“A Year in the Life” of a Wheat Crop

For the DCMS funded 5GRIT project

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Monitoring wheat crop growth using drone carried multi-spectral imagery.

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“Applying inputs only where they are needed and in the appropriate quantity is the best way to align the economics of food production with environmental goals.”

Clive Blacker: Founder and CEO Precision Decisions Ltd

Introduction

This report is part of the broader 5G Rural Integrated Testbed project (5GRIT) funded by the Department for Culture Media and Sport and carried out in collaboration with a number of partners as listed in Appendix 1.

From emergence of the crop in the Autumn of 2018 through the growing season in Spring 2019 until finally, harvest in August 2019, we have tried to capture the main growing events of the crop. The report further shows how this type of information can help farmers make better informed decisions about crop care. Ultimately, this should lead to more efficient use of inputs, such as fertilizer and agrochemicals and therefore, both higher margins for growers and a lowering of pressure on the environment.

Wheat crop growth

Agronomy

A basic knowledge of wheat crop growth is required to better understand the benefits to growers of closer monitoring of crops during the earlier part of the growing season.

Figure 1 shows the wheat growth stages during the season from emergence after sowing through main spring growth to flowering and harvest.

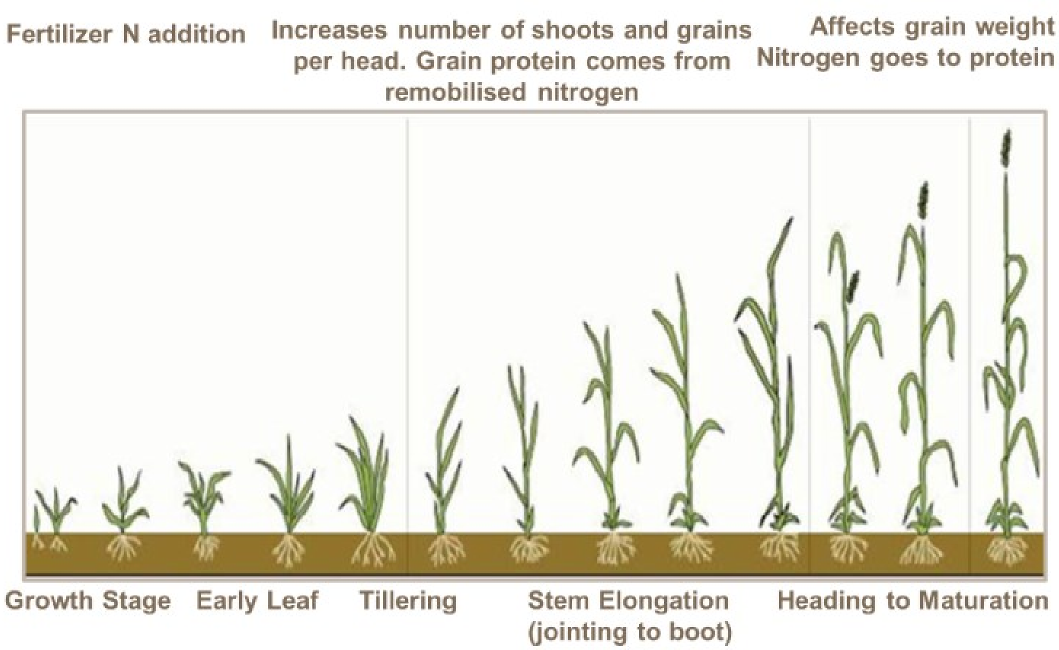


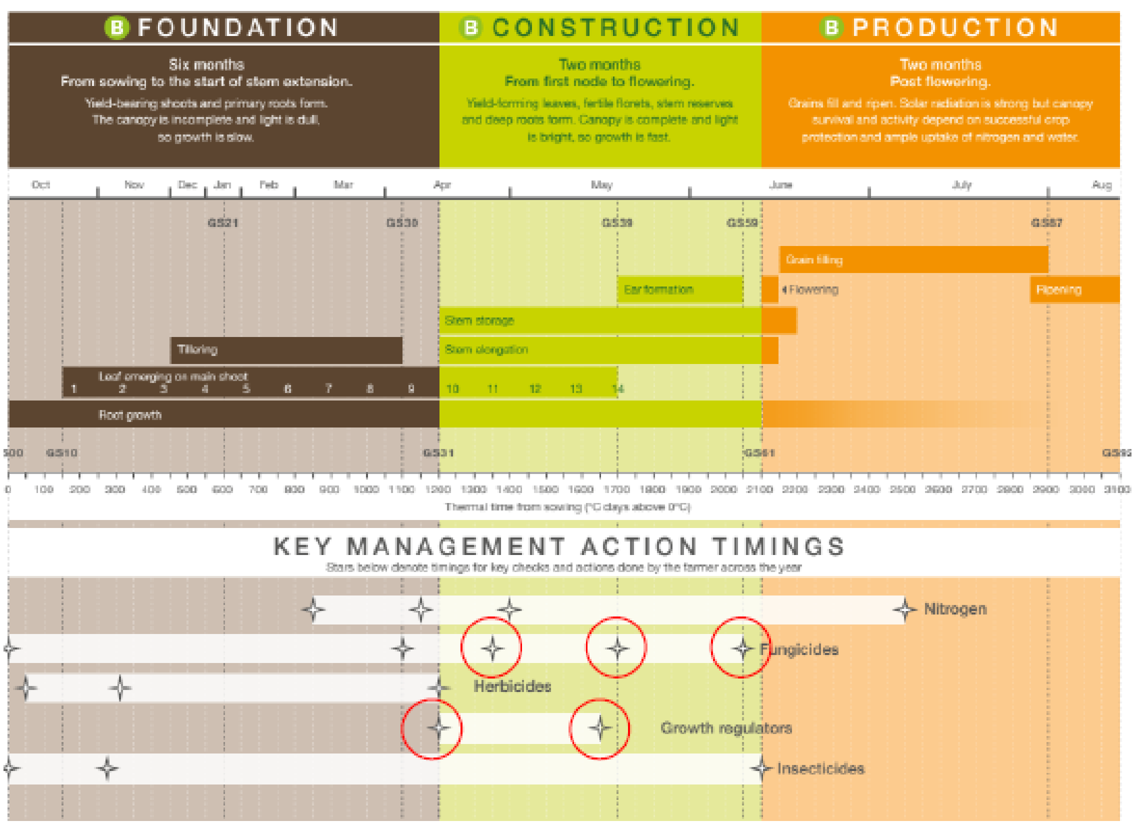
Figure 1. Wheat growth stages after Zadoks, (courtesy of Yara UK).

Along this growth curve, there are certain key decision points growers will be looking to optimize, based on the condition of the crop at that time. The early part of the growing season is crucial to the yield the crop achieves much later in the year. Decisions made in Spring are key to the harvest result. Often, such decisions are based on historical experience - my Grandfather always sprayed at this time- 'gut-feel' or what the neighbour is doing. New technologies and sensors can now quantify the crop stress levels much better and identify in-field variability, enabling the grower to optimize which inputs are applied where and in which quantities.

Key decision points for growers

As the crop grows, farmers must decide the optimal nutritional and crop protection regimes. This is done without exact knowledge of the final yield, which can only be approximately predicted at this stage.

