EARTH
ROVER
PROGRAM

SOILSMOLOGY:
TRANSFORMING OUR
UNDERSTANDING OF SOIL

Foreword

THE EARTH ROVER PROGRAM BEGAN WITH A SHARED CONVICTION AMONG THREE PEOPLE IN DIFFERENT FIELDS —AN ENVIRONMENTAL JOURNALIST, A SEISMOLOGIST, AND A SOIL SCIENTIST —THAT A BETTER UNDERSTANDING OF THE GROUND BENEATH OUR FEET IS CRUCIAL TO SOLVING SOME OF OUR MOST URGENT EXISTENTIAL PROBLEMS.

By bringing together insights from our disciplines, we were able to find new ways of understanding the living system on which humanity is entirely dependent.

We realised that methods long used to study the deep Earth could be adapted to explore its shallowest layer, the topsoil. Seismology, which has helped humanity understand earthquakes, detect hydrocarbons, test materials, and even map other planets, offered an untapped way to read the structure of soil itself.

That realisation gave rise to the Earth Rover Program, a global nonprofit organisation dedicated to mapping and understanding the world's soils based on a new foundation, 'soilsmology'. By studying the distortion of ultrahigh-frequency seismic waves as they pass through the topsoil, we can observe its vital signs non-invasively, efficiently, and at scale. This enables us to produce live readings of soil properties and soil health, which will, as the technologies develop, become immediately useful to farmers and other land managers. However, technology alone cannot transform our relationship with our soil. True progress depends on inclusive collaboration between scientists, farmers, engineers, ecologists, policymakers, and communities. The Earth Rover Program's open-source approach reflects the belief that knowledge must be shared widely and be accessible to even the poorest practitioners.

This report records our progress so far in making soil health visible, measurable, and actionable. We invite you to join us in enhancing the understanding and restoration of this rich and complex ecosystem, on which we all depend.

Executive Summary

Soil is one of the Earth's most important yet least understood ecosystems. It provides 99% of the calories we consume,[1] holds more carbon than the atmosphere and all vegetation combined, and harbours most of our planet's biodiversity. Yet over 75% of the world's soils are now degraded, threatening food security, ecosystems, and climate stability.[2]

The combined pressures of damage caused by poor agricultural practice, erosion, and climate extremes are predicted to cut global crop yields by up to 50% by 2050 in some regions and displace hundreds of millions of people.[3] Despite its central role in sustaining life, soil is still treated like dirt.

For decades, scientists have struggled to measure soil health at the scale and precision required to address this crisis. Traditional methods are costly, invasive, and slow, producing fragmented data that cannot capture the immense variability of soils across landscapes and over time. To build resilience into our food systems, we urgently need tools that can decode the inner workings of soil—tools that are fast, scalable, non-invasive, and accessible to all.

The Earth Rover Program is closing this knowledge gap. By repurposing the proven methods of seismology for soil science, we have established soilsmology, a non-invasive technique that measures seismic waves to infer soil's 'vital signs'. Using ultrahigh-frequency seismic waves, soilsmology reveals the hidden structures of the ecosystem on which we all depend. We aim to provide a detailed picture of soil health at depth and across various scales, relying on the technique's excellent scalability to increase sampling in a robust, cost-effective, and accessible manner. Waves can be generated simply with a hammer and a metal plate, and are recorded by low-cost sensors that, in time, will enable anyone, anywhere, to generate a detailed 3D image of the soil. It is the powerful combination of automated, detailed analysis and scalable, low-cost equipment that has the potential to transform our understanding of this vital ecosystem.

Equally significant is the Earth Rover Program's use of artificial intelligence. Our AI model aims to map seismic, other geophysical, remote-sensing, and direct soil sampling data, including crucial information from farmers, to key soil health parameters. One first application of this framework is 'ERP-GPT', a free, multilingual knowledge platform that translates complex datasets into practical guidance for farmers, scientists, land managers, and policymakers.

