HEALTHY SOILS FOR A GREEN RECOVERY

The Soil Sentinel

The Soil Sentinel JULY 2023

INSIDE THIS ISSUE:

The EU Soil Monitoring and Resilience Directive

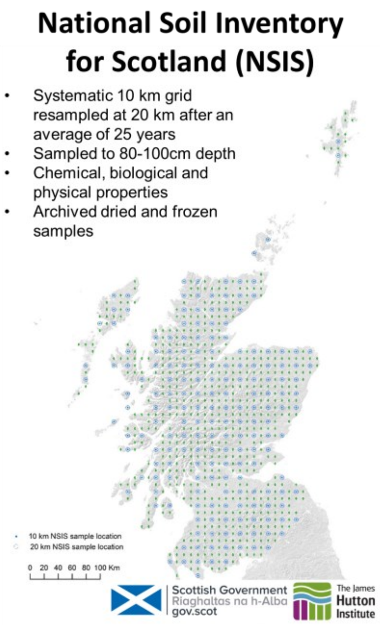
Kenneth Loades, Nikki Baggaley (The James Hutton Institute), and Jackie Potts (BioSS)

The 5th July 2023 saw the EU proposing the Soil Monitoring Law aiming to 'address key soil threats in the EU, such as erosion, floods and landslides, loss of soil organic matter, salinisation, contamination, compaction, sealing, as well as loss of soil biodiversity'. This has been a long time coming, starting in November 2021 where the commission adopted the EU Soil Strategy for 2030 with the aim of achieving healthy soils by 2050, highlighting the need for Scotland to develop its own soil monitoring network. Some of the work in developing this is being done within the Healthy Soils for a Green Recovery project with links to other areas in the wider strategic research programme.

With the need for effective soil monitoring becoming more and more critical what data do we have already that could help establish the baseline?

Recently we have begun identifying existing datasets offering the potential for assessing change. One significant component of the Soil Monitoring Law is the inclusion of data related to subsoils with many datasets excluding subsoil due to a focus on top soils (for example the Land Use and Coverage Area Frame Survey (LUCAS) . Two key Scottish national data sets, that include both topsoil and subsoil, are the National Soils Inventory for Scotland (NSIS) and BioSOIL, with a further 47 offering some, but not all, parameters and soil horizons and therefore varying degrees of applicability for baselining a soil monitoring framework.

NSIS was initially sampled from 1978-1988 (NSIS I) with 25% resampled from 2007-2009 (NSIS II) with the latter sampling including some additional measures. The benefit of NSIS over some of the other 47 data



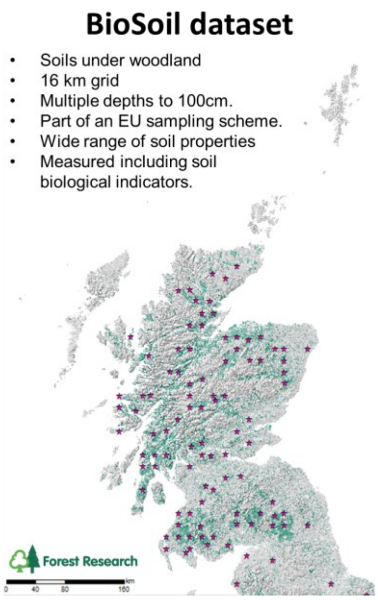
sets is the inclusion of multiple land use types with sampling using established protocols, BioSOIL surveying however was only conducted in woodland. This change in land use types is reflected in the sample numbers, 721 and 183 sites within the NSIS I and II, and 69 for BioSOIL. The Soil Monitoring Law has recommended a resampling time of 5 years with a sampling resolution ensuring that data 'should provide a level of uncertainty of soil health measurement of maximum 5% at national level'.

So, what is being defined as a 'healthy soil'?

This is where some of the challenges begin, key to assessing the health of a soil relies on understanding what measures/indicators should be taken and the thresholds beyond which a soil may be deemed unhealthy. Some measures have had thresholds defined within the law (such as subsoil bulk density required to be less than 1.8 g/cm3 in lighter, sandy soil, and less than 1.47 g/cm^3 in clay soils, thresholds for soil types in between have also been defined), others, such as water holding capacity, have been left for member states to define. It is in these areas that we can potentially utilise existing datasets to set thresholds, once we have these set we can understand where we need more information and data for future monitoring towards achieving healthy soils by 2050.

As this work within the Healthy Soils for a Green Recovery, and wider strategic programme, develops we will keep you updated.

We would welcome your thoughts and questions on this topic also so please don't hesitate to get in touch through emailing healthy-soils@sefari.scot or contacting either Nikki Baggaley (nikki.baggaley@hutton.ac.uk) or Kenneth Loades (kenneth.loades@hutton.ac.uk) directly.



