Innovation Briefing

Trusted soil measurement is the key to scaled regenerative agriculture

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CC in three your key notes to take away

1. The sustainability imperative is driving business and government policy worldwide – but initiatives must be reliably and quantifiably measured to keep net zero on track.

2. Regenerative agriculture is set to unlock a more sustainable future, but only if there is confidence and traceability in soil measurement related to carbon, biodiversity and health.

3. Emerging deep tech, including novel, miniaturised instrumentation, holds the key to obtaining high quality, trusted data sets from the field and enabling regenerative agriculture to scale.

Introduction

Sustainability is now core to the mission, vision and strategy of businesses and nations worldwide. Everyone has net zero targets and grand plans to minimise environmental impact. But questions about implementation and traceability are emerging. Few are more pertinent than the thorny issue of measurement and traceability. How do you reliably and quantifiably measure the impact of initiatives to ensure your net zero ambitions remain on track? And do they stand up to external scrutiny?

In this Innovation Briefing we explore this conundrum through the lens of regenerative agriculture – which promises to unlock a more sustainable future for the planet. But the plain fact is this. Regenerative agriculture will only be successfully adopted at scale if there is confidence and traceability in the measurement data of soil.

As consumers demand products with minimal environmental footprints, CPG/FMCG companies are looking upstream in their supply chains. They're eyeing ways to offset their daily business and generally promote more sustainable practices to enhance their green credentials. This is the core principle of regenerative agriculture – improve yields where possible but do it in a way that doesn't exhaust the soil or overuse fertilisers, fungicides and pesticides.

Consensus is it's the right thing to do, but mass adoption has been challenging. That's partly due to agriculture's risk averse nature, but also down to the issue of traceability – and proving that the regenerative practices adopted have made a demonstrable difference. Nowhere is that challenge of measurement and traceability more acute than in carbon accounting and sequestration.

Many industries are intrinsically carbon positive – air travel, cement manufacture, steel making and mining to name a few. They can't flip the switch to net zero technologies overnight, so the short-term solution is to offset their carbon emissions. This has driven an explosion of companies offering carbon credit trading schemes, verification audits and accreditation services.

But generally, these entities rely on modelling, not measurement to build their conclusions. And where those models are built on shaky assumptions, the consequences and lawsuits can be significant – just ask Delta Airlines and carbon credit broker Verra. Not surprisingly, consumers now expect and demand more accountability on sustainability claims. Some argue for an environmental footprint indicator on food and beverage packaging, much like that used for calories, fat, sugar and salt.

All this means rigorous, trusted measurement data is essential to provide evidence and traceability of carbon capture and effective storage. That emissions really are balanced out. But regenerative agriculture is much more than carbon – it's about optimising nutrient use and improving soil quality by supporting biodiversity and the soil microbiome.

All of these factors need to be measured if farmers, consumer companies, carbon traders and consumers are to believe in the power of regenerative agriculture and drive adoption accordingly. So, what can be done? How do we build the chain of trust in the data that's required to build the wave of widespread adoption? As ever, we need to start with the economics.

The value of trusted data

Regenerative agriculture is fundamentally about the health of the soil – healthy soil stores more carbon, provides more nutrients to crops and supports a diverse biological ecosystem. And at a high level, the soil can be considered as three main constituents: organic and inorganic carbon; nutrients (nitrogen, phosphorus, potassium); and the soil microbiome, the myriad of different living entities within it.

Traditionally, most of the interest in soil science has focused on nutrients as insight there drives how much fertiliser to add to the soil each growing season. But sustainability drivers, geo-political tensions and energy price shocks have seen interest skyrocket – with involvement stretching all the way from the farm, through agritech providers, to CPG/FMCG companies and grocery chains. That's because each of these entities sees an increasing value gain from the soil, from off-setting (and in-setting) emissions, through to transparency and traceability of produce all the way to enhancing production per acre, feeding billions of mouths globally in a sustainable and cost-effective manner.

In short, there are a lot of different customers for soil data and that makes it valuable. This value proposition is key to driving adoption of regenerative agriculture practices – nothing is more effective at changing behaviour than economics. But those three components of soil have a different value proposition to a different set of customers, each with their own demands on the quality of the data and the level of traceability associated with it. Let's start with the hottest and potentially the most controversial of the three: carbon.