Figure 2. Crop growth over a season



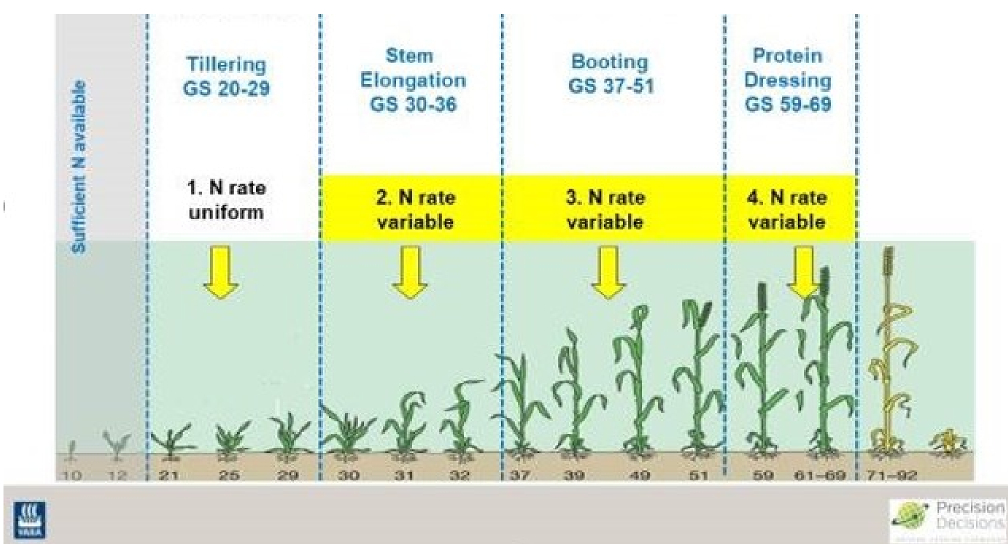
The crop growth can be divided into three main management phases: 1. foundation, this how the crop establishes itself after sowing, 2. construction, how the crop comes through the winter and sets itself for the coming spring, this is when the yield potential is set and 3. production, which is the lead up to harvest.

These three main phases are split into finer growth stages as can be seen in the diagram in Figure 3. There are a small number of key events where farmers must make the right decision based on a huge number of variable factors and this is where we see data and remote sensing playing a key role.

For nutrition, specifically nitrogen applications, there are six main decision points between early Spring after the crop has come through the winter and harvest in August. These are shown below:

- Emergence: Autumn – growth stages 10- 12
- Tillering: March/April – growth stages 20-29
- Stem elongation: April/May – growth stages 30-36
- Booting: May/June – growth stages 37-51
- Protein (maturation): June /July – growth stages 59-69
- Harvest: August/September

Figure 3. Growth stages of the wheat crop

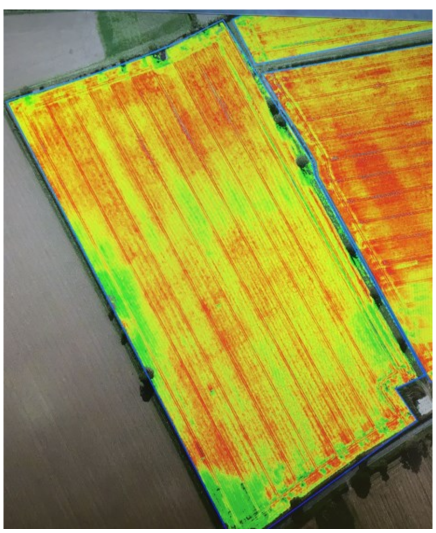


1. Emergence

This is when the crop first emerges after sowing, for winter crops, this being in the autumn. Good emergence is key for the future development and ultimately, yield of the crop.

2. The two photos in Figure 4 show how an overhead, processed photo from a drone flight can give a much better overall picture of the crop state than if the farmer were to stand in the field. Differences in density can be more clearly seen from the processed photo. The processing creates a “normalized difference vegetation index” (NDVI) which basically provides an indication of the ‘greenness’ of the crop area, from which the density can be deduced. The red stripes are the tractor tramlines where there is no crop at all. Red between the stripes means that the crop in those areas is stressed. It may need more nutrition than other areas to compensate.

Figure 4a. Image of test field from drone, Figure 4b. Same field, image taken at ground level



3. Tillering

It is at this phase that the maximum yield potential for the crop is set.

