soil structure/aggegates	3
Above ground biodiversity	3
Infiltration rate	3
% carbon	2
Spade test	3
Above ground biomass	2
Soil fungal/bacterial score	2
Compaction	2
Soil colour	1
Dung beetles	1
Rooting depth	1
Soil respiration	1
Brix	1
Bulk density	1
Smell	1
Absence of waterlogging	1
Absence of erosion/soil wash	1

In summary, there are many potential tests to choose from – of which the earthworm test and the slake test are by far the most popular. Other tests could be included depending upon what you are interested in or what you find most helpful. What is important is that the tests are repeated in the same locations at the same time of year and the results related to your own observations of performance on the farm or to a more formal test such as the level of organic matter or carbon. The idea of comparing the results with the soil under the hedges, as an indicator of what it possible, is an intriguing one.

5. WHAT HAPPENS NOW?

Hopefully this document provides a record of the day for those present and an idea of what happened for those unable to attend.

There are many web links that can take you to sources of more detailed knowledge.

There are technical contacts that you can follow up.

We are in the process of designing a simple on-farm, field trials programme that will seek to evaluate some of these potential proxy measures over three years – working alongside a number of research institutions and FCCT. More on this in due course.

Most importantly, I hope you will absorb the information from the day and from the various links and apply them on your farm. Using a number of these tests on a regular basis should provide an indication of the health of your soil and how it is changing. These can be part of the bigger picture of the carbon story on your farm, which you can check and monitor using the Farm Carbon Cutting Toolkit.

To end with a quote from Ian Robertson: *"The biggest asset on your farm is **not** your soil, it's **you** and how you decide to manage your soil.*

ANNEX ONE: EMAIL FROM BEN MEAD (bhmead@icloud.com) on 21 February 2017

Dear John,

Unfortunately I can't attend the meeting....much as I'd like to. I farm single handed here in Cornwall, with very limited relief available at the moment so it's hard to get away.

I have been thinking about your comment on the rising plate meter equivalent for soil in the flyer for today's meeting, following my suggestion at the first PFLA soil carbon meeting at Sheepdrove.

I don't know if you have used one? With hindsight, it occurred to me that probably only a handful of people in the room knew what they were, let alone regularly used them; what they do is measure the height *and* density of a grass sward. Typically you take 40 of these height/density readings per paddock as you walk across it, apply a conversion factor to produce a measure of the kgs per ha of dry matter for each field on your farm.

Taking these measurements on a weekly basis you can then calculate the total dry matter available on your farm on the day, where the highest covers of grass are, as well as the daily growth rate of the grass. Essentially it is a stocktaking and production forecasting exercise.

Put these results into a fairly simple spreadsheet, together with the numbers of animals on the farm and what the intended dry matter intake is per animal and you very quickly get an accurate, low cost and real-time picture of whether you have enough feed to feed the cattle numbers on a regularly weekly updated basis. In addition, you also know the rate at which your farm is building a surplus of grass or heading into a feed deficit and can take the appropriate action in a timely manner as opposed to crisis firefighting. This is just a simple but surprisingly powerful budgeting exercise.

With regular monitoring it becomes an essential tool to guide decisions on cow numbers, feeding and supplementation, grass cutting and silaging, drying off dates, optimum calving date, total grass productivity per paddock per annum etc. etc. The system works well and is invaluable because grass growth can be fast and volatile, varying from zero to upward of 120kgs/DM/Ha/day, which means it's very easy to be caught on the hop. So the simple stocktaking and budgeting exercises now transform into a powerful planning, What If? and feed/cash flow tool.

Plate meters are cheap, approx. £150-200, surprisingly accurate, easily understood, reasonably robust and will give the same result if another person uses them. The payback is rapid. What more could a farmer ask for?

Unfortunately soil carbon doesn't grow so quickly as grass...so the scope for a plate meter to be such a powerful tool is limited. Where I thought it may have some possible use in soil carbon building management was in being able to measure the residual grass left *post grazing*. This distinction is important because I think people at the meeting who haven't used the plate meter for their grass management may not have understood the idea that I was trying to get across.

In a mob grazing situation I'm increasingly coming to the conclusion that the quantity of residual dunged-on, trampled grass is crucial. Essentially it's the basic feedstock for soil carbon. So if you graze to the floorboards...generally considered best practice by NZ-style paddock grazers as a means of retaining pasture quality... you are already limiting the potential for SOM building because you haven't made the mental leap of viewing 'waste' (i.e. uneaten trampled grass) in its new role as a valuable input.

Extreme/over grazers are violating von Liebig's law of return. Perhaps it would help if we began to look at our forages as part cattle feed/part cover crop/part fertiliser and consider more where the optimum balance lies.

Effectively a mob grazer uses the animal to perform a sheet-composting operation in situ on the field being grazed; a wonderful closed loop, highly efficient symbiotic process of soil organic matter building. Used correctly, the animal flock/herd has the potential to become an appreciating and ecological, solar powered tool to replace depreciating, fossil fuel burning ones which, more often than not, are engaged in an activity that further burns soil carbon!