Looking ahead, the Earth Rover Program aims to work openly and collaboratively with farmers worldwide, with learning travelling in both directions, to create the world's first soil forecast, or 'soilcast'—a local-to-global system for monitoring and forecasting soil health. Just as weather forecasts transformed our relationship with the atmosphere, soilcasts will enable us to anticipate and respond to changes in our soil. This will support both more accurate and transparent carbon quantification assessments and strengthen the resilience of local communities responding to shocks in food production.

Soil degradation by erosion alone costs an estimated **$8 billion** globally each year

The Earth Rover Program empowers more precise and sustainable land management by enabling farmers to visualise the health, structure, and deficiencies of their soils in quasi real time. As each measurement contributes to a growing global soil database, farmers' trials, tests, results, and experiences can be instantly matched to interventions elsewhere to generate adaptive, evidence-based agronomic advice, enabling them to sustain or enhance yields while protecting or improving soil health, carbon stocks and ecological functions

Through our enhancement of soil science and the rapid readings farmers can produce, we aim to accelerate the development of new agricultural techniques built on a better understanding of soil built on biology, chemistry, physics, and dynamical systems. As our insight deepens, we can strengthen the natural relationships between plants and microbes, enhance nutrient cycling, improve carbon stocks, and reduce compaction, erosion, and dependence on synthetic inputs, thereby developing a new approach to farming that delivers higher yields with lower environmental impacts.

While always building on local cultural, socio-economic and agroecological conditions, by bringing together researchers, farmers, and citizen scientists across continents, the Earth Rover Program is catalysing a new, greener agricultural revolution: 'one that, for the first time, enables the wide-scale production of more food with less harm and can unlock the potential to compare and refine restoration techniques that optimise carbon stocks. For so long dismissed as mere dirt, soil is now emerging as one of our most powerful allies in the fight against climate and ecological breakdown, as well as the foundation of more resilient and economically robust communities around the world.

The State of Our Soils

Soil is the foundation on which all terrestrial life on Earth depends. It is essential to our global food system and human health, providing 99% of the calories we consume, both directly via grains, vegetables, and fruits, and indirectly via the crops required to raise livestock.[4]

It is home to at least 59% of all species, including over 80% of all fungi and plants, making it the most biodiverse habitat on Earth.[5] Much like a coral reef, soil is a biological structure, teeming with intricate, interconnected relationships between the organisms that inhabit it.

It is also crucial to the global balance of greenhouse gases. Soils hold more carbon than the atmosphere and the world's vegetation combined. Soils are dynamic, meaning that they can draw carbon out of the atmosphere through photosynthesis, but if they become degraded, such as through burning or draining peatlands, they can also release carbon, accelerating global heating as they emit greenhouse gases.

Yet, despite this ecosystem's enormous significance to the survival of life on Earth, soil has been widely disregarded and neglected. More than 75% of the world's soils are now considered degraded due to poor agricultural practices, erosion, pollution, and climate extremes.[6] Soil compaction is a large and growing issue globally, driven by the increasing size of agricultural vehicles and the growing number of livestock. As soil is compressed, its pore space is reduced, with the result that crop roots cannot penetrate the soil to receive adequate nutrients, reducing yields; water infiltration is diminished, increasing the risk of flooding and degrading water quality downstream; and the habitats of crucial soil species, from microbes to earthworms, are lost.

The costs of inaction are staggering. The combination of land degradation and the effects of climate breakdown is predicted to reduce crop yields by an average of 10% globally, and up to 50% in certain at-risk regions by 2050, resulting in the forced migration of 50 to 700 million people.[7]

Soil degradation is not only a threat to food security and ecosystem health, it is also an economic liability. Erosion alone costs the world an estimated $8 billion each year,[8] while food systems, responsible for a third of global greenhouse gas emissions, receive only 3% of climate finance.[9] There is a profound imbalance in how we value and fund the systems that feed us, one that the world can no longer afford to ignore.

We urgently need to restore the health of our soils, repairing their ability to cycle nutrients, filter water, store carbon, and sustain life – and regulation is beginning to reflect this. In October 2025, the European Union passed its first law on soil health monitoring, requiring member states to track and improve soil health, and setting a non-binding target of achieving healthy soils across the bloc by 2050. Meeting this goal will require far more than good intentions. Governments will need to be provided with reliable data to measure progress, and farmers will require access to tools that enable them to adapt their practices with precision and confidence. We must develop ways to see our soils clearly, for we cannot protect what we cannot measure.