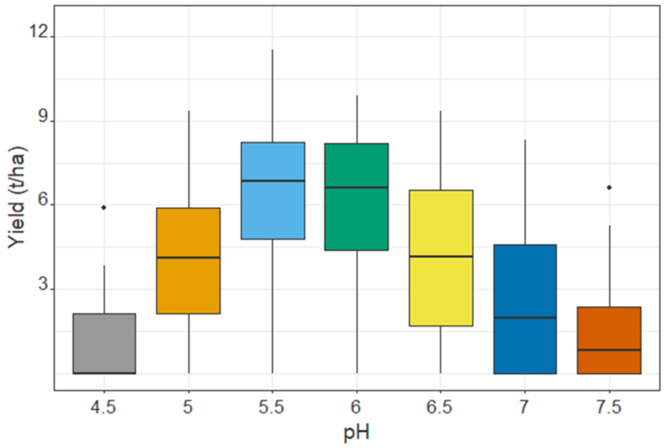
Scottish Government Riaghaltas na h-Alba gov.scot | RESAS Rural & Environmental Science and Analytical Services | SEFARI | SRUC | The James Hutton Institute

60 years of yield data from the pH trial

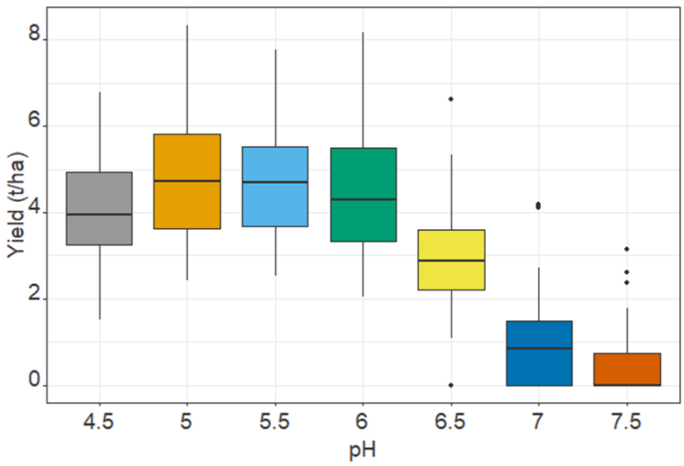
Kairsty Topp, Christine Watson, and Robin Walker (SRUC)

Back in 1961, at the North of Scotland College of Agriculture (now SRUC, Craibstone), a trial was established to demonstrate to the local farming community the effect of pH on crop yields, and the importance of liming to maximise yield potential and nutrient use efficiency.

Winter what yields in response to soil pH



Spring oat yields in response to soil pH



The soil is a sandy loam (Countesswell Association) with an organic matter content (loss on ignition) of 9.3% at pH 6. The trial investigated the impact of different pH levels (on a gradient from 4.5 to 7.5 in 0.5 increments) on the crop performance of an 8-course ley-arable rotation (3-year grass-clover ley, winter wheat, potatoes, spring barley, swede and spring oats which was undersown with the grass-clover ley). Each crop is present in each year, and the pH is adjusted on an annual basis. We have reliable yield data from 1969, and by that time the soils had settled at or close to the target pH. Currently, we have focused on exploring the effect of the pH on the yield of the oats and the wheat over the last 50 years.

Due to the layout of the trial, the impact of the pH gradient on the yields was observable in the field as illustrated for the spring oats crop. All of the crops tended to maximise their yield between pHs 5.5 and 6.0. However, the yield response of the crops varies at the extreme pHs. This is illustrated for winter wheat and spring oats, with the spring oats being more tolerant of the low pHs than winter wheat. The winter wheat yields at pH 4.5 and 5 were on average 15% and 64% of the yield at pH 6, and the comparable figures for spring oats were 90% and 105%. In contrast, at pH 7 and pH 7.5 the winter wheat crop maintained its yield better than the spring oats. Although the general trend in the yields with pH does not change over the 50 years of the trial, the spring oats have become more tolerant to higher pH in the last 24 years of the trial, and the yields at pH 4.5-6.0 were higher for the last 8-year rotation cycle. In the case of the winter wheat, the yield at the higher pHs have become less variable in the last 24 years of the trial. Work is currently focusing on quantifying the response of the yields to pH, and identifying how the weather is modifying the response.

The trial was moved to a new location in 2021. This required moving the topsoil to the new location where the pHs have been randomised, and for every plot that was moved there is a "twin" plot of soil which is being amended to the same pH. Two of the 8-beds are now sown with a permanent crop, perennial ryegrass and a multi-functional ley. A 5-course arable rotation and a 7-course ley-arable rotation are being established in the remaining 6 beds. Thus 3-courses of each rotation will be present in each year. The rotations have been designed so that there are common crops in as many years as possible. The new rotations have been designed to complement the work on the Tulloch organic rotations, which are also located Craibstone.