The plant has come through the winter and begins to develop into the spring as it sets the number of ear-bearing stems, known as tillers. Too many of these, and the competition will result in lower ear yields. Too few, and the overall yield will be lower than the potential. Farmers and crop advisors will go out in early spring to try and gauge the crop and specifically, tiller density.

Traditionally, plants were counted using a ‘metre square’ – a wooden frame exactly one square metre in size thrown onto the field, under which the plants are counted. Images taken from drones can replace this activity and algorithms developed to estimate tiller density across a complete field. This in turn enables the farmer to better plan the optimal fertilizer regime as the crop comes out of winter. Furthermore, a more detailed tiller estimate would enable crop models to better estimate the future yield. Thereby enabling farmers to plan crop protection activities based on potential yield, rather than simply responding to crop pest and disease pressure.

Figure 5. Prescription map for seed rate application based on previously captured drone imagery.

The seed rate varies in accordance with the yield from the previous year or from a remote image from this season.

Farmers can decide whether to apply more seed to compensate for a lower yield potential or can decide to reverse this by applying less seed to an area which will intrinsically yield lower. The latter regime can, in fact, lead to higher margins as the overall input cost is lower.

Figure 6. yield map from previous season

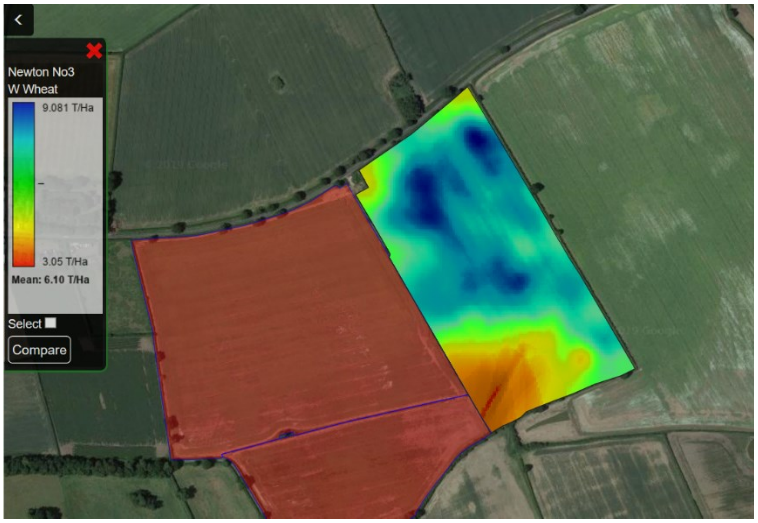


Figure 6 shows the previous season's yield map indicating the poorer yield in the bottom left corner. The farmer in this instance has tried to compensate for the lower yield by increasing the seed rate in this area. The seed rate was set at 195kg/hectare compared with 135kg/ha in the areas with higher potential (the dark blue areas).

4. Stem Elongation:

Another crucial phase in the crop's life, this is where the crop literally lays down its roots and establishes itself for the main part of the growing season. Nutrient demand increases as the crop develops and timing of nitrogen applications and amount applied are critical. Too much can lead to an excess of what the plant requires, leading to losses into the soil. Too little, and the plant will not develop to its yield potential.

5. Booting

This is the phase where a crop of wheat will 'fill out' and the bulk of the yield will be developed. Adequate nutrition at this stage is essential for optimal yield. Across a field, there will be differing zones of crop development and potential yield, which need variable nutrition. Otherwise, too much will be applied to one area and too little to another. Photos from zones and previous images can be used to illustrate these zones and create a 'prescription' map for fertilizer applicators to apply the right amount in the right place.

6. Protein Dressing

The final phase for a quality wheat crop, one from which the flour is classed as bread-making quality, require careful management to ensure that the grain has a certain protein level. Protein is derived from nitrogen so once again, farmers need to ensure that appropriate fertilizer regimes are used. Otherwise, an excess will be applied which will both deplete the margin of that crop and potentially lead to environmental issues if too much has been applied. Too little nitrogen and the crop may well not achieve the protein level required for bread-making (which commands a higher price) and the farmer's margin will be reduced.

