The Soil Sentinel

The Soil Sentinel ISSUE 6 – March 2024

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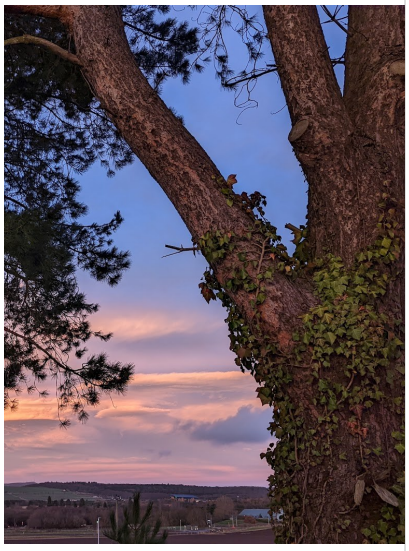
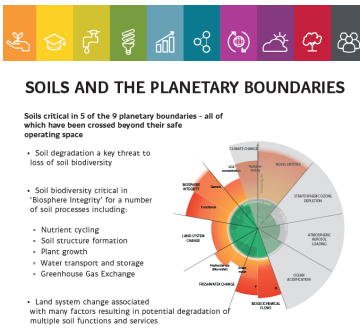


Putting Research into Context for Policy: Healthy Soils for a Green Recovery—Paul Hargreaves (SRUC) and Kenneth Loades (The James Hutton Institute)

The second annual Healthy Soils Event was held at The Royal Society of Edinburgh on 12th March 2024. The day was a mixture of presentations and workshops with this edition of the Soil Sentinel summarising 2 of the workshops, and also presentations from NatureScot and Environmental Standards Scotland. In addition to the workshops, we were delighted to welcome Ellen Fay from the Sustainable Soils Alliance who provided the key note address to attendees.

Within Scotland, and across the UK, there is a lot of work looking at effective measures for monitoring and reporting soil condition, and the wider environment. ClimateXChange recently funded a project on "Understanding metrics for effective environmental measures under the Agricultural Reform Programme (ARP) for Scotland" with Professor Robin Pakeman delivering an interesting talk on the current status of the project. The Healthy Soils for a Green Recovery team were heavily involved in the project and contributed to many of the measures which will be reported upon completion of the study. The final project report is still to be published but will contain information on measurements that could be applied to assess the outcomes of a Vision for Agriculture.

Following on from ARP presentation, Dr Rebekka Artz provided an overview of ongoing work within the CentrePeat project, a summary of which can be found later in this issue. Dr David Boldrin then highlighted opportunities in "Enhancing ecosystem services of 3D field margins through plant-soil interactions", work aligned to the Achieving Multi-Purpose Nature Based Solutions (AiM NBS) RESAS funded project. Magic Margins (MM's) can be implemented in field margins and are a series of ridges and depressions which increase the surface area for both infiltration and also evapotranspiration, reducing overland flow and potential diffuse pollution. Another aspect of this AiM NBS project is to understand how MM's could be managed to increase biodiversity and ecological connectivity. The talk also highlighted changes in soil hydraulic conductivity and evapotranspiration between species, both temporally and spatially, as plants become established. It was also pointed out that following plant death, hydraulic conductivity has been observed to increase due to channels opening in the soil following root decomposition.



The afternoon session was a mixture of research outcomes including an update on the development of Scotland's soil monitoring plan and talks by Dr Clive Mitchell from NatureScot and Luke Bradley from Environmental Standards Scotland. When talking about the development of Scotland's soil monitoring plan, Dr Nikki Baggaley highlighted that we were not starting from scratch and provided an overview on data currently available for Scotland and the potential for these different datasets to contribute as a baseline. New techniques for monitoring soils were also shown including opportunities in the use of Fourier Transform infrared (FTIR) spectroscopy and Attenuated Total Reflectance (ATR) sampling methodology. Such techniques potentially offer the opportunity to predict multiple soil properties from a single spectrum (such as %N, %C, pH, and bulk density). Following this, Professor Bob Rees delivered a stimulating presentation on changes in green-

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RESAS Rural & Environmental Science and Analytical Services
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house gas nitrous oxide (N2O) attributed to crop residues, further information can be found in an article on page 4.

