The Soil Sentinel

The Soil Sentinel ISSUE 7 – July 2024

HEALTHY SOILS FOR A GREEN RECOVERY

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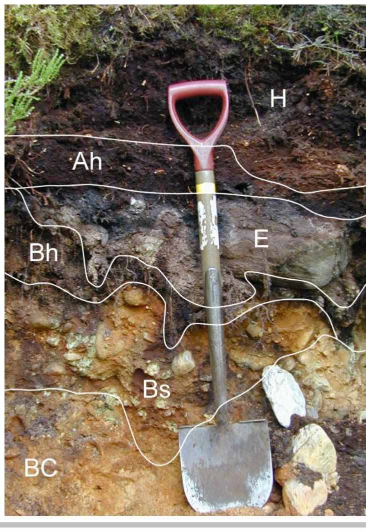
ClimateXChange Securing Scotland's Soils in a Changing Climate —Sarah Buckingham(SAC consulting, part of SRUC) and Nikki Baggaley (The James Hutton Institute)

Soils underpin many ecosystem services such as food production, energy security, forestry, protecting biodiversity as well as playing a crucial role in regulating water and nutrient cycles.

Recently, the Climate Change Committee (CCC) identified soil health as a priority risk for immediate action in the third Climate Change Risk Assessment, highlighting this policy area as being critical to climate adaptation in their March 2022 progress report 'Is Scotland Climate Ready?'. The recent House of Commons Environment, Food and Rural Affairs Committee Soil health inquiry report (2023-24) highlighted a lack of soil-specific policy to directly support and address soil health at a UK level and also highlighted the need for baselining and monitoring change in soil health in an easily measurable and meaningful way. In Scotland, healthy soils underpin and cut across a wide range of policies and strategies including the Scottish National Adaptation Plan 3, Scottish Biodiversity Strategy, River Basin Management Plan for Scotland 2021-2027, Scotland's Third Land Use Strategy 2021-2026 and Scotland's National Planning Framework 4. The Scottish National Adaptation Plan 3 consultation draft identifies a policy outcome that "soils are healthy and provide essential ecosystem services for nature, people and our economy". However, it is acknowledged that there is a lack of a single policy focused on soil health to specifically address this. There is however an opportunity to review existing policies and frameworks for the development of an integrated soil policy framework to better protect Scotland's soils.

The aim of this research project – commissioned by ClimateXChange on behalf of the Scottish Government – is to explore how current knowledge, research and public policy can support the design of a routemap to drive the future security of soil health in Scotland. The project will review Scotland's policy objectives and how these are underpinned by healthy soils as well as the strategic priorities identified at the Climate Adaptation Team and stakeholder workshop in May 2024 (such as revisiting and reviewing policy objectives outlined within the Scottish Soil Framework, 2009). Stakeholder engagement will be an essential component of the project to ensure key stakeholders (e.g. government, agencies, land managers, research, businesses and NGOs) and sectors (e.g. agriculture, forestry, wetlands and peatlands, uplands, water, and urban and greenspaces) within Scotland are considered and reflected within a Scottish policy framework and soil health routemap.



The project will finish in March 2025. and specific project plans are currently being reviewed and refined. There are plans to hold focus-group workshops on 28th and 29th August (which will be advertised via CXC website) focussing on different land uses to build on the outcomes of the Climate Adaptation Team and Healthy Soils stakeholder workshop from May 2024.

For further information please contact either Dr Sarah Buckingham (Sarah.Buckingham@sruc.ac.uk) or Dr Nikki Baggaley (Nikki.Baggaley@hutton.ac.uk)

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

Assessing the socio-economic impacts of soil degradation on Scotland's water environment — Nikki Baggaley , Mohamed Jabloun, Allan Lilly, Kenneth Loades, Thomas Parker, Mike Rivington, Zulin Zhang, Michaela Roberts (The James Hutton Institute), Fiona Fraser (SRUC) and Paul Hallett (University of Aberdeen)

Having healthy soils is important for many parts of the Scottish economy, for example, they improve crop yields, store more water to help limit the effects of drought and floods and regulate water flows to rivers and lochs.

