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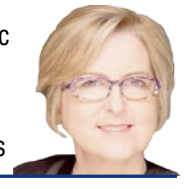

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Welcome to the February 2018 issue

Food is the subject of the magazine this month, as we examine emerging solutions to growing challenges in the global food system. By 2050 there will be almost 2.5 billion more mouths to feed and we will need to produce almost twice as much food as today.

Yet we cannot feed the numbers we have now with current agricultural practices, nor with the amount of food wasted and lost on the journey from farm to fork. And the impact of climate change, which has already caused Saudi Arabia to buy land in water-stressed California and Arizona will only worsen.

Angeli Mehta looks at how big data is revolutionising agriculture as Silicon Valley comes to the farm gate, with agri-tech start-ups offering technologies to allow food to be grown more efficiently and sustainably for companies such as Kellogg and Campbell's Soup.

She also looks at the firms, like AeroFarms and Plantagon, that are growing food in urban farms, using significantly less land and water, as well as innovations in alternative proteins for animals and in omega 3-rich alternatives to feed fish.

Eric Marx reports from Berlin on the apps that are helping smallholders in developing countries achieve optimal harvests, and asks whether agri-tech can sow a green revolution for India's poorest farmers.

We also look at another important solution to food security: the global effort to tackle food loss and waste through the multi-stakeholder Champions 12.3 platform. I interview Liz Goodwin, former CEO of the UK waste reduction charity WRAP, who now heads up the World Resources Institute's food loss and waste effort, while Diana Rojas reports from Washington on some of the companies, led by UK retailer Tesco, that are doing the most to tackle food waste throughout their supply chains.

Plenty of food for thought.

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Pastures new for big data

By Angeli Mehta

Angeli Mehta reports on how technology is revolutionising agriculture as Silicon Valley comes to the farm gate

Data is shaping almost every area of our lives. Agriculture has been slow to embrace new technology but even here it's beginning to have a big impact. There are now hundreds of companies offering everything from farm management and precision tools to bots and drones. Some tractors have computing power that would have turned Nasa's moon-landing mission green with envy.

What started in farm equipment is moving into the field – at least in the developed world. More and more data is available as farmers use sensors for soil sampling and mobile apps, cameras and drones to monitor pests and diseases. Data science teams are using satellite imagery married with historical records to predict crop yields around the world. A bounty of data for machine learning and image recognition has been supported by continual advances in computing power.

"I've lived Moore's law and that's happening here," remarks Dave Stangis, who spent 11 years at chip-maker Intel before moving to Campbell Soup Company.

It was Intel's co-founder Gordon Moore who, in 1965, predicted a doubling of computer processing power every two years.

To be more productive, farmers need technology to help them make timely decisions. "It's easy to forget that farmers get one, maybe two chances a year to get it right," says Diane Holdorf, chief sustainability officer at food manufacturer Kellogg. Indeed their livelihoods depend on it.

Some tractors have computing power that would once have turned NASA green with envy

Investment in technology is big business. According to AgFunder, an equity crowd-funding platform, agri-tech start-ups raised $4.4bn globally in the first half of last year; 21% of that in Europe. Among them is Lille-based Sencrop, whose rain and wind gauges keep track of temperature, humidity, rainfall and wind in the fields. Overlaid with current and historical climate data, its systems allow farmers to make decisions about irrigation and seeding – even anticipating disease, all from their smart phones.

One of the biggest deals in recent years was Monsanto's acquisition of The Climate Corporation. This California-based firm started out selling insurance against extreme weather events, and not surprisingly farmers were among its customers. Now it gathers data from sensors and satellites to analyse soil organic matter and nutrients, and monitor crop yields and local weather patterns, to help farmers get the best out of the soil, water, fertilisers, pesticides, and seeds they use.

As its chief science officer Sam Eathington put it in a company blog last month: "Silicon Valley has moved to the Midwest and is at the farmgate."

Monsanto, itself a pioneer in biotechnology, is moving rapidly into data sciences.

Chief executive Robert Fraley sees advances in both driving the "sustainable intensification" of agriculture around the world, getting more out of existing agricultural land and improving the environment.

The Climate Corporation has plenty of competition. Tractor giant John Deere, cooperative network Land O'Lakes and seed producer DuPont Pioneer all offer equipment, software tools and services for field management. The Sustain platform – originally developed by United Suppliers and the Environmental Defence Fund – has a suite of "precision conservation tools" to improve soil health and better manage water and nutrients.

Data monitoring on the farm enables them to show retailers, and in turn consumers, what has been achieved. Farmers who grow crops for Campbell Soup and Kellogg, for example, are involved in the programme.