For further information please contact Kairsty Topp (kairsty.topp@sruc.ac.uk)

Automatic Sensors – Part of a Digital Farm

Paul Hargreaves and Rosie Barraclough (SRUC)

Did you know that the Cumbria and the Southwest of Scotland is the second largest milk production area in the UK producing around 1.9 billion litres of milk each year? The region includes around 52 dairy manufacturing businesses, adding value to milk produced from 1,300 farms. The Digital Dairy Chain is a collaboration between the UK and Scottish Governments as part of an UK Research and Innovation (UKRI) funded project to put the region of Cumbria and Southwest Scotland at the forefront of innovative, sustainable and digitally connected dairy production, processing and manufacturing. This is a wide-ranging initiative with a £21m budget that aims to develop digital connectivity to help move towards net-zero, facilitate research and development, support business growth and attract skills and talent.

The idea of a digital twin of the dairy at SRUC Barony campus, just north of Dumfries, is a large part of the initiative. A digital twin is a virtual simulation of a physical object or process, in this case it would be the farm covering the livestock, machinery and crops (including the grassland) that is informed by real data being collected as part of the physical 'twin'. This involves being able to collect information as close to real time as possible.

The soils on the farm are not being excluded from this process and in the last few months sets of sensors have been buried in fields at different depths (10cm and 20cm). These sensors are measuring soil moisture, temperature and electrical conductivity every 10 minutes using a LoRaWAN (Long Range Wide Area Network) gateway to capture the data and send it off to the cloud and the Internet of Things.

The aim is to initially test a number of the sensors in close proximity (20 in one field) at two different depths, to investigate the spatial variation along with the temporal variation. As an automatic weather station has also been installed it will be interesting to see the amount of change effected by the weather as well as other field management.

Other aims of the work are to provide useful data to the farmer or farm manager that is quick and easy to understand. Especially, if this data can be related to thresholds for activity, therefore if the soil moisture probes in a field provide data that it is too wet for tractor movements then the activity could be delayed. If there was a strong need for the activity to take place at that time i.e. contractor availability, then an alert can flag up to monitor the soil structure afterwards to assess any structural damage that may lead to a reduction in yield. Ultimately, if the soil sensors can be linked to a predictive element such as weather forecasts more accurate field use would allow greater flexibility, in for example, the application of slurry or grazing without damaging the soil structure.

Automatic sensors can provide vast amounts of data but without some understanding of when changes in the field may cause problems in an easy to comprehend format that is quick the data collection is not going to part of a farm's future investment.

For further information please contact Paul Hargreaves (paul.hargreaves@sruc.ac.uk)

Carbon sequestration in agricultural soils; can it solve the climate change emergency?

Robert Rees, Paul Hargreaves, and Stephanie Jones (SRUC)

Scottish soils are rich in soil carbon. Recent estimates suggest that they contain around 3000 Mt making them one of the richest stores of soil carbon anywhere in Europe. Soil carbon provides a critical role in supporting good soil quality as it contributes to soil fertility, nutrient storage, maintenance of biodiversity and improvement in the soil physical environment. However, there is particular interest in soil carbon storage at the moment given its potential contribution towards climate change mitigation. Soil carbon accumulates over centuries and millennia as a consequence of the uptake of atmospheric carbon dioxide by plants. This plant material is ultimately deposited in the soils or consumed by livestock and returned in the form of animal manures. In circumstances where this addition of organic matter exceeds the rate of decay, then organic carbon will accumulate in the soil in a process that we describe as carbon sequestration. Scotland's climate is particularly conducive to circumstances where this accumulation takes place, since cool and wet conditions tend to retard organic matter decomposition.

There is a renewed interest in the opportunities offered by carbon sequestration given our current concerns about the climate emergency. The Scottish Government has established ambitious targets to reach net zero greenhouse gas emissions by 2045 with soils likely to play a key role in achieving this. The reasoning here is that in order to get to net zero, any residual emissions of greenhouse gases will need to be offset by carbon removals. Soil carbon sequestration is likely to be a critical component of this offsetting approach. It is anticipated that by 2045 there will still be significant greenhouse gas emissions from certain sectors of the economy, with aviation and agriculture still contributing to emissions. These will need to be offset by various greenhouse gas removal mechanisms. These include soil carbon sequestration, biomass energy carbon capture and storage, biochar, mineral weathering, and direct air capture which come with different costs and potential barriers. Many of these approaches require further research and the magnitude of carbon removals that they can achieve remains uncertain. Carbon sequestration in soils is an established process that is unlikely to be associated with any negative impacts. It is anticipated that wetland restoration and afforestation will play a particularly important role in increasing soil carbon stocks within the Scottish landscape. However, the question remains what the potential of agricultural soils is, which cover much of the landscape, to store more carbon.