This is the challenge the Earth Rover Program has set out to meet.

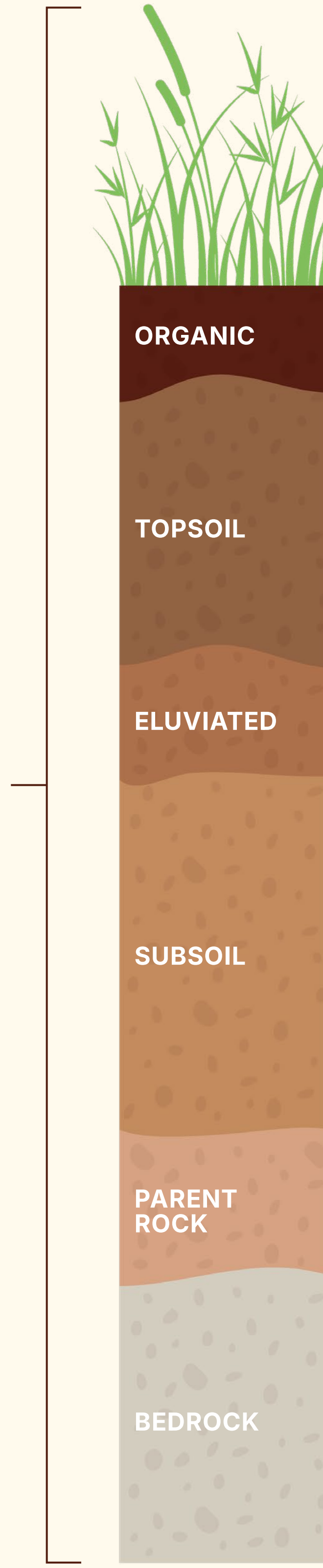
SOIL HORIZONS: FOUNDATIONS OF FOOD, CARBON, AND BIODIVERSITY

Provides **99%** of the calories we consume

Home to **59%** of all species, including **80%** of all fungi and plants

Holds more carbon than the atmosphere and the world's vegetation combined

Erosion alone costs an estimated **$8** billion globally each year



The Limits of Traditional Soil Monitoring

As a complex system, soil is built and sustained by the interactions between microbes, plants, physical properties, and chemistry.

Yet, despite decades of research into soil by scientists, which has led to considerable advances in our understanding of its structure and function, much remains unknown or poorly understood. It is often viewed as a 'black box' because the methods currently used to measure soil health struggle to capture its dynamics over time, in sufficient detail, and across meaningful spatial scales.

Traditional soil sampling is a location-specific, costly, and labour-intensive process that, being invasive, disturbs the very structure it seeks to study. Non-invasive methods, including remote sensing and ground-penetrating radar, have been trialled, but each has drawbacks. Remote sensing is limited in its ability to provide accurate data to depth, while radar techniques often suffer from limited scalability and generality, not least due to the expense of sensors. Despite successful, well-established frameworks for soil health monitoring over landscapes, such as the Land Degradation Survey Framework[10] by CIFOR-ICRAF, there remains a gap in fine-scale resolution, in particular at depth.

As any farmer can attest, crop yields can vary from metre to metre within the same field, owing mostly to soil properties that are undetectable from the surface. Without precise insight, they must rely on broad interventions, such as heavy fertiliser use and intensive tillage, to maximise productivity. These methods are not only very expensive, but they also inflict a severe cost on the living world, contributing to river pollution, increasing global greenhouse gas emissions and threatening future productivity.

If farmers are to reduce their environmental impacts without compromising their yields, we need to be able to map the structures of our soils accurately, down to the decimeter, to unearth the subtle differences that exist from one location to the next, and to address deficiencies in a bespoke, ecologically benign manner at these resolutions.

