LCNR briefing

Leverhulme Centre for Nature Recovery

Photo © Nore Jane Long on Unsplash

January 2026

Author

Ella Browning | Leverhulme Centre for Nature Recovery, Environmental Change Institute, School of Geography & the Environment, University of Oxford

Emerging potential and remaining challenges of monitoring soil health using passive acoustic approaches

Summary

- Monitoring soil health is important for identifying successful management practices to improve outcomes for people and nature, particularly in agricultural contexts.
- Passive acoustics combined with transparent analysis approaches has huge potential for democratising and scaling up soil monitoring. However, current approaches for analysing soil soundscapes do not explain the processes linking soil health to the soundscape.
- Early results of our research into the suitability of passive acoustics for monitoring soil health in UK pastureland systems, highlight the need to explore the mechanisms behind associations between soil health and soil sounds.
- We particularly emphasise that soil ecoacoustics is new area of work, therefore, evidence is still emerging.

Introduction

Improving soil health is vital for achieving equitable, long-lasting environmental recovery that benefits people and nature. Research increasingly demonstrates the positive links between healthy soil and tackling climate change, biodiversity recovery, water quality management, reducing flood risk, increasing crop production, and positive human health outcomes. Earlier this year, in recognition of the holistic outcomes of healthy soils the EU enshrined soil monitoring into law. However, monitoring soil health can be manually intensive, requiring chemical analysis, or expert identification of tiny to microscopic soil fauna. These approaches are not scalable, meaning only a small area of land can be surveyed at a few points in time with scarce expertise, limiting our understanding of the processes driving positive or negative changes in soil health. New technological approaches offer opportunities for enabling essential soil health data to be collected at larger scales, in a more accessible way.

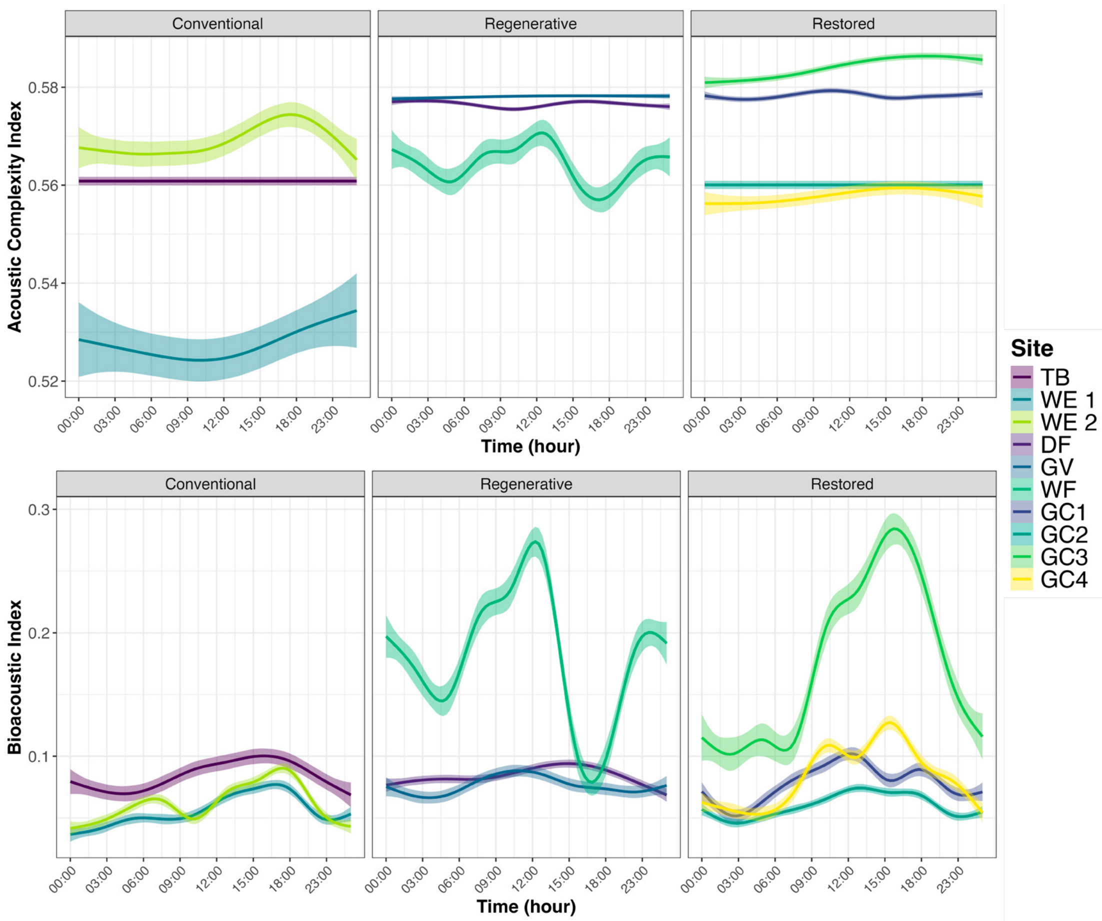
Passive acoustic monitoring, the use of autonomous recording units to collect ecoacoustic data, is now a widely used tool for surveying above ground and underwater habitats. Recent advances in technology now enable passive acoustic sensors to be deployed for extended periods of time and in many locations simultaneously, collecting valuable data at scales relevant for understanding processes driving changes in environmental health. Analysis of ecoacoustic data may focus on identifiable sounds made by animals (biophony), providing information on species presence, activity and density, or whole soundscape analysis, comparing the amount of biophony with the levels of sounds associated with human activities (anthrophony). Soundscape analysis can be used as a method for rapid ecosystem health assessment and has been particularly useful in locations or habitats where there is limited knowledge about animal specific sounds, such as coral reefs and tropical forests. In the last few years, researchers have begun exploring passive acoustics as a scalable approach for soil health monitoring, a realm where the sources of many recorded sounds remain a mystery, making soundscape analysis a logical approach.[1]

