october 2017

cropproduction magazine cpm

best read specialist arable journal*

In this issue...

Machinery
Innovation Insight

The tool that twins science with sense

True agricultural innovation is where data derived from the field is used to make a reliable agronomic decision with no human input. In the fourth of our series on data management pioneers, *CPM* tells the story of the N-Sensor.

By Tom Allen-Stevens

There are two aspects, you could argue, that define the real cutting-edge technological advances in today's agricultural equipment — tools that generate vast arrays of utilisable data, and kit that has the capability to use this information and make decisions in real time that are even better than those made by a skilled operator or agronomist.

But there's one tool that's been combining both these aspects for almost 20 years — Yara's N-Sensor.

"The N-Sensor sets the fundamental benchmark for measuring nitrogen uptake by a crop," says Clive Blacker of Precision Decisions, who's worked with the technology since it first came to the UK. "The primary determinant of the correct amount of N to apply is how much is already in the canopy — if you don't know that, how can you judge how much to put on?"

The N-Sensor first came to the UK in 1999 — a "coffin"-shaped box that sat on top of the tractor cab. Its design and capabilities have moved on considerably since then, but the hardware is essentially

The N-Sensor that first came to the UK in 1999 was a "coffin"-shaped box that sat on top of the tractor cab.

"It's the algorithms within the software that make the N-Sensor what it is."

the same — two sensors scan a 3m strip on either side, sending information on light reflectance from the crop to an on-board computer in the cab.

Here the data's crunched, and this is where the magic happens — light reflectance, measuring specific wavelengths, reveals accurate information on how much N is held by the crop canopy. The software not only generates a point-in-time map of canopy variance across the field, but uses the information to generate fertiliser recommendations in real time. These are transferred to the control terminal of a variable-rate enabled fertiliser spreader or sprayer.

"The hardware is almost irrelevant," comments Yara's Mark Tucker, who joined the company in 2002 to develop the N-Sensor's application. "It's the algorithms within the software that make the N-Sensor what it is.

"The trials work to generate these algorithms in the first place were immense, and the testing we've done since to ground-truth everything has been equally thorough. Yara has almost been too cautious with it, and has insisted everything is so rigorously tested before its commercial release that it's been a bit of constraint, especially in a digital world where technology advances so fast. But the scientific rigour has always paid off in terms of performance and reliability, and it's even given the N-Sensor regulatory clout."

Forefront of technology

By the mid-1990s, Yara was already at the forefront of technology that could accurately measure the N status of a crop and launched the N-Tester in 1995. This hand-held tool operates by measuring the chlorophyll content of the leaf. A year earlier, physicist Dr Stefan Reusch had started a PhD at the University of Kiel in Germany to study optical methods to assess N status.

"There was a group in the scientific community who were keen to address variability in the field," recalls Stefan. "The aim was not only to measure both visible and non-visible variation, but react on it."

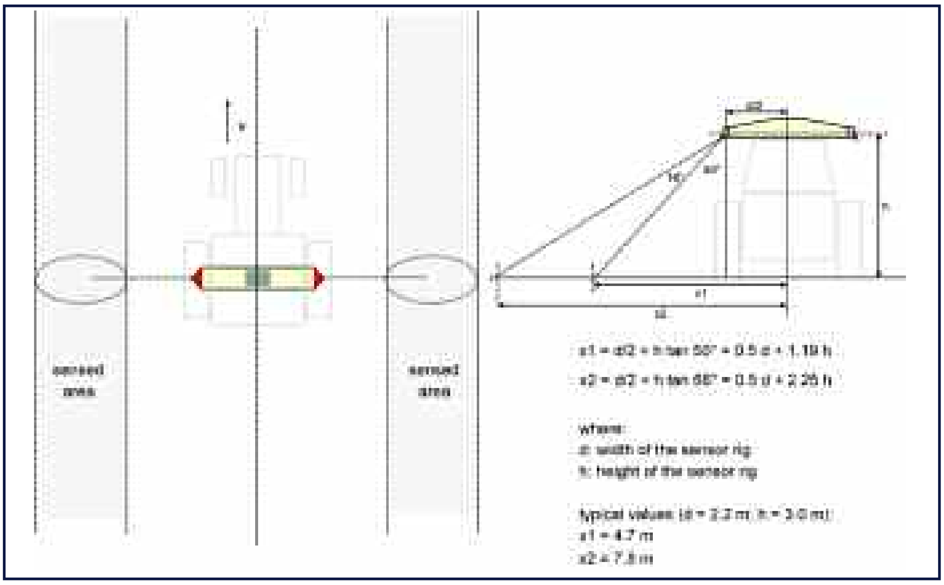
The concept was in its infancy, however, and the influence of soil conditions and topography, that also vary spatially, make it a complex area. "There was very little applied science addressing in-field variability. Most related to satellite imagery