30 SECOND READ

- Investment in technology is big business. Agri-tech start-ups raised $4.4bn globally in the first half of 2017.
- Data sciences, such as weed identification and climate prediction, are providing valuable data from grower to manufacturer.
- Precision tools can target specific plants with water and fertilisers. Herbicide use, a major pollutant, could be cut by around 90%.
- The OpenAg Data alliance is working towards open standards software because currently the various systems being developed don't talk to each other.
- Facial recognition software for cattle and pigs could transform health monitoring. In laboratory simulations they cut antibiotic use.
- Robots can free farm workers for more specialised jobs – and fill the gaps in labour shortages. Robotic harvesting needs to work with genetics to make certain crops easier to harvest mechanically
- Blockchain can make food supply chains more transparent and increase consumer confidence

One of the largest of the world's 'dead zones' is in the Gulf of Mexico, where half of US seafood is caught

John Deere's equipment can precisely control seeding densities, determined by detailed data on conditions across a field. Crop yields can be measured as grain flows into a harvester and in conjunction with GPS data, used to map productivity in minute detail.

Last autumn, the tractor firm bought a California start-up that uses machine vision and artificial intelligence (AI) to detect weeds and deliver a targeted dose of herbicide to each weed. Blue River Technology's See & Spray system of cameras and computers is towed behind a tractor and cuts herbicide use by around 90%, compared with spraying a whole field.

The company's first machine was a lettuce bot, now being used by growers to weed and thin young lettuce plants.

See & Spray uses similar algorithms to those in facial recognition software, and is "trained" on tens of thousands of images to distinguish weed from crop. It makes 5,000 decisions each minute, and has an accuracy to within 63mm, according to business development director Ben Chostner.

CB INSIGHTS

Agriculture has been slow to embrace technology, but that is changing fast

He told a conference audience last year that the data collected while spraying produces mapping for every field so farmers can compare weed pressures over time, and in different parts of a field.

A week later a drone surveys the field to check the weeds have been removed. That learning goes back into the system. Blue River Technology is also working on soybeans, chickpeas, corn and peppers, and anticipates farmers being able to use it to spray fungicides and fertiliser as required across a field.

'You have to be part of a community of farmers to afford access to the data. How can that be made available at a small scale?'

Trouble with fertilisers

Means to cut fertilisers use are urgently needed. In the UK, farming is the most significant source of water pollution and of ammonia emissions into the air, both of which harm ecosystems. The picture is similar in the US and China. The bulk of nitrogen and phosphorous in fertilisers doesn't get taken up by

plants, but makes its way to the sea, where it disrupts ecosystems by triggering algal blooms. These choke off oxygen, killing marine life. One of the largest of the world's "dead zones" is in the Gulf of Mexico where almost half of US seafood is caught.

The precision application of fertilisers and pesticides is transformational, observes Holdorf of Kellogg. The caveat, she adds, is that "you have to be a community of farmers to co-invest to access the data today. The question is how does that data get to be made available at a small-scale level?"

The myriad of systems available now are all measuring slightly different things, and don't yet talk to one another. The OpenAg Data Alliance is working towards open standards software, which would help give farmers all the information they need. After all, information is power.

Stangis, at Campbell Soup, thinks there will be consolidation in the industry and that there will be a platform around analytics, like a Facebook or Amazon.

Alexandra Brand, chief sustainability officer at agrichemicals and seed producer Syngenta, suggests cheaper drones will be a huge driver of productivity for the small farmer. A drone taking pictures of the condition of plants and field will help farmers determine if the soil is dry or whether insect pests are gathering.

CAMPBELL SOUP

'Moore's law is happening here' – David Stangis of Campbell Soup

Syngenta's data efforts are further forward in the US than anywhere else. It collects data from farmers including tilling, soil condition, water use, and fertilisers. When aggregated intelligently, the data provides feedback on sustainability – for example how much carbon is being sequestered.

It is working with the AI for Good Foundation on food security. One project is using algorithms to predict how seeds will behave in different soil types. "A seed is like a child," says Brand. "The soil is the environment in which it starts its life." If the soil is too hard the roots can't penetrate; if it's acidic the seed will need protection.

While Campbell Soup doesn't own any farms, it is investing in metrics and considering what data to collect from growers. One example is tomatoes. It's

Scientists are working on understanding how gut microbes and selective breeding might cut methane emissions from cattle

starting to collect analytics from its growers around fruit quality (as determined by solids and sugars) and water use. Every trailer is sampled and, based on quality, they're called into the plant. All the data is analysed and shared back so an individual farmer can see how he compares and what improvements he could make. More of its farmers are converting to drip irrigation, which works underground to release water at the crop roots. "We've seen some great improvements across the board and water use has gone down," says Stangis.

