

Saving our soils:

Grand challenges for microbial soil recovery



Professor Jack A Gilbert
Director, UC San Diego Soil Health Center and Nutrition for Precision Health Microbiome Center; President, Applied Microbiology International



Dr Lucy Harper
Chief Executive, Applied Microbiology International



Professor Janet Jansson
The Soil Stars, Applied Microbiology International, Cambridge, UK

A new mission-led framework, drafted at The Lost Gardens of Heligan in Cornwall, aims to turn microbial science into interventions and metrics to support measurable improvements in soil health, on which food, water and climate all depend.

Soil is the thin biological skin between rock and atmosphere, and it is being worn away. Globally, soils are eroding at roughly one hundred times the rate at which they form. In Iowa alone, average losses now exceed five tonnes per acre per year, and around a quarter of cropland is reported to have no topsoil left at all. The same loss of structure that releases carbon, contaminates groundwater and undermines food security also cripples the soil's microbial communities, the bacteria, fungi, archaea and viruses that drive nearly every ecosystem service soils provide.

If we are serious about food security, climate resilience and biodiversity recovery, we cannot continue to treat the microbiology of soil as a footnote.

Microbiology also now offers a credible route back. Microbial inoculants can reduce reliance on synthetic fertilisers; biological consortia produce extracellular polymers that bind soil particles and hold water in desiccated soils; and microbial metabolism can be steered toward longer-lived carbon pools. Recent multi-site smallholder trials in Rwanda have shown measurable maize yield and root-biomass gains following microbial inoculation (Bukombe et al. 2026), evidence that the science can perform outside the greenhouse.

Yet field success is inconsistent, validation methods differ between laboratories, and farmers, regulators and investors lack a shared language for describing what 'good' looks like. The result is a paradox: scientific possibility is expanding rapidly while real-world deployment remains fragmented and slow.

Policy opportunity: Establish a UK-anchored, internationally governed Heligan Grand Challenges platform, so that microbial soil-recovery technologies can be validated, regulated and deployed against shared global thresholds.

The Heligan Grand Challenges

In March 2026, an international group of soil scientists, microbiologists, farmers, communicators, investors and policymakers met at Heligan Gardens in Cornwall and the nearby Eden Project to confront this paradox. The result was the first draft of the Heligan Grand Challenges: a portfolio of ambitious, time-bound mission goals for biology-enabled soil recovery.

Inspired by the XPRIZE model, the Challenges are not another funding call. They sit one level higher, defining the outcomes that matter for global soil recovery and providing an organising framework through which scientific, technical, financial and social effort can be aligned. Implementation can take many forms, including challenges, living labs, policy pilots, public-private platforms, but each Protocol describes a clear destination and threshold for success.

Two complementary categories

Intervention challenges target the biology itself. The Carbon Lock Prize calls for biological pathways that drive soil carbon into durable, slow-turnover pools, with credible evidence of stability over 36 months. The Water Sponge Prize seeks

treatments that increase soil water-holding capacity by 30%, or enable a 20% reduction in irrigation demand without yield or environmental penalty, across at least three soil types and climate regions. A complementary Save Our Soils (S.O.S.) Prize challenges teams to demonstrate a 20% reduction in erosion through practices adopted by at least 40 growers across three managed land systems. The Water Filtration Prize aims for a 50% reduction in nitrate, phosphate or pesticide leaching from contaminated lands, while the Biological Fertilisers Prize calls for a 25% reduction in synthetic fertiliser use, including the import-exposed phosphate on which UK agriculture relies, with no yield penalty across three crop systems and two seasons.

Validation challenges do something equally important. They ask how we will know an intervention has worked. The Soil Health Diagnostic Test, effectively a 'soil blood test', challenges innovators to deliver a rapid, affordable assay that tells a farmer within a week whether their soil is healthy, degrading or recovering, validated across at least thirty farms, three regions and three soil types, and predicting at least four key indicators with greater than 70% accuracy. The BIOME Prize tackles biological complexity directly, requiring measurable progress toward a high-biocomplexity reference state using existing metrics.

This combination matters. Without diagnostics that everyone trusts, the most elegant intervention will struggle to attract investment, regulatory approval or farmer uptake. Without interventions

that genuinely shift the dial, even the best monitoring system merely documents decline.

From challenge to deployment

The harder work begins after the prize is won. The Heligan participants identified five cross-cutting enablers that any successful Protocol must address.

1. Shared validation infrastructure. Without harmonised monitoring, common benchmark sites and independent auditing, claims made in one geography cannot be evaluated credibly in another. The European Union has begun to lead here: the EU Mission ‘A Soil Deal for Europe’ is building 100 living labs and lighthouses by 2027, and the EU Soil Observatory Dashboard now tracks 19 indicators of soil degradation. The UK should align with these emerging standards rather than duplicate them.