Immense scientific rigour went into developing the N-Sensor, notes Mark Tucker, which has paid off in terms of performance and reliability.

measuring light reflectance from the crop canopy, using instruments within the crop to ground-truth data. The science was good, but I wanted to improve it."

The standard measurement of crop biomass is the Normalised Difference Vegetation Index (NDVI), which is a measure of the red and near infra-red wavelengths of light reflected by a crop canopy. "I found the index could be ►

The first prototypes involved a large boom, that worked, but wasn't practical...



... So tractor-mounted was deemed the best solution to gather data, and the sensors were put on the roof, angling them so they had an oblique view of the crop.

▸ optimised by looking at slightly different wavelengths," he notes.

It took a systematic search through millions of indices before he finally figured out the wavelengths and the mathematical relationship that provided the best correlation. "The project ended in 1997, the work was published and I presented it at conferences. Yara had been bringing along the N-Tester at the same time, and I had the opportunity to work with them in the final year."

The first challenge was to develop the hardware to house the sensors. Tractor-mounted was deemed the best solution to gather data as there's no time delay between scanning the crop and receiving data, as there is with satellite imagery. What's more, it needs no ground-truthing and crops can be scanned on cloudy days when satellites can't scan the earth's surface.

The first prototype was a front-mounted, W-shaped boom. A year later, the second prototype looked more like a sprayer boom. "They worked but they weren't practical," notes Stefan. "We needed a housing that was ruggedised and easy to maintain. So we tried putting the sensors on the roof, angling them so they had an oblique view of the crop. This wasn't straightforward because they're affected by the sun's position."

An irradiance sensor was also fitted to scan ambient light and correct any changes caused by differing levels of sunlight. It was this version that went out into the field for pilot testing in 1999, with a commercial launch the next year.

Tested exhaustively

The algorithms were also tested exhaustively, notes Dr Jörg Jasper, Yara's head of application tools and services R&D. "We needed to be sure the N-Sensor could reliably take account of N uptake throughout the year and across all crops. Over the years, it's been tested thoroughly and works effectively in cereals, oilseed rape, potatoes, maize, cotton and sugar cane, in both winter and spring. And there's now a new grass algorithm. We're talking tens of thousands of datasets and around 60 man years of work."

In the UK, the technology struck a chord with Clive Blacker, who was helping develop his family's Yorks-based farming and contracting business. "We were farming around 730ha with contracting operations over a further 1600ha. I was an inquisitive young pup wanting to learn what we could do with the technology. We were the first to yield-map with the Claas system, then started applying P&K variably with front and back-mounted spreaders in 1999. In the same year, Yara introduced the N-Sensor and we said we'd give it a go."

From trialling the first commercial prototype, Clive learnt along with the Yara team how to get the best from the technology and integrate it into the farming system. In 2004, he set up Precision Decisions, exclusively supplying, fitting and maintaining sensor systems for UK farmers.

"One of the things that's always struck me about Yara is the science they put behind it," he notes. "There are a number

No more guess work on N applications

With over one million chickens and a large pig unit, J Porter and Son spreads a lot of manure over the 1100ha of the heavy clay soils the business farms, based at Barn Farm, Navenby, Lincs.

