UAVs in Agriculture

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Drone-Based Agricultural Services

Drones are often given a bad reputation for the way they have been misused to breach privacy or shut down airports like Gatwick in 2019. However, the transformative effect they are having on industries around the world must not be ignored. The agricultural sector is one such area where drones are having a larger impact each year, offering smart farming solutions that can improve decision making and farm efficiency and reduce costs.

It is estimated that around 18% of agricultural businesses in the UK are already using drones, with the industry projected to boost the UKs GDP by 1% by 2030 (PwC). Their widespread uptake can be credited to the prices for drones having reduced considerably in recent years. This has allowed practical applications in the sector to expand faster than ever before, offering high quality imagery at a higher resolution than what can be achieved using satellite data (sub-centimetre rather than 10s of metres).

Most advancements in this field have been catered to arable businesses, primarily for looking at crop health, growth and yield. However, a growing amount of research is geared towards livestock management. This practical guide explores some of the core drone applications that are already being used by the agricultural industry to improve farm businesses.

What is precision farming?

Precision agriculture is a method in which farmers manage crops and livestock to apply the right practice, at the right time and with the right quantity. This aims to ensure the efficiency of inputs such as water, fertiliser and pesticides, while also enhancing productivity, quality and yield.

Benefits of using Drones in farming

Remove uncertainty – Receive accurate near real-time data to effectively respond to factors you have no control over such as weather, soil conditions, precipitation and temperature.

Increase yield – Improve farm efficiency, identify crop health issues earlier than you could before.

Save time – Time is money. Drones can be used quickly and frequently allowing farmers to gain information where and when they need it on farm, freeing up time for farmers to focus on other aspects of farm management.

Plan for future – Drone surveys and mapping can be done throughout the year to help farmers improve and streamline land and farm management practices.

Sensors Used for Agriculture

There are several different sensors that can be mounted to UAVs that can provide helpful services to agricultural businesses.

RGB sensors — A normal digital colour camera, capable of picking up image data from the visible (red, green, and blue) wavelengths of light. These sensors are the most common and can be a good starting point for farmers looking to get into using drones for their business.

Near Infrared (NIR) sensors — Capable of capturing image data of a combination of NIR, red, green and blue wavelengths. These sensors are typically modified digital cameras and are cheaper than multispectral sensors, however, lack some of the precision and calibration that comes with the narrow focus on wavelengths available with multispectral sensors.

Multispectral sensors — Can produce calibrated imagery using narrow wavelengths of light that are of importance to agriculture. Typically, multispectral sensors have between 5 and 8 lenses, with each capturing a different wavelength frequency, usually including visible RGB, NIR and Red Edge (between red and NIR) wavelengths.

Thermal sensors — Captures infrared image data that that is emitted from objects to monitor their temperature.

LiDAR (light detection and ranging) sensors — Used to capture detailed 3D models, that can penetrate through vegetation. This means it can be used to create an accurate bare earth model as well as calculate biomass volumes. However, this comes at a far steeper price and therefore will not be explored further in this document.

Table 1. Sensor Agricultural Applications

	RGB	NIR	Multispectral	Thermal	LiDAR
Terrain Mapping	X	X	X		X
Soil Management	X	X	X		X
Crop Establishment	X	X	X		
Vegetation Health Monitoring	X	X	X	X	
Disease Detection	X	X	X		
Vegetation Growth and Yield Estimation	X	X	X		X
Irrigation Management	X	X	X	X	
Weed Detection	X	X	X		
Damage Assessment	X	X	X		
Holistic Crop Management	X	X	X	X	X

Most commercially bought drones come with built in RGB sensors. If you want to use one of the more specialised sensors, then specific drones capable of carrying them will be required. Make sure you enquire about its capabilities before purchasing any drone, to ensure it meets your needs.

The uses of these sensors for agriculture will be explored in the following section.

Benefits of Using Drones in Farming

Pre-Planting

Terrain Mapping

A RGB sensor can be used to generate a terrain/slope model of your field. This can be used as a decision -making tool for seeding and field traffic management. Trials have shown that crop line planning can be completed up to 75% faster using drone produced topographic maps compared to ground methods. Topographic maps of the fields can be uploaded to navigation and autopilot systems found on farm vehicles for more accurate and quick ploughing.

This data will also be needed as a base layer for calculating crop heights later in the season.