The three workshops which were run on the day covered the topics of biochar, forestry, and ecosystem services and facilitated by SEPA, Forest Research, and SRUC respectively. Summaries of the ecosystem services and biochar workshops are included in this edition of the Soil Sentinel and we hope to include a summary of the forestry workshop in our July edition. Overall, the workshops provided a basis for some interesting, and thought-provoking, discussion around topics of significant importance both now and in the future.

Our annual event provided a great opportunity to communicate progress from a number of soils-based projects funded through the Scottish Government's strategic research programme. Discussions were open and it was great to have a number of different stakeholders in attendance, each with their own ideas on where we might be going in the future. The value from such events are in understanding the research need from our stakeholders and listening to the challenges we are facing as we progress towards net zero with greater soil and environmental sustainability and monitoring.

For further information please contact either Dr Paul Hargreaves (Paul.Hargreaves@sruc.ac.uk) or Dr Kenneth Loades (Kenneth.Loades@hutton.ac.uk)

Cover crops in a changing climate— Tracy Valentine (The James Hutton Institute)

Cover crops are one way to increase diversity on farm and potentially have multiple benefits both above and below ground, including adding C and N to the soil, improving soil structure, capturing nutrients and passing them to the next crop, reducing weed burden, depending on the specific cover crop species or mixture grown. Winter cover crops are established after the main crop harvest in August through to September (in the northern hemisphere) and are grown through the winter season before being destroyed usually by frost, herbicide or mowing.

The Scottish Government funded "Crop Improvement for sustainable production in a changing environment", and the "Healthy Soils" projects are exploring the difficulties in establishing cover crops under different climatic conditions and under different management conditions. While climate change projections of Scotland's weather, include an increase in average temperature across all seasons, with warmer and drier summers, and milder and wetter winters, there is significant local variability in both temperatures, and rainfall event patterns across the different months of the year. These variations could have several impacts on cover crop implementation. For example, while projections suggest that central eastern areas of Scotland will become warmer it also projects it to be much drier in the August-September cover crop sowing window, potentially affecting germination rates.

Further north, the projections become much more uncertain, but the issue of quickly fading light for plant growth will still remain whatever the weather brings. There are also farm management interactions. So far data has been collated on multiple species of cover crops, from both the literature, a multiple species plot trial and from Grieves House Tillage Trial (GHTT). In the

2022-2023 growing season cover crop biomass produced (measured in March) in the GHTT, was significantly lower in the no-till plots than in the inversion plough plots for both the Radish and Rye cover crops sown (Fig1 middle), by more than 50%. Cover crops within no-till systems are key approaches to climate change mitigation, through reduced fuel and attempts to increase carbon sequestration, so while biomass is only an indicator of cover crop success reduced effectiveness in this system of particular cover crops species is important information.

Data gathered on responses to management will be combined with seed germination metrics, plant temperature and light growth data in models that link to climate change projections for different regions in Scotland, to help assist the uptake of cover crops.

For further information please contact Dr Tracy Valentine (Tracy.Valentine@hutton.ac.uk)