BLUE RIVER TECHNOLOGY

Blue River Technology's system cuts herbicide use by 90%

More sustainable livestock?

Facial recognition software for cattle and pigs sounds like science fiction, but it could transform livestock health monitoring, whether it's keeping an eye on animals about to give birth or spotting early signs of ill health. Irish firm Cainthus has developed a system that can identify cows that are not eating, or are behaving aggressively.

German-based Evonik Nutrition & Care is working on proof of concept with a large US poultry producer to demonstrate on the farm what has been possible in its laboratory simulations of a chicken's gut. The aim is to cut antibiotic use, saving them only for when disease is real. Scientists at SRUC in Scotland, meanwhile, are working on understanding how gut microbes and selective breeding might cut methane emissions from belching cattle.

Robots on the farm

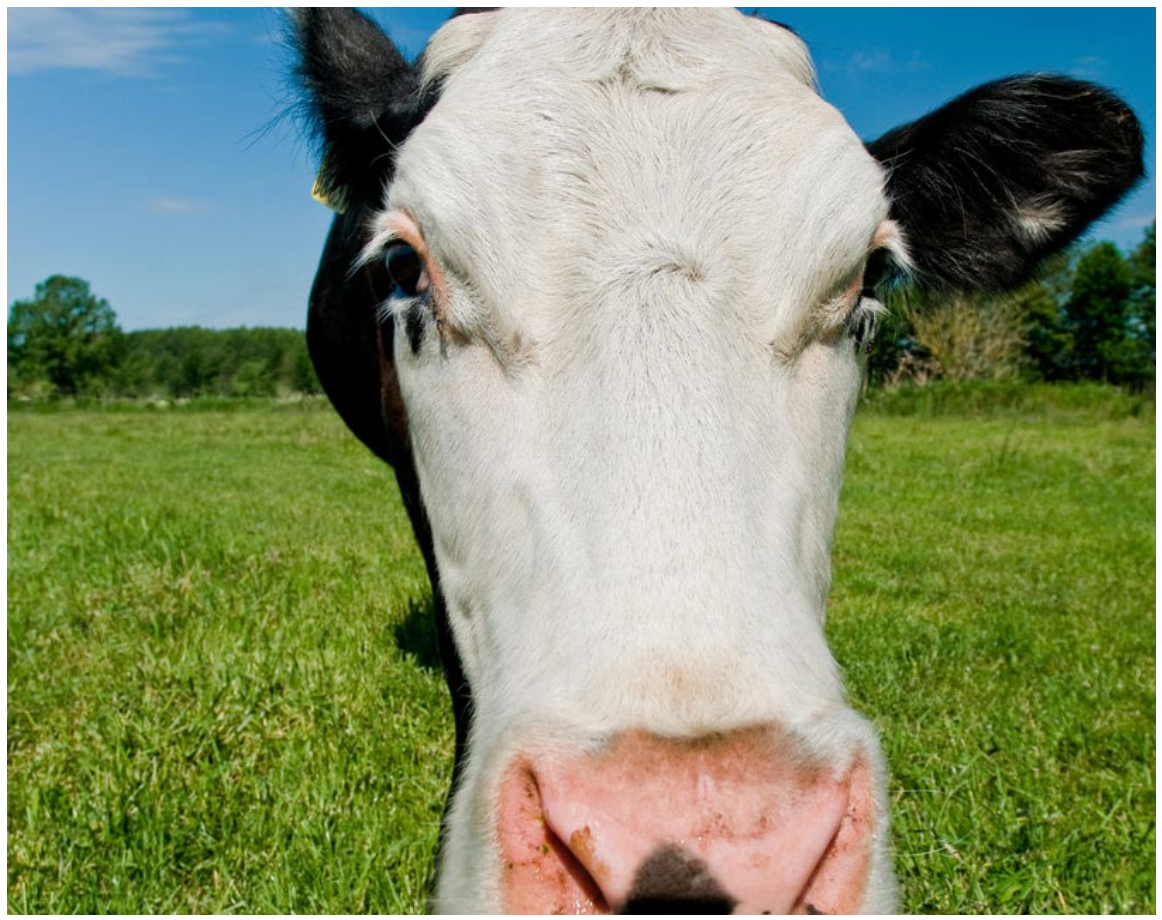
The massive dairy herds maintained in Saudi Arabia are all micro-chipped and data is regularly sampled to try to identify health issues before symptoms actually occur. Robots are appearing in US dairy farms, and improving milk yields.

