Project title:	The application of precision farming technologies to drive sustainable intensification in horticulture cropping systems (PF-*Hort*)
Project number:	CP 107c
Project leader:	Dr Lizzie Sagoo & Dr Paul Newell Price, RSK ADAS Ltd
Report:	Annual Report, March 2017
Previous report:	Annual Report, March 2016
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Location of project:	Field demonstrations at grower sites around the country
Industry Representative:	Andy Richardson, Allium & Brassica Centre
Date project commenced:	01/04/2015
Date project completed (or expected completion date):	31/03/2018

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The results and conclusions in this report are based on an investigation conducted over a one-year period. The conditions under which the experiments were carried out and the results have been reported in detail and with accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.

AUTHENTICATION

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

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GROWER SUMMARY

Headlines

- Soil mapping, canopy sensing and yield mapping provide information on soil and crop variability that can help better target nutrient inputs and soil management.
- Controlled traffic farming (CTF) reduces the field area wheeled by machinery and can lead to improvements in soil structure, efficiency and productivity.
- Targeted nutrient management, soil mapping, crop sensing and CTF are being demonstrated on commercial farms in 2016 and 2017 and the benefits and limitations communicated to growers through on-site interactive workshops.

Background

Improved soil management and targeted nutrient inputs are key agronomic management strategies to improve the productivity, profitability and sustainability of intensive horticulture production systems. Precision technology can help to improve the efficiency of farm operations, including cultivation and accurate fertiliser and agrochemical applications; implemented correctly these techniques can improve the efficiency and profitability of production. Precision farming involves measuring and responding to variability in soils and crops to optimise returns on inputs (i.e. fertiliser applications, soil cultivations etc.). Potential increases in marketable yield of high value crops makes precision farming an attractive option for many growers. Anecdotal evidence suggests that whilst uptake of GPS and soil mapping in horticulture is increasing, the development and uptake of other precision farming techniques such as controlled traffic farming (CTF), canopy N sensing and yield mapping has largely been focussed in cereals and oilseed rape. Some of these precision farming techniques have direct relevance to horticulture and there is now interest from growers in their potential to increase yields and improve profitability and sustainability.

The aim of this project is to evaluate the current and future potential of precision farming techniques to optimise soil and nutrient management in horticulture, and to encourage greater uptake of any commercially available techniques with potential to increase yields and profitability within horticulture.

Phase one of the project (first 14 months; objectives 1-3) included a field survey of soil structural conditions under horticulture crop production and a review of precision farming techniques for improved soil and nutrient management. In Phase Two (years 2 & 3) the precision farming techniques with the greatest potential for uptake are being evaluated through demonstration activities and/or field experiments on six commercial farms.

Summary

Soil structure survey

The soil structure survey was carried out between September 2015 and October 2016 and comprised 75 fields located on 49 holdings. The survey was stratified by crop type and included Brassica, carrots, onions, leeks, leafy salads and vining peas (annual crops) and asparagus, blackcurrants, raspberries, apples, narcissus and cut flowers (perennial crops). For the annual crops the survey was carried out twice (pre- and post- planting/drilling). For the perennial crops, the survey was carried out prior to establishment at some sites and in the growing crop at other sites. The results from the soil survey have been written up as a separate AHDB Research Review Report.

Precision farming review and KE Guide

The precision farming review engaged with industry, including the precision farming companies and machine manufacturers, growers, consultants and researchers to evaluate the potential for precision farming techniques such as controlled traffic farming, soil mapping, remote sensing of crop canopies, variable rate inputs and yield mapping, to increase crop marketable yield and profitability.

The combination of the literature review and the interviews with precision farming companies, machine manufactures and growers has provided a comprehensive overview of what precision farming techniques are available to growers to improve soil and nutrient management and more specifically how these techniques may be applied to horticultural crops. The precision farming review has been written up as a separate AHDB Research Review Report.

The results from the soil structure survey and precision farming review are currently being collated into a KE *Guide to improved soil and nutrient management in horticulture*.

Field demonstrations (year 2)

In Phase Two (years 2 & 3) the precision farming techniques with the greatest potential to improve soil and nutrient management in horticulture are being demonstrated and evaluated on six commercial farms. There were three field demonstrations in year two (2016/17) which focussed on canopy sensing for variable rate nitrogen (N) applications, controlled traffic farming and options for soil mapping.

1. Canopy sensing for variable rate N applications – Glassford Hammond Farming

Canopy sensing measures reflectance from the crop surface. This information is presented in the form of a vegetation index, which can relate to crop biomass and crop N uptake.

Information on crop canopy variation across a field can be used to vary the N rate. The field demonstration at Glassford Hammond Farming aimed to demonstrate the potential for canopy sensing for variable rate N applications to a Savoy cabbage crop. The demonstration included N response experiments and tramline comparisons of uniform and variable rate N application to address the following questions:

- Does the optimum N rate for the crop vary across the field?
- Can we relate canopy sensing information to crop biomass and N uptake during the growing season?
- Can we demonstrate a benefit from variable rate N application?

Nitrogen response experiments were replicated in three different areas of the field to see if there was any evidence of within field variation in optimum N rate – variable rate N management will only be of benefit where there is variability in crop N requirement.

In addition, we compared the farm standard uniform N application rate to variable N application in tramline comparisons. The farm standard N application rate was 240 kg N/ha and was applied in three splits: 80 kg N/ha on 4th July at planting, 100 kg N/ha on 4th August and 60 kg N/ha on 24th August. For the variable rate N treatment we varied the second N application from 60-140 kg N/ha (i.e. +/- 40 kg N/ha from the 100 kg N/ha farm standard) based on crop canopy measurements using a drone/unmanned aerial vehicle (UAV).

Crop canopy measurements from the N response plots showed a strong relationship between NDVI and total biomass, and between NDVI and crop N uptake. The N response plots also showed a significant yield response to N fertiliser; fresh weight marketable yield increased from 10 t/ha (mean marketable head weight of 603 g) on the zero N treatment to a maximum of 44 t/ha (mean marketable head weight of 1174 g) at the highest N rate of 360 kg N/ha.

The large yield response to N fertiliser and the strong relationship between crop canopy measurements (NDVI) and above ground crop biomass and N uptake indicate that canopy sensing can be used as a basis to vary N applications and where N availability varies across the field we could potentially see improvements in crop uniformity and/or an overall yield increase. However, statistical analysis of N response data from the three experiments showed that, in this case, N response was similar across the length of the field.

Comparison of marketable head weights and total marketable yields from the uniform and variable rate N tramline comparisons did not provide any evidence that varying the N rate increased total marketable yield or produced a more consistent sized crop in this demonstration field.

Variable rate N management will only be of benefit if N is the main cause of variability in the crop canopy. At this site, the N response experiments showed that the crop response to N was similar across the length of the field, and we think it is likely that the variability in crop canopy measured by the UAV was due to other soil or crop factors.

2. Controlled traffic farming – Barfoots

Controlled traffic farming (CTF) aims to reduce the proportion of each field area that is wheeled by machinery to avoid widespread soil compaction. CTF has been defined as “confining compaction to the least possible area of permanent traffic lanes” and involves greater discipline in use of routeways and tramlines. Improvements in soil structure can lead to fewer and less energy-intensive cultivations; reduced fuel use; improved seedbeds; better drainage; more machinery work days; improved water and nutrient use efficiency; and increased yields in some years. Increasing yields by 10-15% can result in increased revenue of *c*. £150 to £700 per hectare, depending on the initial yield and crop type. These benefits can be accrued within a few years of adopting CTF systems.

Barfoots of Botley have converted the majority of their machinery to a CTF system across their farms as part of a new soil management strategy that includes the adoption of reduced tillage systems and the use of cover crops to improve soil structure. The CTF field demonstration at Barfoots contains three elements:

i. Capturing detailed technical information on machinery to compare the extent of tracking and fuel consumption under the previous conventional and recently adopted CTF systems.
ii. A short term field study to investigate within-field soil quality and crop variability under the recently adopted CTF system.
iii. A field study to investigate the long term effects of the recently adopted CTF system on soil quality and health; and implications for productivity, versatility and profitability of the cropping system

The tracking study was based on a rotation of sweetcorn, pumpkins, tenderstem broccoli (TSB) and beans with the addition of cover crops at Barfoots’ Little Abshot Farm. Detailed technical information was collated for all the machinery before and after CTF adoption, including track gauges (distance between wheels on an axle) and implement working widths. The gathered data was used to provide a graphical representation of tracking in the four year rotation prior to and after CTF implementation. CTF adoption resulted in a potential 63% reduction (37% versus >100%) in tracked area.

The farm is in the early stages of transition towards a CTF system incorporating the use of cover crops. The demonstration therefore provided the opportunity to capture the soil and crop management challenges encountered in the first few years of the transition. Detailed soil and crop measurements will be taken within the 2017 sweetcorn crop in two fields (one field in the second year of CTF and a second field in the 6th year of CTF) to determine the within-field variability in soil quality and crop yield resulting from adoption of the CTF system. A soil quality baseline has also been established in three fields under CTF, conventional tillage and grassland management, to assess the cost and medium term benefits of a reduced tillage and controlled traffic approach.

3. Options for soil mapping – F.B. Parrish & Sons

Soil variability (i.e. spatial variability in soil properties such as soil texture, soil depth, stoniness, soil compaction, soil pH, soil nutrient reserves and soil organic matter content) is one of the key factors determining differences in crop yield potential within and between fields. Soil mapping is used to delineate the boundaries between soil types and to define or characterise the soil types themselves (e.g. soil nutrient reserves).

A demonstration focussing on soil mapping was hosted by F.B. Parrish & Son in Avenue field (10 ha) at Chicksands in Bedfordshire. The overall aim of this demonstration was to use Avenue field as a case study to discuss options for soil mapping.

A soil EC survey was conducted and satellite soil brightness imagery sourced for the field. Topsoil samples (0-15 cm) were taken in November 2016 using the following sampling methods:

- Single field sample using 'W'-sampling technique – a single composite sample (of 25 soil cores) was taken by walking a 'W'-shaped path across the field.
- 1 ha soil sampling – the field was divided into approximately 1 ha blocks and a single composite sample (of 25 soil cores) was taken from each 1 ha block by walking a 'W' in each block
- Grid soil sampling – topsoil samples were taken on 25 m grid across the field (total of 143 soil samples). Each grid sampling point was GPS located. A single composite sample was taken from a GPS located point; each sample consisted of 16 soil cores taken in a spiral within a 3 m radius of the central point.

The detailed (25 m grid) soil samples showed significant within field variability in soil pH and nutrients; soil pH varied from 5.3 to 7.1, P Index varied from 2 to 4, K index from 1 to 4 and Mg Index from 2 to 4.

The soil analysis results were used to create soil pH and soil extractable P, K and Mg maps for Avenue field to demonstrate grid and zone based sampling strategies and the impact of sampling intensity. These maps highlight the impact of soil sampling intensity on the soil pH and nutrient maps produced. Where there is significant small scale variability, as seen in Avenue field for soil pH, this variability can be concealed when only taking one sample per hectare, which is the typical commercial standard sampling intensity.

The Avenue field demonstration provides a case study to discuss the principles and methods of soil mapping with growers, in particular –

- Soil sensing methods (soil EC scans and soil brightness maps).
- Difference between grid and zone based soil sampling.
- Methods and information that can be used as a basis for creating soil zones.
- Data interpolation – understanding how the precision farming providers produce a contoured map from point soil samples.

Financial Benefits

This project will provide information on the state of horticultural soils and provide guidance on precision farming and other techniques to identify, avoid and alleviate soil compaction, thereby increasing opportunities to carry out field operations; reduce cultivation and other input costs; increase crop yields and farm profitability, while minimising environmental impact.

The project will assess the potential for precision farming techniques to better target soil management and nutrient inputs to horticulture crops. The potential benefit of variable rate inputs (fertiliser/seed) is greatest in fields which are inherently variable, where it can result in a more accurate use of inputs, optimising nutrient availability across the field and delivering a greater proportion of marketable product.

Action Points

- Soil compaction can be a key factor limiting yields. Growers can manage the impact of soil compaction by identifying and alleviating compaction where it has occurred and by avoiding soil compaction in the first place, where possible.

- Assess soil structure when soils are moist. If soils are compacted, identify the depth of compaction and target the depth of cultivations to just below the compacted soil layer.

- Precision farming tools such as soil mapping, canopy sensing and yield mapping can provide growers with valuable information about the variability of their soils and crops. Where growers have identified variability in their soil or crop, they should first seek to identify the causal factors before adopting appropriate techniques to provide an effective return on investment.

SCIENCE SECTION

Introduction

Technical innovation offers growers new opportunities to potentially increase the efficiency of soil based horticulture production systems. The overall aim of this project is to evaluate the current and future potential of precision farming techniques to optimise soil and nutrient management for improved profitability and sustainable intensification for a broad range of horticulture crops. The project has been divided into two phases. This annual report includes a summary of Phase one, soil survey and precision farming review, and Phase two; results from the first year of field demonstrations.

Phase One: Field survey of soil structural condition in horticulture and review of precision farming techniques for improved soil and nutrient management (first 14 months)

Objective 1. To assess the structural condition of horticultural soils and establish baseline information on typical soil management practices across a range of horticultural crops (perennial, biennial and annual).

Objective 2. To review the current commercially available precision farming techniques used for soil and nutrient management and to assess their potential application in horticulture cropping systems.

Objective 3. Collate the outputs from the soil structure survey (Objective 1) and review (Objective 2) into a practical user friendly *Guide to improved soil and nutrient management in horticulture*.

Phase Two: Field demonstration experiments to quantify the benefit of selected precision farming techniques for improved soil and nutrient management in horticulture cropping systems (years 2 and 3)

Objective 4. Project steering group meeting to agree the soil and nutrient management techniques to be assessed in field demonstration experiments on commercial farms in Phase Two of the project (Objective 5).

Objective 5. To carry out 6 field demonstration experiments to quantify the benefits (crop yield and quality and farm profitability) and trade-offs of selected soil and nutrient management precision techniques compared with conventional production on commercial farms (3 sites per year over 2 years).

Field survey of soil structural condition in horticulture

Soil compaction was the principal soil quality issue identified by the AHDB Horticulture panel consulted in AHDB Horticulture project CP 107. A key objective of the current project was therefore to assess the structural condition of horticulture production system soils and establish baseline information on typical soil management practices across a range of horticultural crops (perennial, biennial and annual). The methodology and findings of the survey are covered in a separate AHDB Research Review Report. A brief summary of the methodology is provided here.

The survey was stratified by crop type (perennial, biennial and annual); and for the annual crops selected was carried out twice (pre- and post-planting/drilling) in 47 fields across 31 holdings. For the perennial crops (e.g. asparagus, apples) measurements were carried out prior to establishment at nine sites and in the growing crop at nineteen sites. The soil structure survey sites were distributed from Cornwall in south west England to Perthshire in eastern Scotland. The pre-planting field measurements were carried out between late September 2015 and March 2016 when soils were moist or close to field capacity. Post-planting field measurements were carried out during the late winter to early spring 2016 and for a few late Brassica crops in October 2016. Pre- and post-planting measurements in different fields were taken under comparable conditions.

To characterise the topsoil at each field site, baseline topsoil samples (0-15 cm depth) were taken from each field, and analysed for:

- Soil pH (measured in water; 1:2.5)
- Particle size distribution (i.e. percentage sand, silt and clay content; laser method)
- Extractable P (Sodium Bicarbonate Extractable), K, and Mg (Ammonium Nitrate Extractable)
- Total N (Dumas)
- Organic matter (dichromate oxidation)
- Loss on ignition (LOI)

The soil structure survey focused on topsoil and upper subsoil condition (to a depth of 60 cm). Firstly, a cone penetrometer was used to quantify the range and depth of (maximum) penetration resistance values at twenty randomly selected points across the main body of the field (pre-planting), and, for annual crops, across the drilled/planted area (post-planting) to a depth of 50 cm. For perennial crops, post-planting penetrometer measurements and subsequent assessments were carried out in the beds for asparagus, narcissus/cut flowers and soft fruit (blackcurrants and raspberries); and between the beds and alleyways in apple orchards.

Within each field and at each sampling occasion, the following measurements/assessments were carried out at the three points where the maximum, median and minimum topsoil penetration resistance values were measured:

- Dry bulk density (core cutter method):
    - Mid topsoil (10-15 cm depth)
    - Upper subsoil (30-35 cm depth)
    - Deeper subsoil (40-45 cm depth)
- Visual soil evaluations:
    - Visual Soil Assessment (VSA; Shepherd, 2000) – topsoil
    - Visual Evaluation of Soil Structure (VESS; Guimarães *et al*., 2011) – topsoil
    - SubVESS (Ball *et al*., 2015) – subsoil
- Cone penetrometer tests:
    - 40-60 cm depth (maximum resistance and depth of maximum resistance x 3)

In addition to the compaction survey, a parallel grower survey of soil management practices was carried out at each of the holdings and 75 fields in the soil structure survey. This included questions on attitudes towards soil management, visual soil evaluation and specific soil management practices carried out on farm (e.g. use of soil visual evaluation methods, cultivation sequences and frequency and depth of sub-soiling). These soil management practices were compared with the field soil structure observations to determine whether or not current soil management practices are appropriately tailored to actual observed soil structural conditions.

The soil structure and soil management practice surveys provide case study evidence of soil structural conditions rather than statistical relationships between sectors or cause and effect relationships between soil management practices and soil structural condition. However, the greater number of fields surveyed under annual cropping (47 fields) allowed an approximate assessment of the extent of soil compaction issues for this sector (Figure 1).

