Seeing the big picture

How UAVs can help with monitoring landscape dynamics

Using UAVs in Ecology

Unmanned Aerial Vehicles (UAVs, or "drones" as they are often called) have burst onto the market in the last few years, with many industries exploring how they could be used. This is no different in the environmental sector. The ability to gain a bird's-eye view of an area quickly and cost effectively has seen UAVs begin to be included in the toolkit of environmental professionals.

Knepp in a nutshell

The Knepp Estate is a 1,400ha area of West Sussex. Formerly an intensively farmed area with arable and dairy farming predominating, the estate struggled to be financially viable, and so the owner, Charlie Burrell, initiated the Knepp Wildland Project in a bid to create a way of managing the land and allowing more natural processes to take place. The work of Frans Vera, particularly his book Grazing Ecology and Forest History *(2000), is the driving inspiration behind the Wildland project. Vera proposed that the pre-agricultural landscapes of Western Europe were not just closed forest, but a mosaic of closed forest, open grassland, scrub and wood pasture. This system was a dynamic one, with the mosaic habitat shifting over time, and driven by the grazing and browsing activities of the formerly present large herbivores (such as the tarpan (wild horse), aurochs (wild ox), wild boar, deer, etc.). Therefore, the aim of the Wildland project was to reintroduce these ecosystem drivers to produce this dynamic, shifting landscape.*

The land was taken out of agriculture at different times depending on its location in the estate (which is split into Northern, Middle and Southern Blocks). The Northern Block was taken out of agriculture in 2003 and was reseeded with a grassland mix, and then the Middle Block (which features historical parkland) in 2001 which was reseeded with native grasses and wildflowers. The Southern Block was treated slightly differently; individual fields were removed gradually from agriculture from 2001 to 2006. In contrast to the other two blocks, the Southern Block was not reseeded, but allowed to revegetate naturally. A low density of English longhorn cattle, Exmoor ponies, Tamworth pigs, fallow deer and (more recently) red deer, were then introduced into the blocks at varying times, with the Southern Block receiving these herbivores last in 2009. Wild roe deer and rabbits already occurred naturally in the wider landscape. The time given to the Southern Block to "scrub up" naturally before herbivores were introduced has facilitated a starkly different landscape character, as the vegetation differs from field to field. In general this area of Knepp looks wilder and has less clear cut boundaries than in the other two blocks, with scrub (like sallow, blackthorn and hawthorn) merging with grassland and woodland, producing an intriguing mosaic habitat. Since the Wildland project started, there have been some fantastic results in terms of biodiversity (particularly in the Southern Block), with 90 species of breeding bird (22of which are Red List Species and 18 Amber List Species), 33 species of butterfly and 19 species of earthworm recorded in June 2013 over three transects. Knepp is now also the largest breeding hotspot for purple emperor butterflies in the UK, and the number of nightingale territories has doubled from nine in 1999 (prior to the rewilding scheme) to 18 in 2015.

For some time we have been exploring how we could use UAVs in an ecological context and what benefits they could provide to us and our clients. For example: how can we save costs for our clients? How can we get better data? How can we survey large or inaccessible areas more efficiently? Can we show changes over time? We have conducted a number of flights including a building inspection, an inspection of a viaduct (with the aim of identifying features suitable for bats) and tests of habitat mapping. What we really wanted to do though was use a UAV at a large site to gather imagery and use that to monitor landscape-scale dynamics. The Knepp Wildland Project provided a fantastic opportunity to do just this.

Thomson Ecology on site at Knepp capturing UAV imagery

The Knepp story

The Knepp Wildland Project is an innovative rewilding scheme which has seen the transformation of approximately 1,400ha of formerly intensive agricultural land into a revitalised lowland mosaic habitat. Conventional intensive dairy and arable farming was halted on the estate and free-ranging herbivores (red and fallow deer, Tamworth pigs, English longhorn cattle and Exmoor ponies, along with the naturally occurring wild roe deer and rabbits) were subsequently introduced to drive the vegetation dynamics. The low number of grazers (0.25 livestock units per hectare) allowed the vegetation to develop. The project is process led with no specific biodiversity or ecological “aims” as such; however, seeing whether the landscape develops into closed woodland or semi-open mosaic habitat is a key tenet of the project.