So it would seem logical that the greater the weight and cover of properly trampled, dunged on grass left behind.....the more opportunity for it to break down into soil organic matter and build fertility, microbial diversity and all the other benefits that accrue. Somewhere in that balance there must be a sweet spot where you derive the maximum benefit to both soil and animal and I'm simply wondering how you could measure this.

Unfortunately plate meters struggle to measure accurately the trampled grass AND the very tall covers of multi-species forbs and grasses that are the stock in trade of the mob grazer. Whether the newer generation laser -based models can cope better, or could be adapted to do so I don't know. It would be worth exploring.

This is an important point, because, from my own observations, many of the NZ-style, maximise profit-focussed paddock grazers are subsidising their short-term profits with longer term soil capital erosion. I confess I too was guilty as hell in this respect....but it took me a long time to realise it. I now believe that proper mob grazing techniques, which observe the law of return, offer the best potential for soil carbon building.

Doubting Thomas's only have to consider the most fertile, deepest topsoils of places such as the American Midwest, South African Veldt and the Ukraine....all were created by the action of huge herds of migratory grazing animals....which the mob grazer attempts to imitate....whilst 'modern', 'efficient', 'best practise' chemico-mechanised agriculture destroys this dwindling resource at an ever-increasing pace.

So, moving on, in my quest for nailing carbon back in the soil where much more of it belongs, I have some involvement with Exeter University, who have a carbon flux measuring meter on the farm and have been experimenting with drones to measure biomass accumulation. This may prove to have some benefit. However, like many farmers I have a natural scepticism of expensive, fragile devices in farm situations! They, and my optimism, have cost me too much over the years! Sir Ernest Rutherford's dictum, as he and his team successfully became the first scientists to split the atom has become something of a mantra to me: 'We haven't got the money so we've got to think'.

This remains as relevant today as ever. Perhaps more so.... if the crestfallen look on the face of a PhD student was anything to go by when my battered 10year old 200 quid plate meter produced a more accurate, faster and consistent biomass reading than his temperamental, high tech box of expensive tricks!

I also quickly learnt that a major benefit of the plate meter was that it disciplined you to walk every paddock of the farm regularly and, with the proviso that you kept your eyes open, gave you a huge amount of additional first-hand experience qualitative data about your production platform as well as teaching you other important skills such as being able to gauge pasture DM quantities by eye, and put them into a more holistic and cross-referencing context when related to observations such as

cow condition, milk in tank, animal behaviours etc. My suspicion is that remote monitoring will not provide this critical input.

I hope that all makes sense.

However, you are right to wonder how we measure our soil carbon content cheaply and relatively easily. It is the holy grail. When we in the Tamar Valley Organic Group were looking at the possibility of trading carbon credits with local businesses I did do a little research in this area.

One avenue that did seem interesting was when I was talking with Allan Yeomans in Australia while I was involved in purchasing and importing one of his famous Keyline Plows a few years back. His father, PA Yeomans, wrote the classic book Challenge of the Landscape back in the late 1940s. A geologist and mining engineer turned farmer, he wrote about building soil carbon way back then AND demonstrating how to do it on his own farm....with great success and to much acclaim from farmers, scientists and politicians alike.

Allan, in his 80s now, carried on his father's legacy. Besides building and further developing their farmerproof Plows with a raft of simple improvements and innovations he lectured widely. His presentations in the US provided the motivation for a group of farmers out there to start the Carbon Farmers of America. He wrote a book called Priority One which covers the potential and methods for sequestering carbon back into farmland as a means of climate change mitigation. A true polymath, he has gone on to design and produce solar powered steam turbine generators to produce electricity and a host of other ingenious inventions.

At the time I last spoke with him he was working on a relatively low cost device for farmers to accurately measure soil carbon levels specifically so they could test their soils around the farm, and quickly and cheaply see on a fairly regular basis whether their carbon levels were rising or falling.

This was of interest to TVOG because if we wanted to trade carbon credits we needed an accredited, affordable device to be able to measure soil carbon. We also recognised the benefit of regular monitoring to test whether our management practises were having the desired effect in actually building soil carbon and disseminate the ideas that worked among other members of the group for further evaluation and improvement.

Allan was hopeful that with a change of government in Australia and carbon trading rising up the political agenda there would be a market for his device.

Of course, the whole issue of carbon offsetting and trading is a political hot potato, not helped by various fraudulent schemes and bad science that have come to light as well as the difficulty of setting up a worldwide agreement on measurement and accreditation.

The development of a simple, cheap, accurate tool that enlightened farmers can use to monitor the progress (or not) of their attempts to build soil organic matter seems to me to be a crucial missing part of the jigsaw. Ideas along the lines of the slake test and soil and plant sap chromatography are moving things in the right direction and I feel confident that scientists of the stature of Jenny Dungait have come to this realisation and that this is a major step forward.

