UAVs for analyzing legacy issues and development opportunities on former mine lands

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Abstract

Geospatial technologies are a critical tool within the mining and reclamation sector to monitor and analyze changes on the landscape. One of the newest ways to collect high temporal and spatial resolution data is with unmanned aerial vehicles (UAVs) or drones. Our study highlights the available benefits of using UAV imagery to map and analyze legacy issues with former mine lands. The data that can now be collected over hundreds of acres provides site-level modelling to plan for both the reclamation and future development of former mine lands.

Our approach is unique in the capture of engineering-level site measurements using a fixed-wing UAV at a former mine land site in the southern coalfields of WV. The information collected and processed included an orthophoto, a digital surface model (DSM), and a digital elevation model (DEM). The ability to have this information in a timely high-resolution (4 cm) manner provided for a quick analysis of disturbed areas. Models could be built of overland drainage and topographic constraints to help in the planning of development options.

We found the UAV data collection approach with a specific fixed-wing unit allowed a small crew to effectively and efficiently capture information that resulted in major time and cost savings compared to traditional field sampling and analysis. We were able to construct bare earth as well as vegetation height models to help us identify sites at the former mine land where development options could be compared with costs associated with cut/fill and other volumetric analyses needed for access and development. The detail of the surface model provided a way to track overland flow across the landscape and account for drainage paths. The high-resolution imagery overlaid on the surface models allowed for development renditions in a landscape context. These site plans remove uncertainty in the construction process for post-mining development options.

Keywords: Unmanned aerial vehicles (UAVs), mine lands, development, site analysis

Introduction

The Central Appalachians are characterized by a history of landscape changes from human activities connected to natural resource extraction. Surface mining has been described as the major driver of landscape change in the region for at least the last fifty years; its diffusion was the greatest cause of forest losses (Drummond & Loveland 2010), and its effects have been compared to the effects of urban development on the rest of the Eastern U.S (Townsend et al. 2009; Brown et al. 2005).

In the 21 most southern counties of WV, coal is either depleted, or its extraction too often presents excessive social-environmental costs when compared to the possible revenues (Epstein et al. 2011). Moreover, the large amount of degraded land due to surface mining raises questions that are closely related to the future development of places and communities whose economies have long been bound to the boom and bust cycles of the coal extraction industry and energy markets (McGinley 2004).

The recent $1B Build Back Better Regional Challenge promoted by the US Economic Development Administration, attempts to address the economic development needs to revitalize coal communities, including creating jobs through reclaiming previously mined lands. The reclamation and potential development on sites provide opportunities to a more sustainable future. This study describes the first step for site analysis and planning for potential future development by capturing engineering-level site measurements using a fixed-wing UAV at a former mine land site in the southern coalfields of WV.

Methods

An AgEagle eBee X was the Unmanned Aerial Vehicle (UAV) used to collect Red-Green-Blue Imagery at the Harless Industrial Park in Mingo County, WV. The eBee X is a fixed-wing UAV made from high-density foam weighing around 3.5 lbs (Fig. 1).

Instruments onboard the eBee X used for navigation and flight control of the UAV are a flight controller, radio transmitter and receiver, survey grade GNSS GPS receiver, laser range finder, and a pitot tube. The flight controller uses an Inertial Measurement Unit (IMU) to measure the orientation of the UAV in space. The flight controller also communicates with a ground-based laptop using the onboard radio. The onboard GPS unit receives the location of the eBee X from satellite information before, during, and after flight. The laser range finder on the bottom of the eBee X measures the distance from the UAV to the ground and the pitot tube on the front of the eBee X calculates wind speed and direction by measuring differences in air pressure during flight. These systems combined allow the eBee X to execute a predetermined autonomous flight path generated using the provided flight planning software downloaded on the laptop computer. During flight, information is transmitted from the eBee X to the laptop such as flight location and height, wind speed and direction, and battery charge levels. This allows for real-time decision-making and adjustment to autonomous flight parameters.

