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CAN LOW COST, CONSUMER UAV'S MAP USEFUL AGRONOMIC CHARACTERISTICS?

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Abstract

One of the ongoing challenges for spatial crop modellers has been to provide the high spatial and temporal resolution crop measurements needed to validate the biophysical predictions provided by the crop model and improve crop predictions by incorporating feedback from the crop into the model. Information which may be important to the model such as; plant population, leaf area index, % ground cover, crop height and biomass have been difficult to collect historically in a spatially dense and frequent manner.

One further limitation has been the models lack of spatial resolution, as they cannot recognise spatial variation in the crop, yet we live in an environment where we know spatial variation exists and failure to recognise this lacks credibility. To overcome some of these limitations we must find ways of collecting multi-temporal and spatially dense information using methods that are cost effective and widely available. A further requirement is to integrate information from other sources such as climatic (cloud cover and rainfall) and farm physical data into the crop model to provide daily updates of crop parameters.

This paper describes a cloud processing system provided by SoilEssentials that can use inexpensive UAV's to solve a number of these limitations to crop models using extremely high spatial and temporal resolution RGB imagery. This imagery is captured using commercial off the shelf (COTS) UAV's by relatively unskilled users already present on the farm. This enables farmers and agronomists to plan and execute UAV flights over crops and upload the large number of high resolution RGB images, captured by the UAV, to a cloud computing platform. This processes the imagery into a web based interface where the biophysical parameters are extracted from the images and used in various spatial crop models. The information provided by the crop model can inform variable rate application technologies such as fertiliser application and seeding. A case study using a potato growth model will be demonstrated.

KORE Project

The KORE project (KNOWLEDGE, OBSERVATION, RESPONSE, EVALUATION) is partly funded by the European Space Agency (ESA) and has 2 partners, Deimos Space UK and SoilEssentials Ltd. KORE uses Satellite Earth Observation and Unmanned Aerial Vehicle (UAV) data to augment a precision agriculture service to provide cost effective crop management advisory tools with a high spatial and temporal resolution to agronomists and farmers. The following tasks are covered by the project activities: First, the development of a framework within which several complementary data sources can be integrated with existing farm management solutions. Second, the project prepares for the exploitation of free data from the Copernicus Sentinel-1 and Sentinel-2 missions. Third, an image processing service is created which allows users of UAV's to cheaply and easily produce very high spatial and temporal resolution orthophotos. This is accomplished by adding an Earth Observation imagery data stream into the "EssentialsMap" service. Large variations in a field are detected automatically, prompting the agronomist to survey the field with a UAV. The resulting high resolution maps are used to give targeted crop advice or to produce variable rate applications of crop inputs including fertilizers. With a further processing step, individual plant characteristics can be calculated and used in subsequent operations and calculations. The KORE web application focuses on agronomists so that the service is refined with feedback from experts. A high-powered processing framework is vital to the development of KORE as a fully operational service. Access is also given to large EO datasets, together with bulk processing and integration with the existing web-based commercial applications and data sources.

Users and their Needs

The prime users of KORE are agronomists who act as advisors to groups of farmers. Farmers need the best possible advice from agronomists to help them to manage their crops and exploit new precision agriculture techniques. Their objective is to increase crop yields while also reducing the application of fertilizers, pesticides and other crop inputs. Both these actions result in increased profitability for the farmer and allow higher yields to be produced whilst reducing environmental impact. The project focuses on agronomists specialising in three crop types:

- Potatoes, which are widely grown throughout the world and are an example of a high value, high input system with a relatively small area.

- Wheat, which is the largest cereal crop grown in the UK and Northern Europe and is an example of a medium area/ medium output crop.

- Grassland, which covers the biggest area cropped in Europe and includes many different grass types and uses, from intensive grass used in dairying to upland rough grazing.