Carbon – quantifying the value

The soil has the potential to capture and store an enormous amount of carbon. Project Drawdown estimates that 15-23 gigatons can be captured and stored through regenerative agriculture practices. As such, it has a critical role to play in combating climate change. This ability to act as a significant carbon sink has attracted attention from companies far and wide, particularly those which need to offset business today as they race to find ways to de-carbonise their business in the future. In turn, it has led to an explosion of companies which trade carbon credits, manage carbon offsetting programmes, provide verification of projects and practices – as well as those who provide data that underpins the whole system.

This flourishing ecosystem has also captured the interest of major CPG/FMCG companies and grocery retailers, several of which have set up initiatives and funds to encourage farmers to embrace regenerative agricultural practices and in doing so sequester carbon. PepsiCo and Coca-Cola have been two of the high profile players here to date, allocating $216m to regenerative agriculture and $138m to sustainability funds respectively. Other CPG/FMCG companies have taken a different route; Land O'Lakes has, through its Truterra business, set up an entity which not only connects directly with farmers but offers a platform to manage carbon credits on their behalf. All of this has been driven not only by bold sustainability initiatives but by the value of carbon itself, as indicated in the graph below.

This whole ecosystem relies on data from the farm in order to provide information about the level of carbon captured as a result of regenerative agriculture growing practices. Much of that data today has been provided by models underpinned by satellite imagery – great for providing relatively low-cost approximations but lacking in ground truth.

This ground truth data will significantly increase in value as the nature of the market starts to pivot from voluntary to compliance, driven in part by legally binding government commitments to net zero targets. That data has to come from physical measurement of the soil, but measuring carbon is difficult and relies upon optical techniques that are more traditionally found in the lab, rather than the field.

But that hasn't deterred a wide range of start-ups from developing impressive instrumentation approaches, from the NIR spectroscopic methods of Yardstick and ChrysaLabs, through to Raman spectroscopy at SoilOptix and visual spectroscopy and dielectric permittivity at Landscan. These instruments, frequently underpinned by AI driven data analysis techniques, are providing a wealth of data from the dirt, feeding into the wider carbon market ecosystem and potentially unlocking a new revenue stream for growers.

Indeed, such is the potential of such technologies that the big agricultural equipment OEMs are now getting in on the act, with John Deere and CNH now forming partnerships with start-ups to get access to technology that is otherwise outside of their comfort zone. The value associated with soil carbon is clear and the technology is advancing but as we mentioned earlier, regenerative agriculture is more nuanced than just carbon. So, what about measurement of a much more 'traditional' component of soil – nutrients?

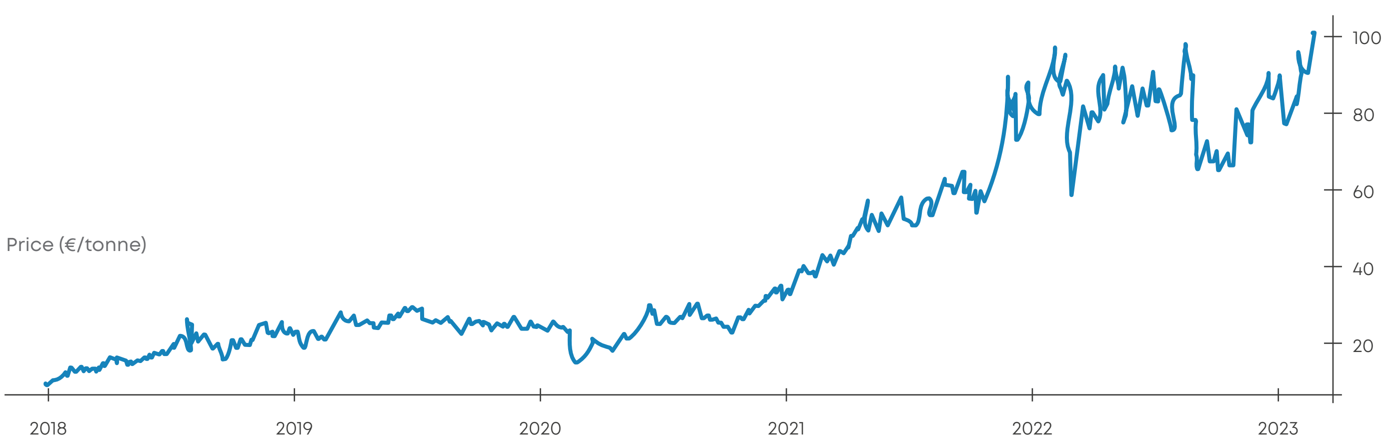


Figure 1: Carbon price increases in the last 5 years **Source:** Refinitiv

Measuring nutrient levels in the field

Nutrient measurement within the soil can embrace many things, but let's keep things simple and talk about NPK (nitrogen, phosphorus and potassium). These three elements and the compounds they form have been the background of agricultural fertiliser since the creation of the Haber-Bosch process. But the energy costs associated with that process, and the fundamental costs associated with mining potash, have made precision measurement of soil nutrient levels all the more important.