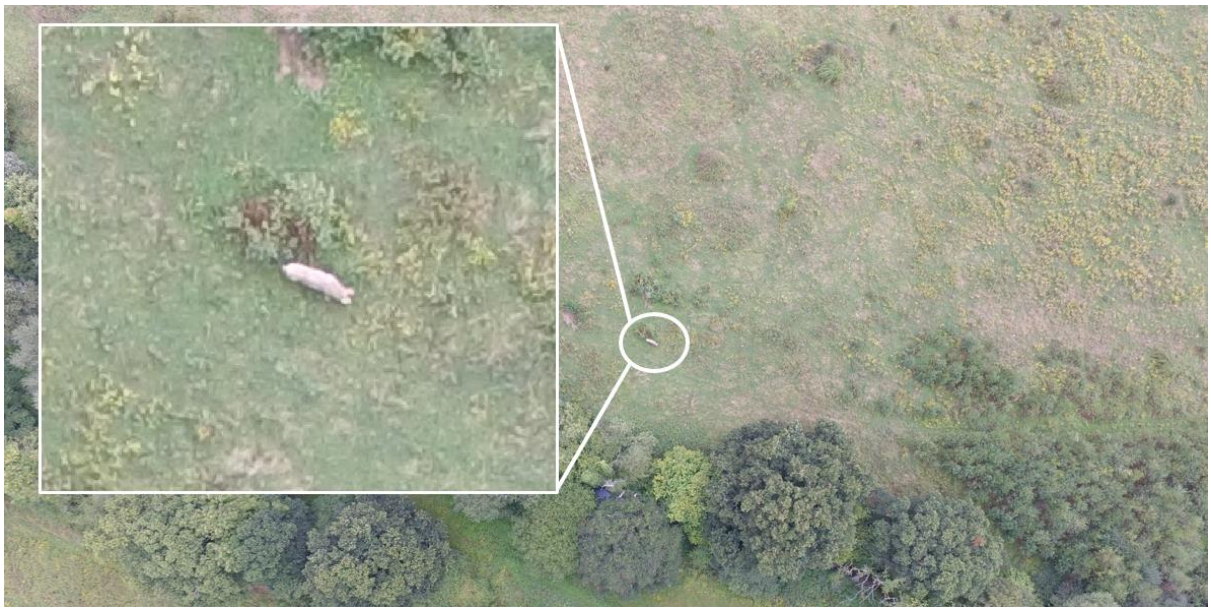
UAVs allow effective monitoring

Monitoring how the vegetation develops over time is, therefore, a key part of the Knepp scheme. The densities of herbivores have to be managed and so monitoring the effect of grazing and browsing is important. As well as this, relating biodiversity developments to developments in vegetation structure and composition could reveal important ecosystem linkages.

Conducting large-scale monitoring using traditional field survey techniques is difficult and time consuming. This is especially true in areas like the Southern Block at Knepp, where the varied nature of the landscape composition means that sample sites provide an incomplete view of the area. Whilst traditional habitat surveys, transects and fixed-point photography can provide a high level of detail at the local scale, these methods are impractical at providing such detail over a large scale. This is where we see the benefits of using a UAV. The high level of detail that can be obtained rapidly over large areas makes it the perfect tool for landscape-scale monitoring.

From flying to data

Earlier this year, we spent a day in the Southern Block at Knepp capturing high-resolution imagery from the air. The UAV was set to fly at an altitude of 100m, in order to maximise the area that we could capture in the time available. At this height, we were able to capture imagery at a pixel resolution of 4cm, which is of a very high quality when compared to available off-the-shelf aerial imagery captured from an aeroplane. The quality of the imagery was good enough for us to pick out individual shrubs and we could even identify some of Knepp's fauna in the imagery, such as red and fallow deer, the Tamworth pigs and some buzzards (who didn't seem fazed by the UAV at all!).



High levels of detail

The high quality of the imagery enabled us to identify some of the animals in the Wildland project, such as this Tamworth pig

The area we captured was just under 2km^2 and resulted in over 3,000 individual overlapping images. Once back in the office we ran this raw imagery through the processing software in order to georeference it so that it was accurately located when in a geographic information system (GIS). We also orthorectified the imagery, meaning that the effects of perspective and relief were removed, creating a planimetrically correct image with a constant scale and features located in their 'true' positions. The software stitched all of the individual images together to create one seamless image mosaic. This enabled the analysis of the captured area within a GIS system, as opposed to having to analyse each individual image captured. Another dataset produced is a 'point cloud' showing a 3D representation of the area. This enables the viewer to explore the site virtually at their desk. It also allows digital surface models (DSMs) to be created which represent the surface of the captured area, including the ground, trees, and any structures.

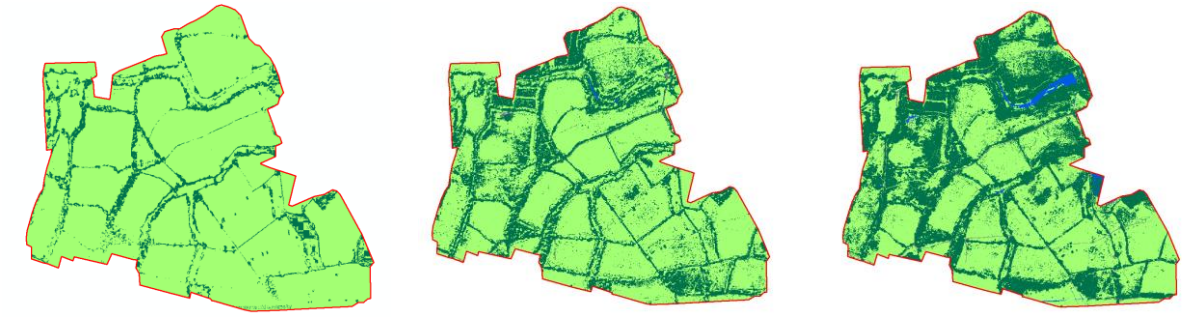
An example of the imagery we captured with the UAV

Once the image processing was complete, we were able to input the image mosaic into the GIS and start analysing it. Firstly, we mapped the vegetation types within the imagery, giving us a quantitative picture of the vegetation and the percentage cover of each type. The DSM also enabled us to gain a picture of the structure and height of the vegetation.

