Applied Microbiology International

POLICY REPORT

JANUARY 2026

Improving Soil Health in the UK

Table of Contents

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Overview

This report presents key recommendations and considerations for:

- Establishing a shared definition of healthy soil that can be applied consistently across the UK's four nations.
- Identifying and selecting appropriate biological indicators to measure soil health effectively.
- Promoting sustainable land use practices to replace those that are currently widespread but environmentally unsustainable.

Drawing on insights from a cross-disciplinary roundtable convened to advance dialogue on key themes from a previous policy publication (1) on soil health in the UK, the discussions focused on three central topics: the need for and complexities around agreeing a definition of healthy soil; the identification of potential biological indicators of soil health; and the implementation of more sustainable land use practices.

The report outlines specific recommendations and considerations under each of these themes, alongside an overarching call for stronger, more effective communication between all soil stakeholders – academia, policymakers, industries, farmers and land managers, funders, and beyond – to build trust and align diverse needs across these communities, to nurture and protect soil health in the years to come.

The glossary available on page 14 defines all scientific terminology used throughout this report.

Key Message

The future of soil, and, by extension, the planet and all its inhabitants, will depend on a shift in communication and mindset, to co-create a soil health agenda that equitably addresses everyone's needs.

Recommendations for...

DETERMINING AN AGREED CROSS-DISCIPLINARY DEFINITION FOR HEALTHY SOIL

01 Adopt an existing definition of healthy soil

A definition such as those developed by the EU Mission or the FAO should be adopted and applied consistently by all soil stakeholders across the UK's four nations to prevent unnecessary duplication of effort and ensure alignment with established international frameworks.

02 Support the development of technical sub-definitions

Adopting an existing definition should not overlook the scientific community's need to develop recognised and standardised sub-definitions that capture the technical aspects of soil health needed for accurate assessment and management in specific contexts.

03 Ensure flexibility within the definition

The definition must allow for flexibility, recognising the dynamic nature of soils and the variation in ecosystem services and characteristics that determine what 'health' means to different stakeholders.

04 Make the definition measurable and actionable

The agreed definition should be measurable, verifiable, and actionable - and established without delay - to keep soil health a visible and ongoing priority for policymakers.

DETERMINING THE MOST PROMISING AND/OR SUITABLE BIOLOGICAL INDICATORS FOR SOIL HEALTH

01 Prioritise scalable, cost-effective and user-friendly methods

Any indicator must be scalable, simple to use, translatable to different soil types and contexts, and cost-effective for the user. Investing and supporting the advancement of technologies such as eDNA and metagenomic technologies will be vital for staying at the forefront of soil health science.

02 Adopt a dual approach

A holistic approach of considering both microbial diversity and function for determining soil health better considers the complexity of soil and soil-dwelling organisms, providing a more accurate representation of soil health and performance.

03 Ensure flexibility within the adopted approach

Though indicators should be standardised and harmonised where possible, the high variation in soil types and contexts will require some specification in indicators across settings.

DISCUSSION ON MICROBIAL SOLUTIONS TO UNSUSTAINABLE SOIL PRACTICES

01 Promote the adoption of sustainable alternatives to current land management practices by fostering collaboration

Supporting the transition to sustainable land management practices is essential to attain future food security and will require involving all soil stakeholders from the outset – including policymakers, farmers, land managers, advisors, agri-business and researchers – to ensure successful adoption.

02 Provide sustained policy, financial, and advisory support

To enable practical and profitable implementation, underpinned by continued investment in research and evidence generation.

DETERMINING AN AGREED CROSS-DISCIPLINARY DEFINITION FOR HEALTHY SOIL

Key recommendations:

1. Adopt an existing definition of healthy soil

A definition such as those developed by the EU Mission or the UN-FAO should be adopted and applied consistently by all soil stakeholders across the UK's four nations to prevent unnecessary duplication of effort and ensure alignment with established international frameworks.

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The definition must allow for flexibility, recognising the dynamic nature of soils and the variation in ecosystem services and characteristics that determine what 'health' means to different soil stakeholders.

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The agreed definition should be measurable, verifiable, and actionable — and established without delay — to keep soil health a visible and ongoing priority for policymakers.

