ISSUE 24 | DECEMBER 2023

TECH FARMER

TECH MAGAZINE

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The robot that uses light to control weeds

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CONTENTS ISSUE 24

TECH FARMER

TECH MAGAZINE

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OLD-FASHIONED FARMING WITH **MODERN TECHNOLOGY**

Written by Chris Fellows

I first encountered this definition of 'Regenerative Farming' about a year ago, and it struck a chord with me. Farmers talk (often nostalgically) about farming like their grandfather used to, but while that is true in the approach, the method has changed massively. Technology has played a pivotal role in enabling regenerative practices to evolve on an unprecedented scale, and scientific studies have deepened our understanding of soil dynamics.

Reviewing Direct Driller Magazine over the past six years reveals a consistent blend of soil-focused content and technological advancements. Building on this foundation, we have decided to take our exploration further. Future magazine issues will alternate between technology and soils, allowing for in-depth discussions on each topic. Our approach, coupled with the launch of Groundswell in 2016, has profoundly shifted the perception of regenerative farming in the UK and increased its visibility throughout the supply chain. This shift is now being recognised with higher commodity prices.

In the realm of technology, our aim is to provide farmers with increased exposure to developments in the UK and around the world. This involves identifying areas for incremental advances and contemplating more extensive changes, envisioning what a modern farm might look like in the next two decades.

We often hear the assertion that "farming is changing", but the crucial question is: changing to what? We hope that the AgTech issues will assist farmers in understanding how to steer their businesses towards greater profitability and sustainability. Even if certain aspects of their farms undergo significant transformation, these changes will contribute to a more robust and adaptive agricultural sector.

Considering the constant evolution in farming practices, the average farmer in 20 years might be quite different. This prompts us to reflect on our own evolution compared with our parents and wonder whether we really anticipate farming for our children will be that different?

IT'S 2030, SO HOW HAVE WE DONE?

Tom Allen-Stevens travels forward to 2030 and imagines what prospects agri-tech pioneers will have.

In just a few days it will be 2030 – for over a decade, this has been seen as something of a milestone year in farming's journey to Net Zero.

It also seems a good point to look back on the first issue of Tech Farmer, that was launched just before Christmas 2023. What were the key issues we picked out then, and how have they developed since?

2023 was the beginnings of the Fourth Agricultural Revolution – a time at which it was first recognised (at last) that farmers are innovators as well as capable practitioners. The Basic Payment had reduced to half its original offering, and uncertainty surrounded how SFI would replace it.

No one had ever heard of ADOPT, the new Defra-funded scheme that's now credited for helping pioneering farmers bring new research into practice. Or at least no one had heard of it until Tech Farmer became the first to announce its arrival (right there on p42 of our first issue, if you have any doubts).

Interesting too that this was announced in the same article that explored the merger of the Agri-Tech Centres and the formation of what then became the Agri-Tech Catapult. Who would have thought back then that these centres would subsequently merge with AHDB?

Robotics was the focal point of that inaugural issue, and the cover story profiled for the first time what was then the relatively unknown potential of CLAWS – Concentrated Light Autonomous Weeding and Scouting (p12). Of course, things have now moved on – it's incredible to think how much we used to rely on glyphosate for weed control.

And do you remember those pre-emergence herbicides we used to apply with gay abandon, until weed resistance rendered them obsolete and regulators decided they'd had enough? Thank goodness for the pioneering solutions that have developed since, some of them shown at FIRA 2024 (p28).

One thing that struck me, looking back at that first issue, was Jonathan Gill's insight into what the next ten years would bring (p35), given his experience as one of the heralds of the hands-free hectare.

"My future hope is a flock of drones performing tasks across the fields, all self-launched and tasked by an AI field manager who knows the best

Whatever happened to John Deere's Gigadrone from its Farm of the Future at the 2019 Agritechnica?

conditions day or night to plant or protect crops even down to a single plant," he says. Wow – just remember, he talked of that at a time when UK regulation made such a hope unthinkable. Thank goodness policy makers took note.

To be fair, that's one aspect that the agri-tech pioneer of 2030 can be grateful for – the foundations for agri-innovation may have been laid down by the last Tory government (remember them?), but it's the Coalition that needed to step up to the task, and to be fair it did soon after the General Election in 2024. I certainly can't remember as much being invested in farmer-led R&D. And its ag policy is clearly proving to be a vote winner, if the recent GE2029 landslide victory for the new Labour administration is anything to go by.

The European picture is now a similar scene of good prospects for those farmers who have grasped the technology nettle and worked to shape it to their advantage. The EU New Horizon for Agriculture Agenda, signed after the end of the Ukraine conflict, at last gave the green light across Europe for gene-edited crops, and put the emphasis squarely on productivity, as the previous Farm to Fork Strategy was quietly dropped. Analysts reckon the policy move aligns the EU much closer to the UK's current agri-tech tract. This explains why some of the businesses we profiled in that first issue of Tech Farmer are expanding rapidly across the EU.

The global picture has been more of a rocky road, however. UK farmers may have benefited from the soya crisis of 2024, but the economic turmoil in South America that ensued has sent shock waves of uncertainty throughout the global ag industry. We've yet to see whether the US president can deliver in her second term of office the promises to support US Agriculture she made in her first, but the impact, in terms of agri-tech investment, is already being felt.

Nowhere was this more obvious than in the halls of Agritechnica 2029. Visitors to the show just six years earlier were treated to innovations such as New Holland's energy-independent farm (p50) and John Deere's Farm of the Future. The worry then was that the developments into autonomy and tech made by these global giants wouldn't be available to UK farms, with our small roads and fields. The UK was in danger of being marginalised out of agri-innovation directed purely at the vast fields and wide, open plains of the Americas and Eastern Europe.

But many who took the treck to Hanover last month were disappointed to find such tech hadn't moved on as much as had been promised – mutterings of 'emperor's new clothes' were not uncommon. What's now more likely, according to analysts, is that the investment needed to bring it to market melted away with the confidence in Big Ag, triggered by the soya crisis – whatever happened to the agricultural partnerships promised by the likes of Google, Amazon and Musk?

What Big Ag failed to recognise was the importance of involving farmers in developing that tech, and now those companies are paying the price. It was to represent the interests of those pioneering farmers that Tech Farmer came into being. We had seen how Direct Driller had gelled the interests of those pioneering a path in regenerative agriculture. It was time to bring those interests together with farmers from other sectors. To become a focal point for the surge of interest in agri-tech. To explore the fascinating and fast-developing realms of new tech, of AI, autonomy, of their possibilities to reshape how we farm.

But most of all it was to represent the interests of those who were resolved to shape it. To tell the stories and share the experiences of the farmers at the cutting edge of the Fourth Agricultural Revolution. Because, as we now know, this new chapter in farming's progression belonged to you. You implemented the innovations, breathed the life and the opportunity into the new tech.

So it's largely thanks to you that with just a decade to go, UK Ag is now well on track to deliver Net Zero – Happy Christmas and here's to a prosperous 2030.

Tom Allen-Stevens farms 170ha in Oxfordshire and leads the British On-Farm Innovation Network (BOFIN).

CREDIT The Summer Berry Company

LABOUR PAINS PUSH **ROBOTIC PICKERS**

Written by Mike Abram

Labour shortages are driving fruit and veg producers to examine robotic solutions. *Tech Farmer* attends the World Agri-Tech Innovation Summit in London to find out more.

Increasingly difficult to find and ever more costly. It's little wonder that some of the UK's most innovative farms and businesses are choosing to investigate and invest in the potential of robotics, rather than relying solely on manual labour.

"The reality is that it has become increasingly challenging to source seasonal labour in the UK," says David Sanclement, Group chief executive officer of The Summer Berry Company.

The firm grows strawberries, blueberries, blackberries and raspberries across 200ha in the UK, including 24ha in glasshouses, and mostly raspberries on 190ha in Portugal. "Our core market is the UK, and we serve most of the major retailers, including Tesco, Marks and Spencer, Waitrose and Asda. We also supply European retailers like Carrefour, Rewe and Aldi."

Each machine uses advanced artificial intelligence to help with key decision making required to harvest the fruit.

With no immediate prospect of the labour market becoming easier, the business has a vision to reduce its dependence on seasonal labour. Robotics is one area it is investigating, although David stresses he doesn't see robotics as a complete replacement for labour.

"It could be useful in a number of situations," he explains. "Most notably, using robots to forecast and potentially to provide a night shift, which is currently not attainable for our workers.

"In the longer term, we hope the use of robotics will support our labour needs eventually meaning less seasonal workers. It would be more efficient to have a stable year-round workforce with the robots supporting at peaks of harvest."

Another important advantage for the use of robots is through better forecasting capabilities, David adds. "This is important to us. We work with historical trends, relying on the expertise of our agronomists and weather forecasts, but with the addition of data coming from the robots we have better forecasting accuracy of when to pick."

Improved harvest data forecasting brings a couple of advantages for the business, David says. "One, it gives us an opportunity to forecast our labour more efficiently. If you can predict very accurately when you'll need to harvest the fruit, the difference between one week and another, you can optimise your labour in a better way.

"And two, you might achieve better returns with the supermarket. A retailer will be keen to receive information three weeks ahead rather than two days because it gives them a better opportunity to plan promotions

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or to plan strategically to allocate your fruit onto the shelf."

The Summer Berry Company trials with robotics start-up Tortuga AgTech began in 2018, with pick quality and picking speed the two most important criteria success was going to be judged on.

"This is a journey"

The business started comparing robots to the best picking performance but quickly realised it should be comparing them to the poorest picking performance. "AI and software are constantly improving, so you need to start from the bottom and progressively raise standards."

Picking speed has also improved significantly over the past three years, although generally it is still not as good as human labour. That doesn't matter that much with David looking at his current 54 Tortuga AgTech robots to replace night shifts or tackle fields where labour is not available.

Eric Adamson stresses that providing a harvesting service first is key as it creates immediate value for the grower.

The purpose-built and designed robots are cart-sized four-wheel machines that can work either inside or outside, with two arms that operate autonomously, explains Tortuga AgTech chief executive officer and co-founder Eric Adamson.

Each machine uses advanced artificial intelligence to help with key decision making required to harvest the fruit. "The most important thing you teach a human picker on their first day is which fruit to pick and which to leave," Eric says.

"Most of the management time after that is whether the workers are doing that right? Are they picking red ones and not the pink ones, or are they picking the pink ones that look red enough? That's actually losing yield for the farm and it's not as good quality for the supermarket.

The Summer Berry Company has 54 Tortuga AgTech robots, currently used to replace night shifts or tackle fields where labour is not available.

"It would be more efficient to have a stable year-round workforce with the robots supporting at peaks of harvest."

"Team leaders at The Summer Berry Company focus on performance, quality and speed. We need the same focus with the robots."

The robots run 17 machine learning models at any given time to help make those sophisticated decisions – where and how to drive, where and what to pick, and whether to pick or not. It's also collecting a bunch of data about the crop's growth at the same time, Eric says.

While the latter is an important add-on service, Eric stresses that providing a harvesting service first was key as it creates immediate value for the grower. "Help to solve the hardest problem first and then add the other things."

Customer service is another key requirement. "We provide a full service to the farm," Eric says.

That was important and a significant change, David adds. "I've worked with

Keston Williams joins the panel on stage at the Agri-Tech Summit to explain that he's looking for new solutions now that accessing labour has become more challenging following Brexit.

some other companies doing robotics and not all of them were able to offer service. Having a number of Tortuga members working at The Summer Berry Company makes a big difference if the robot is not working."

Barfoots target automation

High value vegetable crops are also fundamentally labour intensive making them a logical target for automation, says Keston Williams, chief operating officer of Barfoots. But some are much easier than others to automate.

His firm grows around 3400ha of various vegetable crops in the UK. "The vast majority of the area is sweetcorn, followed by tenderstem broccoli, courgettes, asparagus and green beans."

Like other farm businesses in vegetable and fruit production, accessing labour has become more challenging following Brexit. "I don't see that getting any better any time soon, and it's certainly continued to get more and more expensive, so we're looking for solutions that allow us to reduce labour and improve efficiency."

In some crops, such as sweetcorn and green beans a fully automated system for the crop is in place, in terms of machines for harvesting, grading and packing.

"In green beans we've taken it from a team of what would now be 400 people harvesting green beans to a team of 12 because it's automated.

"But for the sustainability of growing UK premium veg crops, we need to consider how we're going to automate the majority of our crops."

But what makes a crop like sweetcorn relatively straightforward to automate – it's a single destruct harvested crop – is the exact opposite for crops like courgettes and tenderstem broccoli.

"With courgettes we have to go into the field maybe as many as 25 times to harvest or graze it over a period of time. It's not a destructive harvesting process, so therefore you need to look after the crop when you harvest. Tenderstem broccoli, rhubarb and asparagus are the same – multiple passes of the same crop.

"Secondly, you also need the dexterity that's required to pick the crop – see the fruit, or flower in the case of tenderstem broccoli, and then pick it at the right point."

The image processing involved in that to decide on the spot whether to harvest now or leave it for another two days to mature, or if then it will be over mature, plus then the dexterity to pick it and put it in the right container are decisions the human brain can

Barfoots helped Muddy Machines develop its robotic harvesting platform for crops such as courgettes which require multiple passes within a picking window.

ASPARAGUS HARVESTING TOOL SHOWING PROMISE

An asparagus harvesting tool to fit onto Muddy Machines robotic platform, Sprout, is showing potential to be the viable application that unlocks further development uses, says Chris Chavasse, founder and chief technological officer of Muddy Machines.

Muddy Machines developed Sprout as a fully electric platform, with a 16 KwH battery that can run for 12-16 hours depending on the tool inside its payload. It's a 1.8m wide x 1.8m long 350kg platform without a tool – four easily accessible crop storage baskets hang off the back with the tools fitting under the canopy.

"It's four-wheel drive, rear-wheel steering, and has a pivoting front axle to maintain contact with the ground," Chris says. "It drives up to 1 metre/second so relatively slow – that's about 5km/h, but it's much slower than that as it has to stop and start to identify where the crop is."

It's currently slower than a person picking asparagus, which is the first tool that was developed to fit onto sprout. "We've been developing it for the past three seasons. It uses 3D cameras to identify where the crop is, machine learning to identify when we want to harvest, what's right, what's not and avoid all the crop that is immature and only harvest when it is right."

Muddy Machines hopes to offer Sprout as a platform to other innovators or companies on which to develop their own tools, Chris says. "We are proving the platform is a viable solution, so we hope it gives confidence for others to use to develop their own tools so they can get those solutions to growers faster.

"When we started there wasn't any suitable platform so we had to develop our own. It's been hard so we don't want others to have to go through that pain and slow them down."

The machines have been developed so one person can supervise five to 10 robots, and because they are modular with capability of carrying different tools it allows maximum utilisation without large capital investments for growers.

Muddy Machines currently offers the robots on a harvest-as-a-service model, where it operates the robots and gets paid in the same way as a human worker would be, but it wants to transition to a hardware-as-a-service leasing model in future, Chris says.

"Growers would say they need the equivalent of 50 or 100 workers, we would calculate and provide the equivalent number of robots. The grower would pay us the equivalent they would pay for the workers."

Chris Chavasse talks through the attributes of the Muddy Machines robotic platform Sprout to delegates at the Agri-Tech Summit.

make quickly and with great accuracy. "They're much more difficult to replicate on a robotic basis."

For a while Barfoots put those requirements in the too difficult to overcome box, but advances in artificial intelligence and image recognition have brought it into the realm of the possible, Keston suggests.

That's led to three projects beginning with tenderstem broccoli in 2020, then courgettes two years ago and a herd project last year with robotic company Muddy Machines using funding from UKRI and Innovate UK.

The initial project with tenderstem broccoli started by testing image recognition, Keston says. "That's grabbing a camera, pointing it at the crop, move it around and then develop software that can recognise it. As long as you can get around and through the leaves, it doesn't work too badly."

The next phase was to develop a robot, or "end-effector" as Keston calls it, that can harvest the crop. This came in two parts – first Muddy Machines developed a lightweight robot platform, called Sprout. Sprout is then fitted with bespoke tools under the canopy.

"The piece of kit we designed gently pushes the leaves out of the way, and then another arm enters the crop and picks the tenderstem broccoli," Keston says.

"We've developed it as a proof of concept, but we've reached the project's end point where it's proven to be difficult and slow. At the moment, the project is parked because to scale it up and make it work is going to be extraordinarily difficult."

Courgettes are looking more promising. "We've got a stage where we can recognise the courgettes, and have developed a little end effector that can pick them without damaging the main plant.

"The project is reaching its conclusion now, and it is looking more exciting to take forward to the next stage of developing an initial prototype, although I would imagine there would be multiple prototypes before it comes anywhere near being commercially viable."

Five growers, including Barfoots, are involved in the latest "herd" project. The concept is having a harvest team of one person, who controls maybe 20 harvesting robots or rovers, which coordinate harvesting of the crop from one press of a button.

"It's about having some sort of centralised coordination of multiple robots that logically think like a harvest manager."

While the projects are showing the challenges of automating harvesting and processing of some crops, Keston believes it is also highlighting it is achievable. But lack of investment is slowing down progress.

"As an industry, it's being done on a shoestring. It's not like you have a backing of a Tesla or some huge industrial process that's shoving millions at it to get it right. These are literally garages of clever guys making stuff, and because of that I think it will take time to get there.

"But it doesn't have to. The proof of concept shows it is possible, it's just the development and the engineering around it that needs to accelerate quickly and that funding needs to come from somewhere."

Unfortunately, he says the profit margins within fresh produce aren't enough for businesses like Barfoots to fund that development, while there isn't enough volume in the number of robots required for a machinery business to get excited.

"As a consequence it's languishing in a horrible midfield area that doesn't go anywhere. I don't have the answer of how that can change unless a philanthropic entrepreneur wants to give it a go," he concludes.

- The World Agri-Tech Innovation Summit took place in London on September 26 and 27, 2023.

THREE-TERRY TECH

Why have four wheels when three offer more flexibility and stability? The 250kg E-Terry from Germany can adapt to range of widths, can be set to different heights to suit crop growth stage and easily folds for transport and storage, says COO and co-founder Fabian Rösler.

Electrically driven and primarily for weed-scouting, it has a forward speed of 1.5km/h and covers 3ha on a full battery charge in eight hours. Pilot trials on five farms in Germany are set to start in the spring.

ROOTWAVE GOODBYE TO WEEDS

The first 15 commercial Rootwave machines are being delivered to vineyards and orchards over the next few months, says CEO Andrew Diprose.

Available as a 1.8m trailed machine for vineyards or 4m for orchards, a PTO-powered generator packs 10kW of power down to each of six 0.5m-wide electrodes. With a forward speed of 5km/h, the 18kHz high-frequency voltage fries any weeds they come into contact with.

Claimed to be as effective as glyphosate, two-thirds of prospective customers are conventional growers looking to move away from herbicides.

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INDUSTRY-LEADING RESEARCH IN ROBOTICS AND AUTOMATION

Based in the Lincolnshire countryside, a 10-minute drive out of the city, the Lincoln Institute for Agri-food Technology (LIAT) at the University of Lincoln, is an internationally renowned centre for industry-leading research in robotics and automation.

At its Riseholme Campus, LIAT is also home to a working farm with specialist research facilities and sector-leading expertise.

The mission of LIAT is to support and enhance the future of food and agriculture productivity, efficiency, and sustainability through research, education, and technology.

It has been a very busy year for the team, having been involved in many key Agri-tech projects.

In February, LIAT's Reverse Coal Programme was mentioned as a positive case study in the UK Government's Environmental Improvement Plan 2023 and highlighted as an example of how peatlands can be more responsibly managed.

The scheme is taking place at the Lapwing Estate, a 5,000-acre estate near Doncaster known for being an innovative leader in 'rethinking peatlands'.

Peatlands are one of the most fertile lands in the UK for food growth, but the process emits excessive CO2. The alternative is Reverse Coal, which shifts to indoor farming using a sustainable biomass fuel source as its power.

The energy comes from growing biomass feed stock, which is then subjected to a thermochemical treatment (pyrolysis) to create a source of energy. The pyrolysis will also produce biochar which will then be stored in a unique storage facility demonstrating that CO2 can be permanently captured.

Dr Amir Badiee is the Project Lead on behalf of the University of Lincoln.

He said: "Fossil fuels have been used for so long in food production that their negative impact cannot be understated, but this project proves that there is a better way.

"Reverse Coal sequesters carbon and produces food with positive environmental impact. This solves the inherent dilemma of bioenergy crops: the loss of land from food production."

March saw the launch of Agri-OpenCore, an innovation to deliver an accelerated programme of robotic crop harvesting for horticulture.

Agri-OpenCore, funded by the Department for Environment Food and Rural Affairs' Farming Innovation Programme, has been introduced to tackle the lack of seasonal harvest labour in the UK horticulture industry. Many crops have gone unpicked this year, leading to large amounts of unnecessary waste.

LIAT at the University of Lincoln is partner in Agri-OpenCore alongside project lead APS Salads with Dogtooth Technologies Ltd, Wootzano Ltd and Xihelm Ltd.

There is currently no robotic system that can match the speed of human picking. Agri-OpenCore aims to make progress in this area by cutting the time and cost of developing a robotic harvesting system that achieves parity with human picking.

To deliver this, Agri-OpenCore will develop the world's first open development platform for agri-robotic harvesting, with an aim to develop commercial robotic systems for tomato and strawberry harvesting that achieve human-picking-cost-parity in two years.

Also in March, LIAT became a key partner in a new project that will improve farm sustainability and profitability by using nitrogen more effectively.

From Nitrogen Use Efficiency to Farm Profitability (NUE-Profits), funded by DEFRA's Farming Future R&D Fund: Climate Smart Farming, will aim to make the use of nitrogen as efficient as possible for farms by using data taken throughout a season.