Besides potentially freeing farm workers from some of the most back-breaking work, there are economic and political drivers. The availability of migrant labour in the UK is in question through Brexit and there are labour shortages in California thanks to a clampdown on undocumented migrants who pick the state's soft fruit and lettuces. On the other side of the globe, China is striving for self-sufficiency in food production while in Japan a lack of inward migration and an ageing population are pushing innovation forward.

China is striving for self-sufficiency in food production, but consumers have become concerned about the provenance of food

Simon Pearson, director of the Lincoln Institute of Agri-food Technology, believes robotics technology is still developing. “We’re two to three years off really effective robotic harvesting anywhere in the world,” he says. Backed by Innovate UK funding, his team built a broccoli-harvesting system, which it trained to distinguish between weeds and plant; head and leaves.

A follow-on project produced a robot prototype that was successfully tested last year. He argues robotics alone will not be the solution: genetics will be needed to identify traits that make a broccoli head better designed for cropping. Tomatoes and mushrooms could be feasible, but fruit is a far tougher challenge. The proof of concept, he says, is done but processing needs to be faster. “There are a heap of challenges to go from 30 seconds [each fruit] to two.”



MAHEY/SHUTTERSTOCK

Facial recognition software for livestock could transform health monitoring

The Hands Free Hectare project, led by UK-based Precision Decisions and Harper Adams University, successfully grew barley from seed to harvest without a human in the field. Moreover, the team used only off-the-shelf technology and open source software. Now it’s trying to improve the accuracy of the machinery to get a better yield this year, with winter wheat, and has been exploring applications in India.

The Hands Free Hectare project grew barley from seed to harvest without a human in the field

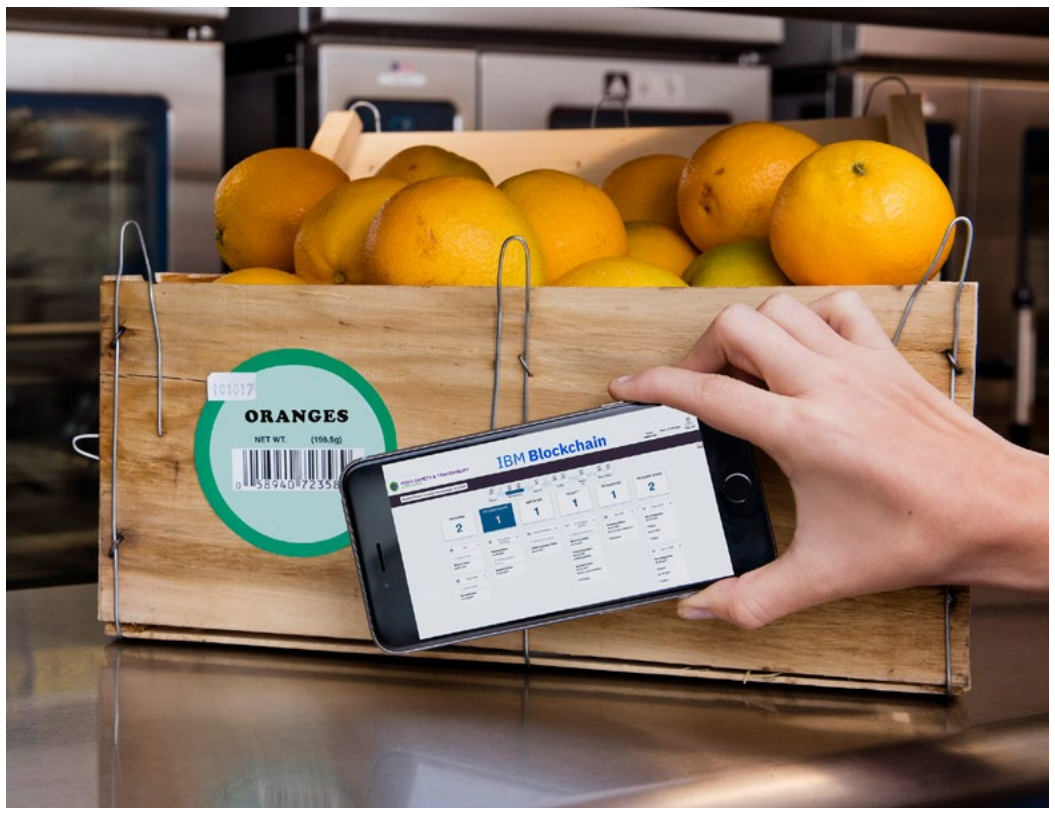
Blockchain

If big data can make farming more sustainable, consumers could help drive that revolution with a better understanding of where their food comes from. The key to unlocking that challenge may lie with blockchain, most often associated with cryptocurrencies like bitcoin. It’s essentially a means to digitally store and share information about every link in a chain in real time, and the information is kept in perpetuity.