CONTEXT:

Agreeing on a definition of 'healthy' soil that considers its biological, chemical and physical aspects has taken the soil community decades, largely due to its extreme variance across different systems and contexts and the lack of agreed indicators for accurately measuring health (2). Though several workable definitions now exist, such as the EU Mission Soil definition for soil health ('the continued capacity of soils to support ecosystem services')(3) and the FAO Intergovernmental Technical Panel's definition ('the ability of the soil to sustain the productivity, diversity, and environmental services of terrestrial ecosystems')(4), the need for a universally agreed definition for soil health that can be used across the UK's four nations was agreed upon unanimously, due to its implications in:

- Setting binding and non-binding targets
- Setting incentives
- Measuring progress made towards said targets and incentives
- Benchmarking land management efforts and practices to assess their impact
- Monitoring changes over time to ensure long-term soil protection and restoration

The roundtable discussion revealed two main perspectives: one supporting an all-encompassing, overarching definition that attempts to cover all soils versus another advocating for multiple, nuanced definitions to capture the variability of soil types and contexts. The main arguments for having an overarching definition included easier comprehension, harmonisation and coherent action across sectors, stakeholders and geography. The main points advocating for multiple, nuanced definitions centred around the danger of an overarching definition being too unwieldy, due to the variability of soils and ecosystems, risking it not adequately covering any soil types.

Despite differing opinions, it was agreed an overarching definition is necessary to facilitate harmonisation and shared understanding between stakeholders, however sub-definitions are equally essential to capture technical nuances within different contexts, even if only used primarily within the scientific community. This would reduce the risk of an overarching definition becoming meaningless in some circumstances due to its brevity. It was also agreed the definition must have scope for flexibility, recognising the dynamic nature of soils and the various ecosystem services valued by different stakeholders. It must also be measurable, verifiable, actionable, and agreed upon imminently to keep soil health firmly visible to policymakers.

Overall, it was agreed that an existing definition such as those used by the EU Mission or UN-FAO should be adopted across the UK's four nations to ensure consistency and avoid unnecessary effort in formulating a new overarching definition, while supporting the scientific community in developing recognised and standardised sub-definitions as needed for specific contexts.

DETERMINING THE MOST PROMISING AND/OR SUITABLE BIOLOGICAL INDICATORS FOR SOIL HEALTH

Key recommendations:

1. Prioritise scalable, cost-effective and user-friendly methods

Any indicator must be scalable, simple to use, translatable to different soil types and contexts, and cost-effective for the user. Investing and supporting the advancement of technologies such as eDNA and metagenomic technologies will be vital for staying at the forefront of soil health science.

2. Adopt a dual approach

A holistic approach of considering both microbial diversity and function for determining soil health better considers the complexity of soil and soil-dwelling organisms, providing a more accurate representation of soil health and performance.

3. Ensure flexibility within the adopted approach

Though indicators should be standardised and harmonised where possible, the high variation in soil types and contexts will require some specification in indicators across settings.

CONTEXT:

While established non-biological soil health indicators (e.g., organic carbon, pH, nutrient levels) effectively capture soil's physical and chemical properties (5-7), there is a recognised need for widely accepted biological indicators to assess soil health. Though consistent application of indicators is important, indicators specific to certain soil types are also needed to account for variation (5,8). Consensus on what biological soil health indicators are most appropriate for monitoring soil health is still being discussed within the scientific community, but some key recommendations can be identified.

Some biological indicators exist and are currently used, such as phospholipid fatty acid analysis (PLFA), the CO_2 burst test, and the plant sap analysis, but these provide limited insight into the vitality of the soil microbiome, the foundation of soil health (9-11). Roundtable participants discussed a range of potential biological indicators including:

- Diversity and spore size of arbuscular mycorrhizal fungi, as indicators of nutrient transfer efficiency from soil to plants
- Food web functionality and/or the presence of key organisms (earthworms, nematodes, mesofauna, pathogens) within soil
- Plant health and broader ecosystem resilience to perturbations
- Environmental DNA (eDNA)

The latter option of eDNA was acknowledged as particularly promising and increasing in accessibility (12). Nonetheless, feasibility is currently an issue due to the cost, data complexity, consistency of approach to sampling/processing, issues around spatial variability and lack of necessary infrastructure (e.g., appropriately curated shared databases that hold highly accurate DNA sequences). Once methods to overcome these barriers are identified it is thought eDNA may become the de facto biological indicator for soil health (12,13).