When soils are degraded there are both direct and indirect impacts. These can have significant costs associated with them to both individuals, society, and the wider economy. To assess the costs of degraded soils to the Scottish economy it is key to know the:

1. Extent of the soil degradation.
2. Impacts of that degradation.
3. Costs of those impacts and to whom

The project has shown that a significant proportion of cultivated soils are compacted and eroded, and degradation is linked to both land use and soil type with some soils more vulnerable than others.

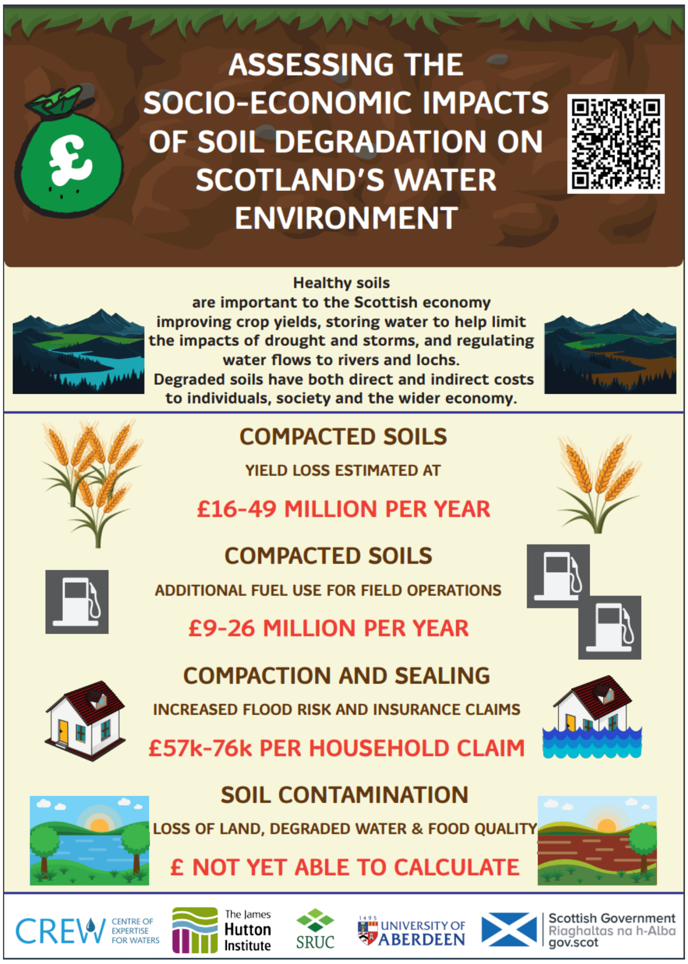
Data show that 26% of cultivated topsoils are compacted and depending on the crop being grown, farmers could face additional costs of between £15 to £209 per hectare in increased fuel usage. This comes on top of a reduction in crop yield of up to 15% and wider landscape scale costs associated with increasing GHG emissions and the exacerbation of soil erosion and the associated increase in sediment and pollutant export to rivers and lochs.

Minimising soil sealing (covering with an impermeable surface) for the protection of ecosystem services such as agricultural production, biodiversity, carbon storage, and flood protection are key elements of the National Planning Framework 4. The combination of compaction and sealing could lead to a 1% increase in the flood area or intensity which would be a cost of £2.6 million for local authorities.

When it comes to soil contamination the impacts are degraded water and food quality and potential damage to human health. We don't know the extent of this due to a lack of data but what we can say is that there are sites in Scotland where soils are contaminated with unknown costs associated with them.

All soil degradation leads to changes in soil biodiversity and the impacts of this are unknown. Changes will likely add to the impacts and costs but are inestimable due to lack of coordinated data collection.

A single framework should integrate the costs of soil compaction and erosion (Rickson et al 2019), the degradation of peatlands and peaty soils being worked on in "Centre peat" and soils under land uses such as forestry with the combined impacts on water bodies. Improving national scale monitoring and collation of soils data will provide additional evidence to link the impacts from soil compaction, soil biodiversity, soil contamination and soil erosion.