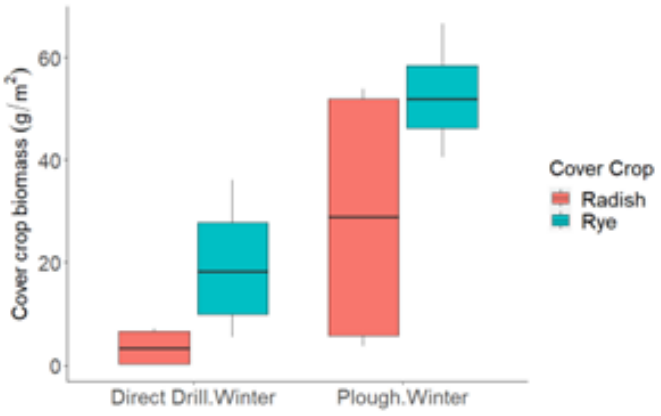
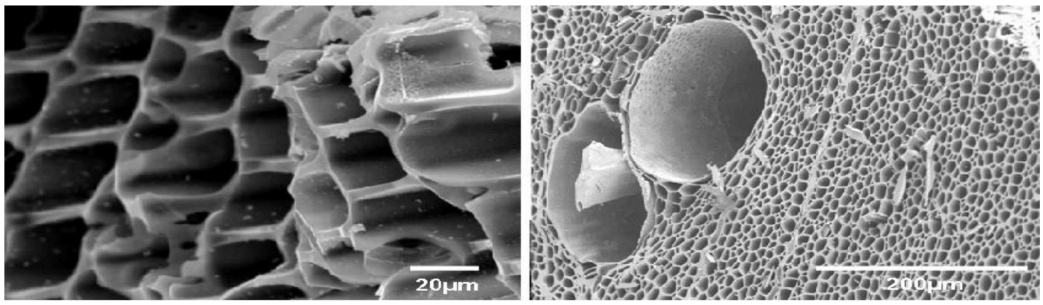


Fig 1. *Fifteen cover crops sow in fully replicated plot trial at the GHTT field site(Top left). Reduction in above ground cover crop biomass under direct drill compared with no-till, in two cover crops species sown in Grieves house Tillage Trial (GHTT). (above).Mixed cover crop (top right).*

EVENT SUMMARY BIOCHAR—Workshop discussion summary— Kenneth Loades (The James Hutton Institute)



Biochar structures (Oni et al, 2019— https://doi.org/10.1016/j.aoas.2019.12.006)

Biochar is a topic of increasing interest from multiple stakeholders and the Scottish Environmental Protection Agency (SEPA), who facilitated the workshop. SEPA were specifically interested in understanding potential risks and also the applicability of biochar use within Scotland.

From the start it was clear that there was a perception that there was a lot known on biochar however questions were raised on whether we really know enough. The workshop included people from a number of different organisations, each with their own interests in understanding both the direct and indirect benefits associated with the application of biochar to soil.

The topic of carbon sequestration is a key one with a comment made that modelling work has shown the potential for farms to achieve net zero with no increases in yield. However, despite its ability to lock up carbon it was also noted that this is not only carbon that is locked up with implications for other processes and functions. It was suggested that if we focus on carbon sequestration a better approach might be in managing soils for carbon storage, an approach which has the potential to increase carbon stocks greater than through the application of biochar. There is much to explore around this alone, if we manage soil for carbon storage what are the trade offs for other functions and services? Could biochar (inert carbon) imply soil carbon stocks are 'healthy' when in reality functions are compromised? GHG emissions could be high due to the over application of fertilisers which results in the processing of soil organic matter reducing carbon stocks and increasing soil emissions of GHGs.

Another key point raised was on the screening of biochar for application and the need to develop an assay to assess biochar. This is critical due to the known variability in biochar associated with different sources and types of material used. The assay should include the screening of physical and chemical properties, plant response, and other soil biological community responses to its application. Regarding biological communities it was noted that it is important to understand if biochar, sourced from different feedstocks, have physical structures that might act as refuges for belowground life. In summary, the functional biological aspect of biochar application is still largely unknown.

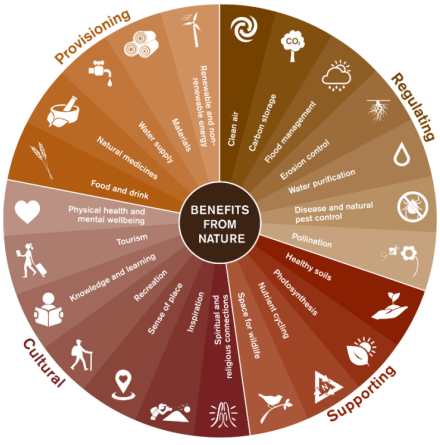
Overwhelmingly it was agreed that there is a need for long-term assessment of changes in the ecosystem services and function in response to biochar applications. There is some work currently testing biochar on grass and cereals in Scotland however this has only been running for a year so far with mixed results. Regarding cereals, the weather proved to be challenging in being able to see any changes associated with biochar applications. However, in grassland an increase in yield was observed in biochar and slurry applications when compared to slurry applications alone.