There have been and still are plenty of enquiring minds out there. Phil Callaghan, a USDA entomologist and author of Tuning in to Nature, developed a soil meter in conjunction with fellow tinkerer and innovator Bob Pike of Pike Agri instruments and, important this, a bunch of interested farmers, that measures low level soil paramagnetism which increases plant growth and aids

prevention of disease and insect attack. I use one as it fits my criteria of being relatively cheap, easy to use and produces consistent results.

Nuffield scholar Phillip Hughes uses a simple, cheap electric circuit tester as a soil conductivity measuring device....a technique he saw successfully applied while on his travels in New Zealand. A number of agronomists have been using radionics boxes with, they claim, encouraging results.

So there's plenty of 'out there' ideas out there and it must be a rich and rewarding area to research. Best wishes for an excellent meeting. I think that it is wonderful that you have shaken such a broad band of scientists out of their respective silos...I know how difficult it can be....but great things often happen when disparate disciplines discuss with a common aim. If I may make one final request it is that the scientists don't forget to engage with the farmers too.....we are not always as dumb as we may at first seem or pretend to be!

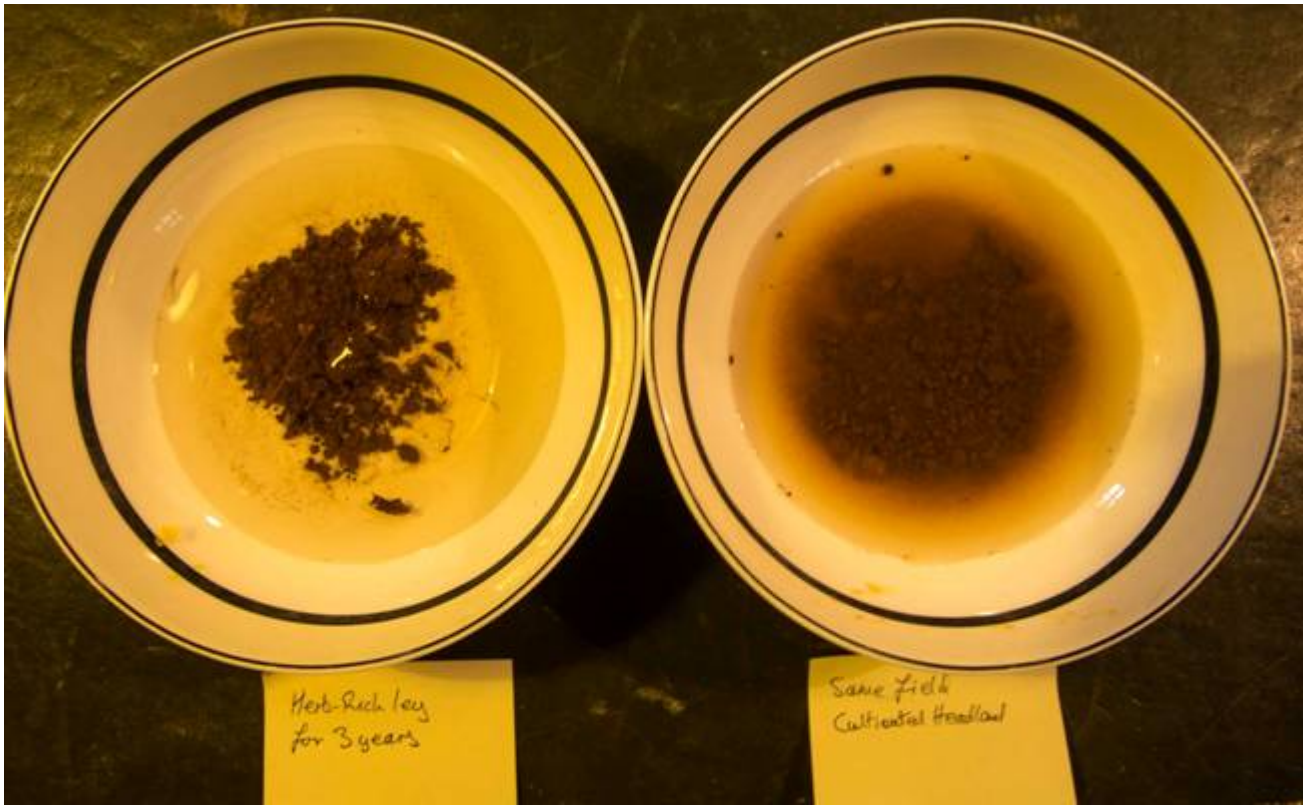
Bestest, Ben Mead

ANNEX TWO. Email to the PFLA discussion group from Ian Boyd on 24th February 2017

Many of us were treated to a fantastically informative day at Fir Farm in Gloucestershire in the grandest Dutch barn I have ever seen.

