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SOIL CARBON NOTE /

Soil Carbon Webinar Series #10

Soil Organic Matter as a Buffer Against Fertiliser Shocks

Against a backdrop of renewed fertiliser supply disruption in 2026, the international "4 per 1000" Initiative convened a scientific webinar that put soil organic carbon at the centre of a conversation. The message delivered by two leading researchers Prof. Stuart Grandy and Dr. Matt Wellenstein was clear: soil carbon is not only a climate asset. It is a nitrogen reserve, a financial buffer, and a form of farm insurance whose value has been systematically overlooked by the markets, lenders and policy frameworks that shape how farmers manage their land.

Fertiliser supply disruptions are often treated as temporary market events. Prices rise, farmers reduce inputs, yields fall, supply chains adjust, and after a period of instability the market is expected to return to normal. Yet this way of looking at fertiliser shocks is incomplete. It overlooks what happens in the soil.

When nitrogen fertiliser prices rise sharply, farmers often apply less nitrogen. Lower nitrogen inputs reduce crop growth and yields. Lower yields mean less crop residue returns to the soil. This matters because crop residues, roots and organic inputs are the raw materials from which soil organisms build soil organic matter and organic nitrogen reserves. A fertiliser shock can therefore continue long after prices have stabilised, through a decline in soil organic matter and a weakening of the soil's capacity to supply nitrogen in future seasons.

WHEN DOES A FERTILISER SHOCK REALLY END?

Dr Matthew Wellenstein asked this question. When a fertiliser supply shock occurs, most analysis focuses on the market: prices spike, demand falls, then supply normalises, and the story moves on. His research suggests the story does not end there. It continues, below ground, in the soil.

Nitrogen fertiliser and soil organic matter are not independent. Fertiliser nitrogen supports crop growth. Crop growth supplies residues and roots. These residues and roots help maintain soil organic matter. Soil organic matter, in turn, stores and releases nitrogen over time.

A fertiliser shock can therefore trigger a negative cycle:

- higher fertiliser prices lead to reduced nitrogen application;
- reduced nitrogen application leads to lower yields;
- lower yields reduce crop residue and root inputs;
- reduced organic inputs weaken soil organic matter formation;
- declining soil organic matter reduces the soil's nitrogen-supplying capacity;
- weaker nitrogen supply increases vulnerability to future shocks.

A fertiliser shock does not end when fertiliser prices return to normal. It ends only when the soil's productive capacity and nutrient reserves have recovered.

Dr Wellenstein's modelling of coupled economic, agronomic and soil carbon dynamics illustrates this point. The results suggest that:

- a 20% fertiliser supply shock, sufficient to double fertiliser prices, can produce a global yield decline of around 4% relative to baseline;
- even after a short-lived shock, yields may not fully recover if soil organic matter has been drawn down;
- a sustained 10-year supply impairment of similar magnitude can push yield losses close to 6% by year ten;
- around one quarter of the additional long-term yield loss may be attributable to the compounding depletion of soil organic carbon stocks;
- at farm scale, low-soil-carbon systems experience sharper gross margin losses than systems with higher soil organic carbon.

The financial effect can be greater than the yield effect. When fertiliser prices remain high, farmers face both reduced output and elevated input costs. Gross margins are therefore compressed disproportionately. Soil organic matter does not eliminate this pressure, but it can reduce its severity by supplying part of the crop's nitrogen requirement from the soil reserve.

This is especially important for regions that combine low soil organic nitrogen reserves with high dependence on imported synthetic fertiliser. Sub-Saharan Africa and South Asia are among the most exposed regions. Other major agricultural regions, including Australia, Brazil, Argentina and parts of China, may also be vulnerable where imported fertiliser dependence coincides with limited soil organic nitrogen buffering capacity.

THE ROLE OF SOIL ORGANIC MATTER IN NITROGEN CYCLING

Professor Stuart Grandy critiques the agricultural sector which typically thinks fertiliser as an annual input-output problem, measured by how much nitrogen is applied, what it costs, and how much ends up in the crop that year. This framing ignores the biogeochemical complexity of how soil actually processes nitrogen. Fertiliser applied to a field enters a living matrix of microbes, minerals, roots and organic compounds. What happens to it inside that matrix shapes not just this year's yield, but the system's resilience across multiple seasons.

Soil organic matter is not a single uniform pool. It includes several fractions that differ in composition, persistence and function. Two broad pools are particularly important for understanding nitrogen buffering:

- particulate organic matter (POM), made up of partly decomposed plant and microbial residues, generally with a higher carbon-to-nitrogen ratio and faster turnover;
- mineral-associated organic matter (MAOM), where organic compounds are associated with soil minerals, generally with a lower carbon-to-nitrogen ratio and a greater contribution to longer-term nitrogen storage.

