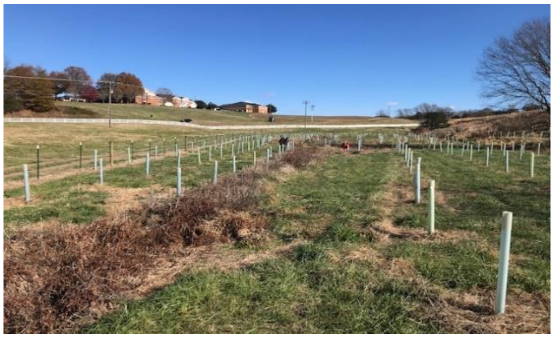

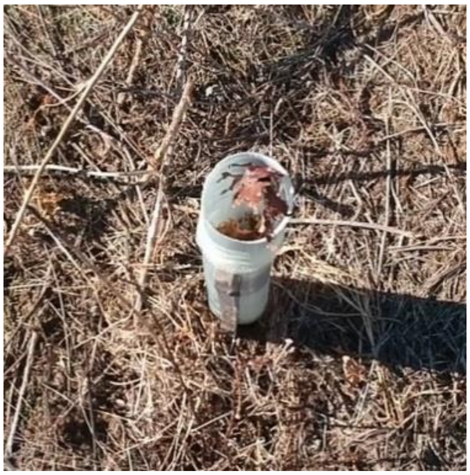

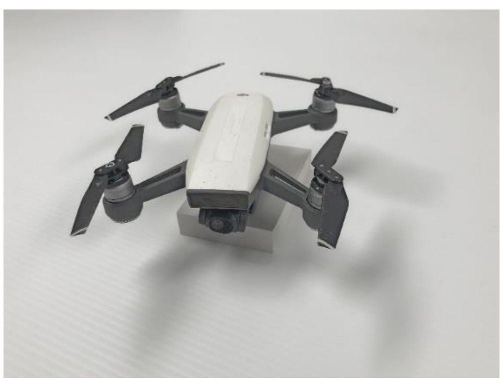

Assessment of Drone Use to Inventory Tree Planting Projects

2021

This project implemented and reported for Virginia Department of Forestry

By: Judith A. Okay, PhD
John L. Okay, PhD
J&J Okay Consulting, Inc.

An Assessment of Drone Use to Inventory Tree Planting Projects

Introduction

Planting tree seedlings is high on the list of actions that can improve watershed health. Improvements in water quality as well as air quality are attributed to the increase of forest/tree cover in watersheds. The Chesapeake Bay watershed is an example of using trees as best management practices (BMPs) to meet restoration goals for improved health of the Bay. Increasing riparian forest buffers, tree planting, and urban tree canopy are featured as valuable BMPs in Watershed Improvement Plans (WIPs) across the six Bay States and the District of Columbia. A high level of accountability is expected to ensure that trees planted as BMPs remain functional for the project's given lifetime. It is the responsibility of the jurisdictions involved to have a verification plan that confirms the longevity of the planting project. The usual verification plan includes planting inventories carried out by foresters or other trained individuals.

The Virginia Department of Forestry (VDOF) sampling recommendation is to take a point every 1-2 chains (66ft) depending on the size of the tract. Adjust the spacing so the whole site is covered in the inventory. The practice is to take 30 samples per site www.dof.virginia.gov (Forms). The very similar random tenth acre plot method is also a common recommended system to inventory large tree planting sites. Either method of inventory can be done by a single person or by two individuals, the latter increases the efficiency of the process, particularly for handling measurement equipment and recording devices.

Metrics collected include:

- Mortality/survival
- Height
- Presence of tree seedling damage from animal browse, shelter net, other
- Vegetative competition
- Invasive species on the planting site
- Tree shelter condition where applicable
- Natural regeneration occurring (note distance to seed source and species)
- Maintenance practiced at the site (mowing – herbicide – wildlife deterrents)

Technology has improved the efficiency of accounting for the success or failure of tree plantings. Computers can be used for recording data, cell phones can be set up to take audio data collection, and now we are suggesting that an unmanned aerial vehicle (UAV) can be used to make and record observations at planting sites. In fact, this is already being practiced in forestry around the world for controlled burns, site analysis, and by industry for planting surveys (Hassaan et al 2016 and Banu et al 2016).

Drone Suitability and Applicability

In recent years, unmanned aerial vehicles (UAVs), more commonly called drones, have grown in popularity due to advances in technology and improved ease of operation. These factors have made highly capable drones available for a variety of uses at prices to fit the budgets of government agencies, private businesses, non-profit organizations, as well as individual consumers.