Because Scottish soils are already carbon rich, it is possible that there may be limited potential for them to increase their carbon storage, and indeed where we report greenhouse gas emissions and removals through the U.K.'s national inventory, there is an assumption that croplands and grasslands are in a steady state in which carbon is neither being gained or lost. This is partly because of a lack of evidence to determine if any changes are currently taking place in the carbon stocks of agricultural soils, and partly because of the difficulty of making such measurements. Scotland maintains a good record of soils data in the form of the national soil archive, and this has been used to judge whether or not the carbon stock of agricultural soils is changing. In the most recent assessment, there was no significant change in the carbon stock of croplands or grasslands in the period between 1978 and 2009. However, this assessment was based on a relatively small number of point samples and doesn't necessarily indicate that all sites have such stable carbon stocks. In order to understand how individual sites are responding to current climatic and management conditions, a detailed inventory of carbon stocks and changes to the stocks is being undertaken as a part of the Scottish Governments Strategic Research Programme 2021 to 2027. In this programme SRUC is working with Agricarbon to sample agricultural soils in our research centres across Scotland (Crichton, Bush, Kirkton, Elmwood, and Aberdeen). At each location a detailed inventory involving the collection of 100 soil cores to a depth of 60 cm is being undertaken. Samples will be analysed for their carbon concentrations and detailed inventory of stocks will be reported. The measurement process will be repeated in 2027 allowing changes in the soil carbon stocks resulting from carbon sequestration to be estimated.

The grassland site on the Bush estate has been sampled on two previous occasions providing the opportunity to assess any changes in soil carbon stock that may have occurred. Previous measurements have indicated that little change is occurring in the carbon stock at the site, however, since those measurements were made the grassland has been ploughed and reseeded and so the new measurements will be able to assess the impact of this management on current carbon stocks.

The overall findings of this research will be published in 2027 and provide us with a clearer idea of the sequestration potential of agricultural soils and guidance as to the best management options that could be used to achieve this.

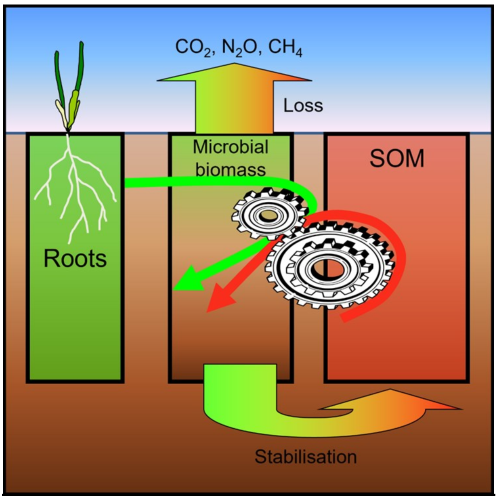
References available on request and for further information please contact Bob Rees (bob.rees@sruc.ac.uk)

Harnessing benefits of natural soil biogeochemical processes for agricultural production

Eric Paterson (The James Hutton Institute)

Given sufficient light and water, plant productivity in agricultural systems is primarily dependent on provision of nutrients from soil to support growth and yields. Throughout the second half of the 20th century, increasing grain yields have largely been supported by intensification of fertiliser inputs and crop breeding for varieties that are efficient in capturing these nutrient inputs. Currently, the demand for food to support an increasing global population, coupled with changes in diet and competing demands on land use, has placed new pressures on agricultural production. However, in many parts of the world yields have stagnated as a consequence of soil degradation and climate pressures. This food security crisis is further heightened by the current rapid increases in fertiliser prices linked to the volatile energy market, and the drive to reduce greenhouse gas (GHG) emissions and water pollution associated with fertiliser use. Particularly for nitrogen (N) fertiliser, these GHG emissions are associated with both in-field processes (denitrification leading to nitrous oxide loss from soil) and the energy-intensive Haber-Bosch manufacturing process (2.7 tonne CO_2 emissions per tonne ammonium produced). In this context there is a strong demand to establish management practices that can maintain, or increase, agricultural productivity, while reducing use of mineral fertilisers.

In natural plant communities the supply of N and other nutrients is mediated by microbial communities that transform organic matter, releasing nutrients into mineral forms that can be acquired by roots. Indeed, even in intensively fertilised arable soil, typically more than 50% of plant-acquired N is from soil biogeochemical cycling, as opposed to from the fertiliser applied. Therefore, soil organic matter (SOM) can be considered to represent a store of nutrients that supports plant productivity, both in managed and semi-natural ecosystems. This stock of SOM also has multiple additional benefits for soil health: maintenance of soil structure that increases water holding capacity and resistance to erosion; supports abundance and diversity of soil biota that mediate nutrient cycling; and an increasing SOM stock represents net removal of CO_2 from the atmosphere. Consequently, the SOM stock can be considered to be analogous to a bank account that is drawn on to support soil functions, including nutrient provision for crop productivity, and potentially can be built up through management practices promoting input and retention of organic C in soil.



Coupling of plant C-inputs to soil with microbial activity mobilising nutrients from soil organic matter.

