Healthy soils

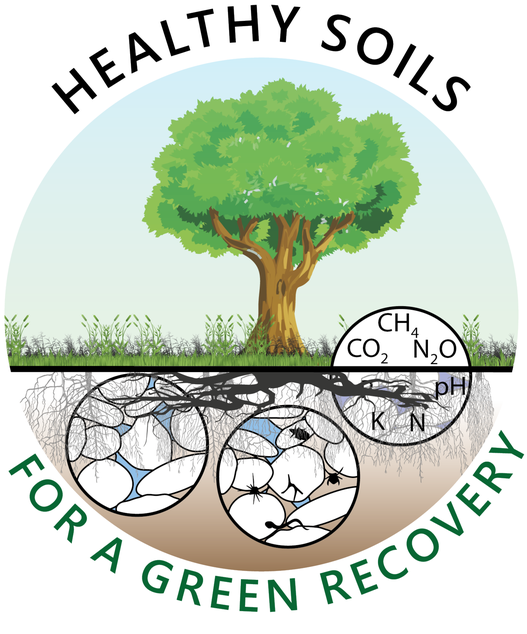
- Healthy living soils keep us, and the world around us, alive
- Understanding plant-soil interactions is key to addressing agricultural sustainability and natural ecosystem management
- Protecting and enhancing soil health will contribute to reaching net zero GHGs policy targets and thus contribute to mitigating the climate emergency
- Development of robust soil indicators is crucial to support a national soil monitoring framework

Threats to healthy soils

- The concept of soil health has become more widely used in recent years and includes a consideration of soil physics, chemistry, and biology
- More extreme weather events are leading to increased soil loss by erosion in Eastern Scotland with areas under cultivation more susceptible to erosion when combined with slope and soil type
- Every year good quality arable land is lost to roads and urban development in Scotland. Soil sealing by concrete leads to biodiversity losses but also increased risks of flooding
- Across the UK arable soils are estimated to have already lost 40-60% of organic carbon. Reintegration of short-term leys and cover crops into arable rotations can help to halt this decline additionally, improving water infiltration and reducing surface disruption to the aggregates
- Many agricultural soils are below optimum pH in terms of both crop and grassland production. This influences productivity, biodiversity and carbon cycling

Scottish Government – Strategic Research Programme 2022 – 2027

- Scottish Government: Rural & Environment Science & Analytical Services new Strategic Research Programme 2022 to 2027 which includes many soils related projects
- Projects include:
  - Healthy Soils for a Green Recovery
  - CentrePeat
  - Agriculture Climate and Carbon
  - Crop Improvement for Sustainable production in a Changing Environment
  - Tools to support provenance of Scottish food produce
  - Integrated Socio-Environmental Modelling of Policy Scenarios for Scotland
  - Understanding the dynamics of antimicrobial resistance Understanding the dynamics of antimicrobial resistance genes (ARGs) flux in the soil, animals and humans in different fertilisation practices for grasslands.
  - Understanding the value of Scotland's agricultural soil natural capital.
- Also funded are underpinning projects including the National Soils Archive of Scotland, the Scottish Soil Database and maps, the Environmental Change Network and the Centre for Sustainable Cropping and Centres of Expertise for example the ClimateXChange