Outputs from this project include a Policy Brief with a discussion of policy implications from this research.

For further information please visit here or contact Dr Nikki Baggaley (Nikki.Baggaley@hutton.ac.uk)

Biochar additions to grassland – positive for yield — Paul Hargreaves (SRUC)

As the concerns about climate change driven by increased greenhouse gases in the atmosphere increases, the focus is now on methods to mitigate the effects. Numerous methods have been suggested for the reduction of agricultural emissions as these contribute a sizable proportion to the overall global emissions. However, the reductions seen in these agricultural emissions have not been as great as in other sectors, such as energy use or waste. Even though reducing the GHG emissions from agriculture is crucial the production of food to feed an expanding global population is still needed.

Biochar has been suggested as one method to capture more of the carbon dioxide (CO_2) from biomass and potentially maintain or enhance the yield of crops through the co-application of biochar with organic matter used as a fertiliser, reducing the required input of other fertilisers.

Biochar is a highly porous carbonaceous solid and a product of heating organic material to high temperatures in a reduced or no oxygen environment, a process called pyrolysis. Almost any organic material can be used to produce biochar, but the preferred source material is woody material from plants and trees to sustainably produce biochar with a high carbon content. This can have an added advantage as the source material can be from waste material from other industries such as waste wood and sawdust from forestry and wood production.

Previous studies have shown that there can be crop yield advantages to the application of biochar as a result of the porous nature of the material and the potential to enhance the cation exchange capacity (CEC) of the soil and improve soil nutrient retention. This increased CEC aids efficiency of the retention of nutrients in coapplied organic material such as dairy cow slurry. This is in addition to the storage of an inert form of material high in carbon within the soil that can be stable for 1000's of years. Work has also shown that through the increase in soil pH, from the application of the biochar, there are reductions in nitrous oxide (N_2O) emissions, a greenhouse gas much more potent than CO_2.

Experimental work has been on going at the SRUC Crichton Farm in Dumfries on grassland plots over the last two years through a NZIP project with Black Bull Biochar (a commercial producer of certified biochar), the UK Centre for Ecology and Hydrology, and the University of Edinburgh. These have studied the effects of lower levels of biochar co-application with dairy cattle slurry on the grass sward yields. This work builds on previous research by the University of Edinburgh looking at the co-application of biochar with organic fertiliser.

Biochar and slurry combined have been applied through dribble bars to the surface of the soil on experimental plots (10m x 10m in size) at the start of the growing season in April and compared with applications of just the cattle slurry. The rest of the year only slurry was applied to all the plots. Three grass cuts have been taken each season.

Slurry residue with and without biochar (photo from Black Bull Biochar)

Grass roots with biochar (photo from Black Bull Biochar)

The results have shown a positive increase in the biochar and slurry treated plots, even though the application rate of the biochar has only been the equivalent of 10 kg of biochar to 1 ton of slurry, with a rate of 50m^3 ha^{-1} of slurry. The total yield increase for the first year for the biochar treated plots was 16.1% or the equivalent of 1.76 t ha^{-1} of dry matter.

The second year of the experiment has focused on both the reapplication of biochar and any legacy effect of the previous season's biochar application. This has shown in the first cut a 0.56 t ha^{-1} increase in dry matter for the biochar applied last year and a 0.6 t ha^{-1} for the added biochar applied this year in April.

The soil carbon and nitrogen content saw improvements of 51% and 22% in the biochar plots compared to the non-biochar plots.

Overall, positive responses to the addition of biochar.

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

The value of frass — Arthy Surendran (SRUC) and Rob Lillywhite (University of Warwick)

The concept of a circular economy underpins the use of insects for animal feed, and it is a rapidly growing industry. Scotland has the potential to become a global leader in insect production thanks to the government's circular economy initiatives. The sector primarily utilises Black soldier flies (BSF) and mealworms, which transform organic waste into high-value protein. This process also produces frass as a waste, a significant byproduct by volume offering an opportunity for use in other areas of agriculture.

Frass is a mixture of manure, insect exoskeleton and uneaten feed substrates. We have characterised various frass compositions from BSF reared on various different feed substrates (***Table 1***).