Given this view of SOM as a dynamic store of nutrients, it is persuasive that it could be utilised as a (partial) replacement for mineral fertiliser applications. However, this represents a substantial contrast, relative to intensive practices, and as such requires development of specific management practices to be effective.

(i) Maintaining and increasing SOM stocks: a central dilemma is that direct physical, chemical and GHG-balance benefits increase with increasing SOM stocks, but benefits for plant production are intrinsically linked to the microbial decomposition of SOM that releases nutrients. Therefore, to be a long-term strategy to reduce fertiliser use, replenishment of SOM stocks must be a focus of management practices, i.e., the draw-down on the SOM bank account to support nutrient provision has to be at least balanced by new organic inputs. In semi-natural ecosystems, stocks of SOM are maintained by inputs of dead litter and exudation of organic compounds from roots, with the C-balance of soils representing an equilibrium between the rates of plant-derived input and their subsequent decomposition. However, in crop production systems the harvested biomass is removed, reducing potential for replenishment of SOM. From a carbon perspective, lost inputs to soil could potentially be compensated for by selection of cultivars that deposit more C to soil (i.e., supported by increased CO_2 fixation from the atmosphere), or more of that C to greater depth (where rates of decomposition are less). However, for N removed in harvested biomass, this has to be replaced by new inputs. Therefore, inclusion of N-fixing legumes in rotations or cover crops is a useful strategy, as is application of manures and slurry. Alternative organic inputs, such as composts from green waste, residues from anaerobic digestion or other industrial co-products represent N sources that are also consistent with circular economy principles, reducing overall emissions.

(ii) Crop breeding and cultivar selection: As discussed, past increases in crop productivity have been partly supported by the selection of cultivars adapted to the capture of mineral nutrients from applied fertilisers and prioritised allocation to grain. This requires specific phenotypic and physiological characteristics that may not be ideally suited to acquisition of nutrients if these are held within organic matter. For example, it is now recognised that plant species and genotypes select for specific microbial communities (microbiomes), largely as a consequence of differential quantity and quality of root exudates. Research within the RESAS Strategic Research Programme and through BBSRC funding has demonstrated that these plant-specific (barley, maize and grasses) effects on soil microbiome composition translate to significant impacts on soil nutrient cycling, C-storage and GHG fluxes. Presumably this corresponds to the type of plant-microbe interaction that supports the competitive ability of plants in semi-natural environments, but may have been lost from modern elite cultivars, where intensive fertilisation practice would negate the benefit of such coupling of plants with their associated microbiomes. This raises the attractive possibility of breeding crops to optimise their use of organic nutrient sources, perhaps even tailored to specific forms of inputs, through plant selection of microbial communities efficient in their transformation to forms accessible to plants.

For further information please contact Eric Paterson (eric.paterson@hutton.ac.uk)

Peatland Erosion and Carbon Loss from Scottish Blanket Bogs

Tom Parker (The James Hutton Institute)

Scotland's peatlands are losing carbon at alarming rates. Eroding blanket bogs are of particular concern because of high greenhouse gas (GHG) emissions as a consequence of the drainage effect of the erosion gully complexes, and direct loss of peat into water systems, causing water quality issues and high GHG emissions further downstream. You can see evidence of this in Scotland's glens after a heavy rainfall when the water is stained dark brown from the material that has run-off local eroding peatlands.

Blanket bogs with erosion features cover an estimated 273,000 ha of Scotland and are, per ha, one of the highest emitters of GHGs to the atmosphere. They are therefore a top priority for restoration - including reprofiling, revegetating and blocking of erosion gullies - processes designed to reduce peat sediment run off and reduce in situ GHG emissions. While we are rapidly gaining a better understanding of GHG fluxes from peatlands within the SCO2FLUX eddy covariance flux tower network, the magnitude of loss of peat carbon through erosion is far less understood. This is the focus of WP4 of the RESAS-funded CentrePeat project.

Researchers in the CentrePeat project are taking a two-pronged approach to the problem. In our first year, we have worked with peat erosion experts from across the UK to review the academic literature and other reports to establish a best estimate for erosion loss rates. We also reviewed what happens to peat sediment once it leaves the erosion gully. Looking forward, we are setting up a series of intensive long-term studies to establish annual loss rates at two 'testbed' sites where peatland restoration has occurred but where adjacent areas that have remained unrestored- uplands of Balmoral Estate and Glensaugh Estate in Aberdeenshire. Here, we are deploying several techniques, from the basic (but still fundamentally important) like manually measuring peat loss from gullies, to cutting-edge organic chemistry techniques to work out which chemical constituents of peat carbon are being lost and what the causes are.

Once we have established the loss rate of peat by erosion, we will have a far better idea of the total loss of carbon from eroding blanket bogs and therefore, a much-improved idea of the emissions savings from peatland restoration. This is critical information because it will not only help inform UK and Scottish GHG inventories but also help inform landowners and stakeholders as to the carbon savings that can be gained from restoration.

