Final Project Summary

Project title	Automating Nitrogen fertiliser Management for cereals		
Project number	RD-2008-3530	Final Project Report	PR561
Start date	01 January 2010	End date	31 December 2014
AHDB Cereals & Oilseeds funding	£180,000	Total cost	£1,458,960

What was the challenge/demand for the work?

Accurate estimation of N fertiliser requirements of cereal crops is important for productivity, profitability and the reduction of environmental impacts through greenhouse emissions, nitrate leaching and ammonia losses. Precision farming technologies are now commonly used commercially for variable rate N fertiliser applications around a pre-set baseline, but no system yet provides a comprehensive estimate of total N requirement on an absolute basis. Fertiliser N requirements vary hugely between fields and current recommendation systems only predict N amounts within 50 N kg/ha of measured N optima 50% of the time. Variation in N requirement is ultimately due to variation in the three components crop N demand, soil N supply and fertiliser recovery. The AHDB guide “Nitrogen for winter wheat – management guidelines” sets out an approach to quantitatively estimate each of these components hence calculate an N requirement for each field. Precision farming technologies offer the opportunity to automate estimation of crop N demand, soil N supply and fertiliser recovery at a within-field scale as well as between fields, providing the potential for an integrated system to automate N fertiliser management at all scales on an absolute basis.

How did the project address this?

The Auto-N project brought together the major providers of precision farming services in the UK to develop approaches and systems that could improve estimation of N fertiliser requirements to farmers within and between fields. There were five work-areas:

(1) A rational framework (Auto-N logic) was developed for automatically integrating spatial data from precision technologies into calculations set out in the N management guide.

(2) The project worked with five farms, collating all available precision farming data on five fields from each. On three farms a grain protein sensor was fitted to the combine harvester. Approaches were developed for dealing with data over several seasons to give reliable estimates of the spatial variation in fields. This included developing routines to process and clean yield data and use of fuzzy k-means clustering to identify cluster groups from yield maps over multiple years.

(3) Six large N response trials were set up with a novel chessboard design using N fertiliser applications made by the farmers with commercial application equipment. The trials had 200–500 plots, each plot approximately 12m x 12m, to give four N rates (typically 0, 120, 240 & 360 kg N/ha) arranged in a regular chequerboard pattern across each field. Yields, grain protein and a range of

other measures were taken from all plots and kriged (a method of interpolation) to give values for each measure in each plot at each N rate. This enabled N response curves to be fitted for each plot and economically optimal N rates determined. These chessboard trials allowed the spatial variation in N requirement to be quantified, causes of variation to be understood in terms of crop N demand, SNS and fertiliser recovery, and they allowed exploration of the potential for predicting N requirements using soil mapping, yield mapping and in-season canopy sensing.
(4) A series of 'calibration trials' was conducted with canopy sensors, to develop rational approaches for judging soil N supply and to estimate crop N uptake, crop biomass and crop N status.
(5) The 'Auto-N logic' was tested in validation trials with the five farmers. Fertiliser N requirement application maps were created based on (i) yield maps to define crop N demand and (ii) canopy sensing (either Crop Circle/Optrx, N sensor, or satellite NDVI) to define soil N supply (using an algorithm with thermal time from sowing, developed within the project). Tramline trials compared uniform N rate with variable rate, as well as with +/- 50 kg N/ha in adjacent tramlines.

What outputs has the project delivered?

The chessboard trials conducted in this project have transformed our understanding of N responses, and the variability in N requirements. Variation in N optima was large (~150 kg N/ha) in all the fields tested, as was variation in optimal yield (typically >2t/ha). There was a strong relationship between yield potential and soil N supply; areas that yielded well also tended to have more N available from the soil. Variation in fertiliser recovery was found to be large, as was variation in grain protein content at the optima. These relationships were explored in a paper published in the Journal of Agricultural Science. Spatial variation in crop N demand and soil N supply was well defined by yield maps and canopy sensing respectively. However, variation in fertiliser recovery has not yet proved predictable. Despite the large variation in N optima, the benefits to productivity, fertiliser savings, gross margins and environmental performance of perfectly matching N requirements across fields (compared to a uniform flat rate at the average optimum) were surprisingly modest. Obtaining an accurate average N requirement for the field is more important than matching intra-field variation. Also, optimising N fertiliser rates did not substantially reduce variability in achieved yields, implying that the major causes of yield variation were not related to nitrogen.
The Auto-N project has demonstrated that absolute fertiliser N requirements could be calculated automatically on farm using precision farming technologies and the framework set out in the N Management Guide: N requirement = (Crop N demand – SNS) / Fertiliser recovery.
Crop N demand can be calculated from expected yield multiplied by 23 kg N/t for feed wheat. Past yield maps can be used to give a reasonable indication of spatial variation in crop N demand (through averaged normalised yields, or by defining management zones or cluster groups. NB A paper was

