HEALTHY SOILS FOR A GREEN RECOVERY

The Soil Sentinel

The Soil Sentinel ISSUE 2 – DECEMBER 2022

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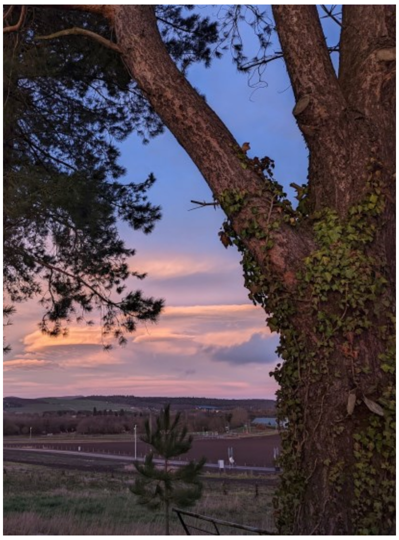


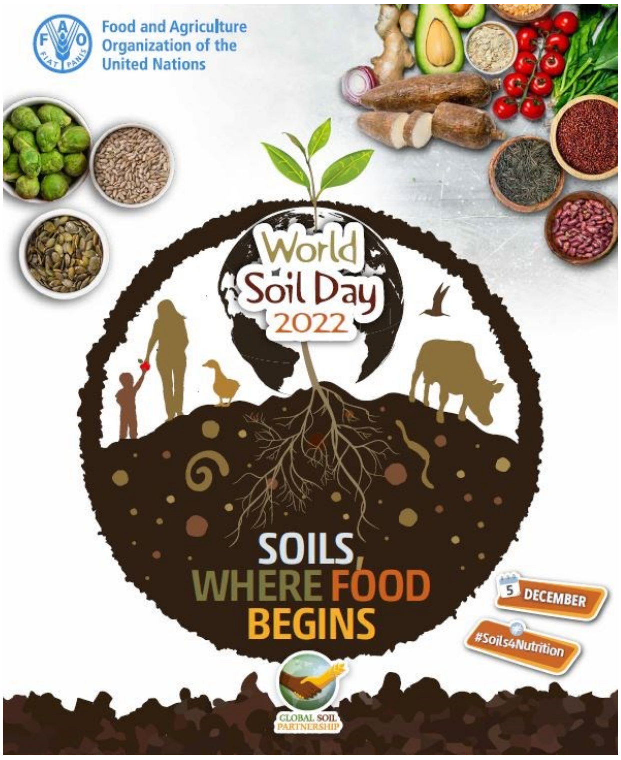
An international day for soil —Paul Hargreaves (SRUC)

The International Union of Soil Sciences (IUSS) is a global organisation that helps to promote all branches of soil science and their applications, along with associated soil scientists. They have been in pursuit of these activities since 1924 and this includes the promotion and organisation of the World Congress of Soil Science. The IUSS in 2002 proposed an international day to celebrate soil. This was proposed under the leadership of the Kingdom of Thailand and leader at the time, H.M. King Bhumibol Adulyade. From this point the 5th of December has been designated as World Soil Day as it was the King's birthday.

The King of Thailand was recognised for his strong interest in soils and soil quality and as such was honoured as the first recipient of the Humanitarian Soil Scientist award for his dedication to soil resource management.

The first official World Soils Day was 5th December 2014 with the Food and Agriculture Organization of the United Nations (FAO) collectively endorsing the idea in June of 2013 and adoption by the 68th UN General Assembly. The designation and observances of International Days by the UN aim to help promote international action on specific issues. This allows organisations from governments to universities, as well as schools and local groups, to use the special days as a springboard to raise awareness both in their local communities and more widely.

There is usually a theme to each of the World Soil Day's, with the first theme in 2014 being 'Soils, foundation for family farming' and the theme for this year (2022) being 'Soils: Where food begins'.



The FAO website for World Soils Day (https://www.fao.org/world-soil-day/en/) now includes a wealth of useful material for the encouragement of an interest in soils, from booklets, that can be downloaded, videos, posters, campaign material and the ability to register your soils event on an interactive world map.

With the theme of this years World Soils Day being 'Soils: Where Food Begins' this not only considers the production of food to feed a planet of 8 billion humans but the quality of the food produced and how this relates back to the quality of soils. Soil nutrient loss is a major soil degradation processes threatening nutrition and is recognized as being among the most important problems, at a global level, for food security and sustainability.