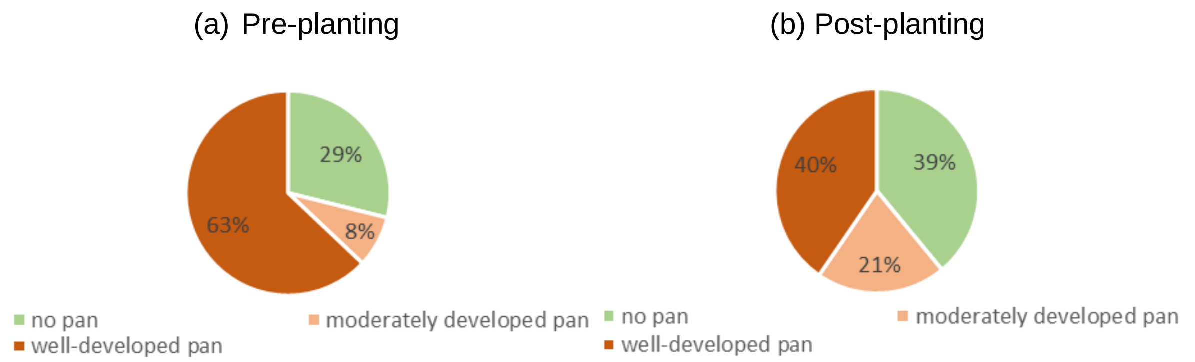


Figure 1. Percentage of annual cropping sites with a tillage pan, (a) pre-planting and (b) post-planting (n = 47).

Review of precision farming techniques for improved soil and nutrient management

The objective of the review was to examine the current commercially available precision farming techniques used for soil and nutrient management and to assess their potential application in horticulture cropping systems.

The precision farming review included a literature review, a survey of precision farming companies and machinery manufacturers and a targeted survey of horticulture growers with experience of using precision farming techniques. The review focussed on techniques that can be used to improve soil and nutrient management to increase crop marketable yield and profitability, including:

- Guidance systems.
- Controlled traffic farming.
- Yield mapping – potential to yield map horticultural crops and the potential to use yield maps from combinable crops grown in the rotation to target management of horticultural crops.
- Soil mapping to zone fields: electrical conductivity (EC) and electro-magnetic induction (EMI) mapping and soil brightness imagery.
- Remote sensing of crop canopies and applications for crop surveillance, variable rate N applications, and use of high resolution imagery to count/size crops.
- Variable rate P, K Mg fertiliser and lime applications.
- Variable rate planting.
- Targeted variable depth sub-soiling to remove compaction.

The combination of the literature review and the interviews with precision farming companies, machine manufactures and growers has provided a comprehensive overview of what precision farming techniques are available to growers to improve soil and nutrient management and more specifically how these techniques may be applied to horticultural crops.

The precision farming review has been written up as a separate AHDB Research Review Report. The results from the soil structure survey and precision farming review are currently being collated into a KE *Guide to improved soil and nutrient management in horticulture*.

Field demonstration experiments to quantify the benefit of selected precision farming techniques for improved soil and nutrient management in horticulture cropping systems

Background

In Phase Two (years 2 & 3) the precision farming techniques with the greatest potential to improve soil and nutrient management in horticulture are being evaluated in demonstrations and/or field experiments on six commercial farms. The project aims to encourage greater uptake of commercially available techniques shown in this project to have potential to increase yields and profitability within horticulture.

Objectives

Objective 4. Project steering group meeting to agree the soil and nutrient management techniques to be assessed in field demonstration experiments on commercial farms in Phase Two of the project (Objective 5).

Objective 5. To carry out 6 field demonstration experiments to quantify the benefits (crop yield and quality and farm profitability) and trade-offs of selected soil and nutrient management precision techniques compared with conventional production on commercial farms (3 sites per year over 2 years).

Approach

The project steering group met on 18/01/16 to agree the precision farming techniques to be assessed in the field demonstration experiments. The ADAS project team presented six options for field demonstrations and the group discussed the strengths and weaknesses of each of the techniques/options presented. The steering group agreed that the field demonstrations should focus on soil nutrient mapping, techniques to help growers understand variability, canopy sensing for variable N rate and controlled traffic farming.

Canopy sensing for variable rate nitrogen applications

Background

Canopy sensing measures reflectance from the crop surface. This information is presented in the form of a vegetation index, which can relate to crop biomass and crop nitrogen (N) uptake. Canopy sensing can give us useful information on spatial and temporal variability in crop growth and can be used as the basis for variable rate N management.

A crop with a well-developed thick canopy will typically have a different N requirement to a crop with a less well developed canopy. We can use information on crop canopy variation across a field to vary the N rate, usually this means applying more N to thinner areas and less to thicker areas.

Canopy sensors are increasingly being used to variably apply N fertiliser to combinable arable crops. This technology may have the potential to improve N use efficiency in horticultural crops. This project includes two demonstrations looking at variable rate N applications. This annual report presents results from the 2016 demonstration on Savoy cabbage at Glassford Hammond Farming. The overall aim was to demonstrate the potential for canopy sensing for variable rate N applications. The demonstration will be repeated on Brussel sprouts in 2017.

Methods

Experimental site

This demonstration was hosted by Glassford Hammond Farming in Peters House Field near Workshop, Notts. The field was planted with a number of varieties of Savoy cabbage on 30th June at a planting density of 38,140 plants/ha. The experimental area was located in an area planted with the variety Tourmaline. The soil was a sandy loam textured soil with P index 2, K index 2- and Mg index 2.

Approach

The demonstration included N response experiments and tramline comparisons of uniform and variable rate N application to address the following questions:

- Does the optimum N rate for the crop vary across the field?
- Can we relate canopy sensing information to crop biomass and N uptake during the growing season?
- Can we demonstrate a benefit from variable rate N application?

Nitrogen response experiments

Nitrogen response experiments were replicated in three different areas of the field to see if there was any evidence of within field variation in optimum N rate (Figure 2) – variable rate N management will only be of benefit where there is variability in crop N requirement.

Each experiment included seven N application rates (0, 60, 120, 180, 240, 300 and 360 kg N/ha) replicated four times and arranged in a randomised block design. Each plot was 6 x 5 m and included 10 cabbage rows.

Topsoil samples (0-15 cm depth) were taken from each of the three N response experimental areas and analysed for pH, extractable P, K and Mg, organic matter and soil texture. Soil mineral N samples (0-90 cm) were also taken prior to planting (one sample from each area) and after harvest (from the 0, 120, 240 and 360 kg N/ha treatments).

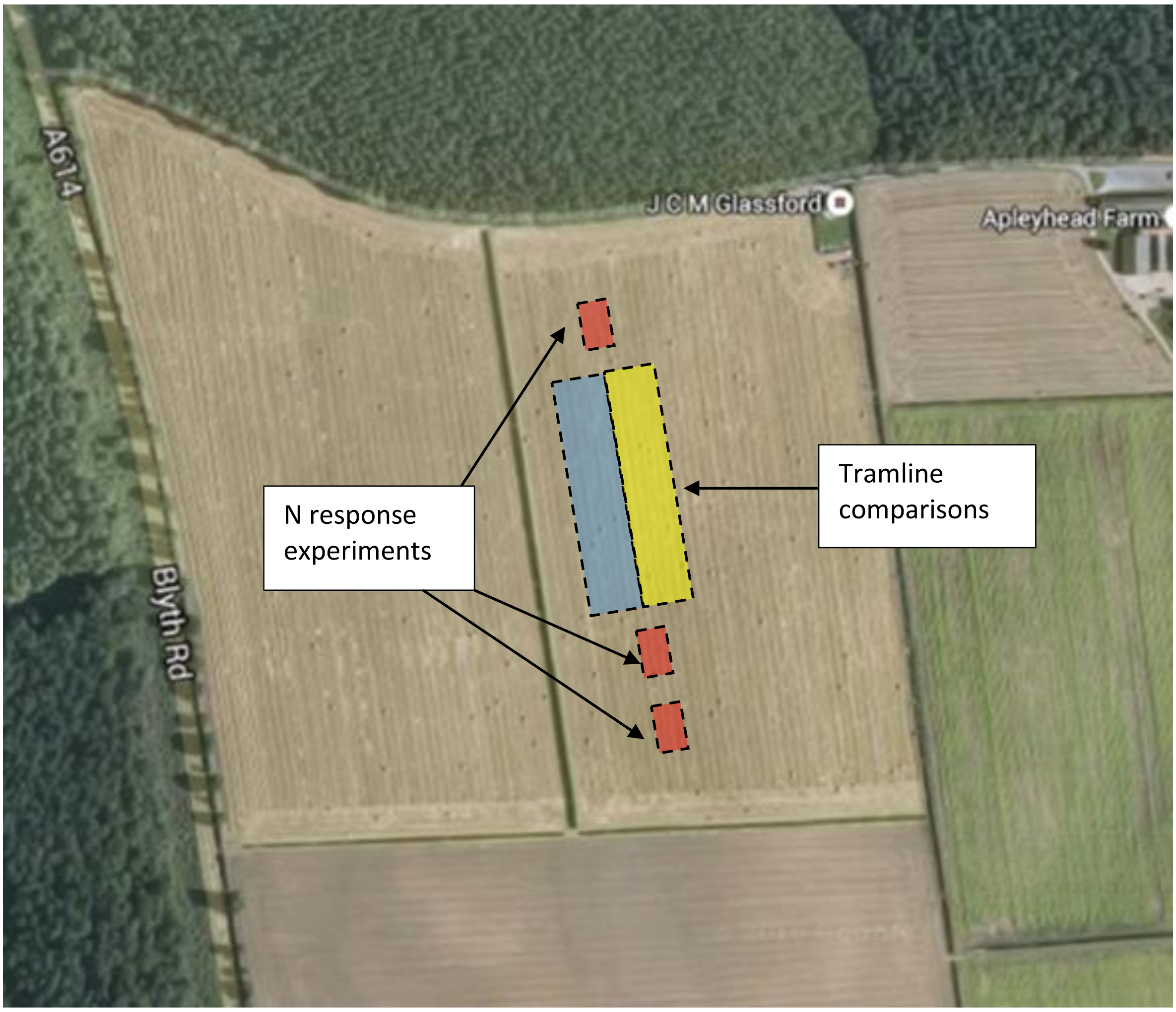


Figure 2. Field demonstration layout

A handheld CropScan sensor (Figure 3) was used to measure reflectance from the crop canopy from each of the N response plots four times during the growing season: 3rd August, 24th August, 18th September and 19th October. Crop samples were taken from the same area as the CropScan measurement from each N treatment; six cabbages were cut at ground level and weighed to determine total biomass, and a subsample taken for dry matter and total N analysis in order to calculate total N uptake.

Figure 3. Use of handheld CropScan sensor to measure reflectance from the crop canopy

The N response plots were harvested between 7th and 11th November. Thirty cabbages were cut and weighed from each of the plots. The total weight was recorded to calculate total yield and a subsample taken from dry matter and total N analysis in order to determine total N offtake at harvest. The cabbages were then trimmed and weighed again individually to give marketable yield. Damaged or diseases cabbages and cabbages <500 g were classed as unmarketable.

Tramline comparisons

In addition, we compared the farm standard uniform N application rate to variable N application in tramline comparisons – each N treatment was applied to an area 36 m x 125 m (Figure 2). The farm standard N application rate was 240 kg N/ha and was applied in three splits –

- 80 kg N/ha on 4th July at planting
- 100 kg N/ha on 4th August
- 60 kg N/ha on 24th August

For the variable rate N treatment we varied the second N application from 60-140 kg N/ha (i.e. +/- 40 kg N/ha from the 100 kg N/ha farm standard) using crop canopy information. The first and third N applications were applied at the farm standard uniform rate to the whole field using the farm spinning disc fertiliser spreader.

The precision farming company SOYL collected crop canopy information from the field using a UAV (drone) on 27th July (the week before the second N application). SOYL used their Tetracam Agricultural Digital Camera (ADC) camera to collect canopy information from the whole field and their Tetracam Multiple Camera Array (MCA) camera to collect canopy information at a higher resolution from the tramline comparison area (Figure 4).

SOYL used the NDVI vegetation index to create a variable rate N prescription map for the trial area (a 96 x 150 m area including both tramline treatments and 12 m buffer around the edge of the trial) (Figure 5). Nitrogen was variably applied to the 36 x 125 m variable rate N tramline treatment only – the rest of the area received a uniform 100 kg/ha N application. Glassford Hammond Farming did not have the facility to variably apply N fertiliser using the farm fertiliser spreader, therefore the N fertiliser was applied by hand to the variable rate treatment at different application rates on a 6 x 5 m grid. The N prescription map for the tramline area was produced on a 6 x 5m grid – N application rates were calculated based on a liner relationship between NDVI and N application rate with the highest N application rate to areas of lowest NDVI and vice versa.

The uniform 100 kg N/ha treatment was applied using the farms modified seed drill which places the N fertiliser between the cabbages. The fertiliser spreader was calibrated prior to use to check the application rate.

The prescription N map was used to identify three 6 x 5 m areas of crop with a lower NDVI and three 6 x 5m areas of crop with a higher NDVI from both the uniform and variable rate N treatment areas. Leaf samples were taken from each of these areas on 4th August prior to the second N fertiliser application and analysed for total N, P, K, Mg, S, Ca, Mn, B, Cu, Zn and Fe to see whether there was any indication that the differences in crop canopy were attributable to differences in any other plant nutrients.

At harvest, marketable yield was measured from the uniform and variable N rate treatments; each 36 x 125 m treatment area was divided into 150 6 x 5m sub-plots and 30 cabbages were harvested and weighed from each sub-plot[1]. We compared the effect of variable rate N application on total marketable yield and crop uniformity.

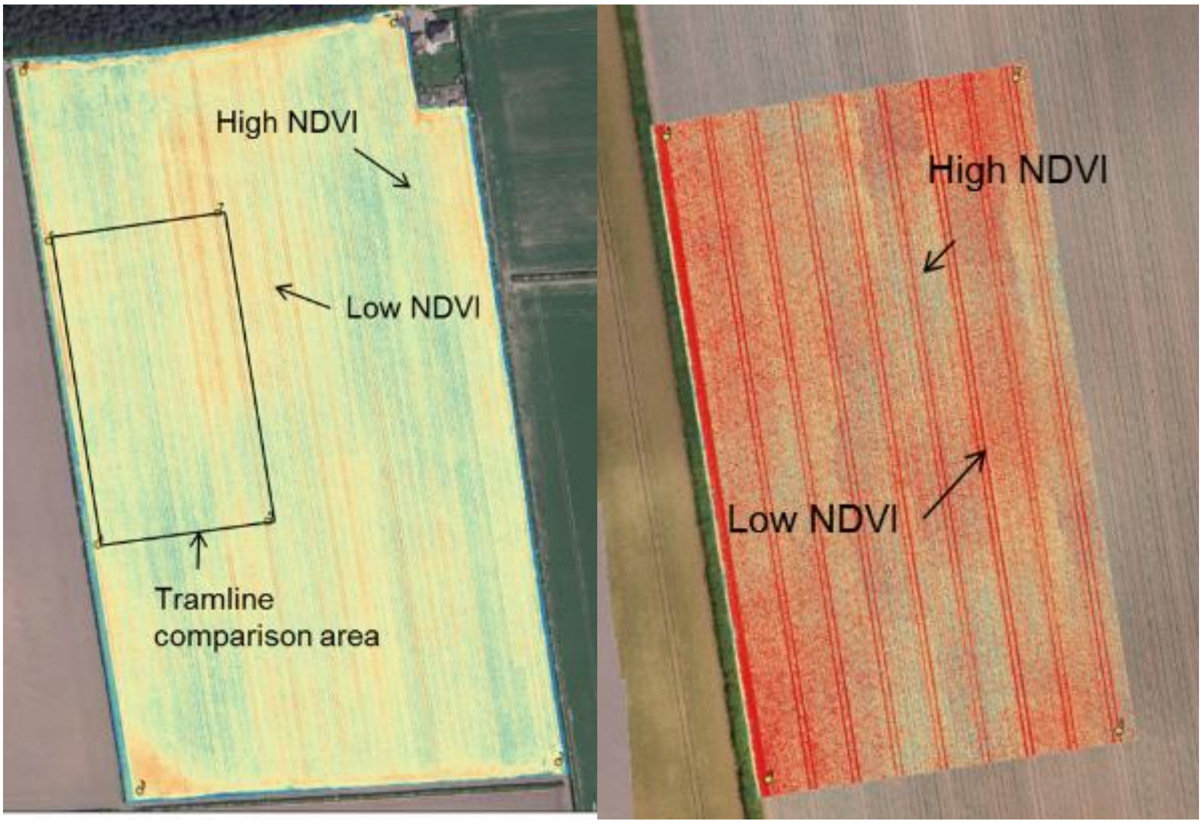
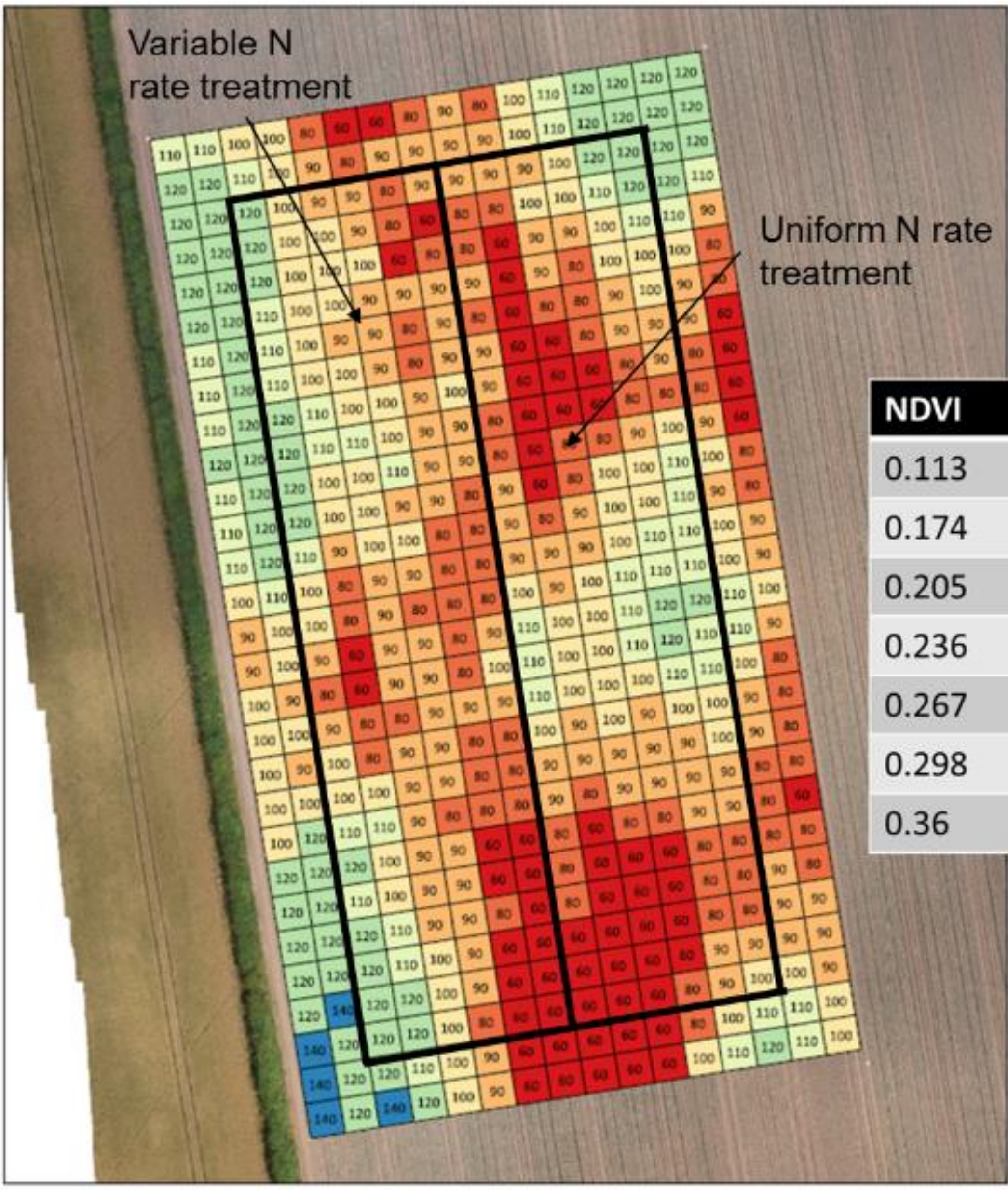