For further information please contact Thomas Parker from CentrePeat (thomas.parker@hutton.ac.uk).

The Soil Sentinel – a busy first year!

Paul Hargreaves (SRUC) and Kenneth Loades (The James Hutton Institute)

Since the first issue of The Soil Sentinel was launched at the Royal Highland Show last year it has been a busy time for activity related to Scottish soils research. There have been another three issues of the Soil Sentinel, with this now the fourth! Through both direct email and the Zenodo Healthy Soils for a Green Recovery community we have engaged with 500 people in the first 12 months. We want to go further however! So, if you know anyone who you think would benefit from receiving a copy, in Scotland or beyond, then simply forward the bulletin and ask them to sign up by emailing healthy-soils@sefari.scot.

In the first year we have also been engaging in person at a number of events across Scotland and wider through dissemination to the global science community. As previously reported, the World Congress of Soil Science was held in Glasgow offering a fantastic opportunity to showcase our research. We also attended a number of farmer field days and attended national events including Arable Scotland, Potatoes in Practice, and the Royal Highland Show. There have been an additional 159 engagement activities linked to the project from workshops and expert panels to invited presentations at international conferences and meetings. Research publications related to the Healthy Soil program have begun with over 30 now having been published in the first 15 months of the project.

Primarily the Soil Sentinel is a newsletter reporting the latest updates from the Scottish Government (RESAS) funded research, especially from the Healthy Soils for a Green Recovery project, we welcome other articles related to soils activity within Scotland.

So, if there is a key topic you would like to discuss or share an opinion on please contact either Kenneth Loades (Kenneth.Loades@hutton.ac.uk) or Paul Hargreaves (Paul.Hargreaves@sruc.ac.uk) to discuss further how it could be included in future Soil Sentinel editions.

It's all about the microbiome…but what is it and how does it influence soil functions?

Maddy Giles (The James Hutton Institute)

Soil is teeming with life, the total biomass and diversity of which rivals that of higher plants and animals. This assemblage is often referred to as the soil microbiome, a term used to encompass the whole range of microorganisms found in soils including bacteria, archaea, viruses, fungi and microeukaryotes (multicellular organisms). These microorganisms within the microbiome can be identified using DNA sequencing approaches outlined in the Box.

Although small, organisms within the microbiome play a key role in a range of soil processes including nutrient cycling (greenhouse gas emissions, soil C sequestration), plant growth promotion and disease spread and resistance. Managing the soil microbiome for beneficial functions offers a potential way for improving soil health and agricultural sustainability.

However, with more diversity in 1g of soil than all higher plants and animals on the planet, microbiomes are complex and there is still a huge amount we do not understand about them. To fully exploit the microbiome we need a better understanding of how the structure and function of microbial communities are influenced by things like the plants present agricultural management practices used.

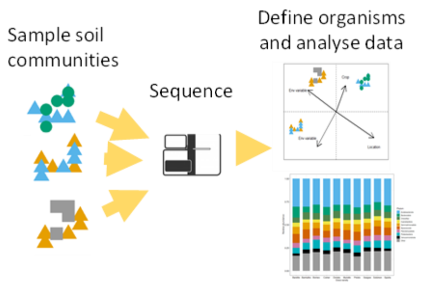
So, what could we improve through better understanding of the microbiome?

Box 1 – Characterising the soil microbiome

The diversity of soil microorganisms means that one of the best ways to characterise these communities is by sequencing DNA extracted from soil samples. To do this, areas of a gene known to vary between organisms (commonly 16SrRNA – bacteria, 18SrRNA -eukaryotes) are copied using the polymerase chain reaction (PCR) and then DNA sequenced, a process which identifies the order of DNA bases in a gene.

A Next Generation sequencing run can produce millions of sequences which are then separated into groups based on the order of bases in the genes of interest. This computational step allows us to identify the number of unique sequences present something which is often taken to be analogous to the number of species present in a sample. To identify what's there these sequences are compared to databases which can provide taxonomy.

While we can identify 10,000's of different sequences in a sample many of these are not yet in databases and can't be named, despite this they will often still be playing important roles within soils and interacting with other organisms.



Carbon and nitrogen cycles comprise of a number of modular parts many of which represent either growth or respiration processes for soil microorganisms. The composition and status of the soil microbiome is therefore fundamentally linked to nutrient cycling process. At its most basic level, we know things like in general fungi are better at degrading complex carbon sources than bacteria, and that pH can affect what functions soil microorganisms can carry out (e.g the reduction of the greenhouse gas N_2O to the inert N_2) as well as which microorganisms are present, but itis likely that other finer scale changes are at play too, such as the selection of unique soil microbiomes by different plants through both active plant signalling and passive microorganism selection caused by root deposited carbon. Understanding the complexities and relationships will increase our knowledge on the fate of carbon and nitrogen in soils, key in developing management practices that aim to promote carbon sequestration and reduce greenhouse gas emissions.