Thorvald in broccoli field

The project will provide farmers with a management system called 'Framework for Improving Nitrogen' (FINE) that uses plants as sensors.

As nitrogen use and emissions are reduced, the partnership will explore new income opportunities for farmers financed by reduced carbon emissions. The aim is to make nitrogen use measurements the new benchmark for farmers to utilise nitrogen effectively to provide more profit whilst improving sustainability in farming.

Reverse coal

The NUE-Profits project is a partnership of AgAnalyst, the University of Lincoln, Velcourt, Dales Land Net, Dyson Farming, Agreed Earth, Assimila, European Food and Farming Partnerships, N Blacker & Sons, Hill Court Farm Research and Navigate Eco Solutions.

In May, the UK Farm to Fork Summit was held at 10 Downing Street. One of the guests at the summit was Professor Simon Pearson, Director of LIAT, who was joined by 70 other attendees from around the food sector.

The Prime Minister and members of the Cabinet viewed agri-tech research displays and spoke with the exhibitors. Additional support for the food sector was announced from the Government with a focus on agri-tech, which will involve research carried out by Professor Simon Pearson and the team at LIAT.

Speaking shortly after the event, Professor Simon Pearson, Director of LIAT, said:

"The Farm to Fork Summit was a fantastic opportunity for key players in the industry to demonstrate how important the food sector will be to the future of this country.

"Rishi Sunak and Cabinet Ministers took great interest in both the agri-tech and glasshouse sectors, which will involve work from LIAT and its partners, and have pledged a significant investment to accelerate growth over the coming years."

In September it was confirmed that LIAT would be home to a new net zero glasshouse research and development facility, set to be built on the University of Lincoln's Riseholme campus.

This new purpose-built glasshouse, funded by the Greater Lincolnshire Local Enterprise Partnership, will offer access to specialist research infrastructure and innovation support services. This will allow SMEs and other businesses in the agricultural sector to adapt or improve their products or services.

The glasshouse will be sub-divided into independently controlled compartments, facilitating the delivery of multiple projects at the same time throughout the year.

Eligible businesses will have access to research and knowledge transfer opportunities from experts at the University of Lincoln who will support businesses within the industry to adopt new technology, implement new processes and develop new products to transition into modern, technology-enabled businesses.

Most recently, in what has been a very busy and prosperous year for LIAT, an announcement was made that the Universities of Lincoln and Cambridge had been awarded a £4.9 million grant to fund the region's drive to become a global innovation centre for agricultural technology.

Simon Pearson outside 10 Dowing Street

The Lincolnshire and Cambridgeshire (LINCAM) region is already a major UK production centre for crop-based agriculture and the associated supply chain, leading to what is recognised as a national agri-tech cluster.

At the Universities of Lincoln and Cambridge, agri-food innovation is focused on digital technologies, including robotics and artificial intelligence, to boost productivity. Now, the hope is that the Place Based Impact Acceleration Account award from the Engineering and Physical Sciences Research Council – the main funding body for engineering and physical sciences research in the UK – will deliver a step change in activity.

Simon Pearson, Founding Director of LIAT, said: "The LINCAM agricultural sector supports 88,000 jobs, generates a value of £3.8 billion and farms more than 50% of the UK's grade 1 land. However, despite this scale, there are still significant challenges and opportunities.

"Food production accounts for 24% of all UK greenhouse gas emissions, leads to significant biodiversity losses and drives challenging social issues – not least from seasonal worker influxes to rural communities. In addition, farmers are under relentless cost pressures which are eroding supply chain equity and local economies.

"These challenges are acute across the LINCAM region, but this funding award offers an opportunity to harness agri-tech to secure sustainable growth, bringing high-value and skilled jobs to the region."

FLASH, CRACKLE, **POP**

Written by Tom Allen-Stevens

Concentrated light technology has passed proof of concept as a form of weed control and is being developed through field trials. Tech Farmer sees the Earth Rover 'CLAWS' in action.

James Miller, Edwin Stretch, John Morgan

CLAWS moves forward, a little more than 0.5m, and stops. There's a flash from under the hood which lights up the young crop of lettuce below. This is quickly followed by dozens of tiny spots of blue light and there's a rasping, crackling sound.

You realise that the spots of light are focused on the weed seedlings around the lettuces, and each one gives up a tiny wisp of smoke as it's momentarily lit. Then there's the rather satisfying smell of weeds being fried to death.

"We call it concentrated light technology – it works in much the same way as sunlight being focused by a magnifying glass," explains Earth Rover CEO James Miller from behind a pair of red safety specs. "You can do the same job with lasers, but this is far more effective, efficient and safer.

CLAWS uses semiconductor LEDs to generate light that is then concentrated precisely onto the meristem of a weed seedling.

"At a distance of more than 2m, you don't really need the safety specs – these are a precaution because the operating regulations haven't caught up with our technology yet. If we were using direct lasers, there'd be a risk of the light bouncing off a shiny surface and causing injury."

One 2m-wide machine will look after about 4ha in a day, depending on weed burden, says James Miller.

Developed as the LightWeeder, it's claimed to be the world's first eye-safe, herbicide-free, carbon neutral, commercially viable weeding system. It uses semiconductor LEDs to generate light that is then concentrated precisely onto the meristem of a weed seedling – the most sensitive area of the plant and the point at which it emerges from the soil.

The rover can scout for the crop, the weeds or both, and have the data available on a laptop, tablet or phone for decision making in real time.

By now the CLAWS rover has finished picking out the weeds and is moving on to the next section – flash, crackle, pop. While it takes a fraction of a second for each weed to be fried, the length of time it pauses over an area of soil – about 1m² – varies, depending on the weed burden.

This machine tackles up to 60 weeds in a second with its three modules of concentrated light units. These are shrouded beneath the branded hood – the heart of the patent-pending technology – and James wasn't about to let an inquisitive journo make a closer inspection. There's a claimed work rate of 1.5ha in an 8hr day.

"Once commercialised and fully autonomous, one 2m-wide machine will look after about 4ha in a day, depending on weed burden, passing continually over taking out the weeds as they emerge," continues James. "There are optional solar panels, which would keep it charged up for a full day, and the battery alone would power it for about half a day from a full charge."

Frying the weeds is just one aspect of the job done by CLAWS, which stands for Concentrated Light Autonomous Weeding and Scouting. On the front and under the hood are eight built-in cameras that detect the exact location of the crop and weed seedlings. This results in a complete data map of the crop after planting, showing the plant's exact location, size, and any early signs of disease.

The meristem detection technology allows the robot to identify the growing point of the weed, which is the most sensitive area of the plant, and apply the precise amount of light needed to eliminate it. The CLAWS makes use of edge AI processing and can create a 3D image of the crop bed. "You can have the rover scout for the crop, the weeds or both, and have the data available on a laptop, tablet or phone for decision making in real time" he adds.

The 3D image is needed so the blue light can then be focused on exactly the right place to fry the weed. "Range of depth is critical, and currently this is something of a limitation. If the target weed sits on a ridge of soil in the bed, that can put it out of range of this prototype," notes James.

Weed identification is continually improving – every pass allows further training of the algorithms. The final limitation is size of weed. "It can control relatively large weeds, but the power consumption can be prohibitive. So it's most efficient and effective when the weeds are at seedling stage with the meristem exposed."

But it is a true kill – independent trials have found the CLAWS technology is as effective as herbicides at controlling both monocotyledon and dicotyledon weeds, and concentrated light offers an improvement over chemistry where there is an element of herbicide resistance. This makes the overall effectiveness of a single pass of the Earth Rover about 60% currently, but James sees no reason why this shouldn't improve to close to 100% as the machine trains itself and the range of depth improves.

"So far, the team has focused on getting the clever bit right. The improvements will come from refining the simple bits," he says.

Currently undergoing trials, the overall effectiveness of a single pass of the Earth Rover is about 60% currently.

The organic challenge

The farming brain and origin of the business concept behind Earth Rover belong to James Brown, director of Pollybell Farms. He manages the 2000ha Lapwing Estate, an all-organic mixed farming business based at Little Carr Farm near Gainsborough, Lincs.

800ha of arable include 200ha of field vegetables, bringing in broccoli, cauliflower, cabbages and leeks, with 400ha of organic wheat and 200ha of barley. These rotate around fertility-building leys that support sheep and dairy youngstock enterprises. "We've moved away from a farm rotation to a field rotation, where the cropping is decided by market demand and field requirement," notes James Brown.

But it's the soil type that probably has most to do with how the farming system has evolved. This is Fenland, lying over sand and clay, no more than 1m above or below sea level. "Organic matter is consistently above 30%. We're farming in compost, which means the soil is incredibly fertile and has a very high weed burden."

The decision to go organic was made in 1997. This may have seemed odd for a business that at the time had its own agchem supply arm, but you get the feeling James Brown enjoys the bigger challenges. "1000 acres of organic are a lot harder to manage than 1000 acres of conventional agriculture. There's no get-out-of-jail-free card, and a zero yield is perfectly possible."

Weed control on a Fenland organic farm soon became the biggest headache, although James points out that the high organic matter tends to erode efficacy of herbicides. "Once you knock out chemistry, the only option is mechanical and that has severe limitations."

Ploughing is used as a rotational tool, usually brought in before the vegetable crop as this is where the yield suffers most from weed competition. "We also use mechanical hoes, and have used a precision-guided model, but there are two fundamental problems with these: firstly, when conditions are wet you can't operate it, but that's when most weeds emerge.

"We've also found the action of the hoe interferes with the roots of the crop. The weeds close to the crop plants are the most important ones to control as these are competing hardest. But yield and quality take a hit from the damage to the roots.

"I came to the conclusion that the best solution for weed control didn't exist, which is why I founded Earth Rover," says James.

The concept behind CLAWS came about through a chance meeting he had about six years ago with Luke Robinson, a scientist with an interest in AI and robotics. "It was Luke who pointed out that lasers are power-hungry and dangerous, but he had previous experience with concentrated light technology."

James provided the initial funding – around £200,000 – to develop the proof of concept for Earth Rover. "It was the time when the Mars Rover was very much in the news, which did provide the inspiration for some of the design, as well as the name."

In 2021, Earth Rover and Pollybell Farms teamed up with Agri EPI and NIAB in a £750,000, 18-month industrial research project, funded by Defra under its Transforming Food Production programme, delivered by Innovate

James Brown, John Morgan, Edwin Stretch, James Miller

UK. "This took the idea from concept to prototype. We also carried out the efficacy trials of the technology with NIAB and developed what the service would actually look like – we carried out interviews with other farmers.

The venture now has the backing of Mercia Asset management, and has developed the concept into two prototype units. There's a team of eight, including Tomàs Pieras, Chief Technology Officer, who has developed the robotics and AI weed detection. "Earth Rover also has an R&D facility in Spain where we have been further developing CLAWS."

The plan is to build the fleet up to a total of five units and run trials on a series of Pioneer farms in 2024. "We put a call out earlier this year, and the places are now all filled, but we're always looking for more triallist farmers. The aim is for 2025 to be our first commercial season. So we'll be selling the unit with a service and maintenance package," explains James.

"The way I see it, up to this point farmers have just had two options for weed control – chemical and mechanical. We've now added a third – thermal."

What is Concentrated Light Technology?

Ancient civilisations are known to have focused the power of the sun through concave reflection or refracted through glass to light fires for cooking and heating. The technology has seen considerable advances in recent years with the increase in renewable, solar power.

The essence of Concentrated Solar Power (CSP) lies in capturing and focusing sunlight to either generate electricity or to enhance the performance of solar arrays. Unlike traditional solar photovoltaic (PV) systems that convert sunlight directly into electricity, CSP focuses sunlight onto a receiver, which then converts the concentrated solar energy into heat. This heat can be used to generate electricity through a steam turbine or stored for later use in thermal energy storage systems.

A similar effect is achieved by focusing light-emitting diodes (LED) into a small focal spot. Applications include medicine, cutting and engraving. LEDs inherently emit light under defined angles of radiation, minimizing divergence losses compared to conventional lighting systems that radiate light all around. This means the light can be intensely concentrated producing very high temperatures at the focal point.

The concept of focusing light to produce intense heat at a point has been used over millennia to focus solar rays, and has applications in renewable energy, medicine, cutting and engraving.

The Carbon Robotics LaserWeeder features 30 industrial carbon dioxide lasers and has a claimed output of about 0.8ha per hour.

The lure of lasers

US startup Carbon Robotics, based in Seattle, has introduced its LaserWeeder implement that fits to a three-point hitch. The 6m wide unit features 30 industrial carbon dioxide lasers, more than three times the number on its original self-driving autonomous LaserWeeder. This gives it a claimed output of about 0.8ha per hour.

The trailed unit draws its power from the tractor, identifies weeds and targets them for elimination. Lasers use thermal energy to destroy the meristem of the weed without damaging nearby crops or disturbing the soil.

Carbon Robotics says growers who use the implements are seeing up to 80% savings in weed management costs, with a break-even period of 2-3 years. It can eliminate up to 5000 weeds per minute, identifying 99% of weeds. The LaserWeeder can operate on over 40 crops and create and deploy new deep-learning crop models within 24 to 48 hours.

The company raised $30M in series C funding earlier this year, and has units active across 17 US states and three Canadian provinces.

AGRONOMIST IN FOCUS...

GENERATIONAL POINTERS

Agrii agronomist, Todd Jex, gets a steer from his grandfather on how he's putting new tech into practice.

I really enjoy talking to the older farming generation about farming systems and the challenges they faced during their careers. My 92-year-old grandfather is often particularly keen to point out that many of the 'fashionable' and talked about practices are far from new. A few years ago, he came along to a winter conference at which I was presenting field scale trial results and observations on a long term regen farming system. At the end I was expecting him to remind me that diverse longer rotations, maintaining green cover and livestock integration were features of his farming system more than 50 years ago. Instead, he remarked in disbelief at how technology has developed.

I've been working as an agronomist for twelve and a half years which, in the context of grandfathers farming career, is the blink of an eye, but the rate of change from a technological point of view has been quite staggering. Back in 2011 precision farming was still in its infancy. We debated electroconductivity scanning versus grid sampling to establish our soil type-based sampling zones.

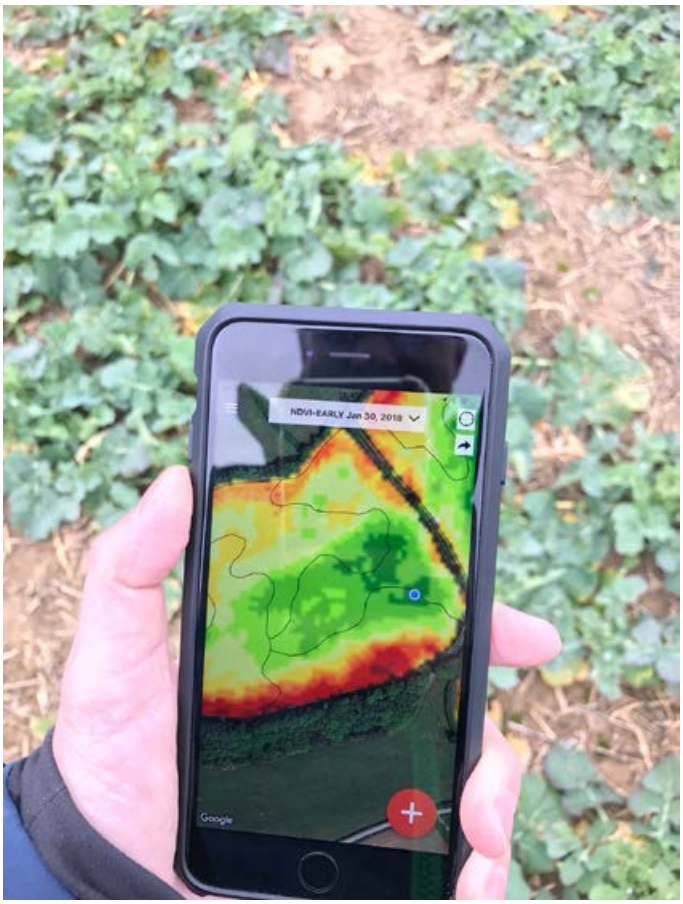
We'd then build variable rate P, K, Mg and lime plans as appropriate. At this stage software programs were still primitive and at times both time consuming and frustrating in equal measure. Trying to extract and use accurate yield mapping data from the combine was an annual duel. As VR capability in machinery became more affordable and widespread growth in VR drilling and N applications became the norm, results became positive and clear, especially in oilseed rape.

Working for Agrii I have access to the Contour digital platform, and the change and improvement from its predecessor is stark. Uploading yield maps is now fast and easy, regardless of manufacturer.

This web-based platform allows me and my customers to have access quickly and easily to:

- Soil type clay/silt/sand content
- Variable rate (VR) planning and mapping
- NDVI satellite imagery
- Uploading and viewing yield maps
- Nutrient Management Planning, NVZ and compliance
- Past, current and trend change in soil test results
- BYDV Tsum calculation
- Disease modelling and forecasting
- Soil temperature and localised weather data

In the past six years monitoring, measuring, and managing soil health has become one of the key cornerstones of agronomy for me. Collecting accurate physical, chemical, and biological data is important but measuring how the practices we implement influence these factors is vital. I use the app to geotag soil pit and data collection points and store the information collected within the Contour platform. We're also looking at how reliable live data from soil probes in the ground will be and how that can be used as a monitoring tool. With the existing SFI options, plus



future options on the horizon, and developing carbon markets there should be an increased emphasis on collecting accurate and meaningful baseline data. The next step will be using technology to help us collect and record baseline data from a farmland biodiversity point of view.

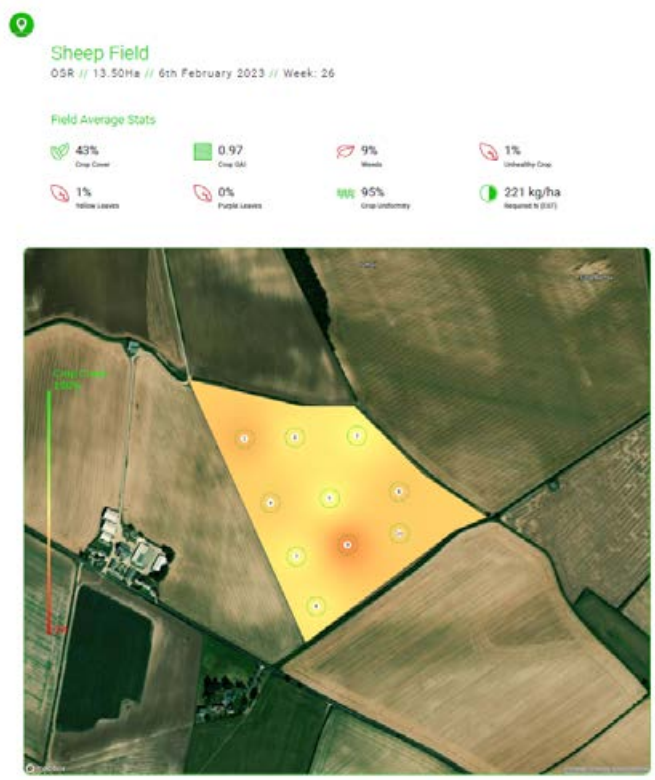
I now use Contour to support field walking. The NDVI satellite imagery is incredibly good at guiding and targeting field walking. It's a very regular occurrence to find that late winter/early spring high NDVI areas correlate directly to patches of grassweeds. It can then be helpful to use this to draw a polygon, whilst in the field, around the grassweed areas to monitor or to mark for rouging/spraying off. This is a salient point, and a reminder that ground truthing satellite imagery before producing a VR fertiliser plan is vital.

For the past 6/7 years I've been using a drone. It started with a DJI Phantom and I flew this myself to support a more targeted approach to particular issues. Generally, this would be to create drainage maps, identify slug areas, or for correlating yield maps with compaction or bird damage in oilseed rape.

Operator inadequacies and battery life were the limiting factors along with the weather, which I've tried very hard to avoid mentioning!

In more recent years I've swapped to a Mavic drone and I'm using the Skippy Scout (SS) software. This has been a game changer. No longer is the drone stuck in a tree or upside down somewhere in a flowering oilseed rape field. The SS system allows me to get on with walking whilst the drone collects an overall

'sphere' of the field and then autonomously travels to pre-determined, user set, scouting points across the field to take pictures from a height of 2m. This is a useful perspective and addition to field walking; the range of data being collected is much broader and far more detailed than what was possible before. From a VR N point of view, it's been very helpful for collecting GAIs in oilseed rape when persistent cloud cover has limited the effectiveness of satellite NDVI imagery. The ability to bring in and use the SS data in the Contour platform will be an important next step, currently being worked upon.



There are some other useful updates coming in Contour including, SFI map layers and integration of the long-standing Maximising Arable Performance (MAP Group) benchmarking system.

The use of precision tools to apply inputs in a more targeted approach is a key piece in the quest to reduce the use of synthetic inputs. The technology exists, and I've no doubt, we are not many years away from broad acre adoption of VR glyphosate, herbicides, PGRs and even fungicides. I've promised my grandfather a ride round once it's a reality on a customer's farm.

It feels like farming is going through one of its more rapid periods of change. The phasing out of BPS, financial difficulties, market volatility and the pressure to make farming systems more sustainable and resilient. They say that adversity always brings with it opportunities, and I'm sure this will make for an exciting future in the farming industry. It will be fascinating to see where we are in another decade's times when you consider the current speed of growth and capability in technology. I'm certain technology and data analysis will play a leading role in solving many of the challenges we face as well as helping the progression and wider adoption of regenerative farming systems.