"We have very accurate spreaders and have the manure analysed for nutrient content," points out Graham Porter. "But with the best will in the world, knowing how much N the crop has actually taken up before top dressing in spring is largely guess work."

They found that either too little N was being applied to the wheat, barley and oilseed rape they grow or too much. This resulted in some thin patches of crop, and frequent lodging, despite growing short, stiff-strawed varieties — all crops are grown for feed, used within the business or to supply the quality animal feeds Porters also sell. This was the main prompt for starting to use an N-Sensor.

"We first came across it in around 2007, and the first one on the farm was one of the original models that uses ambient light. We currently have an ALS N-Sensor which does a remarkable job," says Graham. Mounted on a Claas Axion 850 tractor, it operates an Amazone spreader.

"We apply about half the N most people put on. It determines the right rate, but the main benefit is that it takes the inaccuracies out — we achieve a much more even crop."

of devices and systems now that measure NDVI, but none tell you reliably about N uptake, especially late in the season. Yara's vision for the sensor was clear from the start, and in the early days at times it was royally frustrating — they want everything perfect before it hits the market. But that gives you the reassurance that Yara has been through all the pain barriers, so when an upgrade reaches the farm, it's ready to go."

One important milestone was the development of the ALS (Active Light Source) unit. Since the N-Sensor worked on light reflectance, performance was compromised in low-light conditions and it couldn't operate at night — a serious setback for the large farmers and contractors drawn to the technology.

"In the early 2000s, we started work on an artificial light source," continues Stefan. "We started with a halogen lamp and worked through a number of different systems, finally ending up with a faint red light that pulses on and off ten times a second."

The red light provides just the right spectrum for the wavelengths used by the sensors. The pulse allows the software to eliminate background light, improving the accuracy of the input signal. The ALS N-Sensor was launched in 2006, and the hardware has remained much the same ever since.

One problem that's bugged the N-Sensor, however, is compatibility — an issue throughout precision farming. Any control terminal you have in the cab should be able to operate any spreader, sprayer or implement you attach to it, and run the software to variable-rate apply. The industry standard for this is ISOBUS.

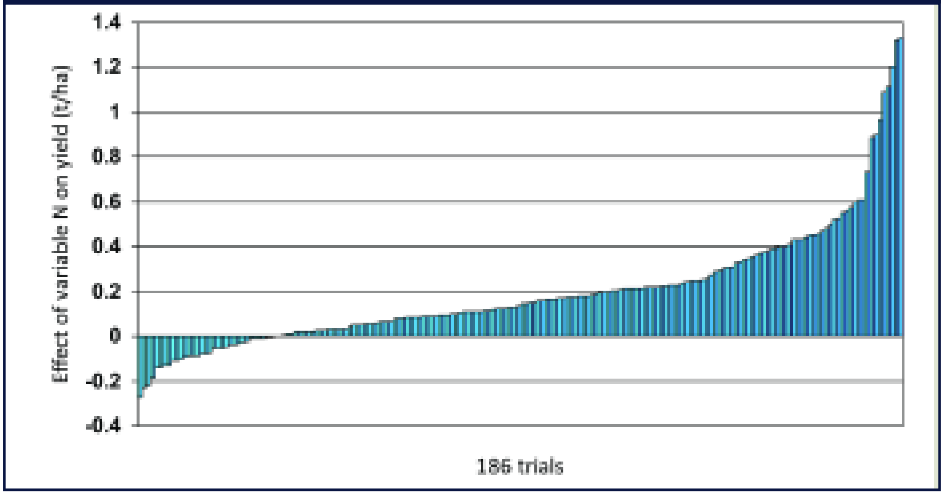
"When Yara first started developing the N-Sensor, they worked with AGCO and Amazone on a system called LBS, that predated ISOBUS," explains Clive. "Unfortunately, the first ISO standards didn't cover equipment that inputs information to a control terminal, so only certain terminals that could support third party inputs would work effectively with the N-Sensor. ▸

Jörg Jasper ensured the N-Sensor was tested thoroughly and could reliably take account of N uptake throughout the year and across all crops.