Most drones in common non-military use today are quadcopters controlled using a smart phone app or wireless remote-control device, or both in combination. The most popular models typically include a camera capable of taking still photographs or videos and saving the images on a memory card for downloading to a computer for later viewing and processing. Many such drones are available at prices ranging from $500 to $1,000, although larger and more sophisticated models may cost $2,000 or more. Special sensors such as near-infrared (NIE) and thermal are extra cost options available for some drones for certain applications.

In the United States the use of drones is regulated by the Federal Aviation Administration (FAA). Those regulations identify two classes of drone operators.

Recreational flyers.

- Use a drone weighing less than 0.55 pounds
- Fly the drone for fun and personal enjoyment or as an educational institution
- Do not require certification (https://www.faa.gov/uas/recreational_fliers/)

Certificated Remote Pilots

- Use the drone for commercial, government, or any other non-recreational purposes
- Register all drones greater than 0.55 pounds https://www.faa.gov/uas/commercial _operators/ or https://faadronezone.faa.gov/#1)

Commercial and Government Uses of Drones

Drones have multiple useful capabilities that are being utilized by government agencies, commercial entities, and individuals in many ways, including:

- Aerial photography for journalism and film production
- Gathering information for disaster management
- For search and rescue operations
- Geographic mapping of terrain and locations
- Electric powerline and gas pipeline inspections
- Development site planning
- Real estate sales promotion
- Natural resources management
- Agriculture crop monitoring and damage assessment
- Law enforcement and border surveillance

- Storm tracking and forecasting hurricanes and tornadoes

Drones for Natural Resource Management

Drones have been deployed in recent years in several areas of natural resource management with innovative applications being developed by commercial and government entities across the US and internationally. Some of the current and potential uses include:

Forest Management: Deploy drones with high-resolution visual sensors and multispectral sensors to map forests, sample vegetation, or monitor and manage the health of forests and wildlife. Drones can replace traditional methods in heavily-vegetated, mountainous areas where access on foot is time-consuming, expensive, and sometimes hazardous.

Wildland Fire Programs: The US Department of Interior has a large-scale drone program that is integral to its detection and response to wildland fires. The US Forest Service has committed to expanding the use of drones for prescribed burns, which are essential for increasing landscape resiliency and creating safe spaces for wildland firefighters to work. This will allow most aerial prescribed burns to be conducted without the need for operators in helicopters. (www.doi.gov/sites/doi.gov/files/fy20-doi-uas-flight-use-report-final.pdf and Shahbazi et al 2014).

Water Resource Management: Mapping around surface water, and outfalls with drones to obtain data on-demand, facilitating resource management and compliance monitoring across vast areas; Flying over rivers, lakes, reservoirs and more to capture data, reduces costs and cuts fieldwork hours; Aerial imagery helps classify water bodies, estimate flooding extent after storm events, and monitor releases of sewage or other hazardous materials (https://enterprise.dji.com/surveying/natural-resource-management)

Methods

Drones for Forest Buffer Inventory

An assessment of the capabilities and practicality of using a drone for forest buffer inventories was carried out from August to November 2021 at four recent buffer plantings in Virginia. The drone used for this was the DJI Spark™, a quadcopter type consumer-level drone (see Figure 1).

The equipment used was identical at each of the four sites:

- Drone
- Remote Controller
- Spare batteries for the drone; batteries are rated to provide up to 15 minutes of flight time
- iPhone 7S smart phone with Wi-Fi activated

- DJI Go 4™ a free proprietary app. This links the phone with the drone through the remote controller. It displays the view in the drone's camera and on the phone's screen throughout a flight. In addition, the app links the phone with the drone's GPS and creates a geofence[1] that indicates whether it is safe to fly in a particular location or if one is within a restricted area such as an airport control zone.