Soil health monitoring is further complicated by soil's extraordinary diversity. In the United States alone, scientists have identified tens of thousands of distinct soil types.[11] With such variety and so many interacting variables, accurate assessment and understanding of soil function typically require a vast number of samples to be collected and compared across various contexts. Any effective method must therefore be widely accessible, simple to use, and affordable, ensuring that anyone, regardless of their resources, can contribute to building the world's soil knowledge base. It must also incorporate the knowledge of local farmers and indigenous populations, whose insights provide context that instantaneous data alone cannot capture.

Meeting these demands may seem ambitious, but the solution lies in crossing disciplinary boundaries and working closely together between farmers, scientists, citizens, and agencies globally, locally, and at scale. By adapting approaches already refined in geophysics, particularly seismology, we can help to open the black box of soil and begin to read and interact with the Earth's living systems in unprecedented detail.

The Story of the Earth Rover Program

THE EARTH ROVER PROGRAM TEAM IN NUMBERS

15 PHDS WITHIN THE TEAM

2 PROFESSORS

12 LANGUAGES SPOKEN

9 NATIONALITIES REPRESENTED

5 HUBS WORLDWIDE

ERP SOIL SURVEYS WORLDWIDE: MAPPING CROPS AND SURVEYED REGIONS

TEAM SPECIALISMS

- Seismology
- Soil science
- Agronomy
- Sensor engineering
- Machine learning
- Modelling
- Geophysical methods
- Environmental Conservation

WHO CAN USE ERP'S SOFTWARE SUITE, MIMIR, AND HOW

FARMERS

Identify crops and areas of land requiring remedial action, enabling precise treatments to improve yields and reduce inputs.

SCIENTISTS

Use high-resolution soil data to design treatments tailored to local conditions, advancing sustainable agriculture through evidence-based innovation.

GOVERNMENT AGENCIES

Access reliable, high-quality soil data to inform climate resilience strategies, such as managing erosion and improving land-use planning.

CONSERVATIONISTS AND LAND MANAGERS

Verify soil carbon content for climate finance and mitigation initiatives, and support ecosystem restoration and biodiversity recovery.

Introducing Soilsmology

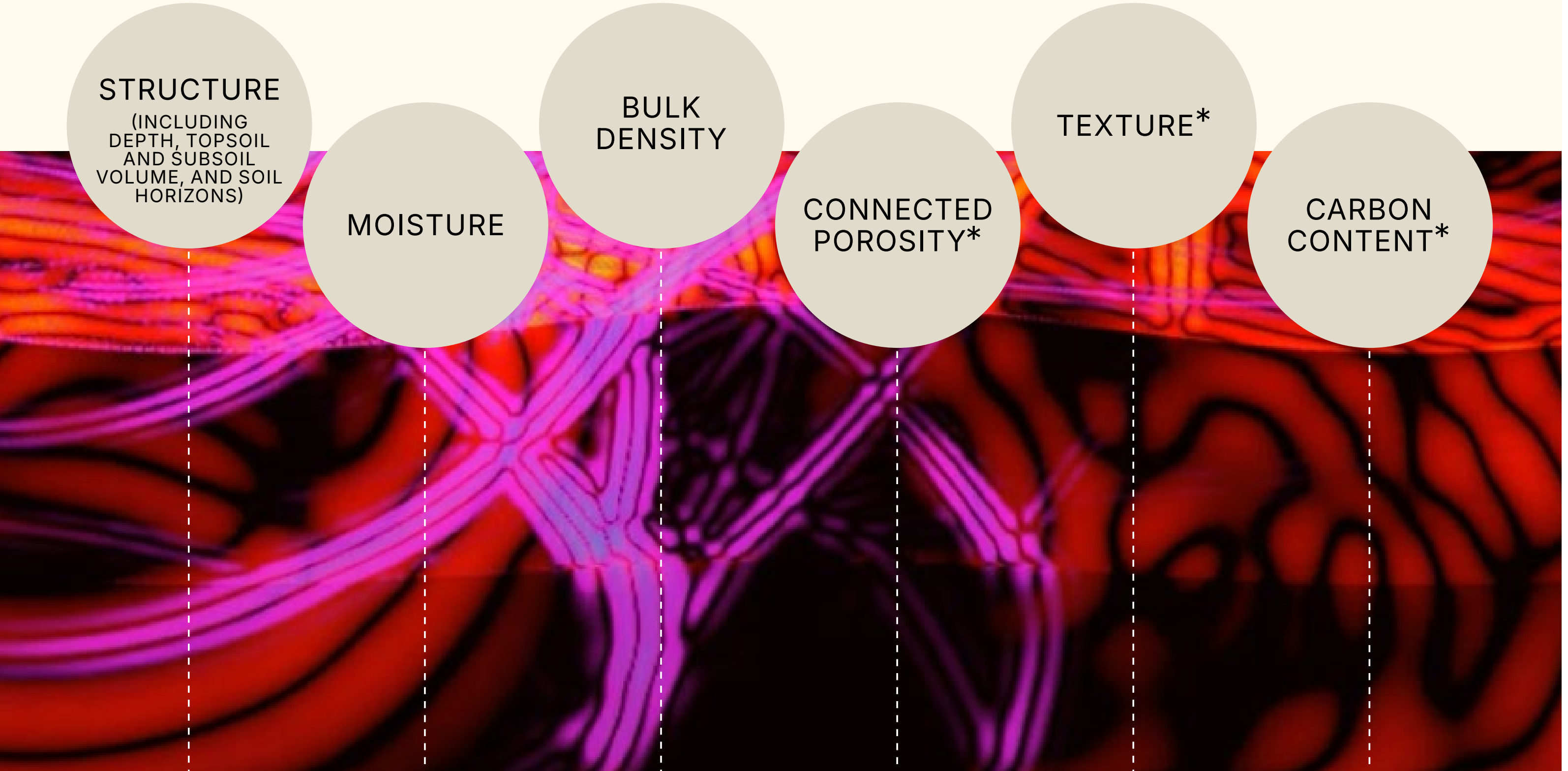
THE SCIENCE OF 'SOILSMOLOGY'