Detecting changes over time

The data produced from this UAV-led approach becomes even more valuable when it is compared to datasets from the same site captured at different times. This enables meaningful comparisons to be made on the ecological development of a site. For example, have any habitat or vegetation types grown or shrunk in area or percentage cover? Or, has the height of any vegetation changed significantly?

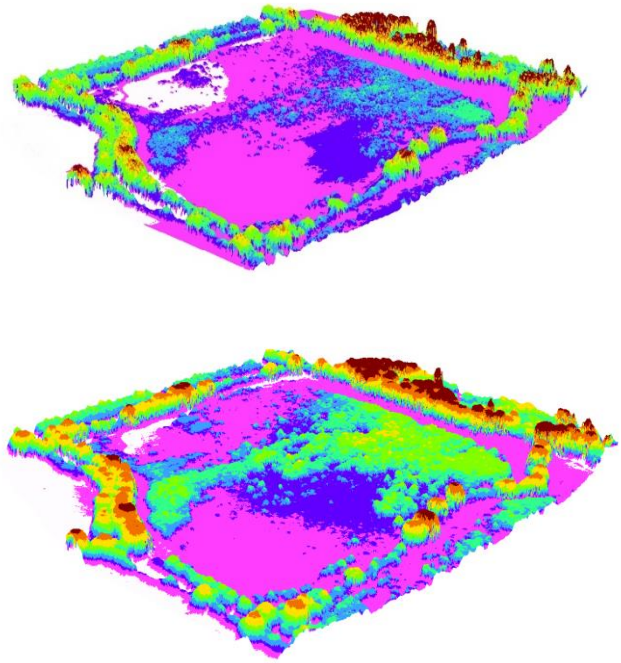
In order to explore whether the capabilities of our UAV data could be used for such monitoring purposes, we obtained satellite imagery from 2001 - before the rewilding of the Southern Block had commenced - and aerial photography from 2014. The quality difference between our UAV imagery and the two off-the-shelf image sets was substantial, so we had to effectively “downgrade” the data from our UAV imagery in order to make a meaningful comparison. This allowed us to quantify how the general composition of the area had changed since the dairy and arable farming ceased, and the Wildland project began. As would be expected, in 2001 before the rewilding of the Southern Block, grassland, pasture and arable fields dominated the area, with scrub, hedgerows and woodland making up only 10% of our study site. In the 2014 data, the proportion of scrub and woodland had increased to 35% and our 2016 UAV data showed that 45% of the area was now made up of scrub, woodland and hedgerows.



Change Detection

We were able to compare broad habitat mapping from our 2016 UAV data (right), and off-the-shelf aerial imagery from 2014 (middle) and satellite imagery from 2001 (left). Dark green represents woodland, scrub and hedgerows, whilst light green represents grassland and agricultural fields.

Not only could we make a comparison of vegetation composition in a 2D environment, we were also able to quantify how the 3D structure of the vegetation had changed by comparing our DSM produced from the UAV imagery, to that of an off-the-shelf DSM produced in 2014. From doing this, we could see that the vegetation in one particular field had developed noticeably in that two year period, with the scrub spreading and growing higher and denser.



3D change detection

By comparing the DSM made from our UAV imagery (below) to once produced from LiDAR captured in 2014 (above), we were able to see the change in vegetation height and density in this field (the pink represents low elevations, with purple, blue, green, yellow, orange and red being progressively higher elevations

The big benefits of UAVs

Being able to accurately and quantifiably monitor ecological developments in the landscape could allow the managers of the Knepp project to relate developments in biodiversity to developments in habitat. For example, Knepp is now a hotspot for the UK's purple emperor butterflies. This is due to the extensive sallow scrub present in Knepp's Southern Block. Sallow is the larval food plant for the purple emperor, and the females lay their eggs on the leaves. Being able to monitor the development of this scrub periodically could be invaluable for informing the research on the success of the purple emperor butterfly at Knepp.

Similarly, this approach could have benefits for the monitoring of nightingale at Knepp. Whilst studying for her Masters degree from Imperial College London, Olivia Hicks identified that nightingales at Knepp prefer overgrown hedges with a width of 8m or more at the base and the presence of protective blackthorn. Relating this information to the data gathered by the UAV could potentially allow large-scale mapping of possible nightingale habitat, again assisting with the monitoring of this nationally declining species.

The Knepp Wildland Project is allowing natural processes to function, providing a space for natural complexity to develop which can reveal the intricate linkages that may otherwise be more obscure over the landscape scale. UAVs are providing us with a pragmatic and cost-effective way of gathering the kind of high detail data needed to monitor and explain these linkages.