Service Concept

The remote-sensing data from satellites provides a frequent-revisit picture (if cloud cover allows) of the crop areas under surveillance and allows generation of geophysical parameter products (NDVI or similar) and of change detection maps based on the previous data gathered. The image data acquired by the UAV's (which may be triggered by the satellite-based EO) are used to derive geophysical products and / or change maps, based on the latest available image of the area concerned. The KORE service is web based which has benefits in terms of flexibility for upgrades and scalability. It offers online access to a suite of mapping and monitoring services at a fraction of the price of existing farm data management systems, thus making it a viable option for smaller farm businesses.

The main benefits for the farmers adopting KORE are:

- Increased productivity thanks to identification and delineation of management zones on which specific growing processes can be applied.
- Better crop canopy development based on nitrogen, fungicide and growth regulator regimes.
- Improved disease/pest management and treatment monitoring.

From an environmental angle, KORE has the potential to reduce the risk of over fertilization and related pollution of the soil and ground water.

The economic need for crop models

Increasing the depth & breadth of crop management information available to growers & agronomists before planting, and within season, can optimise economic, agronomic & logistical crop value. The opportunity to increase potato marketable yield by 15-20% from optimised variable-rate management is worth ~£70Kpa to the average 53Ha farm (equates to £150M return to the UK potato industry) & is fundamental to lowering production costs & improving the efficiency of the whole supply chain from grower to retailer. As the platform technology is truly sector-cross cutting, once the spatial crop models for improving crop production are proven, they can equally be applied to other root & arable crops.

Tuberzone Innovate UK Project

Agriculture is now a data-rich environment. A multitude of proximal & remote sensors capture many different aspects of agriculture production systems, particularly cropping systems. Nowadays, growers are able to record & change the rates of most agronomic inputs or operations. However, growers rarely use the capabilities at their disposal because they are unable to translate the available data streams into information & then into good agronomic decisions. Incorrect analysis generates incorrect decisions. Because of this, growers are wary to adopt decisions based on information that they do not understand well. One clear, potentially very important way in which these spatial data can be used is within crop models. Crop models are invaluable to the agricultural community to predict how crops develop under different scenarios (alternative management and/or evolving in-season climate variations). While many well developed crop models exist, these are built on an assumption of modelling a point, which is an average response for a field or farm. They are not designed for high-resolution spatial modelling & usually collapse when used as such. The objective for this project was to integrate a point crop model with spatial data to generate an effective spatial crop model for potato production. This has an emphasis on predicting crop yield and tuber size distribution (TSD) & managing the various drivers (environmental & managerial) of TSD.

By empowering an existing crop model with spatial information, it is possible to remove the grower/agronomist directly from the data analysis & the decision-making. Expert knowledge is captured within the crop model, but there is no direct involvement between the spatial data & the end-users, removing this source of error and confusion. The spatial crop model is therefore a method for spatial data-fusion & value-adds to the original spatial data. The model provides a relatively simple integrated spatial output (recommended variable-rate management operations) that the grower can access for adoption. The modelling also allows estimates of uncertainty to assist growers in risk assessment with differential management.

Using UAV imagery in spatial crop models.

Commercial off the shelf (COTS) UAV's have now progressed to a development stage where they can be flown by relatively unskilled operators. Farmers and agronomists are ideally placed to decide when their crops need to be flown and are on site at the optimum time to get high quality imagery. This, along with their low cost (around NZ $ 2000 at time of writing) offers the possibility of getting very high resolution aerial imagery on demand at very low cost. The resolution of the imagery can be controlled by the operator setting the flying height of the UAV. This must be less than 120 meters in NZ (and many other countries). Most operators use a range from 50m to 120m above ground level which gives a ground resolution of around 1cm to 3cm per pixel depending on the camera model.

At this resolution in many crops individual plants can be seen and their agronomic characteristics mapped and measured for use in crop models. The UAV generates around 6 to 7 images per ha at 7 mb each, so a typical flight can produce 200 to 600 images of a field. This equates to around 1.4 to 4.2 gb to be processed into an orthomosaic, viewed by growers and further processed into biophysical measurements for use in crop models. Although there are many image processing systems available for use on desktop computers, it has been found that the computing requirements needed to process this imagery makes it impractical for commercial use.