In the past, I have always felt soils to be a rather boring subject that I knew was meant to be important but could not see what to do about whilst trying to conventionally farm for profit on my arable area.

But the penny has finally dropped. Introducing the multi-species herb-rich Leys into the arable rotation is being transformative in the soils.



This is a variation on the slake test I learned on the Soils day. The left bowl is soil from a 3rd year herb-rich Ley. The right is from the cultivated headland just 10 meters away. Just put soil samples in water and see whether the soil has got enough organic goo to hold it all together or whether a rain storm is going to lead to soil runoff.

Now this is slightly ironic as, when I joined HLS in 2007, I set up a lot of Conservation Headlands which was meant to be the part of the field to help farmland wildlife by ploughing every spring, planting a spring crop and leaving whatever that germinated grow and set seed and be biodiverse. But it has done nothing for my soils and now it is the other way round – the middle of the field is more biodiverse with healthier soil! And all winter I have had snipe feeding in the field which I have never seen before on our thin Cotswold brash. This must be indicative of the increased earthworm numbers.

Interestingly, when I first told the birdwatcher who monitors our bird numbers, that I was going to be sowing grass over the arable area, he was full of gloom as he does not see many birds on many grass areas. He is only now beginning to appreciate how important the soil is to his bird numbers.

I took this photo on Andrew Brewster's farm recently. The kestrel and heron are both hunting for voles and Andrew tells me they have now been joined by a short-eared owl.

I do feel that grazing, especially mob grazing with the rest periods, is much better for wildlife than mowing where the crop takes so long to recover by comparison.

I am really quite excited now that, after years of seeking a farming system that increases my farmland wildlife, I now have something to really work with that has a future. It should go a long way to achieved Andrea Leadsom's stated ambition and her department's vision "to be the first generation to leave the environment better than they found it...."

Best wishes
Ian

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ian@whittingtonlodgefarm.com

ANNEX THREE. SUMMARY OF WORK INTERESTS OF PARTICIPATING TECHIES
(This includes those who completed the form, presented in alphabetical order by first name)

Name	**Dr Angela Wright**
Name of organisation	Compassion in World Farming
Contact details	**Email: angela.wright@ciwf.org** **Phone(s): 01483 521 950**
Role/job title	Head of Research & Education
Focus of work *Please summarise in not more than 300 words the focus of your work – with particular reference to gaining a better understanding of the nature of soil under pasture and monitoring its health*	I work predominantly on sustainable food systems and animal welfare. From a food security perspective livestock reared on pasture is a nett input into the food system, whereas intensively reared livestock reared on grain competes with food sources suitable for humans and results in systems that have a low welfare potential. A sustainable food system depends upon fertile, healthy soils. Healthy soils produce quality forage and livestock reared on pasture is production systems that – if well managed – provide a good quality of life for those animals, thus achieving high animal welfare. These pastures function as a carbon sink thus ameliorating GHG emissions therefore a win-win on the two crucial issues facing humans: food security and global warming. I sit on a couple of advisory boards: - Food Research & Climate Network – Oxford University (FCRN) - Innovative Food Systems Teaching and Learning programme – a multi-University post-graduate initiative (IFSTAL), and - Co-chair the UK Food Group (UKFG) I'm also involved in the UN FAO High Level Panel of Experts on Food Security and Nutrition working groups on various food and agriculture issues such as the role of livestock in sustainable agricultural systems and nutrition and food systems.
Please add any other comments that you think will be helpful.	It is very useful to understand the soil carbon mechanisms that underpin the key solutions to sustainable food systems and climate change. I can utilise this knowledge and promote mixed rotational farming, permanent pastures and pasture-fed livestock at CIWF and in the various arenas listed above, and more.

Name	**Chris Uttley**
Name of organisation	Stroud District Council
Contact details	**Email: chris.uttley@stroud.gov.uk; Phone(s): 01453 754464**
Role/job title	Rural Sustainable Drainage officer
Focus of work *Please summarise in not more than 300 words the focus of your work – with particular reference to gaining a better understanding of the nature of soil under pasture and monitoring its health*	My work involves working with farmers and woodland owners to develop and implement ways of reducing flood risk by using natural flood management techniques that reduce the speed at which run-off and flood peaks travel downstream. I develop simple and straightforward proposals with farmers to allow them to make a contribution to reducing flood risk and then often directly contract the landowner to implement the proposals to develop skills and ownership of the work. Work often includes safely exploiting springs to provide water for stock, reducing water bills for owners and/or pollution & erosion.