The FAO website states: '*Over the last 70 years, the level of vitamins and nutrients in food has drastically decreased, and it is estimated that 2 billion people worldwide suffer from lack of micronutrients, known as hidden hunger because it is difficult to detect.*

Soil degradation induces some soils to be nutrient depleted losing their capacity to support crops, while others have such a high nutrient concentration that represent a toxic environment to plants and animals, pollutes the environment and cause climate change.'

Enjoy reading about the soils work and concerns in this issue of The Soil Sentinel and maybe think about how you can celebrate and raise awareness for the next World Soils Day in 2023.

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Identifying soil carbon sources in river sediments—Miriam Glendell (The James Hutton Institute) and Katy Wiltshire (Cranfield University)

Identification of soil erosion "hotspots" is critical for sustainable land and water management. Soils are the largest carbon pool on Earth and provide vital ecosystem services, including biomass production, grazing land, forestry, and water filtering. The ability to store carbon and absorb water makes soil an indispensable part of climate change mitigation and adaptation. However, soil erosion compromises soil function, leading to loss of fertility and damaging off-site problems due to sedimentation, including water pollution and damage to infrastructure and aquatic environments.

Soil erosion reflects the combined effect of land management intensity and soil properties, hence identifying erosion hotspots and the sources of soil organic carbon (SOC) in waterways is challenging. Hence, a PhD study by Dr Catherine Wiltshire, funded by the NERC STARS Doctoral Training Partnership tested a novel sediment tracing technique to improve identification of dominant terrestrial land-use sources of organic carbon in freshwater sediments in river catchments. Three interlinked studies were conducted in two catchments, including Loch Davan in Aberdeenshire.

The first study combined sediment fingerprinting using land use specific plant biomarkers (n-alkanes) with soil erosion modelling to understand the origin and fate of eroded SOC. The study assessed the role of features such as riparian buffer zones in intercepting sediment delivery to streams. The results showed that riparian woodland disconnected the upslope delivery of eroded soil organic matter to water while also providing an input of woodland-derived organic matter to the streams.

A second study tested novel combinations of biomarkers (i.e. *n*-alkanes, *n*-alkane isotopes) in combination with biomarkers that characterise

the soil microbial and fungal communities (short chain neutral lipid fatty acids) to compare their ability to discriminate sediment sources. The results showed that a combination of *n*-alkanes and their isotope fingerprints improved discrimination between arable and pasture sources while the combination of *n*-alkanes and neutral lipid fatty acids improved discrimination between all land within the catchment (incl. arable, pasture, forest, and moorland).

Finally, the understanding of the sources of sediments provided by sediment fingerprinting was used to evaluate the ability of two soil erosion modelling approaches to identify potential sources of streambed sediments. Predicted soil erosion rates from a process-based model and soil erosion risk maps were compared using the sediment fingerprinting as a benchmarking tool. The freely available erosion risk maps developed at the James Hutton Institute (https://bit.ly/3W6jfsP) were confirmed to be the most reliable in identifying likely sources of sediments and organic matter in the Scottish Loch Davan catchment.

These cutting-edge sediment and organic matter tracing techniques, in combination with the erosion risk mapping, have the potential to evaluate the effectiveness of catchment management practices aimed at improving soil health and reducing soil loss. The study assessed riparian management initiatives that seek to reduce the connectivity of eroded sediments and water courses, and also to inform and mitigate its off-site impacts.

This study was supported by scientists from the James Hutton Institute (Miriam Glendell, Barry Thornton, Steve Addy, Nikki Baggaley), Cranfield University (Toby Waine, Bob Grabowski) and University of Liege (Jeroen Meersmans).

For further information please contact Dr Catherine Wiltshire (katy.wiltshire@cranfield.ac.uk) or Dr Miriam Glendell (miriam.glendell@hutton.ac.uk)

Optimising composts for use in the horticulture industry - Kenneth Loades (The James Hutton Institute)

Soilcom is a project which started in February 2019 and will run until June 2023 looking into the benefits in the application of composts, of different characteristics, to soils across Europe. Funding is through the European Regional Development Fund and Interreg North Sea Region with partners from Scotland, Denmark, Belgium, Germany, and the Netherlands. It is widely accepted that compost improves soil health, however, there are significant research gaps on understanding the relative impacts of compost produced using different production techniques and source materials from which the compost is derived.