“Blockchain enables data verification through consensus and provenance. By using blockchain, organisations and individuals can attain greater confidence in data on the ledger because consensus of all parties is required for that data to be added, and provenance ensures that the existence of data

can be traced back to its source," according to Don Thibeau, offering manager for IBM Blockchain.

Last August, IBM announced a collaboration with a group of food suppliers, including Walmart, Unilever and Nestlé, with the aim of strengthening consumer confidence in the global supply chain. Walmart ran two pilots, one with mango, to see how long it would take to trace back through the supply chain to find the farm where the mango originated. Without blockchain, the exercise took almost a week. Using blockchain, it took about two seconds.



IBM

Blockchain can help consumers understand where food comes from

Such speed will transform the detection of the source in an outbreak of food poisoning, but Walmart's vice-president for food safety, Frank Yiannas, says a big driver is transparency. Consumers will be able to discover immediately how an item of food is produced, and whether it is sustainably grown.

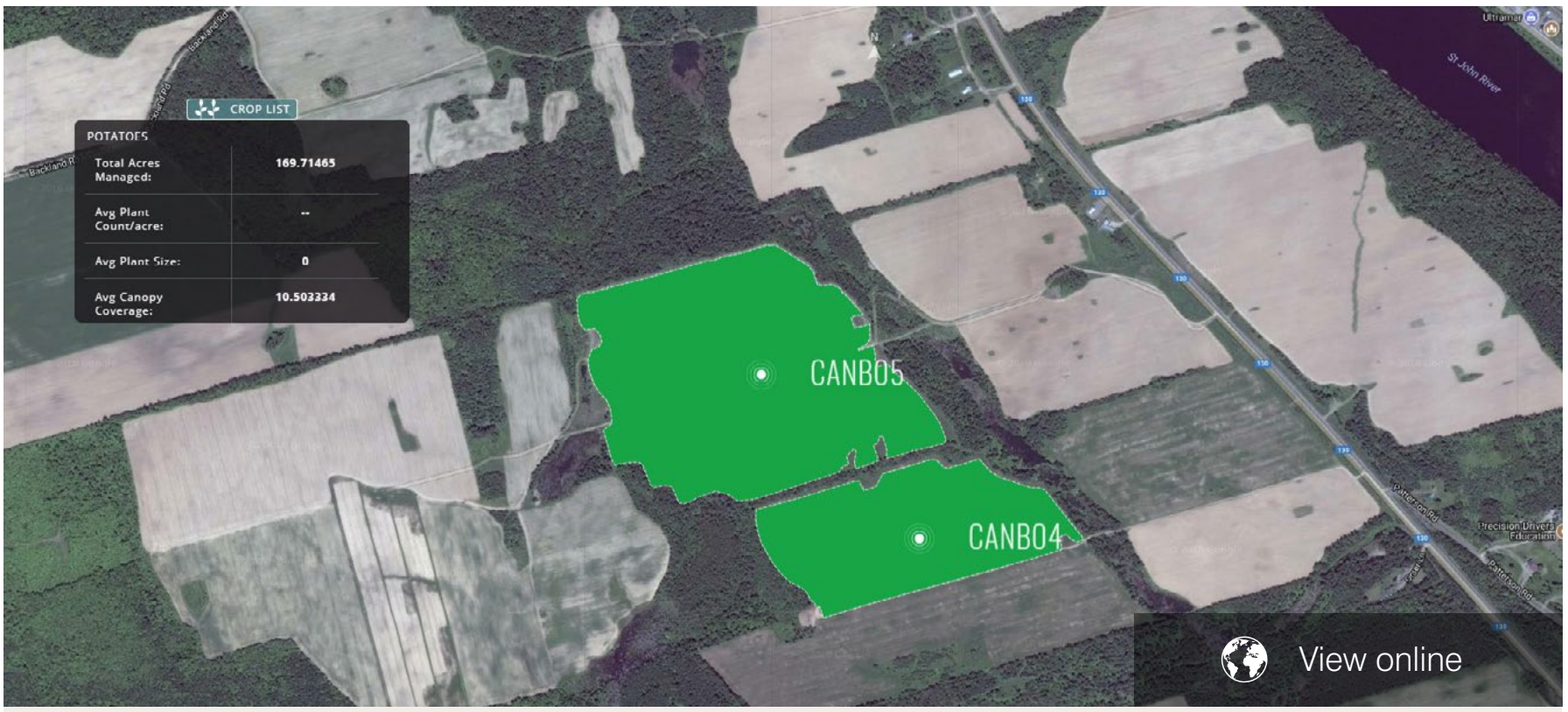
Walmart and IBM followed up in December with an announcement that they'd work with Beijing's Tsinghua University on food tracking, traceability and safety in China. The Chinese government is striving for self-sufficiency in food production, but consumers have become concerned about the provenance and safety of food. Although clearly, China doesn't have a monopoly on food scandals.