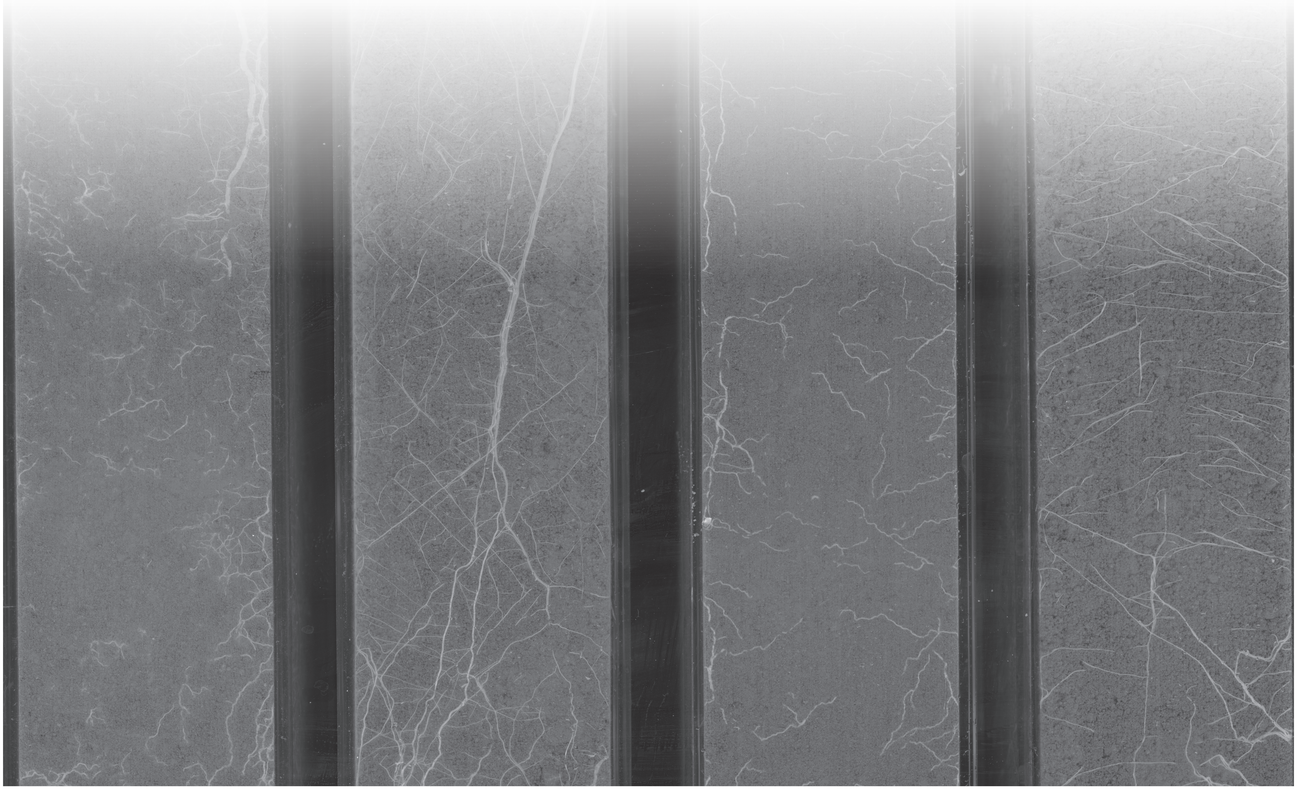


Arable soils

- Arable soils are required to produce food, feed, and other bioproducts (e.g., medical & biofuels)
- Increasing pressures on farmers to improve the local environment, reduce pollution (e.g., via run off), and to mitigate climate change through reduction in greenhouse emissions while maintaining increasing yields
- Arable soils can be exposed to pressures, such as tillage, changing crop/plant cover, chemical inputs (nutrients, pesticides and herbicides) effects of local climate and climate change, with short and long-term impacts on soil physical and biological status
- Long-term trials supporting research into the interaction between soil management, diversification, crop performance and soil sustainability are supported at both The James Hutton Institute and SRUC farms

Plant and soil interactions

- The interface between roots and soil controls the dynamics of many of the earths most critical biogeochemical cycles including carbon, nutrients and water
- This interface is also at the forefront of approaches to improve the adaptation and mitigation of agricultural systems to climate change and therefore wider agricultural sustainability
- The root soil interface is a zone of great complexity and understanding interactions between physical, biological and chemical properties in paramount with interactions between specific root traits and the rhizosphere microbiome being important
- Projects funded by the Scottish Government and the EU have been focussing on this critical zone