Within Scotland we have been looking at our long-term compost application trial at the James Hutton Institute outside Dundee which was established in 2004. The site had an initial application of 50 t ha of Discovery compost from Dundee council before higher rates of 200 t ha were applied 2005 and 2006 in a small number of plots and an additional treatment of 100 t ha added in 2007. After 2007 all plots (except control) received 35 t ha. Some 18 years since the field trial was established, we examined what the long-term benefits were in soil physical functions associated with the long-term application of compost. It is important to note that throughout the soil has been managed through a minimum tillage approach and planted with a monoculture of barley.

Findings in the surface soils were not unexpected with soil bulk density shown to decrease from an average value of 1.3 g cm3 in non-amended plots to 1.1 g cm3 in those with 200 t ha compost additions. Declines in bulk density were also observed in plots with 50 and 100 t ha additions when compared to the control plots. It was a little surprising to see that the legacy of the high rates of compost addition can still be observed. Other measures included looking at soil structure with measures of water stable aggregates showing the percentage of water stable aggregates increased from 66% in the control, untreated plots, to just over 80% in plots with 200 t ha compost applied. To understand how the soil would respond to rainfall we also looked at hydraulic conductivity which showed that the plots which had received the 1 or 2 years of 200 t ha and 100 t ha had increased capability to allow water to travel through the soil. A little surprisingly the average hydraulic conductivity was higher under 100 t ha than 200 t ha with the 50 t ha treatment showing a decrease in hydraulic conductivity when compared to the unamended plots. Organic matter content was also analysed and converted to soil organic carbon which showed increases from the control (3.3%) to 5.0%, 5.9%, and 6.5% for 50, 100, and 200 t ha application rates. Yield was not shown to be significantly different between treatments.

In addition to looking at the surface soils we also investigated the impacts of compost addition in the sub soils. This region of soil (below the plough pan) is soil which is very difficult to manage and one which is important in improving the function of soil and also in allowing plant roots to access nutrients and water deeper in the soil profile. Sub soils in all legacy plots had lower levels of hydraulic conductivity than surface soils however there were significantly higher rates of hydraulic conductivity under the higher compost application rates. The same was true of soil organic carbon with control plots having 2.3% increasing to 2.8%, 3.0%, and 3.7% in 50, 100, and 200 t ha application rates. This finding was a little unexpected with increases in organic carbon likely to be associated with the action of the roots in transporting the compost deeper under the minimum tillage management system.

Future work is planned within the compost trial to better understand further benefits associated with compost application. For example, will compost improve soil temperature in the spring resulting in earlier emergence? Can the addition of cover crops improve soil organic carbon in sub soils? What impacts does compost have on crop quality? Do proposed soil health indicators show improvements in soil functions?

What has been discussed here is one aspect of the Soilcom project. Other work within the project by the James Hutton Institute has shown that the characteristics of the composts from other countries has the potential to influence the functions that they confer following incorporation into soil. For example, 15 composts screened from Soilcom partner countries have shown differences in their ability to hold water. This observation is not only true of the compost itself but also when it is mixed with a silty loam soil. Findings suggest that a compost could be chosen dependent on the desired function required for the soil, be that improved water holding capacity in a lighter textured soil or reduced water holding capacity in a heavier soil. Further analysis is required to understand why composts differ between producers before composts can be produced for different functions and benefits.

For more information contact Kenneth Loades (kenneth.loades@hutton.ac.uk)

World Congress of Soil Science soil judging Competition and post-congress soil tours—Richard Hewison and Matt Aitkenhead (The James Hutton Institute)

As part of the World Congress of Soil Science 2022 (WCSS), an International Soil Judging Competition was organised at Stirling University. *I*t was hosted by The British Society of Soil Science (BSSS) along with staff of The James Hutton Institute on behalf of the International Union of Soil Science (IUSS) and was ran between 27-31 July.

It was an opportunity for students to learn how to describe and classify soils according to international standards such as the 'World Reference Base for Soil Resources' and 'Soil Taxonomy'. Teams consisted of four students and countries represented included the UK, Germany, Spain, Italy, Hungary, the USA, Mexico, South Korea, and Australia. The teams got the chance to spend time in training with some of the foremost experts in the field of soil science, before representing their country in a competition at sites across the Stirling region. The programme comprised four days of classroom and field-based training before taking part in the competition on day five.