Sepehr Mousavi, sustainability strategist at Sweden's vertical farming pioneer Plantagon (See: From vertical farms to new proteins) wants to build a blockchain model that shows a consumer nutritional information, and precisely how far a product has travelled. He hopes consumers will be able to scan one of Plantagon's leafy greens to discover who harvested it, and how old it is.

Holdorf of Kellogg suggests it's still early days in terms of how blockchain is being applied to track fresh fruit and vegetables, where there is "a clear line of sight" from field to store. But she ponders that it might also provide a tool for increasing the transparency of grains, where a grain store takes the input of many farms. And it works the other way too: "A lot of farmers like to know how their crop connects to food."

Kellogg has made some big commitments to responsibly sourcing 10 priority ingredients by 2020, and to support climate smart agriculture. With blockchain, its customers may just be able to hold it to account. ■

Angeli Mehta is a former BBC current affairs producer, with a research PhD. She now writes about science, and has a particular interest in the environment and sustainability. @AngeliMehta



RESSON

How big data is transforming the humble potato

"We're going from precision agriculture to decision agriculture. And we're trying to drive that revolution," states Giri Baleri, VP for marketing at Resson, a university spin out from New Brunswick in Canada. Resson uses imagery combined with farm data to provide a range of analytics to growers.

One goal, he explains, is to detect issues like disease and pests, and preferably before they arrive.

Resson has been working with potato chip producer McCain to improve its growers' harvests. Thanks to machine learning, its systems can diagnose the presence of viruses and pests, such as the beetles that eat potato foliage and so dent crop quality. This year it will have a limited commercial roll out with potato farmers across more than 10,000 acres in eight different geographies, and separately with a spinach grower in Arizona.

Water is also a target. "Often there's no rain during an entire summer when plants are growing and ripening, so you have no option but to pump water, which costs money both for energy management and water rights," says Baleri.

Resson has been working with potato growers in the US and Canada, and in California's Salinas Valley on a moisture assessment module for their valuable baby spinach and soft fruits crops. Thermal imagery gives a relative water index across a field, which can be correlated with soil moisture readings. Trials with tomato crops are about to begin.

The company has almost 50 people working in engineering and image analytics. Image collection costs are coming down all the time, especially with drones, says Baleri. The data itself provides valuable opportunities for research and development. Analytics costs vary but Baleri argues that $20-30 an acre for a crop value of over $1,000 an acre is a small price if they deliver an 8-10% increase in yield. On top of that, avoiding the application of fertiliser across an entire field can cut costs by more than 50%.

Angeli Mehta

AEROFARMS

From vertical farms to new proteins: innovating to feed the planet

By Angeli Mehta

Angeli Mehta reports on emerging technologies tackling the threats to food security from diminishing biodiversity, climate change and population growth

We have a problem. By 2050 there will be almost two-and-a-half billion more mouths to feed on planet Earth. To sustain them, we need to produce almost twice as much food as we do now.

Irrigation has been a big contributor to increasing yields, but the challenge of a changing climate means water will not be available where it is needed most.

And farming is itself a big contributor to climate change, generating some 14.5% of global greenhouse gas emissions.

A burgeoning agricultural sector in the developed world has led to diminishing biodiversity, deforestation, soil and water contamination, and air pollution, while elsewhere subsidence farming denies food security to billions. How can we produce more from our agricultural systems – and produce it sustainably?

“There’s a tremendous urgency around connecting the challenges of human health and planetary health and having a really sustainable food system,” says Diane Holdorf, chief sustainability officer at Kellogg.

“The swirl of risk is going to be coming quickly; there’s a lot of work to be done. It’s going to impact everyone even if this is not the sector you work in.”

‘There’s a tremendous urgency around connecting the challenges of human health and planetary health’

"Speed is of the essence," agrees Brande Wulff, project leader for crop genetics at the UK's John Innes Centre in Norwich. Staff there, he says, are "working in a race against time to … develop crops better equipped for tomorrow's climate and more sustainable to grow."

