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<u>**EOS[3] 2017 Project Report:**</u>

Conducting Tree Surveys Using Unmanned Aerial Systems at Green Valley Farms Living Laboratory

by

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INTRODUCTION

Long-term landscape monitoring of forested areas allows for the examination of phenomena over time providing valuable information for researchers and landowners including changes in the vegetative community, invasive species encroachment, and effects of extreme weather events. Conventional methods required to collect a supporting data set involve ground surveys that are intensive, costly, time-consuming, and often times inconsistent due to human error (Torres-Sánchez et al., 2015). Traditional remote sensing platforms (i.e. satellite, manned aircraft) have also been used, independently or together with ground surveys, but they are also costly and often impractical for small-scale or local projects (Whitehead & Hugenholtz 2014). In recent years, more and more researchers have begun exploring the availability of low-cost unmanned aerial vehicles (hereafter "UAVs"), aka drones, for ecological monitoring as they look to increase data output and accuracy (Birdal et al., 2017, Whitehead et al. 2014). Remotely-piloted UAVs can be flown over sections of forested lands and used to capture high-resolution images which are then digitally stitched together to form a three-dimensional (3D) photomosaic of the area (Seul et al., 2015; Torres-Sánchez et al., 2015). This 3D photomosaic can be used to identify the size, age, and species of individual trees and provide land managers or property owners with pertinent information on tree crop production and status with minimal physical effort (Gatziolis et al. 2015, Seul et al., 2015; Torres-Sánchez et al., 2015). We aimed to test this method on a smaller scale at Green Valley Farms Living Laboratory (GVFLL).

GVFLL is a privately-held 3,500-acre property located in Cleveland County, Oklahoma along the Canadian River. The property hosts a mixture of active-use grazing pastures, unmanaged riparian zones, and several sections under row-crop cultivation. As a living laboratory, GVFLL is uniquely positioned to serve as a focal point for collaborative research and technology commercialization and function as a research, demonstration, and testing venue for people pursuing academic, technological, and entrepreneurial endeavors. GVFLL is being considered for conversion to a large-scale experimental ecology station, especially as it relates to the use of UAVs. With this in mind, we wanted to explore the feasibility of using an off-the-shelf UAV and readily available software to create high-resolution imagery and 3D models of tree stands (and their surrounding area) from which we could then use to identify individual trees and tree heights. We used ground-based surveys to collect data on individual trees for comparison and validation of the UAV method. Potential outcomes of this project and the would include estimates of the number, density and carbon sequestration, in terms of ecosystem service value, of standing tree stocks in this site, with applicability to the rest of GVFLL. This would also provide a baseline for future studies related to vegetation communities, habitat use, or management targets. Additionally, the workflow created here has the potential to be monetized in the form of a start-up consulting operation designed to help both Forest Service and private industry map and monitor tree stocks using UAVs.

STUDY AREA

<u>Study Site</u>

For our project, we selected a section of GVFLL (Figure 1) that contained areas of varied tree densities and patch structure and that provided relatively easy access for survey vehicles and personnel. This section runs along the east side of the Canadian River and encompasses riparian and open savannah habitats (Figure 1, center). Within this section, we chose four small study plots, each approximately 1000 m^2 (~0.25 acres) in size, for our ground and UAV-based surveys. These plots were centered around a patch of trees or a single tree stand and were selected to provide us with a variety of tree heights and densities (Figure 1, Plots 1-4). We also chose plots that were manageable in size for our ground-based and aerial surveys.

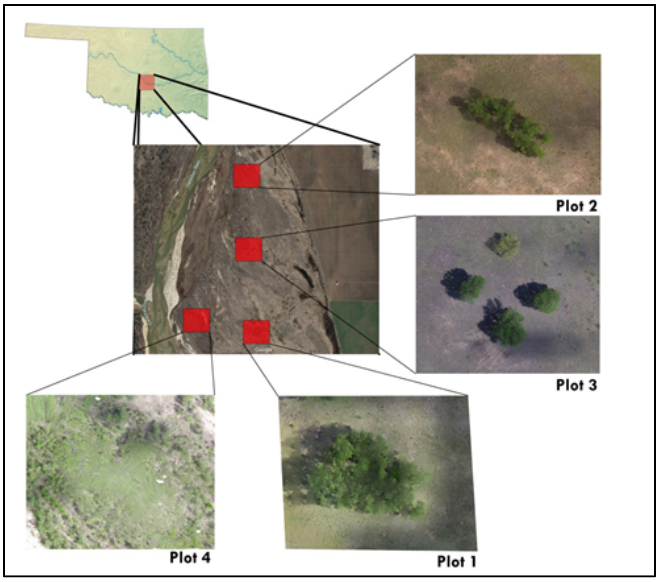

Figure 1. ***Overview of the study area (Green Valley Farms Living Laboratory) and locations of the four survey plots. The section of land containing survey plots is adjacent to the Canadian river in central Oklahoma. Outer images (Plots 1-4) show orthographic images generated from the aerial photographs captured during our project.***

