UAVs in grasslands: A brief guide

Ben Roberts

About this handbook

This handbook offers a brief initial insight into the general considerations of using unmanned aerial vehicles within grassland research. As UAV development is a fast-moving area, readers should make sure they seek up to date information, and not rely solely on the contents of the guidebook. There is much information available on the use of UAVs online, and any readers wishing to undertake UAV based activities should seek guidance first from a certified training provider.

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1.0 An Introduction

Figure 1. An image taken from a UAV of grasslands during winter in the UK. Source: Linford Miles on Unsplash.com

1.1 A general background to UAVs, and opportunities that UAVs offer

Simply put, an unmanned aerial vehicle (UAVs) (commonly referred to as drone) is an aircraft without a human pilot on board. Instead UAVs operate under various degrees of autonomy, either under remote control by a human operator, or semi/fully autonomously by onboard computers. UAV technology is rapidly changing and developing, with considerable impact estimated for the UK economy. A 2018 study by PwC estimate UAVs to contribute £42bn to the UK economy by 2030, creating 628,000 jobs (PwC 2018). The number of applications for UAVs has increased considerably in the last few years as practitioners and researchers seek to take advantage of the accelerated technological progress.

Many of the recent applications have been within emergency services, however their use within research is becoming commonplace. The term ‘sensor platforms’ is being increasingly used to describe UAVs within research (Bürkle, Segor & Kollmann 2011; Bhardwaj *et al.* 2016), as academics seek to explore new applications for UAVs through the incorporation of different sensors. Examples are extremely varied and for land based research can include anything from the use of LIDAR (light detection and ranging) for tree detection in forest operations (Wallace, Lucieer & Watson 2014), the use of imagery for detecting forest fires (Yuan, Liu & Zhang 2017) or mapping of glaciers (Ryan *et al.* 2015), or even radio tracking whole herds of animals over large enclosures (Roberts *et al.* 2020). Within grassland research, UAVs are currently most used for image acquisition to enable mapping or surveying of vegetation.

1.2 UAVs within grassland research

The ability of UAVs to travel long (many km) ranges quickly (particularly fixed-wing UAVs) at a low altitude has facilitated their rapid uptake as platform for conducting image surveying. Correctly integrated, hundreds or even thousands of images may be taken in the space of a single 30-minute flight. Though the precise area covered in each image will vary according to camera specifications and UAV altitude, utilising the latest photogrammetric software, these images may be stitched together to form single georeferenced orthomosaic maps. Digital elevation models (DEMs) may also be produced through the same software using Structure from Motion (SfM) techniques. From here, a varied number of GIS analyses may be performed. Examples of which are provided in section 4.3 of the guide.

2.0 Choosing the UAV set up

This section will provide some of the general considerations for selecting the most appropriate UAV set-up. Predominately, this will focus on selecting the most appropriate UAV for the task at hand, selecting and integrating an appropriate sensor, as well as detailing the options on flight planning.

2.1 Selecting the most appropriate UAV for the task at hand

In deciding what type of UAV is most suitable for a given study, the following points are useful to consider.

2.1.1 Survey area size

UAV aircraft can be assigned into either of two categories: fixed-wing or rotary wing (Figure 2). Fixed-wing's resemble a typical airplane; that is, they have a rigid wing design and fly by generating lift from the UAV's forward airspeed. This airspeed is generated by forward thrust from a turning propeller and is adjusted using control surfaces built into the wing itself (e.g. ailerons, elevator and/or rudder). A rotary wing on the other hand features rotor blades that revolve around a fixed mast, known as a rotor. The number of rotors varies between different designs, but one (helicopter) or four (quadcopter) rotor setups are common. For surveying larger areas, the fixed wing design is more suitable because of its greater range capability compared to rotary wings. Primarily this is because fixed-wing's require less power to stay in flight, and operate at a higher airspeed then multi-rotor UAVs. Though dependent on the survey characteristics (e.g. operational altitude, image overlap etc.) a fixed-wing may well be able to survey >30 ha from a single battery use, whereas a standard multi-rotor will usually only be able to complete <5 ha. That said, where possible multi-rotor UAVs will often be preferable to new users. They are after all far more widely available then commercial fixed wing UAVs. As a result, they are also comparatively low cost (£1000-3000) for a basic setup compared to compared fixed wing's (£3000-£18,000), and their ease of use make them more appealing to beginners. For experienced UAV pilots, self-build fixed wing designs can be very low cost (£500-£700 set up using a Skywalker X8), however this obviously requires a competent level of knowledge when it comes to avionics and UAV design.