CREDIT Tim Scrivener WTML

THE WIN-WINS OF REGENERATIVE AGRICULTURE

LLOYDS BANK

Written by Ben Makowiecki, Agriculture Sustainability Director, Lloyds Bank.

Regenerative agriculture has experienced a sharp rise from a niche concept to a commonplace strategy across the UK agricultural sector. It holds promise as a win-win strategy to address net zero and long-term farm productivity.

Centred around improving and revitalising soil health, regenerative agriculture can be defined as any form of farming, which at the same time benefits the environment.

Regenerative agriculture's loose definition offers farms the freedom to interpret it as most appropriate to their system, encouraging widespread uptake across a diverse range of farm businesses. The rapid growth of Groundswell, the UK's annual festival of regenerative farming, illustrates the momentum behind this movement.

The prospect of cutting inputs and costs, against a backdrop of volatility in feed, fuel and fertiliser markets, is appealing to most farms. When also considering the need for businesses to adapt to the restructuring of the farming subsidies and to reverse declining soil carbon stocks, it is clear to see the major role regenerative agriculture could play for years to come.

It is shaped by a set of five core principles which cover a range of holistic land management practices. By embracing the following principles farms can begin to regenerate their soils:

1) Minimise soil disturbance

A large proportion of regenerative agriculture focuses on the key principle underpinning a healthy ecosystem, the soil. Soil is the foundation of the ecosystem and without it, plants cannot grow, and animals cannot be sustained. Minimising soil disturbance, and ultimately soil degradation, can be achieved through reduced tillage agriculture, which lessens the amount of carbon released from the disturbed soil, and allows for the regeneration of organic matter below the topsoil. The connectivity of the agroecosystem is affected by soil disturbance and tillage. Consistent soil disturbance affects water infiltration as well as the movement of gases, nutrients and water within the soil and roots through soil pore networks. Soils with poor structure limit the interaction between organisms within the soil and fungal networks, all contributing to healthy functioning soils. Under regenerative models, as soils increase in fertility their water holding capacity also increases, thereby increasing the natural, biological productivity of the land and encouraging species growth. Allowing for the soil to regenerate, with minimal disturbance from conventional cultivations, facilitates the organic matter in the soil to contribute towards the growth of crops on the surface. This enables a

reduced reliance on artificial fertilisers to improve the fertility of the soil and leads to an overall improvement in the condition of the land.

2) Maximise crop biodiversity

Establishing and maintaining as much plant diversity as possible creates a good environment within the soil for maximisation of the microbial population. In the absence of diversity, through continuous cultivation of the same crop species, imbalance develops within the soil leading to reliance on artificial fertilisers to provide specific nutrients. This leads to reduced soil organic matter, degradation of soil structure and soil biology. A greater diversity in crops creates greater root depth diversity within the soil, allowing for more organic matter to be left in the soil once these plants die off. Companion cropping and intercropping, as well as diverse main crop rotations, are methods to increase diversity within an arable crop during rotations, delivering benefits including pest reduction, weed suppression and increased nutrient accessibility and uptake of nitrogen and phosphate. As a result, improvements in crop yield and crop resilience will lead to long-term benefits to overall soil health and less reliance on artificial fertilisers.

3) Keep the soil covered

There are a number of benefits to covering the soils with cover crops, cash crops or with a mulch of crop residue. These practices protect the soils beneath to a variety of threats; wind and water erosion, compaction and weed growth, whilst maintaining evaporation rates and soil temperatures. Exposed soil is at risk from water and wind erosion, therefore keeping it covered all year round minimises the risk of damaging the soil. The estimated annual costs of soil degradation in England and Wales total between £0.9–£1.4 billion.

Cover cropping can be both short-term and long-term options for the soil, acting as a shield and covering the soil surface. The extended period of growing is also often described as 'solar powered soil building' due to the physical, chemical and biological benefits derived from the crop capitalising on the sun's energy through photosynthesis. Short-term cover crop mixes include faster growing species, such as radish, mustard, buckwheat and linseed. Over-winter mixes are longer-term options which include winter rye, spring oats and stubble turnips as some examples. Mulching can be achieved with natural or synthetic materials but natural materials on farm are most common. Leaves, plant residues, grass clippings, hay and straw are examples of mulch, acting as a source of carbon and nitrogen as they breakdown on the surface.

4) Maintain living roots year-round

The presence of plants and active roots within the soil is key to optimal soil health and structure, as they provide the energy for the biological processes within the soil. The absence of plants causes carbon to be released, as carbon dioxide, via respiration due to the soil biota metabolising the soil organic matter. This would have otherwise been used as energy for the root and plant growth. Plant and soil biology share a close relationship, centred around plant roots where a host of organic substances are excreted by the plants. Mycorrhizae are a particular type of fungi connecting plant roots, growing in smaller soil pores enabling them to acquire and pass on nutrients, particularly phosphorus, at a quicker diffusion rate through the soil. Considering integrating cover crops directly after harvest is one way to ensure active roots are kept within the soils. This is when the soils would otherwise be left bare for over four weeks and as a result beneficial microbial populations start to decline rapidly. Living roots provide the constant energy source for nutrient cycling, soil fertility and maintenance of soil structure. Cover crops also increase access of nutrients to micropores which most arable crops are unable to reach, increasing the availability of 'free' nutrients within the soil. This contributes to increased nutrient cycling within the soil and nutrients in crop-available form. The presence of living roots in the soil also helps reduce the risk of leaching, particularly during winter months. Residual nutrients, particularly nitrogen, are held in the soil before being made available to the next crop in the ground. Maintaining ground cover and retaining living roots in the soil using plant species with vigorous and active rooting systems enables farmers to manage soil structure using biological systems, particularly with cover crops that can use complimentary but different rooting properties. Using this as a primary form of management then enables application of mechanical amendments to the soil structure only when necessary.

5) Integration of livestock

One strategy to complement regenerative principles is to integrate livestock on to farms. Some arable farms have not had livestock for many years, resulting in a loss of soil organic matter and reduction in the range of perennial crop species. This form of land management through the introduction of grass leys and pastures, gives the land longer rest periods in order to regenerate and recover whilst building soil fertility and improving the microbial diversity of the soils through grazing and organic manure application. This acts as a cornerstone for the other four principles in providing cover and living roots through a diverse species of plants whilst limiting mechanisation and inputs. Integrating livestock also offers greater resilience to businesses by spreading financial risks over different enterprises.

Rotational and mob grazing bring a number of benefits to soil health, grass growth and diversity of plant species. Mob grazing highlights the importance of rest periods for the grass, allowing the soil more time to recover. As a result, soil health improves, cattle are healthier and there is a reduced need for inputs. The system also allows for a reduction in the time animals are housed which contributes to reduced costs. The greater rest periods also allow for plants to grow taller, leading to a larger and more complex root system leaving more organic matter when the plants die off.

There are several win-win outcomes associated with regenerative agriculture, with the evidence base rapidly growing. Applying these five principles undoubtedly provides an array of environmental and social benefits, including reduced emissions, increased biodiversity and enhanced public goods, whilst also boosting farm financial performance.

Recent findings from a research partnership between the Allerton Project, NIAB and Syngenta have associated UK regenerative agriculture with higher farm profitability.

The project offers independent scientific evidence of up to 36% increase in net profit versus a conventional plough-based arable system, despite a slight drop in yield. This is alongside consistent improvements in carbon footprint, earthworm number and soil carbon.

Regenerative agriculture is not only good for farmers, it also delivers clear win-win contributions to the agricultural sector's shared goals of progressing towards net zero targets and reversing nature decline.

To read the full technical fact sheet visit lloydsbank.com/sustainable-agriculture-insight

ROBOTS FIND THEIR WAY INTO FARMERS FIELDS

Written by Martin Rickatson and Tom Allen-Stevens

Autonomous farm vehicles have moved beyond development projects and prototypes into full commercial production and sale. *Tech Farmer* assesses the main offerings for the UK farmer.

Not long ago, autonomous or robotic agricultural vehicles, particularly those for fieldwork, were the stuff of prototype areas on stands at big international shows, or demo zones at field events. The question of market-readiness was something many manufacturers seemed to stall when asked.

Over the past couple of years, though, there has been a shortening of the time to market quoted for such machines from 'soon' to 'now'. From conventionally-engined autonomous vehicles to solar-powered robots, there are a number of units now working on UK farms, particularly those growing precision-sown crops, where the regularity of plant spacings lends itself to automation of field tasks.

From their power sources to the way they put that power to the ground, and the implements they can work with, different products lend themselves to different cropping systems. And while initial autonomous field vehicle developments were targeted chiefly at establishing and weeding precision-drilled row crops, there are now machines available capable of combinable crop land preparation and other tasks.

With skilled staff hard to find and repetitive tasks lending themselves to automation, the attraction of high daily workrates with 24-hour working all stack up in favour of autonomous vehicles. Here are the key options of machines now available which are creeping their way on to UK farms.

Agrointelli Robotti

One of the first machines sold to a UK farm was a Robotti 150D unit from Danish manufacturer Agrointelli, supplied and supported by its UK agent, West Midlands-based Autonomous Agri Solutions.

With two Kubota 75hp diesel engines, one powers the hydrostatic wheel motors and the hydraulics, and the other the PTO. A total fuel capacity of 220 litres is reckoned sufficient for approximately 24 hours' operation. The Robotti is autonomously controlled with 2.5cm repeatable accuracy by RTK GPS via an onboard computer terminal, to which can be loaded a pre-programmed planned field route map.

The new version of the Agrointelli Robotti requires only a single engine, thanks primarily to hydraulic system upgrades.

Tom Beach, who founded Autonomous Agri Systems with fellow ex-Harper Adams University graduate Jack Wyatt, says Agrointelli's design deliberately blends concepts with which most farmers will be familiar – such as diesel power and conventional hydraulics – with key autonomous technology principles.

"One of the key tasks for which the machine is suited is continuous light inter-row cultivation of row crops to keep weeds at bay, providing a broader window of opportunity during potentially short spells of good weather," says Tom.

"By moving surface soil in the early stage of weed growth with guaranteed precision, weeds can be uprooted early before they can affect the crop, and the machine's light weight means multiple, frequent passes can be made where necessary with little land impact."

Mapping a field and logging the weeding plan into the software takes a matter of minutes, explains Tom.

"The online Robotti portal provides owners with real-time updates of machine progress, fuel data and images from its cameras, while text alerts notify of any issue with operation, and of job completion."

Agrointelli has now developed a new Robotti design, the LR, which features a number of updates, says Tom.

"Most significant is a move from twin engines to a single 75hp powerplant, made possible through the development of an updated hydraulic system. This has helped boost fuel capacity to 310 litres, providing up to 60 hours' run-time, good

SRC's Tom scouting robot is now on version 4, with a more rigid boom, an upgrade to its eight cameras and a modular design.

for around 90ha of weeding, depending on circumstances.

"Retaining conventional engine power means farmers know and understand its maintenance and management, whereas electric power, for example, would require specialist knowledge and support, and batteries don't offer this sort of run-time or capability. But with regard to emissions and CO_2 neutrality, it is fully biodiesel-compatible.

"The machine's light weight means multiple, frequent passes can be made where necessary with little land impact."

"There is a full PTO and a 1200kg three-point linkage, and Agrointelli is building partnerships with implement firms including Stanhay Webb, Kverneland, Pöttinger and the German company Kult Kress, although any conventional implement is compatible within reason. Plans are also afoot to extend the machine's weed control capabilities to include electrical and laser-based systems, for targeted control of larger weeds without soil disturbance. Precision-sown row crops remain its forte, though, and we have worked with Sentry in particular to illustrate the Robotti's capabilities to carry out the full suite of sowing, hoeing and band-spraying operations through the sugar beet season, for example."

Interested parties are able to purchase directly from Autonomous Agri Solutions, with finance offered, says Tom.

"However, we have also now developed a model that offers robot as a service (RAAS) as an alternative, for those preferring to rent a machine at a price/ha depending on planned operations and usage level.

WEED-MAPPING ROBOT SET TO MICROSPRAY

It's been a year of ups and downs for the Small Robot Company (SRC), the British agritech start-up part-owned by farmers, with farmers also helping develop the technology. Its autonomous Tom scouting robot now has the ability to detect and map blackgrass in a wheat crop. The company has also taken its PerPlant concept forward, developing the ability to microspray for pests and diseases.

Rather than buy the robot, the company is developing Farming as a Service (FaaS) whereby a 'pod' is set up to service a number of local growers, who sign up to a fixed number of visits over the season.

A pilot version of this ran during the 2022/23 cropping season with twelve farmers around its base in Wiltshire. Each committed 20ha to the trial and received four visits: before crop emergence (detecting green on brown), mid-tillering, post-vernalisation in February and before the canopy closed in around April.

While the service delivers plant density information, it's the weed detection on a per-plant basis that may have more value. During the season, the SRC team developed a detection model for early stage grassweeds, claimed to perform well against an expert agronomist.

SRC says it is the "only company in the world" capable of detecting and mapping grassweeds. The service gives farmers the ability to accurately track blackgrass populations, and the data can feed into a sprayer with individual nozzle or section control to deliver herbicide savings. While few growers would rely on the service to spot spray grassweeds, it can be used to focus application of more expensive herbicide stacks, according to the pilot farmers.

The Tom scouting robot itself is now on version 4, with a more rigid boom, an upgrade to its eight cameras and a modular design. This platform makes it a more robust and flexible tool to carry payloads and complete various actions in the field. Along with scouting, Tomv4 is designed to carry out micro-spraying or non-chemical weeding, making it ready to take the next step to precision application.

SRC has also developed its Wilma AI system, providing field-scale actionable insights at a per-plant level and allowing spray technology to be optimised to reduce chemicals. This PerPlant data enables farms to transition to regenerative practices safely and profitably, says the company.

Working with partners, SRC has just completed a collaborative two-year project with funding from Innovate UK to develop a prototype for robotic microspraying for pests and diseases. The design of sprayers, and algorithms for pest detection was led by Strathclyde University, while SRC provided the robotic hardware and integrated the algorithms into its Wilma AI system. Agri-EPI aided the analysis, development, and optimisation of data collection.

With the sprayer boom design set for completion this year, the robotic platform is poised for commercial field trials, according to SRC CEO Ben Scott-Robinson. "Microspraying could be game-changing for the industry. Pressure is increasing from regulators, leaving farmers short of options. Precision spraying could enable a new generation of spot-treatment chemicals, reduce costs, and significantly reduce the impact on biodiversity."

Commercial roll-out of SRC's services suffered a setback earlier this year when a potential investor pulled out, leaving the company dangerously close to having to call in receivers. A crowd-funding campaign successfully raised £1.6M and SRC has reached heads of terms with another backer.

The company is looking to set up franchise agreements with partners to roll out the pods, with the first franchise expected to be trialled in September 2024. Full commercial rollout is set to get underway in the 2024/25 cropping season.

"List price of a Robotti LR is around £175,000, or approximately £200,000 with a full suite of equipment including precision drill and weeder suiting an annual 200ha workload. However, we have developed a £35,000/year rental model, a cost that can ultimately be offset at a £25,000 annual reduction against a purchase price, as an option for those who want initially to work out how a Robotti will fit their system before buying."

Opico FarmDroid

Marketed in the UK by Opico since early 2022, with 16 units now on UK farms, is the Danish designed and built FarmDroid FD20. It was conceived in 2011 on Jens Warming's family farm, targeting a simpler, cheaper way of inter-row weeding sugar beet.

Joined subsequently by his brother Kristian, and by specialist robotics engineer Esben Østergaard, the three developed an autonomous machine for seeding and subsequent weeding of row crops. This revolved around the principle that by using ultra-high precision RTK placement of seed, recorded placement data could then be used to subsequently weed not just between plant rows, but also between plants in each row, without the need for camera systems. A further principle was harnessing solar energy for propulsion, reckoned to be practical given the relatively low energy requirement of such a machine.

The first production version was shown at Agritechnica 2019, and 12 machines were working on Danish farms by 2020, with an updated model developed by that autumn. Power comes from four solar panels charging two lithium batteries. Two further spare batteries can be charged remotely if required, although charging takes place during daylight operation whatever the light level. 24-hour operation is possible from battery storage of solar-generated power, although dull days can halve this and an optional additional power pack is recommended. Should it run out of power during darkness, the machine simply begins moving again when the sun rises and the solar panels again become active. A rain sensor stops the machine or notifies the user's app if a certain amount is detected.

Propulsion is via a 400W electric motor on each wheel, and operation is therefore fuel and emission-free, and CO_2-neutral. Farmdroid points out this will particularly aid farmers whose produce buyers are pressuring them to fulfil environmental demands along with crop supply contracts. Electric motors also engage and power the seeding and weeding units.

Steering is via drive motors on the front wheels, which work constantly at different forward speeds to keep the machine running straight. There is a single wheel at the rear, although Opico reports a four-wheel option has become increasingly popular, and early three-wheel models can now also be converted.

The 3.0m FarmDroid can be equipped with four, six or eight precision drill and inter/intra-row cultivation element sets, both developed and manufactured in-house. Although cameras aren't required for guidance, one unit provides the person monitoring the machine via FarmDroid's smartphone app with an anytime view of its activity, which also provides operating data and any error message alerts.

Weighing 900kg without attachments, the machine is transported between fields by tractor, and because it operates at less than 1.0 km/hr (working speeds can be set from 450-950m/hr), and is fully equipped with safety stop and smartphone app alert features should it come into close proximity with an object or person, it isn't subject to any further safety legislation during operation. Farmdroid suggests that, where practical/required, it can be left in the field for the season to make repeated passes, and calculates that despite its sedate pace it has a 6.0ha/24hr potential workrate.

The FD20 is guided around the field perimeter to record the corner points, thereafter setting a geofence from this to recognise the field boundary and set the headlands. In addition, any obstacles, the number of headland bouts and the seed spacing are set at this point. From this, the machine calculates the best working path plan. FarmDroid's own RTK system works to a repeatable 0.8cm accuracy, using front- and rear-mounted machine-mounted antennas. These communicate with a farm-installed fixed base station which must be within 10km of the field, enabling the FarmDroid to work within 5mm of each seedling between the rows and 20mm in the row.

"If we can seed it, we can weed it," says Eddie Pedersen, FarmDroid's sales manager.

Imported into the UK by Opico, the FarmDroid FD20 uses solar power stored in batteries as its sole source of energy.

"If we can seed it, we can weed it," says Eddie Pedersen, FarmDroid's sales manager, pictured left with Opico MD James Woolway.

"For drilling, once the field parameters are set, it's simply a matter of programming in the required plant density and spacing, and setting off the machine. Roller disc pairs are followed by a furrow opener that creates a V-shaped slot. The individual six-litre seed hoppers each supply an electrically-driven seed motor. These

feed individual seeding discs, with a range of interchangeable units 3D-printed in-house. There are different hole diameters, disc thicknesses and disc diameter.

"The machine remembers where each seed has been placed within a variation of 0.8cm. Once drilling is complete the tool units can be changed over – the seeding units simply flip up and the weeding ones drop down. The FarmDroid can then be set for pre-emergence 'blind' weeding soon after drilling, and for repeated passes at intervals in the weeks afterwards. While the weeding wires passively remove weeds between rows, separate active weeding knives interject between each plant, based on the known seed positions.

Harvey Sherwin, Opico's FarmDroid product manager, says weeding is best done in relatively dry conditions that will cause uprooted weeds to desiccate and die.

"The passive inter-row hoes are constantly engaged with the soil, and when the machine is set up the row width is fixed," he explains.

"Conversely, the active intra-row hoeing, with the knives moving in and out between plants, can be altered down to 10cm spacing, according to crop type and stage. While vegetable and root crops remain the system's forte, trials with Bayer are assessing FarmDroid's capability to establish and early-weed oilseed rape."

Beyond zero fuel cost and low maintenance, a key advantage of solar power is that the machine's zero emissions could help growers meet carbon obligations, points out Harvey.

The cost of a four-row FarmDroid is around £70,000, with additional rows at approx £4000 each and about £6000 required for the necessary high-accuracy RTK base station. Opico suggests those costs could be recouped in two years through reductions in labour, herbicide and other machinery costs.

AgXeed AgBot

The AgBot tractors from Dutch firm AgXeed are for those seeking something to automate heavier draft tasks requiring high traction. In England and Wales, tracked and wheeled autonomous AgBots are available from ASC Autonomy, part of precision farming firm AS Communications, while Soil Essentials looks after other UK areas.

AgXeed offers three- and four-wheeled autonomous tractors, but promotes this 156hp tracked version as its primary arable offering.

Andrew Williams, who works alongside AS founder Will Mumford, says the units can be purchased for around £70-85,000 depending on specification.

"The AgBot models, particularly the tracked versions, suit a broader range of tasks than some other autonomous tractor options, and outright purchase suits the needs of most farmers we talk to," suggests Andrew.

ASC Autonomy suggests two or three AgXeed tracked tractors could replace one large conventional tracklayer.

While there's a three-wheeled design largely aimed at orchard and horticultural rowcrop work, it is the four-wheeled and particularly the twin-tracked AgBot versions that primarily suit arable field tasks.

The four-wheeled 2.055 W4 is powered by a 75hp four-cylinder Deutz engine with 170-litre diesel capacity. An electric drivetrain provides a 0-13.5km/hr speed range, plus optional electric PTO and 55kW/700V electric implement power connection.

Implement operation is more conventionally overseen by an 85 l/min hydraulic system operating at 210 bar with optional load-sensing, feeding up to three double-acting remote valves, a 4.0t rear linkage and 1.5t front hitch.

"Electric drive motors provide the most efficient and controllable transfer of power, but in all other aspects these are essentially standard tractors without cabs," explains Andrew.