Soilsmology is an emerging scientific concept that is being advanced by the Earth Rover Program's team of geophysicists and soil scientists to finely map the world's living soils. It adapts the principles of seismology to study the Earth's shallowest layer, its topsoil, by passing ultrahigh-frequency seismic waves through it to reveal its vital signs: its structure (including depth, topsoil and subsoil volume, and soil horizons), moisture, bulk density, and conceivably its connected porosity, texture, and carbon content. These measurements can be made non-invasively and principally processed in quasi real time, offering an unprecedented window into the health of the ground beneath our feet.

Seismology, as a scientific foundation widely used in earthquake science, hydrocarbon exploration, non-destructive testing, citizen science, and planetary exploration, lends itself naturally to this adaptation. Mechanical waves are an exceptionally efficient means of transmitting information, capable of travelling long distances while capturing fine-grained details about the medium they traverse. Soilsmology can use these capabilities to illuminate soils from the micro-plot to the landscape scale, and across diverse ecosystems around the world—from peatlands to drylands and the Arctic to the tropics—without disturbing the living systems it observes.

SEISMIC WAVE PROPAGATION SIMULATION SHOWING HOW SOILSMOLOGY REVEALS THE SOIL'S VITAL SIGNS

*This is conceivable



OUR METHODOLOGY

While wave-based approaches to soil characterisation have been explored before, the Earth Rover Program's innovation lies in the fine-scale resolution and scalable, accessible, and automated nature of the seismic analysis. By generating and analysing waves above 500 Hz, soilsmology detects small-scale variability within structures of less than 10 centimetres, which is required to explore Earth's topsoil. This precision bridges a long-standing gap between coarse continental soil models and the field-level data required for specific land management decisions.

Crucially, generating these waves is both simple and inexpensive: they can be produced by something as ordinary as striking a metal sheet with a hammer. The accessibility of this method is central to the Earth Rover Program's mission to develop robust, scalable science that anyone can use, regardless of resources or access to capital.

The technique is extraordinarily efficient. Within a single hour, more than 10,000 waveforms can be collected to produce fine-scale, 3D images of the subsurface. This creates datasets that are far larger, faster to obtain, and more informative than those produced through traditional sampling.