The results show that the BSF frass has potential for the use as a biofertilizer containing both plant macro and micro nutrients . However, the nutrient content of the frass is significantly influenced by the feeding substrate and the environmental conditions. BSF reared with a cereal-based substrate produced frass with higher ammonium content compared to that produced from a fruit and vegetable diet. Interestingly, frass produced from fruit and vegetable diets was found to have a high potassium content.

To assess the biofertiliser potential of frass we have conducted a field trial to evaluate frass derived from the cereal diet on cabbage plants to evaluate weight gain. Within the study we

Batch	Rearing substrate	Moisture (%)	pH	N (%)	NH4 (mg/kg)	P (%)	K (%)
1	70% grains, 30% wheat bran	60	6.1	3.1	2,293	1.5	1.7
2	70% grains, 30% wheat bran	44	6.1	3.1	3,915	1.5	1.8
3	70% grains, 30% wheat bran	68	7.7	2.9	2,612	1.8	1.9
4	70% grains, 30% wheat bran	46	7.7	5.3	16,865	2.6	2.5
5	70% chicken feed, 30% wheat bran	55	7.3	5.1	17,682	2.3	2.1
6	90% fruit (citrus/grape/melon), 10% wheat bran	60	7.4	3.0	159	1.2	3.8
7	25% carrot, 65% potato, 5% bread, 5% wheat bran	58	7.5	2.7	4,685	2.1	6.6
8	38% carrot, 25% potato, 25% bread, 12% wheat bran	63	9.1	1.4	93	0.8	4.6
9	80% grape + 20% barley	64	7.8	2.8	640	0.8	3.8
10	70% grape + 30% wheat	57	6.2	3.4	4,016	0.8	3.8

Table 1. Variability in frass properties in response to differing rearing substrates

Field trial assessing the application of frass to cabbage plant yield

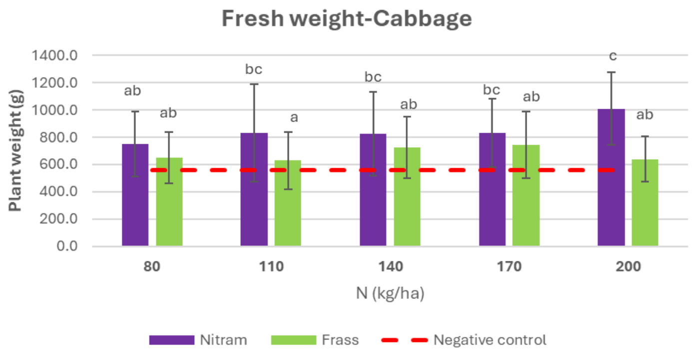


Figure 2. Fresh cabbage weight in response to application rates of nitram (ammonium nitrate) and frass.

applied five different concentrations of frass and nitram (ammonium nitrate) to cabbage plants. The results are shown in ***Figure 1*** indicating that each of the five nitrogen (synthetic nitrogen) application rates outperformed the frass treatments. Frass at 170 kg/ha was shown to be approximately equivalent to 80 kg/ha N synthetic fertiliser. These results suggest that the frass performance is more or less 70% of that observed following the use of nitram. However, when compared to the highest concentration of nitram (200 kg N/ha) frass was observed to reduce the yield. These results are similar to those observed in other plant species, as reported by Siddiqui et al. (2024).

So what could potentially have caused this reduction in yield? The negative effects of the frass might be due to its salinity and the high ammonium content of frass obtained from the cereal-based diet (Watson et al., 2021).

The results state that the frass is a promising biofertiliser with a value slightly higher than that of compost, digestates and farmyard manure. However, our results to date suggest that it has to be applied at an optimal concentration to increase the plant growth with high application rates indicating a potential yield penalty.