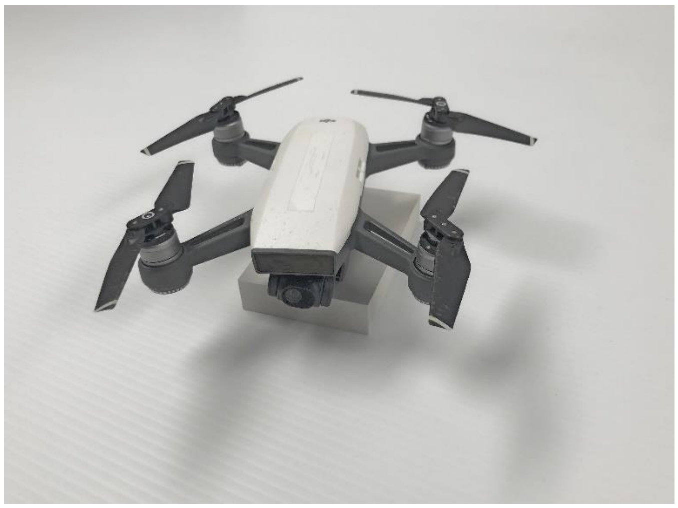

Figure 1. DJI Spark™ drone used in this project

For this project the trial at each site varied somewhat to test different methods of image capture. But in each case, following the field work the image files were downloaded from the drone's Micro SD to a PC. Results were interpreted by viewing the images on the PC monitor. Physical inventories were done at each site using the Virginia Department of Forestry Form 84 template. The goal was to examine thirty seedlings at each site. The seedlings selected for examination were in groups of ten based on the variation of topography, aspect, and their general location in the field. Edges of the sites were considered atypical of the general field condition and were avoided. The seedlings inventoried physically were marked with survey tape and the drone was operated in the same areas of the physical inventory attempting to examine the same seedlings. In an effort to remove bias, the operator of the drone was independent of the person conducting the physical inventory and was not consulted on the physical inventory findings.

[1] A Geofence is a virtual barrier system that surrounds a specific area that warns a pilot when they are approaching the boundary. In terms of drones, a Geofence would prevent a drone from flying into a restricted zone, an airport for example. Geofences are created by using position location technology such as GPS and the drone's software. As the drone approaches the restricted GPS location, a warning alert is displayed via the app used to fly the drone. And in some instances, the drone will stop flying to prevent entering the area.

Site 1 – Albright Scout Reservation see (ASR) Figure 2.

Three sample areas of approximately 0.1 acre from within the 3.75 acre site were marked with survey tape, (Fig 3). A drone flight was made over each sample area with continuous video while ensuring capture of each tree or tree shelter in the 0.1acre plot. Interpretation of planting success was done by viewing the video and pausing playback at each tree.

Site 2 – Powhatan State Park, see Figure 4. Three sample areas were selected from the 3.4acre site, each sample consisting of a row of ten (10) trees or tree shelters. A separate flight was made over each sample area and captured a separate video for each. Continuous video was used to record images of all trees in the selected area. Inventory was completed by viewing the video and pausing at each tree. During the analysis phase, a still photo of each tree was extracted from the video file using Adobe Premium Elements™ video editing software. This more than doubled the total amount of time to complete the inventory compared to simply reviewing the video.

Site 3 – Augusta Forestry Center (Figure 5) – A single flight was made over a 5acre planting area. Continuous video was used to record images of all trees in the selected area. Inventory was completed by viewing the video and pausing playback at each tree.

Site 4 – State Farm (Powhatan Correctional Center) see Figure 6 – Three sample areas were identified from within a buffer planting of approximately 5acres. The first three were in a relatively level portion of a large field near a small stream. A drone flight was made over each of the three sample areas on the level ground using continuous video to capture images of all trees in each sample area. Interpretation was done by viewing the video and pausing playback at each tree. A fourth sample area on an adjacent slope could not be flown due to high winds. The drone could not be controlled with accuracy due to wind gusts moving down the slope of the field. A local weather report indicated winds in the area of 18-20 mph with gusts to 30 mph.