Soil Mapping

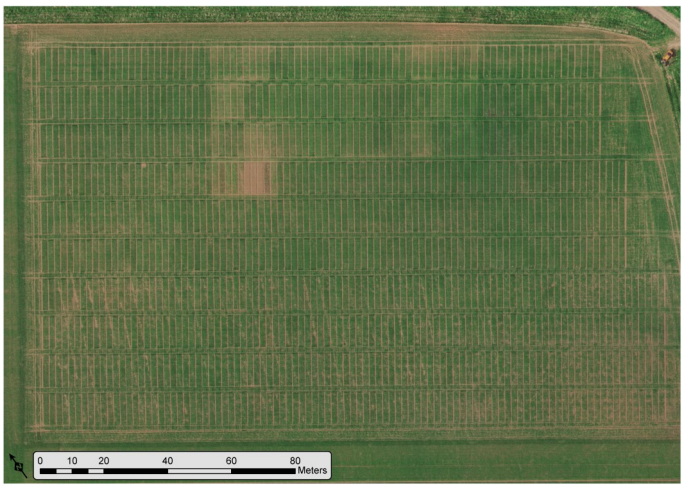
Drones offer an ability to optimise soil monitoring by being able to quickly collect valuable soil data. By using such technology uncertainty surrounding the status of farm land can be removed, facilitating improved decision making and reducing the amount of time needed on the field.

Using drones equipped with an RGB sensor, soil data can be collected that highlights soil compaction, erosion pathways and poaching throughout your farm. By using a NIR or Multispectral sensor, different soil types and moisture levels can also be identified.

Post-Planting

Crop Establishment

When using drones, farmers can improve their awareness on the uptake rate of a crop after planting. In near real time, farmers can use RGB, NIR or Multispectral sensors to complete stand counts, identifying how many plants successfully established themselves. Mis-plants can then be detected to determine where replanting needs to occur and the data collected may be used as evidence for insurance claims conducted by a farmer. However, make sure to check weather or not your insurance provider accepts evidence in this form.



Mid-Season

Vegetation Health Monitoring and Disease Detection

One of the key strengths that drones can bring to a farm is the ability to quickly and accurately monitor the canopy health of crops, covering larger areas far faster than traditional field walking. Early detection of potential diseases and pests is key in reducing impacts to the rest of the crop. Using data collected with drones, plant health algorithms can be used to create field scale maps of visible crop surfaces highlighting potential deficiencies and disease throughout the field, saving both time and money.

Vegetation health is most commonly monitored using drones equipped with RGB sensors, NIR sensors or multispectral sensors. Using RGB sensors crop variability can be assessed using the visual atmospheric resistance index (VARI), however NIR and multispectral sensors are better at detecting and distinguishing crop stress using Normalised Difference Vegetation Index (NDVI). Normalised Difference Red Edge (NDRE) is also often used in conjunction with multispectral data, offering more accurate crop health analysis in later growing stages. This however comes with a significant price increase, with sensors prices starting at £2,500 and going up to £5,000 - £10,000 for more advanced sensors (not including drone purchase). Thermal cameras can also be used to determine crop water stress, by picking up variations in temperature within a crop indicating irrigation issues.

Application Decisions

Data collected using drones offer unique opportunities for advanced crop management. for instance, data on crop health can be used to zone fields and create detailed application maps for use with variable rate applications of fertilisers and pesticides, reducing consumption and therefore cost as well as reducing the risk of diffuse pollution into waterways.

Using data collected with RGB, NIR or Multispectral sensors, maps identifying areas of bare ground and nutrient requirements can be created. While this can be completed using RGB sensors it is recommended that a NIR or multispectral sensors equipped to capture Red Edge light should be used if accessible. This will allow for the use of an index such as NDRE, which is far more effective at estimating plant chlorophyll/ nutrients at later crop growth stages.

Plant health algorithms explained

Healthy plants reflect light differently than unhealthy plants. This allows us to pick out plants that may be under stress from disease, pests, dehydration etc. This is done by using plant health algorithms such as the Visual Atmospheric Resistance Index (VARI), Normalised Difference Vegetation Index (NDVI) and Normalised Difference Red Edge (NDRE). These algorithms are the most commonly used for agricultural purposes.

VARI was designed to be used with RGB sensors and measures how green an image is. Healthy plants tend to reflect more green light and less red light. This allows VARI to highlight areas where less green light is being reflected, suggesting plant stress.

NDVI was designed to be used with NIR and multispectral cameras and measures the ratio between NIR and red being reflected from a plant. Plants that are healthy should be absorbing red light for photosynthesis and reflecting more NIR than stressed plants, allowing for this algorithm to indicate the health of plants.

NDRE was designed to be used as an index for multispectral cameras and measures the ratio between NIR and red edge being reflected from a plant. This algorithm is typically better in the later growth stages of crops as Red edge is absorbed less than red light by surface leaves giving a better overview of plant health when plant canopies are dense. NDRE gives a picture of leaf chlorophyll content which is a good indicator of foliar nitrogen levels.