One of the tenets of precision agriculture is the ability to grow more using less, driven by ever more precise application technologies in the form of AI-enabled sprayers and planters (Deere's See & Spray system being a case in point). The technology to apply accurately already exists. But to know where to apply and how much to apply, you first need information about how much NPK is in the soil today. Granular data on that has been lacking – until now.

Nutrient measurement has traditionally been conducted in a lab where a soil core sample taken weeks previously is exposed to heat, undergoes pyrolysis and the vapourised components measured using spectroscopy. The process is robust and accurate, but it's slow and expensive. Furthermore, it's not set up to scale in the way it needs to given the progress of precision application machinery and the surge in demand prompted by the increasing cost of fertiliser. A method of detecting in-field NPK levels is needed to really close the loop between what is present, where and how much to apply.

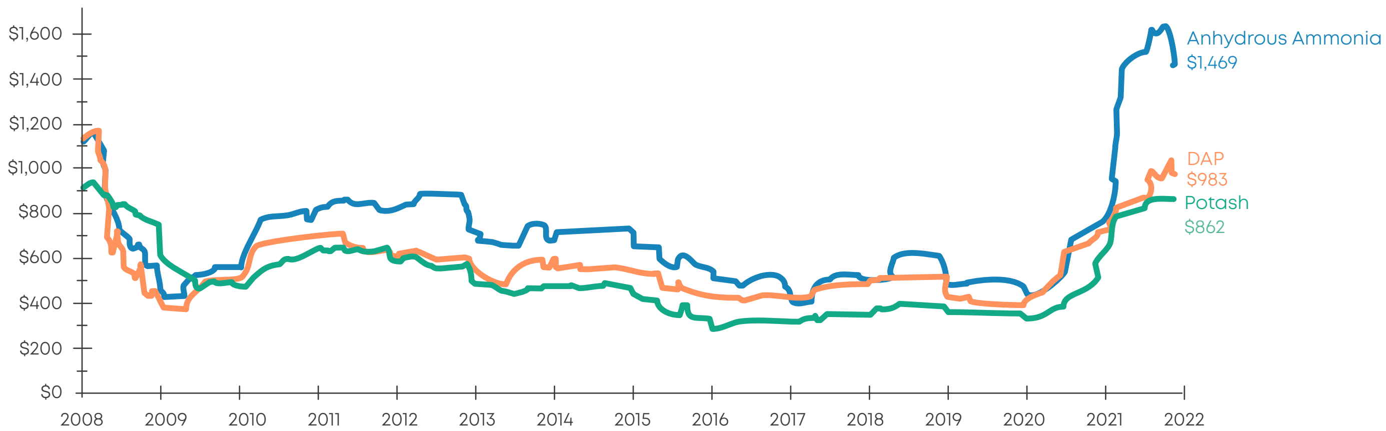


Figure 2: Fertiliser costs per ton **Source:** US Department of Agriculture. Agricultural Marketing Service