The challenge cannot be underestimated, he contends, even here in the UK. That's because we grow a lot less of our own food than we did 30 years ago, making us vulnerable both economically and politically.

With climate change, much of the breeding is just to stand still. "If you take a cultivar [plant variety cultivated by selective breeding] from just a few years ago, the conditions have changed so much it would likely produce less."

It is not just agricultural researchers who are focused on cracking this issue. According to equity crowd-funding platform AgFunder, agri-tech start-ups raised $4.4bn globally in the first half of last year; 21% of that in Europe. (See: Pastures new for big data)

30 SECOND READ

- By 2050 there will be almost two-and-a-half billion more mouths to feed, but existing agricultural challenges and growing demand for protein mean there is an urgent need to create more sustainable food systems.
- Vertical farms help cut land and water use, transportation emissions and storage costs. Sky Greens, in Singapore, is growing plants in rotating troughs using water-powered hydraulics and recycling water and soil.
- Vertical farming pioneer AeroFarms, in New Jersey, has taken advantage of low energy-consuming LEDs as well as using closed-loop systems to recycle water and nutrients and reduce waste. The farms also offer community benefits and employment opportunities.
- Meeting an increasing demand for animal protein means diverting more land for livestock feed. Evonik, part of sustainable business platform Forum for the Future, has developed amino acids that build proteins in animal crops, helping to free up arable land.
- French firm Ynsect is growing mealworms to produce fish feed. Results suggest the insects create healthier fish, and by-products, such as fertiliser, help increase crop yields.

Urban farming

One focus of investment is in urban farming. Siting farms in urban centres cuts at a stroke land and water use, slashes transportation emissions and storage costs. Singapore-based Sky Greens has come up with a water-powered hydraulic system to rotate tiers of growing troughs hung on a 9m-high frame, so plants get equal shares of light and nutrients. Water and soil are recycled and re-used.

In the northern hemisphere, vertical farming is made possible by LEDs (light emitting diodes), which use far less energy than sodium lamps and, crucially, produce light in the wavelengths plants need to produce their own food through photosynthesis.

Growers like New Jersey-based AeroFarms have created recipes of wavelength and intensity to get the most out of their crops of baby leaves, and to cut energy use further. Thanks to closed-loop recycling, the company says it

uses just 5% of the water that would be needed in the field. The plants aren't grown in water or soil, but rather misted with ideal quantities of water, nutrients and oxygen, called aeroponics.

No pesticide is required. Seeds are germinated and grown on a reusable cloth made from post-consumer recycled plastic. It's a highly controlled operation: AeroFarms monitors 130,000 data points for every harvest for continual fine-tuning. Founder and chief executive David Rosenberg describes the business as a data sciences company as much as a farming one.

AEROFARMS

AeroFarms' vertical farms cut land and water use

In Stockholm, Plantagon has used crowd funding to help finance the imminent opening in April, of its first city farm in an underground room that once housed newspaper archives. Its green produce is already reserved by Sweden's largest retail chain ICA for its store just 800m away.

Despite using renewables, the operation is still energy-intensive. Plantagon aims to recover all the heat from the LEDs and send that to the host building in winter, or use it to warm the water in summer. Water use is minimal: a kilogram of lettuce grown outside would use 250 litres of water, explains sustainability strategist Sepehr Mousavi. Plantagon uses on average 1.2 litres.

The ultimate aim is to have a negative carbon footprint. As at AeroFarms, a huge research effort has gone into creating the optimal environment for growing, providing just the right nutrients to ensure yield and taste. Again sensors and big data are key.

The company had hoped by now to have built a hi-tech demonstration facility further south in Linköping, but it was held up for two years by campaigners concerned that migratory birds might fly into the glass walls. What they learnt during the hiatus has been invaluable. "You need a real estate owner and a retailer," explains Mousavi. "They [the real estate owner] want to know how much money they will make and will it help my sustainability?" The next lesson was having control of the value chain. The big issue is not the growing, but logistics. "You need to shorten the chain from seven to nine actors, to just one or even zero."

'The big issue is not the growing, but logistics. You need to shorten the chain from seven actors to one, or even zero'

Both companies have a wider social purpose. AeroFarms is contributing to urban regeneration, trying to inspire a local population about the technology on their doorstep, and providing employment to those locals and to ex-offenders. A mini farm in a Newark school has given students a connection to their food, explains Rosenberg, and it's changed eating habits there.

Plantagon is providing work opportunities for people with disabilities, who find it had to get employment.

Because Plantagon uses pumice, rather than soil, as a growing medium it can't achieve organic status. So it is focusing effort on developing a certification system and a means of demonstrating provenance and nutrition.