Key differences on the twin-tracked AgBot T2 include more than double the power output, with 156hp available, and a doubling of both front and rear hitch capacities. Available track widths span 300-910mm, and track spacing can be adjusted between 1800-3000mm or 1800-3200mm, depending on chassis and track type specified.

As with other manufacturers' autonomous tractor developments, work planning, monitoring and control is via an internet portal and app, and tasks can be pre-planned on a PC. A full suite of sensors ensure the safety of the machine and anything around it.

"We are working with all options to get machines onto farm, including direct sales where possible, working with a finance company for finance and leasing agreements, and are looking at hire ideas.

"With three years' warranty and servicing, a T2 tracked machine costs around £320,000. It's a challenge to change mindsets, but with the AgBot T2 tracked machine's capabilities, we see scope for some farmers to consider changing a large tracked tractor for perhaps a trio of T2 units, overcoming labour challenges and boosting productivity."

BAYER AND MICROSOFT FORGE A NEW FRONTIER IN AGRICULTURAL CONNECTIVITY

Seamless data exchange in agriculture is the focus for the two corporate giants, according to content and exhibits on show in November at Agritechnica in Hanover.

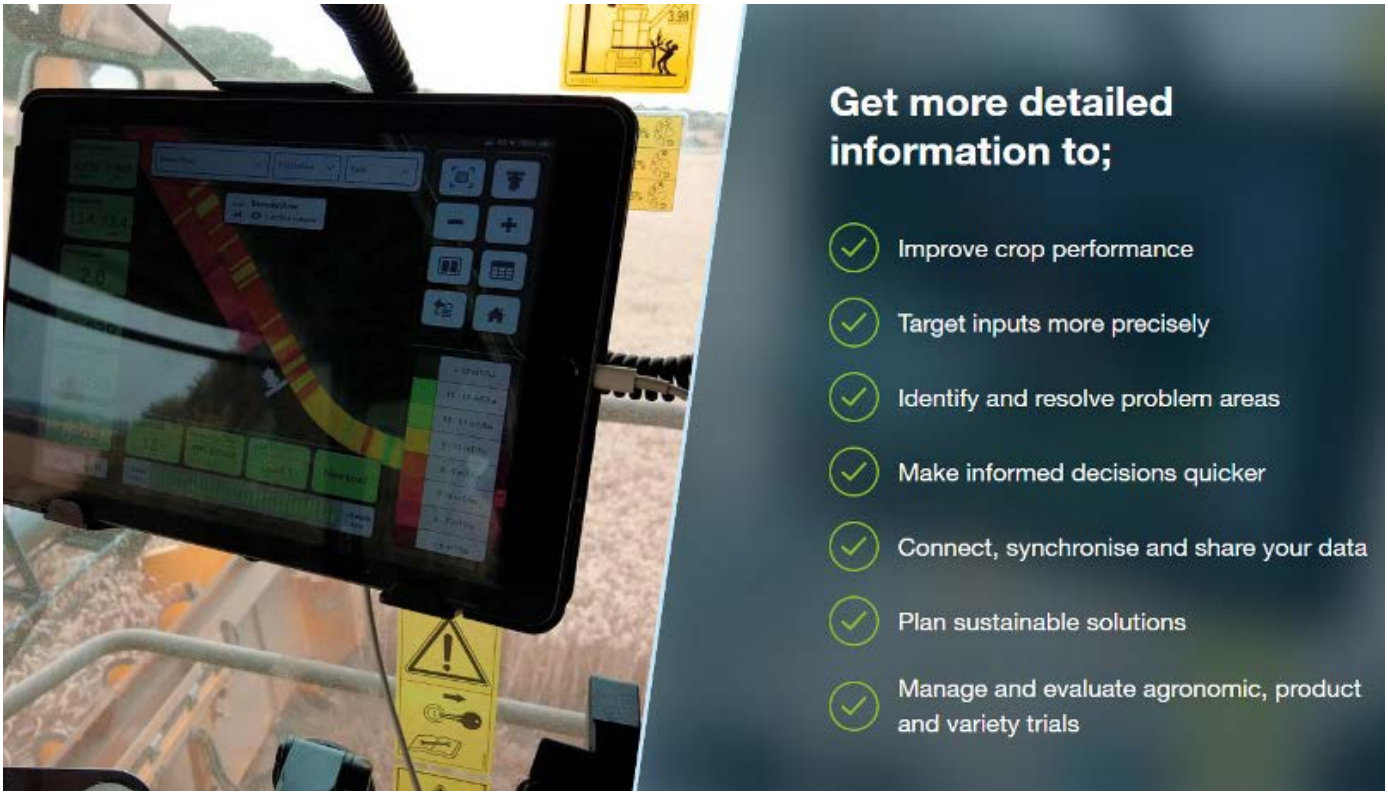
Bayer unveiled at Agritechnica the latest developments in its strategic collaboration with Microsoft. The alliance aims to address the longstanding challenge of data interoperability in farming by introducing innovative data connectors. These connectors facilitate the secure and compliant exchange of farm data between Bayer's flagship digital farming product, Climate FieldView, and original equipment manufacturers (OEMs) through Microsoft's Azure Data Manager for Agriculture.

Fieldview OEM device

Jeremy Williams, Head of Climate LLC and Digital Farming at Bayer's Crop Science Division, emphasises the transformative nature of evolving technology in agriculture. "Agricultural data is nothing new, but technology has evolved tremendously, and so should the ways farmers are able to collect, share, and benefit from the data they generate on the farm," he states.

The introduction of Bayer AgPowered Services on the Microsoft Azure platform earlier this year paved the way for further advancements.

Leaf Agriculture (not UK Leaf) which you can read about more here – www.withleaf.io/products/field-operations/ leveraging Sonata Software's capabilities, now offers a solution to enhance accessibility to farm machinery data. Simultaneously, OneSoil is introducing new solutions for in-season crop identification.



Jeremy highlights the significance of this collaboration. "Our industry can now rally around an infrastructure, data connectors, and readymade capabilities that can further deliver on the potential of digital farming solutions and the value we can bring to customers."

The lack of data interoperability has been a persistent challenge in agriculture. While on-farm platforms have made strides in connecting data, the ability to extend these connections to services beyond the farm has been limited. The collaboration between Bayer and Microsoft addresses this gap.

Bayer claims its data connectors for OEMs represent a significant leap forward in improving farmer and industry connectivity. In addition to FieldView connectivity, Bayer, in collaboration with Sonata Software, is developing AgPowered Services that enable machine data connectivity with leading OEMs like Stara, Topcon, and Trimble. This integration aims to create a seamless and compliant connection to key data sources for farm machinery data, reducing the technical investment required by companies.

Moreover, the collaboration extends to include additional data sources, such as weather and imagery, providing companies with a unified platform for comprehensive insights. The introduction of AgPowered Services, such as the Bayer Farm Machinery Decoder powered by Leaf Agriculture, addresses the challenge of diverse data formats. Working with consistent data in a single format to unlock new value from existing data, is key, says Leaf.

Another notable addition to the platform is Bayer In-Season Crop Identification powered by OneSoil. This service leverages remote sensing capabilities to detect key cash crops like corn and soybean during the growing season across North America, South America, and Europe. The applications of this technology span from verification for carbon platforms to government subsidy programs for sustainable farming practices, demonstrating the vast potential it holds for the agricultural value chain.

The collaboration between Bayer and Microsoft is not only addressing current challenges but also preparing for the future. Microsoft's end-to-end analytics platform, Fabric, provides a unified foundation for data and analytics tools. Satish Thomas, Microsoft Corporate Vice President of Industry Clouds, highlights the platform's support for greater interoperability and its ability to ingest data from disparate sources, offering a single AI-powered analytics platform for agriculture-specific scenarios.

"The AgPowered Services from Bayer, combined with Azure Data Manager, are positioned as ready-to-use capabilities for a broad spectrum of businesses and organisations, from startups to global enterprises," he says. "This collaboration empowers companies to harness cloud infrastructure and core capabilities to build digital tools that support favourable agronomic outcomes or provide valuable insights into nutrients, sustainability, and production practices."

ROBOTICS AND PERCEPTION IN AGRICULTURE: **SMART FARMING GETTING SMARTER.**

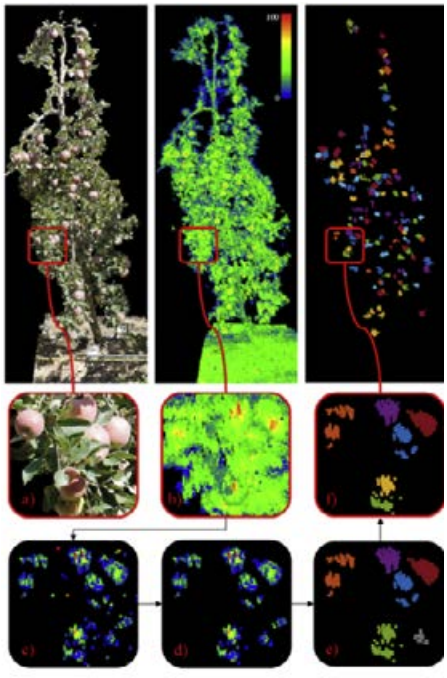
The National Robotarium has been set up to help bring to the field the UK's inherent R&D expertise in robotics, Associate Professor *Dr. Fernando Auat Cheein* sets out its plans.

Agricultural processes worldwide are experiencing fundamental changes motivated by different technology revolutions. Examples include the improvement of connectivity resources (such as 5G or 6G) and the Internet of Things with its inherent capability of connecting devices, such machines, into existing process. In this scenario, we see farming practices changing and adopting different (not necessarily new) technological resources that go beyond the precision agriculture as known no more than 10 years ago. We can find drones acquiring data through specific cameras and generating maps; electrical tractors decreasing the carbon footprint and being able to be connected to the grid; robots manipulating, pruning, moving assets; digital platforms for data handling, data management and for enhancement of the decision-making process, among many other examples.

Such technology jargon is motivated by the fact that processes must be greener if we want a healthier soil, a more efficient production, a more profitable industry, or to decrease chemical applications, among many other expectations. What's more, in most developed countries (and many third world countries as well) we are experiencing a lack of human labour force, which is ironic considering that world population is increasing. This situation represents an ever-present challenge.

The National Robotarium at Heriot-Watt University, Edinburgh campus.

One initiative this has spawned is the National Robotarium. This is a partnership between Heriot-Watt University and the University of Edinburgh which combines Heriot-Watt's engineering heritage and strengths in robotics for hazardous environments, manufacturing, healthcare, and human-robot interaction with the University of Edinburgh's expertise in space, construction, and humanoid robotics. The National Robotarium facilities are based on the Heriot-Watt University campus, in Edinburgh. And within the National Robotarium and the School of Engineering and Physical Sciences (EPS), we are starting the Field Robotics Group, focused on robotics and perception for agricultural purposes.



Apples detection and harvesting estimation, a joint work developed with Spanish institutions, using low-cost sensors.

I started the Field Robotics Group when I joined the EPS, UK and the National Robotarium, as associate professor. The group gathers several PhD students (from UK, Chile and Italy) under my supervision, as well as several master students, and colleagues from the HWU. The mission of the group is to consolidate a task force to offer Scottish and UK farmers specific solutions to specific problems in the agricultural sector. The group is supported by the strong collaboration network we've created over the past decade, which includes researchers and institutions from UK, Italy, Spain, Poland, Portugal, USA, Latin America (Brazil, Chile and Argentina) and most recently, Greece, China and Turkey.

The Field Robotics Group is currently tackling the following themes, in which their projects are associated with:

Plant phenotyping and characterisation.

Using recent advances in artificial intelligence and sensor technology, we are currently able to monitor a crop's water footprint, detect and classify weeds, computationally model crop canopy, detect disease (especially on tomato plants but this extends to other crops), and more than 24 vegetation indices that provide health information regarding the crop.

Our work is limited to gathering and processing information, and offers farmers guidelines on how to proceed, but the decision remains on the farmer's side. A clear example is what we are doing to species monitoring, in which we classify the different species, automatically. We can retrieve the moisture content, height and width of the canopy, the leaf area index, both from drones and from the ground. One of the most important outcomes of our applications is that right now we can predict the amount

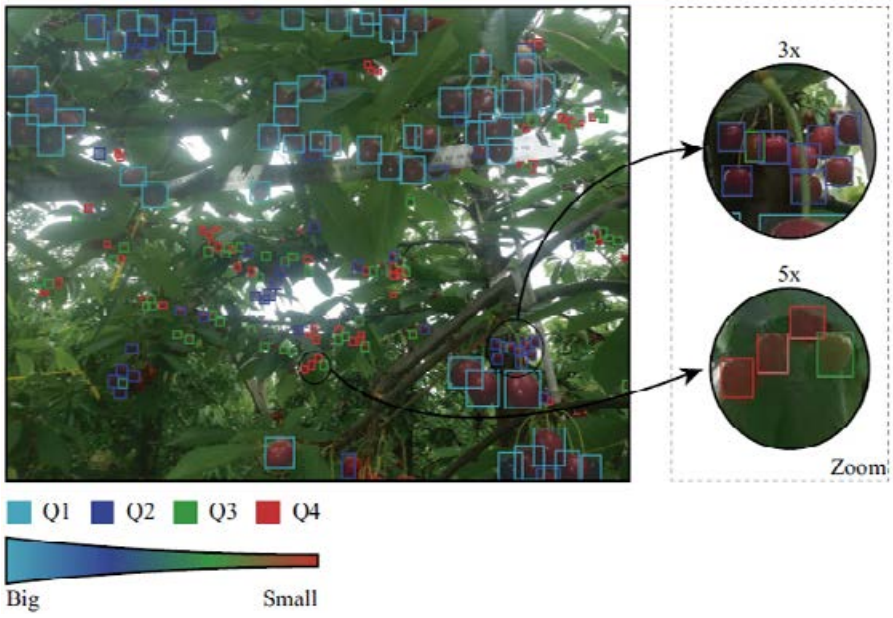
to be harvested with an error less than 10% on different crops, including apples, avocados, lemons, cherries, grapes, and others. To this end, we use low-cost sensors connected to our algorithms (usually most applications regarding harvesting estimation use cameras from mobile phones). We have validated our work in Spain, California, and Chile, and we are currently exploring partners to apply our knowledge in the UK.

Robotics solutions and deployment. One of the fundamental parts of our work is the study, design, and implementation of new robotic solutions for the farming process. There may come a point in the future when robots will be able to do everything on the farm. But right now, they are limited to specific tasks, such as pruning, irrigation, herbicide and fertiliser management, fruit manipulation and interaction with field workers.

Right now, in our group we are facing the micro-fertilisation problem: spraying at a leaf level, and not the entire canopy, thus protecting the plant and the soil. To do this, we are currently designing a new robotic solution that could work under the UK farming weather and according to our regulations and certifications. Although the system is still being developed, we are confident that our solution will highly benefit farmers.

We are also starting a new line of research and development, purely based on improving the potato harvesting and potato plant monitoring, using ground technology. Although we are focusing our efforts on autonomous machinery, autonomy is not yet ready, worldwide, from an energy management point of view: when using electrically powered machinery, their performance is still below that of combustion engines. So we are continuing our research line in improving the power consumption of electrical machinery in the agricultural context.

To achieve that, we are using commercial vehicles for proposing new energy prediction strategies: the power autonomy as provided by the manufacturer changes according to the weather and environment conditions, including the type of terrain, and our work is focused on a more realistic, efficient approach. Our field results so far have shown that we are able to predict the energy consumption up to 30% more accurately than when using the manufacturer's specifications, and therefore farmers can plan their activities with more realistic costs and data. Our findings can be extended to any kind of electric vehicle.



Cherries detection, size classification and counting. Work developed in Chile.

Technology surveillance.

Our commitment as a group is to be prepared to the UK farmers needs. As part of our work at the National Robotarium, the Field Robotics Group is constantly seeking for new solutions and evaluating the feasibility of existing ones. Farmers and agricultural industries are welcome to engage with us in such activities. One of our main goals is to be able to provide recommendations to specific needs.

Vehicle used for modeling the energy consumption in electric vehicles.

The new agricultural initiatives at the National Robotarium open opportunities to farmers and to the agricultural industry and there is an invitation to approach, since problems need to come from the farmers side, from the sector that seeks innovation.

Dr. Fernando Auat Cheein is an Associate Professor in Robotics and Autonomous Systems, UK National Robotarium, Edinburgh Centre for Robotics School of Engineering and Physical Sciences, Heriot-Watt University, Edinburgh, Scotland. He has published more than 100 journal articles, several conference papers and applied (and granted) several patents. He is the author of two books and editor of another two. He is associate editor of Computers in Electronics in Agriculture, Biosystems Engineering (both Q1 journals in the field), Robotica-Cambridge, Journal of Field Robotics and IEEE OJ on Intelligent Transportation Systems. He is also technical editor of ASME/IEEE Transactions on Mechatronics and IEEE Senior Member since 2021. His graduates are academics or researchers in several universities around the world, including University of Lincoln (UK), Carnegie Mellon University (USA), UC Davis (USA) and several universities from Chile and Ecuador. His innovation interests are: robotics/mechatronics and perception in agriculture, electrically powered machinery, automated process, fruit packaging and manipulation, crop monitoring. (f.auat@hw.ac.uk)

WHAT WILL APPEAR AT **FIRA**?

FIRA is the global event for Agricultural Robots in Action, held from February 6-8, 2024 in Toulouse, France. *Tech Farmer* will be partnering with the event to bring you all the latest robotic content.

If you have the merest interest in the latest innovations in advanced robots or yearn to see autonomous machines in operation, then it's worth attending World FIRA 2024.

With five real-world demo zones that put robots in real-life conditions in different crops – vines, orchards, vegetables, field crops – FIRA lays claim as the largest agricultural robot playground in the world where you get to be the first to get a sneak peek at what agriculture of the future has in store for us.

Attend more than 20 robot demos, from prototypes to commercially available robots. From weeding to spreading fertiliser, including harvesting, picking and sowing, automation is in the spotlight, whether for large crops, vegetables, orchards, vineyards, market gardening or livestock! Here we've picked out some highlights that'll appeal to the in-field automation pioneer.

Aigro Up – Aigro UP has an agriculture robot that assists you with weeding and mowing. It focuses on tasks that are realistic to automate, but highly time consuming right now.

The robotic vehicle is a narrow machine, so it can navigate to orchards easily. In addition, the robot uses sensors which allow for continuous motion across terrains that would need other vehicles to stop and operate only in specific locations on their route. It achieves this not through relying solely on RTK GPS, but by making use of a set of smart sensors.

Aigro UP is an electrical power robot that can run up to 10 hours on a single charge and has two swappable battery packs, allowing a full day's operation without any hassle or inconvenience. We believe the price of the Aigro robot is between €25.000 and €30.000, depending on the options.


K.U.L.T.iSelect

K.U.L.T.iSelect – This is a robotic hoe claiming the highest precision in the row and between the plants.

It brings precise single-plant detection, high processing precision and tool depth guidance through automatic exact parallel guidance of the entire machine to the soil surface.

There's a user-friendly and intuitive terminal, which allows easy machine monitoring and adjustment from the tractor cab. Hydraulic and electric power supply comes from the tractor with very low power requirements.

Modular design allows for individual operational needs. Also available as a multi-section version, for three- or two-step processing in one pass.


Afara

Afara – Based in Turkey, Afara has developed an autonomous cotton-picking robot, which collects cotton spilled on the ground after harvest. Afara-Cotton uses image-processing electronic-mechanical systems.

Afara also produces two other systems: Afara-Sprayer is an autonomous agricultural robot claimed to efficiently perform operations such as fertilisation, irrigation, spraying, etc., according to the location of the plant with image processing. Afara-Terminator is an autonomous agricultural robot compatible with organic farming that detects and destroys weeds with image processing.

Aigro Up

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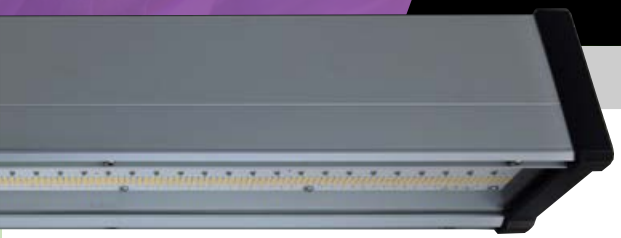

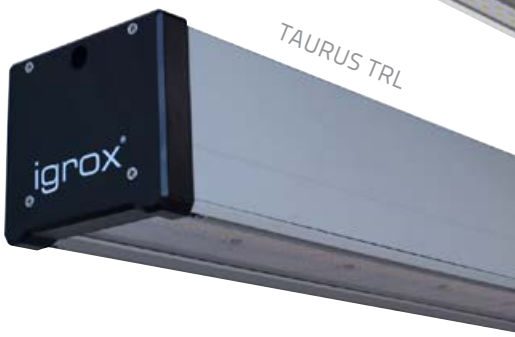

- **TAURUS TRL** is an industrial grade LED system for horticulture, designed to operate in greenhouses. **TAURUS TRL** ensures high performance, reliability and flexibility in project design. It fits to any greenhouse geometry and suspension height.
- **TAURUS TRS** family is available in 200 W, 400 W and 600 W versions. It is a flexible and adaptable LED system for horticultural lighting.
- **LYBRA** is a modular, flexible and scalable solution that adapts to vertical farms with fixture-canopy distance between 15 cm and 35 cm.
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Weta Robot

Weta Robot – Weta is an autonomous all-terrain platform designed for use in agriculture and forestry. It can be loaded with tools and packs for autonomous surveillance, inspection, pulverisation, pruning, land clearing, and harvesting. This EV comes packed with radar, lidar, communication systems, articulated axles, and low-impact tyres to ensure ease of movement in complex terrains such as the terraced vineyard slopes of Portugal's Douro region, where it was developed.