Name	Claire Horrocks
Name of organisation	Rothamsted Research
Contact details	**Email: Claire.horrocks@rothamsted.ac.uk** **Phone(s): 01837 883530**
Role/job title	Post-Doctoral Research Scientist
Focus of work *Please summarise in not more than 300 words the focus of your work – with particular reference to gaining a better understanding of the nature of soil under pasture and monitoring its health*	I have an interest in soil health and its relation to ecosystem service provision, including soil carbon storage, above and below ground diversity, improved structure and nutrient cycling efficiency. My current project involves assessing the suitability of soil health indicators for use by farmers in temperate (UK) and tropical (Colombia and Kenya) soils. I am focussing on grassland soils and hope to identify how different forage varieties affect soil health as measured by the multiple proxies I am trialling. Previously I worked on a project assessing the effect on soil health of species-rich grassland creation under agri-environment schemes.

Name	Ian Robertson
Name of organisation	Sustainable Soil Management
Contact details	**Email:ian@soiladvice.com** **Phone(s):07970 286420**
Role/job title	MD
Focus of work *Please summarise in not more than 300 words the focus of your work – with particular reference to gaining a better understanding of the nature of soil under pasture and monitoring its health*	Primary focus is detailed Cation soil testing. Taking this information and then implementing practical nutrient management plans to increase biodiversity and productivity not at the expense of soil health. This covers the 3 pillars of healthy soils, Physical, Chemical and biological. We understand how these interact and then we help producers understand how best to work with each pillar. We work across all production systems and crop and livestock types.
Please add any other comments that you think will be helpful.	Soils are very complex and there is no silver bullet solution. When thinking/working with soils you must always think of how your actions will affect the Physical, chemical and biological aspects of the soil. The biggest asset on your farm is **not** your soil, it's **you** and how you decide to manage your soil.

Name	Dr Jackie Stroud
Name of organisation	Worm group, Rothamsted Research
Contact details	**Email: Jacqueline.stroud@rothamsted.ac.uk** **Phone(s): 01582 938244**
Role/job title	NERC Soil security fellow (soil scientist)
Focus of work *Please summarise in not more than 300 words the focus of your work – with particular reference to gaining a better understanding of the nature of soil under pasture and monitoring its health*	Deep burrowing earthworm populations. The presence of earthworms in soils improves crop productivity and soil management practices impact on their populations e.g. good link between clover improving earthworm populations which I'm currently testing.

Name	**Dr Jeanette Whitaker**
Name of organisation	Centre for Ecology & Hydrology
Contact details	**Email: jhart@ceh.ac.uk** **Phone(s): 01524 595888**
Role/job title	Senior Research Scientist
Focus of work *Please summarise in not more than 300 words the focus of your work – with particular reference to gaining a better understanding of the nature of soil under pasture and monitoring its health*	My research is focused on the effects of land management and climate change on the cycling of carbon by plants, microbes and soil. Maintaining and increasing soil carbon stocks is critical for mitigating climate change. In addition, soils with greater soil carbon and organic matter content are more resilient to flood and drought, require lower nutrient inputs and can be more productive. Understanding how different grassland management practices affect soil health will therefore provide evidence to develop best practice for grasslands.

Name	**Jennifer Dungait**
Name of organisation	Rothamsted Research
Contact details	**Email: jennifer.dungait@rothamsted.ac.uk** **Phone(s): 01837 883534**
Role/job title	Principal Research Scientist
Focus of work *Please summarise in not more than 300 words the focus of your work – with particular reference to gaining a better understanding of the nature of soil under pasture and monitoring its health*	Jennifer's key research objective is to provide evidence for the value of soil organic matter as natural capital in global agricultural systems. Jennifer's research aims to develop a fully quantitative understanding of soil organic matter dynamics and its fundamental relationship with ecosystem service delivery by agricultural soils, and ultimately to optimise the management of food production systems for improved farmer livelihoods. Jennifer's research has three major and inter-related themes: 1. climate change mitigation through measurable increases in soil organic matter ('soil carbon sequestration'); 2. avoiding and remediating soil degradation by optimising soil organic matter management in agricultural land; and, 3. improving the livelihoods of farmers by realising the economic benefits of soil health, which is driven by soil organic matter. Jennifer's technical expertise is in soil biogeochemistry, with particular skills in compound-specific stable isotope and biomarker applications that quantify organic soil matter dynamics at scales from the rhizosphere to the field-scale, by distinguishing organic molecules from specific sources (e.g. plants versus animals versus microorganisms).
Please add any other comments that you think will be helpful.	Growing plants are the best tools to increase soil organic matter.

Name	Jenny Phelps
Name of organisation	Farming and Wildlife Advisory Group
Contact details	**Email: jenny.phelps@fwagsw.org.uk** **Phone(s):07876687272**
Role/job title	
Focus of work *Please summarise in not more than 300 words the focus of your work – with particular reference to gaining a better understanding of the nature of soil under pasture and monitoring its health*	FWAG represents farmers and land managers that care about the environment. FWAG supports its members and partners by helping to enable sustainable land management through advice and support. This is done primarily by implementing the Rural Development Programme for England, Payments for Ecosystem Services; Natural Flood Management Projects. FWAG works to enable farmers and communities to build resilience by working together using the integrated local delivery approach (www.ccri.ac.uk/ild) to deliver multiple public goods though sustainable land management.
Please add any other comments that you think will be helpful.	The event could have focused a bit more on how farmers could build their organic matter through promoting Countryside Stewardship that have options designed specifically for soil health.

