MICROBIOLOGY SOCIETY

Soil Health Explainer

> Soils are critically important to the functioning and sustainability of the planet. They provide a range of essential functions, including producing the vast majority of our food, filtering our water and regulating climate. Most of these functions are underpinned by the micro-organisms, making the knowledge of how they work of vital importance.
>
> *Dr Fiona Brennan, Irish Agriculture and Food Development Authority*

Key Points

- Soil health is vital for maintaining food security, preserving biodiversity and combatting climate change. Microbes are an important component of soil health and play a role in a range of processes from nutrient cycling and carbon storage, to plant disease.
- Ensuring healthy soil and achieving the United Nations (UN) Sustainable Development Goals (SDGs) are intrinsically linked. Microbiology can help to achieve the SDGs by exploring new possibilities for the restoration and promotion of healthy microbial populations in the soil.
- Despite some scientific research and policy developments, urgent investment in monitoring and measurable targets are needed to achieve sustainable management of healthy soil.

The quality of soil and its suitability for growing crops has been important since humans developed agriculture. Back in 1888, *Rhizobium* spp. were found living in the roots of leguminous plants; first suggesting the importance of soil microbes. It is now known that soil microbiomes are diverse communities with complex interactions, made up of a vast array of bacteria, fungi, archaea, protists and viruses, which are crucial for carbon and nutrient cycling, plant health and even soil structure.

Food production depends on croplands and water supply, which are under strain as human populations increase. Microbiology plays a key role in securing a future in which healthy and sustainable soils can effectively support agriculture and food security, while preserving our limited land resources.

Antimicrobial Resistance and the Sustainable Development Goals

In 2015 the United Nations (UN) adopted the Sustainable Development Goals (SDGs), a set of targets for the world to achieve by 2030. Soil health is vital for achieving the UN SDGs, particularly those associated with food production, health and wellbeing, clean water, climate change and biodiversity (see box 1).

Goal 2: Zero Hunger

Soil microbiomes are an important component of many processes which influence soil fertility, including nitrogen cycling, and may help to reduce the reliance on artificial fertilisers and promote the sustainable intensification of agriculture. The recognition that intensive agricultural methods such as tilling and excessive fertiliser application negatively impact soil microbiomes, has led to a move towards farming methods that improve soil health, such as cover cropping and minimum tillage.

Goal 3: Good Health and Wellbeing

Bioremediation of polluted soils removes contaminants in an efficient manner, by adding microbes to the soil or promoting the growth of those already present. These contaminants often impact human and environmental health and wellbeing. By removing them, more land becomes available for recreation, housing and agriculture.

Goal 6: Clean Water and Sanitation

Bacteria and fungi influence the physical structure of soil, affecting water resource availability, flood mitigation and soil erosion mitigation. Wastewater sludge is often applied to soils, both to increase soil fertility and as a method of disposal. Research has also shown that soils can be polluted with pathogens and noxious compounds present in wastewater sludge.

Goal 13: Climate Action

Microbial activity is vital for the decomposition of organic matter and carbon storage. Microbes are also involved in the cycling of important nutrients in soil, such as phosphorous and nitrogen, which contribute to climate change in the form of potent greenhouse gases. Understanding and regulating their availability and concentrations is important for combatting climate change.

Goal 15: Life on land

Microbes can help halt biodiversity loss through increased nutrient availability and the breakdown of organic matter, which allows other organisms to prosper. Microbial components also form a large part of diversity in the soil and should be considered when assessing and conserving soil biodiversity.