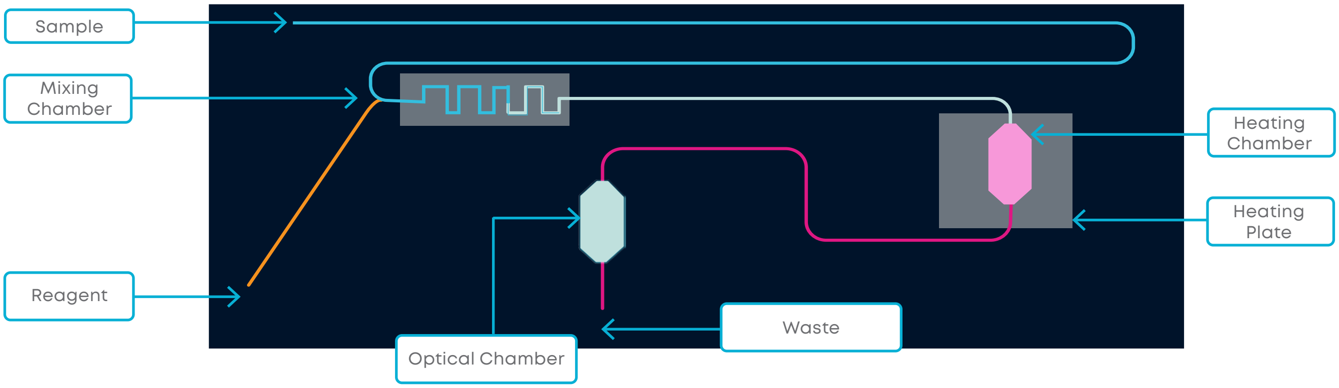
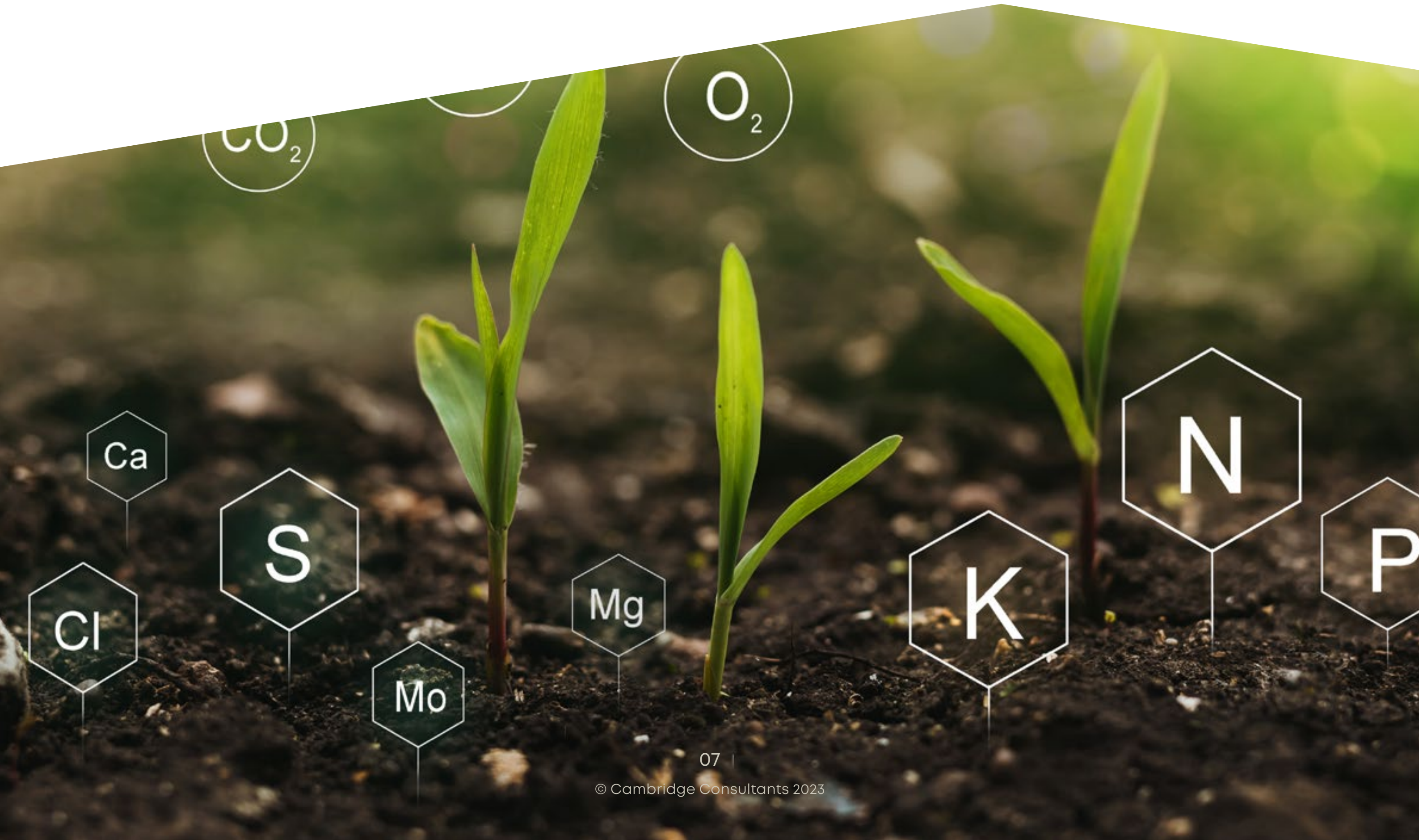


Figure 3. Concept design for automated measuring

This is where the world of optical physics and chemistry combines to create infield diagnostic tools, taking principles from technologies used in point-of-care diagnostics in the medical industry, to bring low-cost instrumentation to the farm field. One such example has been developed for nitrate sensing. By combining chemistry and microfluidics in a single, consumable cartridge it is possible to measure nitrates and nitrites to better than 5ppm accuracy with a reusable optical sensor and control system for cents per test.