Name	John Kay
Name of organisation	Dr John Kay Agriculture and Environment
Contact details	**Email: agri.environment@rocketmail.com** **Phone(s):**
Role/job title	Farmed Environment and Resources Adviser
Focus of work *Please summarise in not more than 300 words the focus of your work – with particular reference to gaining a better understanding of the nature of soil under pasture and monitoring its health*	Control of pollution from farmed livestock with particular reference to soil and water protection by reduction of wastes at source. Assessment of livestock housing needs, farm infrastructure asset management, cost-effective compliance with agricultural regulation, nitrate vulnerable zone (NVZ) compliance, risk mapping, soil protection and nutrient management, landspreading of biowastes and composts.

Name	**Luppo Diepenbroek**
Name of organisation	Straight Line Nutrition Ltd, TVOG (+B), Soil Gener8ion Ltd www.improvingfarming.uk
Contact details	**Email:** luppod@gmail.com **Phone(s):** 07970 163 228
Role/job title	Consultant/Facilitator to Group of Organic Farmers
Focus of work *Please summarise in not more than 300 words the focus of your work – with particular reference to gaining a better understanding of the nature of soil under pasture and monitoring its health*	The aim of Tamar Valley Organic Group (+ Biology), 10 years this year, is to increase SOIL FERTLITY. In Order for this to be recognised we came to the conclusion after 5 years, that it is not Nitrogen driving the Fertility system in an Organic System but Carbon. To recognise this the group founded a subsidiary Soil Gener8ion Ltd, set up to reward farmers for sequestrating Carbon, as farmers sought to increase Soil Organic Matter. In 2015 we had obtained funding for independent testing of our Hypothesis through Rothamsted Research, working with Prof Jennifer Dungait to prove that different Management Practices lead to different Soil Organic Matter content. This again made us realise that Organic Tillage Rotation, which had been practiced to increase fertility was incorrect, and the land should stay in Pasture as long as feasible, building Soil Organic Matter in the process, especially when initially coming out of Organic 4 -5 year Tillage Rotations. On top of this increasing Biodiversity of the Pasture and type of Grazing Management also influenced positively Soil Organic Matter Content. Most important items to consider are: 1. Keeping soil Covered at ALL times 2. Increase Rooting Depths, Biodiversity. 3. Introduce Biology into system. 4. Rest period between Grazing's 5. Keeping Soil alive at all times 6. Ultimately Increasing Long Term Soil Carbon to retain nutrients and help Short Term Soil Carbon to cycle quicker.
Please add any other comments that you think will be helpful.	 There is no Substitution for keeping on Learning. Abdicating this process and relying on external Products Inputs as a substitute can be costly.

Name	**Dr Martin Wood**
Name of organisation	Earthcare Technical Ltd
Contact details	**Email:** martin@earthcaretechnical.co.uk **Phone(s):** 07889106754
Role/job title	Director
Focus of work *Please summarise in not more than 300 words the focus of your work – with particular reference to gaining a better understanding of the nature of soil under pasture and monitoring its health*	Having spent over 25 years researching and teaching soil biology I am now interested in simple tools that can be used to support farmers in understanding and managing the health of their soil. My current focus is on the use of soil respiration as a simple, quantifiable and meaningful indicator of soil health. One example of a commercially available test for soil CO_2 production is the Solvita soil test. Recently, with my colleague Audrey Litterick, I have written a short review paper for Soil Use and Management titled "Soil Health - What Should the Doctor Order?" due out later in 2017.

Name	**Niels Corfield**
Name of organisation	Niels Corfield Farm Advisors
Contact details	**Email: info@nielscorfield.com** **Phone(s): 07858 300668**
Role/job title	Advisor
Focus of work *Please summarise in not more than 300 words the focus of your work – with particular reference to gaining a better understanding of the nature of soil under pasture and monitoring its health*	Farm advisor. Delivering whole farm planning advice and services. Including: agroforestry, soils and grazing management. Delivering through Regenag, holistic management and permaculture frameworks. Focussing on soil-, plant- and animal health. Setting-up monitoring and testing systems on-farm. Designing regenerative farms. Providing training and education to the ag sector.
Please add any other comments that you think will be helpful.	Main limitations are around recording and presenting data gathered on farm, and aggregated with lab tests

