Habitat restoration in the Pennines

Mark Brown describes a novel application of Unmanned Aerial Vehicle (UAV) technology in northern England

The Yorkshire Peat Partnership (YPP) has been using Unmanned Aerial Vehicles (UAVs) since 2012 to survey and map areas of degraded upland habitats. The work is conducted across the mountains and hills that comprise the low-rising Pennine mountain range in northern England.

Blanket bogs

A very special type of ecological habitat known as blanket bog is found here. Although treeless, such areas have been described as Britain's version of the Amazon rainforest and are home to many unique plants and animals. Carnivorous plants such as Round-leaved Sundew (Drosera rotundifolia) grow in this environment and blanket bogs provide important breeding and nesting grounds for upland birds such as golden plover (Pluvialis apricaria) and dunlin (Calidris alpina).

These 'blankets' of peat have formed over thousands of years through the accumulation of partially decayed vegetation such as Sphagnum moss and can be up to several meters deep. As such, they act as a massive carbon sink, sequestering carbon from the atmosphere and providing a buffer against climate change. They are also a very important source of much of our drinking water and help to regulate water quality and mitigate flood risk. In addition, blanket bogs are an invaluable resource in terms of our scientific and cultural heritage. Archaeological artefacts are preserved intact due to the anaerobic conditions, and preserved pollen, insect fragments and testate amoeba can provide an excellent record of past climate conditions. These uplands provide important grazing for sheep and, not least, are widely used for leisure and recreational activities.

Yet many of these habitats are in a heavily degraded state. Mismanagement of the land through burning and overgrazing, as well as natural causes such as wild fires, are causing much of it to erode away. Once peat is exposed to the elements it rapidly wears away, releasing carbon and entering waterways where it turns clear water into a colour similar to that of tea. Peat that is dissolved in waterways causes a problem for water companies as they have to spend millions of pounds each year to remove the dissolved organic carbon through chemical treatments.

Restoration work

The Yorkshire Peat Partnership (YPP) aims to reverse this degradation by establishing the stable conditions necessary for its recovery. This entails the building of dams and barriers to block drainage channels and erosion gullies. The result helps raise the water table and encourages the deposit of peat sediment behind the dams instead of it being carried off into the waterways.

The sides of gullies that are suffering erosion are often too steep for re-colonisation by vegetation. In order to aid its recovery, we re-profile the gully sides to a shallower angle before carrying out bare peat revegetation.

Re-vegetation techniques are used to stabilise the peat and allow colonisation by natural bog species. This includes the application of lime to raise the soil pH, fertiliser to support root establishment, and seeding with amenity grass to act as a nurse crop.

A variety of techniques are being trialled to reintroduce sphagnum mosses to blanket bogs.

LiDAR, DEMs and UAVs

The use of UAVs by the YPP was primarily dictated by the need for high resolution elevation data for hydrological modelling purposes within GIS software. We were interested in determining where water was flowing, as well as detecting distinct hydrological units within our restoration sites. This information could be used to inform our habitat restoration schemes.

We found that the currently available Digital Elevation Models (DEMs) were of insufficient resolution to detect most of the erosion features in which we were interested. LiDAR of 1m resolution was available, albeit of limited coverage, but even this wasn't of sufficiently high resolution to meet our needs.