Odd Bot

Odd Bot – Odd Bot promises to bring farmers of high-density crops the future in smart and sustainable precision weeding. The company claims its mechanical weed removal robot provides a higher yield with less manual labour, reducing and eventually eliminating the need to use any chemical herbicides.
The unit removes weeds at an early stage through autonomous mechanical in-row weeding, allowing crops more space to grow, which in turn improves yield, say its makers. 100% organic, the robot does not use any chemicals and does not damage the crops. It's also on demand , so you decide when the weeding needs to take place, and Od Bot takes care of the rest.

Robot One V2023 – Pixel Farming Robotics' Robot One is equipped with 14 depth-sensing cameras and dual GPS antennas, making it suited for large-scale and biodiverse environments.
Robot One is claimed to help farmers transition to regenerative farming, easing establishment of cover crops and reduced tillage with specialised tools.
All electric, solar panels are mounted on the roof and power Robot One autonomously through the fields, charging the battery while driving. The electric drivetrain and lightweight construction enable Robot One to handle the various agricultural terrains.


Robot One

Robotti – Agronintelli's Robotti is an autonomous, versatile field robot designed to be integrated into many everyday jobs in the fields, in horticulture and in tree nurseries or similar areas with row or bed crops. It is diesel powered, uses a standard three point linkage so it can be fitted with standard farm implements.

Robotti

There are two models of Robotti – 150D and LR. The two Robotti models differ in the number of engines, availability of a PTO drive, lifting power and tank volume capacity and thus in the autonomous range.
The three-point hitch makes the Robotti an implement carrier designed for a wide variety of implements. The typical tasks are sowing, planting, hoeing, spraying and light tillage. The working speed is adjustable and allows autonomous continuous operations of up to 20 hours for the 150D and up to 60 hours for the LR.

Trektor – Sitia claims its Trektor is the first hybrid robot for agriculture. It can work on different crops – viticulture for both narrow and wide rows vineyards, market gardening, vegetable field crops and arboriculture – and performs many repetitive tasks, such as soil cultivation, spraying and hoeing.
Trektor can change its width (wheelbase) or height (adjustable ground clearance) to adapt to the crop.It's also compatible with existing implements, thanks to a standard three-point linkage (cat. 2) and points of attachment behind and between the wheels.

Trektor

Arow Box – Arow Box is a high-tech component of Ullmanna's Decimal platform designed for precision weed control in agriculture. Using artificial intelligence and machine vision, Arow Box identifies and targets crops in real-time, providing a chemical-free, environmentally friendly solution for weed control.


Arow Box

It's an intra-row weeding system that includes features such as visual odometry, innovative lighting for cameras, and depth sensors claimed to ensure optimal operation even under challenging field conditions. The unit spots crop plants in real time and its makers have set out to achieve the fastest intra-row hoeing operation available. The Arow Box forms the hardware backbone of the Decimal platform, while the software services are offered to end users, typically farmers, on a SaaS model.

RoboCut360 – this tool from Leger Innovation helps arborists manage their orchard without any use of pesticides and with a limited number of staff. It's a self-propelled and self-driving vehicle equipped with the EcoCut360 head which prunes the


RoboCut360

suckers from around the base of fruit trees. A weeding head as well as a mulcher can be mounted on the tool holder in order to weed the soil between the trees and in the aisle.

Robotic Perception – This autonomous electric vehicle from Isreal is a sprayer, mower and crop monitor for vineyards. It scans the crop, analyses irrigation requirement and checks for virus stress.


Slopehelper

Slopehelper – Designed for a challenging terrain, this robotic low-voltage electric agrosystem automates routine tasks in vineyards. Place it at the beginning of a passage between rows in the field and use the six-button interface to program the left and right row numbers and the number of rows (or entire field) for operation; then press the start button. The TeroAIR application on your smartphone will keep you informed in real time about the entire progress of the operation and any events that occur during the process.

Slopehelper operates without GNSS navigation (satellites), and it's independent of weather conditions, allowing your agrocycle operations to run continuously, say the bot's maker.

Oscar – French robotics company Osiris Agriculture have designed Oscar as a complete, season-long irrigation service. Oscar will stay in the field, surveys your irrigation needs day after day to deposit exactly the dose of water the plant needs. Osiris claims the bot gathers Its knowledge of the plot thanks to artificial intelligence and modulates its action according to local needs


Robotic Perception

Crover Grain Storage Management – The Crover robot swims through bulk solids and powders such as cereal grains and pulses stored in sheds and warehouses. This maps the condition of the grain with a higher resolution and data points density than a static solutions, says its makers, and at a lower cost per measurement location compared to sites with 20+ static sensors.

Crover stirs the grain bulk, helping prevent and break crust, arching and ratholing. Collecting samples at depth within the bulk, the data collected by the Crover robot can be either downloaded locally, fed into existing digital systems, or visualised via its companion web app. Claimed to be the first device in the world able to move omni-directionally in granular bulks, the Crover robot is also a platform that enables different technologies, be it sensors, sampling modules or pest control agents to reach areas of the bulk that they couldn't otherwise.

Alpha – Those for whom the now ubiquitous drone simply doesn't cut it will be drawn to Alpha's newest fuel-powered helicopter UAV. Built STANAG-compliant to target maritime security requirements, it boasts a longer flight time – up to four hours endurance – a 4kg payload capacity and four Payload Bays.

Traxx – Exxact Robotics calls Traxx a pragmatic and sustainable technical solution for farmers and winegrowers. Traxx straddle the vine for autonomous tillage and spraying applications in narrow vineyards. A powerful unit, it treads lightly for minimal soil compaction, and achieves the spray quality and precision to accurately apply biocontrol products. Traxx puts the same precision and regularity into its soil work, says Exxact, with recognized and reliable tools.

SoftiRover – Softivert is developing the SoftiRover e-K18 agricultural robot, intended for large-scale cultivation. This French company, specialising in precision agriculture, launched the autonomous project two years ago internally, with its own funds.

YV01 – Designed for European winemakers, Yanmar has developed the YV01 as an autonomous sprayer. The YV01 treads lightly, keeping compaction to a minimum while the robot can go up and down slopes of up to 45%, while its straddle design suits narrow vine spacing.

At the heart of the YV01 is electrostatic spray technology claimed to reach all surfaces of the vine efficiently and economically with spray applications, whether exposed or hidden.

Pats-X – This bat-like drone moves through glasshouses and indoor units, targets moths and terminates them mid-flight. This prevents damage to crops and reduces the need for spraying rounds. This automated solution will be available for all kinds of greenhouse crops such as high-wire vegetables, fruits, flowers, and plants.

Orio – This is Naïo Technologies' high-precision weeding robot. Orio will work in your fields with accuracy thanks to its guidance system based on RTK GPS signal. Designed for row crops and beds of vegetables, the bot works on lettuce, onions, carrots,


Orio


Ted


Oz


Jo

parsnips, cabbage, leeks, cauliflower, various herbs (garlic, cilandro, mint, etc) among others. Orio is also suitable for arable crops, large growers and contractors, looking for greater autonomy and precision, says Naïo. Easy to set up, this tool-carrier can be used for seeding, cultivating, weeding and collecting data.

Jo – Naïo Technologies designed this autonomous crawler for narrow vines. Jo has 10 years' experience in guidance systems and follows its lines with accuracy and reliability, says Naïo. Fully electric, two 3000W, 48V motors allow you to use a range of tools.

Ted – Again from Naïo Technologies, Ted is Jo's larger brother, dedicated to vineyards, and offers an alternative to the use of herbicides. Ted provides precise mechanical weeding, with an 8-hours per day autonomy. Its universal mounting frame offers the possibility to adapt various tools.

Oz – Completing Naïo Technologies' family is its compact Oz robot. This farming assistant for time-consuming and arduous tasks has caught on in 48 countries where Oz can already be found. It works autonomously or obediently follows you around. A multifunctional robot it carries brushes, seeders, hoes, ridger, leaf bumper or Torsion springs.

Pathfinder – with Pathfinder, maker Bluewhite has combined hardware and software into what it calls a single end-to-end platform for fleet and data management. This allows you to run all farm operations autonomously from anywhere. The spray, disc, mow, and other operations work with any existing tractor. Pathfinder's smart implement integration and control will operate all year round and takes account of any condition for any crop to operate safely. It does this through Lidar as well as cameras and different sensors that guide its navigation. You can also retain the ability to drive the tractor manually when needed.


Pathfinder

FARMER FOCUS
THOMAS GENT

How I think I can achieve scalable no till organic farming.

In my opinion the Holy Grail of farming is to find a way both to use no till drilling methods and achieve a conventional farm level of yield with no artificial inputs. One sunny summer evening, this was something I was discussing with my dad and contemplating if it were even possible.

One idea is to use cover crops to fix nitrogen and then crimp them to be able to plant the next cash crop. The problem with this of course is you can't crimp blackgrass and you can't rely on being able to drill a good cover crop straight after harvest as the dry summer of last year taught us all. The other problem with all rotational cropping is the minimal amount of time the roots are in the ground and therefore the effect they can have in turn on the soil is limited.

The ideal we discussed would be to have a constant understorey of clover that would act both as a nitrogen fixing cover crop when there was no cash crop growing and, if you could get it to grow thick enough, a weed-suppressing layer. The tricky and costly thing is to get a clover established well. Once you have done that you then need to plant your wheat crop into the growing clover crop and somehow control the clover so that the wheat crop can flourish. So I chimed in with a random idea about robot lawn mowers – surely we could get one of them and just run it through the wheat crop and it would mow the clover, effectively strip cropping.

Roll on about six months later and we are delighted to be working closely with Listt.io and Kristof Hayes. They are a team looking to bring practical, simple and usable robotic

solutions on farm. As I write this I have just been notified by DHL that our robotic platform coming in from California will arrive this week, the first one to be delivered to Europe. We are planning to fit several different implements to the robot platform and test its capabilities.

Having been at Agritechnica I have to say I was slightly underwhelmed by the lack of really good innovation in the robotics sector. Everyone seems to be either over complicating it, making giant (expensive) tractor-sized robots or stuck in the research phase. There is a concern in my mind that there are large scale robotics being developed that will bring huge revolutions to large agro holdings with hundreds of thousands of hectares to farm. This will I am sure revolutionise how commodity food crops are produced and bring great strides in cost reduction and quality increases. However they will be unusable here in the UK making our scale of farming even less competitive globally.

From my admittedly limited experience and knowledge it does seem however that there is an opportunity for UK farmers to do what we do best – test robotic systems out in the field, let them get dirty, and find ways to bodge them together to make them work. If we can find simple and practical applications for robotics this will be very useful for farming. Robotics need not be something only available to universities and large corporate farms. I can already see a future where they are out on my farm performing a huge range of tasks in a simple, uncomplicated way.

listt.io

FROM HANDS-FREE HECTARE TO **AERIAL DELIVERY**

10 years after starting a project that delivered a fully autonomously managed crop, *Jonathan Gill* looks forward to what the next ten years may bring.

I have spent 20 years working with robotics in a professional capacity and have seen massive benefits with machines being programmed to perform the dull, dirty, dangerous tasks that we do not want to do.

Ten years ago, while working at Harper Adams University I discussed many times that automated agricultural machinery would be in our fields by now. That led to being the co-creator of the Hands-Free Hectare, a pioneering project to show the capabilities of automation in farming where we were the world's first to grow a crop from start to finish with autonomous machines.

After completing the first year of the Hands-Free Hectare I had the opportunity and honour to be awarded a Nuffield farming scholarship where I travelled the world asking the question to universities, companies and individuals "How do we embrace automation in agriculture?" (You can find my report on the Nuffield farming scholarships website https://www.nuffieldscholar.org/)

Four years on from presenting my report I have not been disappointed. In my home county Shropshire, there are over five farms using the solar powered Farmdroid to precision plant and weed their crops.

There are challenges still with automation regarding safety concerns and the ability of machines used for farming to be left to their own devices without a human in the loop. Investment into automation in agriculture is a huge business. However, it's still not easy combining the information of multiple sensors and cameras to make real time decisions. Therefore, machines in agriculture classified to achieve true level 5 autonomy are still few and expensive. In my opinion the next 10 years will be the birth of true automation in agriculture.

I'm still constantly surprised by the ingenuity and innovation in farming and this creativity should not be lost to programmers who may not be talking to a skilled but ageing workforce. I expect to see tractors not looking like tractors, machines without cabs and electric powertrains working in our fields. The operations of these field robots now being made by smart implements rather than the vehicle, and these decisions made on the local soil and crop conditions etc.

The gateway to robotics and automation in agriculture is drones. Let's not forget they are now commonplace. These are after all autonomous robots which are simple, affordable and reliable and are in use by many farmers and landowners. Not only do they have cameras for their 'eye in the sky' enabling crop inspection but have enhanced features such as AI-enhanced obstacle detection and return home functionality. However, their uses are still being realised with the larger spray drones coming popular due to their affordability and versatility for additionally being able to deploy seed.

I have seen so many benefits for drone-based crop protection globally from Brazil to Indonesia in fields and trees, and watched the tech-savvy older farmers using drones to protect their crops from their mobile phone to great advantage. However, the UK's prohibitive regulations are preventing agrochemicals being applied to crops and thus holding us back from developing pioneering applications.

Unfortunately, with drones I'm seeing history repeat itself as seen with tractors increasing in size for work capacity where they had to have a single driver. The legality of only allowing one operator to fly one drone at any moment has led to current models made by DJI and XAG now weighing in excess of 80Kg where they used to be sub 25Kg, three times the weight and double the size.

While they are definitely able to perform field tasks at higher work rates, they are now producing the negative effect of increased downforce that can flatten crops. Additionally, it makes these drones harder to carry, store and transfer

to the field. Lessons learned from swarming operations like those seen with drone displays seen at major world events such as the Olympics and Kings Coronation are not being transferred across to our industry, as could be with smaller drones in flocks performing tasks in cooperation.

My future hope is a flock of drones performing tasks across the fields, all self-launched and tasked by a AI field manager which knows the best conditions day or night to plant or protect crops even down to a single plant.

With the advancement of drone technologies there may be opportunities to plant seeds in a completely different way. We are very familiar with our modern farming methods that require big machines to place seeds at the correct depth in our soils. I see inspiring developments to technology and agriculture in all corners of the world and one potential is the nature inspired air dropped E-Seed. This is packaged into a compostable carrier planting itself, with all the fertilisers and mycorrhiza fungi to establish successfully.

"The seed of these plants is carried inside a thin, tightly wound stalk. During rain or high humidity, the corkscrew-like stalk unwinds and twists the seed into the soil, where it can take root and is safe from hungry birds and harsh environmental conditions." https://www.cmu.edu/news/stories/archives/2023/february/engineered-magic-wooden-seed-carriers-mimic-the-behavior-of-self-burying-seeds

When I was asked to write this article, I spoke to Justin Gong, senior director at XAG which is one of the pioneering technology companies looking to use drones and automated machines to revolutionise farming in China. Putting their money where their mouth is, XAG

Jonathan Gill and Justin Gong

have two demonstration farms: 200ha for cotton and 50ha for rice production. Justin was proud to declare his cotton was grown "Hands Free" while passing over a white towel with a latitude and longitude printed on it. The other farm has a focus on rice due to this being the staple crop in China.

Justin believes education, demonstration and involvement is the only way future farmers will opt into new methods of growing crops. So I asked him three questions:

1. How is AI helping with the development of technology XAG is bringing to market?

"Farm management software is the Key. Information fed back from the thousands of drone flights daily is being assessed by a trial AI to simulate and determine disease and pest prediction while also pinpointing areas that may need drone crop protection and additional resources and thereby aiming to increase production of crops for food stability."

2. Is XAG working on any seed coating or primed seeds?

"Yes, to rice crops increasing their yield from 70-75% up to 90–95% with coatings of pesticide, herbicide, fertilisers and natural plant products. Confirming this we are running tests to verify these numbers on our trial farms and with cooperative farmers."

3. What are your predictions for the future of farms in the next 5-10 years?

"The average age of a farmer in China is 53 years old. In another 10 years they will be over 60 looking to retire. We are looking to a future with potentially no younger farmers coming in to help feed the potential 8bn+ global population. There is a company shift for the focus to be not just hardware but to make a predictive software platform to help make better decisions.

"Before all these farmers are going into retirement it is imperative to get all this experience & knowledge recorded and used. Currently farmers are carrying too much weight on their shoulders to be efficient and profitable, so i believe more advanced technology and precision application of modern chemicals are key to unlocking this."

The four years on since my Nuffield report I have seen the advancement of connectivity to all new mobile phones having 5G capability. However this has not solved the coverage challenge in this country with many areas still having communication blackspots that hold back some advanced technologies in agriculture.

I still stand by my original Nuffield report final statement, The 4th Industrial Revolution for agriculture is happening right now - the farmers who do not adopt and embrace will be left behind.

I am hopeful that automation, robotics and AI will not only improve the experience of farmers and operatives but increase food production in a better and more sustainable way in a world that requires both.

Jonathan Gill is a Nuffield scholar (2018) and an agri technology consultant
www.AgRobotjon.co.uk

The farmer of the year 2000 directs his robot machines illustrated by George Englert

FARMER FOCUS
DANIEL DAVIES

REGEN AND TECH – HAND-IN-HAND

Daniel Davies, Arable Division at Lower Pertwood Farm

The concept of regenerative agriculture is continuing to gather momentum across the globe. To me, it is clear that technology is going to play a bigger part than ever in farming, as methods continue to change and evolve to embrace this new farming concept with its exciting market potential in the years to come.

There is much talk at the moment surrounding the lack of an official definition for regenerative agriculture, and what (if anything) may be done to produce such a definition. A big part of the regen appeal to farmers is the wide spectrum of approaches that can be adopted in the regenerative farming system. Rigid rules and regulations deter farmers from adopting the organic farming system, depriving the farmer of necessary inputs and ultimately preventing their rigid system from being able to function.

Regen is taking off fast because this lack of prescription allows farmers the opportunity to try out new ideas and concepts, whilst still being able to do what they need to in the near term to maintain a functioning profitable enterprise. This is a positive step, because farmers can go at their own pace, introducing change that works for them. In time, these continued changes can move us towards farming systems which exercise better practices not only for the production of better quality and healthier food, but also for the environment.

In my day-to-day, there are two areas – crop establishment and crop protection – where the role of tech in the regen journey is obvious.

Starting from the beginning: crop establishment. I have always taken issue with 'blanket' systems, i.e. we plough everything, or we cultivate, or we direct drill. This doesn't do the crop, the bank account or the environment any favours. The idea behind regen is to produce good quality, healthy food with minimal negative impact and a central objective of soil restoration. With our winter wheats across the farm this autumn we have covered all methods, from ploughing and power-harrowed, to min-till cultivations, and direct drilled crops, all dependent on the conditions on the ground. We are fortunate to have a variety of cultivation equipment at our disposal to be able to do this, however the jewel in our crown here is our drill.

We run a Horsch Avatar, and to me this machine fits the regen model to a T. Flexibility is the name of the game here, because being able to do what a unique set of circumstances dictates at the time can be the difference between the success and failure of a crop, and what may previously have required several passes with multiple machines, if possible at all, can now be achieved in one pass. The precision metering technology and accurate depth control allows us a huge range of options when it comes to drilling, and the option of applying small seeds, slug pellets or Avadex to the surface on the back often saves time and money from additional passes and in some cases gives us the ability to apply these products at all when weather windows are tight.

Many regen concepts, such as bi-cropping, have been

around for years, but being able to do this in one pass with one machine not only makes previously unviable options possible, but can bring about added benefits to the ground and the environment. These include reduced compaction from a lesser number of passes, and specifically in the case of bi-cropping providing a greater variety of species in a field for wildlife to take advantage of.

Moving on from establishment, we look at crop protection. Here we enter a new arena which has seen a real desire for change in recent years, as the environmental pressures to reduce chemical usage increase. A need to cut costs also plays a big part of this. Whether looking at mechanical weeding options, such as spring-tine harrows, or inter-row cultivators, or spraying and fertilising technology, there are many avenues where tech can make these practices possible for farmers.

It really doesn't matter whether your stance is an environmental or financial one, if there is an option to save 50% or more chemical usage (with some boasting even bigger savings than that), whilst maintaining yield, any farmer would jump at the chance. Spot spraying is something which I personally am very interested in, and I think it is inevitable that it will eventually become mainstream. The use of cameras on the sprayer booms to identify upcoming plants, and then treating only those areas necessary, has got to be the way forward. Why spray an area when the chemical is being wasted, landing on non-target species which don't need it?

This is another part of the regen approach that I can really get behind, because it is sensible from both ideological and practical standpoints and has historically been an area where organic has proven impractical. If regen can bring about a precision middle ground whereby chemical application is reduced to only target species, it is a strong step in the right direction.

Now more than ever, farmers have to look very hard at their costings, and make savings wherever possible. If technology can help to do that for them, then it can only be a good thing. Any new technology is expensive, and justifying the costs of these progressions will take time. If farms can gradually alter their practices, and each time they replace a piece of equipment look seriously into the options available to them, the advantages of flexible and precision tech described above should result in long-term savings, making the transition worthwhile.

Over the next 10-15 years, I don't think we are going to have any choice but to adapt and review our methods. As with every other industry, technology is going to play an ever-increasing part in our day-to-day work, challenging methods which have sat pretty steadfast for a number of years. Outside of agritech, the ever-increasing presence of social media with its access to global communications is allowing what we do as an industry is becoming ever-more publicised. This digital ecosystem brings accountability, and is a chance to show that we are committed to moving forward. It is also a learning opportunity, where we can see how farmers, researchers, input producers and equipment manufacturers are rising to the regen challenge while continuing to produce excellent quality, healthy food.