This is something we are investigating through the Healthy Soils for a Green Recovery research project. Where we have been looking to identify whether greenhouse gas emissions vary between soils planted with different grass species and grass varieties and if this is in part driven by the ability of grasses to create their own unique microbiomes. A range of work both in laboratory and field conditions suggests that this is the case and that both CO_2 and N_2O emissions vary between soils planted with different grasses. In the case of CO_2 we have been able to identify that up to 10% of the variation in soil CO_2 emissions is driven by differences in the microorganisms present between soils planted with different grasses.

While this work is still at an early stage its hoped that information on the promotion of greenhouse gas production both by different grasses and crops will help add to the information farmers have when selecting what to plant.

For further information please contact Maddy Giles (maddy.giles@hutton.ac.uk) or Victoria Buswell (victoria.buswell@hutton.ac.uk).

Sustainable Forestry: The imperative and methods of soil mapping in the Scottish forest resource inventory

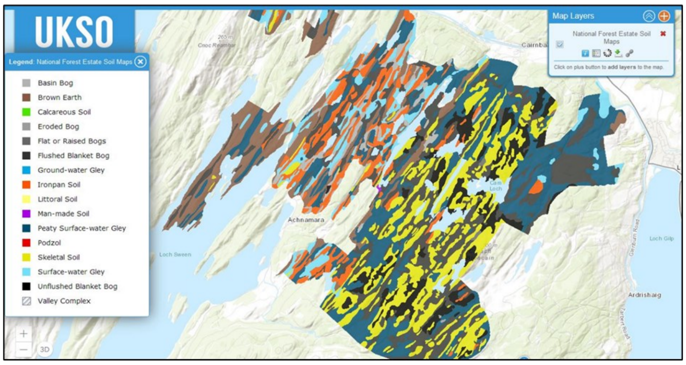
Richard Hewison (The James Hutton Institute)

Scotland has a very wide diversity of climatic, topographic, soil-forming parent materials and landscape processes operating within a relatively small area which has led to a highly complex pattern of soils across its area. Knowledge of the nature and distribution of soil resources and their characteristics is a vital component in understanding their potential contribution to societal needs and the implications in relation to their requirement for appropriate management. The James Hutton Institute already holds a huge amount of strategic information on the soils of Scotland as well as many maps of soil types across the country but much of this information is at a scale that is now deemed to be insufficient for modern detailed forest planning.

Over the last circa. 15 years an important prerequisite in forest planning or re-establishing forest cover and the choice of tree species is the carrying out 1:10,000 scale surveys to map the distribution of different soil types and their main attributes. This information will allow forest planners to make more appropriate decisions on:

+ Where or where not to plant certain species,
+ Areas where planting should be avoided altogether such as on weakly flushed or unflushed peats, very shallow or indurated soils,
+ Allow better water resource management,
+ More sustainable soil management and,
+ Potential increased biodiversity benefits.

Information is gathered in the field using either a free survey method, with the frequency of inspection pits determined by the complexity, variability and predictability of soil patterns or a grid pattern (100m grid intervals). Soil inspections are either small pits dug with a spade or augerings or often a combination of both and allocated to a soil type along with any phase characteristics that are observed. Assessments of soil texture, stoniness, rootable depth, forest type and main vegetation characteristics are also recorded in some instances.



A Forestry Commission soil key and booklet have been produced which helps assign profiles to their most appropriate soil type and to allocate their phase characteristics. The main soil types and their codes include Brown Earths (1), Man-made Soils (2), Podzols (3), Ironpan Soils (4), Groundwater Gleys (5), Peaty Gleys (6), Typical Surface Water Gleys (7), Basin Bogs (8), *Molinia* (Flushed) Blanket Bogs (9), *Sphagnum* Bogs (10), *Calluna-Eriophorum-Tricophorum* (Unflushed) Blanket Bogs (11), Calcareous Soils (12) and Rankers and Skeletal Soils (13).

Results are presented in maps, tables and reports to Forestry and Land Scotland. The data is digitised at the Institute so it can go straight into the FLS Forester Web database. We believe that we have greatly improved connectivity between the Institute and a key CAMERAS partner and developed an excellent relationship with staff in FLS/Forest Research and delivered outputs that facilitate better forest design, more appropriate management of soil carbon and water resources and will help to achieve greater biodiversity benefits from Scotland's forests.

By 2023, around 800 square km have been mapped at this scale. This long-term work has given the JHI a great opportunity to train and mentor new staff in soil survey and mapping skills which were in danger of being lost.

This article represents work involving:

Soil Surveyors: Andrew Nolan, Richard Hewison, David Henderson, John Bell, Willie Towers, Luke Beesley, David Riach, Ben Butler and Steve Addy.

GIS Support: David Donnelly.