For further information please contact Arthy Surendran (Arthy.Surendran@sruc.ac.uk) or Rob Lillywhite (Robert.Lillywhite@warwick.ac.uk)

References:

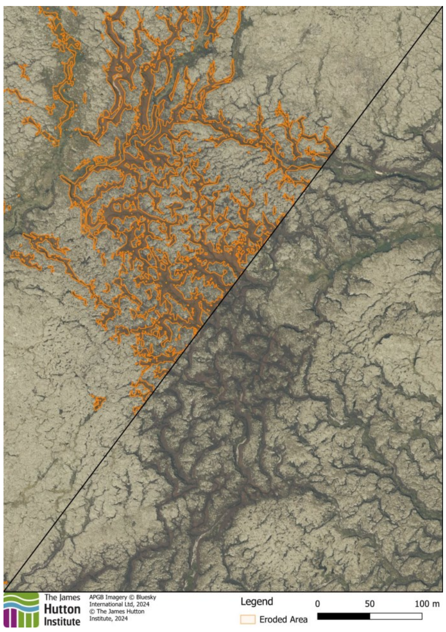
Siddiqui, S. A., Gadge, A. S., Hasan, M., Rahayu, T., Povetkin, S. N., Fernando, I., & Castro-Muñoz, R. (2024). Future opportunities for products derived from black soldier fly (BSF) treatment as animal feed and fertilizer-A systematic review. Environment, Development and Sustainability, 1-82.

Watson, C., Preißing, T., & Wichern, F. (2021). Plant nitrogen uptake from insect frass is affected by the nitrification rate as revealed by urease and nitrification inhibitors. Frontiers in sustainable food systems, 5, 721840.

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 Soil Sentinel edition, we highlight some of our emerging research outputs.

Drainage mapping



Erosion mapping

A recent publication documents our national-scale mapping of peatland drainage and erosion features (***Figure 1 and 2***). This new approach 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. The researchers used high resolution (25 cm) aerial imagery, combined with a convolutional neural network approach, to detect and map individual drainage features and improve the mapping of bare peat within eroded peatlands. The new approach estimates 40,000 km of drainage channels and 42 kha of bare and eroding peat across Scotland. For details, please follow this link to the publication, which can also be requested from the primary author Fraser Macfarlane (**fraser.macfarlane@hutton.ac.uk**). A deep learning approach for highresolution mapping of Scottish peatland degradation - Macfarlane - 2024 - European Journal of Soil Science - Wiley Online Library.

We also concentrated on publishing some of our emerging datasets. All our publicly accessible reports and datasets can be found on the project Zenodo space (https://zenodo.org/communities/centrepeat). In order to provide 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. While these datasets are evolving, the first annual surface retreat rate dataset has now been made publicly accessible. We also combined these datasets with the improved mapping of erosion features from the highlighted publication above, for the Aberdeenshire and Angus areas, to show how hotspots of POC losses could potentially be mapped and to inform potential future restoration projects. This work is led by Dr Tom Parker.

Our efforts to model water table dynamics using Earth Observations has also resulted in two open access datasets. The first is a compilation of monthly water level data from this project and a wider compilation of European datasets. We then used these water level data to develop a model that predicts water level dynamics in space and time, and applied this to some test areas around the Flow Country and Flanders Moss. At present, a single, climatically extreme year (2018) has been simulated. This model is currently being extended in both space and time, but the interim 2018 outputs described above have been deposited under Open Access. This work is led by Dr Alessandro Gimona. We welcome any feedback on these data products.

Finally, our work led by Dr Klaus Glenk on the costs and benefits of peatlands and rewetting has resulted in a dataset of restoration costs, merged with environmental and geographic variables. Two workshops with stakeholders involved in the policy development and implementation of peatland management, led by Dr Michaela Roberts, has resulted in an evidence gap report of Scottish peat values and ecosystem services.

The project brings together expertise at James Hutton Institute and SRUC. For further information on the project, please contact the project PI (Rebekka.Artz@hutton.ac.uk).

Building Scotland's soil resilience—Kenneth Loades (The James Hutton Institute)

As part of Arable Scotland, which took place on the 2nd July at Balruddery Farm, I was asked to deliver a seminar on building soil resilience. As a soil physicist the focus was on building soil physical resilience and was framed around the challenges that Scotland's soils are already facing and what they will be facing in the future.