CATAPULT PLANS FOR UK AGRITECH

Written by Tom Allen-Stevens

The Government has set out a strong desire for the UK to be an agri-tech powerhouse. *Tech Farmer* looks behind the ministerial announcements to what they may mean for on-farm R&D.

George Freeman wants to make the Agri-Tech Centres interfaces of much deeper industrial investment and commercialisation.

UK Agriculture is set to get an Agri-Tech Catapult, following the announcement by the Government that three of the four Agri-Tech Centres are in merger discussions to create a new "integrated capability".

George Freeman, Minister of State* at the new Department for Science, Innovation and Technology (DSIT) announced at the World Agri-Tech Innovation Summit in London that the Agri-Tech Centres are looking to merge.

"These companies were designed to be the model showcase testbed farms, but in my view, we need to commercialise better. We need to make these the interfaces of much deeper industrial investment and commercialisation," he said.

"So we are reviewing those centres with a view to creating a Catapult. This is a big commitment [by Government] in the UK research ecosystem. It's ring-fenced long-term funding, and we are absolutely determined to set out a long-term framework so that companies, from the big agri-food majors around the world to UK companies, can come and invest i n it."

The three Agri-Tech Centres coming together are Crop Health and Protection (CHAP), the Centre for Innovation Excellence in Livestock (CIEL) and the Agricultural Engineering, Precision and Innovation Centre (Agri-EPI). They were set up in 2015/16, along with Agrimetrics, which aims to use agricultural data to build a better food system, and will remain a separate company.

The Centres exist to drive agri-tech innovation and adoption through "world-class" facilities, expert knowledge and business and project management support. They're designed to strengthen the connections between science, business and funders, to accelerate R&D and tackle the agri-industry's most critical challenges.

As a combined, Agri-Tech Catapult it would join the nine others in gene therapy, medicine, electronics, connected places, digital, energy, high-value manufacturing, satellite applications and offshore renewables. These Catapults are established by Innovate UK, part of UK Research and Innovation (UKRI), the government's R&D arm that has an annual budget of around £8bn. They aim to accelerate the commercialisation of innovative technologies, thereby driving economic growth.

An Agri-Tech Catapult would seek to improve productivity, efficiency, and sustainability in farming and agriculture by helping to accelerate innovation. Minister Freeman is hoping it will act as a channel for private investment into the sector. "For too long in this country, we've incubated bioscience in all sorts of technologies, grown great businesses and then seen them disappear across the pond," he said.

"We are finally going to make that move and unlock some of the trillions here in London in the pension funds that aren't investing in UK equities. Just a tiny fraction of the money under management here in The City, properly connected, would help us pull through these companies."

The Government already spends £400M/year on agricultural R&D, he said, and had identified "engineering biology" as one of five critical technologies to prioritise. This will be backed up by "a clear, reliable, long-

A capital-only funding model may have left genetic innovation behind.

term framework" to give confidence to farmers and to investors in supply chains.

New R&D "clusters" were also promised. "If we're really going to deliver the strength of this innovation economy, it can't just be Cambridge, Oxford, London. We will shortly be unveiling the first ever digital cluster map – a heat map to show investors what's going on around the UK in agri.

"You will see incredible strength in Norwich, Yorkshire, Scotland, Wales, Aberystwyth, Kent. And through the work that UKRI is doing, we intend to pull that together through that Catapult network."

Not all are convinced by the Minister's words, however. Plant scientist and former NIAB CEO Professor Tina Barsby notes that so far, the Agri-Tech Centres have delivered a return on investment of just 0.6:1, constrained by a risky 'capital-only' funding model, and lacking a core focus on genetic innovation.

Writing for Science for Sustainable Agriculture, she says "the legacy of the centres of innovation is not one of unmitigated success", pointing out that growth in UK agricultural productivity has continued to fall behind other countries.

"I would struggle to name specific projects where the three Centres have translated agricultural innovation into commercial success over the past decade. Maybe there are some, but are they sufficient to justify the considerable government spend which the Centres have had access to? And does this bode well for a Catapult?"

The Centres have received capital-only funding from Government. There are large infrastructure projects, such as CHAP's Advanced Glasshouse facility at Stockbridge Technology Centre (STC) near Selby which allows for testing of new production approaches and growing media. Extensive precision machinery equipment located at Newcastle University is used to test new regenerative farming techniques.

These rely on industry stepping up to fund projects delivered through them. Tina says the plan has only partly been successful and in 10 years, they have translated government investments totalling £162M into projects worth £99M to the agri-food sector.

A fundamental flaw, she says, is that genetic innovation, "the single most important factor in driving on-farm productivity gains", was not a core focus for any of the Centres. "Consequently, the John Innes Centre, our flagship genetic institution, has hardly interacted with them at all."

Tina calls for "a more strategically targeted approach, and a focus on tangible, deliverable outcomes, for the next phase". So will this happen?

"Crop improvement is an important part of the cropping system. But other considerations such as crop nutrition, plant and soil health and efficiency, on which the Centres also work, are essential for on-farm profitability," points out Fraser Black, CEO of CHAP.

"In addition, the Centres are also working across many production systems including animal health, aquaculture, horticulture and robotics where collaboration across the industry is also needed."

Fraser Black wants to get good technology into the hands of farmers.

He argues that 10 years is a short timeframe on which to assess return on capital-only funding in innovation. "It takes time to reap the rewards of both capital investment as well as highly novel and entrepreneurial projects. It is often necessary to stress-test new innovations and approaches at an early technological stage before they can be fully utilised on farm."

The merger talks will take place over six months, with the combined Centre due to be complete by April 2024, he explains. He believes combining forces would give the Centres the capacity and ability to work together more effectively.

"There are obvious crossovers, such as between CHAP and CIEL on rotational grassland and cover crops,

The Agri-Tech Centres have partnered with a number of UK start-ups to advance robotics and highly novel and entrepreneurial projects on farm.

and in robotics for Agri-EPI and CHAP. A single portal provides one place to go," he says.

Fraser recognises CHAP has not always engaged directly with farmers, and it may be that many don't know what the centre actually does. "This is because CHAP's primary goal is to get effective technology market ready and then to work with farmers as part of the supply chain. We are still a young organisation, and it takes some time for innovative technology to be scaled up and usable on farm.

"Few projects we're involved with have specifically been about engaging with farmers – most are taking technologies to proof of concept or pre-commercial stage. CHAPs strength has been in bringing consortium members together, connecting with SMEs, start-ups and industry to accelerate real-world solutions to real-world problems. We tend to work with others, such as BOFIN (British On-Farm Innovation Network), who provide the connection to farmers.

"Looking ahead, though, and with the expectation we will become a Catapult, bringing the strong networks we've built up closer to farmers will be one of the key priorities, as will being even more joined up across the whole of the agri-tech ecosystem."

Fraser points to the Crop Storage and Post-harvest Solutions (CSPS) facilities, located across three locations in the UK, as a recent example of the use of capital investment to support the industry. The need for this was driven by the closure of the Sutton Bridge facility after the loss of the potato levy. These facilities provide much-needed R&D opportunities for companies to test new sprout suppressants and storage options to reduce energy use, he notes.

Agri-EPI already has a network of 20 commercial farms across the UK, notes CEO Dave Ross. These are all equipped with the latest precision sensor technologies that are purpose-built to measure agricultural innovation.

"The concept is to create many insights of farming systems and gather data through on-farm trials to optimise productivity within environmental and physical constraints. In essence, it's about getting actual data to help farmers manage a biological resource," he explains.

Examples of farmer-facing projects Agri-EPI has been involved with include Earth Rover (see page 12) and the Crover – a sensor that burrows through a heap of grain gathering data on quality and condition.

Agri-EPI's network of 20 commercial farms are equipped with the latest precision sensor technologies that are purpose-built to measure agricultural innovation.

The Crover is a sensor that burrows through a heap of grain gathering data on quality and condition.

For Fraser, the difference when the Centres combine is that there will be a single point of contact for farmers, agri-tech innovators and the whole agricultural sector to come to. This will provide access to all of the facilities and individuals with a high level of expertise.

"We want to get new innovation into the hands of farmers as soon as possible and to be the trusted place to come to for that – we're independent and not-for-profit, and here to make things happen – I am very excited for the future," he says.

*NOTE: George Freeman resigned his post as Minister of State at DSIT on 13 November, following 13 years in which he had served in various ministerial roles championing science and the importance of an active strategy for innovation.

Farmers encouraged to ADOPT new technology

Defra has announced plans to launch a new scheme for farmers to adopt new technology and take part in on-farm R&D. £40M over five years is set to be made available for farmer-led projects under its new ADOPT Fund (Accelerating Development of Practices and Technologies), due to be launched in late 2024.

"Next year, we'll launch a new scheme to support farmers in leading their own on-farm trials, testing the viability of your approaches and driving adoption of what works." announced Defra Farming Minister Mark Spencer at the World AgriTech Summit in London.

"Our brand-new approach seeks to transform innovative concepts into practical solutions that drive productivity, economic growth and environmental benefits."

Mark Spencer Spencer seeks to transform innovative concepts into practical solutions that drive productivity, economic growth and environmental benefits.

The new fund is part of Defra's £270M Farming Innovation Programme – the R&D strand of its post-Brexit approach to funding for agriculture up to 2029. A few farmers have already received funding from this through various rounds of projects delivered by Innovate UK, with £120M committed to date.

Most of the budget has so far been awarded to UK tech start-ups, supply chain companies and research organisations that have typically come together in consortia on collaborative projects each worth a total of £200,000 to £6M. All projects have had to demonstrate farmer engagement and a route to commercialise the technologies that have received funding. That's involved some farming businesses joining as partners or even leading bids. Significantly, there have also been three rounds of smaller Research Starter Projects – one-year projects worth up to £56,000, led by farmers looking to explore a new idea.

Uptake by farmers and involvement in these projects as a whole has been very low, however. Part of the difficulty has been the process of tendering for and then obtaining funds through Innovate UK. This is a system that's largely designed for ambitious, multi-million pound projects tendered by research organisations with dedicated finance departments. Tech Farmer has spoken to several farming businesses that will "never want to work with Innovate UK again" following successful bids for funding.

To get round the difficulties, some organisations have taken farmers on as contractors. BOFIN (British On Farm Innovation Network), for example, is leading or partnering on six projects, worth a total of over £10M over the next four years. Within the company's budget are total payments to farmers worth £800,000, that may be shared by around 200 farmers taking part in trials. While BOFIN has to submit timesheets, invoices, and payslips as proof of expenses to claim funding, as well as attend regular project meetings, meet milestones and deliver update reports, the farmers, paid as contractors, simply agree to a protocol to follow and submit an annual invoice to BOFIN.

The new ADOPT fund is designed to get farmers directly involved in projects without the administrative burden of dealing with Innovate UK. Farmers or groups of farmers will be invited to propose one to three-year projects worth £25,000-75,000 each. Brand new will be an Innovation Support Service (ISS) – a third-party organisation that will promote the fund to farmers, manage applications and provide support and resources.

The grant-funding will be competitive, but two levels of support will be offered – firstly a grant of up to £2500 is available to submit an application. Farmers could use this to fund an Innovation Manager (IM) – an industry consultant hired to assist them, design an application more likely to be successful, and submit it to the level of detail required by the Innovate UK platform. If successful, the full grant (£25,000-75,000) would be awarded and the IM may then help manage

the project for a fee, drawn from the award.

The IMs would play a key role, both in applying for the grant and running the project, and Defra envisages these will be farming industry "experts" (e.g. farm consultants or advisers) already proficient with the Innovate UK bidding process "with skills beyond basic facilitation and project management". They would need to register with the ISS, who would be responsible for maintaining standards.

While the tender process for appointing an ISS provider is now underway, much is still unclear about ADOPT. A key question is to what level farmers will be asked to fund their own projects – typically commercial partners in Innovate UK projects contribute 30-50%, depending on the size of the company. How a farmer's time will be valued is also unclear – in current projects, they can claim no more than £176/day for their time, unless they can present PAYE slips that prove they are paid more.

Once the ADOPT fund gets underway, Defra is planning to support up to 40 farmer-led projects per quarter. In addition, Minister Spencer pledged support to leverage more private funding into agriculture, and to address regulations around robotics, autonomous vehicles and genetics that may present a barrier to adoption of new technologies at present.

"The world faces many challenges that demand innovative solutions, and that also offers huge opportunity. Together, we can develop a world-leading Agri-Tech that empowers farmers and growers to combine productive and profitable businesses where they thrive in a thriving, natural environment," he said.

Farmers will be invited to bid for awards worth £25,000-75,000 to explore new ideas on farm with support offered to manage the administration.

SHEDDING LIGHT ON LED GROW LIGHTING

In the first part in a series of five articles that are going to look into how modern LED lighting can be used to grow food, *Alex Martin and Alessandro Oliveri from Dextra and Igrox Srl* looks at some of the fundamentals

The question of how LED grow lighting helps horticultural, and potentially other crops, to grow is being asked more and more. However, as with all new technology this can raise more questions than it answers. An example of this is the type of grow lights required for different plant types and environments. Most seem to assume that all LED horticultural lighting is the same but that is very far from the truth.

In recent years, advancements in lighting technology have revolutionised the way we can grow plants in artificial environments. Light-emitting diodes (LEDs) have become a popular choice for horticultural applications due to their energy efficiency, longevity, and the ability to tailor their light spectrum to meet the specific needs of plants. To elaborate on this, we will explore the main differences between the LED lighting spectrum for greenhouse and for vertical farming applications. In doing this, hopefully we will highlight the unique considerations for each setting.

The Basics – The Electromagnetic Spectrum

When we discuss light in everyday terms, we typically refer to visible light – the portion of the electromagnetic spectrum (EM spectrum) that our eyes can naturally perceive. But isible light constitutes only a small segment of the entire EM spectrum, as illustrated in the picture, and when growing food using LEDs we talk about a wider range of light.

Wavelength, a term frequently used in this context, describes the oscillation of a passing photon through an electric field as it traverses space. The EM spectrum encompasses all possible energy levels that photons may possess, with higher energy corresponding to shorter wavelengths.

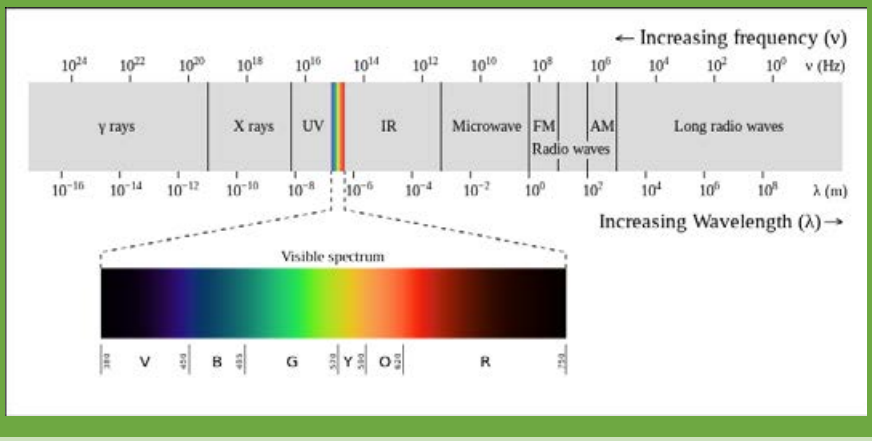
Visible light wavelengths span from around 380 nanometers to 760 nanometers. However, both the sun and artificial electric lamps can emit waves shorter and longer than those within the visible light range.

Moving along the EM spectrum, we encounter various energy levels emitted as cosmic rays, possessing wavelengths a million times smaller than what is visible to us. Subsequent to this, there are gamma rays and X-rays, utilised for imaging bones within living tissue.

Just beyond the realm of visible light lies the ultraviolet (UV) portion of the spectrum. Named for being "beyond" the colour violet in the visible spectrum, UV light, a component of sunlight, is responsible for causing sunburn and encompasses a broad range of wavelengths.

Descending below the threshold of visible light brings us to infrared (IR) radiation, often referred to as heat radiation. This electromagnetic radiation, emitted by all objects, correlates with temperature—the warmer an object, the higher it registers on the IR scale. In instances where objects become sufficiently hot, they transition to incandescence, emitting EM radiation in the visible spectrum, a principle observed in incandescent lamps.

Further down the scale, we encounter microwaves, utilised for heating food, and radio waves, employed in long-distance communication. The EM spectrum thus unveils the expansive range of energy levels and wavelengths beyond what is perceptible to the human eye.



Greenhouse Lighting

Greenhouses are structures designed to harness natural sunlight while providing a controlled environment for plant growth. When supplementing natural light with artificial sources, the LED lighting light spectrum must complement the sunlight to optimise photosynthesis and plant development. Greenhouses receive varying sunlight throughout the day and seasons. LED lighting in greenhouses aims to supplement the natural light, filling in gaps and extending photoperiods when necessary.

The LED light spectrum for greenhouses often mimic the sunlight spectrum, providing a balance of red light, that has a wavelength of 600-700 nm(manometers)and blue 400-500 nm – both of these ranges are crucial for photosynthesis.

Plants have specific light requirements during different growth phases. For example, blue light is essential for vegetative growth, while red light promotes flowering and fruiting.

Vertical Farming Lighting:

Vertical farming involves cultivating plants in stacked layers or vertically inclined surfaces, often in indoor environments. Unlike greenhouses, vertical farms are not reliant on natural sunlight, allowing for precise control over the lighting environment.

In vertical farming, LED lighting is the primary source of illumination. The light spectrum can be precisely tailored to meet the specific needs of crops without considering the natural sunlight spectrum.

Red and blue light spectrum are still crucial, but vertical farms can leverage a more targeted approach, emphasising light wavelengths that directly contribute to photosynthesis and plant growth efficiency.

Vertical farms are designed to maximize space efficiency. LED lighting can be strategically positioned to ensure uniform coverage throughout the vertical growing space.

Furthermore spectral optimisation in vertical farming aims to minimise wasted energy and enhance the overall yield per sqm.

In addition to that different crops have varying light requirements. LED lighting in vertical farms can also allow for multiple tailored spectrums based on the specific needs of the cultivated plants, ensuring optimal growth conditions for diverse crops within the same facility.

In conclusion, the main difference in LED lighting light spectrum for greenhouse and vertical farming applications is the degree of control over the light conditions. Greenhouses seek to complement natural sunlight. On the other hand, vertical farms exploit the freedom to customise the light spectrum , optimising efficiency and space utilisation. As technology continues to advance, the integration of LED lighting in both settings is set to play a pivotal role in meeting the increasing demand for sustainable and efficient agriculture.

DRILLING DOWN INTO **FIXED COSTS**

Written by Will Foyle from Hutchinsons
New Machinery Tool provides in depth fixed cost analysis

Will Foyle

Improving financial performance on combinable crops relies on a true and accurate understanding of fixed costs, says Will Foyle farm business consultant with Hutchinsons.

"Whilst a focus on yield is still important, understanding and being able to control overheads or fixed costs, is key to financial integrity. We know that a higher wheat yield improves financial output, however, it is a lower level of fixed costs that will make the greatest difference to performance/hectare," he says.

Mr Foyle recognises this is a complex area as machinery depreciation costs are often misunderstood or incorrectly valued which can make a large impact on profit/hectare. "It can be difficult to clarify the metrics of depreciation of machinery, linked to areas worked and work rates for example, alongside the more visible labour and diesel costs."

"You don't receive a monthly statement for your fixed costs in the way you do for variable costs."

As a business looking at costs of producing a crop is an area that Hutchinsons has been working towards making simpler. This began last spring with the launch of the Business Performance Module on the Omnia digital farming platform, which allows for retrospective calculation of the cost of production of field operations in both £/tonne, CO2/tonne or CO2/hectare, based on a slider measurement for where those costs sit.

The new Machinery Tool takes this one step forward, providing a simple way of calculating actual and accurate operational machinery costs before committing to field operations, for individual farm businesses based on its own figures.

"This is done by breaking down all the components of cost related to running a particular piece of machinery to realise the true, not approximate, costs of operation," explains Mr Foyle.

Within the Machinery Tool, depreciation ranges take in to account the age, value, areas/hours worked per annum, alongside servicing and repairs to give the fixed costs of a particular piece of machinery, so instead of an approximate figure being used as was previously the case, real costs can be inputted. Work rates alongside diesel and labour costs are then calculated giving a total cost per ha and per ha for running both the tractor and machine.

This cost can then be added into the virtual machinery shed in the Business Performance Module on the Omnia platform and when overlaid with yield and variable costs gives the real costs of producing a crop.

It is possible to use the tool to look at how invisible or fixed costs may be better managed. For example, if the depreciation cost is higher than anticipated is it that the capacity of the machine is greater than needed?

Mr Foyle quotes an example of how a farm changing over from a mixed tillage system using a 2015 4m Vaderstad Rapid to a direct drilling regime with a new Claydon Hybrid.

Looking at what the Vaderstad is used for – it was retained for drilling 40ha of grass seed annually but alongside power unit fixed costs, fuel and labour the calculated depreciation of £1,680/annum across a small area meant this operation was now costing £66/ha as opposed to £27/ha when covering 200ha annually.

"So in this situation, a discussion around whether to keep the drill for flexibility purposes or sell and use a contractor for the grassland re-seeds, would be sensible."

Perhaps it is possible to run the machine for longer say six years rather than four?

Helix host farmer, Thomas Todd, of Bareless Farm, Cornhill upon Tweed, Northumberland was one of the first to trial the new Machinery Tool.

"With the demise of the BPS it is more imperative than ever before to have an accurate figure for fixed costs. This is for two reasons, one just to know exactly what it is costing to grow a crop, but also for future planning and making decisions over cultivation changes and the implications of buying new machinery.