While LED technology is enabling indoor farming, it could also be used to speed up plant breeding. Going from one generation of seed to the next takes time, which is why Wulff at the John Innes Centre and his collaborators in Australia started to experiment with "speed breeding".

With each generation of a crop, breeders try to improve wanted traits like resilience to drought and remove unwanted ones like susceptibility to disease. So Wulff is using light to trick plants into staying awake for up to 22 hours a day, and has been rewarded with six generations of wheat in a year as opposed to just two or three. Such research could also have an impact on vertical farms.

PLANTAGON/SWECO

Plantagon's projected high-tech 'plantscraper'

The crops still have to be proven in the field, but Wulff hopes to walk into a field in 10 years' time and see newer and better crops produced with the help of speed breeding. "These are exciting times" says Mousavi of Plantagon. "To meet global sustainable development goals, we need to start somewhere."

Competing demands

The world's population is also becoming more affluent, which suggests we'll spend more of our income on protein. In the US and Europe, we eat more protein than we need. Indeed, the UN's Food and Agriculture Organisation

'Saudi dairies are buying land in California and Arizona to grow hay that will be shipped back home'

BY KRUMANOP/SHUTTERSTOCK

More than 70% of food for pigs and chickens could feed humans

expects the daily diet of a 2050 Earth inhabitant will contain more protein and vegetable oils than it does today. At the moment, the most efficient way to get it is by farming animals and fish.

A third of global agricultural land is used for livestock feed production, according to Forum for the Future, a non-profit organisation that tackles sustainable development. Almost all water used in animal production (98%) goes into the feed crops, while more than a fifth of wild fish that are caught go into feed.

One example of the competing pressures comes from Saudi Arabia, where its large and highly automated dairy industry has contributed to a depletion of the country's water reserves.

In response, the Saudi government has cut domestic production of forage, which means millions of tonnes will have to be imported. As a result, Saudi dairies are buying land in California and Arizona – both with their own water supply issues – to grow hay that will be shipped back home.

"It's almost impossible to compare different feeds," says Simon Billing, who leads Forum's work on proteins. Moreover, he says, "promising solutions are at very small scale..... and there's very little good practice to point to." Working with a range of companies in the food supply chain, Forum is developing a sustainability assessment tool to help the industry compare different types of feed that will guide purchasing decisions.

While chickens and pigs produce more meat (and hence more protein) than cows and sheep, more than 70% of their diet could be consumed by humans, explains Thomas Kaufmann, head of sustainability development at Evonik Nutrition & Care, one of the companies working with Forum for the Future.

Evonik is developing the vital amino acids that build proteins in crops for animal feed

Soy bean provides ideal animal nutrition, but it's a major driver of deforestation in the Amazon basin.

"The overarching need is to move from soy bean to locally produced feed as 40-50 years ago," says Kaufmann. Billing thinks that is, in part, an issue for government, although there is no real policy on feed anywhere in the world: "It's a big beast that won't restructure overnight … but we do need to be starting now.."

YNSECT

Shrimp and salmon fed on mealworm protein are more resilient to bacteria

Evonik's approach is to develop the vital amino acids that build proteins in crops consumed by animals. Using these as a feed supplement frees up arable land for other crops: its estimates suggest that their use today is freeing up 11.6m hectares of land, roughly the size of Ohio or Malawi. They can also be produced closer to home.

"This is, for us, a business decision, as well as an environmental one," says Kaufmann of Evonik. "In the past [a growing demand for protein] was good for business – but we have to change."

There are other solutions for feeding animals and fish. French firm Ynsect has a demonstration plant near Dole where mealworms, larval forms of the mealworm beetle, are grown to produce fish feed, with some unexpected benefits.

Initial trials suggest farmed shrimp nourished with Ynsect's protein meal had much better resistance to pathogenic bacteria, while in farmed salmon mortality during the stressful transition from fresh water to sea water was lower.

Chief executive Antoine Hubert has theories for the underlying mechanisms, but these need more research. Given that animals and fish eat insects in the wild, they are perhaps well adapted to them.

Ynsect is not wasting any part of the creatures bred on its farms, producing protein, oil and fertiliser as well as chitosan, a sugar that comes from the larvae's protective exterior and has anti-microbial properties.

Ynsect's fertiliser is being put through its paces now. A crop of rapeseed sown in September had – by December – grown three times as big as rapeseed treated with chemical fertilisers. Hubert says his firm hopes to start building a commercial production facility next year. ■

Angeli Mehta is a former BBC current affairs producer, with a research PhD. She now writes about science, and has a particular interest in the environment and sustainability. @AngeliMehta

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