The eBee X has flight times of up to 1 hour and 30 minutes. Standard multi-rotor UAVs generally fly for a maximum time of around 45 minutes. Fixed-wing UAVs are more efficient as the lift generated during flight comes from wings as opposed to multi-rotor UAVs that generate lift directly from motor-driven propellers. Fixed-wing UAVs generally map at higher flight speeds than multi-rotor UAVs as well, allowing them to map larger areas in less time. The other factor allowing the eBee X to map large areas faster than standard multi-rotor UAVs is the specialized RGB camera. This sensor attaches to the payload bay of the eBee X. The RGB camera is supported by a motorized gimbal that points the camera up to a 40° angle to the left and right (Obliques) as well as straight down at the ground (Nadir). (See attached images.) While the eBee X flies autonomous mapping flight lines, the RGB camera takes a picture angled to the left, then straight down, then angled to the right. These series of images capture a greater lateral area of the ground compared to images taken only looking straight down. Due to this, the autonomous mapping flight lines that the eBee X follows can be further

***Figure 1** Hand launch of eBee X fixed-wing UAV*

Figure 2 *Flight lines UAV followed across the site*

apart, decreasing mapping flight times while still capturing enough lateral image overlap to stitch images together into a map using photogrammetry software.

A crew of two traveled to the James H. Harless Industrial Park in Mingo County West Virginia on September 4th, 2023 to fly the site (Fig. 2). The first day, the eBee X collected 1556 RGB images over an area of approximately 676 ac (274 ha). It was flown at 375 ft (114 m) above ground level using a digital terrain model within the flight control software. The image overlap specifications were 65% lateral and 80% longitudinal and were kept the same for all data collections. The flight took approximately 60 minutes to complete using 1 battery. Throughout the flight, the crew had to move several times around the collection area to keep the eBee X within visual line of sight.

The second flight was on September 5th, 2023. The eBee X collected 2334 RGB images over an area of approximately 945 ac (382 ha). It was again flown at 375 ft (114 m) above ground level. The flight took approximately 80 minutes to complete. The crew had to move several times to keep the eBee X within visual line of sight.

The third flight was on the same day, September 5th, 2023. The eBee X collected 268 RGB images over an area of approximately 280 ac (113 ha). It was again flown at 375 ft (114 m) above ground level. The flight took approximately 20 minutes to complete. The crew had to move a few times to keep the eBee X within visual line of sight.

Once the field collections were complete, back in the office, the flight planning software called eMotion then applied GPS coordinates to each image knowing very accurately the Latitude, Longitude, and Elevation coordinates of where each image was taken. The image GPS coordinates were collected using the GPS receiver on the eBee X which were updated to be far more accurate using the Real Time Kinematic (RTK) GPS service hosted through an internet connection by the West Virginia Department of Transportation's WVRTN CORS Network. The CORS Network is a series of GPS receivers stationed around the state on known coordinate positions. These GPS receivers look at some of the same satellites as the eBee X GPS receiver while it is flying. Through an internet connection, the eBee X's GPS coordinates can be updated to a higher spatial accuracy using the GPS corrections measured by the CORS Network in real-time. This process is known as "using RTK GPS".

Ground control targets were not used to increase the spatial accuracy of output maps since RTK GPS was used. In a scenario without RTK GPS, one could put out ground control targets in an area to be mapped. A handheld survey GPS would be used to collect the coordinates of each ground control target. Then imagery would be collected for the area to be mapped. The targets would be identified in the imagery during photogrammetry processing making the output maps more accurate. This method is far more time-consuming than using RTK GPS.

Once the RGB images from each of the 3 flights had highly accurate coordinates applied to each image using RTK GPS, they were imported into 3 separate instances of Pix4D Mapper photogrammetry software. Photogrammetry software uses overlap in consecutive images to create a single large photo called an orthophoto. It is also able to accurately estimate and map elevations of the ground using the camera's focal length, the GPS elevation coordinates of the photos, and the overlap between photos in a similar fashion to how we can judge distances using two different views from our eyes.

