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LEADING IDEAS
FOR BETTER LIVES
Leading ideas on
Soils and Biodiversity
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# Leading ideas on soils and biodiversity

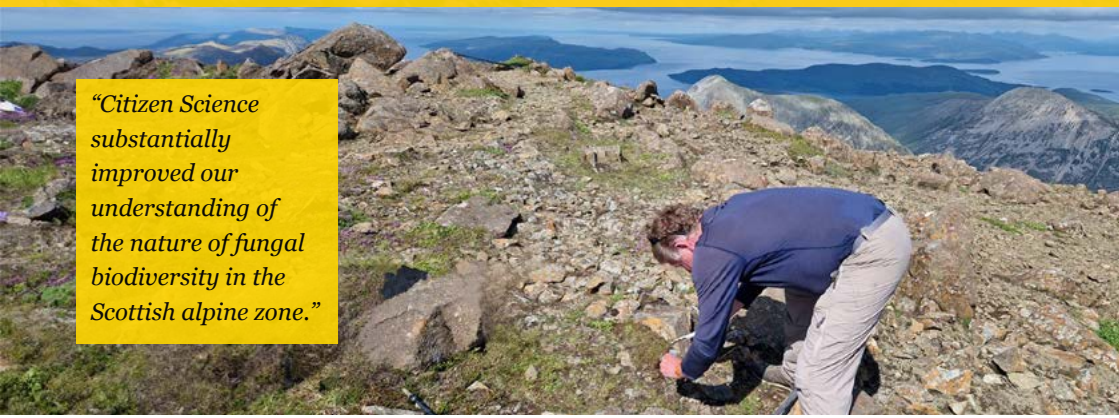
## Introduction:

**The Scottish Government's Strategic Research Programme (SRP) for environment, land use, agriculture, food and rural communities is delivered by the Scottish Environment, Food and Agriculture Research Institutions (SEFARI).**

The SRP is the mid to long term research component of the Scottish Government's Environment Natural Resources and Agriculture (ENRA) Strategic Portfolio focused on environment, natural resources, agriculture, food and rural communities research. The Portfolio also underpins national resources at SEFARI, including research farms and national data sets and funds policy-responsive centres of expertise which bring together the expertise of Universities, SEFARI and Agencies. This work is brought together under an ethos of "leading Ideas for better lives" by SEFARI Gateway, the Portfolio's Centre of Expertise for Knowledge Exchange and Innovation.

This Leading Ideas Booklet provides insights into some of the soils research undertaken and the positive benefits it delivers to Scotland, UK and Global soil health, biodiversity productivity and climate resilience. This research is developing better policy agendas, delivering innovation, new practices and engaging society; contributing to Scotland's National Outcomes as aligned to the United Nations Sustainable Development Goals.

# Mountain heights, hidden depths



*"Citizen Science substantially improved our understanding of the nature of fungal biodiversity in the Scottish alpine zone."*

**Soil biodiversity is critical to ecosystem functioning, but understanding of the diversity and distribution of soil organisms lags far behind that of biodiversity above ground.**

This is particularly true in the alpine zones which support some of our most natural habitats and provide important ecosystem services, including supporting unique biodiversity, carbon storage and water supply. The difficulty of accessing remote locations in alpine areas, the challenges with detecting organisms that spend all or most of their time below ground, and a shortage of skilled taxonomists have all contributed to the current lack of knowledge.

The Mountain Heights, Hidden Depths project aims to considerably increase our knowledge of alpine soil biodiversity, and also to raise public awareness, by bringing together hill-going Citizen Scientists and DNA technologies to map soil biodiversity across Scotland's 282 Munros (mountains over 3000ft).

Citizen Scientists are collecting soil and photographing mountains across Scotland. In a successful pilot study in 2021, conducted in partnership with conservation charity Plantlife:

- 73 volunteers collected soils from 55 Munros in the Cairngorms National Park
- Analysis of DNA in the soil, detected 2748 fungal taxa, including several species new to the UK
- This substantially improved understanding of fungal diversity in the Scottish alpine zone
- Accompanying media and outreach significantly increased the public profile of our alpine soil biodiversity

This successful approach is being extended to explore the distribution of a wider range of soil organisms and covers the diverse range of mountain climates and geologies present in Scotland.