This combination of efficiency and affordability makes soilsmology inherently scalable. With accelerometer sensors already present in mobile phones, a simple mechanism to generate seismic waves, and automated data streaming and analysis, soilsmological sampling can, in principle, be carried out by anyone, anywhere, quickly, affordably, and with minimal disturbance to the soil itself.

Soilsmology should therefore be understood not merely as a reliable foundation for large-scale soil monitoring worldwide, but also as a call to action for everyone to contribute: the task of assessing all soils around the world is momentous and requires mobilisation by and for humankind altogether. As global soil datasets expand upon the work of ongoing collective efforts, the accuracy and monitoring performance of soilsmological models will continue to improve, reducing uncertainty and refining our ability to assess soil health.

1HR

10,000

waveforms

SEISMIC SENSORS: TECHNOLOGY MADE ACCESSIBLE

Central to the Earth Rover Program's mission is accessibility. In just three years, we have reduced the cost of our preferred seismic sensing equipment by 99.9%:

Year	Sensor Type	Approx. Cost per Unit
pre-ERP	Laser vibrometers	$10,000
2023	High-end accelerometers	$1,000
2024	High-frequency geophones	$100
2025	MEMS accelerometers	$10

The Earth Rover Program's MEMS sensor kit, currently under development, is built around a millimetre-scale accelerometer and a host of other sensors, including soil moisture and weather data. It will be easily portable as a stand-alone sensor kit available to anyone at a small cost. We are, however, also working towards soilsmological sampling using mobile phone sensors at no extra cost, with the aim of merely putting a phone to the ground to retrieve information about the soil beneath. The sensors' size and affordability will enable the roll-out of this technology at scale: soil health data collection and analysis will be available within the palm of a farmer's hand. Equipped with GPS time synchronisation and data transfer via mobile networks, these novel sensors will enable soil health monitoring through time, creating dynamic soil maps.

The Earth Rover Program is also committed to an open-source approach, in both hardware and software, to foster collaboration and expand access to knowledge. Through open hardware, users will be able to study, customise, and innovate, building bespoke sensor kits suited to their own ecosystems and research needs. At the same time, data protection and encryption remain paramount, ensuring the security of information flow along the entire data pipeline.

A GLOBAL ENDEAVOUR

The Earth Rover Program is an international collaboration uniting scientists and engineers across continents. Our current team members hail from Colombia, China, France, Germany, Iran, Italy, Kenya, Romania, and the United Kingdom.

Our team of 17 scientists and engineers comprises 15 PhDs and two professors across various disciplines, including soil science, agronomy, agroforestry, ecology, seismology, geophysics, numerical modelling, artificial intelligence, sensor engineering, and software development. our strategic partnerships in Kenya and Colombia, with the Centre for Ecosystem Restoration and Alliance of Bioversity International and CIAT, respectively encompass some of the most innovative regions in terms of agroecological progress, local climate resilience, and biodiversity conservation. Our university partnerships in the UK with Harper Adams University and the University of Exeter, where the Earth Rover Program is a Core Research Theme in the Centre for Environmental Intelligence, provide world-leading research environments in both soil and agriculture science, and climate and environmental AI science, respectively.

INTEGRATING MACHINE LEARNING

The Earth Rover Program is not only pioneering innovation in soil sensing technology, but also transforming how that data is processed and interpreted. By combining advanced open-hardware sensor design with artificial intelligence, we are building a system capable of translating soil's hidden patterns into clear, actionable knowledge – developed with and for any Earth citizen.

Soil science is well-suited to machine learning. Extensive soil databases already exist worldwide, providing rich training sets that enable AI models to identify relationships between physical measurements and underlying soil properties. Building on this foundation, the Earth Rover Program is developing an AI model that maps seismic and other data, including farmers' knowledge, key indicators of soil health, such as density, moisture, structure, and inferred carbon content. The resulting analyses are then transformed into accessible, decision-ready insights through ERP-GPT, the Earth Rover Program's emerging free, data-driven, multilingual knowledge-sharing platform.