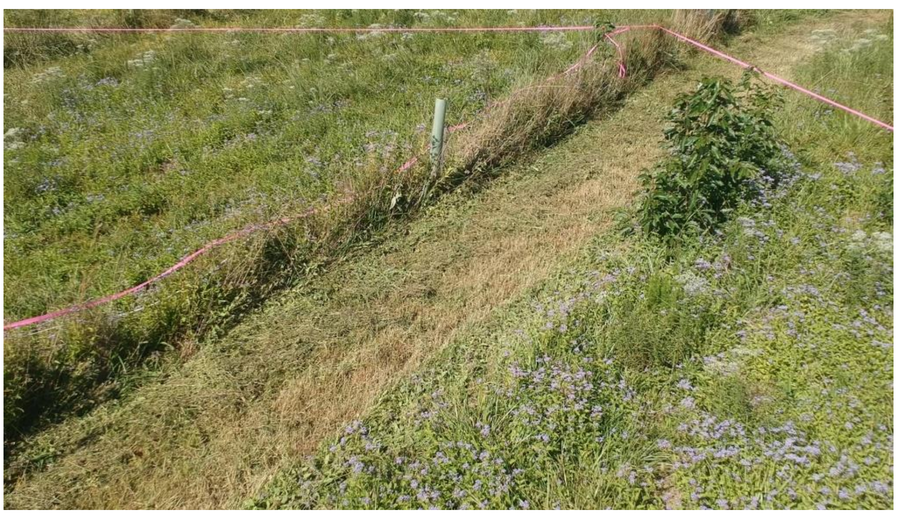

Figure 2. Albright Scout Reservation field

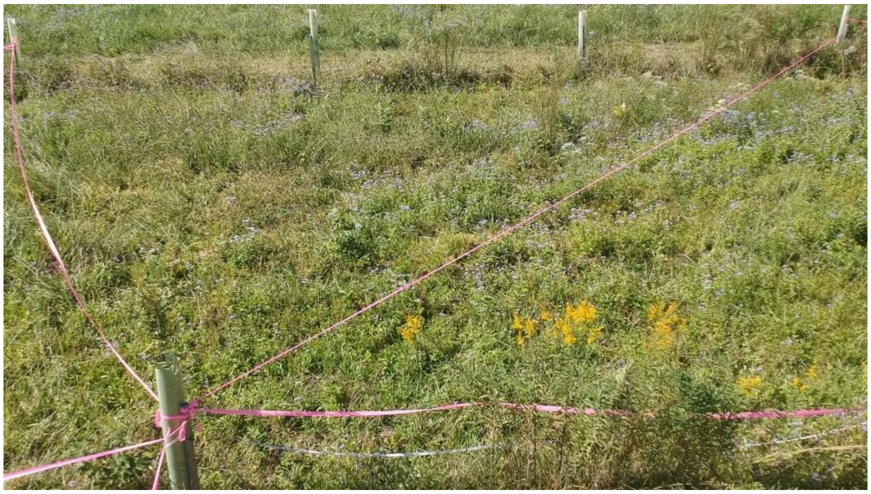
Figure 3. Albright Scout Camp tenth acre plot set up showing plot center.