So what do we do now? The plan is to look at opportunities to apply for funding from the Scottish Environment Food and Agriculture Research Institutions (SEFARI) Gateway to establish a Specialist Advisory Group (SAG) to investigate the topic further. It was acknowledged in the workshop that the knowledge shared was only that known by those present and there is likely more known with relevance to the Scottish landscape. The SAG will also help in understanding what the target and goal might be and whether the co-benefits exceed those benefits associated within the soil only environment.

For further information please contact Dr Kenneth Loades (Kenneth.Loades@hutton.ac.uk)

EVENT SUMMARY ECOSYSTEMS SERVICES —Workshop discussion summary—

Tracy Valentine (The James Hutton Institute) and Alistair McVittie (SRUC)



What are Ecosystem Services? (NatureScot—https://bit.ly/3TFg1Mv)

Soil is a key natural capital asset providing multiple ecosystem services through dynamic processes. Land has traditionally been managed for food and fibre production (crops, pasture or trees), with current soil monitoring metrics usually linked to production systems. But we should be managing for multiple ecosystem services benefits. There will always be trade-offs in the pursuit of multiple private and societal benefits, particularly in the context of climate change. These should be considered within a broader concept of resilience.

In a stable climate it is much easier to pick a crop/variety suitable to grow. Whereas in an increasingly unstable climate, resilience requires potentially more expensive, more diverse/complex cropping systems. Diversification via cover crops, however, in northern regions can be difficult, due to establishment issues and failure can result in soil damage. The impact of disease carryover within multi-year rotation was also discussed.

The overall benefit of increasing soil carbon (C) was acknowledged but increasing C is not possible in all soils and may sometimes have negative consequences (interactions with nutrient pathways, increased nitrous oxide outputs). We need to understand the fine balances between the different pathways under different land management systems, and in different soils. Maps of soil ecosystem services capability and the resilience of the soil to perform those services could be developed

to assist policy along the lines of land capability maps. While yield should be one of the metrics (yield stability), ranking of other metrics and trade-offs between metrics were discussed in the context of who holds the burden of the cost of monitoring.

Soil is not properly valued by society (more money is spent on monitoring air quality vs soil monitoring), with issues such as soil capping and (soil) construction waste going to land fill not high on agendas. There is a need for more education on the importance of soil (at all levels), its multiple benefits and ecosystem services, which could take the form of visual guides (like VESS). This would assist in gaining support for the cost of soil monitoring..

In summary:

- We should be managing land for multiple benefits and accept there will be trade-offs, with, individual metrics, viewed in terms of soil (and land management system) resilience and boundaries.
- More education would increase the understanding of the value of soils, and soils should be treated as both a National asset as well as an ecosystem service provider.

For further information please contact Dr Tracy Valentine (Tracy.Valentine@hutton.ac.uk) or Dr Alistair McVittie (Alistair.McVittie@sruc.ac.uk)

Greenhouse gas emissions from crop residues — Bob Rees and Kairsty Topp (SRUC)

Most of the greenhouse gas emissions from cropping systems arise from emissions of nitrous oxide (N_2O). This results partly from the direct emissions that originate from microbial transformations of N inputs derived from fertilisers and manures. Our understanding of these emissions has improved in recent years, but another source of emissions resulting from crop residues is much more uncertain (Olesen at al, 2023). Around half of the fertiliser N applied to crops is returned to soils via crop residues. In national reporting it is assumed that emissions from this source can be estimated by using a default fertiliser emission factor and multiplying this by the quantity of residues returned. Our research has shown that this simplistic approach disguises a more complex underlying pattern. Immature residues such as those from cover crops or leafy vegetables have much higher emissions than those from mature residues such as straw (Fig. 1). We were also able to show an interaction between crop residues and fertiliser addition. Thus the application of crop residues together with organic manures and substrates led to higher N_2O emissions than when crop residues were added together with synthetic fertilisers (Abalos et al, 2022). Improved reporting of greenhouse gas emissions from agricultural systems could be achieved by accounting for the nature of crop residues and their interaction with soil management.