This approach is completely scalable across a wide range of form factors, from a handheld unit that can measure ~100 samples from a single cartridge, to an automated system on the back of a tractor capable of measuring thousands in parallel.

The potential of these optical/chemical technologies is huge given their form factor is compatible with current agricultural equipment and implements. Expect to see 'agricultural grade' optical components to be commonplace in the field in the next five years, much in the way that AI-enabled spraying technologies are becoming increasing mainstream today.



Monetising the microbiome

Soil is not a bland support structure for plants – it is teeming with life in a complex, delicate and dynamic balance. In fact, two thirds of the world's biodiversity lives in the soil. The commitments made at the Biodiversity COP15 in Montreal 2022 highlight the importance of preserving biodiversity not just for its own sake, but because our economy is utterly dependent on the ecosystem services it provides. In agriculture, monitoring the microbiome is a useful indictor of soil health.

It can offer insight into the diversity of organisms in the soil, the levels of plant pathogens present and could be used to determine if any soil remediation practices are making an impact. The most common way of measuring the microbiome is through molecular biology and sequencing to either look at the microbial community as a whole or for indicator species. This requires sample preparation which can be challenging in the field. It is usually sent away for sequencing and analysis of the sequence data at a central laboratory, with similar parallels to the measurement of nutrients described above.

Monitoring the microbiome in the field is hard, but the answer could be right in front of us, in the form of the plants themselves. One such example is being pioneered by the start-up InnerPlant which is redesigning plants to act as sensors, indicating early onset of disease or water stress before they are visible to the human eye using fluorescence. Detecting this requires either spectroscopic or AI-enabled camera based methods, depending on whether a passive or active approach is taken. This prompts another question: how to make such systems 'agriculture proof'.

Highly precise machine vision cameras are entering the mainstream now – see the John Deere See & Spray system cited earlier – but spectrometry is different. Spectrometers are typically expensive, delicate instruments which hate vibration and require expert handling in order to achieve accurate results. In short, not ideal for the world of agriculture. But these characteristics can now be overcome thanks to technology advances from the world of semiconductors: photonic integrated circuits (PICs).

PICs have the potential to bring the sensitivity of laboratory-based spectrometers into the field in a form that is smaller than a mobile phone and at a cost that is less than one hundred dollars per unit. Unlike in traditional optical instruments, a PIC light is confined to achieve quantised behaviour. This allows precision control for higher bandwidth, lower power and greater sensitivity for sensing applications.

Furthermore, the design dose not rely on sensitive moving parts, making PICs vibration resistant. This combination gives rise to the potential of small, light, highly precise spectrometers, tailored to the agricultural environment and enabling capture of data on plant health and the microbiome that previously were restricted to expensive, cumbersome laboratory instruments.

Conclusion

The novel, miniaturised instruments described above hold the key to unlocking the challenge of obtaining high-quality, trusted data sets from the field. Given such instruments can be time stamped and geo referenced with relative ease, they provide the traceability required of regenerative agriculture customers throughout the value chain. Carbon traders and buyers can be confident in the provenance of their credits. Farmers can point to data that enables them to be paid for sequestering carbon. CPG/FMCG companies can reference demonstrable improvements in soil health and sustainability through their regenerative agriculture programmes. And consumers can have confidence in the quality and environmental footprint of their chosen food.

Regenerative agriculture has enormous potential to drive positive change, not only for the agrifood sector but for humanity in general. It will only reach that potential if it reaches mass adoption. Seizing this colossal opportunity will require collaboration across the value chain, from CPG companies through agricultural equipment vendors all the way to farmers and agritech start-ups.

What can your organisation bring to bear in this global challenge and where will you start? Answering that question brings not only business benefit today, but much wider, grander, societal benefits for future generations to enjoy tomorrow. It's time to start planning, collaborating, designing, developing and most of all, measuring.

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If you'd like to discover more about the subject – or would like to discuss your ambitions for the new bioeconomy – please get in touch with:

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