Figure 4. NDVI (26th July) from the whole field using ADC camera (left) and from the tramline area using MCA camera (right)

[1] An area of each of the tramline treatments was mistakenly harvested by the farm. The actual number of 6 x 5m plots harvested and weighed for the trial was 105 for the uniform nitrogen rate and 121 for the variable nitrogen rate treatment.



NDVI	N Rate
0.113	140
0.174	120
0.205	110
0.236	100
0.267	90
0.298	80
0.36	60

Figure 5. Prescription N application plan for tramline treatment areas

Results and discussion

Nitrogen response experiments

Soil mineral N samples (0-90 cm) were taken mid-June prior to planting. The three N response experiments had SMN levels of 69, 64 and 82 kg N/ha respectively, and the tramline experimental area had 78 kg N/ha– giving an average site SNS index of 1.

Crop canopy measurements from the N response plots showed a strong relationship between NDVI and total biomass (Figure 6) and between NDVI and crop N uptake (Figure 7)[2]. An exponential model fitted to the total biomass data accounted for 95% of the variation in NDVI, and an exponential model fitted to the crop N uptake data accounted for 88% of the variation in NDVI. This indicates the canopy sensing can be used to provide a good proxy measure of variation in Savoy cabbage biomass and N uptake during the growing season.

The CropScan sensor measures reflectance at 17 wavelengths which can be used to calculate a number of different vegetation indices. The results presented here only consider the NDVI vegetation index; however additional on-going data analysis is looking at whether any of the other vegetation indices provide a better fit to the biomass and N uptake data.

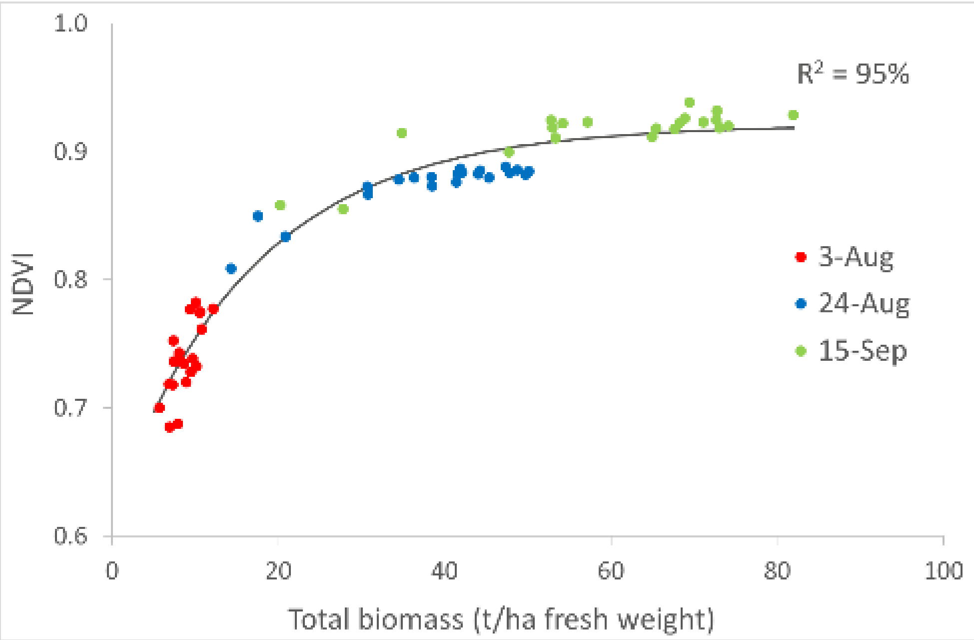


Figure 6. Relationship between NDVI and total biomass

[2] Data presented here excludes the final measurements on 19th Oct. The relationship between NDVI and biomass (but not NDVI and N uptake) is altered when including the 19th Oct measurements; this is possibly due to a combination of senescence of older leaves and the large number of overlapping leaves at the latest sampling date. The relationship between NDVI and biomass/N uptake is most relevant when it can be used to inform N fertiliser applications; the 19th Oct measurements are beyond this time.

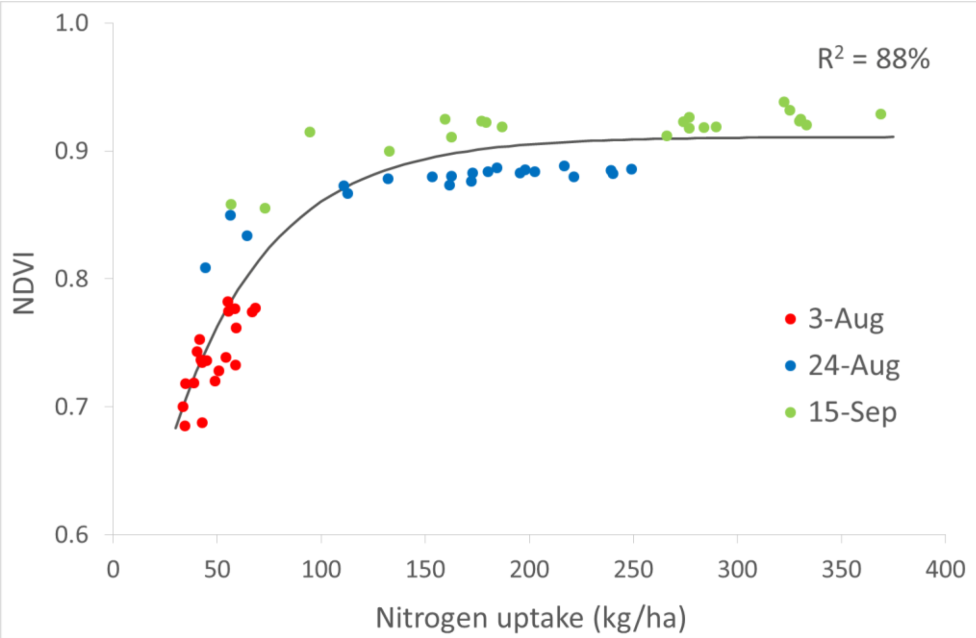


Figure 7. Relationship between NDVI and crop N uptake

There was a significant yield response to N fertiliser (**Table *1***). The percentage of marketable heads (undamaged heads >500 g) increased from a mean of 39% on the zero N treatment, to 90% at 60 kg N/ha and to >97% at rates >180 kg N/ha. Fresh weight marketable yield increased from 10 t/ha (mean marketable head weight of 603 g) on the zero N treatment to 40 t/ha (mean marketable head weight of 1060 g) at the farm standard N rate of 240 kg N/ha and to a maximum of 44 t/ha (mean marketable head weight of 1174 g) at the highest N rate of 360 kg N/ha (Figure 8 and Figure 9).

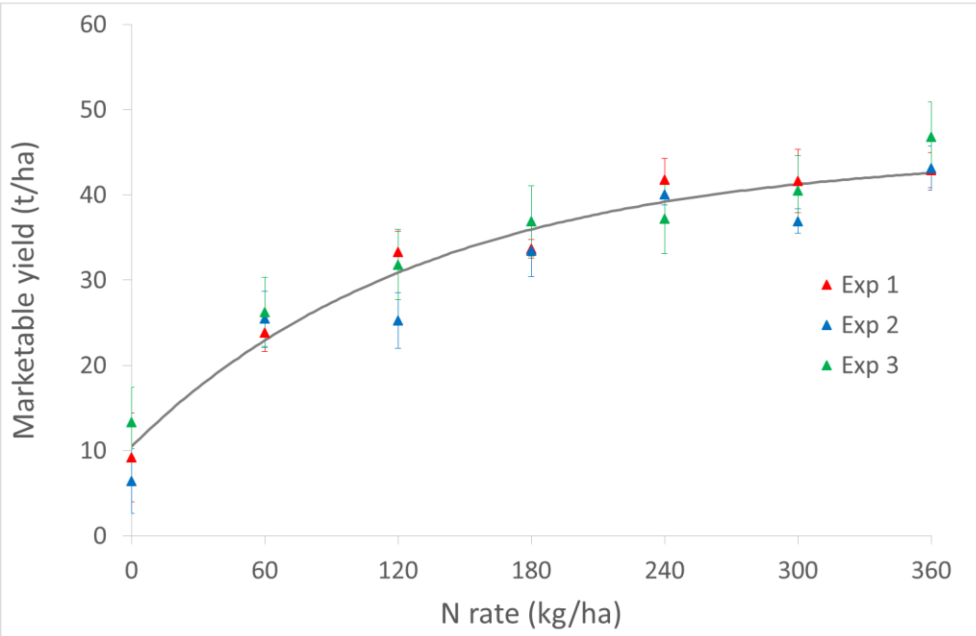


Figure 8. Marketable yield - response to N fertiliser

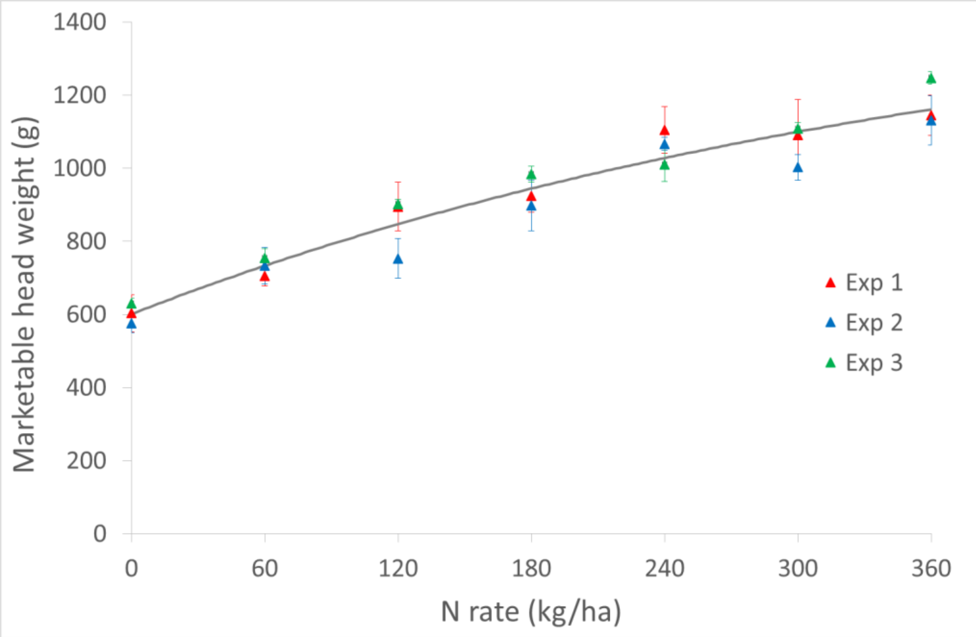


Figure 9. Mean marketable head weight – response to N fertiliser

The savoy cabbage crop is sold at 12 p/head for 500-600g heads (as whole fresh produce for retailers) and at 14 p/kg for heads >600g (for processing). The value of the crop at the different N fertiliser rates was calculated after taking into account the price of N fertiliser (assuming £240/tonne for ammonium nitrate, equivalent to 70 p/kg N). The majority of the crop was sold for processing; at the farm standard N rate of 240 kg N/ha only 2% of heads were in the 500-600g range. Crop value increased from £1650/ha at the zero N treatment, to £5450 at the farm standard N rate of 240 kg N/ha and to a maximum of £5979 at the 360 kg N/ha treatment (Figure 10). The value of the crop after taking into account the cost of the N fertiliser continued to increase with N rate up to the maximum N rate tested of 360 kg N/ha indicating that the economic optimum N rate at this site was >360 kg N/ha.

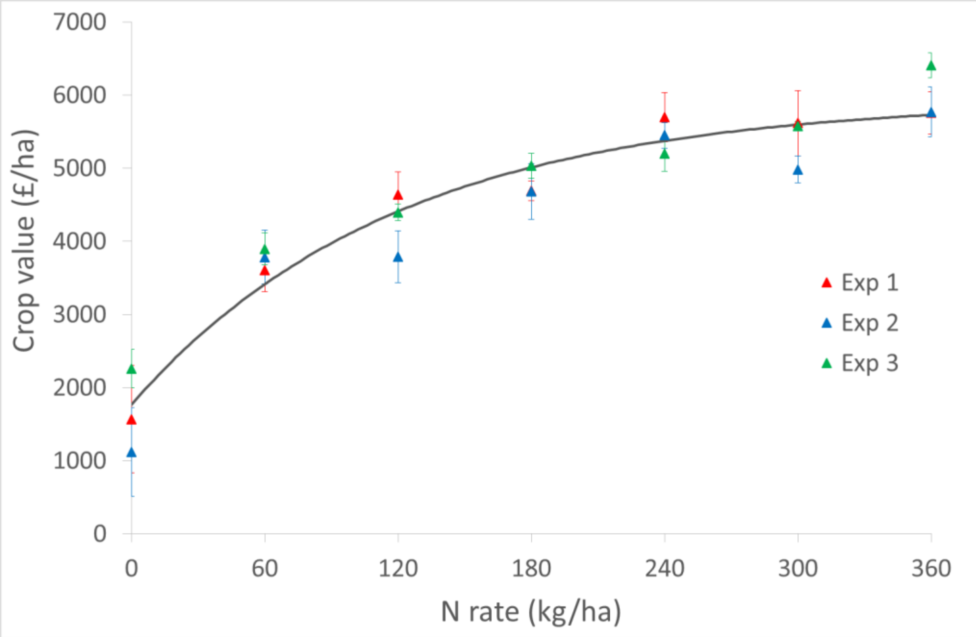


Figure 10. Increase in crop value with N fertiliser (after taking into account cost of N fertiliser)

Genstat was used to fit curves to the marketable yield, marketable head weight and crop value data from the N response experiments. Regression analysis showed that fitting separate curves for marketable yield, marketable head weight and crop value data for each of the three N response experiments was not statistically justified, i.e. the crop response to N did not vary between the three N response experiments. An exponential model was fitted to marketable yield data, marketable head weight data and crop value data from all three N response experiments and explained 81%, 79% and 79% of variation in the marketable yield, marketable head weight and crop value data, respectively.

The total above ground crop N uptake at harvest increased from a mean of 59 kg N/ha on the zero N treatment to 281 kg N/ha at the farm standard N rate of 240 kg N/ha and to a maximum of 326 kg N/ha at the 300 kg N/ha fertiliser rate. Fertiliser N use efficiency[3] decreased from a maximum of 116% at the 60 kg N/ha fertiliser rate to a minimum of 68% at the 360 kg N/ha fertiliser rate. Fertiliser N use efficiency at the farm standard N rate of 240 kg N/ha was relatively high at 92% (RB209 assumes a typical fertiliser N recovery of 60%) indicating that the crop had effectively taken up the applied N fertiliser.