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# The Scottish Biodiversity Strategy to 2045

*"The Strategy shapes actions for halting biodiversity loss and to be nature positive by 2030."*

**In a similar manner to climate change, the loss of species and degradation of our natural environment is a severe threat to humanity. The action required is both urgent and transformative.**

The Scottish Government strategy sets out a framework and a vision for a future where Scotland's natural environment is restored and supports thriving communities and wildlife. The strategy proposes outcomes and key actions to deliver this and establishes the platform for the government delivery and the collaboration with partners, stakeholders and land managers. This identifies six objectives which have shaped the actions to deliver the high-level goals, to halt the loss of biodiversity and to aim to be nature-positive by 2030, through:

- Accelerating restoration and regeneration
- Protecting nature on land and at sea, across and beyond protected areas
- Embedding nature-positive farming, fishing and forestry
- Protecting and support the recovery of vulnerable and important species and habitats
- Investing in nature
- Taking action on the indirect drivers of biodiversity loss

Examples of evidence contributing to this strategy from the SRP are the Alliance for Scotland's Rainforest and the partnership programme Peatland ACTION, putting more than 35,000 hectares of peatland on the road to recovery, with Flows to the Future Project (2014 to 2019) restoring large areas of blanket bog in the heart of the Flow Country, an area of peatland and wetland within Caithness and Sutherland, that had been previously damaged by forestry planting.

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# The 2023 State of Nature report


**Research staff in the SRP have been contributing to the 2023 State of Nature reporting (in Scotland and the UK).**

These influential reports contain information on many species in the UK and focus on three measures of biodiversity change: abundance (the number of individuals), distribution (the proportion of sites occupied), and extinction risk.

These measures have been assessed for hundreds and in some cases thousands of species native to the UK.

Results show:

- The number of species that have increased or decreased in abundance over time
- The average change in abundance or distribution across species over time
- The proportion of species at risk of being lost

The 2023 State of Nature report UK

The 2023 State of Nature report for Scotland

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# Scotland's soil health

*"Research on soil health is providing essential data to support informed decision-making, protecting the soil resource for future generations."*

**Soil health is a broad term that can be related to the capacity of soils to sustainably deliver ecosystem services such as carbon storage, food production, reducing water pollution and supporting biodiversity provision.**

Scotland's soils are incredibly diverse, due to a diverse underlying geology, climate gradients and land uses, and consequently, their capacity to provide specific ecosystem services is highly context specific. Research funded by the Scottish Government ENRA SRP has a focus on management options to protect and enhance the benefits that soils provide, across the wide range of soil types and land uses in Scotland:

- Research on peatlands has established a network of sites, quantifying greenhouse gas emission-reduction (and other) benefits of restoration practices, as an important element of achieving national Net Zero targets
- Research on agricultural soils is evaluating indicators of soil health in the context of restorative management options that aim to balance requirements for food production, while minimising environmental impacts of production systems

Research in this area is timely, with the recent EU Soil Monitoring and Resilience Directive and the UK developing payment schemes for land management that promotes environmental benefits. Research on soil health is linked with the design and development of a Scottish Soil Monitoring Framework aiming to effectively capture the spatial diversity of soils, and their changes over time, providing essential data to support informed decision-making, protecting the soil resource for future generations.

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# Indicators for monitoring Scotland's environmental health

*"Strategic Research is providing indicators for environmental health to help target the most appropriate action on areas most in need of protection and restoration."*

**We need suitable environmental indicators to monitor the state of our natural environment and to aid stakeholders in targeting the most appropriate action on areas most in need of protection and restoration.**

The SRP has been working with key stakeholders, in particular NatureScot, on a range of indicators, including:

- Using existing habitat preference indicators to identify drivers of species loss and gain in both bryophytes and lichens. Bryophyte species of warmer, more nutrient richer and shadier areas all increased, whilst there was evidence of a replacement of lichens by bryophytes
- Developing methods to link species' trends to individual habitats to allow the targeting of action for conservation efforts to be more effective
- Updating the Ecosystem Health Indicators that show how nitrogen and climate are affecting our biodiversity. This has been developed using long-term national-scale bryophyte records and allows the tracking of pollution and climate change impacts at a national and at regional scales

Link to indicators

Link to the research

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# Harnessing natural plant-soil interactions for sustainable production and soil health


*"SEFARI is pioneering research into management practices that reduce soil greenhouse gas (GHG) emissions and promote the long-term sustainability of the soil resource."*