Topics that were covered in the classroom included, an introduction to the soils of Scotland, their formation, history, survey, and mapping; soil forming parent materials of the Stirling region; soil functionality concepts: Linking soil characteristics to multiple ecosystem functions and services; soil governance and how soils fit into Scotland's environmental legislation; and concepts of soil classification.

In the field, students were introduced to the methods used to describe and evaluate soil characteristics such as the assessment and depth of horizons and their associated boundaries as well as properties such as colour, texture, structure, redox features, stoniness, and how to recognise impediments to root growth such as shallowness over bedrock, compaction or induration.

The Stirling region, with its great diversity of landscapes, geology and parent materials provided a perfect location to visit a wide variety of Scottish soil types. World Reference Base soil groups that were visited included Histosols, Technosols, Leptosols, Gleysols, Podzols, Planosols, Stagnosols, Phaeozems, Umbrisols, Cambisols and Fluvisols. Field sites included, the Carse of Stirling, Flanders Moss, The Ochills, Devilla Forest, the west Dunfermline low hills and the Stirling University campus.

Post congress tours - Following the Congress, six soil tours were organised to give WCSS delegates the chance to see some Scottish soils in a landscape context and to learn about their characteristics, development, function, and challenges facing their management and sustainable use. The tours included: a 4-day tour examining the soils of northern Scotland; a 3-day tour of the soils, geomorphology and landscape of Galloway; and four 1-day tours of, the soils of the Isle of Arran; soils of the Boghall Glen on the Bush Estate outside Edinburgh, a tour concerning the Impact of Glasgow's Industrial legacy on soils, urban regeneration and greening as well as a tour of some of the profiles visited on the soil judging course in the Stirling area.

For further information please contact Richard Hewison [(richard.hewison@hutton.ac.uk)](mailto:richard.hewison@hutton.ac.uk)

Update on all things CentrePeat! —Rebekka Artz (The James Hutton Institute)

The CentrePeat project aims to inform the protection and restoration of peatlands across Scotland. In the first 6 months of this 5-year programme, funded by the umbrella of the current Strategic Research Programme, we have made progress on jointly developing a draft methodology for a low-cost monitoring network for proxies of greenhouse gas exchange and condition of peatlands, initially with partners at James Hutton Institute, NatureScot and BioSS. At this stage, we are exploring the geospatial design of such a network and begun to explore the potential methodologies that could be used. Alongside these developments, Hutton staff have harmonised the compiled data that have been gathered on carbon dioxide and methane emissions from the Scottish Greenhouse Gas flux network sites on peatlands. This network currently contains nine monitoring stations on peat, with a further four to be added soon.

We have also expanded our monitoring capability for dissolved and particulate organic carbon (POC) lost via water courses at two of our monitoring sites, the data from which will feed into an ongoing evidence review of the emission factor for POC from peatlands. This project will also provide spatially explicit information about where and when restoration should be considered, and how much benefit could be achieved at each restoration site and across all of Scotland to achieve net zero by 2045. For this element of the project, we are currently compiling and harmonising how peatland condition data are collated by various organisations. We are working towards an integrated categorisation that will ultimately feed into a consistent national Peatland Monitoring Framework that will aid national scale peatland condition mapping and monitoring.

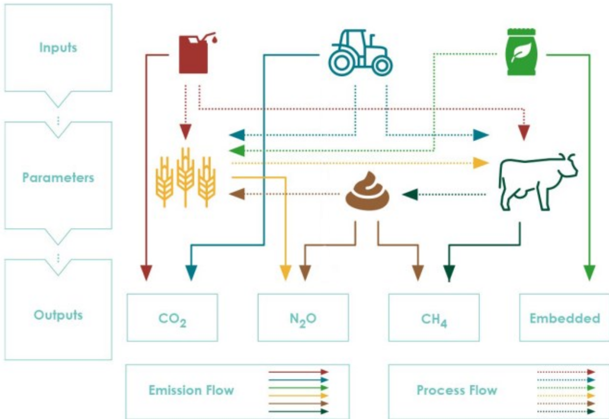
Further elements of this research programme also include the development of

Earth Observation-based indicators of water table dynamics as a proxy for emissions and a methodology to monitor restoration trajectories. In an effort to improve wider Natural Capital accounting, Hutton and SRUC partners in the project are working on an evidence-mapping review on ecosystem services and are beginning to explore a conceptual Marginal Abatement Cost Curve framework. A final piece of the programme is aiming to improve the ways we may be able to model the fate of peatland carbon and nitrogen cycling. For this component of the project, we have completed a sensitivty analysis of a meta-model.