To put this in some context, Mike Rivington and colleagues (James Hutton Institute) produced a report in 2023 which highlighted that the number of dry days (←1mm of rainfall) in April had decreased by 4 in the period 1989-2019 when compared to that between 1960-1989. Conversely, the number of heavy rain days (→10mm of rainfall) has increased by 3 in February alone in the same time frames when compared to between 1960-1989 with a similar increase in very wet days. With evidence suggesting an increasing number of dry days at some points in the year, and an increasing number of wet days during other periods, there is a need for soil to both hold more water during the dry periods, allowing crops to establish and thrive, and also release/drain more water during the wetter periods, the question is how?

Fundamental to much of the solution is to improve soil structure and soil aggregation which allows improved soil pore distributions. Soil pores largely drive how the soil responds, large macropores improve soil drainage whilst smaller pores, associated with soil aggregates, hold the water more tightly. It should be noted however that different soils have an inherent ability to hold and release water naturally due to the size of the particles which drive their texture, sandy particles being the largest, clay particles the finest and silt sized particles in the middle. The relative proportion of each of these 3 particle sizes drives what is referred to as the soil texture (**Figure 1**). Lighter, sandy, soils typically drain more freely than heavier, clay, soils which hold water more tightly. Aggregates are groups of soil particles that form together through biological and chemical activity, such as funghi, microbial community activity and root exudates, into a structure. These structures then act to protect soil carbon from degradation, improve physical resilience to compaction and also hold water more tightly, the spaces between the aggregates acting as flow paths for water under heavy rainfall. It should also be noted that these flow paths are only of use when rainfall intensity is less than the ability of the soil to absorb the water, if rainfall is too intense there can be excess infiltration overland flow which has the potential to cause significant erosion and flooding.

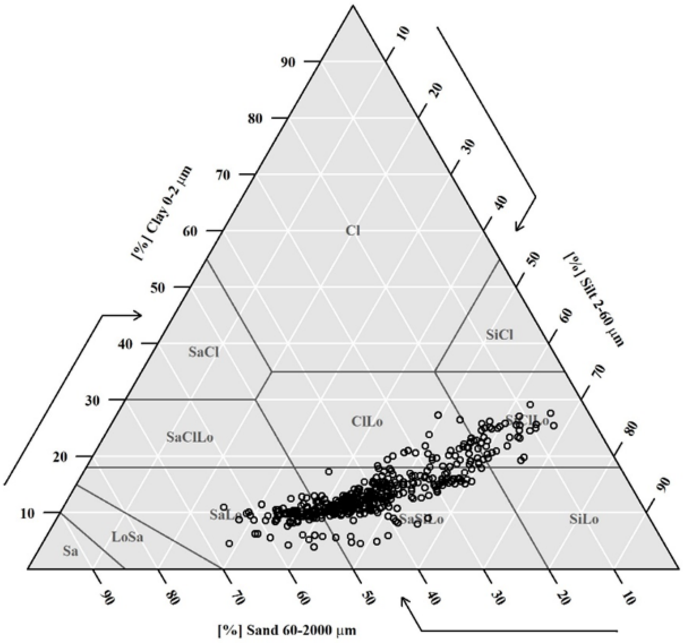


Figure 1. Soil texture for arable fields across England and Scotland, texture defined by the sand, silt and clay content of soils and can influence the propensity for a soil to store carbon.

Applying organic amendments, such as compost, to soil can not only increase water stable aggregates (**Figure 2**) but also the resilience of a soil to trafficking (see an example of tramline compaction in **Figure 3**). Soil compaction is a significant issue, in this edition of the Soil Sentinel there is an article on a recent project "Assessing the socio-economic impacts of soil degradation on Scotland's water environment" which estimated the cost to be £16-49 million each year on yield alone. Work within Healthy Soils has shown an increased ability of soil amended with compost to rebound following the application of a load similar to that of a tractor under wet conditions. Such research indicates the potential to increase soil physical resilience and links to soil structure.