Multi-spectral imagery

Technology today enables farmers to have much more real- and near-real time data available about the status of their crops. In addition to the drone imagery shown throughout this report, there are tractor mounted sensors and satellite imagery which provide growers with insights. Using our trial fields as an example, we can demonstrate the information available and how farmers would use it at various times during the year.

Figure 7 shows the conductivity levels within a field. Conductivity is measured by a trailed electro-magnet which effectively measures the water retention capacity of the soil, which in turn is an indication of good soil health.

Again here, we can see that the lower left corner of our trial field has the highest level of conductivity, which indicates a high clay content. If this is not managed accordingly, yield potential will be lower in these areas, which we have seen to be the case.

Figure 7. Map showing conductivity level

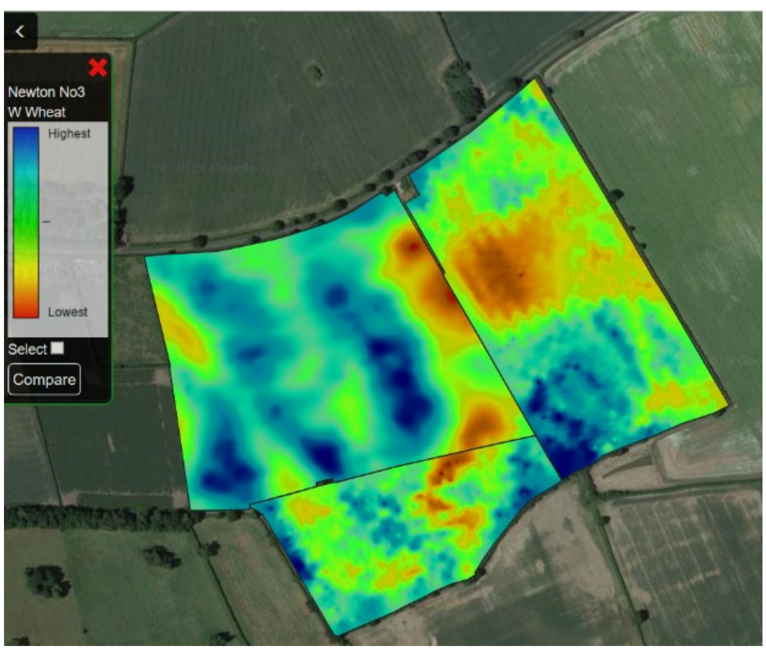


Figure 8. Satellite image of the field in early spring

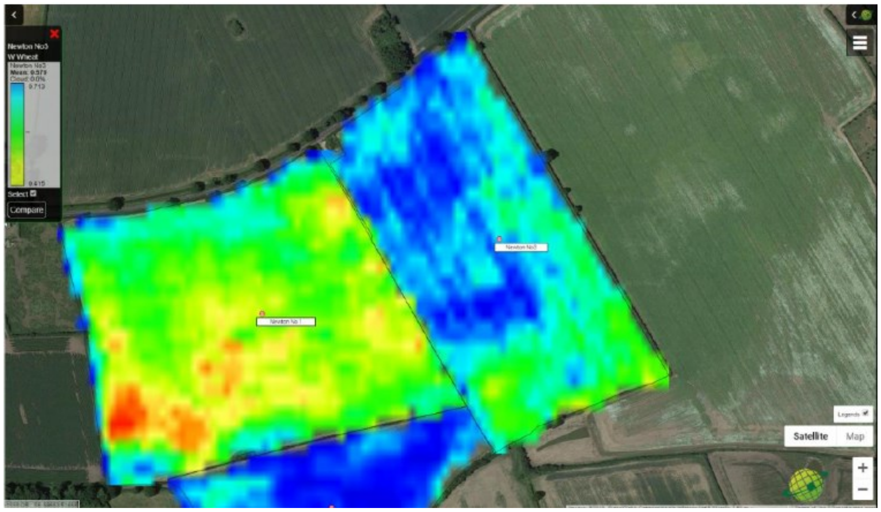


Figure 8 is a satellite image of the same field which shows a similar pattern of variability.