Figure 2. Fixed-wing and Multi-rotor UAVs. Left: eBee senseFly fixed-wing UAV (Source: robots.ieee.org). Right: DJI Phantom 4 multi-rotor UAV (Source: DJI.com).

2.1.2 Sensor type

The second consideration is the type of sensor to be mounted on the UAV and therefore the payload capacity the UAV would require. Whether the sensor would attach into the UAV power supply or require its own dedicated battery will also influence the weight. It is typical that a 500-1000 g payload capacity is enough to support most cameras required. For conducting image surveys for photogrammetric purposes within grassland environments, there are three types of the camera available: RGB, Multispectral and Hyperspectral.

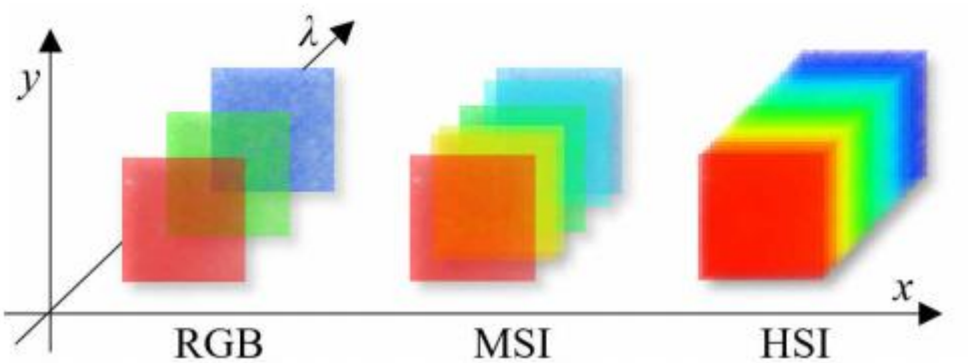

Figure 3. Differences between RGB imaging, multispectral imaging (MSI) and hyperspectral imaging (HSI). Source: Gevaux (2019).

RGB cameras refer to the spectral bands that they acquire, in this case; Red, Green and Blue. As a colour model, it is typically the most utilised within everyday display devices (e.g.

televisions, digital cameras, computers, mobile phones). As such, it is often favoured for its simplicity and familiarity to users.

Multispectral cameras capture multiple different wavelength ranges within the electromagnetic spectrum. Aside from Red, Green and Blue wavelengths, Near- Infrared (NIR), and Red-edge (RE) are commonly measured, as they are effective for measuring different aspects of vegetation properties. Long Wave Infrared (LWIR) (commonly known as 'thermal') is also becoming increasingly measured in newer cameras. Though they typically offer greater analysis options, multispectral cameras are also generally more expensive then RGB cameras. Examples of multispectral cameras for UAVs include the Micasense Rededge/MX, Parrot Sequoia, and SlantRange 4P series.

Figure 4. Multispectral cameras. Left: Micasense Rededge MX & DLS (Source: Micasense.com). Centre: Parrot Sequoia+ & DLS (Source: Parrot.com). Right: SlantRange 4P series (Source: Heliguy.com).

Hyperspectral imaging collects and processes information from across the electromagnetic spectrum. The objective is to obtain the spectrum for each pixel. Unlike multispectral imaging which measures spaced spectral bands, hyperspectral imaging measures continuous spectral bands. As such, there is a large volume of data collected for each acquisition. Whilst this may be crucial to certain analysis which require unique band combinations, it may prove cumbersome for standard processes. Currently, hyperspectral sensors are also very expensive, and require fast computers, and large data storage capacities.