Figure 4. Powhatan State Park Site

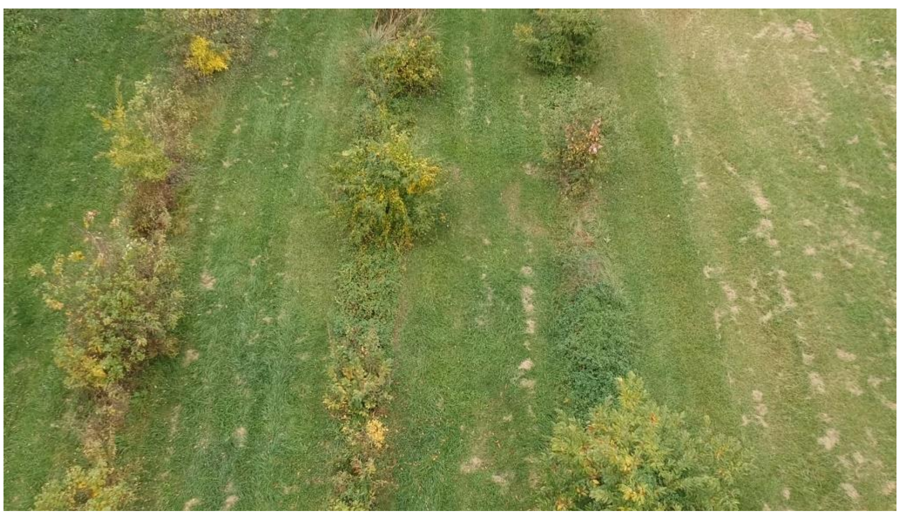
Figure 5. Augusta Forestry Center Site

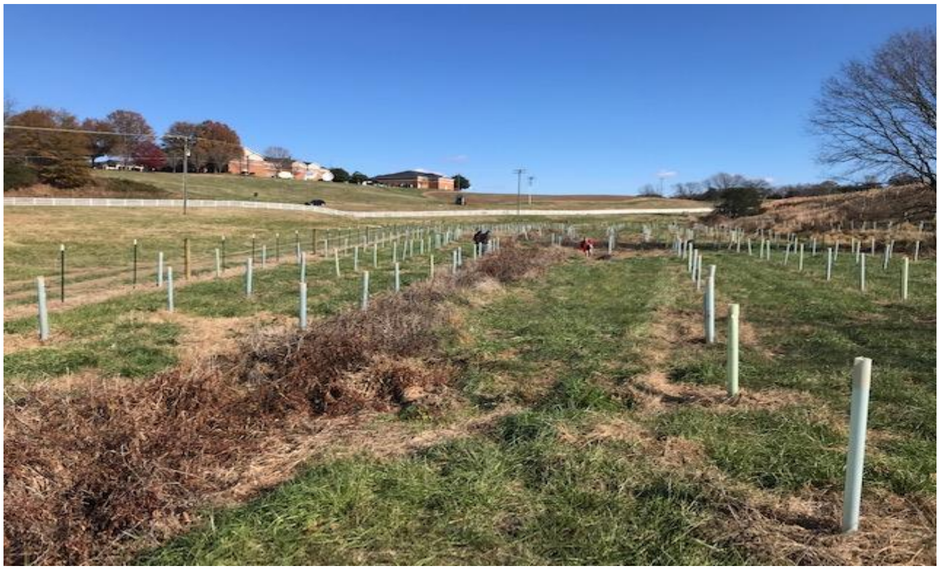

Figure 6. State Farm Site Overview

At all of the sites, the drone operator using a slow flight speed, captured video photos and was able to complete the inventory in approximately one third of the time it took to do the physical inventory. This was particularly the case at the Powhatan State Park site. The individual doing the physical inventory was subjected to walking through a very thick network of vines, briars, and tall herbaceous vegetation. The drone operator finished the inventory in 30 minutes, the physical inventory took 1.5 hours. At the Albright Scout Reservation tenth acre plots were used to designate the inventory area. Setting up the plots took considerable time. The drone operator found working within the plot more difficult to inventory than just doing a video of the respective tree seedling/shelters within a row.

While this method of buffer inventory is highly reliable for determining survival rate, species detail may be identified in some images depending on the age and condition of the tree. At ASR the physical inventory detected three of the seedlings as dead and by drone two seedlings were detected as dead. In most instances as the drone is hovered over each shelter the absence of a seedling is quite obvious (Fig. 7).

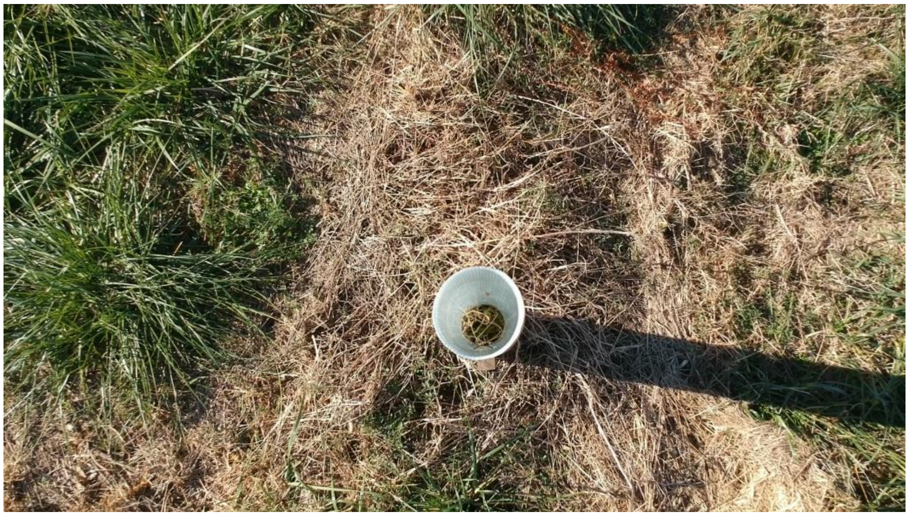

Figure 7. Drone photo into shelter shows the absence of a seedling indicating mortality.

The highest mortality was at the State Farm Site where 12 seedlings were recorded as dead by both methods of inventory. Prior to this project, some tubes at this site had been marked with an orange dot indicating a dead seedling. The dot was visible in the drone photos (Fig. 8).

Figure 8. In a previous inventory an orange dot was marked on shelters with dead seedlings, this made mortality easier to determine in drone photos at the State Farm site. The dot is just above the top of the wooden stake (follow arrow).

Mortality for Powhatan State Park and the Augusta Forestry Center were in agreement for the drone and the physical inventory with 3 seedlings at each site indicated as dead. These inventories were done during leaf on period making the recognition of dead or alive easier. Agreement in species identification varied for each site for different reasons. Three species were not in agreement for the Augusta Forestry Center site. Because seedlings had been overgrown by other vegetation (Figure 9) and was more difficult to assign a species in drone photos.