The photos from the first flight took 6 hours to process. The second flight took 8 hours, and the third flight took 1 hour. Pix4D Mapper outputs an orthophoto (Fig. 3), a digital surface model (DSM) (Fig. 4), and a digital elevation model (DEM) scene for each of the 3 flights in the horizontal coordinate system NAD83 UTM Zone 17 North and the vertical coordinate system EGM96. The DSM is a map of elevations that includes the surface of everything in the mapped area. The elevation of buildings and trees shows up in the DSM map. The DEM only maps the elevation of the ground, so buildings and trees are removed, and the elevation of the ground is estimated using the ground elevations nearby. By draping the orthophoto over the DEM (Fig. 5) insights can be visualized of varying terrain characteristics. All the data was imported into ArcGIS Pro where the 3 orthophotos were mosaiced into 1 large orthophoto. The same mosaic process was done with the DSMs and the DEMs. The final orthophoto and DSM had a pixel resolution of 4.5 cm and the DEM had a pixel resolution of 20 cm. The DEM of the entire area mapped in the 3 different flights was then used to generate 2-ft (61 cm) contour lines.

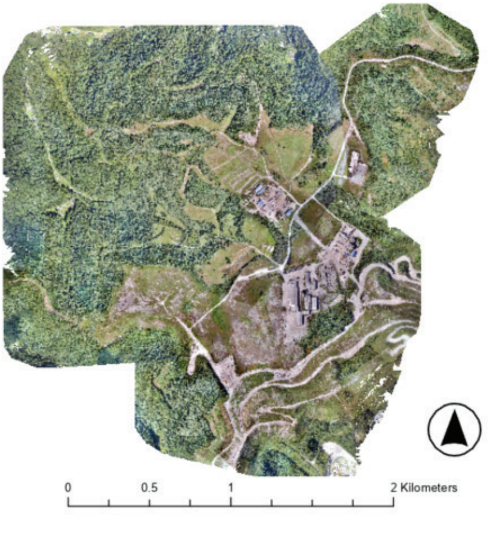

***Figure 3** Orthophoto at 4cm resolution*

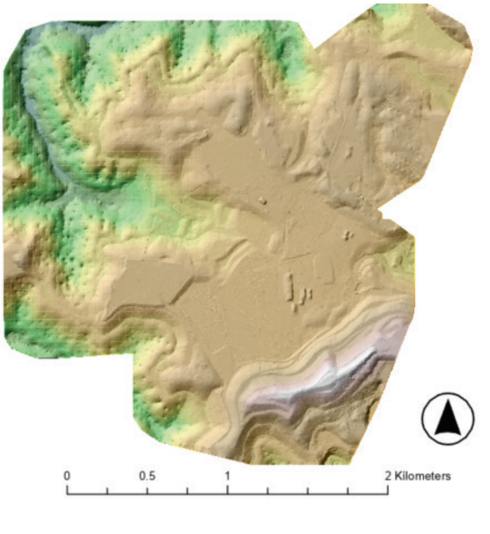

***Figure 4** Digital Surface Model*

***Figure 5** Digital Elevation Model with Orthophoto Drape*

Conclusions

Former mine lands present unique challenges in planning for future development due to complex topographic and vegetation alterations. The need exists for capturing high temporal and spatial resolution data at engineering level scales to aid in the design process for future sustainable development. This study highlighted the use of a fixed-wing UAV to create a current 4 cm resolution orthophoto image and 20 cm resolution surface and terrain elevation models to be used in the planning and design process of the site. Similar to Benner et al. (2023), which highlighted the benefits of drones for right-of-way compliance and monitoring, we found this technology especially useful for capturing high-resolution data safely for areas that may not be the most accessible. In addition, future models using these datasets are planned to be used for analysing water surface flow paths to account for drainage and runoff concerns from development. The 3D scenes also provide insights into complex topographic variations to account for which influence development options. Any insights that can limit uncertainty on site analysis and planning are critical to the success of the construction process for post-mining development options.

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