One of the KORE project functions is the ability to upload the UAV imagery to a web application which orthorectifies, mosaics and georeferences the multiple images into a very large orthomosaic. This is then split up into smaller tiles and delivered into a web browser or mobile application to be made available to users in a secure web portal. Other precision agriculture products are integrated with the UAV imagery like satellite imagery, yield and soil type maps, weather and disease risk and soil fertility. Once the imagery is available to the user other tools are run on the image to extract information needed by crop models. Examples would be a plant counting algorithm and ground cover calculation. (see below)

Example with UAV Imagery

Figure 1 Intuitive web application for processing and viewing UAV imagery

In order to encourage use by non technical users the system has been specifically designed to be very intuitive and easy to use with simple, industry standard layouts and clear navigation.

Figure 2 Image of whole field of potatoes from UAV

Once the images have been processed the UAV image is displayed over a background of a bing or google map. Crop problems are usually easily seen and identified at this stage.

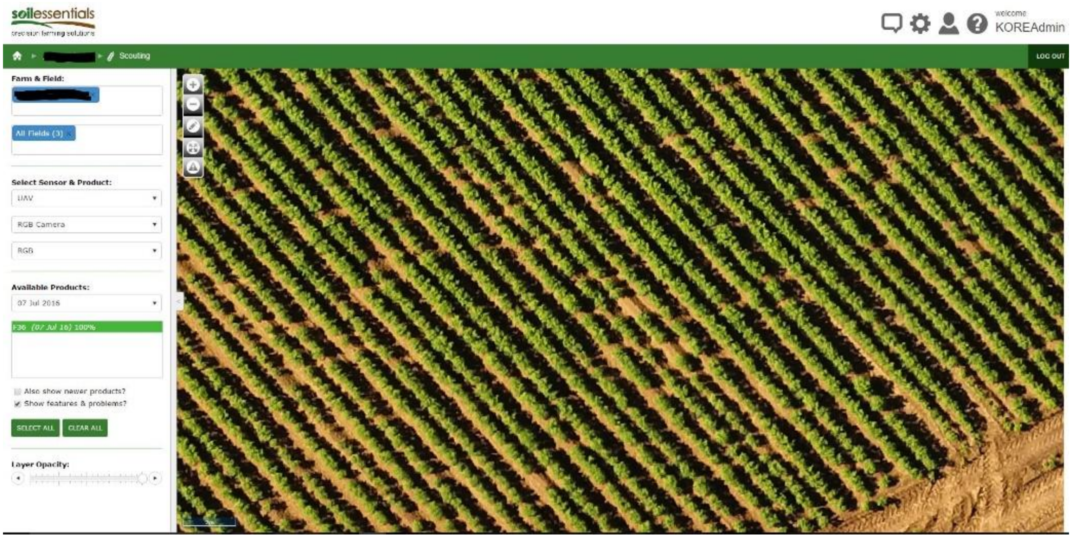

Figure 3 Detail from the field of potatoes

Users can zoom into various areas of the field to examine crop problems in high resolution. Experienced farmers and agronomists can identify many disease, soil and operational issues from these images