Ultimately, the decision as to which sensor is used should be driven by the analyses to be conducted. In that way, any data acquisition is cost effective and efficient. Aside from spectral types, aspects such as the required camera resolution should also be considered.

2.1.3 Flight planning software

If the intention of using the UAV is to conduct surveys (e.g. for imaging purposes), the required precision in the flight path is best achieved using an autonomous flight mode. For this to happen, an autopilot module and flight planning software are required. Most mainstream commercial UAV manufacturers (e.g. DJI, Parrot) include their own autopilot modules within their systems, and more recently even their own flight planning software. However, flight planning software vary in the different functions they have available and it may be necessary to adopt different software depending on what is required. For example, whether the topography of a site is flat or hilly influences what flight software may be used. Currently, many of the available software do not contain terrain following capability, and instead fly according to a set altitude which is calibrated from the launch point (i.e. the launch point is 0m). This means that if there are any moderate undulations in the survey path, the UAV may risk; collision, flying above regulatory limits, or being out of line of sight. From a data acquisition point of view, when collecting imagery, it is important that imagery is taken at a similar above ground height so sufficient overlap is maintained. An inability to do so can result in stitching failure. Therefore, in any event it is important to investigate what functionality different UAV autopilots have, and match this to the mission properties to be considered. Some of these software exist purely as applications for mobile devices (which connect to the UAV transmitter), whereas others also include desktop versions.

A few examples of different flight planning software include: Mission planner, UgCS, Litchi & Pix4D capture.

Ultimately, the decision on which flight planning software to use will depend on the circumstances of the UAV mission. In some cases, a user may choose to use different software depending on the different circumstances and not rely on any one software. Some mission planning software may be available to use on a PC, but in most cases will be controlled and integrated to the UAV through a mobile device (e.g. phone or tablet).

3.0 Considerations for the flight

When operating a UAV, there are a number of practical and regulatory considerations.

3.1 The regulatory considerations

Fundamentally, no UAV operations should be undertaken until a pilot is certain that they comply to regulatory requirements of the Civil Aviation Authority (CAA). They should be sure that they have the received the level of training required to operate the UAV safely and have the correct level of insurance for the activities they wish to undertake. Given the regulations are changing at the time of writing, this document will not advise on the current regulatory requirements. Instead, it is recommended that interested readers look at the latest material online, particularly the CAA (https://www.caa.co.uk/Consumers/Unmanned-aircraft-and-drones/), and Dronesafe (https://dronesafe.uk/) websites. Additionally, readers can contact certified training providers.

3.2 The practical considerations

Figure 5. Operating UAVs in upland grasslands can be tricky. Thorough preparation is essential to successful surveys. Source: Annie Spratt on Unsplash.com

3.2.1 Site characteristics

Before surveying a site for the first time, it is important to consider certain characteristics of the site. The first thing to consider is where the launch and land location need to be. For multi-rotor UAVs, their ability to launch/land vertically means this area need only be small. However, with fixed-wing UAVs, a sufficient strip of ideally flat land will be required to land safely. Launch and land locations should ideally be flat, covered with sparse vegetation, and with no aerial obstructions. Finally, the launch/landing area should be sufficiently far away from buildings/people. The exact distance should be checked with CAA regulations prior to flying, but at the time of writing is 30m.

3.2.2 Conducting the survey within the regulations

In most cases, pilots will have designed the surveys in their flight planning software prior to arriving on the site. However, some apps such as 'Pix4D capture' enable users to quickly design surveys on site. In this event, pilots should make sure that the surveys are conducted within the regulatory permissions. At the time of writing, this means an altitude limit of 400ft, and distance no greater then 500m from the pilot, and uninterrupted line of sight to the UAV at all times during the survey. Regulations concerning distance to people/buildings should be less prevalent when operating in grasslands, but pilots should be aware of them if such situations are present.