2. Scalability. Microbial inoculants must not only work in glasshouses; they must also be manufacturable, storable, distributable and robust to local conditions and resident microbiota. Heligan participants argued that formulation, delivery, farmer co-design and regional adaptation are part of the innovation challenge, not afterthoughts.

3. Regulation. Microbial products do not fit neatly into policy systems designed for chemicals. OECD guidance has long recognised that environmental uses of microorganisms need their own evaluation frameworks (OECD 2014), and recent analyses argue that microbes may even require a distinct environmental risk-assessment approach from genetically modified plants because their persistence, dispersal and ecological interactions after release can be difficult to predict (Eckerstorfer et al. 2025). Risk-governed stewardship (Beattie et al. 2026) must be built into Protocol design from the outset.

4. Economics policy alignment and public legitimacy. Farmers face strong “wait-and-see” incentives because the costs of transition are immediate while the benefits of soil restoration accrue slowly and often outside the farm gate (Kroh et al. 2026). Without crop-insurance reform, soil-health-linked payments and clear public communication, even excellent technology will sit on the shelf.

5. Engaging public narrative. The scientific case for microbial soil recovery is now largely settled and the dominant rate-limiter for global action is narrative, attention, and trust. The Heligan Challenges were therefore designed not only as research targets but as communicable stories with measurable thresholds. The grand challenge names and the deliberate XPRIZE framing are part of that design.

Why the UK is well placed to lead

Britain has a credible claim to host this work. The Heligan Protocols were drafted on Cornish soil, and the UK already supports world-class microbial science at Rothamsted Research, the Quadram Institute, the John Innes Centre and an expanding network of farmer-led research groups. DEFRA’s Soil Health work and the Sustainable Farming Incentive provide a policy scaffold; UKRI and Innovate UK can resource the translational science; and Applied Microbiology International and the new IUCN Microbial Conservation Specialist Group offer global convening power (Gilbert et al. 2025). Britain’s combination of dense agricultural innovation, mature research councils and a world-class AI ecosystem (the Alan Turing Institute, DeepMind, UKRI) is well suited to anchoring an internationally trusted Protocols platform.

Policy actions

To turn the Heligan Challenges from a workshop output into a durable global instrument, four UK policy actions would help.

Anchor the platform. Back a peer-reviewed framework paper and a public platform presenting each Protocol as a mission with measurable thresholds, judging criteria and partner opportunities.

Fund living labs that benchmark, not duplicate. Resource UK living labs that align with the EU Soil Mission and serve as international benchmark sites for Protocol validation, ensuring British farmers and land managers are co-designers, not late adopters.

Modernise microbial regulation. Reform the regulatory pathway for microbial inoculants and biological soil amendments so products meeting

Protocol thresholds can move from trial to deployment without losing rigour, with risk assessment built around microbial behaviour rather than chemical regulation.

Reward measurable soil recovery. Integrate Protocol-aligned soil-health metrics into the Sustainable Farming Incentive, Nature Recovery Network and Environmental Land Management schemes, so public money rewards measurable soil recovery rather than activity alone.

Conclusion

Soil degradation is one of the most consequential and least visible crises of our time. Microbes are central to the solution, but only if success is described in ways scientists, farmers, regulators and investors all recognise. The Heligan Protocols are an attempt to build that shared language: a portfolio of clear, measurable, time-bound goals for microbial soil recovery, deployable through prizes, living labs and policy pilots alike. With early UK leadership, they can become an operating system for the soils on which our food, water and climate all depend.

References

- Beattie G et al (2026). Microbial inoculants for soil restoration: a practical framework for risk-governed stewardship. *EcoEvoRxiv* (preprint). doi.org/10.32942/X2QH3F.
- Bukombe B et al (2026). Microbial inoculation increases maize yield and root biomass across smallholder farming systems in Rwanda. *EarthArXiv*. doi.org/10.31223/x53r2p.
- Eckerstorfer M F et al (2025). Environmental applications of GM microorganisms: tiny critters posing huge challenges for risk assessment and governance. *International Journal of Molecular Sciences* 26 (7): 3174.
- Gilbert J A et al (2025). Safeguarding microbial biodiversity: microbial conservation specialist group within the species survival commission of the International Union for Conservation of Nature. *The ISME Journal* 19 (1). doi.org/10.1093/ismejo/wraf239
- Kroh G E et al (2026). Centering resilience in US federal agricultural policy. *Frontiers in Sustainable Food Systems* 9: 1695529. doi.org/10.3389/fsufs.2025.1695529.
- OECD (2014). *OECD Guidance to the Environmental Safety Evaluation of Microbial Biocontrol Agents*. OECD.