Our work

We are investigating whether passive acoustic monitoring of the soil is a suitable approach for assessing soil health and the performance of nature recovery approaches in UK grassland agricultural landscapes. In the summer and autumn of 2024, ecoacoustic data were collected at 10 grassland sites in Oxfordshire across three farms and one ex-farm, along a gradient of intensive cattle farming, regenerative cattle farming, and passive rewilding site. Alongside passive acoustic sensors deployed in the soil for 24 hours at each site, traditional soil biodiversity monitoring was conducted, collecting hundreds of specimens of large and tiny soil dwelling animals, such as earthworms, ants, woodlice, millipedes, beetles, and insect larvae. Earthworms made up the majority of soil invertebrates collected, with a particular dominance in the autumn.

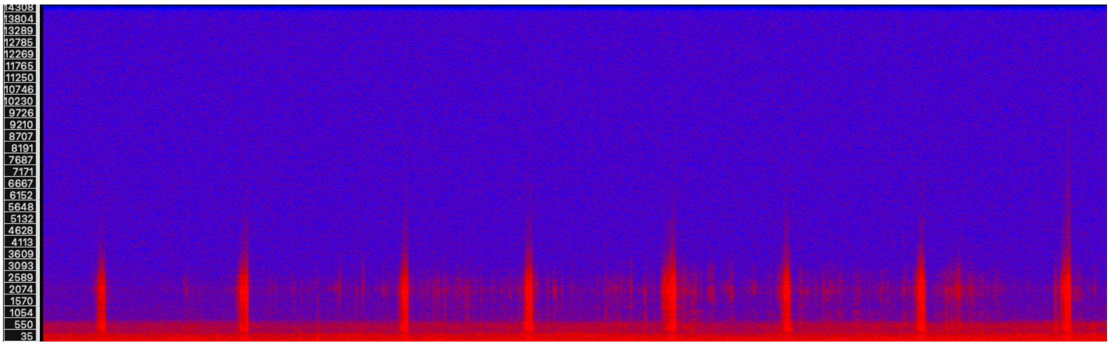
We have first used soundscape analysis approaches to assess whether there are significant differences between the grassland management types. Applying a suite of acoustic indices,[2] which seek to quantify habitat health through a numerical description of soundscape dynamics, early results indicate that the soundscapes of the restored sites may be significantly different to the conventional sites (Figure 1). However, it is unclear whether these differences in the soundscape are due to the outcomes of restoration or other factors. We think further work is needed to unpick the mechanisms linking soil soundscapes to soil health and possible confounding factors. For instance, the impact of soil type and moisture on sound transmission is not well known, yet it will impact the sounds recorded. Furthermore, given the field's infancy, there is a need for standardisation in data collection protocols, including passive acoustic sensor and recorder types, and audio data processing methods.