As part of our commitment to sustainable innovation, we ensure that this novel data is processed and

stored with minimal environmental impact. Wherever possible, computations are performed locally, close to where data is collected, thereby reducing energy consumption and improving efficiency and resilience. The strength of the Earth Rover Program's database also depends on open and equitable collaboration. By establishing a reciprocal flow of information between indigenous communities, farmers, scientists, and policymakers, we can build a knowledge base that is scientifically robust and ensures that no one is left behind in the global transition towards resilient and regenerative land stewardship.

By integrating AI with low-cost, non-invasive soil sensors and open-access frameworks built upon strong data security, reproducibility, and transparency, the Earth Rover Program is closing the gap between cutting-edge science and on-the-ground action, building trust in evidence-based decision-making. This approach democratises access to environmental intelligence, which, in turn, accelerates the pace of analysis and empowers those often excluded from scientific infrastructure to make informed land-use decisions that strengthen climate resilience and restore soil fertility and carbon stocks anywhere.

The Earth Rover Program is demonstrating how open science and engineering can serve both people and the planet. Our approach is guided by a concept we have termed 'Eightech', which stands for technologies that are electronic, ecosystem-positive, energy-efficient, economical, easy to use, edge-computing, enduring, and expandable. Together, we are demonstrating that innovation can build systems that are smart, equitable, and sustainable.

EARTH ROVER PROGRAM'S KEY ACHIEVEMENTS AND BREAKTHROUGHS TO DATE

- Earth Rover Program secures ~GBP 3M in initial funding
- High-end accelerometers are used at an approximate cost of GBP 1000 per unit
- High-frequency geophones are used at an approximate cost of GBP 100 per unit
- The Earth Rover Program develops its MEMS sensor kit at an approximate cost of GBP 10 per unit
- Scalable soil sampling in operation across dozens of agroecological zones on 3 continents
- Mapping topsoil properties such as bulk density at 10cm scales
- Earth Rover Program secures GBP 1.1M in additional funding
- ERP-GPT is developed by the Earth Rover Program

The Way Ahead: Creating a Global Soilcast

For the first time, we can work together towards sustaining high crop yields with lower environmental impacts. The Earth Rover Program's innovations allow us to bridge the gap between global food demand and the urgent need to preserve the living world.

As we scale up, the Earth Rover Program aims to develop the world's first global soilcast, a new system to capture the current state of our soils and anticipate their future health. Just as the weather forecast revolutionised how humanity responds to atmospheric change in daily lives and society, a soilcast aims to transform how we understand and manage soil and agricultural systems. By analysing vast soil datasets, in combination with local farmer knowledge and AI-supported inference, we can generate forecasts, nowcasts, and hindcasts that are locally relevant, actionable, and continuous, guiding the decision-making of community growers, research institutions, government agencies, small and large farmers and other land managers.

Unlike meteorologists, who can measure the atmosphere from within without disturbing it, soil scientists have long lacked the tools to study the ground in this way. The Earth Rover Program's non-invasive sensor technology addresses this challenge, making it possible to map and measure the living structure of soil without digging or damage. By designing affordable tools that can be used by non-experts, we will be able to scale up to the point of forecasting.

This new soilcast represents a profound shift in environmental intelligence. It will allow us to observe and interpret the living interior of the soil, creating forecasts that strengthen the world's ability to sustain yields and livelihoods, and accelerate the transition to regenerative farming and ecological restoration. It will quantify and monitor soil carbon, both its current state and its potential, in both shallow and deep soils at an unprecedented resolution. Data assimilation and causal inference models will allow us to assess soil carbon behaviour under changing climatic conditions, crop choices, and management practices. In this way, carbon storage efforts can be made transparent, credible and locally precise, creating the conditions for food systems and societies that are both productive and resilient to climate extremes.

Beyond yields and carbon, the soilcast will enhance soil safety, with the additional potential to assess, by inference, the prevalence of toxins, pollutants, and plastics before they reach our crops and water systems. As global soil data accumulates, we will be able to forecast shocks and strengthen resilience across supply chains, particularly those affecting local, exposed communities.. In the long term, this knowledge could even redefine how we value land, as we begin to prioritise soil function, resilience, nutrient density, and ecosystem contributions over extractive productivity alone.