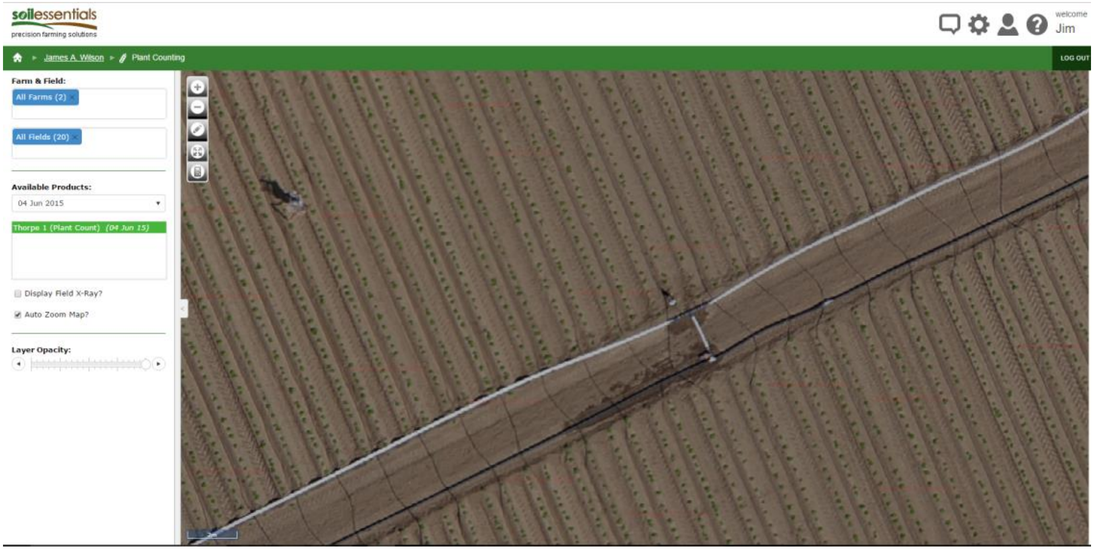

Figure 4 Potato crop at early emergence. Note drip irrigation lines, water leaks and wheeltracks.

In this image, the potato crop is just emerging and at an ideal growth stage for plant counting. Other features and problems can be identified like water leaks, compaction from tractors and drip tape.

Figure 5 Areas of the crop can be defined and plants counted automatically.

Plant population is a key component of many crop models. In this example an area of crop has been defined and plant population calculated. For this area of 3.889ha there are 115,644 plants which is 29,740 plants / per ha.

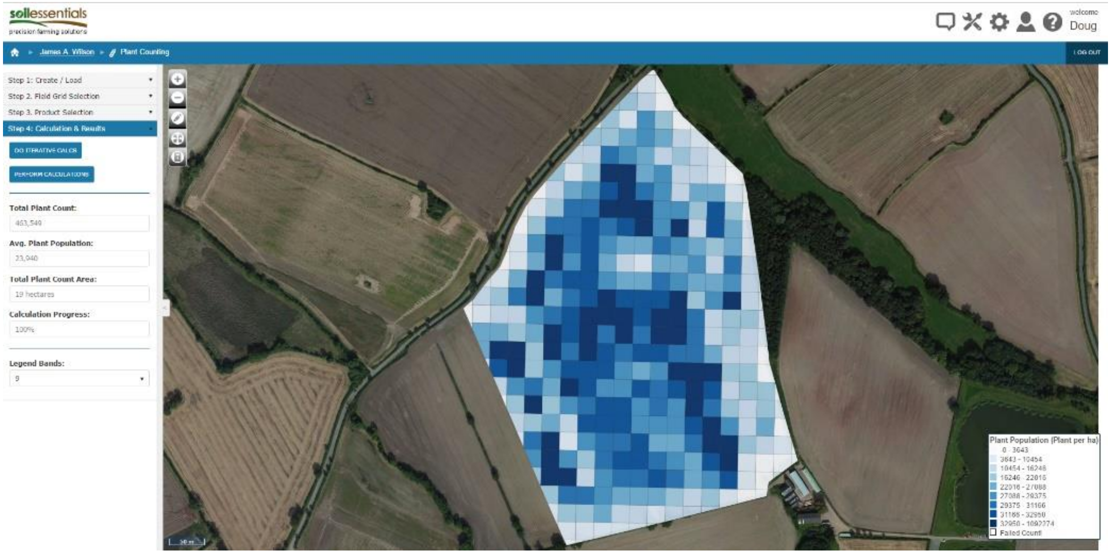

Figure 6 Whole field analysis of plant population from UAV

Or the same algorithm can be run on a grid or zone to create a map of the plant population that can be used for assessing plant population variability and to feed the plant population criteria in the crop model for each grid.