Land-use

- Around 70% of Scotland's land area is under some form of agricultural management and woodland covers 18%
- Scotland's soils hold more than 3,000 megatonnes of carbon, around 60% of which is held in deep peat soils
- Restoring Scotland's peatlands is a major priority for future land management
- Implementing Scotland's Land Use Strategy presents challenges with the multi-functional middle grade land which has to provide clean water, biodiversity, recreation and food production
- Co-products from the whisky industry provides additional organic matter and trace elements for coarse textured arable and grassland soils

Legacy soil datasets and maps

- Scotland also has a considerable amount of good quality soil data due to a long history of soil mapping, quantification of soil properties and long-term field trials supported primarily by public funding
- Soil maps are available in digital and hard copy that show the distribution of the different soil types found in Scotland
- The James Hutton Institute hosts the National Soils Archive of around 60,000 physical soil samples and a related database of around 15,000 soil profiles from all over Scotland
- The Scottish Soil Fertility database has agronomic data from around 180,000 soil samples primarily from cultivated land

Climate change

- Climate change is affecting Scottish soils, through changing weather patterns, and increasing the occurrence of for extreme weather events, with consequences such as flooding, drought and soil erosion and compaction will large scale consequences. These changes need mitigation strategies
- Studies investigate the fluxes involved in the release of climate change related gases, consequences of climate change and mitigation strategies within, for example, arable and pasture farming, peat systems and forestry and the combined consequences of overall land use choices
- The Glensaugh Climate Positive Farm is home to the climate positive farming initiative – Tackling the climate and biodiversity crises with transformative farming and technological innovations
- The ClimateXChange is Scotland's centre for expertise connecting climate change research and policy

Nature based solutions to soil threats

- Nature based solutions can mitigate threats to soils while providing wider ecosystem benefits
- Some Nature Based Solutions act directly on soil processes while others are implemented within the landscape to protect the wider environment
- Achieving maximum benefits from nature-based solutions requires land to be managed at a landscape-scale using a right measure right place approach
- Threats to soil functions and the potential for mitigating these through Nature Based solutions have been assessed through key reviews, modelling and the development of decision support tools

Urban soils

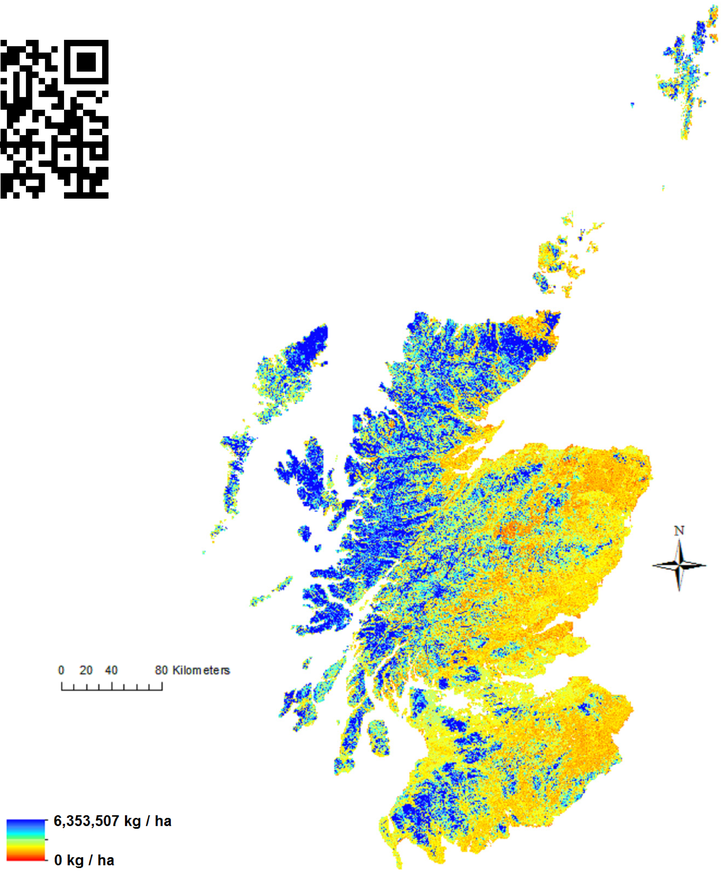
- Scotland generates about a million tonnes of construction and demolition (C&D) waste per year, much of which goes to landfill where its potential geochemical value is lost, because it is mineralogically similar in many ways to soils
- Our research tests the viability of using locally produced waste materials to produce ‘technosol’ to mimic a real soil, and for a range of non-foods applications. We created mixtures simply by combining C&D with green waste compost (GWC) using a cement mixer
- We will be working with industry partners in the next phase of work to help select C&D materials with lower gypsum contents, so that we can refine the technical soils (technosol) recipe further