The cabbages were trimmed in the fields and the crop residue (i.e. trimmed leaves) left on the soil surface. The quantity of crop residue increased from 29 t/ha (fresh weight) on the zero N treatment to 47 t/ha at the farm standard N rate of 240 kg N/ha and to a maximum of 49 t/ha fresh weight at the 360 kg N/ha fertiliser rate (**Table *2***). The N in crop residue

[3] Fertiliser N use efficiency = [(Crop N uptake – crop N uptake on zero N control)/Fertiliser N applied] x 100

increased from 29 kg N/ha on the zero N treatment to 151 kg N/ha at the farm standard N rate of 240 kg N/ha and to a maximum of 179 kg N/ha at the 300 kg N/ha N fertiliser rate.

Soil mineral N (0-90cm) measured after harvest in November from the 0, 120, 240 and 360 kg N/ha fertiliser treatments was 7, 10, 13 and 39 kg/ha N, respectively. Although SMN concentrations increased with increasing N fertiliser rate, these SMN concentrations are comparatively low and represent a low risk of overwinter nitrate leaching losses from the farm standard N rate of 240 kg N/ha.

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Table 1. Effect of N fertiliser rate on percentage of marketable cabbage heads, total fresh weight yield, marketable fresh weight yield and average marketable head weight

N rate kg/ha N	% cabbage heads marketable				Total yield (t/ha fresh weight)			
	Exp. 1	**Exp. 2**	**Exp. 3**	**Mean**	**Exp. 1**	**Exp. 2**	**Exp. 3**	**Mean**
0	36	28	55	**39**	38	34	44	**38**
60	88	90	91	**90**	56	57	62	**59**
120	98	87	93	**92**	67	60	76	**68**
180	96	98	98	**97**	75	72	85	**77**
240	99	98	97	**98**	86	86	86	**86**
300	100	97	96	**98**	89	81	94	**88**
360	98	100	98	**99**	91	92	98	**93**

N rate kg/ha N	Marketable yield (t/ha fresh weight)				Mean marketable head weight (g)			
	Exp. 1	**Exp. 2**	**Exp. 3**	**Mean**	**Exp. 1**	**Exp. 2**	**Exp. 3**	**Mean**
0	9	6	13	**10**	603	575	630	**603**
60	24	25	26	**25**	705	733	754	**731**
120	33	25	32	**30**	895	753	902	**850**
180	34	33	37	**35**	923	898	984	**935**
240	42	40	37	**40**	1105	1067	1010	**1061**
300	42	37	40	**40**	1091	1002	1107	**1067**
360	43	43	47	**44**	1144	1131	1247	**1174**

Note – marketable heads are >500g not damaged or diseased.

Table 2. Effect of N fertiliser rate on total N uptake, fertiliser N use efficiency and crop residues

N rate kg/ha N	Total N uptake (above ground at harvest)				N use efficiency (%)			
	Exp. 1	**Exp. 2**	**Exp. 3**	**Mean**	**Exp. 1**	**Exp. 2**	**Exp. 3**	**Mean**
0	58	52	68	59	*	*	*	*
60	122	124	135	127	106	120	111	113
120	159	141	179	159	84	74	92	83
180	207	198	234	213	83	81	92	85
240	280	281	280	281	93	95	88	92
300	332	300	347	326	91	82	93	89
360	295	296	316	303	66	68	69	68

N rate kg/ha N	Crop residues (t/ha FW)				Crop residues (kg N/ha)			
	Exp. 1	**Exp. 2**	**Exp. 3**	**Mean**	**Exp. 1**	**Exp. 2**	**Exp. 3**	**Mean**
0	29	27	31	29	44	42	47	44
60	32	32	36	33	70	69	78	72
120	34	34	44	37	81	81	104	88
180	41	38	48	42	114	106	132	117
240	44	46	49	47	144	151	159	151
300	48	44	53	48	178	163	197	179
360	48	48	51	49	156	157	165	159

Tramline comparisons

Comparison of marketable head weights and total marketable yields from the uniform and variable rate N tramline comparisons showed that marketable yield was an average of 2 t/ha lower ($P<0.05$), and mean marketable head weight was an average of 45 g lower ($P<0.05$) from the variable compared to uniform N rate treatments, respectively. The crop value[4] was equivalent to £4858/ha from the uniform N rate tramline and £4615/ha from the variable N rate tramline.

Lower yields from the variable compared to uniform N rate treatments may indicate that the lower N rate in some areas reduced yields. The N fertiliser rates for the variable rate treatment were allocated based on measured NDVI and the total quantity of N fertiliser applied to the entire variable rate N treatment area was 92 kg/ha N – slightly lower than the 100 kg/ha N applied to the uniform N treatment.

However, comparison of yields from 6 x 5 m sub-plots with comparable initial NDVI values from the variable and uniform rate treatments indicates that the lower overall yield from the variable N rate treatment was unlikely to be due to N;

[4] Crop value (after taking into account cost of nitrogen fertiliser) based on 12 p/head for heads 500-600 g (as whole fresh produce for retailers) and at 14 p/kg for heads >600g (for processing).

Table *3* shows that marketable yields and mean marketable head weights were consistently lower from the variable N rate compared to uniform N rate treatment across the range of measured NDVI values; sub-plots from the variable rate treatment which received 100 kg N/ha (i.e. the same as the flat rate treatment) yielded 33 t/ha compared to 36 t/ha from uniform N rate treatment. There was no evidence that higher N rates (110 and 120 kg N/ha) to thinner areas of crop increased crop yields compared to the standard uniform N rate (100 kg N/ha). These results indicate that the initial variation in crop canopy assessed as NDVI four weeks after planting was not a result of differences in N availability or crop N demand.

Table 3. Marketable yields and mean marketable head weights from the variable and uniform N tramline comparisons

NDVI	N fertiliser rate (kg N/ha)		Marketable yield (t/ha fresh weight)		Mean marketable head weight (g)	
	VR N	Uniform N	VR N	Uniform N	VR N	Uniform N
0.36	60	100	34	37	899	979
0.298	80	100	36	36	943	950
0.267	90	100	34	35	893	932
0.236	100	100	33	36	878	938
0.205	110	100	33	35	883	914
0.174	120	100	34	35	897	907
		Overall mean	***34***	***36***	***898***	***943***

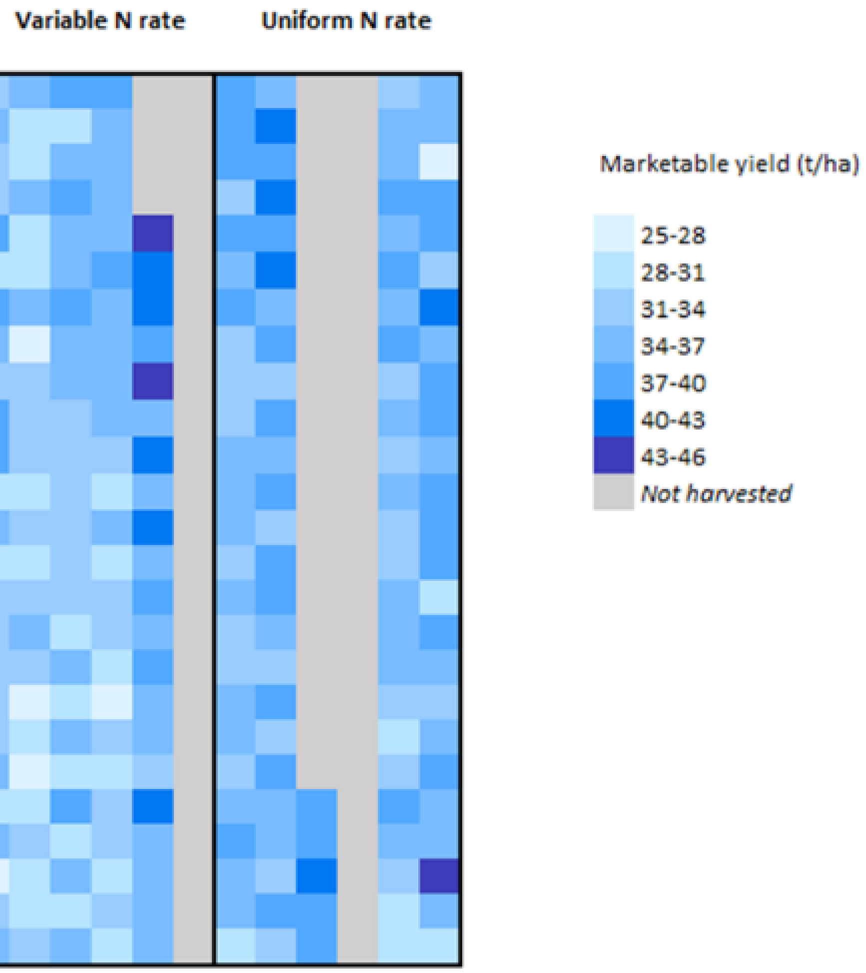


Figure 11. Yield map of tramline comparisons

However, comparison of leaf tissue analysis (sampled at the second N application four weeks post planting) from areas of cabbage which were identified as having low and high NDVI values (i.e. thinner and thicker crop canopy) did not provide any evidence that the differences in crop canopy could be attributed to differences in the availability and uptake of other plant nutrients (Table 4). There were no significant difference in leaf tissue analysis between low and high NDVI areas with the exception of Zn (P<0.05) and Fe (P=0.05). Leaf tissue Zn concentrations in the low NDVI areas were lower (31 mg/kg Zn) than in the high NDVI areas (33 mg/kg Zn). However Zn deficiency is very rare in the UK and Zn tissue analysis from the low NDVI areas was still above the threshold of 15-20 mg/kg Zn for indicating Zn deficiency[5]. Leaf tissue Fe concentrations were actually slightly lower in the high NDVI areas.

Table 4. Leaf tissue analysis from area of lower and higher NDVI

	N	**P**	**K**	**Mg**	**Ca**	**S**	**Mn**	**Cu**	**Fe**	**Zn**	**B**
	%					**mg/kg**					
Low NDVI	5.3	0.6	4.1	0.3	2.0	1.1	198	5.9	93	31	23
High NDVI	5.3	0.6	4.0	0.3	1.8	1.2	207	6.0	88	33	24
P-value	*0.71*	*0.16*	*0.28*	*0.36*	*0.25*	*0.34*	*0.39*	*0.56*	*0.05*	*0.03*	*0.35*

Figure 12 shows the frequency distribution of marketable head weights from the variable and uniform rate N treatments. There was no evidence that varying the N rate improved uniformity of cabbage head weights; the standard error of marketable height weights was similar between treatments (3.1 g and 3.2 g from the variable and uniform rate N treatments, respectively).

[5] AHDB Nutrient Management Guide (RB209) Section 6 Vegetables and bulbs (in press)

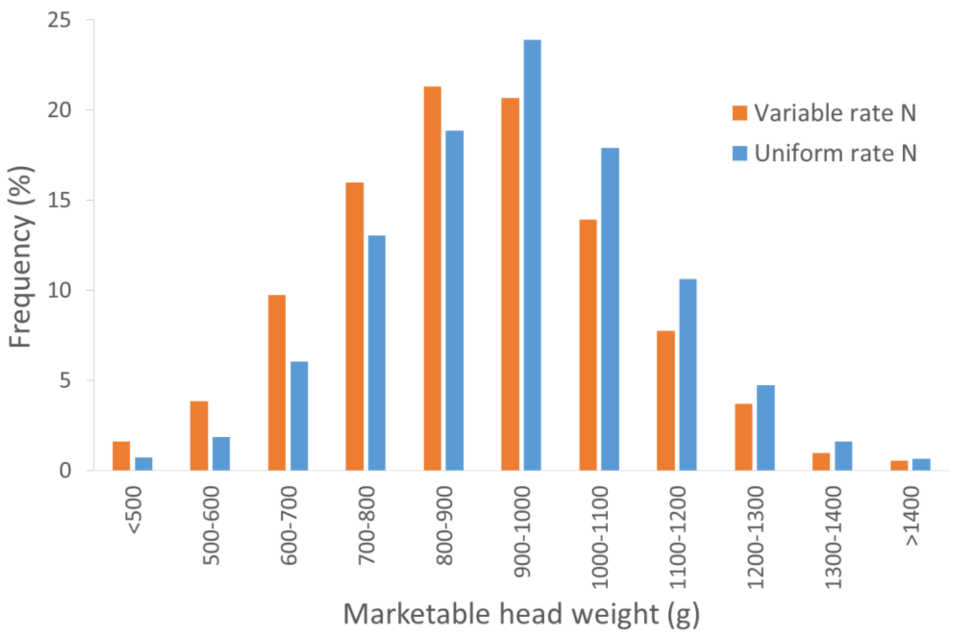


Figure 12. Frequency distribution of marketable head weights

Conclusions

The large yield response to N fertiliser and the strong relationship between crop canopy measurements (NDVI) and above ground crop biomass and N uptake indicate that canopy sensing can be used as a basis to vary N applications and where N availability varies across the field and N is the main factor determining yield variability, we could potentially see improvements in crop uniformity and/or an overall yield increase. However, statistical analysis of N response data from the three experiments showed that, in this case, N response was similar across the length of the field.

Comparison of marketable head weights and total marketable yields from the uniform and variable rate N tramline comparisons indicated that varying the N rate did not increase total marketable yield or produce a more consistent sized crop in this demonstration field.

Variable rate N management will only be of benefit if N is the main cause of variability in the crop canopy. At this site, the N response experiments showed that the crop response to N was similar across the length of the field, and we think it is likely that the variability in crop canopy measured by the UAV was due to other soil or crop factors.

Demonstration open day

A demonstration open day was held on 22nd September 2016. The open day included morning presentations on the project with a specific focus on variable rate N management and the demonstration at Glassford Hammond Farming. In the afternoon, delegates visited the field site and were able to view the N response plots. A soil pit was used to demonstrate methods of visual soil evaluation and methods to avoid and alleviate soil compaction were discussed. In addition, Mount Liming brought an Isaria tractor mounted sensor to show delegates. The programme for the demonstration open day is included in Appendix 1.

The demonstration open day was attended by 21 delegates (excluding ADAS and AHDB staff), including growers, agronomists and representatives from the precision farming industry.

This canopy sensing for variable rate N management demonstration at Glassford Hammond Farming has been written up as a feature for AHDB Grower Magazine (April 2017 edition).

Controlled traffic farming

Background

Barfoots of Botley is a large horticultural grower in southern England with farms at Trotton, Chichester and Little Abshot in Hampshire. The company is developing a long term soil management strategy including the use of cover crops, controlled traffic farming (CTF) and reduced tillage. The main drivers for this strategy were reducing costs (reduced fuel consumption – minimal cultivation, fewer machinery passes, reduced depth of cultivation where possible); soil quality benefits; and associated increases in crop yield. Neil Cairns, the farm manager at Little Abshot Farm, agreed to host the field demonstration, as the farm was in the initial stages of adopting a CTF system for horticultural crops; and the demonstration activities provided the opportunity to compare the previous cultivations and tracking system with the recently adopted CTF system. It was also possible to take baseline soil quality measurements within a year of CTF implementation, with a view to repeating measurements in 4-5 years' time.

The CTF field demonstration at Barfoots contains three elements:

i. Capturing detailed technical information on machinery to compare the extent of tracking and fuel consumption under the previous conventional and recently adopted CTF systems.
ii. A short term field study to investigate within-field soil quality and crop variability under the recently adopted CTF system.
iii. A field study to investigate the long term effects of the recently adopted CTF system on soil quality and health; and implications for productivity, versatility and profitability of the cropping system.

CTF tracking study (Tim Chamen, CTF Europe)

As CTF has been relatively recently adopted at Little Abshot Farm, Barfoots were keen to establish a baseline from which they could measure the percentage reduction in tracking that could be achieved within different rotations.

The field demonstration tracking study was based on a rotation of sweetcorn, pumpkins, tenderstem broccoli (TSB) and beans with the addition of cover crops whenever possible. Detailed technical information was collated for all the machinery before and after CTF adoption, including track gauges (distance between wheels on an axle) and implement working widths. This data was then used to establish an operational sequence of field operations for both the conventional and CTF systems, as indicated in Table 5.

Table 5. Operations before and after the introduction of CTF in a rotation of sweetcorn, pumpkins, tenderstem broccoli and beans

Crop	Operations	Width, m		Operating width, m
	Before CTF		*After CTF*	
All	Subsoiler	3	Primary cultivation	5
	Subsoiler	4	Targeted de-compaction	5
	Primary cult	3	Seedbed preparation	5
	Primary cult	3		
	Primary cult	3		
	Seedbed	5		
	Rolling	6		
	Spraying	24	Spraying	25
	Fertiliser	24	Fertiliser	25
	Irrigation	72	Irrigation	70
	Topping	6	Topping	5
	Topping post harvest	6	Topping post harvest	5
Sweetcorn	Drilling	4.5	Drilling	5
	Plastic laying	4.5	Poly removal	5
	Poly removal	4.5	Hoeing	5
	Hoeing	4.5	Harvesting	5
	Harvesting	4.5	Harvesting	5
	Harvesting	4	Harvesting	5
	Harvesting	10	Harvesting	4
	Harvesting	10	Harvesting	10
Pumpkins	Drilling	4.5	Drilling	5
	Hoeing	4.5	Hoeing	5
	Harvesting		Harvesting	
Tenderstem broccoli	Planting	5	Planting	5
	Fleece removal	5	Fleece removal	5
	Hoeing	1.67	Hoeing	5
	Harvesting	20	Harvesting	20
Beans	Drilling	5	Drilling	5
	Hoeing	1.67	Hoeing	5
	Harvesting	1.67	Harvesting	1.67
Cover crops			Drilled with Topdown	5
			Rolling	5

Results

Before introducing CTF

Figure 13 shows the tracking overlay for all the operations involved in the four-year rotation prior to CTF, including the preparatory operations for all crops each season. This only provides an image of the last series of tracks whereas Figure 14 quantifies these in terms of intensity of coincident passes.