Mid to Late-Season

Vegetation Growth and Yield Estimation

Monitoring growth rate and variability can offer a range of benefits; ranging from monitoring how many plants established themselves to estimating crop yields to improve financial planning and decisions making.

Using RGB, NIR or Multispectral sensors, data can be collected at various stages through the crop growth cycle (e.g. just before fertilising the crop), and when coupled with a soil base layer created at the start of the season (see pre-planting section) offers a quick and cost-effective tool for understanding and gauging crop growth and potential yields. Using such tools removes much of the uncertainty surrounding productivity, allowing farmers to make informed decisions around areas such as future purchasing and planting.

Post-Season

Holistic Crop Management

Over time, the data collected from individual years can be used to identify trends and anomalies specific to each field. By evaluating seasonal data and maps, farmers can highlight patterns in crop emergence, identifying areas where soil quality or other factors such as poor irrigation or blocked drainage may be reducing crop yields. By understanding these issues effective decisions can be made on future crop and farm management, saving money and ensuring efficient farm management.

Throughout the Year

Weed Detection

Using the same algorithms used to establish plant health and by determining canopy cover and height, regions of the field where weeds have developed may be detected. As with crop health and growth monitoring this can be done using RGB, NIR or multispectral data. This can be done pre-sowing to get rid of weeds prior to planting, at the establishment phase to identify weed pressure on emerging crop, and towards the end of crop growth to map areas of weeds for management post-harvest. Detecting weeds with this technology reduces the amount of time needed on field and can highlight areas of weeds that may be missed at eye height when completing crop walks.

Irrigation Management

Irrigation and drainage management is a challenge all Scottish farms face. When something goes wrong it can damage your crop and end up costing thousands in lost revenue. Spotting these issues before they can have a large negative impact is vital. Using RGB, NIR or multispectral data terrain/slope maps can be produced. These can give an overview of your land's drainage patterns, highlighting where water might accumulate and where your field may be vulnerable to erosion. This is most effective during the beginning of the crop cycle when the bare earth is visible.

Later in the crop cycle thermal sensors can be used to pick out poor drainage by identifying the temperature difference between wet and dryer soil. Thermal sensors can also pick out irrigation issues through detecting crop temperature variations, as higher temperatures in crops is an indication of water stress.

These applications will enable farmers to detect and quantify damage caused by drainage and irrigation issues far earlier than can be achieved through field walks. Such early detection will mitigate loss and ensure farmers stay in control, saving time and money that could be better spent on other aspects of their business.

Damage Assessment and Mitigation

Large and often more extreme weather events can wreak havoc on a farmer's livelihood. In the aftermath of extreme weather events, taking stock of the damage done to your farm, crops and livestock is key. Drones can offer a quick and detailed overview of crop losses, pinpointing affected areas that may normally have been missed during a crop walk. Such uses save time and ensure that farmers have an almost real-time overview of their yield loss, improving decision making and providing evidence to back up insurance claims.

Other uses include using an RGB sensor to get a birds eye view of farm structural damage or livestock locations. NIR or Multispectral sensors can be used to give a more accurate portrayal of plant health that make monitoring longer term impacts of crop damage far more efficient. Thermal sensors can also aid in detecting livestock and any flooding or water pooling that may occur in such situations.

The effects of livestock on the land can also be assessed by looking at the historical data. High quality soil is a precious commodity in Scotland, however each year soil is being removed from agricultural land through erosional processes that are being exacerbated by issues such as compaction, poaching and overgrazing. Doing all we can to keep soil on farm is pivotal in ensuring the long-term sustainability of Scottish agriculture. Through the use of drones, farmers can get a better understanding of where these issues are occurring on their farm, improving long term management decisions.

Limitations

It should be noted that drones are not a silver bullet for agricultural businesses. There are a large number of areas where drones will either never be practical or lack the capabilities due to current technological or regulatory restrictions. Additionally, for many of the services discussed in this publication further software, algorithms and/or services are required for data processing and analysis, which can increase operation costs significantly.

Further Information

For more information on the impacts of drones on the UKs economy go to:

https://www.pwc.co.uk/intelligent-digital/drones/Drones-impact-on-the-UK-economy-FINAL.pdf

The CAA website has the most up to date information on current UK drone operation regulations and requirements:

https://www.caa.co.uk/Consumers/Unmanned-aircraft-and-drones/

For further information regarding the rules and regulations surrounding the use of drones for your business refer to the UAV Rules and Regulation document on the FAS website.