LAND USE for NET ZERO >>> HUB

Twelve things we learned about soil carbon sequestration and cycling with Joel Williams

Talking Heads

This conversation is the seventh instalment in a series of Talking Heads interviews with the LUNZ Hub Soil Health and Carbon Dynamics TAG community. Throughout this series, we explore the key themes that the community will be working on throughout the LUNZ project lifecycle.

In this instalment, TAG co-leads Ellen Fay (Sustainable Soils Alliance) and Professor Pete Smith (University of Aberdeen) speak to Joel Williams, independent plant and soil health educator and consultant, about the scientific, biological, and practical aspects of soil carbon sequestration and carbon cycling. Drawing from his work across Europe, Australia and North America, Joel brings both global insight and grounded, on-farm relevance to the discussion.

The article below provides a summary of the key takeaways from the interview. The full interview can be viewed on the LUNZ YouTube channel.

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1. Maximising soil carbon starts with root biomass, not yield

The fundamental principle behind soil carbon sequestration is capturing atmospheric carbon through photosynthesis and directing it below ground. Joel Williams emphasises that while agricultural productivity often focuses on above-ground yield, it is root biomass that plays the most significant role in soil carbon accumulation. Modern crop breeding has often been selected for varieties with greater above-ground productivity, inadvertently reducing root-to-shoot ratios. This has shifted carbon allocation away from the soil, limiting our ability to build organic matter.

To reverse this trend, Joel recommends selecting species and varieties — particularly within cover crop blends — that favour deeper and denser rooting systems. Increasing root density enhances carbon inputs into the rhizosphere and supports soil structure and microbial activity, both of which are key to long-term carbon retention. Integrating perennials into rotations further boosts root contributions, improving both soil health and resilience.

2. Root exudates are powerful, efficient builders of stable soil carbon

While plant roots themselves are important, it is their exudates — the sugars, amino acids, and lipids secreted by living roots — that offer one of the most efficient pathways for building stable carbon in the soil. These lower molecular weight compounds are quickly consumed by soil microorganisms, which in turn build microbial biomass. When these microbes die, their decaying bodies form microbial necromass, a major component of stable, long-lasting soil organic matter.

Recent scientific advances show that this necromass is especially effective at forming mineral-associated organic carbon (MAOC), which binds tightly to clay and silt particles and is highly resistant to decomposition. Joel highlights that the carbon use efficiency of root exudates — their ability to be quickly converted into microbial biomass rather than respired — makes them far more effective than surface-applied plant litter in building stable carbon. Maintaining continuous living roots in the soil is therefore critical, not just for biological activity, but for ensuring that this highly efficient carbon pathway remains active year-round.

3. Above-ground biomass plays a secondary but context-dependent role

Although much of the focus is rightly placed on below-ground processes, above-ground biomass does still contribute to soil carbon, particularly where biological activity supports its incorporation. However, Joel cautions that this contribution is minor relative to root inputs — especially in systems lacking biological mechanisms like earthworms to draw litter below the surface.

Research suggests that roots are approximately five times more likely to become stable soil organic matter compared to shoots of equivalent mass. This is largely due to their location within the soil and their immediate proximity to microbial decomposers. However, in systems with high earthworm activity and favourable soil biology, surface residues may be drawn into the soil, increasing their potential to contribute to carbon pools. In these situations, residue management strategies can be optimised to complement living root systems and maximise overall carbon gain.

4. Bare fallows and excess nitrogen are major carbon liabilities

Of all the management practices discussed in the interview, Joel identifies bare fallows as the most harmful to soil carbon. Not only do they halt photosynthetic carbon inputs, but they also accelerate carbon loss through oxidation and microbial decomposition. Maintaining green cover through diverse cropping or permanent vegetation is therefore essential to sustaining and building soil organic matter over time.

In addition to fallowing, overuse of synthetic nitrogen fertilisers can also have a suppressive effect. While modest nitrogen applications can promote plant growth and thus carbon capture, excessive inputs can inhibit root development and microbial activity. High nitrogen availability can lead to lower carbon use efficiency in the rhizosphere, destabilising the microbial carbon cycle. Optimising fertiliser use and supporting plant nutrition holistically are therefore vital for aligning productivity with carbon sequestration goals.

5. Compost is an effective carbon input — but scaling requires in-field strategies

Compost and manures stand out as effective tools for building soil carbon, particularly in cropland systems. Joel references a 2021 European review that found compost to be the most effective practice for increasing soil carbon, thanks to its pre-stabilised, biologically digested nature. As compost breaks down, it delivers microbial necromass and stable organic compounds directly into the soil carbon pool.

However, Joel cautions that compost is often sourced from off-farm, meaning it brings with it an economic cost for purchase and transport. Where possible, farmers should focus on in-field practices that enhance carbon flows directly — including the use of cover crops, reduced tillage, and deep-rooted species. These practices not only avoid the logistical constraints of compost but also stimulate local microbial populations and improve soil structure, supporting longer-term resilience.