Much of the nitrogen held in soil organic matter is associated with mineral surfaces and microbial residues. This nitrogen is not immediately available to plants, but it is not permanently locked away either. Through microbial activity, root processes and mineral-organic interactions, part of this nitrogen can be released and made available to crops.

This process is central to the buffering role of soil organic matter. A soil with stronger organic matter and mineral-associated nitrogen pools can store part of the nitrogen surplus in favourable years and release part of it when fertiliser inputs are reduced.

Experimental results from Grandy's laboratory underline the practical significance of this pathway:

- Adding root litter alongside fertiliser significantly increases the proportion of fertiliser nitrogen recovered in the MAOM fraction, particularly in low-organic-matter soils
- A very small in-furrow nitrogen application of just 5 kg N per hectare at planting achieved faster and more precise recovery in the MAOM fraction than conventional broadcast applications, and subsequent crop uptake was more efficient
- Diverse crop rotations built nitrogen specifically in the MAOM fraction and, in follow-up experiments using isotope tracers, reduced crop dependence on external nitrogen inputs — even sustaining nitrogen uptake under drought conditions[2]

Using a scenario model, Grandy demonstrated that improving fertiliser nitrogen recovery from 50% to 70%, a target already sought by many in the industry, opens the door not just to reduced inputs at equivalent yields, but to the active accumulation of organic nitrogen stocks. When a shock then arrives, and fertiliser is cut to 75 kg N per hectare, a system that has built those stocks can sustain yields for one to two seasons by drawing on banked MAOM nitrogen. The shock is absorbed.

FINANCIAL INCENTIVES AND RISK ASSESSMENT

One of the main barriers to building soil organic matter is not only technical. It is institutional and financial.

Farmers often understand the long-term value of soil health, but they operate within annual budgets and short-term financial constraints. Investments in soil organic matter may take several years to generate measurable benefits. These benefits are also not always visible to those who finance agricultural production.

At present, many financial assessments rely heavily on past yield records, farm income histories and current asset values. These are useful indicators, but they are mostly backward-looking. They may not capture whether a farm is becoming more resilient or more vulnerable.

Soil organic carbon could play a role as a leading indicator of agronomic risk. A farm that is building soil organic matter may be improving its capacity to withstand drought, input price volatility and fertiliser supply disruption. Yet this improvement is rarely reflected in loan conditions, insurance premiums or risk ratings.

This is a missed opportunity. If lenders, insurers and policy makers recognised soil organic carbon as part of farm risk assessment, the incentives for soil health investment would become better aligned with long-term resilience.

This does not mean that soil carbon should be reduced to a simple financial metric, but its role in nutrient buffering and risk reduction, should be made more visible.

WHAT THIS MEANS FOR THE "4 PER 1000" AGENDA

The fertiliser shock issue reinforces the central message of the International "4 per 1000" Initiative. Building soil organic carbon at scale delivers not one benefit but several simultaneously: climate mitigation through carbon sequestration, improved yield, nitrogen use efficiency, reduced dependence on synthetic inputs, and measurable protection of farm livelihoods during supply shocks.

These benefits are now quantifiable at the farm, regional, and global scales. The tools to measure soil organic carbon exist. The science of the mechanisms is advancing rapidly. What remains is the harder institutional work: making that value legible to lenders, insurers, policy makers and market designers — and creating the incentive structures that would reward farmers for building it.

The webinar, chaired by Professor Budiman Minasny (The University of Sydney / 4p1000 Scientific and Technical Committee Chair), featured presentations by Dr Matthew Wellenstein (Syngenta Group) and Professor Stuart Grandy (University of New Hampshire). The recording is available through the 4p1000 Initiative.

REFERENCES

Grandy, A.S., Daly, A.B., Bécu, T., Cardinael, R., Fontaine, S., Jilling, A., MacLaren, C. and Phillips, R.P. 2024. A microbial framework for nitrogen cycling solutions in agroecosystems. One Earth, 7(12), 2103–2107.

Grandy, A.S., Daly, A.B., Bowles, T.M., Gaudin, A.C., Jilling, A., Leptin, A., McDaniel, M.D., Wade, J. and Waterhouse, H. 2022. The nitrogen gap in soil health concepts and fertility measurements. Soil Biology and Biochemistry, 175, 108856.

Link to webinar recording :
https://www.youtube.com/watch?v=I-MLDGZyX4Y&list=PLJVn8dEjGgHt0olLrwt9DL1Cu4KYrZ1yQ&index=10