At the Albright Scout, tree shelters were marked with different colors of spray paint to indicate the species at the time of planting (Figure 10). However, the paint had faded and the difference between red and orange was not detectable in the drone photos. The red oak and red maple were not distinguishable in drone photos.

Figure 9. In this drone photo a sapling at the Augusta Forestry Center is unidentifiable because it is overgrown by vegetation.

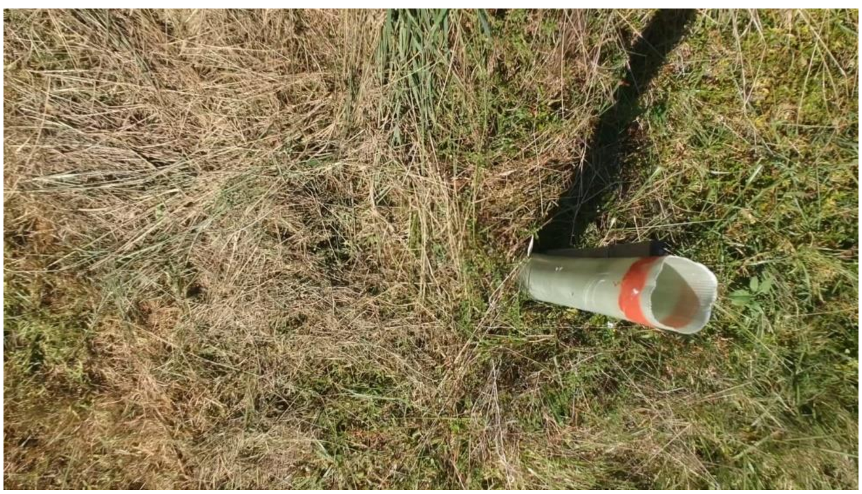

Figure 10. The ASR site tree shelters were marked with spray paint to indicate the species. The difference between red and orange paint was not distinguishable.

Results

Key factors considered in selecting sites to inventory for this project were accessibility, age of the project, size of the project and ownership. Although the Albright Scout Reservation is privately owned, access was granted by the Scouting Coordinator. All of the other sites were owned by the state of Virginia. This factor made approval for flying the drone over and on the property less complicated since the work was being done in cooperation with and for a state agency (VDOF). The age of the project was important because simulating newer tree plantings was an objective of this project. The seedlings for 3 of the 4 sites were still in tree shelters and they were one to two years old. This is an age bracket at which most plantings for water quality projects are inventoried for the first time.

There were differences in numbers of seedlings observed in the physical inventories and in the drone inventories. Over all, the physical inventories included 124 seedlings and the drone inventories included 115. The most discrepancy in numbers took place at the Powhatan State Park where the vegetation around the tree shelters was in some cases taller than the shelters or growing over them and they could not be detected in the drone photos (Figure 11), but could be detected walking down the row. At all other sites, regular maintenance increased the tree shelter visibility. A summary of results regarding species identification and mortality can be viewed in Table 1.

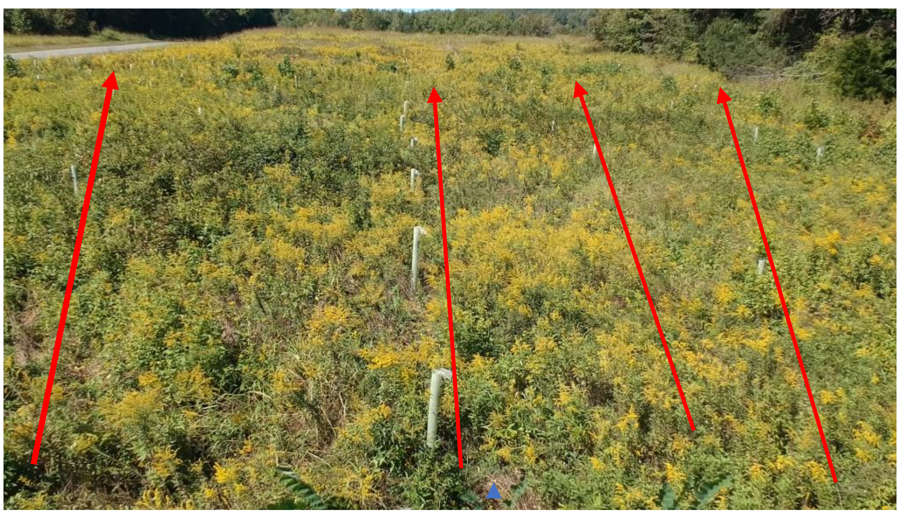

Figure 11. The individual shelters are not all visible in these four rows due to vegetative competition.