When considering the soil microbiome as an indicator of soil health, the main point of debate lay in whether microbial biomass, diversity or function should serve as the principal indicator of soil health.

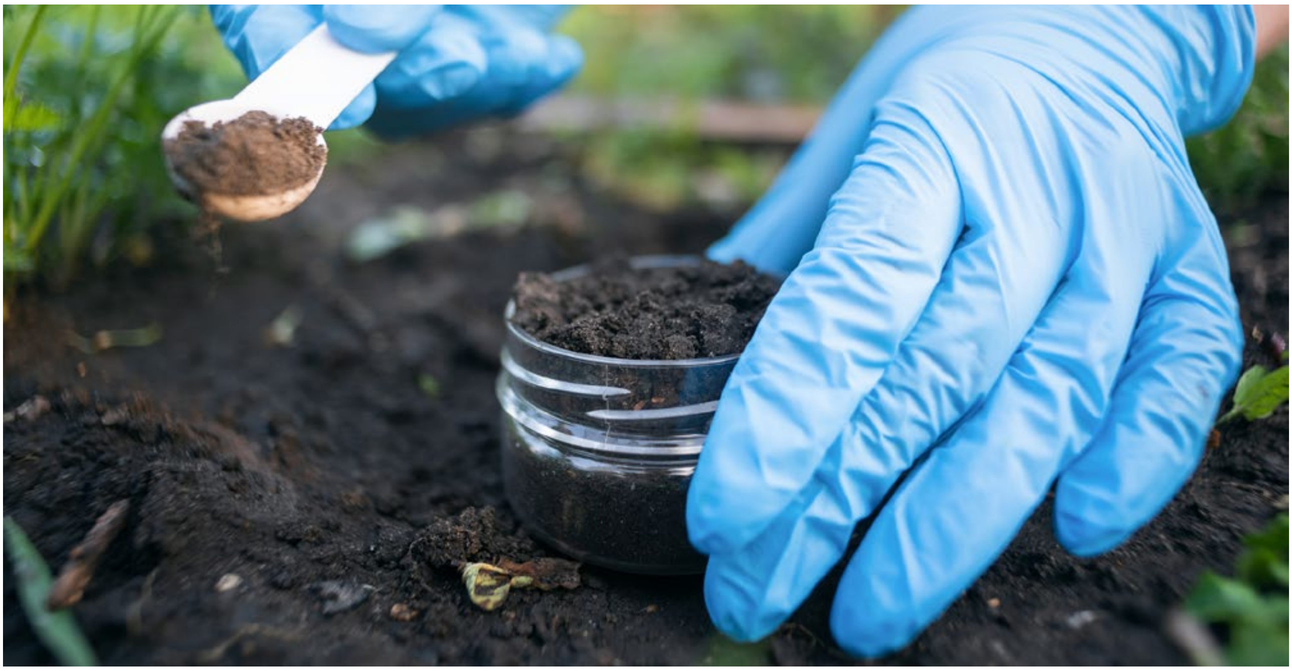
Microbial biomass alone was viewed by most as insufficient, as it offers only a broad measure of microbial presence rather than ecological performance (14). Those who still thought it had merit, recommended combining it with other microbial diversity indicators or looking at it in tandem with fungal:bacterial ratios.

Taxonomic diversity, while historically viewed as a reliable indicator of ecosystem health (on the basis that greater diversity implies more functions and resilience), was seen by several participants as limited in this context. This is because it does not account for microbial function, and high redundancy among taxa means that greater diversity does not always translate into improved ecosystem functioning (10,15).

Microbial function provides critical insights into soil health that measures of diversity alone cannot capture. However, assessing function is considerably more complex and illustrates where more nuance around the definition of 'healthy soils' is needed, to more specifically address the variance in both the 'optimal' function of a specific soil, and the microbial taxa within that soil that provide that function. Moreover, while functional data offer depth, they may overlook the broader ecological benefits of diversity that also underpin healthy soils (15).