For any further information, please contact Rebekka Artz (rebekka.artrz@hutton.ac.uk)

Mitigating the Climate Impact of Farming—Rachael Ramsey (SRUC)

The agricultural sector is facing unprecedented pressures from the complex challenges of rising global food insecurity, biodiversity loss, increasing global food demand, increasing cost of inputs, and climate change. In this current uncertain environment, coupled with ambitious legislative net zero targets (in Scotland by 2045), the agri-food sector is facing increasing demands to measure and monitor progress against carbon equivalent (CO2e) reduction targets. Alongside this, there is also a growing need to provide meaningful analysis of on-farm data, benchmark individual farms against peers/others in the sector and provide targeted mitigation strategies to reduce carbon emissions.



Agrecalc is an agricultural resource efficiency and greenhouse (GHG) emissions calculator that was developed 15 years ago by industry experts in SAC Consulting, in partnership with academic researchers from SRUC. Agrecalc is designed to identify, measure, and baseline the main GHGs associated with agriculture: carbon dioxide (CO2), nitrous oxide (N2O) and methane (CH4), from land use and crops, livestock, energy, waste, woody biomass, and soil. The farm carbon footprint report produced aims to support and enable farmers to make strategic decisions unique to that farm, that reduce carbon emissions, whilst making more efficient use of resources – often also reducing production costs and benefiting whole farm productivity and efficiency.

The growing urgency to reduce GHG emissions coupled with government incentivisation of soil testing and the emergence of soil carbon markets, have caused increased interest in accurately measuring soil carbon sequestration and improving the capacity of agricultural soils to store carbon, contributing towards climate change mitigation goals.

Although Agrecalc first released a novel soil carbon sub-module in 2020, that allowed estimation of soil carbon stock changes at the whole farm level, the development of this module is an actively evolving process! The current iteration of Agrecalc's soil module is based on IPCC Tier I methodology (2019 refinement guidelines), which considers the influence of land use change, agricultural management, and inputs applied on soil carbon stocks – and considers mineral soil only, for now.

However, later this year sees an exciting stage in Agrecalc's evolution with the launch of our new cloud-based platform and the addition of new modules and features, but also key updates going forward to existing modules.

For our soil carbon module, as a first step, this includes recognition of organic soils and allowing the farmer to input actual measured soil test results (specified to be to 30cm depth), which aligns with the various devolved Government incentivised soil test programmes around the UK, including the Scottish National Test Programme. Into early 2023, will see further exciting updates, to include a peatland module and the inclusion of the IPCC Tier II steady state model for soil carbon, with horizon scanning of the potential to include Tier II/III biophysical models for soil carbon stock change estimation. The overarching aim of our soil carbon module development will always be to reduce uncertainty in the tool, and increase the reliability and robustness of Agrecalc, so that we can measure and understand the benefits or trade-offs of changing soil management practices on farms.

The challenges facing the agricultural sector in the short and medium term is great, and careful management of our agricultural soils is crucial to help achieve our net zero targets. Our mission in Agrecalc is to support farmers on this journey of understanding, identifying, and baselining their emissions, with a tool underpinned by the best science, research and specialist industry and academic knowledge available.

For more information please visit Agrecalc or contact Rachael Ramsey (Rachael.Ramsey@sac.co.uk)

EU backs research for designing crop systems ready for future environmental change —Tim George (The James Hutton Institute)

Funded by the Horizon Europe program*, the project Root2Res "Root phenotyping and genetic improvement for rotational crops resilient to environmental change" started on 1st September 2022.

As agricultural systems face more and more constraints due to climate change, identifying and developing new crop cultivars able to make production more resilient is a priority. In this context, root systems play a major role as an essential component of the tolerance against abiotic stress (water deficit or excess, nutrition deficiency) and for their contribution to carbon storage in soils. Addressing root traits for breeders, geneticists and agronomists is a real challenge that needs efficient tools: root phenotyping tools both in field and controlled conditions, genetic tools with a set of relevant markers and genetic resources and modelling tools to extrapolate the results in other environments and agricultural contexts. This is exactly the ambition of Root2Res: to develop such tools and use them to define and test innovative cultivar ideotypes able to enhance the tolerance to abiotic stress and carbon sequestration in soils.