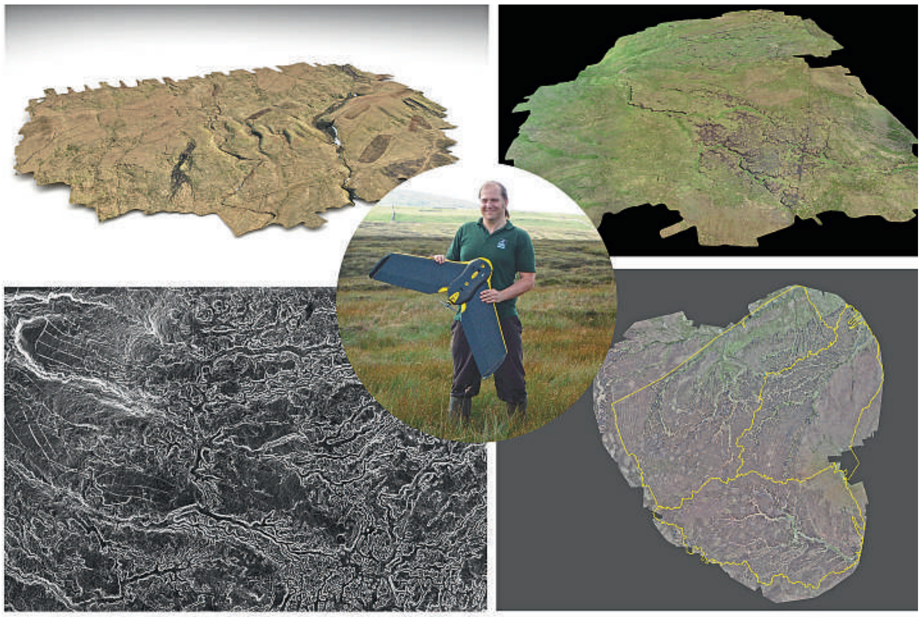
The commissioning of helicopter or fixed-wing aircraft LiDAR surveys was prohibitively expensive. In fact, the cost of conducting a bespoke survey for just one of our sites would equal that of purchasing one of the first commercial UAVs that were then becoming available. This made the acquisition of a UAV such as SenseFly's eBee very appealing. Not only would we be able to collect our own imagery to produce DEMs and RGB orthophotos; we would also be able to carry out repeat surveys, thereby making it a useful tool for the temporal monitoring of our restoration sites.

Indeed, since conducting UAV surveys at our restoration sites we have been able to collect and generate data at a previous inaccessible scale. Typically, we process data to around 3.5cm using PixeD's Mapper photogrammetry software. Prior to this we were working with 25cm resolution RGB imagery and 5m resolution DEMs.

A realm of possibilities

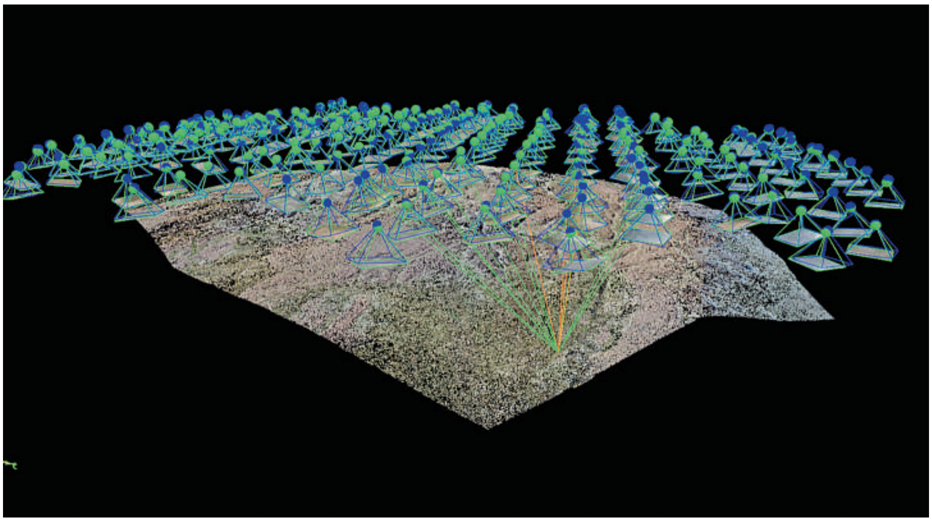
The resolution of this data has opened up a whole new realm of possibilities for the geospatial analysis of blanket bogs. We can now identify and quantify areas that are either undergoing or at most risk of erosion and use this information to inform us where best to target our limited resources.

We use the data generated from UAV flights to carry out a whole range of analyses. We are a big proponent of Open Source software and conduct most of our analyses within the QGIS Open Source GIS package. These include, but are not limited, to surface analysis, hydrological analysis, feature extraction, Object Based Image Analysis (OBIA), 3D visualisation, and the creation of cross- sectional profiles to determine the dimensions of eroding gullies.