Table 1. Species identification and mortality using physical inventory and drone inventory.

AFC	Phys	Drone	ASR	Phys	Drone	PSP	Phys	Drone	STF	Phys	Drone
Species			Spec.			Spec			Spec		
Chink Pin	7	5	Ches. Oak	7	7	Black Loc	3	4	Will Oak	3	0
Maple	1	1	Black Loc	1	0	Mul-berry	4	2	Pin Oak	10	11
Mix	2	3	Red Maple	4	4	Un-known	20	13	Bal. Cyp.	24	24
Dead	3	3	S.Red Oak	3	4	Dead	3	3	Scar. Oak	3	3
			Will Oak	11	13				UK	0	1
			Dead	3	2				Dead	12	12
%survival	77	75		89	93		90	86		77	76
Total #	13	12		29	30		30	22		53	51

Statistical analysis of the inventory results comparing findings of the physical inventory with use of the drone shows a 0.95 percent probability that there is no difference between the data sets in determining survivability. Analysis of the species identification data shows a lower probability (0.87 percent) of no difference between the two (drone and physical) data sets. Identification from the drone photos or video was possible when vegetation was at least within 6-8 inches from the top of the shelter or out of the shelter (Figure 12). Any seedling shorter than 30-36 inches was not identifiable.

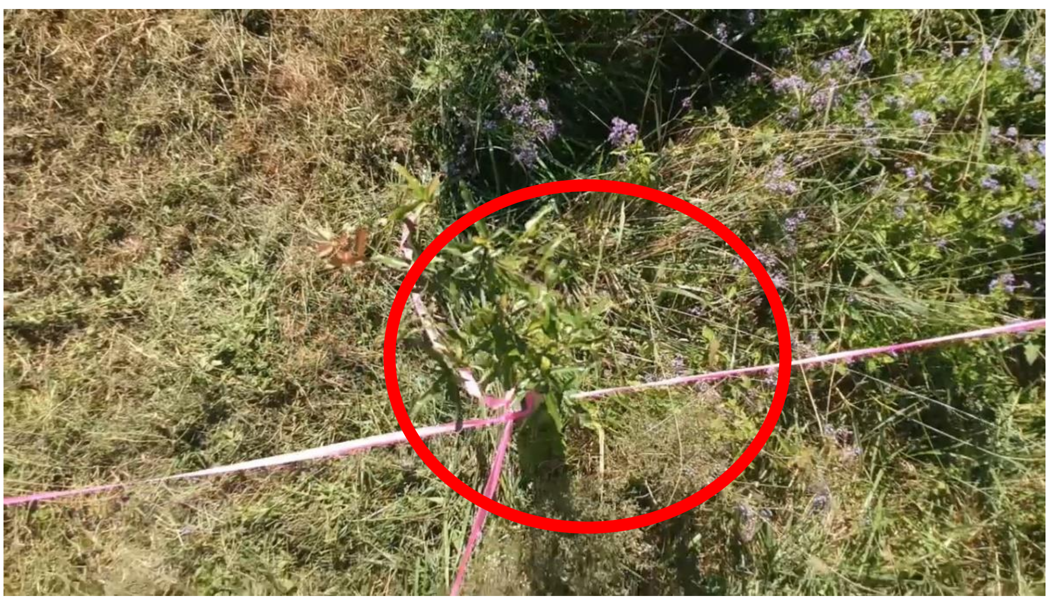

Figure 12. Willow oak taller than 48- inch shelter.

Vegetative competition is one of the factors that leads to the failure of tree plantings. In this project, the drone picked up the presence of vegetative ground cover. In most cases the vegetation was identifiable from the drone photos Figures 13-15.