We are still in the early stages of this global endeavour, but the foundations are in place. With hubs on three continents, the Earth Rover Program is building an inclusive network of scientists, research partners, and farmers dedicated to revealing the extraordinary world beneath our feet. Just as the Human Genome Project revolutionised medicine by decoding the human body, mapping the planet's soils will transform our understanding of the ground that sustains it, creating a shared, trusted source of knowledge for the benefit of people and the planet.

This is not simply a scientific challenge; it is a moral, health and ecological imperative. By accurately taking soil's vital signs, we can act with foresight, sharing the knowledge and the tools that will enable anyone, from smallholder farmers to global policymakers, to plan for a regenerative future – a healthy one, for humans and the planet alike.

Together, we can catalyse a new, greener agricultural revolution. By understanding our soils, we can create abundance without exhaustion, restore balance to our ecosystems, and ensure that the planet which feeds us can thrive for generations to come.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REFERENCES

1 Pimentel, D. (2006), 'Soil Erosion: A Food and Environmental Threat', Environment, Development and Sustainability 8(1), 119–137.

2 Cherlet, M., Hutchinson, C., Reynolds, J., Hill, J., Sommer, S. & Von Maltitz, G. (2018), World Atlas of Desertification: Rethinking land degradation and sustainable land management(3rd ed.). Publications Office of the European Union, Luxembourg.

3 Scholes, R., Montanarella, L., Brainich, A., Barger, N., ten Brink, B., Cantele, M., Erasmus, B., Fisher, J., Gardner, T., Holland, T. G., Kohler, F., Kotiaho, J. S., Maltitz, G. V., Nangendo, G., Pandit, R., Parrotta, J., Potts, M. D., Prince, S., Sankaran, M. & Willemen, L. (2018), 'Summary for policymakers of the assessment report on land degradation and restoration of the Intergovernmental Science- Policy Platform on Biodiversity and Ecosystem Services.', Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) pp. 1–44.

4 Pimentel, D. (2006), 'Soil Erosion: A Food and Environmental Threat', Environment, Development and Sustainability 8(1), 119–137.

5 Anthony, M.A., S.F. Bender, & M.G.A. van der Heijden, 2023. Enumerating soil biodiversity, Proc. Natl. Acad. Sci. U.S.A. 120 (33) e2304663120, https://doi.org/10.1073/pnas.2304663120.

6 Cherlet, M., Hutchinson, C., Reynolds, J., Hill, J., Sommer, S. & Von Maltitz, G. (2018), World Atlas of Desertification: Rethinking land degradation and sustainable land management(3rd ed.). Publications Office of the European Union, Luxembourg.

7 Scholes, R., Montanarella, L., Brainich, A., Barger, N., ten Brink, B., Cantele, M., Erasmus, B., Fisher, J., Gardner, T., Holland, T. G., Kohler, F., Kotiaho, J. S., Maltitz, G. V., Nangendo, G., Pandit, R., Parrotta, J., Potts, M. D., Prince, S., Sankaran, M. & Willemen, L. (2018), 'Summary for policymakers of the assessment report on land degradation and restoration of the Intergovernmental Science- Policy Platform on Biodiversity and Ecosystem Services.', Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) pp. 1–44.

8 Sartori, M., Philippidis, G., Ferrari, E., Borrelli, P., Lugato, E., Montanarella, L. & Panagos, P. (2019), 'A linkage between the biophysical and the economic: Assessing the global market impacts of soil erosion.' Land Use Policy 86, 299–312. https://doi.org/10.1016/j.landusepol.2019.05.014

9 Savage, S. (2024), 'UN blasts "shamefully" high hunger levels.' Financial Times, 24 July. Available at: https://www.ft.com/content/d909cbe4-5011-4eab-8118-34c649b690b8

10 Vågen, T.-G. & Winowiecki, L. A. The LDSF Field Manual. (World Agroforestry (ICRAF), Nairobi, Kenya, 2023).

11 NRCS: National Resources Conservation Service, US Dept of Agriculture, Official Soil Series Descriptions (OSD). https://www.nrcs.usda.gov/resources/education-and-teaching-materials/official-soil-series-descriptions-osd-fact-sheet

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