**In the context of the Scottish Government vision for sustainable and regenerative agriculture, SEFARI is pioneering research into management practices that reduce soil greenhouse gas (GHG) emissions and promote the long-term sustainability of the soil resource.**

To achieve these goals significant shifts in land management are required, including replacement of GHG intensive chemical fertilisers. As modern crop varieties have been selected for optimised use of chemical inputs, there is a need to develop new cultivars that are adapted to use of alternative nutrient sources, such as organic amendments. SEFARI has investigated variation in crop germplasm in use of organic nutrient sources in soil and have discovered interesting findings, including:

- Significant variation in capacity to use soil organic nutrient sources amongst current elite barley cultivars, wild relatives and crosses has been identified
- Variation mediated by plant-specific interactions with root-associated microbiomes which was demonstrated to have a plant genetic basis

This research continues within the SRP and also in partnership with industry to support goals of Net Zero and environmental sustainability. The research has also been translated for application to maize production systems in southern Africa, where climate resilience and soil health are imperatives for food security.

Link to research

Link to maize article

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# Soil management for healthy and resilient soils

*"60% of European soils being unhealthy with soil degradation currently estimated to cost over £40 billion each year through the loss of essential services."*

**Soil is key to many ecosystem services and functions such as water regulation, carbon storage, and food production.**

There is an increasing awareness of the need to promote practices to both maintain and improve the contribution soil makes to the wider environment. Understanding soil management practices which improve these services and functions will potentially facilitate support in their adoption. The scale of unhealthy soil is significant, with 60% of European soils being unhealthy with soil degradation currently estimated to cost over £40 billion each year through the loss of essential services. July 2023 saw the EU publish the Soil Monitoring and Resilience Directive which aims to tackle this and achieve healthy soil by 2050 highlighting the need to adopt approaches which improve soil health. Through the SRP we are looking at changes in soil health and function through the incorporation of organic soil amendments, such as green waste compost.
Key findings to date have shown:

- Increases in soil organic carbon in both the surface (0-25cm depth) and also subsoils (30cm depth)
- Improvements in soil structure through compost application when compared to unamended soils
- Greater water holding capacity in surface soils, and some improvement in subsoil
- Increased plant available water in surface soils
- Improved resilience to soil compaction with soils rebounding more following application in plots with increased compost application rates

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# Improving soil literacy in society

*"To fully deliver healthy and functional soils will require knowledge and awareness across society."*

**Soil health is the ability of soil to maintain productivity, diversity, and multiple benefits for terrestrial ecosystems. Healthy functioning soils provide and regulate a broad spectrum of services and play a fundamental role in sustaining life on earth. Soils and their capability to function are under pressure due to a changing climate, erosion, loss of organic matter and land management practices.**

While the importance of soil is recognised by many, there is a disconnect between wider society and the importance of soil to their daily lives. To fully deliver healthy and functional soils will require knowledge and awareness of the importance of long-term soil health and its value across society. This is one of the eight principles of the European Mission for Soil to support the EU Soil Strategy for 2030. Key to delivering this is citizen engagement.

Along with European partners, researchers in the SRP, using methods developed through SRP funding, will be delivering a major European initiative to increase soil literacy. This will be achieved through engaging citizens in soil science, increasing their knowledge by generating new data, and raising awareness on the ecological and societal importance of soils. This will be delivered through a co-funded project by Horizon Europe and UKRI (The road to healthier soils, ECHO).

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# European collaboration to support soil literacy

*"Creating a long-term open access repository aligned with the European Soil Observatory and supported with citizen science data to be used not only by scientists but also by the public and end-users alike."*

**A co-funded project by Horizon Europe and UKRI , The road to healthier soils (ECHO), is based on three main principles:**

- To engage citizens motivating them to protect and restore soils
- To empower citizens by providing knowledge and an active role in data collection
- To enable citizens to directly participate in decision-making on soil issues

ECHO will achieve this through co-creation with societal groups as a cornerstone of delivering a step change in increased soil literacy in society. As part of this SRP researchers are one of three hubs that will generate DNA-based soil biodiversity data from 16500 sites across Europe, including Scotland. ECHO will create ECHOREPO, a long-term open access repository aligned with the European Soil Observatory and supported with citizen science data to be used not only by scientists but also by the public and end-users.