Figure 1: Trends in two acoustic indices used to analyse soil soundscape data collected over a 24 hour period in the Oxfordshire pasture gradient study sites. The lines are coloured by site names.



There were significant correlations between the number of earthworms collected and many of the acoustic indices, suggesting they contribute to the soundscape through the sounds they make moving and eating, such as a distinctive 'scrape' (Figure 2). We think that identifying such faunal specific sounds will give us better insight into the health of the soil and above ground habitat, enabling us to unpick what is driving differences between sites. Starting off with the earthworm 'scrape', we are developing an open-source machine learning model to automatically detect this and other soil faunal sounds in the data. Estimating activity and densities of soil fauna from passive acoustic monitoring data would better indicate soil function and the effects of regenerative or restorative management practices to be identified. Our work ultimately aims to fill in evidence gaps in the suitability of passive acoustics for monitoring soil health across multiple sectors and environments in the UK, but particularly agricultural systems. If successful, this monitoring approach could empower farmers and land managers to more easily collect and analyse their own soil health data and enable soil health data collection at the scale needed for identifying sustainable practices.

Figure 2: Spectrogram of an earthworm ‘scrape’ recorded in Oxfordshire grassland. Listen to the earthworm scrape and other examples of our soil soundscapes on Soundcloud.



Glossary

Term	Definition
Acoustic indices	Quantitative metrics which seek to describe patterns in the sound of an audio recording, such as temporal changes in amplitude or frequency. Used as proxies for ecosystem health.
Anthropophony	Human generated or associated sounds, such as speech, music, traffic, machine noise, and domesticated animals.
Biophony	Sounds made by wild animals vocalising, such as bird song, bat echolocation, insect chirps, alarm calls.
Ecoacoustic	The study of environmental sound.
Geophony	Non-biological natural sounds, such as waves, rain, wind, leaves rustling, and ice breaking.
Passive acoustic monitoring	The use of acoustic recorders to collect ecoacoustic data.
Soundscape	All sounds present at a location, including natural and human associated sounds.
Spectrogram	A visual representation of an audio recording.

References

1 Robinson, J.M., Annells, A., Cavagnaro, T.R., Liddicoat, C., Rogers, H., Taylor, A. and Breed, M.F. 2024. Monitoring soil fauna with ecoacoustics. *Proceedings of the Royal Society B: Biological Sciences*, 291 (2030): 20241595. doi: 10.1098/rspb.2024.1595

2 Bradfer-Lawrence, T., Duthie, B., Abrahams, C., Adam, M., Barnett, R.J., Beeston, A., Darby, J., Dell, B., Gardner, N., Gasc, A., Heath, B., Howells, N., Janson, M., Kyoseva, M.-V., Luypaert, T., Metcalf, O.C., Nousek-McGregor, A.E., Poznansky, F., Ross, S.-J., Sethi, S., Smyth, S., Waddell, E., Froidevaux, J.S.P. 2025. The Acoustic Index User's Guide: A practical manual for defining, generating and understanding current and future acoustic indices. *Methods in Ecology and Evolution*, 16, 1040–1050. doi: 10.1111/2041-210X.14357

About us

The ongoing loss and degradation of nature is one of the greatest challenges of our time. In response, the Leverhulme Centre for Nature Recovery (LCNR) was created in 2022 as a hub for innovative research on nature recovery. It brings together experts from a broad range of disciplines across the University of Oxford. The team collaborates with partners in communities and organisations around the world.

What is nature recovery?

We define nature recovery as the activity of helping life on Earth to thrive by repairing human relationships with the rest of the natural world.

Our aims

- To understand the societal, biophysical, policy and systemic factors that enable or challenge nature recovery
- To collaborate with partners in case study landscapes to test and enhance frameworks, technologies, and tools for effective, inclusive, scalable, nature recovery delivery that also provides for society and its wellbeing
- To establish an inclusive nature recovery community at Oxford, leveraging its intellectual capital and interdisciplinary convening power to address key debates and challenges in the field.

Leverhulme Centre
for Nature Recovery

Contact us

naturerecovery@ouce.ox.ac.uk
www.naturerecovery.ox.ac.uk
@naturerecovery.bsky.social
@NatureRecovery
Leverhulme Centre for Nature Recovery
The Nature Recovery podcast

LEVERHULME TRUST

The work of the Leverhulme Centre for Nature Recovery is made possible thanks to the generous support of the Leverhulme Trust.