METHODS

<u>Ground Surveys</u>

We were able to complete a full tree census at three of the four plots (Plots 1-3). Due to the density of trees in the riparian plot (Plot 4), we performed a partial, transect survey diagonally through the center of the plot, where only trees on the transect line were used for the census. For each tree, we recorded its diameter at breast height (DBH) using forester's tape or calipers and estimated its height. Approximate tree height was calculated by the tangent of the angle from the observer to the visible top of each tree multiplied by the distance of the observer to the base of each tree added to the observer's height. We also recorded the species (whenever possible) and latitude and longitude point locations for each tree.

Aerial Surveys and Data Processing

We used a DJI Phantom 3 Professional rotary-wing quadcopter to conduct our aerial surveys (Figure 2). This UAV, with props and battery included, weighs less than three pounds, has its own global positioning system, a max flight time of approximately 23 minutes, and an onboard camera system that captures 12 megapixel photos and 4K video footage at up to 30 frames per second. Programmed automated flight plans were created and uploaded to a smart phone using the website and mobile application DroneDeploy® (Figure 3). These flight plans were centered on our tree survey plots, and where possible, we constrained the flight plan to maximize photogrammetric coverage of the tree stands present.

Figure 2. Our UAV (DJI Phantom 3 Professional. Photo credit - Dr. Phil Philson.

Just before each flight, we conducted a series of pre-flight check plans in the field to ensure the proper functioning of the UAV and the safety of the flight crew and surrounding area. We did not operate the UAV in rainy or extremely windy conditions. The UAV flew autonomously along preprogrammed paths at heights between 23 and 38 meters above ground level. These paths included multiple linear transects, followed by an orbital sweep around the center point of each tree stand (Figure. 4). Aerial photographs were taken with a side-lap and front-lap of between 60% and 80%. When necessary, manual operation of the UAV was controlled by a certified pilot-in-command who possessed the UAV's wireless remote control (Figure 5). All flights were conducted in

Figure 3. ***Preprogrammed flight path for one of our survey sites.***

accordance with regulations set out by the Federal Aviation Administration. Flight plans were also reviewed and approved by the University of Oklahoma's Department of Risk Management and the Department of Aviation prior to each flight.

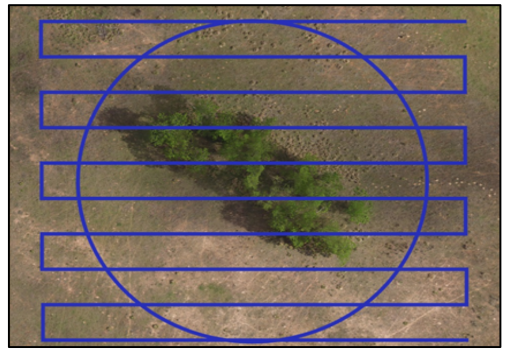

Figure 4. Schematic example of our automated UAV flights designed and executed through DroneDeploy using the DJI Phantom 3 Pro. Linear transect spacing was optimized to increase the side-lap of aerial images up to 80%.

We used DroneDeploy® software to digitally stitch together aerial images into one large image (i.e. a photomosaic) per site. These photomosaics were later processed using DroneDeploy software to generate digital elevation models, 3-dimensional renderings, and orthographic images. We conducted additional flights at study plots 1 and 2 to determine whether increasing the number of aerial photographs taken at each site can improve the resolution and quality of our 3-dimensional models.

Figure 5. Pilot-in-command (Kyle Broadfoot) watching the UAV. Photo credit - Dr. Phil Chilson

RESULTS

Our UAV flights yielded close to 2,600 images across the four study plots at a resolution between 0.5 and 1 inch per pixel depending upon image density and flight height. Aerial photomosaics, DEMs, and 3-dimensional models were created for each study plot (see Figure 6 for Plot 1 data products). We counted 216 trees of four known species across the four study plots during our ground-based surveys (Table 1). Average tree height per plot ranged from 11.3 to 17.6 m and average tree DBH per plot ranged from 11.1 to 29.2 cm. More than 90% of trees surveyed were eastern cottonwoods (*Populus deltoides*).