To achieve these objectives, Root2Res will work during the 5 years on cereals (barley, wheat), potato, legumes (faba bean, pea, lentils) and sweet potato. Beyond the deep scientific investigations, Root2Res also includes strong links with stakeholders (breeders, farmers, and policy makers) and an ambitious dissemination and exploitation plan.

For more information contact Time George (tim.george@hutton.ac.uk)

The rising of the pHoenix —Christine Watson (SRUC)

This story starts around 60 years ago when a demonstration trial was established in the Woodlands Field by staff of the former North of Scotland College of Agriculture (now SRUC) at Craibstone Estate near Aberdeen. The trial investigated the impact of different pH levels (on a gradient from 4.5 to 7.5 in 0.5 increments) on soil properties and crop performance of an 8-course rotation comprising: 3-year grass/clover ley, winter wheat, potatoes, spring barley, swede and spring oats (undersown with grass/clover). Each crop in the rotation is present every year enabling a comparison of the response of all crop types within the same season. The soil is a sandy loam of the Countesswells Association with a soil organic matter content of 9.3 ±0.4% at pH 6 (loss on ignition). The long-term annual rainfall is 843 mm and average daily temperature 8°C (1961-2020).

The trial has provided a unique dataset showing the influence of soil pH on crop yield over a 60 year period, and in more recent years samples have been analysed for crop quality. Historically barley yield shows a maximum at pH 6 but spring oats show a rather different pattern with a maximum between pH 5 and 5.5 and very low yields above pH 6.5. When the yield data is analysed by rotational periods there are emerging trends over time, for example, the yield of winter wheat at high pH appears to be increasing with time. Plots of older varieties of cereals have been grown in the same field at different pHs over the last few years and these results will help us to separate the impacts of breeding and climate on yield.

Photo credit: Ross Johnston

Much of the original Craibstone Estate has now been developed for residential purposes and it became evident early in 2021 that we were going to lose the Woodlands Field. We felt this was too important a resource to lose from Scottish agriculture as those soils have developed unique microbial communities over 60 years which cannot be recreated in the short term. So, we decided to move a field (!) and the soils from the Woodlands Field pH experiment have entered a new chapter in history and become the pHoenix experiment. In July 2021 the topsoil (to 20cm) was removed from the plots and relocated to a field at nearby Ashtown on similar parent material. This was not as easy as it sounds! We moved 450 tonnes of soil in just 5 days thanks to an excellent local team. The "lift and shift" was carried out by a local farmer who remembered being impressed by the original Woodlands Field experiment when he was a student at Craibstone. The bright side of this is that it has allowed us to redesign the experiment based on modern statistical understanding. The original experiment was laid out on a pH gradient (4.5 to 7.5) making it difficult to analyse the significance of differences between treatments. In the new experiments we have randomised the pH treatments and for every plot of soil that we moved there is a "twin" plot of field soil which will be amended to the same pH.

As this is not a direct continuation of the old experiment, we will not be reinstating the original rotation. We are just completing a participatory exercise with scientists, farmers and advisors to design the cropping on the new experiment and will soon be ready to reveal the new experimental design. This is part of the Aberdeen Cropping Experimental (ACE) Platform which is a new research, education, and knowledge exchange initiative between SRUC and the University of Aberdeen. Over the years the original experiment has led to dozens of publications and PhD theses and has had thousands of visitors in the form of students, farmers, advisors and scientists from all over the world. We invite you to come and visit the new pHoenix experiment and to collaborate with us on seeking answers to contemporary questions about how soil pH can be managed in the context of food security and net-zero agriculture as well as more fundamental questions about the soil microbiome.

For more information contact Christine Watson (christine.watson@sruc.ac.uk) or Robin Walker (robin.walker@sruc.ac.uk).

Comments and upcoming issues: *This is the second edition of The Soil Sentinel with Issue 3 scheduled to be released in April 2023. For the third issue we are planning to focus on **soil carbon** and we would welcome articles on the topic. Alternatively, if you would like to propose a contribution to the bulletin please don't hesitate to get in touch through **healthysoils@sefari.scot**. Also, if you would like more information on the Healthy Soils project, or have suggestions on special issues, please reach out to us!*