Current and former Forest Research/Forestry and Land Scotland staff: Bill Rayner, Andy Kennedy, Julie Gardiner, Jens Haufe and Hamish Mackintosh.

For further information please contact Richard Hewison (Richard.hewison@hutton.ac.uk).

How does the 100 m tall tower atmospheric observatory aid in research towards achieving NetZero?

Jagadeesh Yeluripati (The James Hutton Institute) and Tim Arnold (The University of Edinburgh)

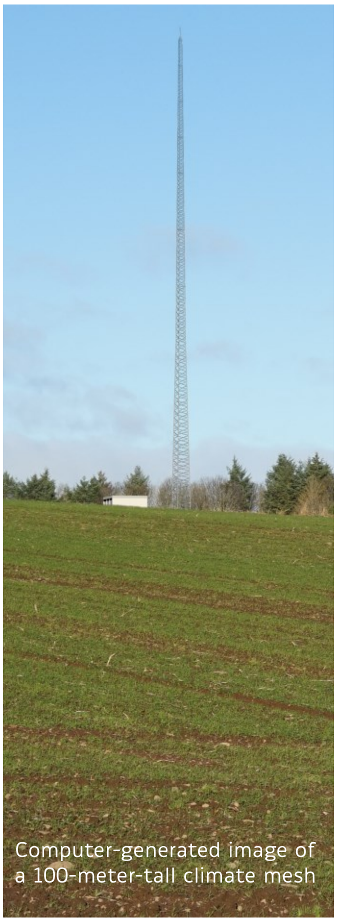
Plans are in place to construct a 100 m tall tower in Scotland for greenhouse gas research at Balruddery Farm near Dundee's James Hutton Institute. It is envisioned as a 100-metre-tall tower with state-of-the-art scientific equipment. The facility is estimated to cost £1 million and aid environmental scientists in determining the greenhouse gas composition to forecast GHG changes in Scotland over the next few years and decades. The University of Edinburgh and James Hutton Institute are spearheading the initiative, with assistance from the National Physical Laboratory, to establish high-quality measurement infrastructure at the location.

Why is it necessary?

During the COP26 conference in Glasgow in 2021, nations agreed that climate change is the most significant challenge facing humanity, and immediate action is necessary to decarbonize the global economy. The Scottish Government has set an ambitious goal for Scotland to achieve 'net-zero' greenhouse gas emissions by 2045. Science played a crucial role in COP26 by presenting evidence of the damage caused by greenhouse gases due to climate warming. However, there are still debates about the amount of greenhouse gases produced from land and the effectiveness of planned mitigations. To address these challenges, the tower will enable monitoring and mitigate climate change by allowing scientists to directly measure the composition of atmospheric greenhouse gases. By mathematically modelling changes over the coming years and decades, the tower will provide insights into whether emissions are deviating from expected declines, providing an early indication of the effectiveness of actions and policies. This information will enable governments to adjust their plans accordingly.

What will it do?

The tower is designed to collect air samples from the top 100 meters high. This will enable scientists in the UK to monitor and mitigate climate change by directly measuring the composition of atmospheric greenhouse gases. They will then model changes, mathematically based, on prevailing winds as they move across Scotland. Ground-level instruments and sensors will measure concentrations of the gases that cause climate change. Scientists across the UK will interpret changes in the levels of these gases to calculate greenhouse gas sources and sinks, such as emissions from and uptake by land.



Computer-generated image of a 100-meter-tall climate mesh

Why Balruddery?

Due to its location in eastern Scotland and the prevalent westerly winds, Balruddery is a prime location for tracking atmospheric gas emissions. This allows emissions from across Scotland, including agriculture, to be monitored. The current UK Tall Tower greenhouse gas monitoring network only has stations in England and is not able to effectively measure Scottish emissions. This new facility will allow scientists to cover the current blind spot in greenhouse gas monitoring.

This research will aid policymakers in determining the necessary policies for reducing greenhouse gas emissions, as Scotland and the UK work towards achieving their net-zero targets.

The project's estimated completion date is now September 2023, Further details are available: https://blogs.ed.ac.uk/soar or contact Jagadeesh Yeluripati (Jagadeesh.yeluriapti@hutton.ac.uk) or Tim Arnold (Tim.Arnold@ed.ac.uk). This project is supported by a NERC capital grant (NE/V017144/1) and RESAS-JHI-C2-1.

Comments

The Soil Sentinel was produced as part of the Healthy Soils (JHI-D3-1) project with input from CentrePeat (JHI-D3-2) and the Achieving Multi-Purpose Nature Based Solutions (AiM NBS) (JHI-D2-2) project. We acknowledge funding through the Rural & Environment Science & Analytical Services Division of the Scottish Government.

This is the fourth edition of The Soil Sentinel and we would welcome suggestions for articles, or requests for more information on any soil and plant interactions topics. If you would like to propose a contribution to the bulletin please don't hesitate to get in touch through ***healthysoils@sefari.scot***