For further information please contact Professor Bob Rees(Bob.Rees@sruc.ac.uk) or Dr Kairsty Topp (Kairsty.Topp@sruc.ac.uk)

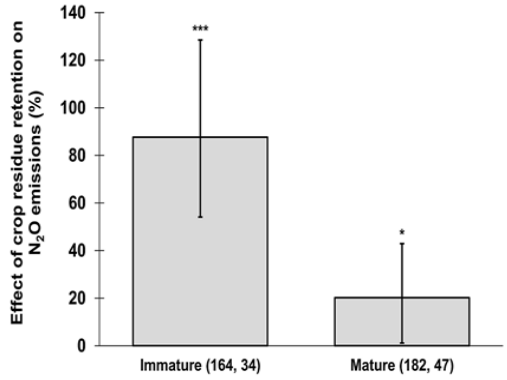


Fig 1. *Nitrous oxide emissions from immature and mature crop residues (Abalos et al, 2023).*

References:

Abalos et al. 2022
doi.org/10.1016/ j.scitotenv.2022.154388

Olesen et al. 2023
doi:org/10.1111/gcb.16962

EVENT SUMMARY **Regenerative land management practices and the importance of diversity for resilience** —Talk summary by Paul Hargreaves (SRUC)

As part of the Healthy Soils event held at The Royal Society of Edinburgh Clive Mitchell from NatureScot spoke about transforming landscapes with an emphasis on what makes soils compelling for policy and practice.

On taking a broad approach to nature, including all life everywhere, then thoughts about landscapes need to include as many components as possible. We ignore a specific component at risk to the whole landscape. How important a certain landscapes development is, or maintaining that landscape, can depend on something that maybe over-looked. If only certain aspects that you might believe to be the most important are considered, a controlling fact may be missed. The example was given of the development of the plant leaf resulting in a major transformation to the landscapes of the past, especially in the movement of water from rainfall down through streams, rivers and lakes into the sea. As the organic material became more abundant, slowing the water movement, water channels started to meander and change the landscape to include more diversity, and resilience.

The climate has been seen to become more chaotic over time in response to a changing climate. The rainfall patterns, and drought periods, in Scotland have reflected this over recent years. These become more of a challenge when attempting to manage climate change. There is a need to build resilience through sustainable intensification and consider multiple risks, not just one or the most pressing, in a changing landscape.

A focus on nature networks could be the start in developing an answer to the challenges we are facing. In connecting up areas, through a series of networks, across a landscape will help build resilience and protect genetic diversity in species rich areas. However, cropped areas need to be included in the whole of the landscape patchwork to ensure greater resilience. The thinking needs to be not just of nature in small, but connected, areas, but nature as all life that is considered as everything, everywhere, all at once.

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

EVENT SUMMARY Determining the risks to Scotland's soils—Talk summary

by Kenneth Loades (The James Hutton Institute)

Luke Bradley from Environmental Standards Scotland (ESS) provided a great talk at the annual Healthy Soils event on the role of ESS including work currently in addressing some of the challenges facing soil. It is important to understand the role of ESS with the media reporting them as the 'environmental watchdog'. The reality is that they aim to ensure that Scottish environmental law is effective, that public bodies apply the law correctly, and that Scottish law aligns with EU law. Post Brexit there was no external body ensuring compliance and hence the establishment of ESS post-Brexit.

In relation to soils ESS have been working on 'Determining the risks to Scotland's soils' and understanding the current status of soil health and its control and monitoring. Although the project is not yet completed (completion planned by May 2024), Luke was able to share some of the risks which have been identified so far.

The majority of the risks have been known for some time, such as compaction, erosion, water retention, and drought. Others have become more prominent in recent years, such as pests and disease, soil sealing, and biodiversity loss. It was important to note that soils are accepted as being highly valuable and yet soil is still being considered a waste. One of the other highlighted risks was around soil health indicators, another topic which has historically been challenging but recent work has begun to identify suites of indicators that can

be applied dependent on land-use indicating that progress is being made.

How these are indicators applied within the development of a Scottish soil monitoring framework is still to be fully seen. It will also be crucial to understand the time-scales over which soil should be monitored and at what spatial resolution.