Due to time constraints and limited access to subscription software, comparisons of tree heights between ground survey data and aerial images are not available. Results yielded from data collected during this project will be added to this report in the future as appendices.

Table 1. Summary of ground-based tree surveys at the four study plots.

	Plot 1	**Plot 2**	**Plot 3**	**Plot 4**	**Total**
Known Tree Species Present (common name)	Eastern Cottonwood, Eastern Red Cedar, American Elm	Eastern Cottonwood	Eastern Cottonwood	Eastern Cottonwood, Boxelder	
Avg. Tree Height (meters)	17.6	12.4	13.9	11.3	
Number of Trees	79	42	61	34	**216**
Avg. Tree DBH (centimeters)	29.2	22.3	24.8	11.1	

*DBH = diameter at breast height

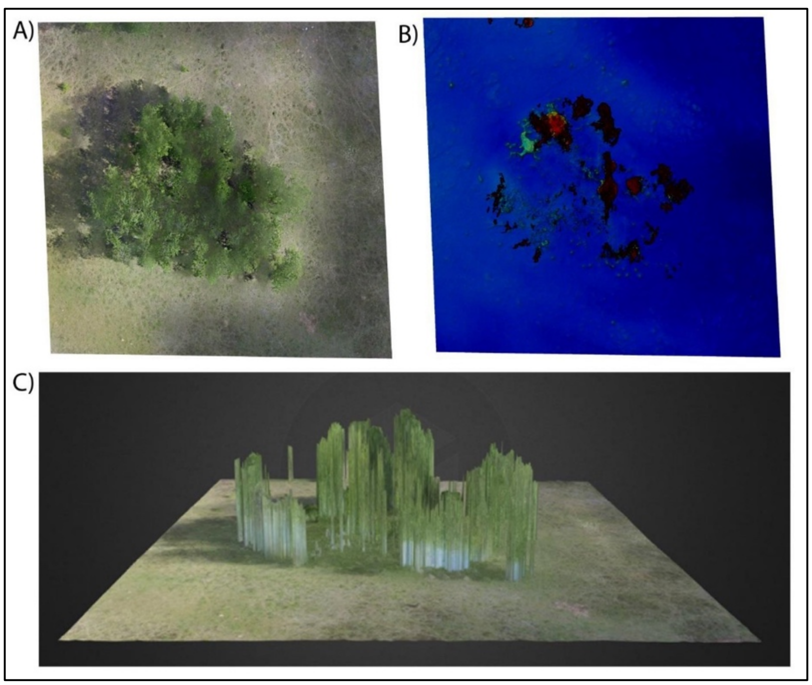

Figure 6. ***Data products for Plot 1. These images were created from 668 aerial photographs taken by the UAV on April 24, 2017. A) Aerial orthomosaic image; B) Digital Elevation Model (DEM); C) A 3D model generated by stitching together image composites.***

DISCUSSION

While unable to complete the initial purpose of this project, we were successful in the preliminary development of a method and workflow for interested parties to aerially observe GVF and use those recorded images for monitoring and decision making efforts. Through testing and assessment of this method we have discovered an efficient, cost-effective approach to collecting long-term landscape visuals that can be applied to various projects and stored in a database for future use.

This new area of UAV use is an emerging market for tech-savvy entrepreneurs. As one example of this, UASs have been employed to survey crops using normalized difference vegetation index, or NDVI, to indicate where certain sections of plants may need additional irrigation or fertilizer (Primicerio et al., 2012). Additionally, some UAVs have even been created to apply pesticides more precisely and less wastefully than traditional methods (Faical et al., 2016). Silviculture, as with agriculture, could benefit just as well from the application of precision agriculture, especially in the form of UAVs.

Further short-term projects at GVFLL conducted by students can consider social applications of UAS use as well. For example, understanding the effects of human encroachment on GVFLL, occupied by the endangered Interior Least Tern (*Sternula antillarum*), would increase our understanding of the extent to which human activity affects the tern population. The utilization of all-terrain vehicles by off-roading enthusiasts, a popular activity bordering GVFLL, can be recorded and monitored by UAVs to view nesting and habitat disruption of tern occupied land for which special protections can be implemented.

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GVF Living Laboratory
Research, Demonstration & Testing Venue
The UNIVERSITY of OKLAHOMA
OKLAHOMA BIOLOGICAL SURVEY

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