Link to ECHOPRO

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# Forgotten foods, forgotten visions


*"the vision of a UK, and even Scottish based canning industry is at least 60 years old."*

**In the 1950s researchers were supported to breed pulse crop types especially adapted to the Scottish climate, and to help develop local food processing ventures and therefore food- and nutritional -security.**

You may already have heard about 'Henry Taylor's Scottish Faba Bean', if not more can be discovered here. Henry was not working alone and in parallel with his interests were the efforts of W. Greta Priestley, another pulse crop breeder who helped develop three varieties of common bean (*Phaseolus vulgaris L.*), the same crop species which gives us navy or haricot beans - which are used in the UKs most popular pulse food, baked beans.

Common beans are the most consumed bean globally, yet their production in the UK remains elusive, with millions of tonnes being imported every year. Recently, varieties developed for the UK through the University or Warwick are currently undergoing commercial trials in England. Yet, the vision of a UK, and even Scottish-based bean canning industry, is at least 60 years old as witnessed by the types developed by Henry and Greta. Greta's dream was to create a bean canning industry in Scotland.

- Three of Greta's Scottish common bean cultivars had been all-but forgotten and were recently rediscovered in the seed store at one of the research Institutes; these are Glamis, Glencarse, and Glen Lyon
- In collaboration with Richie Walsh, Scotland's Seed Sovereignty Coordinator of the Gaia Foundation, the three varieties have been regrown in polytunnels with a view towards field trials from 2024

With the upsurge of interest in locally produced forgotten foods, we hope that Greta Priestly's vision of improved local food security via processing by Scottish-based food companies may be revisited.

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# Managing soil pH for crop productivity and soil functions

*"field trials provide a fantastic resource to understand the impact of chemical changes on the soil using modern techniques unimaginable when the original treatments were begun."*

**Soil acidification (where soil pH drops below 5.5) is a major cause of soil degradation and poor crop productivity thought to affect approximately 40% or arable land globally. While knowledge exists on the chemical principles of soil acidification, changes in atmospheric deposition and climate are continuing challenges.**

- Using lime to increase soil pH is a cost-effective solution for farmers but its impacts on greenhouse gas release are complex, generally causing increases in soil respiration and $CO_2$ emissions but potentially resulting in decreases in nitrous oxides and methane emissions
- There is however less understanding of how pH influences soil biology in relation to soil function, particularly the relationships between soil biology, soil health and crop production

In 2021 a new long-term field experiment was established using a unique soil resource where soil had been managed at different pH levels from 4.5 (very acidic) to 7.5 (alkaline) since 1960. These plots have been paired with new plots where, over preceding decades, the soil has been subject to conventional agricultural practice but is now in the process of being managed to produce pH changes to mimic the original plots. This provides a fantastic resource to understand the impact of these chemical changes on the soil microbiome and the stress responses of community members using modern techniques unimaginable when the original treatments were begun. The experiment also includes both permanent plots of perennial crops (grass and herbal leys) and rotations including different functional crop species (grain legumes, cereals and brassicas) and short-term herbal leys.

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# Improved mapping of peat soils and effective monitoring of peatland conditions

*"there is an urgent need to better understand where peat soils are located, what condition these peatlands are in, and how much they emit before and after rewetting or other changes in management."*

**Peatlands are the world's largest terrestrial carbon store, despite only occupying 3-4% of planet's land surface. Degradation through active drainage, land cover conversion, and extraction, of only a small proportion of peatlands globally have turned what was once a global carbon sink into a source of carbon contributing 3% to global emissions.**

The two global hotspots of such degradation are Europe and South-East Asia. Peat-rich nations in these areas, such as Scotland, where at least 25% of the land surface is covered in peat soils of over 50 cm in depth, therefore have a moral obligation to protect remaining peat carbon stores and reduce further emissions as much as feasible. This means that there is an urgent need to better understand where peat soils are located, what condition these peatlands are in, and how much they emit before and after rewetting or other changes in management. In the current SRP, alongside ongoing European projects, we are developing:

- Better validation datasets for digital soil mapping approaches
- Earth Observation-based tools to understand and monitor peatland degradation features and rewetting trajectories
- Directly monitoring greenhouse gas emissions and losses of carbon through erosive processes or use water table and soil moisture proxies across a network of sites in Scotland on different land cover types on peat
- Collating data on the values of peatland ecosystem services. This work is enabling better estimates of the baseline losses of carbon from our peatlands, establishing robust data on the abatement potential that can be achieved by full or partial rewetting practices, and paves the way to better monitoring of our peatland resources

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