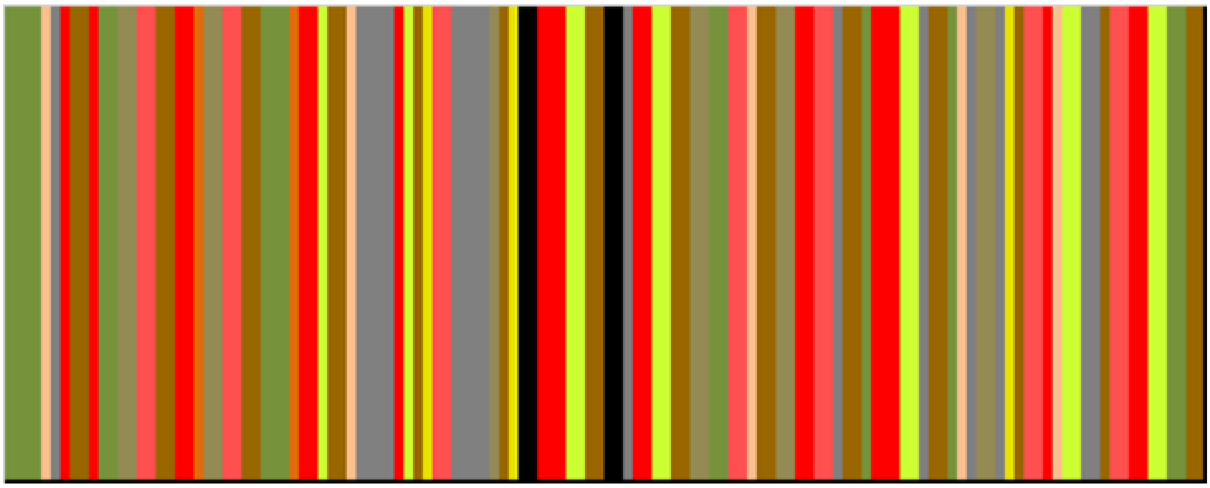


Figure 13. Overlays of tracking for all crops prior to CTF. 100% of area was tracked at least once – see Figure 14 for more detail.

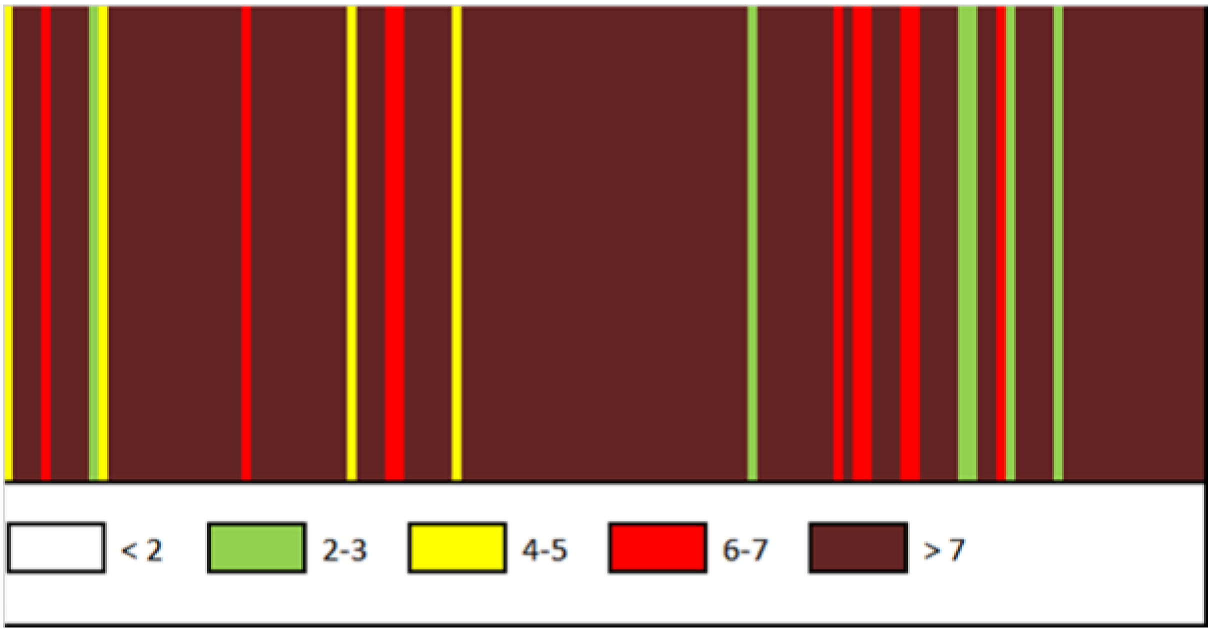


Figure 14. Intensity of tracking – number of coincident passes for all crops prior to CTF.

After introducing CTF

Figure 15 shows tracking for the CTF system, which indicates a 30% reduction (70% versus 100%) compared with the previously less precise operations. However, a large proportion of this tracking is created by just two machines, the 4 m bunker harvester and the 1.67 m bean harvester, which only operate on a small proportion of the harvested area. If these two harvesters could be aligned with all the other machines, tracked area would fall to just below 37% (**Error! Reference source not found.**), i.e. a 63% reduction compared with the traditional system in all areas. **Error! Reference source not found.** presents the tracking for each individual machine in the sweetcorn crop, indicating the degree of tracking overlap under each system.

Figure 15. Overlays of tracking for all crops with CTF. 70% of the area is tracked.

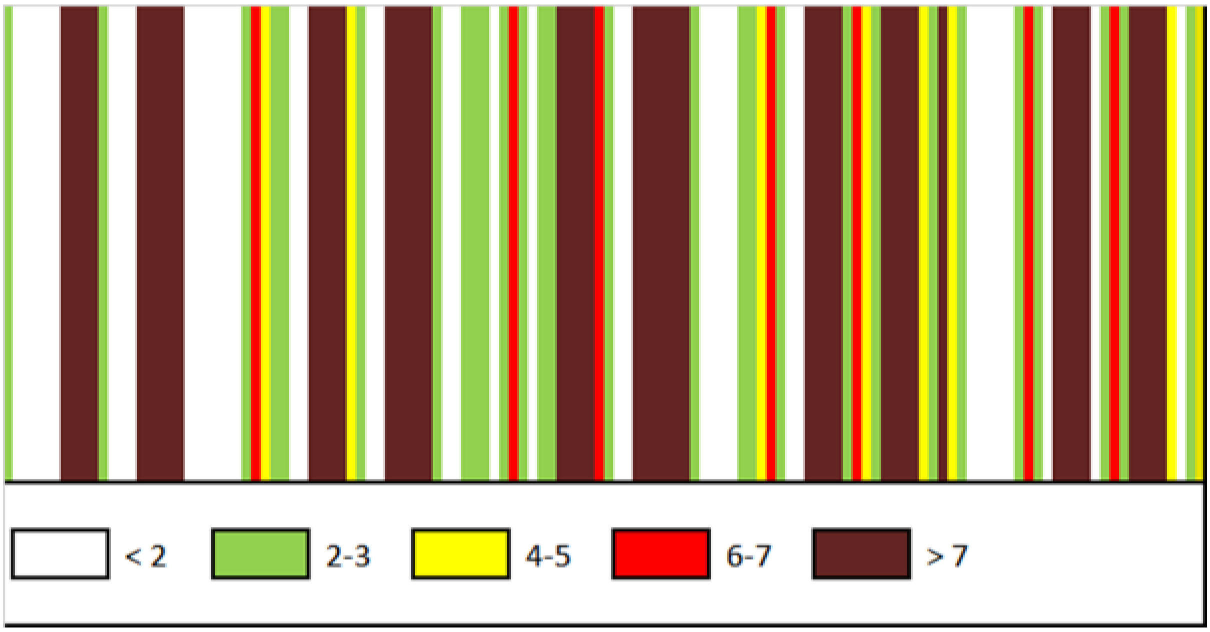


Figure 16. Intensity of tracking - number of coincident passes associated with CTF shown in Figure 15.

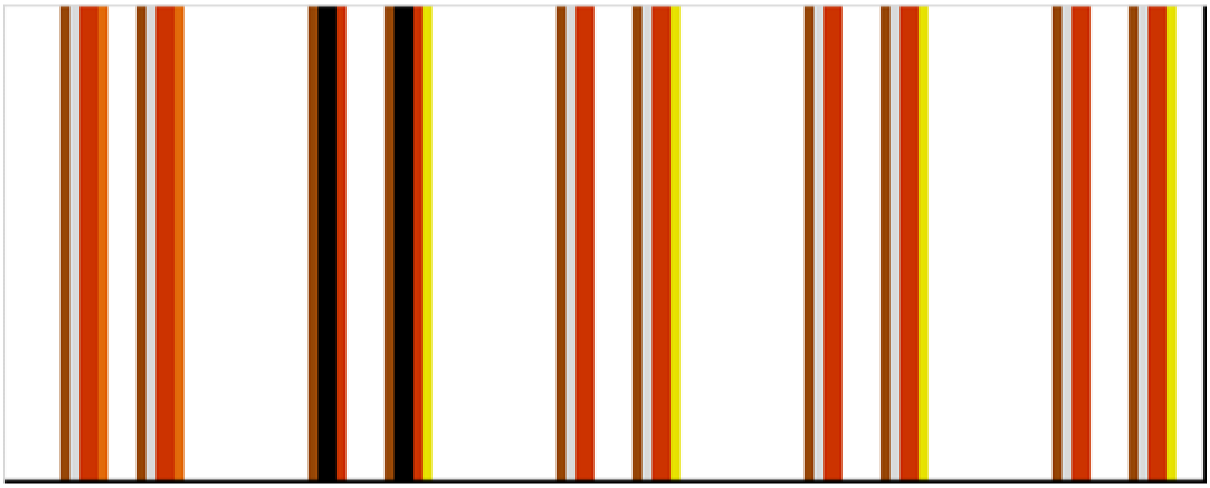


Figure 17. Tracking for all crops without the 4 m bunker harvester or trailed Oxbo harvester. Tracked area is just under 37%.

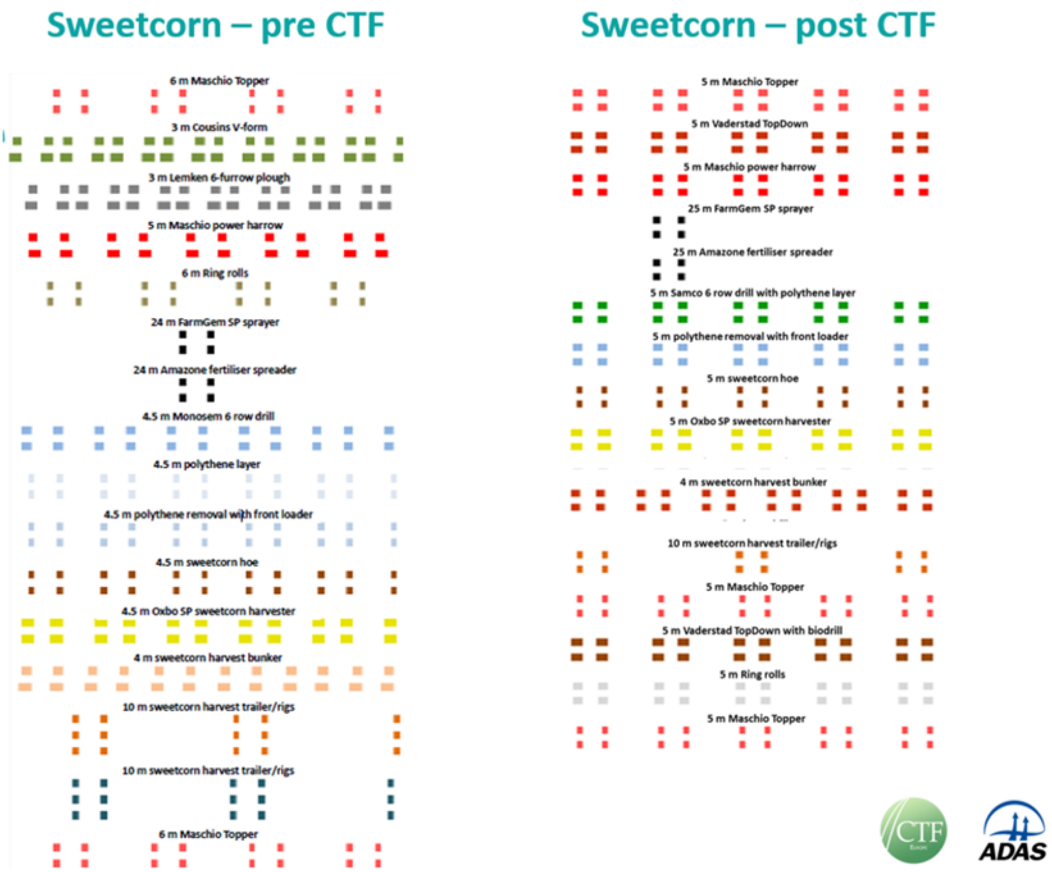


Figure 18. Comparison of tracking in sweetcorn before and after introducing CTF.

Short-term field study - 2017

The short term (1 year) study aims to investigate the effect of CTF and intermediate wheelings, and wheelings from non-CTF traffic on soil quality and crop yield in two sweetcorn fields:

- Yards Field at Easton farm with sweetcorn at 1.67 m wheelings in 2017, following courgettes on 2 m wheelings in 2016.
- Parrett 1 Field at Little Abshot Farm, managed under CTF in 2016 and 2017.

Soil quality and crop growth/yield will be assessed in rows:

i. Adjacent to the drilling wheelings
ii. Where the non-CTF wheelings were in the previous courgette crop
iii. In the non-traffic area (i.e. in the bed).

Both fields were scanned using electro-magnetic induction (EMI) in September 2016 to establish homogeneous soil zones for the field demonstrations.

In spring 2017, sweetcorn will be planted in both demonstration fields and replicated plots (1 row by 20 m) marked out in the following treatments/rows:

- TRT 1 row between intermediate wheelings (least traffic)
- TRT 2 row next to intermediate CTF wheeling
- TRT 3 row next to main wheeling/tramline
- TRT 4 row away from wheelings but near main tramline (in Parrett 1)
  (In Yards Field) Row on previous courgette wheeling

In April/May 2017, the following soil physical measurements will be made:

- Penetrometer measurements to 50 cm depth - maximum resistance and depth of maximum resistance (x 5)
- Dry bulk density at 10-15 cm depth (x 3)
- Visual Evaluation of Soil Structure (VESS assessment) (x 1)
- Assess presence of a tillage pan (x 1)

Sweetcorn establishment will be assessed within each field:

- Number of plants per metre at 5 points per plot
- The height of plants at 10 points per plot

In summer 2017, plant biomass will be measured and crop yield (marketable and unmarketable) and quality assessed. In each plot, a sub-sample of 3 sweetcorn cobs will be taken for determination of dry matter and quality:

- Plant biomass will be harvested to ground level from the first 3 m of each row and the number of plants recorded and weighed.
- The primary cobs will be picked from the remaining 7 m of row including marketable and unmarketable yield from the yield assessment area in each row/plot.
- Number of cobs and total fresh weight will be recorded and photographed.
- Barfoots staff will finally assess cobs for marketable yield counts and weight and sweetness by the Brix method.

The measurements will help determine improvements in soil quality and crop yield resulting from CTF adoption and associated implications for land suitability and versatility for growing high value horticultural crops.

Longer term study - 2016 onwards

The long term study aims to establish baseline measurements in three fields at Little Abshot with contrasting management/land use (CTF; inversion tillage; and permanent grassland) with a view to resampling in 4-5 years. The treatments are the contrasting management/land use in each field:

- Parrett 1 – CTF
- Chilling 3 – Conventional (random traffic) inversion tillage
- Meon – Permanent grass

The three fields were EMI scanned in September 2016 to establish homogeneous soil zones for sampling. Following EMI scanning, the following baseline soil measurements were taken in November 2016:

- 20 penetrometer measurements to 50 cm depth. Penetrometer measurements provided points of maximum, median and minimum resistance. At these points the following assessments were then made:
    - Visual Soil Assessment (VSA) topsoil assessment
    - VESS topsoil assessment
    - Mid topsoil (10-15cm) BD
    - Upper subsoil (30-35 cm) BD
    - Mid subsoil (40-45 cm) BD
    - 40-60 cm penetrometer resistance (maximum resistance and depth of maximum resistance x 3)
    - SubVESS subsoil assessment (30-60 cm depth)

These measurements were also carried out to characterise Yards Field (see short term study).

At the three long term CTF sites (Parrett 1, Chilling 3, Meon) nine additional bulk density measurements were taken from a 10 m x 10 m grid and earthworm counts carried out to further characterise baseline soil physical and biological properties. The location of the bulk density samples and earthworm assessments were GPS logged.