For more information please contact Dr Kenneth Loades (Kenneth.Loades@hutton.ac.uk).

CentrePeat update — Rebekka Artz (The James Hutton Institute)

The CentrePeat project, funded by the umbrella of the current Strategic Research Programme, aims to inform the protection and restoration of peatlands across Scotland. In this edition, we provide a brief overview of highlights from the second year of the project (April 2023-March 2024) in the 5 Workpackages (WP) of this five-year project.

The first WP (Scottish National Peatland Observatory) combines the analysis of data from several greenhouse gas monitoring stations on peat with the development of low-cost solutions to monitor baseline emissions and vulnerability of the soil to changes in management and climatic extremes. Within this network of sites, we are now compiling a first publication on the effectiveness of forest-to-bog peatland restoration on carbon dioxide emissions, with partners at UKCEH, UHI and RSPB Scotland. Also in this monitoring network, we have now gathered sufficient data to enable the first comparison of baseline emissions from three eroding peatlands across Scotland. We have also compiled →5 years of water level dynamics monitoring data from a joint experiment with RSPB Scotland at the

Forsinard Flows NNR, which examines the effectiveness of two different restoration techniques. We also provided the first full year of evidence of the aqueous losses of carbon, via dissolved organic carbon, from one of two upland eroded blanket bog monitoring sites and show, using Fourier Transform Infrared Spectroscopy, that exposed gully banks and gully floors have different potential vulnerability to future degradation.

In WP2 of this project, we aim to provide national, high resolution, coverage of condition indicators of all Scottish peatland areas using Earth Observations (EO). In year 2, we completed national-scale mapping of peatland drainage and erosion features, which has the potential to provide evidence to peatland restoration project developers and also could be used to refine peatland baseline emissions reporting in the UK National Atmospheric Emissions Inventory. Also in WP2, we refined a novel method to map water table depth (WTD) over large peatland areas and at monthly intervals, using satellite imagery.

In WP3, we reported on the continuation of work on Scottish peat values and ecosystem services and identified important evidence gaps in the valuation of water quality, flooding, energy, timber and carbon storage related ecosystem services during workshops with key stakeholders. We also added 33% more data to a restoration cost database.

In WP4, we focused on providing better evidence of the baseline losses of particulate organic carbon (POC) into water courses via erosion. We measured both erosion and resedimentation rates of POC within gullies at two upland blanket bogs and used the data from these sites to provide further evidence on baseline emissions of POC as a component of overall losses of carbon from eroding peatlands. We combined these datasets with the improved mapping of erosion features from WP2 for the Aberdeenshire and Angus areas to show how hotspot of POC losses could potentially be mapped and to inform potential future restoration projects.

In WP5, we develop a meta-model, based on the wetland-DNDC model, that aims to help provide spatially explicit information about current peatland emissions, areas where restoration could be considered, alongside mapping of emissions mitigation potential. In Year2, we adapted the meta-model to be able to run drought scenarios and tested this adapted model on ground observations from WP1. We also adapted the model to be able to be able to run simulations of drainage and re-wetting in future. This element of the model is still undergoing further testing.

We were also honoured to have received a team Conservation Science award at this years's Nature of Scotland award ceremony. All our publicly accessible reports and datasets can be found on the project Zenodo space (https://zenodo.org/communities/centrepeat). The project brings together expertise at James Hutton Institute and SRUC.

For more information please contact the project PI Dr Rebekka Artz (Rebekka.Artz@hutton.ac.uk).

A busy year of engagement for Healthy Soils for a Green Recovery, CentrePeat and Achieving Multi-Purpose Nature Based Solutions (AiM NBS) Scottish Government funded research projects

Healthy Soils for a Green Recovery produced 28 publications including a number of reports, information booklets, conference abstracts, and international journal articles. Example publications which demonstrate the breadth of research within the Healthy Soils project include Grass variety selection of microbial community composition is associated with differences in soil CO_2 emissions, Increasing crop rotational diversity can enhance cereal yields, Rhizosphere carbon priming: a plant mechanism to enhance soil nitrogen accessibility?, A closer look at root water potential: experimental evidence based on drought stress of *Chrysopogon zizanioides*, and Concepts and consequences of the hyphosphere core microbiome for arbuscular mycorrhizal fungal fitness and function.