Box 1. Sustainable Development Goals relevant to soil health

Sustainable agriculture and soil security

Climate extremes and climate smart agriculture

Water resources and filtering

Pathogens, contaminants and nutrient cycles

Land degradation and biodiversity loss

Tackling Soil Health

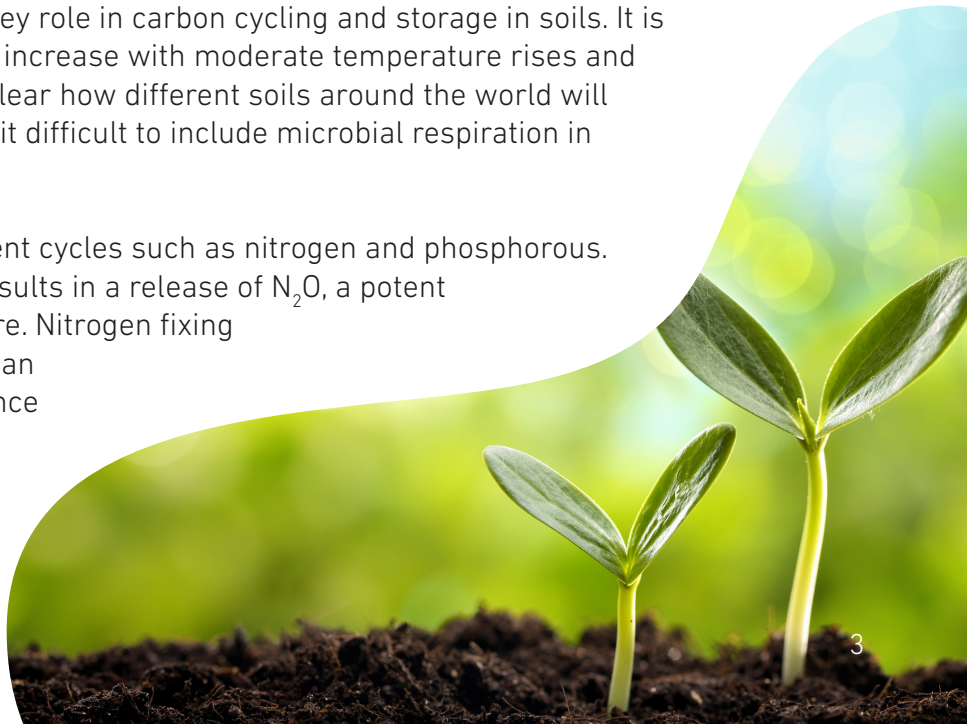
Defining a 'healthy' soil

There is currently no generally accepted definition of a 'healthy' soil microbiome, and therefore no way of categorising soil into good, bad or indifferent. The soil is a hugely complex environment which varies temporally and spatially, and this complexity of soil types means that categorisation and transferability of bioindicators, is not currently achievable. The link between taxonomic diversity and function also makes describing a healthy soil microbiome difficult, as many of the pathways are not understood. Many molecules identified in the soil have no known function and identifying the taxa that produce them is very challenging.

Nutrient cycling

The link between function and diversity is particularly important for soil health under a changing climate. Microbes play a key role in carbon cycling and storage in soils. It is likely that microbial respiration will increase with moderate temperature rises and water availability. However, it is unclear how different soils around the world will respond to climate change, making it difficult to include microbial respiration in climate models.

Soil microbes influence other nutrient cycles such as nitrogen and phosphorous. Excess use of nitrogen fertilisers results in a release of N_2O, a potent greenhouse gas, into the atmosphere. Nitrogen fixing microbes and their genes may play an important role in reducing the reliance on artificial fertilisers and reduce the concentration of N_2O released into the atmosphere.



Box 2. New Technology

Improving the understanding of soil microbiota is more challenging, because a large proportion of soil microbes are not currently culturable. New methods, such as metagenomics, and new technology, such as nanopore sequencing, are allowing increasingly rapid and detailed analysis of microbial diversity. Integration of metagenomics with methods such as mass spectrometry is leading to a better understanding of microbiome function, especially with the development of mechanistic models and machine learning. However, in order to fully utilise emerging technologies, an increase in skills training and computational power is required.

Soil Health Policy

Soil health in the UK is captured in several devolved policies and strategies. In England, Defra's 25-year Environment Plan (2018) sets out a goal to improve England's soils by 2030, and the new Agriculture Bill establishes subsidies for managing healthy soils. In Wales, the Well-being of Future Generations Act (2015) refers to improving biodiversity and sustainable land management. In 2016 a State of Scotland's Soils Report, published by the Scottish Environmental Protection Agency highlighted the importance of soil health, and the Scottish Soils Framework draws together measures from different policy areas to form a cohesive framework for soil management.

Recently, although the absence of a government in Northern Ireland has prevented new legislation and policy from progressing, the Executive is currently considering how farming subsidies will change following the UK leaving the EU, with an expected increased focus on environmental improvement to mirror the new Agriculture Bill in England and similar policies.

Most of the soil policy applicable in Ireland comes from the European Union (EU). This includes the Soil Thematic Strategy (2006) and the Roadmap to a Resource Efficient Europe (2011), which aims to achieve sustainable resource management with no net land take, by 2050. However, several reports have shown that the EU is not on target to achieve sustainable management of land and soils by 2050.

Box 3. A Sustainable Future

To mark the Society's 75th anniversary, we are embarking on a project that will celebrate and champion the role of microbiology in addressing the world's biggest challenges, within the global framework of the United Nations Sustainable Development Goals.

The 'A Sustainable Future' project focuses on three areas where the contribution of microbiology in achieving the goals is particularly significant. These include antimicrobial resistance, the circular economy, and soil health. If you have expertise in one of these areas and would like to share your work with us in the form of a case study please contact us at policy@microbiologysociety.org

Further Reading

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