This image is from early spring where the reflectance of the crop is converted into the blue and green colours.

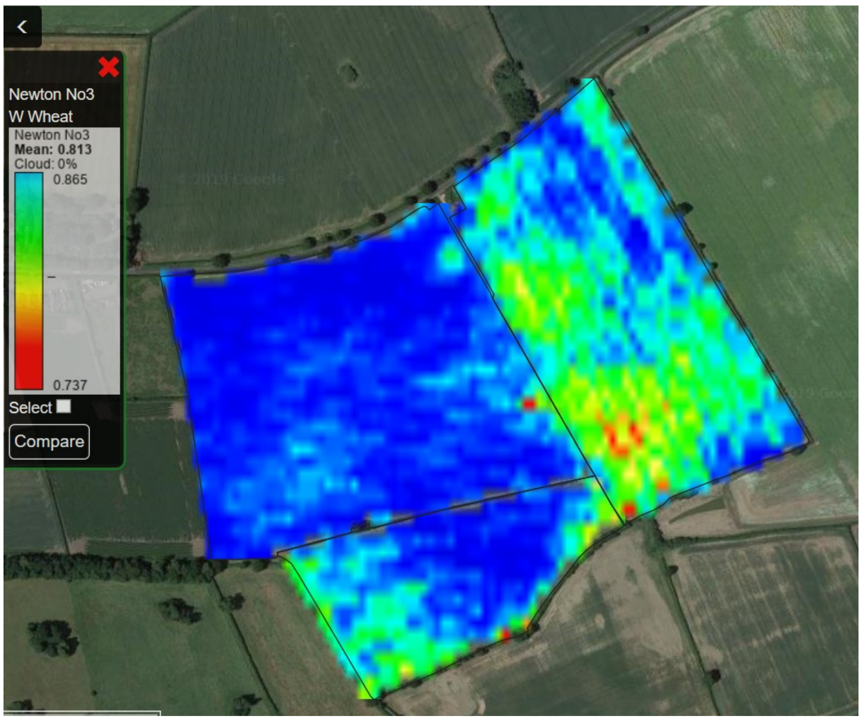
The green areas again reflect slightly poorer status compared to the rest of the field (blue).

Figure 9. Image of the field in early spring on the taken at ground level

Figure 9 shows the crop in the field at the same date. From this perspective, which is the normal one a grower would see, variability is not apparent. The variability can only be visualized with multi-spectral processed imagery

Satellite images can be processed further to show what is referred to as NDVI or Normalised Distributed Vegetation Index. This index gives a further indication of the health of the crop which is then used to determine the appropriate application.

Figure 10. Satellite images showing NDVI



This photo is taken in same field at same time of year as the image in figure 10. Again, it shows no clear sign of variability of crop health or growth.

Effect on Yield and Margins

Famers normally treat their fields as one, in other words, the application rates do not vary across a field. This prophylactic approach ensures that the crop receives the right nutrition – on average – and that the pests and diseases are treated across the whole field. It is a safe regime. The appropriate imagery can assist farmers to make better application decisions.

Yields can be affected significantly through the use of these images. The two images in Figure 11 show these effects. The image on the left shows the wheat yield in 2017, the red areas showing the poorer areas of the field, where yield averages 3-4 tons per hectare and the dark green depicts areas where the yield is 10-11 tons per hectare. The average yield across the field in that year was 10.4 tons per hectare. Variability of yield is very pronounced.