6. Perennial leys in arable rotations are a game-changing opportunity

One of the most promising strategies discussed was the reintroduction of fertility-building perennial leys into arable rotations. These grass-clover or herbal leys not only support root development and microbial activity but also provide opportunities for livestock integration and nutrient cycling. Joel views this as a way of “banking” soil carbon and fertility, which can then be drawn upon during subsequent cropping phases.

This building-drawing cycle aligns well with the concept of a soil “carbon account,” where fertility phases focus on depositing organic matter and cropping phases make strategic withdrawals. Over time, this rotational approach has the potential to stabilise soil health, improve productivity, and deliver measurable carbon gains. Given the UK’s temperate climate and variable rainfall, Joel sees this as a particularly effective and context-appropriate strategy for British farmers.

7. Soil carbon saturation is real — but we're not there yet

Soil carbon does not increase indefinitely. Mineral-associated organic carbon (MAOC) forms through binding to clay and silt particles, and these binding sites are finite. Once these sites are filled — a state Joel likens to a full car park — further sequestration through this mechanism slows. However, he stresses that most agricultural soils in the UK are far from reaching this saturation point.

Additionally, other forms of soil carbon — notably particulate organic carbon (POC) — are not limited by mineral surfaces and can continue to accumulate. While POC is more vulnerable to loss, deeper rooting and better aggregation can stabilise these pools over time. Joel also emphasises the potential for carbon storage at depth, particularly in subsoil layers where mineral binding capacity remains untapped. This underscores the importance of practices that support deep rooting and vertical carbon distribution.

8. Subsoil compaction is a widespread but surmountable challenge

Despite the potential for deeper carbon sequestration, subsoil compaction presents a major barrier. Decades of mechanised farming have led to dense, impenetrable layers that restrict root access and limit the biological activity needed for carbon cycling at depth. Joel describes compaction as one of the most consistent issues he observes across geographies and farming systems.

While long-term solutions lie in biological remediation — using deep-rooted species to restructure the soil — Joel is pragmatic about the need for short-term interventions. Strategic, one-off mechanical disruption (such as subsoiling or deep ripping) can provide an initial opening, allowing biological processes to take hold. These interventions must be followed by living root systems to prevent the soil from re-compacting and to promote long-term structural resilience.

9. Carbon cycling and sequestration must work together

There is often a perceived tension between carbon cycling (which involves carbon being released back into the atmosphere) and sequestration (which seeks to retain it in the soil). However, Joel stresses that these processes are not in conflict — rather, cycling is the precursor to sequestration. Without active biological cycling, there is no stabilisation of organic matter.

Microbial respiration and turnover drive the transformation of plant carbon into stable soil fractions. These processes inevitably involve some CO_2 release, but this is part of a productive system that supports long-term carbon retention. Keeping the soil biologically active — through green cover, root exudates, and minimal disturbance — ensures that carbon continues to flow through the system, with a portion of it being stabilised and stored.

10. Stabilisation is key to turning cycling carbon into sequestered carbon

For carbon to remain in the soil long-term, it must be stabilised. Joel outlines two primary stabilisation pathways: chemical stabilisation, where microbial residues bind to mineral surfaces, and physical stabilisation, where organic matter is protected within soil aggregates. Both processes are critical to ensuring that carbon cycling translates into sequestration.

Management practices that support stabilisation include maintaining soil structure, reducing tillage, and fostering microbial diversity. Disturbance, particularly ploughing, breaks apart aggregates and exposes protected carbon to decomposition. Maintaining continuous cover, fostering aggregation through root biomass, and ensuring pore space connectivity are therefore essential to creating a stable, carbon-rich soil environment.

11. Simple field tests are effective indicators of soil carbon dynamics

Farmers do not need access to expensive equipment or lab analyses to monitor soil health. Joel recommends a suite of simple tests that offer reliable proxies for carbon cycling and soil condition. Infiltration tests, slake tests (aggregate stability), earthworm counts, and soil smell all provide accessible, on-the-ground insights into soil function.

These methods are particularly useful because they reflect the physical and biological properties that underpin carbon cycling and sequestration. For example, good infiltration indicates porosity and aggregate stability, which support microbial respiration and root development. A soil that smells earthy and rich is typically biologically active and well-aerated — conditions conducive to building and storing carbon.

12. Baseline measurement and ongoing tracking are essential for audit-readiness

As interest in soil carbon markets and environmental audits increases, establishing a reliable baseline becomes more important. Joel emphasises that carbon monitoring must begin before any management changes are made, to ensure that progress can be meaningfully measured and verified.

He highlights platforms like Soilmentor, which allow farmers to log and track indicators such as infiltration rates, worm counts, and soil structure over time. For more formal schemes — such as carbon offset or biodiversity markets — Joel advises careful attention to project requirements and consistent, scheme-aligned data collection. By pairing rigorous baselining with farmer-friendly monitoring tools, land managers can position themselves for future opportunities and ensure credibility in sustainability reporting.

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