He used the machinery tool to look at the potential implications of moving from min-till to predominantly direct till. "We have been looking at going down the direct till route. Currently we min-till but this would require buying a new machine.

"What it showed was that the costs just didn't play out, particularly as we would not be using it for 100% of our cultivations."

"Thew tool has allowed us to look at using our machinery more efficiently, and we have even thought about dropping some cultivations, for example on the rape."

"Using the Machinery Tool has certainly challenged our perception of which crops are the most profitable;

Autumn Cereal Drilling

for example, our spring barley can be as profitable as winter wheat, in terms of lower fixed costs, but also lower variable costs."

"We are going to carry out the same exercise with other break crops and it will be interesting to see what comes out on top."

"We are very fortunate as Helix farm hosts as we are privy to trialling exciting new tools and technologies to improve farm profitability and the Machinery Tool is the perfect example of this. We have found it straightforward and easy to use and invaluable to managing profitability going forward. It certainly challenges us against taking the approach 'I've always done it this way so why change'.

FARMER FOCUS
SIMON BEDDOWS

John Deere's Harvest Lab

TRIALS TEST THE TECH

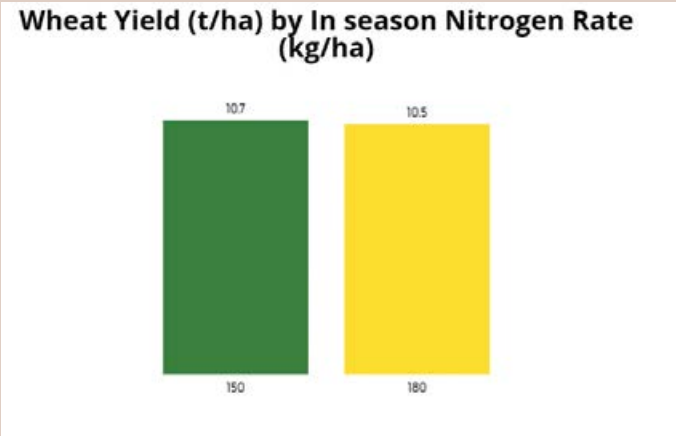
On-farm trials have always played a key role in exploring new tech, and helped Simon Beddows develop a new use for John Deere's Harvest Lab.

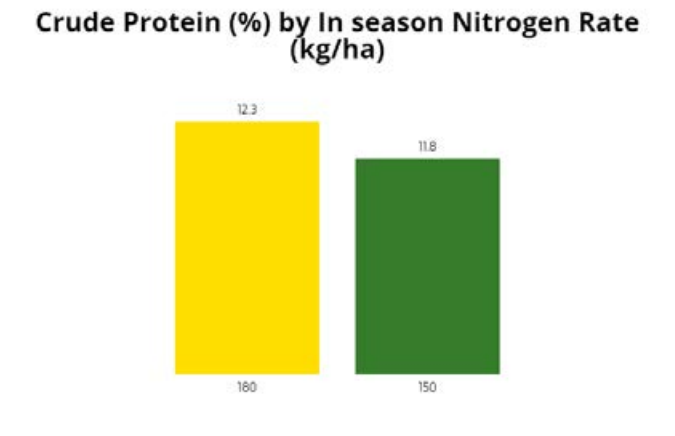
For the past 30 years I have been a farm manager, firstly in Kent and latterly in South Oxfordshire. For 25 of those years, after successfully completing my BASIS and FACTS courses, I have undertaken all my own agronomy. An inquisitive mind and a desire to find out what works best on my farm led me to get involved with on-farm trials.

Life sometimes throws you a curved ball. In October I took on a new position with a John Deere dealer, Farol, as their in-house agronomist. My role will develop over time, but essentially I am there to help farmers and growers work with current and new technology, using data from machines to make agronomic decisions and improve productivity.

My journey into technology began in the early 2000's,

Ops Centre Protein map





firstly to replace the unreliable foam blob marker on the sprayer with GPS generated A-B lines. Wanting more from my purchase, I added autosteer and began looking at variable rate fertiliser initially using SOYL to provide variable P and K maps based on soil test results. Farming very variable soil types it seemed a good idea to try adjusting the rate of nitrogen according to crop growth. To prove it worked I set up three years' worth of trials comparing the technique with standard blanket applications. So began my introduction into creating my own farm trials. In the last few years I have worked with major manufacturers and universities covering a diverse range of topics.

It was my link with Reading University on a three year project looking at the probability of profitability that bought me to John Deere and their development of HarvestLab on combines. The project was investigating which factors, during the crop's growth cycle, had the greatest influence on final yield. Using this knowledge, growers could attempt to influence crop growth before harvest, or tailor inputs according to predicted yield. Part of the analysis was taking hand samples of the crop at pre-determined GPS marked points just prior to harvest. Protein content was the main grain quality aspect that was of interest, because of its link to nitrogen fertiliser. Finding students to help the research staff was always a challenge, especially at short notice and I had heard that John Deere were looking to develop their Near Infrared sensor, already proven on forage harvesters, to work on combines.

HarvestLab sits on the clean grain elevator and uses an auger to take grain continuously past the sensor. 4000 readings are taken every second. My local dealer, Farol, put me in contact with John Deere who were keen to get a UK grower on board. The first year was spent getting to grips with the system and confirming the calibration curves by collecting samples and sending them for analysis. In my various meetings with John Deere, they were keen to emphasize the value of being able to segregate the grain according to protein content going into the store. At our first harvest wash-up meeting, as we sat looking at the maps generated by the combine, I pointed out that this was a powerful tool for making agronomy decisions particularly around nitrogen fertiliser.

I have always liked John Deere as a manufacturer because they are happy to listen to the customers and look for solutions to the problems they have identified. Still, I knew I had to show them something concrete, so for harvest 2022 I set up a fertiliser trial.

The price per tonne of nitrogen had skyrocketed in the spring and £700/t looked good, so what better time to see how low we could go. The field I chose was milling wheat following a crop of maize and farmyard manure. Two 30m tramlines were selected for each treatment to get over the overlap problem with a spinning disc spreader. The rates were totals of 150kgs/ha and 180kgs/ha of nitrogen. Following on from harvest I had both protein and yield data from the two plots. Every load that went back to the farm passed over a weighbridge, so combine yield data could be checked post-harvest. Grain samples were collected for the trial and sent off for analysis as before, to check on protein.

I used John Deere's Operation Center for machine integration, data collection, work planning and analysis, which allowed me to view the differences in yield and protein maps side by side. The results showed yield to be statistically the same in each plot at just over 10.5t/ha. However, the protein content was 0.5% lower in the 150kgs/ha of nitrogen plot, much as expected, with grain testing showing that both treatments had been above the 11% protein content necessary to reach maximum yield, all other factors being met. Now I had got John Deere's attention and they could see the added value of HarvestLab as an agronomy tool. They now have a team of agronomists working for them in their technology department, so expect more exciting developments to come.

As part of my new role, I now get access to Agronomy Analyzer. It is a dealer only tool developed to allow much more detailed analysis of farmers and growers own trials. I have run some of my trials through it including this nitrogen trial.

Hopefully I can work with more of our customers in the future to produce reports for them that can be accessed through Operation Center. With a loss of support systems and more extreme weather events, it becomes even more important that farmers and growers can back up decisions with accurate and relevant data.

MAKING METHANE PRACTICAL

A new project is set to explore the concept of an energy-independent farm.

If you went to Agritechnica, you may have seen New Holland's T7 Methane Power LNG (Liquefied Natural Gas) tractor as an industry first. the latest development in the brand's Methane Power tractor offering. The tractor itself offers farmers high performance for an alternative fuel tractor while also boosting overall farm sustainability. It's as good as the diesel equivalents, says New Holland.

But with its LNG power solution, this tractor more than doubles the autonomy capability of the current methane powered range: using liquefied methane delivers four times as much fuel storage capacity when compared to compressed gas (CNG). With fuel autonomy for a working day and with its 270hp, there's no difference in performance between the LNG and a diesel tractor.

However to make the tractor truly part of a solution that you can implement on your farm, The LNG tractor can be fueled by fugitive methane, strategically captured from livestock waste slurry lagoons. The methane is converted into fuel-grade liquefied natural gas (LNG) using patented cryogenic processes solving the low boiling point challenge historically seen with this fuel source.

Now Bennamann is undertaking a project that aims to demonstrate a revolutionary new approach to energy independent sustainable farming and:

- maximise the use of on-site renewable energy resources in combination with animal waste, such as cow manure, to supply all the energy needed for the farm, taking the site off-grid and reducing operational costs;
- deliver commercially viable net zero carbon energy products (biogas and liquid biofuel) from animal waste for local sale and distribution, providing an additional income to the farm business;
- improve the sustainability of farmland management practice through minimisation of artificial inputs such as manufactured fertiliser, lowering operational costs and reducing pollutants;
- provide site assessment methods and business models that will enable roll-out to scale across Cornwall and the Isles of Scilly, the UK and the rest of the world.

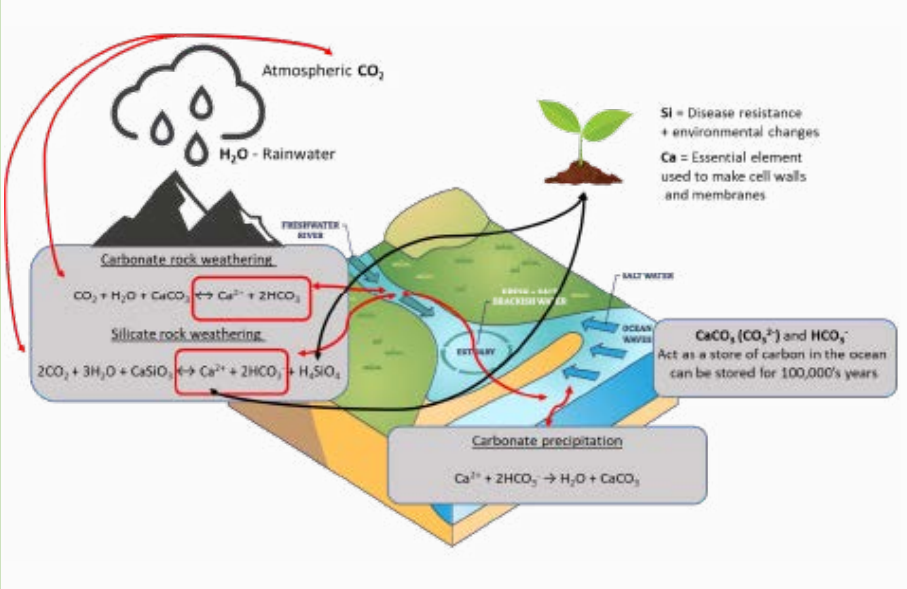
The three local knowledge and innovation partners that have come together to collaboratively deliver this project are Bennamann (lead partner), Chynoweth Farm Partners and the University of Exeter.

FPT Industrial presents an energy independent farm concept based on their Smart Hybrid Hub and our fugitive methane capture, process and use technologies.

HITTING ROCK BOTTOM

Silica rocks may have potential as a route to mitigate agricultural emissions, argues Dr *David Cuttress* of IBERS, Aberystwyth University.

- Silicate and carbonate reactions could offer a route for long-term carbon storage
- Whilst issues surround carbonate minerals, silicates, like basalt rock, appear more promising
- Applying crushed silicates to agricultural soils could benefit carbon footprints, nutrient availability, pH, soil water retention and plant growth and yields
- Currently, there is very limited field-based evidence of the possible off-target long-term impacts of this strategy on global ecosystems
- More research is needed before further highlighting the environmental potential of silicate weathering and providing incentives to utilise such practices



Rock weathering and agriculture?

The current climate focus along with environmental warnings are making carbon capture and storage activities a higher focus than ever before. Whilst strategies such as increased tree planting, min/no-till, bioenergy crops and legume integration are well noted for their potential in reducing agriculture's carbon footprint there are some other less direct tools to consider. Rock weathering involves the ability of silicate and carbonate materials to remove carbon dioxide (CO_2) from atmospheric cycles. This acts as a natural control for climate change/global warming and has been known for a long time. It has relatively recently come to the forefront for its potential as a mitigation tool directly for agriculture's high emission profiles. Articles have noted the potential to include silicate-rich materials such as basalt into agricultural soils so that they can draw down extra CO_2. An article in *Nature* in 2020 highlighted the potential of this strategy and received a great deal of interest and further citations (over 150 within 2 years) demonstrating a high level of attention.

This draw-down function is a part of the carbonate-silicate geochemical cycle or the 'Inorganic carbon cycle'. This involves reactions between elements of rocks with atmospheric CO_2 and water (H_2O).

The diagram above shows the route which could be used within agriculture towards carbon storage but it should be noted that this is a cycle (though a long-term cycle) and CO_2 is eventually re-released (1000's years). This re-release occurs via mechanisms such as the volcanic breakdown of calcium carbonate ($CaCO_3$) and silicon dioxide (SiO_2). Weathering processes are also under investigation for "artificial" weathering in reactors for carbon capture and utilisation strategies, though there appears as yet to be no commercially ready solution to achieve this efficiently.

What does this mean in practice?

Essentially this strategy would involve the application of fine silicate dust (such as basalt) onto agricultural lands similar to the process of applying lime. In arable studies, a suggested addition of 40t/ha of basalt per year was used as it was shown to be within range for improving crop production in field trials. Whilst other trials have noted figures between 0.5 and 10kg of basalt per m^2 (equivalent to 5-100t/ha). The finer the particles the higher the surface area and CO_2 removal from the atmosphere, however, it has been noted that there would need to be a balance between particle size and energy needed to produce finer

powders. The process involves basic cations (positively charged particles) being released into the soil/water interface during mineral weathering meaning that this can also act as a tool to reduce soil acidification. Reducing soil acidification could allow silicates to act as a replacement liming material which like lime itself increases soil pH and reduces N_2O emissions associated, this is powerful as N_2O is roughly 270 times more detrimental than CO_2. In systems where there are natural occurring high quantities of silicate minerals (areas with high volcanic ash), it has been noted that, long-term soils are largely neutral or only minorly acidic and that these soils also show interesting potentials for organic carbon (C) storage over time.

Alongside CO_2 benefits, silicate weathering also releases other plant nutrients into the soil, for example, basalt (the main rock considered across literature) includes Silica (Si), potassium (K), phosphorous (P) and calcium (Ca) that can be utilised by crops to improve vigour and yields giving added benefits. Equally, there is an association between this process and the reduction of nitrogen (N) present in runoff as well as reduced acidification of soils (reducing the need for lime addition in intensive systems). This has been understood since the late 1800s with silicon wastes used as fertiliser in US systems, though historically the CO_2 reduction implications were not realised. One benefit to consider with this strategy is that there may already be pathways in place that would enable the large-scale application of silicates like basalt to croplands due to similarities to the current liming practices.

Whilst the increased need for mining silicates would be a consideration for supplying this resource globally, there is also the possibility of utilising waste resources such as slag from iron and steel manufacturing (2.7% already used for fertiliser nutrients in Europe), demolition waste, cement wastes and by-product silicates from other current mining endeavours.

CO_2 uptake via this system is influenced by temperature, level of runoff and the available surface area of the rock/mineral in question. Temperature is a key factor with weathering being more efficient at higher temperatures. In natural systems, weathering acts as a partial natural buffer to global warming (as global temperatures rise, more weathering draws down more carbon from the atmosphere). What this means in practice is that countries with higher average temperatures will see increased benefits to the inclusion of weatherable rocks onto landscapes (as long as they have the high precipitation levels to go along with this). This was noted in one model where Indonesia and Brazil showed high carbon dioxide removal potential due to a combination of their extensive available agricultural land (on which to apply the minerals/rocks for weathering) and their warm/wet climates which are conducive to weathering efficiency. Whilst this might suggest that the temperate climate of the UK might not be the best for this system of CO_2 removal a follow-up *Nature* paper, in 2022, noted that employing this strategy across UK croplands could remove 6-30M tonnes of CO_2 a year representing 45% of the C removal required to hit net zero-emissions by 2050. If this modelling proves correct this offers a substantial opportunity for agriculture as a sector which is already known to be vital for its potential role in carbon sequestration. Other studies have suggested reductions of 2.5 Gigatonnes (Gt) of CO_2 a year (1 gigatonne = 1 billion tonnes) over 50 years following a single one-off application of basalt dust (In this specific instance assuming the land was not disturbed for arable use). In studies of application on cropland it was noted that applying basalt to around 10% of croplands at 0.039 – 0.84 Gt a year should lead to 0.5 Gt CO_2 reductions. Whilst silicate application values can be enlarged to increase the CO_2 reductions achieved it has been noted that thresholds exist where higher basalt dust addition had far less impact on CO_2 reducing the efficiency of its application.

Of course, the processing and transport of silicate minerals have CO_2 emissions associated as well as costs. Whilst the emissions have been calculated in many of the models (though production in different countries has different impacts depending on their main source and efficiency of energy production) these along with the costs would need consideration to make this strategy appealing and feasible overall. It is suggested that the direct valuation of C is a current question throughout agriculture concerning the value farmers can see from their climate mitigation actions. The World Bank forecasts $100-150/t of CO_2 by 2050. The 2020 *Nature* paper found the cost of silicate application to range from $53-220/t CO_2 extracted per year depending on country and intensity of applications. This suggests that even in the most expensive scenarios, CO_2 capture value would mitigate between 1/3 and 2/3rds of the costs incurred.

The costs of rock weathering are therefore equivalent to other strategies being considered from bioenergy with carbon capture and storage (BECCS) strategies being explored such as biochar and direct air capture and storage.

The use of basalt for weathering as noted also provides a source of

P and K for the soil with P being noted as an essential nutrient which limits biomass production globally thus adding a co-benefit to basalt dust addition. Increasing biomass production by alleviating P constraints concurrently means more CO_2 will be taken from the atmosphere and stored in plant biomass. This suggests an even higher potential for basalt dust in tropical (warm/wet regions) with depleted P levels in soils. Alongside CO_2 reductions, this process should play a role in increasing the alkalinity of oceans with a beneficial impact on the growth of corals and diatoms (key in removing CO_2 via photosynthesis and providing nutrients in ocean food chains) thus likely a positive impact on biodiversity. Also increasing the alkalinity of oceans makes them able to store more C providing positive feedback on C sequestration overall.

What are the uncertainties?

As noted in the inorganic carbon diagram the reactions for carbonates and silicates are reversible. There is the suggestion that this action could mean that soil chemistry in certain conditions leads to the promotion of carbonate minerals which acts as a store of C rather than HCO3- and CO_3^{2-} making their way to the ocean for storage. Whilst this function in itself has been investigated for its potential as a carbon sink it was noted in one paper that this action is only half as efficient in sequestering CO_2. The other issue with considering carbonate minerals, rather than silicate, is that in acidic agricultural soils (which are more common in intensive systems) it can lead to negative CO_2 fluxes out into the atmosphere increasing carbon footprints, making silicate weathering more promising. Equally important is the understanding that reactions can occur that slow and inhibit this carbon storage aspect in field conditions, which have not been expansively enough researched. For example, the cations produced by weathering could bind to ion exchange surfaces or react to form other secondary minerals and never reach the ocean where the major sequestration benefits are suggested to occur.

What is also a worry are the impacts on eutrophication of aquatic systems, biosphere-atmosphere feedback, biodiversity and air, water and soil pollution impacts of long-term silicate dust applications as this is currently under-researched. Such aspects could play a significant role in the functionality of ecosystems so would need further study. Also, as with many particles of small size the finer the basalt dust used (<10µm) the more impact it will pose to human/animal health via wind transport and inhalation. This would likely be an issue in management scenarios with increased soil erosion such as high tillage (and other physical soil disturbances like heavy machinery use) and strategies which allowed the presence of repeated bare soil and a lack of substantial root/plant coverage year-round to aggregate soils, which in themselves also have negative impacts environmentally relating to emission profiles.

Whilst basalt is the main silicate mineral considered within this article and many research publications, silicate strategies would likely work most efficiently by utilising nearby locally sourced minerals. Equally, to achieve a suggested 2mm coverage require 40t/ha so to employ across all UK cropland would require >240 Million tonnes of silicates. This means a range of silicate minerals would need to come into consideration with different geochemical compositions which could lead to the release of different trace metals and other compounds into environments which may have different positive and negative effects that need researching. For example, it was noted that antimony and selenium leaching from demolition and construction wastes could lead to concentrations in the environment above the acceptable range for water quality standards. Such by-products and leachates would also have considerations on uptake via crops from soils and food safety which would need to be assessed further.

Summary

Silicate application onto both agricultural landscapes and other conservation/rewilded landscapes and forestry theoretically appears to have a lot of potential as a carbon capture tool. Silicates have suggested benefits to systems which incorporate plants (forests, arable and pastoral) as co-products released during the weathering process should improve plant growth and yields. Despite suggested benefits, there are many unknowns due to a lack of field-level experimentation with such strategies. As such efforts should be made to research potential off-target ecosystem implications before considering advising and incentivising landowners towards incorporating such strategies into their management considerations. Despite this, use of silica-based fertilisers in the US (and to a small extent in Europe) and equivalent issues of utilising lime applications on soil may be enough to make silicate application an alternative and alluring strategy.

BASICS BEST FOR HI-TECH WINE

Written by Mike Abram

Knowing basic infrastructural information about fields is a key requirement to unlocking technological progress for an Oxfordshire wine producer. Tech Farmer visits JoJo's vineyard.

CREDIT Mike Abram

Three simple words explain why Ian Beecher Jones, and his partner Tess, started the 2ha JoJo's vineyard that nestles on the chalky slopes of the Chiltern Hills, not far from Henley on Thames.

"We like wine," he says.

"It was as simple as that. We had a field, don't have any kids and thought this would be a jolly good idea to do for the next 20-30 years.