This complexity of considering diversity vs function is compounded by the need for periodic re-evaluation of taxonomic databases and the challenge of linking taxonomy to function in a robust, standardised way. Yet, this landscape is changing rapidly. Advances in long-read metagenomics now allow metagenome-assembled genomes (MAGs) to be resolved from soil at scale (16). These advances will create comprehensive genome databases that link taxonomy to function and enable more cost-effective eDNA methods, such as 16S rRNA gene sequencing, to serve as soil-health indicators, especially when combined with complementary approaches for measuring absolute microbial abundance (16).

Overall opinions differed on the value of diversity versus function as indicators, with some favouring pragmatic compromises such as the agronomic "stoplight" approach, which recognises key beneficial taxa rather than overall diversity. However, there was broad agreement that assessing both diversity and function provides the most comprehensive insight into soil health. Measuring function remains more complex — particularly in terms of cost and infrastructure — but rapid technological advances, as seen with genome sequencing, are thought likely to ease these challenges by many. Across all perspectives, the message was unanimous: any biological indicator must be scalable, practical, easy to understand, adaptable to different soils and contexts, and cost-effective for end users.



DISCUSSION ON MICROBIAL SOLUTIONS TO UNSUSTAINABLE SOIL PRACTICES

Key recommendations:

1. Promote the adoption of sustainable alternatives to current land management practices by fostering collaboration

Supporting the transition to sustainable land management practices is essential to attain future food security and will require involving all soil stakeholders from the outset – including policymakers, farmers, land managers, advisors, agri-business and researchers – to ensure successful adoption.

2. Provide sustained policy, financial, and advisory support

To enable practical and profitable implementation, underpinned by continued investment in research and evidence generation.

CONTEXT:

To protect and restore the soil microbiome and overall soil health, land management practices must shift away from unsustainable approaches currently used across agricultural and non-agricultural systems. The previous AMI brief outlines several potential solutions – including regenerative agriculture, integrated pest management and microbiome engineering – which offer more sustainable alternatives (1, 17). Additional solutions raised during the roundtable included selecting for or adding certain bacterial species to soils to promote plant growth, improve crop health and/or enhance carbon capture, as well as capitalising on New Genomic Techniques to develop innovative crops capable of conjugating profitable yield with a positive impact on soil health.

These practices could accompany soil health indicators in determining soil health, through monitoring trajectories of change following adoption. Monitoring the impact of incrementally transitioning to these alternatives could help policymakers with target setting, but this will take time and must be supported by long-term policy commitment.

Successful adoption of these practices depends on aligning the diverse needs of soil stakeholders. Policymakers require clear definitions and indicators of soil health to inform regulatory frameworks, set targets, and justify funding decisions. Farmers, land managers, and supply chain actors must be directly involved in discussions about practical, economic, and environmental impacts of changing practices. The role of soil advisors should be strengthened to support smooth transitions, while agri-businesses need evidence of return on investment or assurance of policy and financial support in making riskier decisions. Researchers and academics play a key role in providing cohesive, evidence-based guidance on the most effective practices for different soil types — supported by continued investment from funding bodies (18,19).

The growing number of microbial and non-microbial solutions is promising but identifying those that best meet the differing yet interwoven needs across the soil health spectrum will require sustained consideration and cooperation across all stakeholder groups.

CONCLUSION

As highlighted in the original AMI brief, a holistic, microbiome-centred view of soil health remains essential to developing effective, evidence-based policies that secure the UK's food systems, ecosystems, and climate resilience for the future. The key recommendations outlined in this policy report that build on this original message can be found summarised on pages 4-5.

Effective communication is fundamental to achieving these recommendations, improving soil health and, by extension, ensuring food security, nutritional quality, and climate resilience. Balancing clear understanding for all stakeholder groups, from non-experts to academics, with the scientific detail needed for sustainable impact in the complex, nuanced field of soil is essential. For example, careful and open-minded communication will be necessary to reach a consensus on an agreed soil health definition(s) and to demonstrate the risks versus the benefits of investing in sustainable land management practices. Finding a middle ground that is accessible, practical, and affordable — while meeting the differing needs of diverse stakeholders — is critical to (at least initially) building the trust and adaptability required to effect actionable and lasting change.