Earthworms were sampled using the following method:

- Three blocks of soil (30 x 30cm x 25 cm deep) per field were extracted and hand searched for a total of 5 minutes
- The base of each hole was then irrigated with two 1.5 litre applications of 100 mg/l allyl isothiocyanate (AITC) at ten minute intervals to bring deep burrowing earthworms to the soil surface for counting
- Earthworms were collected for 10 minutes after each application, washed with water and placed in a labelled sample container
- The adult earthworms were split into three ecotypes (anecic, epigeic and endogeic) counted and weighed for biomass (g)

Field operations will be recorded in each field and, after 4-5 years, sampling areas will be relocated to carry out the same measurements and assess any changes in soil physical, chemical and biological properties, and associated implications for the production system.

Barfoots Demonstration Open Day – 3rd November 2016

Around 50 delegates attended the Barfoots demonstration open day in November 2016 (Appendix 1). The morning session was held at the Queens Head pub in Titchfield, and featured presentations from James Rome (Barfoots) on soil management, Paul Newell-Price (ADAS) on the AHDB Horticulture soil structure survey, Lizzie Sagoo (ADAS) on precision farming tools, and Tim Chamen (CTF Europe) on the principles of CTF in horticultural production and the tracking assessments described above.

The afternoon session comprised a field visit to one of the Barfoots field demonstration sites (Parrett 1), with knowledge exchange sessions on cover cropping and assessing soil structure (introduced by Grant Lumsden of Barfoots and Paul Newell Price of ADAS); and CTF (introduced by James Rome of Barfoots and Tim Chamen of CTF Europe). The open day was featured in an article in the AHDB Grower magazine for December 2016/January 2017, entitled “Taking the pressure off”.

Options for soil mapping

Background

Soil variability (i.e. spatial variability in soil properties such as soil texture, soil depth, stoniness, soil compaction, soil pH, soil nutrient reserves and soil organic matter content) is one of the key factors determining differences in crop yield potential within and between fields It can also affect how fields are managed and the effectiveness of field operations, such as cultivation and seed drilling/planting for crop establishment. Soil mapping is used to delineate the boundaries between soil types and to define or characterise the soil types themselves (e.g. soil nutrient reserves). In the past, this has been achieved using soil survey techniques and a knowledge of how soil types vary within the landscape. However, more recently soil mapping has been carried out using a combination of scanning/sensing techniques to delineate boundaries between soil types; and soil sampling and/or soil survey to determine soil characteristics.

The overall aim of this field demonstration was to use a case study field to demonstrate options for soil mapping, including soil sensing techniques (i.e. soil electrical conductivity/electro-magnetic induction scans and soil brightness) and soil nutrient mapping, and comparing the effect of soil sampling intensity and a grid-based compared to zone-based approach to soil sampling on the soil nutrient maps produced.

Methods

Experimental site

This demonstration was hosted by F.B. Parrish & Son in Avenue field at Chicksands in Bedfordshire. Avenue field is a 10 ha field in an arable and horticultural rotation. The field will be planted with potatoes in 2017 and was previously cropped with:

- 2016 Quinoa
- 2015 Wheat
- 2014 Onions
- 2013 Wheat
- 2012 Potatoes

The soils in this area have developed in a sandy water deposited landscape resulting in significant within-field variability in soil types with most fields having three or more soil series (Figure 19).

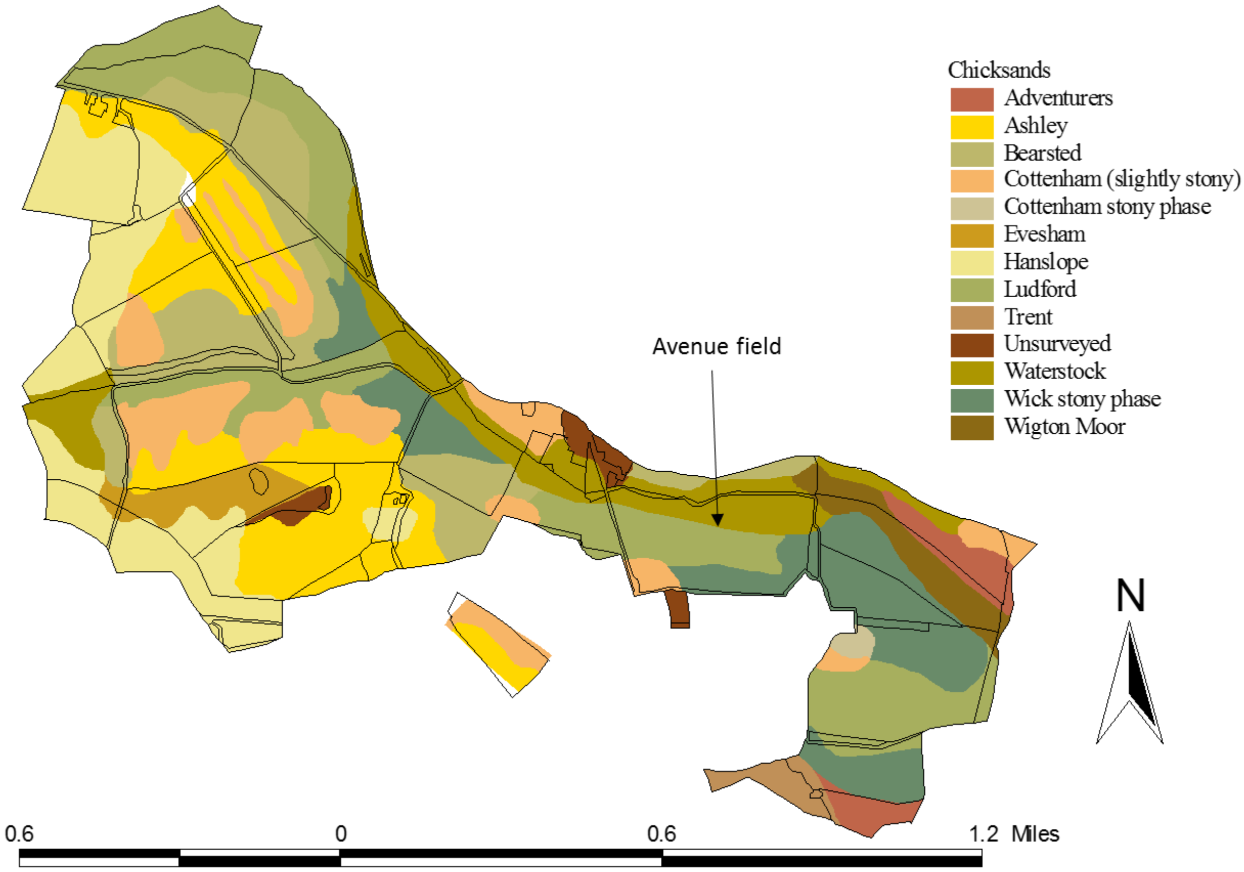


Figure 19. Soil series at Chicksands

Soil sensing

Information on soil electrical conductivity (EC) was collected using a non-contact electro-magnetic induction (EMI) scanner by SOYL on 21/10/16 and using a contact Veris MSP3 scanner by Agrovista on 01/11/2016 (Figure 20). Both surveys were carried out when the field was in stubble prior to cultivation, at bout widths of 24 m across the field. Satellite soil brightness imagery for the field was provided by IPF.

Figure 20. Measuring soil electrical conductivity using a non-contact EMI scanner (left) and a contact Veris MSP3 EC scanner

Soil sampling

Topsoil samples (0-15 cm) were taken from Avenue field in November 2016 using the following sampling methods:

- Single field sample using ‘W’-sampling technique – a single composite sample (of 25 soil cores) was taken by walking a ‘W’-shaped path across the field (Figure 21).
- 1 ha soil sampling – the field was divided into approximately 1 ha blocks and a single composite sample (of 25 soil cores) was taken from each 1 ha block by walking a ‘W’ in each block (Figure 21).
- Grid soil sampling – topsoil samples were taken on a 25 m grid across the field (Figure 22). The 25 m grid was created to include a 10 m ‘no sampling’ buffer zone around the edge of the field (total of 143 soil samples). Each grid sampling point was GPS located. A single composite sample was taken from each GPS located point; each sample consisted of 16 soil cores taken in a spiral within a 3 m radius of the central point.

All soil samples were analysed for pH, extractable P, K and Mg. In addition, the whole field and 1 ha soil samples were analysed for organic matter and particle size distribution (soil texture).

Each green dot represents a single soil core; soil cores were bulked into a single field sample (left) or individual 1 ha samples (right)

Figure 21. Soil sampling at Avenue field; whole field sample (left), 1 ha samples (right)

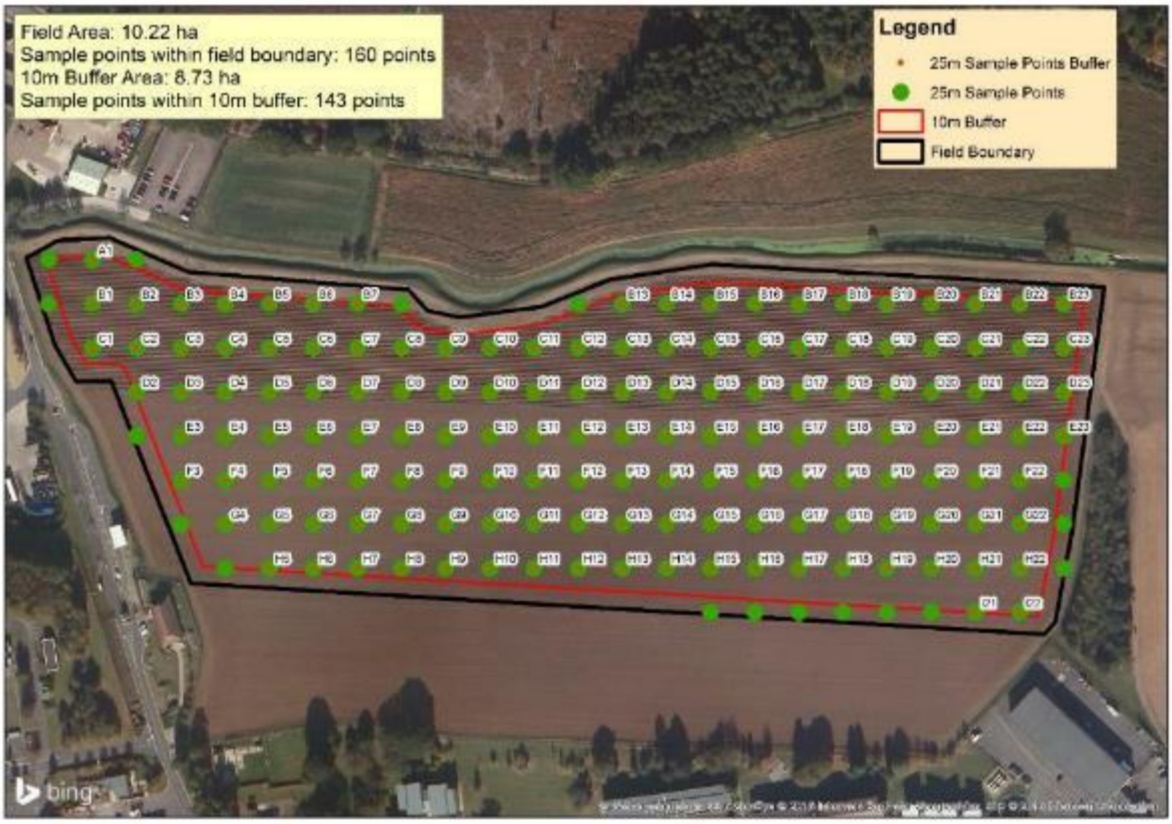


Figure 22. Soil sampling at Avenue field based on 25 m grid

Soil nutrient mapping

The soil analysis results were used to create soil pH and soil extractable P, K and Mg maps for Avenue field. Maps were created to demonstrate grid and zone based sampling strategies and the impact of sampling intensity.

Soil pH and nutrient maps were created using samples taken on a regular 25m, 50m, 75m, 100m and 125m grid. In order to create maps from the individual samples we used a process of spatial interpolation to estimate values at other unknown points to create a contoured map.

Soil pH and nutrient maps were created using three methods of spatial interpolation: inverse distance weighting, nearest neighbour and kriging.

Zone based or targeted soil sampling uses existing knowledge of within-field soil variability to direct soil sampling. Typically the field is divided into a number of zones and each zone is soil sampled separately. Avenue field will be zoned based on:

- Field soil survey (working with IPF www.ipf.co.uk) - *complete*
- Field zones based on soil EC survey – *in progress*
- Field zones based on normalised yield maps – *in progress*

Soil pH and nutrient maps will be created based on the three zoning approaches by taking the average soil analysis result from all of the soil samples taken within each zone. *This work is in progress and is due for completion by the end of May 2017.*

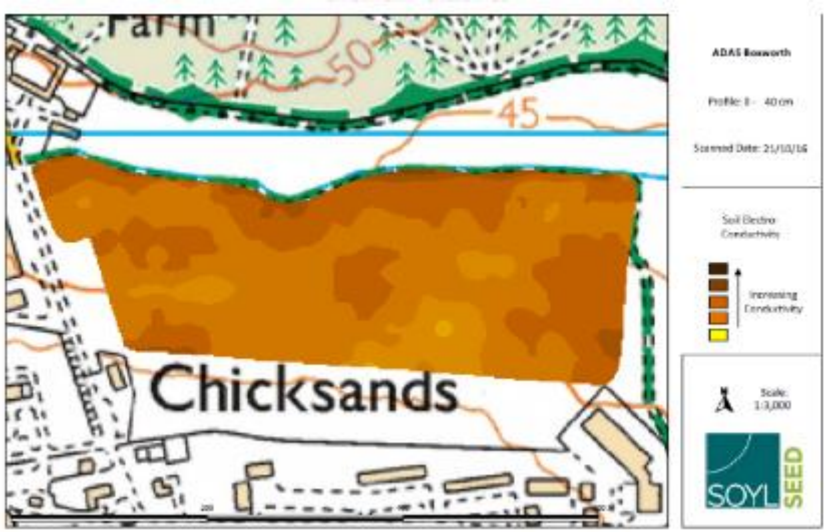
Results and discussion

Soil sensing

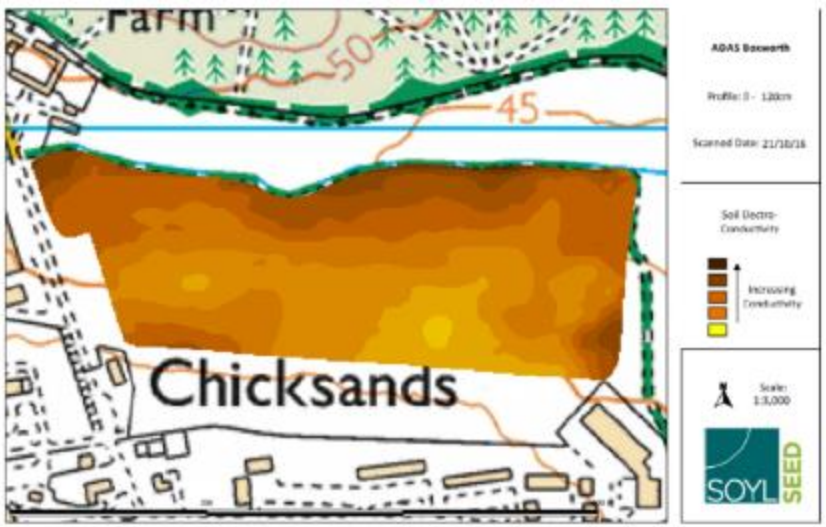
Soil electrical conductivity (EC) surveys can be used to map within-field soil variability. The main factors affecting soil EC are soil texture, organic matter content, moisture content and bulk density. Light sandy soils have lower EC and heavier textured soils have a higher EC. Figure 23 shows soil EC maps for Avenue field produced from the SOYL non-contact EMI scanner and Agrovista's contact Veris MSP3 EC scanner. Both machines measure EC/EMI at two depths; SOYL's EMI sensor measures shallow EC to 40 cm depth and deep EC to 120 cm, the Veris MSP3 sensor measures shallow EC to 30 cm and deep EC to 50 cm depth.

Both the EC and EMI maps of Avenue field identified lighter textured areas on the south side of the field (on a slight ridge) and heavier textured areas on the north and North West side of the field. Both EC and EMI scanners provide information on soil variability that is broadly comparable. Any apparent differences between EC/EMI maps may reflect:

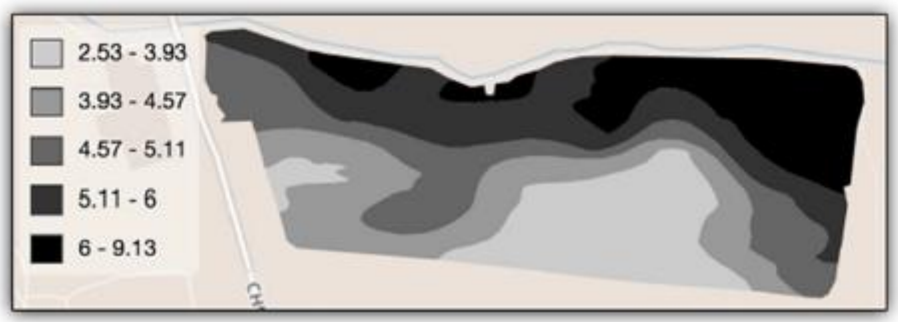
- Differences in scan points between mapping (i.e. machines not driving in exactly the same place).
- Data interpolation between measurements.
- Scale used for the map.
- Depth of measurement (the Veris MSP3 scanner provides shallower readings).