Name	**Paul Muto**
Name of organisation	Natural England
Contact details	**Email:** paul.muto@naturalengland.org.uk **Phone(s):** 02080265420 07508948288
Role/job title	Senior Specialist – Grassland Agronomy
Focus of work *Please summarise in not more than 300 words the focus of your work – with particular reference to gaining a better understanding of the nature of soil under pasture and monitoring its health*	My role is to support the delivery of grassland options within Natural England's agri-environment schemes. I provide advice based on the latest evidence to guide how current schemes are managed and how future schemes will be developed. My particular focus at the moment is on monitoring the success of our legume and herb-rich ley option. This is an important option for achieving biodiversity outcomes on our more productive agricultural soils while helping to diversify arable rotations. I also have an interest in the harvest of seed from species-rich meadows for the purpose of facilitating future meadow restoration and creation. My other area of focus is on grazing management, particularly with the aim of optimising livestock performance which achieving secondary benefits from grassland such as provision for pollinators, conserving soil and water and increasing the botanical diversity of existing grasslands.
Please add any other comments that you think will be helpful.	There is some difficulty in applying diversity measures to assess soil health in low pH situations. Very acid soils may have unique and fairly diverse grassland communities, but I would not consider the soil to be "healthy". It is very difficult to achieve good soil structure in low pH soils. Soil carbon may also be particularly high in these soils, but it can be due to a decrease in the activity of the decomposer community. For this reason, soil organic matter may not be the best measure of soil health.

Name	**Rob Havard**
Name of organisation	Natural England – Havard & Co Organic Farms
Contact details	**Email: rob@phepsonfarm.co.uk** **Phone(s): 07973771832**
Role/job title	Farmer/Lead Adviser
Focus of work *Please summarise in not more than 300 words the focus of your work – with particular reference to gaining a better understanding of the nature of soil under pasture and monitoring its health*	Organic pasture farmer Natural England Lead adviser

Name	**Peter Brown**
Name of organisation	Biodynamic Association
Contact details	**Email: peterbrown@biodynamic.org.uk** **Phone(s): 07803932283**
Role/job title	Biodynamic Association Agricultural Advisor
Focus of work *Please summarise in not more than 300 words the focus of your work – with particular reference to gaining a better understanding of the nature of soil under pasture and monitoring its health*	As a biodynamic farmer for 40 years I am very excited and encouraged to see, just in the last couple of years, such a growing number of people becoming aware that true fertility is about having high organic matter soils, with structure, created by an abundant soil life, created by diversified plants growing by the power of the sun. Biodynamic farming is about working with this holistic reality, which includes the livestock and what they bring and even the social reality of communities of people, be they on the farm or circles of customers. I am particularly interested in what diversified plant species cover crops, as well as pastures, can do for soil fertility when combined with mob grazing, minimum tillage, compost making and the biodynamic preparations and principles. I have experience in using minimum tillage and a rotovator set up to work in cover crops or a pasture, but literally only a couple of inches deep. In my view, it is by far the best method compared to using chemicals or shallow ploughing etc. I have been a hands-on farmer all my life, setting up Tablehurst Farm as one of the first CSA's (Community Supported Agriculture) in the country, with 600 people owning the farm business. Until recently I was the Director of the Biodynamic Association. I have experience with livestock and compost making and strongly believe in the principles of pasture fed as well as the principles behind biodynamic farming. Biodynamic farming is practiced world-wide and shows that it is not necessary to bring in fertility from outside the farm in the form of fertilisers or animal feed.

Name	**Richard Spyvee**
Name of organisation	Gloucestershire Wildlife Trust
Contact details	**Email:** Richard.spyvee@gloucestershirewildlifetrust.co.uk **Phone(s): 07774725342**
Role/job title	Living Landscape Manager
Focus of work *Please summarise in not more than 300 words the focus of your work – with particular reference to gaining a better understanding of the nature of soil under pasture and monitoring its health*	**What is a Living Landscape?** We are working to transform the environment we live in: **restoring, recreating and reconnecting wildlife-rich spaces** in rural and urban areas by working in partnership with local communities, landowners, schools and businesses. We want wildlife to thrive, to disperse and re-colonise our landscape so future generations can encounter, experience and enjoy our natural heritage, and so that we can too. Our nature reserves provide great protection for wildlife, however species find themselves enclosed in these 'islands', surrounded by land, such as intensive farmland, which they are unable to occupy or expand into. Nature reserves on their own are not large enough to support stable and healthy populations over long periods of time. To address this, we have adopted the Living Landscape approach – a long-term vision to conserving nature. **A living landscape is** not just a big nature reserve, but a mosaic of reserves, farmland, amenity land and built-up areas managed in such a way that wildlife and people can share it and which continues to function ecologically.
Please add any other comments that you think will be helpful.	Needs to be repeatable. No comparing to other holdings just change on theirs.