"And it still is, despite the trials, tribulations, traumas and costs."

It was what Ian considered a simple request post-planting in 2019 that led him down a route of actively seeking projects and partners that could improve the use of technology in vineyards.

"When we planted, the contractors were using a New Holland tractor equipped with an IntelliView IV monitor, they'd set up their RTK base station, so I was thinking this is wonderful," he explains. "The planter will be connected, and I'll be able to get a USB stick with data pinpointing where each and every vine had been planted.

"But when I asked for that USB, it was as if I was asking for meteorite from Mars because they had never been asked for vine position data before. No one saw any value in it."

The value in Ian's mind is that because a vineyard's infrastructure – the vines – are in the same place year after year, it lends itself to automation, for example. "But if I want to get a robot, drone or section control working in the vineyard, I need to know my infrastructure, where my rows are to then calculate where my mid-row is.

"Once I have that, I can navigate robots or tractors through that. Or if I'm using drones, I want to know where the mid-row zone is, the non-vine signal.

"In our vineyard, it's about 1.8m which is just grass or cover crop, and if you are looking at NDVI maps or satellite imagery, you have a huge amount of distortion from non-vine signal information. And that comes back to infrastructure. If you know where the row is, you can draw a polygon around it to give the mid-row area that can be cut out of the imagery being gathered."

Virtually all providers of precision agricultural services concentrate on the perceived high value data, such as sensing, scanning or agronomic information, he points out. "But first we need the fundamentals of the digital farm set up correctly.

The simple premise for JoJo's vineyard is that Ian Beecher Jones likes wine.

"We need our grower, farm and field information, our rows, which then turn into AB lines and our boundaries. From a viticulture point of view it's more complex than broad-acre agriculture as we have variety boundaries, root stock boundaries and clone boundaries all of which can be different.

"If we don't get this right, precision agriculture won't work," he says.

What is desperately needed is a simple mechanism for farmers to store their infrastructure data only, which would save huge amounts of time when setting up with service providers, such as robot or drone companies.

"People will say we have shape or ISO files to do that, but it is only part of the story. There's lots of other pieces of data that are important – telegraph poles, for example, from a safety point of view, footpaths, where gates are and toilets for contractors. There are not many software providers from an ag point of view record that information as it has no agronomic value."

Without it, each provider has to scan that information before starting which is a cost to somebody, as well as a time requirement. With it, a provider could deploy a robot in perhaps 15 minutes, he suggests.

"That means farmer engagement will be much higher because they're seeing deployment and results much faster."

It will also manage risk when using robots or autonomy on farm. "In the Regulatory Horizons Council white paper, the Regulation for the Fourth Industrial Revolution, one of the concerns is manging risk on farm. For me it's the farmer's responsibility to help manage that risk, not the tech company. The tech company uses the tools they have to practically reduce that risk.

"But if the robot provider doesn't know where a telegraph pole is, they always have to be guessing where an obstacle is. If I can digitally pinpoint

An EU-based i4Trust project helped Ian map all his vines and posts, using an RTK surveying tool to create a hyper-local GPS grid of the vineyard.

where my telegraph poles are for example, you can put an exclusion zone around the pole and feed it to the navigation planning software."

In the vineyard, an EU-based i4Trust project helped Ian map all his vines and posts, using an RTK surveying tool to create a hyper-local GPS grid of the vineyard.

"The attention to detail needed is much greater in this environment because of the consequences of getting it wrong. If you overlap a spray in a broadacre situation, it's inconvenient and not good practice, but you just lose some crop. Get accuracy wrong here from a steering point of view and I wipe out a row of vines that's thousands of pounds and at least three years' production."

The farm has been involved in a lot of projects (see box) since planting, but it's logistics where Ian sees, at least initially, the greatest opportunity for technology. "From an immediacy of engagement in tech, logistics in and around a site has a faster win than agronomy."

For example, removing prunings is, as Ian describes it, a nightmare job. These can be flailed and mulched, which is relatively quick, easy and inexpensive, but potentially leaves a disease source; they can baled and removed, or removed by gangs, he says.

Robotics could help with mowing grass between vines, for example. "FJ Dynamics have a self-propelled one which theoretically is able to do it, which we want to have a look at next year, while you could also pull a mower using a robot, such as the AgileX one we've got from Autodiscovery."

Other brands such as Husqvarna and Luba are also options. "Automating or reducing the management time means I can do other more skilled jobs."

Jobs such as carrying frost candles out, which protect vines against late frosts, are also suitable for transport using robots around the vineyard, particularly in wet weather when a tractor and trailer would cause more damage to the soil.

"It takes some of the grunt work out, and will be half the weight of a tractor and trailer."

Robotic harvesting, while being developed for soft fruits and vegetables, is likely to be more difficult with grapes, he reckons. "It's more difficult with bunches."

An EU-based i4Trust project helped Ian map all his vines and posts, using an RTK surveying tool to create a hyper-local GPS grid of the vineyard.

Theoretically, depending on system and use, a camera could also be mounted on the robot to gather agronomic data at the same time and not cost anything extra, he suggests.

"In spring we want to count the number of buds on the shoot, and how many burst. From there, we can start to predict yield, or identify whether a vine is underperforming and needs to be managed differently, for example pruned back further so it pushes all its energy through a lower number of shoots.

"But you can only do that with good imagery and by assigning it to an individual vine."

Generally, the issue with agronomic data currently is while it is relatively easy to acquire, acting upon it is much more difficult. "At the moment there aren't a lot of tools that actually help me do something with the data."

The main one is the sprayer but the risk-benefit is heavily skewed towards not taking chances because getting it wrong will have serious consequences, but he is looking at whether nutrition can be variably applied after realising this year that he had probably applied too much, increasing plant vigour at the expense of fruit production.

"Unfortunately not too many vine sprayers have controls to variably apply currently from a GPS point of view, so the first step I'm hoping to have is just automatic start and shut off at the start and end of rows. If we can do that, as we have in broadacre crops for 20 years, it will immediately save 10-15% of sprays," he concludes.

Ian reckons robotic harvesting, while being developed for soft fruits and vegetables, is likely to be more difficult with grapes.

While getting agronomic data is relatively easy to acquire, acting on it is much more difficult – getting it wrong with the sprayer would have serious consequences.

Photocopier technology could pave way for underground insights

A soil project using a mini-rhizotron, which effectively is similar technology to a photocopier scanner, could begin to help unravel some of the mystery of what happens underground, Ian says.

"You basically put a plastic tube in the ground containing the mini-rhizotron into the ground at a 45 degree angle, which the plant roots grow around.

"The rhizotron scans the roots 360 degrees to make a flat image, and because it is in the same place all the time you can compare root growth and mycorrhizal fungi activity around the roots.

"We're hopefully going to put 32 of these in the vineyard, and hopefully gain a real insight into what's going on in the soil."

It also potentially opens up the opportunity to look at various biological or biodynamic products in the soil to see the impact on microbial activity and root growth, or impact of various different cover crops, he says.

Technology being tested at JoJo's vineyard

- Node and cordon counting and yield forecasting with Bitwise Greenview
- Yield mapping with eVineyard
- Canopy density scanning with TopCon
- Coverage mapping with Trimble
- Vine health with DeepPlanet
- Robots with Autodiscovery and Antobot
- Mowing and logistics with Agile X (Autodiscovery) and Logic equipment
- Steering with New Holland & Trimble
- Weather station with Davis Instruments & Ladybird technology
- Soil moisture and leaf wetness with Davis Instruments
- Soil scanning with SOYL
- Direct drilling and biostimulant application with the home-made S-Rex drill
- Mini rhizotron with Reading University
- Agri-Epi Centre smart farm.

The ups and downs of making English wine

The first batch of wine from JoJo's was produced from grapes harvested in 2021. Unusually for a vineyard of this size, Ian decided to plant seven different varieties.

"Normally it's just the three – Pinot Noir, Minot Meunier and Chardonnay – that are used to make traditional sparkling. But we went for a broader selection because we like still wine, and didn't have the patience to wait an extra three years for the sparkling to come online."

In addition, the farm grows Pinot Precocé, which is an early ripening red to blend to produce a sparkling rosé wine, a Pinot Blanc that can be both added to sparkling wine blends and used by itself, Bacchus and Seyval Blanc.

"Usually those two, Bacchus and Seyval Blanc, are used on their own to make still white wines, but our winemaker put them together and made something really quite interesting, as people say, in a good way."

The blend even won a silver medal at the independent English Wine Award, he says. "The thing that's amazed me was the wine was bottled in June 2022, and we opened the first bottle in August, and it was acidic. It was nice but acidic.

"So we had to keep drinking it every month to see if had changed because it was our own wine. In December it was still quite acidic, but get to February 2023 and oh my god it changed – it totally softened out and the acidity disappeared."

That was down to something called bottle shock, he suspects. "They've been kept as two different varieties in four different vessels, some in a stainless steel tank, some in oak barrels. When they are blended together, you've almost got fighting inside the bottle between the different varieties and types and they have to learn to love each other," he explains.

"Once they're happy in each other's space and become friends that's when the softening out happens and how wine matures. We think this wine can probably stay in a bottle and improve for a couple of years."

The still white wine retails at around £20/bottle, with a profit margin of around £4/bottle. Taxation at £6.23/bottle is the largest chunk of cost, while growing costs are around £2.50/bottle, and processing £6/bottle.

Around 1700 bottles of that blend were produced from harvest 2021, with a similar amount of sparkling white and sparkling rosé, which will be ready to drink at the beginning of 2025. Last year's harvest produced similar bottle numbers, but the business is taking a different path with this year's harvest.

"The one thing we've learned is the amount of cash needed in this business is ridiculous, so we've had to reassess the way we do things. It's not until you're in business do you realise how much cash is tied up that's sitting in bottles as an asset."

That means this harvest's production will be limited to a sparkling white, with the remaining grapes sold to other producers to cover the cost of looking after the bottles for next two to three years.

The farm grows Pinot Precocé, an early ripening red to blend to produce a sparkling rosé wine, a Pinot Blanc that can be both added to sparkling wine blends and used by itself, Bacchus and Seyval Blanc.

BIOCHAR VENTURE WINS EQUITY INVESTMENT FUNDING

Climate Robotics has brought biochar production and use into focus, winning the AgSharks Pitch Competition in the US.

The first stage of any innovation in farming involves getting your projects funded. That makes them one step closer to commercial reality, although this is still no guarantee a product will make it to market. This is the aim of the AgSharks Pitch Competition, co-ordinated by US-based Western Growers and S2G Ventures. They have revealed Climate Robotics as the winner of the 2023 contest. The victory comes with a substantial equity investment offer of $250,000 from the panel of judges.

Climate Robotics has pioneered mobile biochar production systems for commercial agriculture. Biochar, a carbon-negative soil amendment derived from waste biomass, is credited as having substantial potential to address climate change. When applied to agricultural soils, biochar is claimed not only to enhance crop yield but also improve water and nutrient retention. The potential impact is substantial, with global biochar production capable of durably sequestering up to two billion tons of atmospheric CO2 in agricultural soils annually, alongside the generation of valuable carbon removal credits.

Climate Robotics have developed what they claim is the world's first automated, in-field biochar production system. The prototype trailed pyrolysis unit can process 10t/ha of grain maize crop residue into biochar, picking it up off the field and incorporating it into the soil in a single pass. What's more, they signed a deal with Microsoft who have agreed to buy the carbon credits that result.

Jason Aramburu, co-founder and CEO of Climate Robotics, expressed his excitement about winning the prestigious competition. "Biochar offers an immense opportunity to leverage existing resources to sequester billions of tons of CO2 on farms. We are grateful for events like these that help companies such as Climate Robotics scale their tech innovations to decarbonise the atmosphere and improve soil health."

In addition to the significant investment capital, Climate Robotics will receive mentoring from Western Growers (WG) and S2G, potential access to farm acreage for piloting their technologies, and exposure to WG's network of leading fresh produce companies.

Audre Kapacinskas, Principal at S2G Ventures, emphasised the importance of addressing real-world challenges through technology partnerships. “By working in partnership with Western Growers, we seek to accelerate the adoption of new technologies that can solve real-world problems and work in tandem with industry to ensure we are directing capital to its highest and best use."

The AgSharks competition is recognised as a pinnacle event during the Western Growers Annual Meeting, providing a platform for agri-tech innovators like Climate Robotics to showcase their solutions. , commented, “There is nothing like the pressure cooker of telling your story to hundreds of top produce industry leaders to prove you are ready to take your technology to market," said Walt Duflock, SVP of Innovation at Western Growers.

The two other finalists were:

1. Cultiva, who develop plant cuticle health technology and offer products like Parka and Kallur to protect specialty crops from environmental stresses.
2. Provision, a company simplifying compliance and data insights for growers through cloud software and streamlining paperwork.

s2gventures
a Builders Vision team

Biochar is a carbon-rich material produced through the process of pyrolysis, which involves heating organic biomass in the absence of oxygen. This results in a highly porous and stable form of charcoal. Biochar can be a valuable tool in farming due to its numerous claimed benefits for soil health, nutrient management, and overall agricultural sustainability. Here are several ways in which biochar can be used in farming:

1. Soil amendment:

- Improved soil structure: Biochar's porous structure is credited to improve soil aeration, water retention, and drainage. It enhances soil structure, making it more conducive to root growth.
- Increased water retention: Biochar's ability to retain water can be particularly beneficial in arid regions or during dry periods. This can reduce irrigation needs and help plants withstand drought conditions.

2. Nutrient retention and availability:

- Nutrient absorption: Biochar has a high cation exchange capacity (CEC), which means it can absorb and retain essential nutrients such as nitrogen, phosphorus, and potassium. This can prevent nutrient leaching, making these nutrients more available to plants.
- Slow release of nutrients: Biochar can act as a reservoir for nutrients, releasing them slowly over time. This helps provide a sustained supply of nutrients to plants, reducing the need for frequent fertilisation.

3. Carbon sequestration and climate change mitigation:

- Carbon storage: Biochar is believed to be a stable form of carbon that can persist in the soil for hundreds to thousands of years. Adding biochar to the soil can contribute to carbon sequestration, helping mitigate climate change by removing carbon dioxide from the atmosphere.
- Reduced greenhouse gas emissions: Biochar application may reduce emissions of greenhouse gases such as nitrous oxide from the soil, contributing to climate change mitigation.

4. Microbial activity and soil health:

- Microbial habitat: Biochar is thought to provide a habitat for beneficial soil microorganisms. It fosters the growth of mycorrhizal fungi and beneficial bacteria, which can enhance nutrient cycling and promote plant health.
- Reduction of pathogens: Biochar has been shown to suppress certain soilborne pathogens, helping to protect crops from diseases.

When using biochar in farming, it's important to consider the type of biochar, its source material, and the specific needs of the crops and soil. Proper application methods, such as incorporation into the soil, should be employed to maximise its benefits. Additionally, biochar application should be part of a comprehensive soil management strategy tailored to the local agricultural conditions.

FARMER FOCUS
CLIVE BAILYE

I last attended the Agritechnica show in Hanover, Germany in 2019. It was my inaugural visit, and the sheer scale of it all was unlike any agricultural machinery show I had ever seen. Some of the major exhibitors boasted stands almost as large as entire UK agricultural shows. After three days of covering several miles walking a day, I realised I had only scratched the surface of the sprawling event, with countless machines and brands previously unknown to me.

The immense scale of Agritechnica serves as a stark reminder to a UK farmer like myself of our relatively small and perhaps inconspicuous role in global food production. While wandering through the exhibits, I found myself puzzled by a machine whose purpose I couldn't fathom (it turned out to be a peanut harvester). It was a humbling experience that highlighted the vastness and complexity of global agriculture, revealing how much there is to learn.

During the 2019 show, one of the standout features for me was at the John Deere stand. They offered a glimpse of what the farm of the future might look like, featuring a "mission control" style operator seated at a "command hub," surrounded by monitors displaying data from various sources. They were in live communication with drones and other conceptual autonomous machinery carrying out crop-related tasks. Other manufacturers presented similar concept machinery, mostly smaller in size, envisioning a future where numerous compact machines would work 24/7 to revolutionise agriculture.

Agritechnica is a biennial event, and I vowed to return in 2021 to witness the progress in autonomous agriculture that I had eagerly anticipated. Unfortunately, the COVID-19 pandemic led to the cancellation of two shows, delaying my return by four years. I was eager to see how many of the concepts from my previous visit had become commercial realities and if the sharp-suited salesmen would be ready to take orders.

I scoured the halls of the major manufacturers in search of the production-ready versions of the drones and small

robots showcased before, but they were nowhere to be found. However, automation was still very much present and, to my surprise, now commercially available. The big industry players seemed to have chosen to focus on fully automating existing equipment, starting with their largest machines. This evolution, while logical, began when the first basic autosteer systems were added to tractors, raising questions about the future job security of operators. As these systems evolved, incorporating features like auto-turn and headland management, the addition of fail-safe and anti-collision systems made operator-free full automation a commercial reality.

Despite the discreet sensors and cameras that can be found upon close inspection, these smart tractors still closely resembled their non-autonomous counterparts, with cabs designed to accommodate operators still in place. While these machines were smart enough to work in the fields without constant human oversight, we hadn't reached the point where no human intervention was needed. Operators were still required to transport these tractors to the correct fields, assess field conditions, and "teach" the machine the desired routines across the field. Operators would receive alerts about blockages or obstructions via an app and would have to provide manual assistance in such cases, as well as handle tasks like refuelling and reloading seed and fertilizers. At best, the commercially available automation reduced the need for constant human attention but didn't entirely replace operators.

So, if operators were still necessary, where did the savings and increased efficiency in agriculture come from? The answer lay in how many machines a single operator could now manage. I met a Canadian farmer who had operated nine of John Deere's fully autonomous 8RX tractors in one season. A single operator had monitored and serviced these robotic machines, covering a vast area of cultivation work during the autumn. This efficiency significantly lowered the Canadian farmer's production costs.

While I should have been as excited as I was during my 2019 Agritechnica visit when I saw the smaller "future" machinery that could easily integrate into my UK farm business, this larger-scale automation left me feeling disadvantaged. It seemed that I couldn't compete profitably against such efficient imported competition.

Despite being a larger-than-average UK arable farm, justifying the use of even a single tractor the size of an 8RX remained challenging. Our average field size and logistical challenges meant that the time spent on calibration, loading, and getting to the field for planting, fertilising, or spraying often equalled the time spent doing the actual work. There simply seemed to be no suitable application for a large fleet of such massive robotic tractors in the UK, as there was in other parts of the world.

Even if logistics and topography allowed for it, current UK legislation prohibits machinery from operating untended. Furthermore, even if it were legal, and despite assurances of robust safety mechanisms, one would still question their peace of mind while a 500hp, 30t robot operated near a motorway, housing estate, or school. It became evident to me that the UK was not the primary target market for this type of autonomy by manufacturers.

So, does that mean we're at a disadvantage and exposed to import competition due to automation? Is our hope now pinned on the smaller robots initially showcased during my first Agritechnica visit? I inquired about them, but none of the major manufacturers were forthcoming with information. This led me to believe that perhaps, as these smaller robots approached commercial viability, secrecy surrounding intellectual property and patents might be the real reason for their conspicuous absence for this year's event? Maybe, eventually, UK farmers will gain access to the commercial reality of automation available in other countries. Perhaps, we'll find out at Agritechnica 2025.

MANUFACTURERS IN FOCUS...

Väderstad's director of tillage product management, Wolfram Hastolz, explains the thinking behind new developments on the company's TopDown and Opus cultivators.

If autonomy is to become the future of farming, implements will need to match the technology seen on the tractors that will be pulling them.

This is why Väderstad has introduced prescription map tillage and E-Services to the TopDown and Opus range.

The technology brings farmers a new generation of the Väderstad TopDown and Opus cultivators for 2024. In addition to an updated design, it puts the iPad-based control system E-Control on the two implements, as well as the ability to apply prescription map tillage via ISOBUS Task Control.

From model year 2024, the combination cultivator TopDown 400-700 and heavy cultivator Opus 400-700 can be equipped with gateway, sensors and updated electronics. These allow it to be operated via E-Control via an iPad, as well as through the tractor ISOBUS terminal.

The changes mean farmers can optimise the tillage operation by being able to tailor the machine setting to the conditions in the field. This is done through the use of prescription maps, to control the machine setting automatically on the go using a field map.

The farmer, before going to the field, can program how the individual working elements - discs, tines, levellers and packer - should behave at specific spots in the field based on for example soil type, or field characteristics. This prescription map is then inserted to the tractor ISOBUS terminal, which then will connect to the Väderstad E-Control system to take control of the machine.

This approach applies to tillage the same thinking on savings as we've seen before with variable rate application of seed and fertiliser – the rule of "as much as necessary, as little as possible". Some of the benefits come as diesel savings and improved soil health, others by the possibility to increase the working speed as well as reduce the wear. What's more, it enables an autonomous farming future.

But it's not just about autonomy. Using the iPad-based control system Väderstad E-Control, the operator will also be able to gain full control of the machine directly from the tractor cab. With a touch of a button, the driver can set the individual working depth or intensity of the discs, tines, levellers, or packer on the go. To assist the field work, four pre-set buttons can be used to store different machine configurations.

The control system is designed to support the driver to optimise the tillage operation, while also increasing the user experience. With the pre-set buttons the farmer can store their own most common machine configurations. For example, using pre-set 1 for standard field work, pre-set 2 for tramlines, pre- set 3 for tough areas, and so on. When one working zone is changed, the others will compensate automatically to keep their individual selected depth.

But field work can become hectic, and unexpected situations occur. When this happens, the TopDown and Opus can be quickly switched back to manual and traditional control, so the operator can take back command.

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