published in Computers & Electronics in Agriculture demonstrating the clustering approach). However, the variability in optimal grain protein content contributed substantially to variation in crop N demand; understanding its causes and enabling its prediction requires further research.

Estimates of SNS at the field scale are best made from measurements of soil mineral N or from estimates of N residues following the previous crop adjusted for over-winter leaching (dependent on rainfall and soil type) and likely mineralisation from soil organic matter. An approach was successfully developed to estimate variation in SNS from differences in NDVI in early spring, adjusted for thermal time since sowing.

A large dataset was used to test calibrations of sensor data for crop biomass, N uptake and N status. However, no adequate rational basis was found for including these in the Auto-N logic.

Accurately predicting variation in fertiliser N requirements across fields is challenged by the close correlation of crop N demand and soil N supply, the variability in optimal protein content and the variability in fertiliser recovery. In principle the approach of applying more N to poorer parts of the field with early N applications, and less with later applications makes sense.

The project demonstrated the power of on-farm spatial experimentation particularly to explore soil variation and soil effects in a way that isn't possible with conventional experiments. It showed that getting average N rates right for each field (as a whole) is of primary importance, and that precision farming technologies commonly available on farm can be used by farmers to test their own decisions. Hence, they can use tramline comparisons (of say 50 kg N/ha more and less than their standard N rate) to gauge whether N rates are about right on each field, and on their farm as a whole. This is now being developed through the AHDB 'LearN' project.

Who will benefit from this project and why?

The learnings made through this project should benefit all cereal farmers in improving guidance and recommendations on their N fertiliser management. The project also informed the revision of the Fertiliser Manual (RB209). It evaluated for precision farmers benefits from use of precision technologies, hence should help inform farmers considering investment in precision technologies.

Precision farming companies have the opportunity to utilise the approaches developed here as services for farmers. Particular services that could be offered are; digitisation of the N management guide approach; use of cluster analyses with series of yield maps and other spatial data to help define management zones; use of the algorithm with thermal time to estimate SNS spatially from canopy reflectance (NDVI) in spring.

Perhaps the biggest indirect beneficiary from this project is the research community. The chessboard and tramline trials have demonstrated very useful research techniques that enable questions to be asked by soil and crop scientists that aren't possible with conventional experiments. They also

demonstrated large spatial variation in yield to be due to soil, but not to N nutrition; hence it raises significant questions about how soil affects arable crop performance. ADAS has developed a new methodology for spatial experimentation with networks of farmers, called Agronōmics, arising directly from learnings made in the Auto-N project.

If the challenge has not been specifically met, state why and how this could be overcome
The project demonstrated that there is scope for commercial development and deployment of systems using the Auto-N logic to help farmers better estimate fertiliser N requirements between and within fields. However the complexities of the interactions between the components of the N requirement and the variability of protein content and fertiliser recovery mean that benefit from the new prediction of N requirement is insufficient to justify its extra cost. Furthermore, the economic payback from variable any rate applications were found here to be modest, so there has not been an over-whelming case for investment in commercialising the Auto-N logic. Opportunities exist for AHDB to develop web platforms or 'free' software applications using the Auto-N logic to enable growers to calculate their N requirements both between fields and within fields.

Lead partner	ADAS UK Ltd
Scientific partners	Rothamsted Research, NIAB-TAG
Industry partners	Agrii, AgLeader, BASF, Farmade, FOSS, Hill Court Farm Research, Precision Decisions, SOYL, Soilessentials, Yara, Zeltex
Government sponsor	Sponsored by Defra through the Sustainable Arable LINK programme