3.2.3 Site access

Ease of access to and within the site should also be checked beforehand. On small sites, this may not be a problem. On large sites however, particularly in upland areas, it may be difficult to navigate across a site with a vehicle. UAV pilots must therefore be aware how far they are going to need to carry their equipment. For small multirotor UAVs this may not be a concern, but for larger UAVs (particularly fixed-wing's), this could be an issue.

3.2.4 Checking the equipment

Pilots should undertake a thorough check of all the equipment they require before going on site. Aside from the UAV and associated sensor, SD cards (for storing imagery on the cameras), batteries, tablet/phone/laptop, safety equipment (e.g. cones, high- vis jackets, first aid kits), spare clothing, and often more, need to be considered. Given the time often taken to get to the field sites, and the reliance on favourable weather conditions, failure to complete a survey simply due to missing/faulty equipment is a common and frustrating situation for many new pilots.

3.2.5 Weather

Local weather conditions have a massive impact as to whether a survey can be undertaken or not. Flying in reduced visibility (e.g. mist) should not be undertaken if line of sight to the UAV is compromised in any way. Different UAVs have varying water resistance ratings, but in general flying in rain/drizzle should be avoided. Not only does moisture increase the chances of hardware failure on the UAV, but the quality of imagery is likely to be negatively affected as well. Wind speed should be measured prior to flying using an Anemometer. These can be purchased fairly cheaply and are good for providing an empirical value as to the conditions at the time. All commercial UAVs will have a maximum wind tolerance value stated in their manuals, and pilots should make sure these are not exceeded. Even if the wind speed is below the stated limit, pilots should be aware of the payload weight of the

UAV, and distance to be covered within the survey. Afterall, increased wind speed will inevitably require the UAV to use more power to maintain a stable flight, and therefore pilots should be confident that the UAV can complete the survey with the battery power available.

4.0 Data processing and analysis

4.1 Data storage

Most UAV sensors use SD cards as a means of storing data. Once a survey has completed, one of the main priorities of the pilot will be ensuring that data on the attached sensor is transferred to a more stable storage device. For image acquisition surveys, these datasets can be large (several Gigabyte or more). If pilots are likely to be undertaking frequent surveys, it is worth investing in large capacity hard drives/cloud storage or even both.

4.2 Image stitching

Image stitching is the process of combining multiple photographic images with overlapping fields of view to produce a segmented panorama or high-resolution image. For UAV imagery several commercial software packages exist. These include:

Agisoft Metashape   PIX4D   DroneDeploy   OpenDroneMap

Some of these software exist as cloud processing services, whilst others are desktop applications. In general, the main outputs from the software will be an orthomosaic (stitched image), and digital elevation model (DEM). A DEM is a 3D computer graphics representation of elevation data to represent terrain and surface and may be further refined as either Digital Surface Models (DSMs) or Digital Terrain Models (DTMs). DTMs include only the terrain, and no above ground features. DSMs contain the terrain, and all above ground features. In several software, both DTMs and DSMs may be generated. Another additional output may include reflectance maps. Reflectance maps represent a calibrated form of the orthomosaic, where the value of each pixel is adjusted to faithfully indicate the reflectance of the object. This calibration can be achieved through using camera information (vignetting, dark current ISO etc.), or sun angle and irradiance data from a downwelling light sensor (DLS) attached to the UAV camera, or calibration panels placed on the ground during image surveys. As all UAVs used for surveying come equipped with GPS for navigation, images from the attached sensor are usually geotagged. This means that all outputs will also be georeferenced and can therefore be incorporated into GIS software with ease. This can be particularly beneficial in grassland research, where on ground measurements can be accurately cross referenced with the UAV outputs.