EMI scan – shallow 0-40 cm



EMI scan – deep 0-120 cm



EC scan – shallow 30 cm

EC scan – deep 50 cm

Figure 23. Avenue field soil electrical conductivity surveys

Soil brightness maps are obtained from satellite imagery and describe how intensively the surface layer of bare soil reflects incoming sunlight. They provide an integrated measure of the combined effects of soil texture, organic matter content and soil moisture at the time the image was taken. Figure 24 shows a soil brightness map of Avenue field. Soil brightness can be used to identify spatial variation in soils, although the imagery does not provide absolute values and the colour range will vary depending on time of data acquisition, soil moisture and method of cultivation. Soil brightness images only provide reliable information when the soil is completely bare. The presence of stubble or other crop residue will affect the image and hinder interpretation.

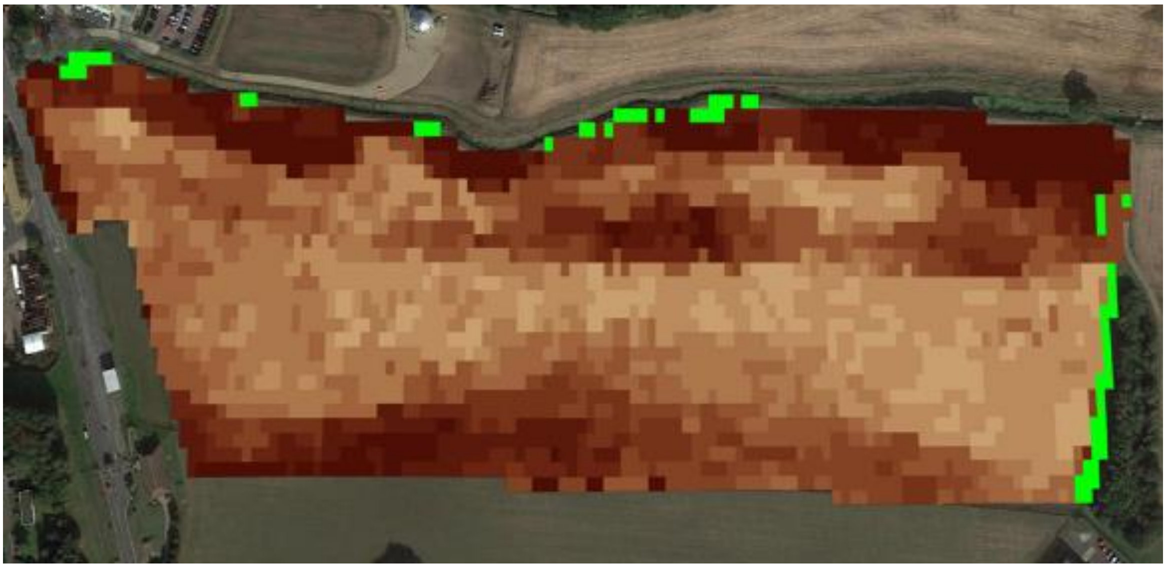


Figure 24. Avenue field soil brightness map

Soil sampling

Table 6 compares soil analysis results from the single (i.e. bulked) whole field sample with the mean and range of soil analysis results from the 143 grid soil samples for pH, P, K and Mg. The whole field soil sample provided a good measure of the mean field value for pH and P Index, but underestimated soil K and Mg Indices. The 25 m grid soil samples indicated significant within-field variability in soil pH and nutrients; soil pH varied from 5.3 to 7.1, P Index from 2 to 4, K index from 1 to 4 and Mg Index from 2 to 4.

Table 6. Avenue field soil analysis for pH, P, K and Mg – comparison between the whole field soil sample and range and mean values from intensive grid sampling (143 samples)

	pH	**P**		**K**		**Mg**	
		mg/l	Index	mg/l	Index	mg/l	Index
Mean	6.1	35	3	217	3	110	3
Min	5.3	16	2	92	1	53	2
Max	7.1	55	4	428	4	215	4
Whole field	6.1	33	3	171	2-	77	2

Table 7 compares soil analysis results from the single whole field sample with the mean and range of soil analysis results from the ten 1 ha grid samples for organic matter and % sand, silt and clay.

Table 7. Avenue field soil analysis for organic matter and % sand, silt and clay – comparison between the whole field soil sample and range and mean values from 1 ha soil sampling (10 samples)

	Organic matter	% Sand	% Silt	% Clay
Mean	3.1	63	22	15
Min	2.1	54	16	10
Max	4.1	73	26	20
Whole field	2.6	67	20	13

Soil zoning

Soil zones were created for Avenue field by IPF (www.ipf.co.uk), based on a field soil survey and soil brightness imagery. Figure 25 shows the soil zones for Avenue field; a description of the soil zones is provided below.

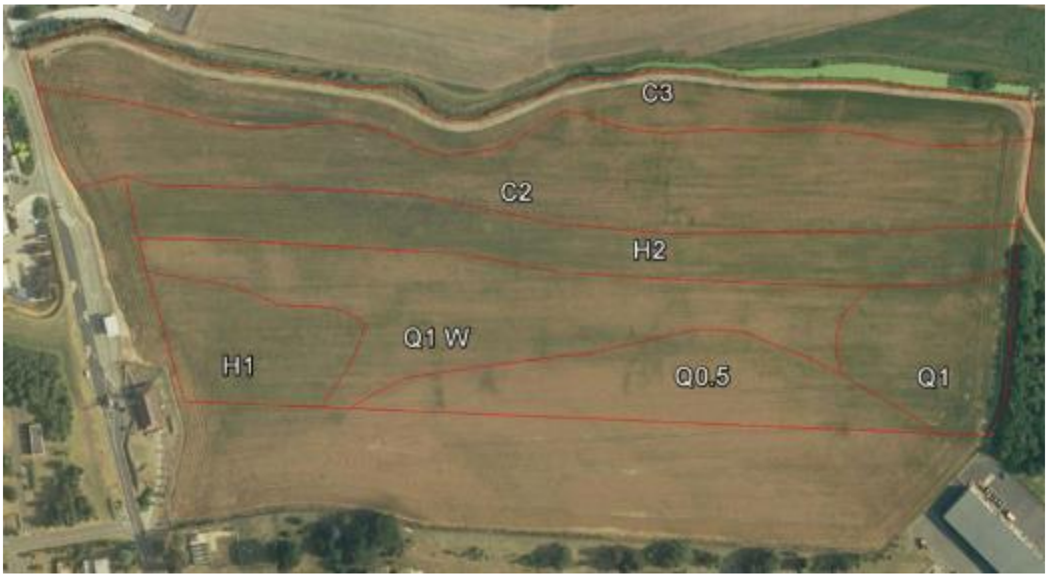


Figure 25. Avenue field soil zones

Description of the soil zones (as shown in Figure 25)

- H1 is deep stoneless sandy loam; H2 is deep stoneless medium clay loam. H1/H2 soils are developed from Lower Greensand.
- C2 is medium clay loam with few stones; C3 is heavy clay loam over mottled clay with few stones. C2/C3 soils are developed from Head (clay, silt, sand and gravel). C3 is prone to seasonal drainage impedance due to low lying position and clayey subsoil.

- Q0.5 is loamy sand over stony sandy loam and loamy sand. Q1 is sandy loam over stony loamy sand. Q0.5/Q1 soils are developed from glaciofluvial deposits. Q0.5/Q1 is prone to drought due to light textures and light, stony subsoil.

In addition to the soil survey method of defining soil zones, soil zones will also be created based on soil EC maps and a 'normalised' (averaged) yield map. Yields maps were available from winter wheat in 2010, 2013 and 2015. A normalised yield map was created for the field by Farmplan using the GateKeeper software (Figure 26).

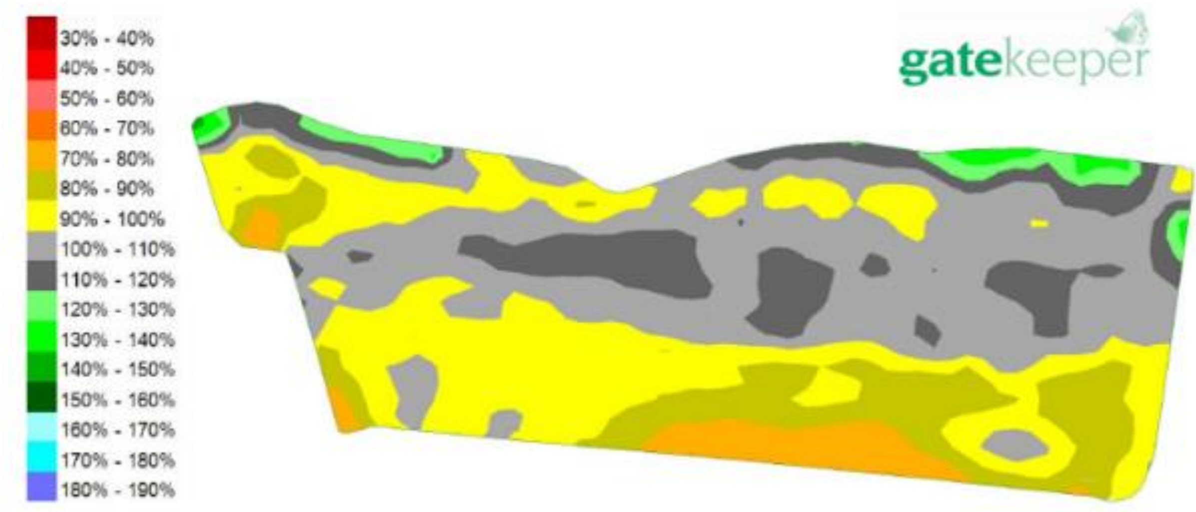


Figure 26. Normalised yield map for Avenue field based on 3 years of winter wheat yields (2010, 2013 & 2015)

Once the soil EC and yield map zones have been defined, soil pH and nutrients will be mapped based on the soil zones. *This work is in progress and due for completion by end of May 2017.*

Soil mapping

The soil mapping work is in progress and the maps presented here are provisional.

Figure shows the soil analysis results for pH and extractable P, K and Mg from the 25 m grid-based sampling, displayed as data points on a map of the field. Soil pH and extractable K exhibit significant small scale variability. Soil extractable P and extractable Mg maps show gradients that appear to relate to soil texture; soil extractable P concentrations were higher and soil extractable Mg concentrations lower in the northern, heavier textured part of the field.

The raw data points were converted into contoured maps. ***Figure*** shows soil pH maps and Figure soil extractable P maps based on 25 m, 50 m, 75 m and 100 m grid samples. These maps were created using the Inverse Distance Weighting method of data interpolation;

additional maps are being produced using Nearest Neighbour and Kriging methods of data interpolation.

Typically, when taking grid-based soil samples, most precision farming companies will take one soil sample per hectare (on a 100 m grid). These maps highlight the impact of soil sampling intensity on the soil pH and nutrient maps produced. Where there is significant small scale variability, for example soil pH in Avenue field:

i. This variability can be concealed when only taking one sample per hectare.
ii. Taking point soil samples within a confined area (e.g. within a 3 m radius of a sampling point) may give undue weight to the soil property value at that single point, particularly at lower sampling intensities.