Clockwise, from top left: Photorealistic terrain model generated from data captured during UAV surveys visualised within Blender (an open source 3D modelling software package); 3D Model; A site separated into restoration management zones through the identification of distinct hydrological units using tools within QGIS; Application of a standard deviation filter algorithm within QGIS to identify areas of erosion. All images: © Mark Brown @ Yorkshire Peat Partnership except central photo: © Kay Waite

Top: Gully re-profiling with a low ground pressure digger in the Yorkshire Dales National Park. Photo © Matthew Roberts. Below: Aerial image of an area of degraded blanket bog captured using a SenseFly eBee with a Canon WX (18.2 MP) camera. © Mark Brown @ Yorkshire Peat Partnership



Photogrammetry software (Pix4D Mapper) is used to process imagery captured using the UAV. © Mark Brown @ Yorkshire Peat Partnership

THE YPP GEOSPATIAL TOOLBOX

- The Yorkshire Peat Partnership conducts UAV surveys using a SenseFly eBee. (https://www.sensefly.com/drones/ebee.html). This small, fixed-wing drone is proving to be one of the most popular commercially-available airframes for surveying and mapping purposes. The UAV is fully automated and flies along pre-defined transects taking photographs along the way.

- The imagery captured by the eBee is processed within Pix4D Mapper (https://pix4d.com/), a photogrammetry suite that is used to generate point clouds, Digital Surface and Terrain Models, orthomosaics, and textured models.

- All geospatial processing of the datasets produced from these surveys is performed within QGIS (http://www.qgis.org). Due to its user-friendly interface and wide variety of processing options, this Open Source software is fast becoming the GIS software of choice for ecological and conservation applications.

- 3D modelling is carried out in Blender (https://www.blender.org/), another Open Source package more commonly used for 3D art, animation, and the creation of computer games.

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Surface analysis

There are numerous ways in which a high resolution Digital Elevation Model (DEM) can be used to analyse the terrain of a peat bog. By assuming that exaggerated changes signify likely areas of damage to the bog, a standard deviation filter can be run across the dataset to identify those areas with the greatest variation in topography. By applying a threshold to the resulting dataset, it is possible to accurately extract those areas that are undergoing significant erosion. We can use this data to quantify the total area of erosion and to map where restoration needs to be carried out.

Hydrological analysis

A very important area of our work involves blocking grips and gullies to restore the hydrological integrity of peatland. In areas of dendritic gullying, it is confusing, both on the ground and from aerial photographs, to assess in which direction water is flowing. By performing hydrological analysis, we can identify the direction of water flow and therefore map gully systems. Furthermore, identifying sub-basins within watersheds allows us to target distinct hydrological units.

3D visualisation

By importing the data into 3D modelling software, we can examine our restoration sites from every possible angle without the need to return to the field. We're literally bringing the blanket bog back into our office.

Image classification

By using image classification techniques with aerial imagery captured by a UAV, we can automatically map areas of bare exposed peat. Work that would have previously taken weeks employing head-ups up digitising can now be performed in a day using the methodologies we have developed. These areas undergo a treatment of liming, heather brashing, seeding and fertilising. In sensitive areas, the required materials are often carried onto site by helicopter .... an expensive exercise, and one where it is important to have an accurate estimate of the quantity of material to be transported in this way.

Cross sectional profiles

It is important for us to know the dimensions of erosion gullies in order for our contractors to calculate the cost to carry out restoration work. Gullies undergo a process of re-profiling whereby the eroding sides are smoothed and levelled to make them suitable for re-vegetation. We also need to know how wide the gullies are in order to calculate the dimensions for required dams. It is important to know the amount of wood required, as once the materials have been transported onto site, it is expensive to take them back off.

Modelling peat reserves

Our field staff collect a wealth of important information when out surveying our peat bogs. Equipped with a sub-meter accuracy GPS mobile field computer (Spectra Precision Mobile Mapper 120), they record plant species such as sphagnum mosses and take measurements to assess the depth of peat.

The latter is particularly important to ensure that we are carrying out restoration on blanket bog.

By using geostatistical techniques such as kriging, we can predict the depth of peat throughout the blanket bog. By combing the elevation data collected by the UAV with the peat depths collected by our surveyors it has been possible to produce 3D models of sub-surface peat reserves. We can then use this data to calculate the volume of peat beneath our sites and in turn calculate how much carbon is stored there.

Conclusion

Weather conditions prove to be a major constraint in applying UAV surveys for peat bog habitats. Yet when such conditions are favourable, the resolution of the collected data is far in excess of anything that we could purchase through commercial means. Large file sizes put a strain on server capacity and geospatial processing necessitates long processing times. However, this data allows us to map and analyse peat bogs in ways that were previously impossible and has revolutionised the way in which we carry out restoration work.

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