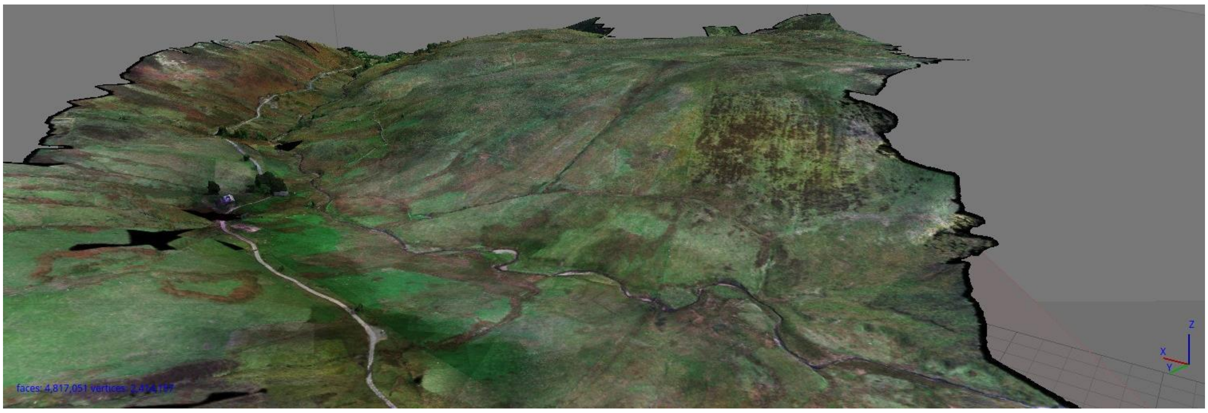

Figure 6. A Digital Elevation Model (DEM) overlaid with an Orthomosaic showing a hillside in Mid Wales. This was produced from 12250 images using a Micasense Rededge camera. Source: Ben Roberts.

4.3 Analysis

The number of applications and the types of analyses that can be used for UAV derived data is expanding rapidly. It is therefore not feasible to discuss all current analyses available. Instead, included are a few commonly used examples. These include vegetation indices (VI), colour rendering effects, and uses for DEMs. The precise methodologies, as well as guidance for completing each analysis can be found in numerous places online (see https://www.microimages.com/documentation/TechGuides/81VegIndices.pdf as example).

Table 1. Common examples of analyses and their applications using UAV derived imagery. Source: Micasense.com

Analysis	**Applications**
NDVI (Normalized Difference Vegetation Index)	• Plant vigour • Differences in soil water availability • Foliar nutrient content (when water is not limiting) • Yield potential
CIR Composite (Colour Infrared)	• Assessing plant health • Identifying water bodies • Variability in soil moisture • Assessing soil composition
NDRE (Normalized Difference Red Edge)	• Leaf chlorophyll content • Plant vigour • Stress detection • Fertilizer demand

	• Nitrogen uptake
OSAVI (Optimized Soil-Adjusted Vegetation Index)	• Differentiate soil pixels • Related to LAI at some levels where NDVI saturates • Accounts for non-linear interactions of light between soil and vegetation • Used as a structural index for some combined indices designed for chlorophyll detection
DSM (Digital surface Model)	• Estimate relative crop volume • Identify surface properties • Model water flow & accumulation

The analyses above represent but a tiny fraction of the possible applications of UAV data in grassland management and research. For researchers, it is advised that they study material or undertake courses relating to remote sensing and GIS, should they wish to fully explore all the potential analysis options. For farmers/land managers, many image stitching/sensor companies (e.g. Micasense, PIX4D, Sentera) offer packages that include easy-to-use image analysis tools, even going as far as full workflow integrations (i.e. from selling UAVs/sensors, to image stitching software, then analysis).

5.0 Concluding remarks

Though still in its infancy, the use of UAVs within grasslands both for research and management is becoming increasingly utilised. The acquisition of such high-resolution data over large areas, is offering new insights into grassland systems, and represents a major breakthrough in a sector that has often lagged behind arable farming in precision technology uptake (Schellberg *et al.* 2008). It is hoped that this guide has given readers a brief understanding of the different aspects that should be considered in wishing to undertake UAV work in grasslands, and will facilitate them in being able to pursue the topic further.

6.0 Acknowledgements

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