It is essential to communicate the necessity of investing in more complex and costly options – such as measuring microbial function – to secure the necessary buy-in and justify the allocation of resources, including financial, human, cultural, psychological and infrastructural, for implementing these changes. For example, while most recognise that any indicator should be specific, measurable, actionable, scalable and affordable, the need for an indicator to also be *meaningful* was identified as a non-negotiable for ensuring adoption.

Beyond communication, achieving sustainably managed soils will require a shift in mindset and a willingness to embrace risk. This transition will entail upfront costs for farmers and landowners, necessitating robust financial and policy support structures (20, 21). Clear and transparent communication about the need to invest before benefits become visible will be key to sustaining this momentum.

Ultimately, the future of soil, and, by extension, the planet and all its inhabitants, will depend on a shift in communication and mindset, to co-create a soil health agenda that equitably addresses everyone's needs.

BACKGROUND

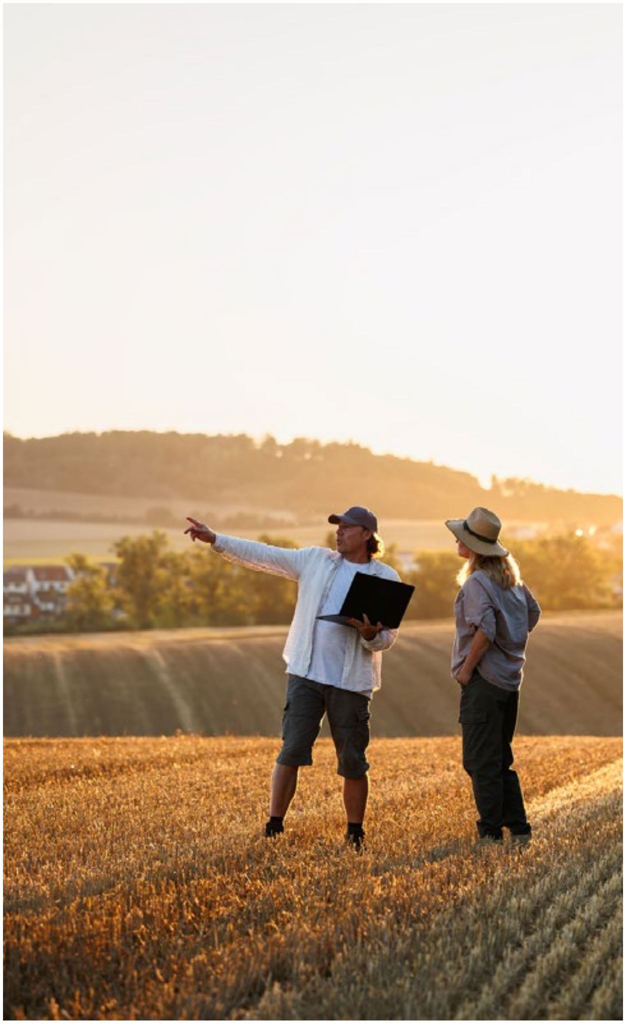
Applied Microbiology International (AMI) brings the microbiology community together across international borders and disciplines, as it believes global challenges need to be solved by global experts. AMI is centred around six of the UN Sustainable Development Goals (SDGs), all of which are underpinned by soil health. In 2023, AMI hosted an event at the John Innes Centre in the UK on 'The Power of Microbes in Sustainable Crop Production', which focused on the impact of microbes in national agricultural settings and food security. The discussions from this event resulted in a policy brief which aimed to:

- Highlight the opportunity of taking a harmonised microbiome-based approach to soil health across the UK, explaining why this could be beneficial over current approaches and how such an approach could be implemented across the UK's four nations; and,
- Propose microbial solutions that can be deployed now – if supported by policymakers and key industry players across all four nations – to improve UK soil health, whilst exploring and building the basis for a microbiome approach.