Name	**Simon Parfey**
Name of organisation	SoilBioLab
Contact details	**Email: simon@soilbiolab.co.uk** **Phone(s): 07764 680959**
Role/job title	Director
Focus of work *Please summarise in not more than 300 words the focus of your work – with particular reference to gaining a better understanding of the nature of soil under pasture and monitoring its health*	The full Soil Food Web analysis requires a series of extractions from a sample of soil. This involves taking portions of soil from a sample to make a series of subsamples. From these, separate cultures are made and light sensitive dyes are used to stain the microorganisms so that they are more readily countable in their particular state. The laboratory staff make an assessment by direct observation – counting the microorganisms using a light microscope. The counts are considered in the context of the moisture content of soil, season and plant type that the sample relates to, we are able to provide further understanding and guidance of not just the dynamics within the biomass (including total and active populations of bacteria and fungi) but also the relationship and ratios between the different organism types. In soil under pasture, it is expected that microbial conditions are indicative of a balanced community (in terms of bacterial and fungal population) and in general, the more established the pasture, the greater the range and number of organisms present.
Please add any other comments that you think will be helpful.	There is a limited number of methods for farmers to measure biomass at field level, but basic microscopy is an option, to develop a skill set that enables qualitative assessments. A benchmark of the SFW (total and active bacteria and fungi) against some of the alternative systems available may indicate a positive way in which some of these tools can be applied.

Name	**Dr William Stiles**
Name of organisation	IBERS, Aberystwyth University
Contact details	**Email: wvs@aber.ac.uk** **Phone(s): 01970 823039**
Role/job title	Knowledge Exchange Fellow
Focus of work *Please summarise in not more than 300 words the focus of your work – with particular reference to gaining a better understanding of the nature of soil under pasture and monitoring its health*	As KE Fellow my role centres around providing current and applicable scientific knowledge to the agricultural industry in Wales through Farming Connect which is a high profile, integrated project supplying focussed training, support and advice, delivered through a pan-Wales programme of knowledge transfer activities, specialist advice and support for innovation. Farming Connect is funded through the Rural Development Plan (RDP) 2014 - 2020, which is funded by the European Agricultural Fund for Rural Development and the Welsh Government. In terms of research, my areas of interest are ecosystems and their function, particularly in terms of ecosystem service provision in the agroecosystem; chemical/nutrient cycling in the environment and how this relates to soil carbon, particularly with regard to nutrient pollution from nitrogen deposition and how this influences ecosystem function, both in natural and agricultural systems.

Name	**Becky Willson**
Name of organisation	Farm Carbon Cutting Toolkit / Duchy College Rural Business School
Contact details	**Email: becky.willson@duchy.ac.uk** **Phone(s): 01579 372376 / 07875 356611**
Role/job title	Project co-ordinator (FCCT), Technical specialist resource management (Duchy)
Focus of work *Please summarise in not more than 300 words the focus of your work – with particular reference to gaining a better understanding of the nature of soil under pasture and monitoring its health*	FCCT – works on encouraging and supporting farmers and growers to reduce greenhouse gas emissions, increase farm energy resilience and improve their farm business in the future. Our soil work looks specifically at soil carbon, and we aim to demonstrate the benefits of building soil carbon and highlight practical methods to do so. We build a network of farmers who are interested in soil carbon and building resilience soils and facilitate knowledge and ideas sharing and run events / discussions to share information. Carbon calculator that includes the carbon sequestration element within the calculator. Soil farmer of the year competition to showcase farmers who are passionate about soil management and building soil health and carbon. Demo farm project looking at what farmers can practically do on-farm to reduce emissions and what the impact is on the business / practicalities. About to start a new crowdfunded carbon farming project working with 10 trial farms across the UK to monitor carbon footprint, and provide the much need data on what practices make a difference to soil organic matter levels. Duchy RBS – translation of research into farmer friendly material that allows for uptake of new practices, including the Farm Crap app, the SWARM Hub website, and other publications. Current Nuffield scholar (2016) looking at Communicating Carbon Reduction schemes to farmers, busting preconceptions, driving efficiency and profit.

Name	**Prof. Chris Stoate**
Name of organisation	GWCT Allerton Project
Contact details	**Email: cstoate@gwct.org.uk** **Phone(s): 0116 259 7609**
Role/job title	Allerton Project Head of Research
Focus of work *Please summarise in not more than 300 words the focus of your work – with particular reference to gaining a better understanding of the nature of soil under pasture and monitoring its health*	As well as having a small mixed farm of my own, I coordinate agri-environmental research on and around the Allerton Project research and demonstration farm at Loddington, Leicestershire. For well over a decade, this research has focused on the relationship between land use and water, and specifically soil management, from experimental plot to landscape scale. Although most of this has been on arable land, many of the principles apply equally to grassland, and there is an increasing focus on grassland in our research. Throughout, our approach is to involve farmers in setting the research agenda and to combine economic objectives for farm businesses with environmental benefits. Our most recent projects include the Defra funded Sustainable Intensification research Platform (www.siplatform.org.uk), the EU funded 'SoilCare' project (www.soilcare-project.eu), the AHDB funded 'Soil Biology and Soil Health' project, and research council funded soilquality.org project. All relate to both arable and grassland systems.