Figure 11a. Yield in 2017

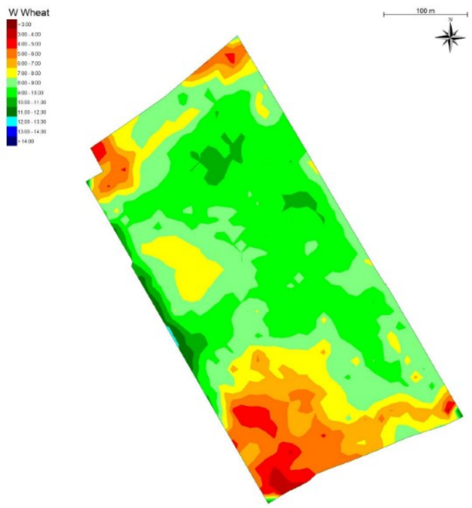
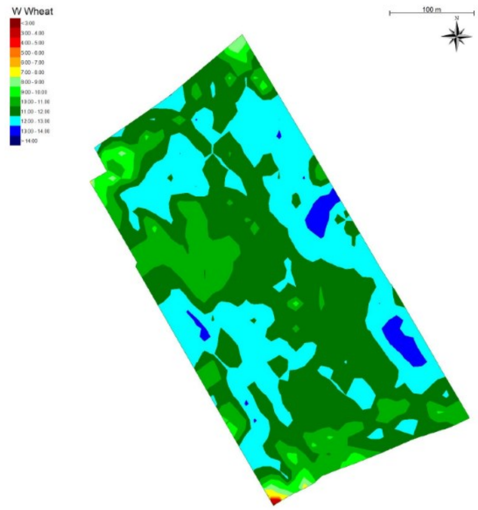


Figure 11b. Yield in 2019



The image on the right shows the actual yield in August 2019 following the work done with this project. Fertiliser was applied variably in accordance with the imagery from the drones throughout the season as well using data from other sensors. The range of yield this year - in other words, the variability of the yield - is significantly lower, with much more of the field being ‘normalised’. This has the effect of not only making it easier operationally for the harvester to combine the crop, since the crop is more uniform, it also has an effect of optimising the profit margin across the field. A field such as this is easier to manage as the variability is minimised and controlled. Inputs are optimised and the margin per hectare greater than a field showing higher variability.

The blue areas depict yields of 13-14 tons per hectare and the light green areas 8-9 tons per hectare. Even allowing for variability between the seasons, it is clear that a field managed for variability generates higher yields and provides better margins for the farmer.

At a wheat price of £50 per ton, the difference in average yield between 10.4 and 11.7 tons per hectare equates to £195 per hectare increase in revenue, or across the whole field, an increase of £2,395.

Effect on Environment

Clearly such precision agricultural techniques can lead to a more optimal and potentially lower usage of expensive inputs such as fertilizer and agrochemicals. This in turn can lower the pressure on the environment as only the right amount of inputs will be applied and there is potentially a benefit of lower 'run-off' of excess applications.

Future commercial usage

Possible cost of service

We do not envisage that farmers will own their own drones. Rather we see that this technology will be picked up by service providers who will then 'sell' the information and insight to the farmer for a fee. In this way, the grower will not have the capital costs and will not have to train as a drone pilot.

Costings are difficult to evaluate at this early stage, but the following could be a hypothesis.

To provide a drone imagery service, the following will be required:

- Drone: £50k depreciated over 5 years = £10k per year
- Multi-spectral camera: £10k depreciated over 5 years = £2k per year
- Image processing: estimated at £15k per year
- Labour: estimated at £35k per year.
- Other costs (admin and vehicles) £5k per year

In total, we estimate there would be an annual cost of approximately £67k to run the service. To be commercially viable, we estimate such a service would need to cover 60,000 hectares to ensure the cost per hectare is close to £1 to £1.25.

We think an acceptable commercial price would have to be close to £1 per hectare flown.

Item	Capital Cost	Annual cost
Drone	£ 50,000	£ 10,000
Camera	£ 10,000	£ 2,000
Processing		£ 15,000
Labour		£ 35,000
Admin		£ 5,000
Total		**£ 67,000**

Hectares flown	Cost per ha
50,000	£ 1.34
66,979	£ 1.00
75,000	£ 0.89
100,000	£ 0.67