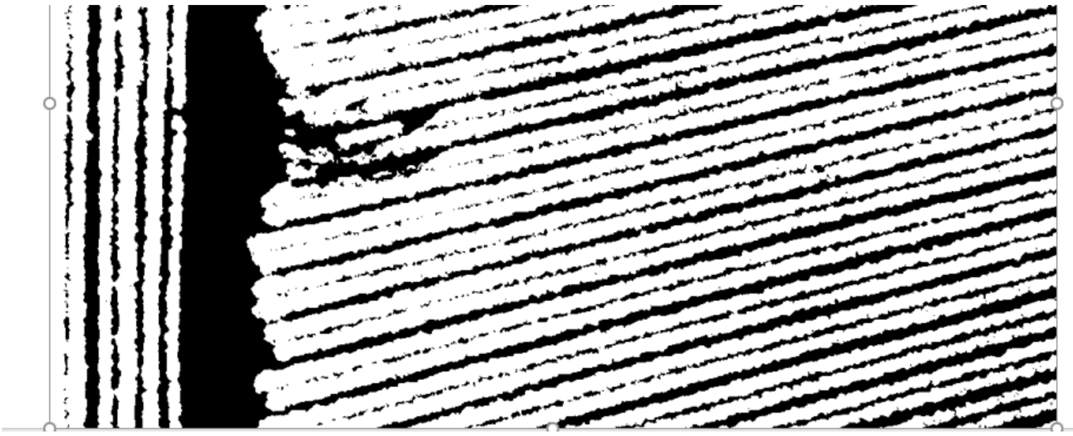

Figure 7 UAV image processed into % ground cover map

Using multiple flights through the growing season ground cover extent and spatial variability can be quantified quickly and cheaply. This is then used to inform and update crop models to forecast yield and tuber size distribution.

Potato Yield Model Results

Informed from Plant numbers and canopy size.

(Tonne/ha)	Yield	Y30-40	Y40-50	Y50-60	Y60-70	Y70-80
TuberZone Prediction	46.85	*3.461*	*14.553*	*19.575*	*7.977*	*0.931*
Measured (field average)	48.52	*4.536*	*14.559*	*17.000*	*9.158*	*2.694*
Error(%)	3.44					

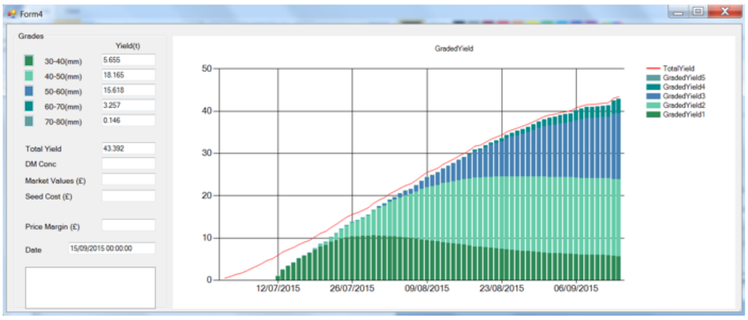

Figure 8 Tuberzone potato yield and tuber size distribution model.

Crop models can be run on demand at high temporal and spatial resolution to incorporate the agronomic characteristics mapped by the drone. In this example the yield and tuber size distribution results are displayed along with actual results.

Conclusion

Commercial off the shelf drones have now advanced sufficiently to be useful in production agriculture for a range of applications. However, the main limiting factor is the software system required to process the very large amounts of imagery into something useful. This need is being met by web apps built for precision ag which make it easy for unskilled operators to take, process, view and share high resolution orthophotos on demand. A further benefit of these web applications is that they can run high temporal and spatial resolution crop models to predict key commercial and agronomic characteristics of the target crops. In order to improve spatial crop model predictions at low cost UAV's are used to map key agronomic characteristics which are then used to validate model predictions and improve subsequent predictions.