Forensics and pollutants (micro plastics)

- Soil forensic science links environmental science (including soils, geology, ecology, botany and eDNA) with the law and delivers intelligence and evidence to the criminal justice system
- Soil, water, dust, air, food, alcohol, honey and water have all been analysed and characterised to the highest quality standard and have been used in civilian and criminal courts across the world
- On-going research in soil science is developing new and improved methods that can be applied to increasingly smaller and older samples, allowing the approach to be used in cold cases in an increasing number of cases, including soil contamination with both inorganics and organics
- Organic wastes introduced to soil showed an increased/ accumulation of contaminants. With multiple applications of organic fertilisers there were higher antimicrobial resistance genes (ARGs) in the soil in comparison to the conventional inorganic fertiliser

Digital soil mapping and remote sensing

- Digital Soil Mapping (DSM) is used to map soil properties and functions, along with uncertainty of prediction, by coupling soil survey information with Remote Sensing (RS)
- Data mining and machine learning are used for predicting spatial distribution of soil properties, soil types and soil water regulatory functions
- DSM outputs are being used for conducting Digital Soil Assessments (DSA) designed to support the sustainable management of natural resources
- DSM outputs include maps of peat extent and condition in Scotland produced with combined DSM/RS approaches, and national spatially-disaggregated maps of soil hydrological classes that are used to predict hydrological response in ungauged catchments



Biodiversity and microbial processes

- Understanding soil biodiversity and their associated function is key to defining soil health, a metric of strategic importance
- Managing soils for diverse soil communities has the potential to yield multiple benefits including better nutrient management and soil structure
- Microbial communities may also provide a mechanism to offset GHGs, sequester C and act as a repository for antibiotics
- Long term field trials looking at agronomic management and biological stressors offer a means to test the potential effects of management on complex soil communities
- Soil biology is considered an important indicator of soil health, with the assumption that there is a diversity of soil organisms (microbes & mesofauna) and a low level of pathogenic or harmful microbes

Data and innovative monitoring

- Novel field sensing methods to improve the speed and cost-effectiveness of soil analysis and condition assessment
- Equipment and techniques we are developing can allow multiple soil properties to be measured or estimated with a single scan
- Machine learning and image analysis approaches are being developed for rapidly assessing topsoil condition using smartphones in the field
- Infrared (IR) Spectroscopic analysis in the field will make soil monitoring possible on a far greater temporal and spatial scale

Education

- Education and training, including flexible learning approaches, are fundamental for developing the next generation of soils experts for policy, practice and academia
- The SRUC/University of Edinburgh MSc in Soils and Sustainability, attracts students from all over the world
- Our scientists provide material and activities for school children from primary to senior levels
- Scotland has a strong community of PhD students studying both fundamental and applied aspects of soil science
- The Scottish Farm Advisory Service provides events and training for farmers and land managers on soil health

Policy and communication

- Communication with policy and stakeholders are key in delivery of scientific outputs
- Scottish Government funded research delivered through direct engagement with policy teams (for example meetings, soils cafés, soil awareness sessions) and also regular bulletins (The Soil Sentinel)
- Targeted research for government through Scotland's Centres of Expertise – an example of this is ClimateXChange and recent work on soil health indicators
- Collective dissemination of soils research from multiple organisations funded by Scottish Government through the SEFARI Gateway, another of Scotland's centres of expertise, to the public, industry and stakeholders at a national scale
- Collaborative working between government, SEPA, and NatureScot for delivery online through Scotland's soils website