This brief was distributed to stakeholders such as the UK Government, research institutes, and non-governmental organisations, resulting in over 20 meetings between AMI and various organisations and individuals interested in the UK's soil health. These meetings resulted in the decision to host a roundtable to cover overarching themes that emerged, namely:

- The need to agree on a cross-disciplinary definition for 'healthy' soil
- The need to determine the most promising and/or suitable biological and microbiological indicator/s for soil health
- The need to discuss the original brief's recommended microbial solutions for sustainably managing soils, refining them based on multi-disciplinary input and perspectives (and potentially expanding them beyond the agricultural setting).

The roundtable was hosted virtually, chaired by Dr Marcela Hernández (environmental microbiologist at the University of East Anglia), and had 34 participants representing academics, governmental and non-governmental organisations, research institutes, agri-businesses and union representatives. This brief summarises the discussions and pulls out the key message of the need to foster effective communication across the soil stakeholder spectrum to build the trust and open-mindedness to risk that is necessary for enabling wide-scale, lasting change.



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GLOSSARY

Arbuscular mycorrhizal fungi – Beneficial native microorganisms (defined below) that can be used as an inoculant to increase nutrient uptake in soil (1, 2).

CO2 burst test – Test of soil health that provides an estimate of soil microbial biomass (defined below). Microbial activity in soil releases CO2 which this test measures (3).

Ecosystem services – Goods obtained from ecosystems that benefit people's wellbeing and society. For soil, this includes the provision of food, raw materials for uses such as medicines and climate regulation amongst other uses (4).

eDNA – Genetic material left by organisms in the environment. This includes DNA from cells, tissues, fluids & excrement. Measuring it provides insight into the presence of organisms and overall biodiversity (5).

Integrated pest management – A sustainable approach that combines multiple strategies to minimize damage to land caused by pests, weeds and diseases on land. It reduces reliance on chemical pesticides, and its key principles focus on prevention & monitoring pest levels to inform when to act (6).

Mesofauna – Small organisms that live in soil such as worms that perform ecosystem services such as decomposition, nutrient and water cycling and reducing pathogen transmission. Their abundance is impacted by soil health and land use practices (7, 8).

> **Nematodes** – A thin worm that can be used as an indicator for soil health for multiple reasons including their abundance and sensitivity to the environment (9).

Metagenomic technologies – A method that allows the identification and characterization of organisms using DNA sequences from all kinds of samples, including soil (10).

> **Long-read metagenomics** – A metagenomic technique that provides longer DNA sequences than comparative metagenomic techniques. This is particularly useful to study complex microbial communities (11).
>
> **Metagenome-assembled genomes (MAGs)** – Microbial genomes (the entire set of DNA found in a cell (12)) reconstructed using metagenomic technologies (13).

Microorganism – A living thing which on its own is too small to be seen without a microscope, also often referred to as a 'microbe' (14).

Microbial biomass – Total number of microorganisms (including viruses, bacteria, fungi & protozoa) in a given area (15).

Microbial function – The various activities of microorganisms, which includes nutrient cycling, carbon sequestration, and reducing the risk of pathogen transmission and more (2, 16).

Microbiome – The communities of microorganisms within an environment (such as soil) that underpin many ecosystem services (defined above) (2, 17).

Microbiome engineering – A type of engineering that seeks to improve the function of an ecosystem by manipulating the microbes that are present (18).

Pathogens – An organism that can cause disease, that can include bacteria, viruses, fungi and parasites (19, 20).

Phospholipid fatty acid analysis (PLFA) – Test of soil health that measures the fatty acids found on cell membranes. This provides data on the quantity and composition of microorganisms within soil (21).

Plant sap analysis – A test of soil health that measures the nutritional status of plants by testing their sap, providing insights into plant health and nutrient uptake (22).

Regenerative agriculture – A farmer-led movement that uses nature-based solutions to improve ecosystem services such as resilience to climate change, water quality, and food production. It includes practices like no-till farming, cover cropping, reducing pesticide use, and integrated livestock to cropping system (23).

Soil microbiome – The communities of microorganisms within soil that underpin many ecosystem services (defined above) including the provision of food, raw materials for uses such as medicines and climate regulation, amongst others (2, 17).

Taxonomic diversity – Taxonomy is a systematic classification of organisms where each distinct group is referred to as a taxa. As such, taxonomic diversity refers to the number and relative abundance of species within a community (24).

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