In addition to the delivery of papers in peer reviewed journals the project also contributed to 12 public and policy development consultations including a 'Just Transition to Net Zero', the Agriculture and Rural Communities (Scotland) Bill, tree planting and forestry in Scotland, and the Agricultural Knowledge and Innovation System (AKIS) in Scotland. 112 other knowledge exchange activities took place including talks to independent agronomists, visiting policy makers from European countries, and at industry events including Arable Scotland and Potatoes in Practice. Additionally, multiple project members discussed project outputs with key stakeholders and additionally delivering invited presentations at both national and international conferences and meetings. In total over 150 engagement activities took place in the previous 12 months demonstrating both the relevance of Healthy Soils funded research and also potential impact. It is also important to note that the project team also leveraged additional funding totalling £12 million with multiple other organisations and delivered projects to three of Scotland's centres of expertise, CREW, ClimateXChange, and the SEFARI Gateway. Two projects highly relevant to the Healthy Soils project in particular were 'Assessing the socio-economic impacts of soil degradation on Scotland's water environment' funded by CREW and 'Understanding metrics for effective environmental measures under the Agricultural Reform Programme for Scotland' with ClimateXChange.

For further information please contact Dr Roy Neilson (Roy.Neilson@hutton.ac.uk).

Achieving Multi-Purpose Nature-Based Solutions (Aim NBS) contributed to authoring 10 publications on a range of topics related to developing and applying nature-based solutions. Example publications included Navigating or adding to complexity? Exploring the role of catchment partnerships in collaborative governance, Long-term daily stream temperature record for Scotland reveals spatio-temporal patterns in warming of rivers in the past and further warming in the future, and Nature-based solutions and restoration are intertwined but not identical: Highlighting implications for societies and ecosystems.

The project team has also engaged with a number of key stakeholders from across the UK and also contributed to working groups on the woodland water code. Just under £1 million was also secured in additional funding from a wide range of sources including Scotland's centres of expertise.

For further information please contact Dr Mark Wilkinson (Mark.Wilkinson@hutton.ac.uk)

CentrePeat were involved in authoring 15 publications this year, ranging from academic papers to policy briefings and reports. Example publications include Mapping and monitoring peatland conditions from global to field scale, and Potential for Peatland Water Table Depth Monitoring Using Sentinel-1 SAR Backscatter: Case Study of Forsinard Flows, Scotland, UK and Understanding the role of fungi in peatland degradation after drainage. The project also had outputs to policy and practice contributing to the Scottish Peatland Programme Science and Technical Advisory Group, the Technical Advisory Board of the UK Peatland Code, and at a European scale to an EC Carbon Farming Focus Group. Utilising alternative delivery mechanisms, project members showcased peatland research on BBC Scotland Landward and BBC Radio 4's 'On Our Farm' Show. In August 2023 the team also published a podcast on 'Measuring and monitoring Scotland's peatlands, 600 m high on the Balmoral Estate' as part of 30 other engagement activities during the second year of the project. The project team also secured further funding of £2.6 million.

***For further information please contact* Dr Rebekka Artz (*Rebekka.Artz@hutton.ac.uk*)**

STOP THE PRESS! POSTDCTORAL POSITION AVAILABLE

Postdoctoral research opportunity in healthy soil

climateXchange
Scotland's centre of expertise connecting climate change research and policy

Research into securing Scotland's soils in a changing climate, with ClimateXChange and the Scottish Government. ClimateXChange (CXC) seeks to offer a one-year postdoc research role to aid the Scottish Government in creating a comprehensive plan for enhancing soil health across Scotland. The researcher will work with policy leads from the Scottish Government to design a routemap for the key actions that enable soils that "are healthy and provide essential ecosystem services for nature, people and our economy", as identified in the consultation draft of the Scottish National Adaptation Plan 3. **More information on the position can be found here**.

Comments and upcoming issues: *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 6th 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**.*