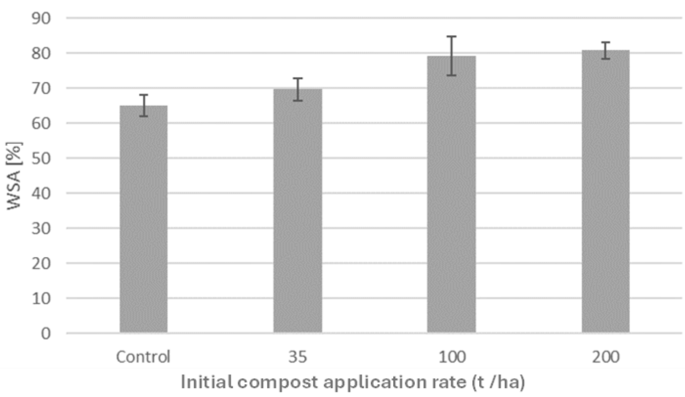


Figure 2. Water stable aggregate (WSA) increases associated with different initial compost application rates. Plots were established at rates of 35 – 200 t ha in ~2004 before all plots (excluding control) received lower, annual, applications.

Moving forward it will be critical to understand the time frames by which this resilience can increase. Increases in soil carbon can take at a minimum 5-6 years to be seen with equilibrium reached after a predicted period of up to 150 years. Soil structure may increase over shorter time periods, we are currently seeing preliminary evidence that suggests increases in aggregate stability over a short, 12 month, period under cover cropping or green manure (a cover crop grown for a longer period). With changes in rainfall patterns, both temporally and spatially, increasing the soils capacity to buffer during wet and dry periods is key. Evidence is suggesting that cover crops maybe a way to help but there is still a need to have better cover crop growth within a Scottish climate.

Figure 3. Example of tramline compaction resulting in preferential transport pathway for overland flow.

Research is ongoing into alternative approaches to cover crop management and quantifying these changes in soil resilience and health. In the future, multiple benefits may be achieved through better cover crop growth resulting in increased soil carbon, reducing the amount of fertiliser applied and improving soil water availability to sustain crop growth in dry periods and reducing flooding and erosion during periods of heavy or extreme rainfall.

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

Below are some recent publications from the ***Healthy Soils (JHI-D3-1)***, ***CentrePeat (JHI-D3-2)*** *and the* ***Achieving Multi-Purpose Nature Based Solutions (AiM NBS) (JHI-D2-2)*** *projects.*

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Journal of Hydrology
Volume 635, May 2024, 131164

Research papers

New data-based analysis tool for functioning of natural flood management measures reveals multi-site time-variable effectiveness

Martyn T. Roberts[a b], Mark E. Wilkinson[b], Paul D. Hallett[c], Josie Geris[a]

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Geoderma Regional
Volume 38, September 2024, e00833

Spatial disaggregation of a legacy soil map to support digital soil and land evaluation assessments in Scotland

Zisis Gagkas, Allan Lilly

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European Journal of Agronomy
Volume 158, August 2024, 127214

Future proofing a long-term agricultural experiment for decades to come: Relocation and redesign

C.A. Watson[a 1], C.F.E. Topp[b 2], A. Mead[c 3], F. Fraser[a 4], M. Fernández-Huarte[d 5], J. Horne[a e 6], G.I. Paton[e 7], P.D. Hallett[e 8], G. Norton[e 9], R.I. Graham[a 10], R.L. Walker[a 11]

Global Change Biology

RESEARCH ARTICLE | Open Access

Crop rotational diversity can mitigate climate-induced grain yield losses

Alessio Costa, Riccardo Bommarco, Monique E. Smith, Timothy Bowles, Amélie C. M. Gaudin, Christine A. Watson, Remedios Alarcón, Antonio Berti, Andrzej Blecharczyk ... See all authors

First published: 07 May 2024 | https://doi.org/10.1111/gcb.17298

Review Article

Management of and future perspectives on plant parasitic nematodes associated with *Narcissus* grown in the UK

Vongai Chekanai, Roy Neilson, Mark Clark, Simon G. Edwards, David Roberts & Matthew Back

Published online: 19 Jul 2024

Cite this article https://doi.org/10.1080/14620316.2024.2380398 Check for updates

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 7th 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****.*

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