Clive Blacker learnt along with the Yara team how to get the best from the technology and now exclusively supplies, fits and maintains systems for UK farmers.

Absolute N requires no calibration and the system decides for itself how much N to apply, which for some is a leap of faith.

Results of stripe trials in cereals, 1999-2005



Source: Yara stripe trials on large farmers' fields with alternating stripes of uniform and variable rate N applied, both treatments receiving the same optimum average N rate; average yield increase due to N-Sensor based redistribution: +0.26t/ha (+3.1%).

▸ "The situation is vastly improved today — John Deere and TopCon systems are now fully compatible, for example, and for two years there's been a new ISO standard called peer-to-peer, that assures compatibility. There are still issues with certain equipment, but part of the Yara service we supply is to address those, and we always advise growers to speak to us first before investing in the technology."

This is a fundamental backbone to how the N-Sensor is distributed, stresses Jörg. "We have dedicated distributors and service providers in all 38 countries where it's used — there are now 1871 N-Sensors operating worldwide, with 266 in the UK. All users get specialist advice from the outset to ensure compatibility isn't a problem. Back up includes remote diagnostics where a technician can dial into your system and solve a glitch without even having to visit the farm. On top of that, you get the agronomic know-how, to a level no one else provides."

So much work and refinement has been put into this aspect that now the machine can think for itself. Absolute N first appeared for OSR in 2011. "Calibrating the N-Sensor can be quite cumbersome. We wanted a system where you just drive into the crop and the system decides for itself how much N to apply — you don't even have to set an average, max or min rate," he continues.

"At first, the concept itself was a huge barrier for us — it took quite a few years and many more trials before we were confident the algorithms were good enough to be given control."

One important milestone was the development of the ALS unit with its own built-in light source.

Mark recalls the first time he presented Absolute N to a group of growers at an Agrovista Growcrop Gold trials site. "The general reaction was 'you gotta be kidding!' Even today it's a big challenge to trust the tool, and you get growers ringing up who can't believe it's cut down to 50kgN/ha on an area they were going to spread at 140kgN/ha. But you'll generally find the N-Sensor is right."

As well as testing the concept, the many trials have proven the benefits of the N-Sensor, he points out, and these fall into four categories:

1. **Yield:** Stripe trials in large cereal fields have shown an average yield benefit of 0.26t/ha, where both stripes have received the same overall rate (see chart above).
2. **Quality:** In trials carried out by University of Kiel in Germany on high protein wheat, the N-Sensor lifted the average protein content from 14.28% to 14.67% and closed the range from 13.5-15.25% to 14.1-15.2%.
3. **Efficiency:** Considerably less lodging and a more even crop. Trials conducted by Feiffer Consult over three very different harvests in Germany showed combine efficiency improved by 12-20% on average.
4. **Environment:** Reflectance data can be used to improve targeted use of chemistry, such as 42% less product used to destroy potato haulm and 15% less PGR used to achieve the same lodging control.

The Image IT app, free to download to iOS or Android smartphones, has now been developed, using the same technology as the N-Sensor. It determines N uptake from pictures taken of a crop, and turns these into fertiliser recommendations. "In France, where you now have to base spring N inputs on an assessment of need, the app is an officially accepted means of doing this," notes Mark.

The ALS N-Sensor works effectively in low-light conditions and at night.

Clive's convinced it's a worthwhile investment. "The results you get are staggering, especially when you set it on Absolute N — often it'll put on less than half what you think should be applied," he says.

"It can be a concern to put your trust entirely in a tool developed by a fertiliser company. But Yara simply wants its product applied precisely where it's needed using the best sensing technology, and that's what it's delivered with the N-Sensor." ■

Innovation Insight

CPM would like to thank Yara for kindly sponsoring this article, and for providing privileged access to staff and material used to help put the article together.