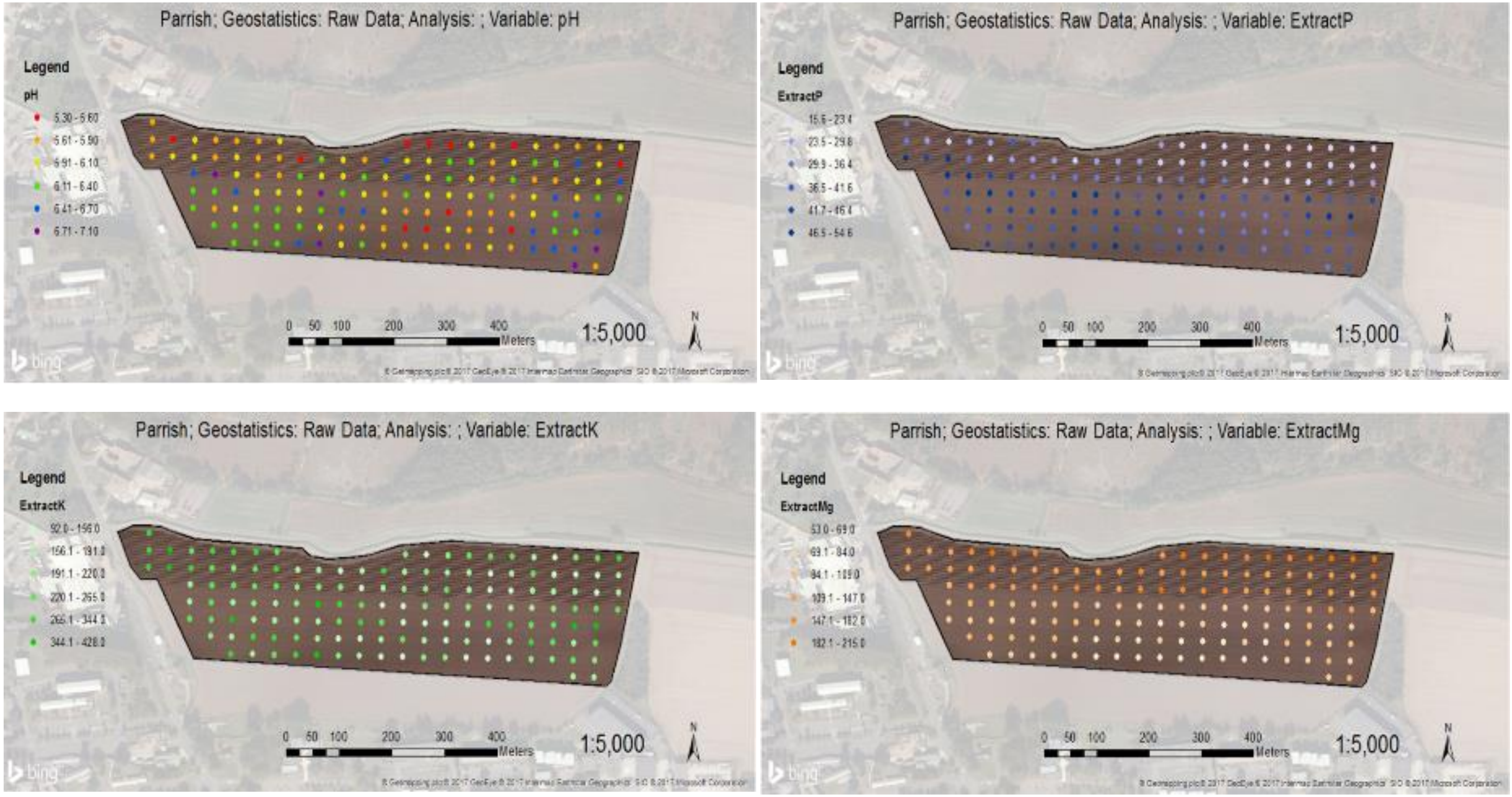


Figure 27. Avenue field soil pH, extractable P, K and Mg - raw data points

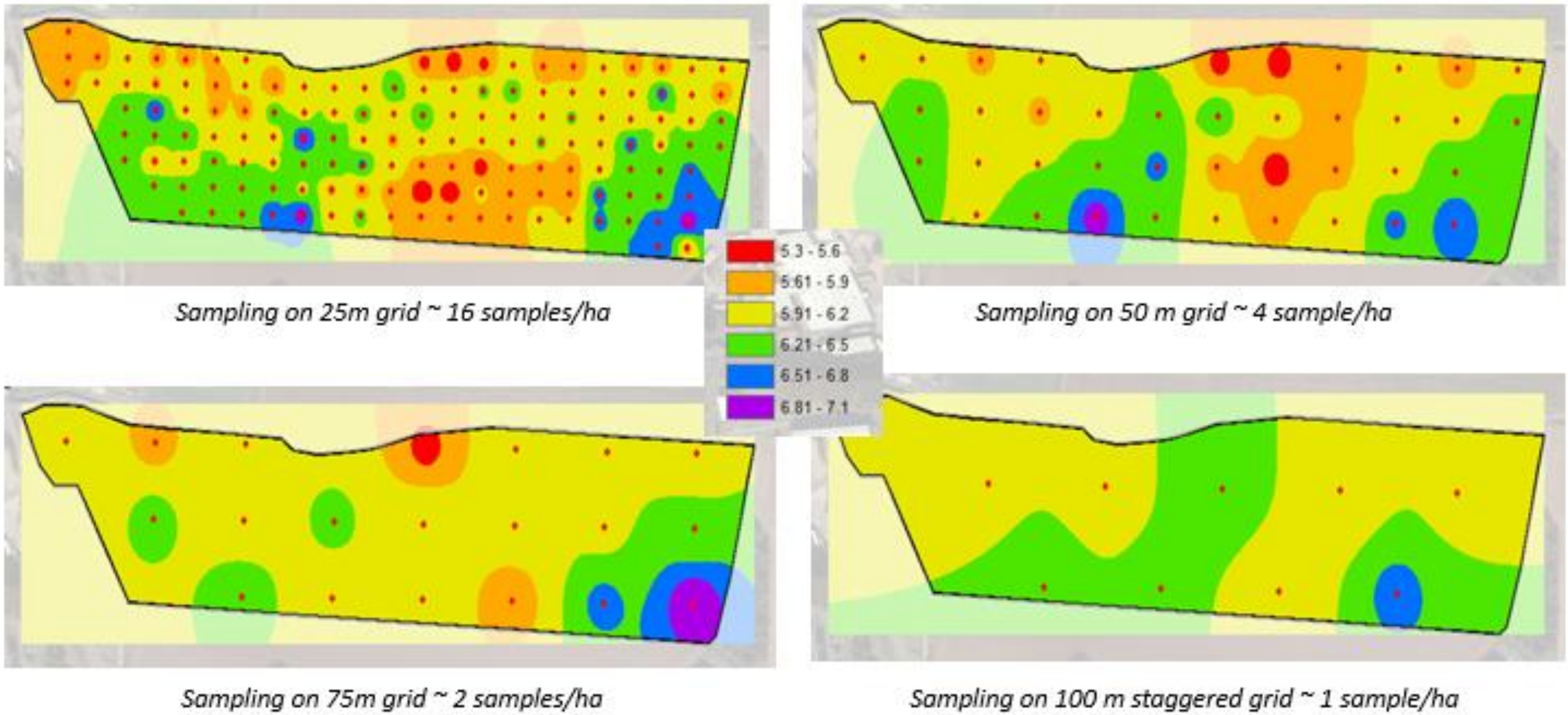


Figure 28. Avenue field soil pH

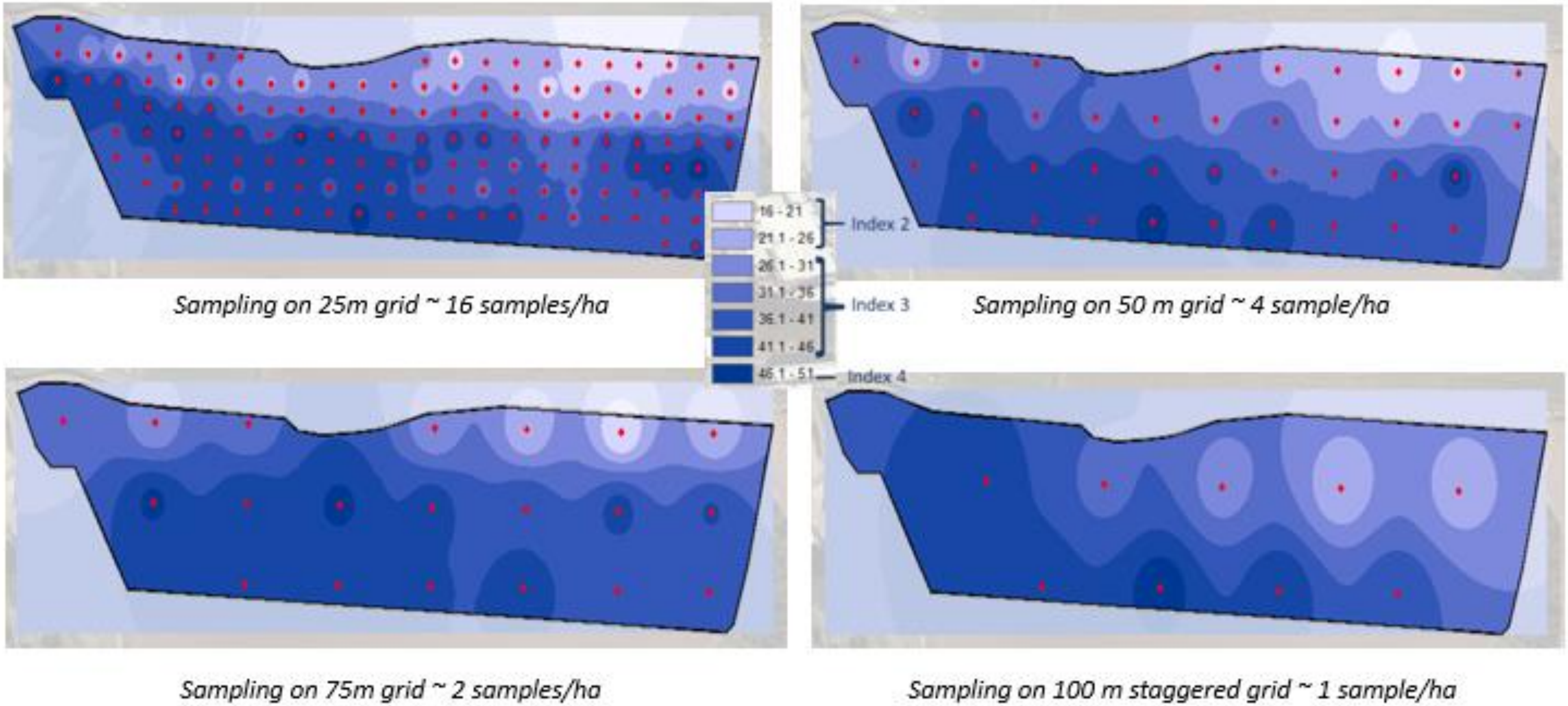


Figure 29. Avenue field soil extractable P

Conclusions

The Avenue field demonstration provides a case study to discuss the principles and methods of soil mapping with growers, in particular –

- Soil sensing methods (soil EC scans and soil brightness maps).
- Difference between grid and zone based soil sampling.
- Methods and information that can be used as a basis for creating soil zones.
- Data interpolation – understanding how the precision farming providers produce a contoured map from point soil samples.

Both grid and zone based soil sampling are valid options and both have advantages and disadvantages. Unless the grid is dense enough, grid sampling may miss patterns and boundaries evident from looking at soil surveys or yield maps. The soil pH maps from Avenue field demonstrate the impact of sampling intensity on soil maps; the 100 m grid soil samples did not identify some of the areas of low pH apparent on the 25 m grid sample map.

Grid sampling is typically more expensive than zone sampling as a greater number of soil samples are usually taken. Zone sampling uses other sources of information to help decide where to target soil sampling. However, there may be patterns in soil fertility, which could be identified using grid sampling, but may not be detected using zone sampling.

Once created, soil pH and nutrient maps can be converted into prescription maps for variable rate fertiliser or lime application. A prescription map is an electronic data file which is used to control the variable rate fertiliser spreader. Variable rate fertiliser application maps are typically based on RB209 fertiliser recommendations at different soil indices and lime recommendations for different soil pH values.

Potential advantages of variable rate fertiliser or lime include:

- Cost savings in fertiliser or lime through not over applying to areas of higher soil nutrient Index or soil pH.
- Potential for increased yields where lower index areas of a field would otherwise have been under-fertilised/limed.
- Reduced variation of within field soil pH and nutrient variability over the longer term.

Demonstration open day

A demonstration open day was held on 7th February 2017. The open day included morning presentations on the project with a specific focus on soil mapping and the Avenue field case study. In the afternoon, delegates visited the field site and were able to look at how soil texture varied across the field. Soil pits were dug in contrasting soil types and used to demonstrate methods of visual soil evaluation and discuss methods to avoid and alleviate soil compaction. In addition, Mount Liming brought the Veris MSP3 scanner to show delegates. The programme for the demonstration open day is included in Appendix 1.

The demonstration open day was attended by 25 delegates (excluding ADAS and AHDB staff), including growers, agronomists and representatives from the precision farming industry.

This soil mapping demonstration at F.B. Parrish & Son is due to be written up as a feature for AHDB Grower Magazine later in 2017.

Year 2 (2017) field demonstrations

The final year of the project includes three additional field demonstrations experiments. The field demonstrations aim to quantify the benefit of selected precision farming techniques for improved soil and nutrient management in horticulture cropping systems

Canopy sensing for variable N applications – North Yorkshire, Brussel Sprouts

Background

Canopy sensors for N fertiliser management measure crop light reflectance and use this information to adjust N fertiliser rates accordingly. Canopy N sensors are increasingly being used on cereal and oilseed crops in the UK. There is interest from growers in the potential of variable rate N applications to improve crop uniformity and yields in horticultural crops.

Aim

To demonstrate the potential for canopy sensing for variable rate N applications in selected horticultural crops.

Approach

- N response experiments within different areas/zones of a single field to understand how the optimum N rate varies across the field.
- Measurement of crop canopy and production of prescription variable rate N fertiliser maps.
- Validation of variable N rate using tramline comparisons of variable rate and standard rate.

Focus on variability – G's growers, Cambridgeshire (lettuce)

Background

Precision farming tools such as soil mapping, canopy sensing and yield mapping can provide growers with valuable information about the variability of their soils and crops. Better understanding of the variability within fields enables this variation to be managed.

Aim

To demonstrate the precision farming tools available to identify variation and how best to use these tools to help quantify, understand and manage variability.

Approach

- Use available precision farming tools to gather information on variability within a single field (i.e. EMI scanning, soil brightness maps and canopy sensing).
- Targeted field investigations to understand the cause of measured variation.
- Produce a decision support checklist to guide growers through the process of assessing, investigating and managing variability.

The demonstration day will be held as part of the NIAB Lettuce varieties open day on 22nd June.

Controlled traffic farming – location to be confirmed

Background

Controlled traffic farming aims to confine soil compaction to the least possible area of permanent traffic lanes. The benefits of CTF include increased yields, lower production costs and benefits to the environment. The main challenges in adopting CTF in horticulture are the costs associated with adjusting the machinery system.

Aim

To demonstrate and discuss the benefits, limitations, challenges and trade-offs associated with adopting controlled traffic principles in tree nursery and top fruit production systems.

Approach

- Discuss soil and nutrient management challenges and strategies within tree nursery and top fruit systems; drawing from project case studies and other demonstration activities on assessing soil and crop variability.
- Capture the potential changes in machinery set up and use associated with adopting a CTF system; and related costs, benefits, challenges and trade-offs within a tree nursery or top fruit production system.
- Detailed measurements of soil physical properties (soil structure) and soil health to provide baseline soil information and enable longer term assessments of improvements to the condition of the soil.

Knowledge and Technology Transfer

Demonstration open days

Each of the 6 field experiment/demonstration sites will host an open day (3 open days in years 2 and 3). Three demonstration open days were held in year 2 of the project:

- Canopy sensing for variable rate N management: 22nd September 2016 at Glassford Hammond Farming, Notts.
- Controlled traffic farming: 3rd November 2016 at Barfoots, West Sussex
- Options for soil mapping: 7th February 2017 at F.B. Parrish & Son, Beds.

A further three events are planned for 2017. Dissemination and knowledge exchange activities at the demonstration plot sites will help growers to assess tools and techniques that would be most likely to improve soil and nutrient management practices and production efficiency on their farms. Each field demonstration open day will include:

- Demonstration of the precision/management technique featured at that site. Including machinery and field demonstration plots specific to the site.
- Soil pits for the demonstration of visual soil evaluation and information on methods to avoid and alleviate compaction.

Other project meetings and knowledge transfer activities

There were a number of additional project meetings, events and press articles in year 2 of the project (April 2016 to March 2017).

Meetings & events

- Third project steering group meeting, 18th January 2016
- GREAT soils event, 21st September 2017 at Riviera Produce Cornwall. Presentation:
    - *'Taking the compact out of compaction'*
- Elsoms open day 12-13th October 2016. 'Mini' presentations:
    - *'Soil structural condition in horticultural systems'*
    - *'How can we use precision faming tools to improve soil and nutrient management in horticulture?'*
- Brassica and leafy salads conference, 25th January 2017. Presentation:
    - *'State of our soils and potential for precision farming to improve soil and nutrient management'*

Press articles

- AHDB Grower magazine, June 2016
    - *'AHDB demonstrates soils research results'* (in news section)
- AHDB Grower magazine, June 2016
    - *'Breaking new ground'* (feature article including results from soil structure survey and precision farming review).
- Vegetable Farmer magazine, August 2016
    - *'Increased awareness of soil health does not make management easier'* (feature article)
- AHDB Grower magazine, December 2016/January 2017
    - *'Take the pressure off'* (feature article from CTF demonstration day at Barfoots).
- AHDB Grower magazine, March 2017
    - Cover crops and precision farming feature in soils events (in news section)
- Vegetable Farmer magazine, March 2017
    - *'Precision farming project demonstrates savings'* (in news section based on CTF demonstration at Barfoots)
- AHDB Grower magazine, April 2017 (in press)
    - *'Does it pay to be precise?'* (feature article on variable rate N demonstration at Glassford Hammond Farming).

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Knight, S., Miller, P and Orson, J. (2009). An up-to-date cost/benefit analysis of precision farming techniques to guide growers of cereals and oilseeds. HGCA Research Review 71.

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Appendix 1: Demonstration open day invites

AHDB HORTICULTURE

GREAT soils
Resilience, productivity and life

Improving soil and nutrient management in horticulture

With a focus on precision technologies and field demonstration of variable rate nitrogen fertiliser application to savoy cabbage

ADAS Gleadthorpe, Meden Vale, Mansfield, Nottingham, NG20 9PD
Followed by
Farm visit to Glassford Hammond Farming
With kind permission of Phil Lilley, Glassford Hammond Farming

Thursday 22nd September 11 am – 3 pm

Precision technologies offer growers opportunities to improve soil and nutrient management, with the potential to increase yields and profitability.

AHDB Horticulture Project CP107c aims to evaluate the current and future potential of precision farming techniques to optimise soil and nutrient management in horticulture. Join AHDB Horticulture, Glassford Hammond Farming and ADAS to discuss soil and nutrient management and view field demonstrations on variable rate nitrogen applications to Savoy Cabbage.

10:45	**Registration and refreshments**	
11:00	Welcome & introductions	Andy Richardson, Allium & Brassica Centre
	How can we use precision farming tools to improve soil and nutrient management?	Lizzie Sagoo, ADAS
	Canopy sensing to improve crop N management	David Whattoff, SOYL
	Soil structural condition in horticulture systems	Paul Newell Price, ADAS
12:30	**Lunch**	
13:15	Introduction to Glassford Hammond Farming	Phil Lilley, Glassford Hammond Farming
	Variable rate nitrogen experiment	Lizzie Sagoo, ADAS
13:45	**Depart for Glassford Hammond Farming**	
	Plot tours – Nitrogen response in Savoy cabbage	Lizzie Sagoo & Angela Huckle, ADAS
	Assessing soil structure	Paul Newell Price, ADAS
	Demonstration of Isaria crop sensor	Chris Argyle, R. Hunt Ltd
15:00	**Close**	

To register: email jane.stead@adas.co.uk or phone 01623 844331

AHDB HORTICULTURE

GREAT soils Resilience, productivity and life

Controlling traffic for profitable and resilient soils

With a focus on the new soil management and precision technology strategy at Barfoots

Queens Head, High Street, Titchfield, PO14 4AQ
Followed by
Field visit to Abshot Farm, Barfoots
With kind permission of Neil Cairns, Barfoots

Thursday 3rd November 11 am – 3 pm

Controlled traffic farming and other precision technologies offer growers opportunities to improve soil and nutrient management, with the potential to increase yields and profitability.

AHDB Horticulture Project CP107c aims to evaluate the current and future potential of precision farming techniques to optimise soil and nutrient management in horticulture. Join AHDB Horticulture, Barfoots and ADAS to discuss soil and nutrient management and view controlled traffic and cover crop strategies in the field.

10:45	**Registration and refreshments**	
11:00	Welcome & introductions	
	Introduction to Barfoots and the Hampshire farms	James Rome, Barfoots
	Soil structural condition in horticulture systems	Paul Newell Price, ADAS
	How can we use precision farming tools to improve soil and nutrient management?	Lizzie Sagoo, ADAS
	Principles of Controlled Traffic Farming	Tim Chamen, CTF Europe
12:30	**Lunch**	
	Soil management and CTF strategy at Barfoots	James Rome, Tim Chamen, and Paul Newell Price
13:45	**Depart for Posbrook Lane, Abshot Farm, Barfoots**	
	CTF approach and machinery modifications at Barfoots	James Rome, Barfoots & Tim Chamen, CTF Europe
	Cover crop trials and assessing soil structure	Neil Cairns, Barfoots & Paul Newell Price, ADAS
15:00	**Close**	

Includes BASIS points

Places will be limited so please register via:
email jane.stead@adas.co.uk or phone 01623 844331

AHDB HORTICULTURE

GREAT soils Resilience, productivity and life

Smart soil mapping for improved soil and nutrient management in horticulture

With a focus on options for soil mapping and precision technologies

Millennium Barn, F.B. Parrish & Son, Lodge Farm, Chicksands, Shefford, Beds, SG17 5QB

With kind permission of F.B. Parrish & Son

Tuesday 7th February 11 am – 3 pm

Precision technologies offer growers opportunities to improve soil and nutrient management, with the potential to increase yields and profitability.

AHDB Horticulture Project CP107c aims to evaluate the current and future potential of precision farming techniques to optimise soil and nutrient management in horticulture. Join AHDB Horticulture, F.B. Parrish & Son and ADAS to discuss soil and nutrient management and options for soil mapping.

10:45	**Registration and refreshments**	
11:00	Welcome & introductions	Andy Richardson, Allium & Brassica Centre
	Introduction to Parrish Farm	Adrian Baker/Nick Parrish, F.B. Parrish & Son
	Soil structural condition in horticulture systems	Paul Newell Price, ADAS
	How can we use precision farming tools to improve soil and nutrient management?	Lizzie Sagoo, ADAS
12:30	**Lunch**	
13:15	Options for soil mapping – Parrish Farm Avenue field case study	Lizzie Sagoo, ADAS
14:00	**Avenue field visit**	
	Demonstration of Veris MSP3 scanner	Graeme Barrett, Mount Liming
	In field variation in soil – Avenue field case study	Dan Munro, ADAS
	Assessing and managing soil structure	Paul Newell Price, ADAS
15:00	**Close**	

Includes BASIS and NRoSO points

Places will be limited so please register via:
email jane.stead@adas.co.uk or phone 01623 844331