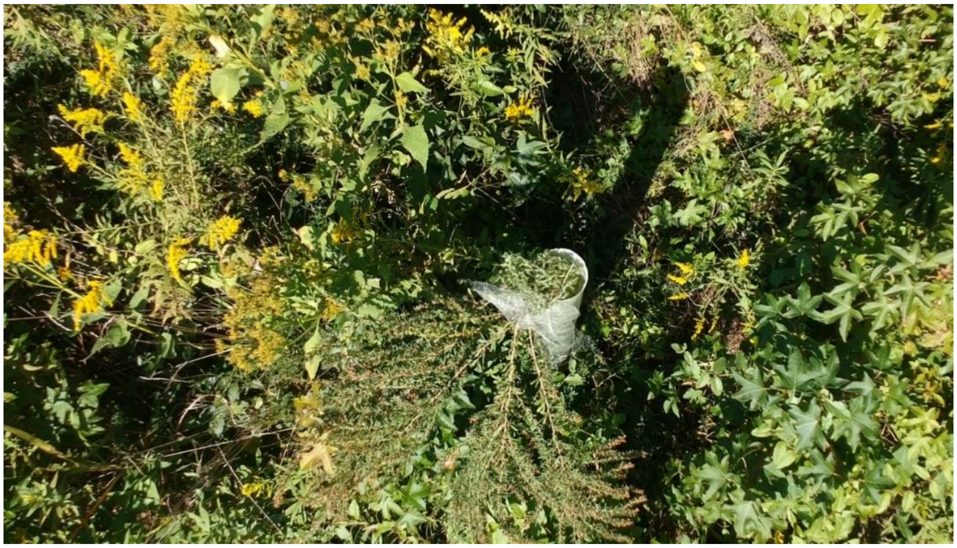

Figure 13. Lespideza in shelter as well as, Goldenrod and Sweet potato vines.

Figure 14. At ASR drone photo shows blue Ageratum along with grasses (foxtail) as the vegetative cover.

Figure 15. Ironweed is viewed as a component of vegetative cover at ASR.

Regeneration is an important element of tree planting inventories because they increase the stocking of plantings and in some instances can make the difference of the planting being considered a success or failure. At the Powhatan State Park site a total of 80 stems of regenerating seedlings were tallied. They were comprised of Sweet gum, Tulip poplar, Green ash, and Black cherry. The ASR site and Powhatan sites had Persimmon and Sweet gum seedlings (figures 16 &17). They are identified as regeneration because of patterns of randomness and clumping.

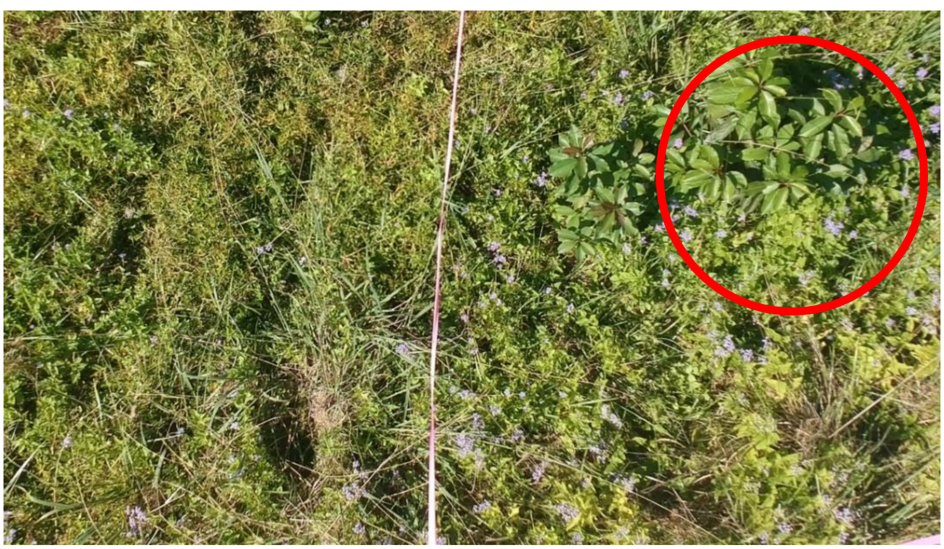

Figure 16. Drone photo of Persimmon regeneration at ASR site.

Figure 17. Drone photo of Sweetgum seedlings at PSP site.

Conclusions and Lessons Learned

The use of drones for forest buffer inventory shows high potential as a way to carry out tree planting and riparian buffer monitoring. The results from drone inventories were found to have a significant positive match with physical inventory data. For all the sites the method of flying at a slow speed over designated rows capturing the scenes in video format took far less time than doing the physical inventory, particularly in situations where fields are densely vegetated with vines and briars. Where the objective is to verify that a planting site is well stocked with living seedlings the drone method is a viable option.

Depending on the age and size of seedlings they can be identified in drone photos. It took about 4 minutes to identify seedlings from drone photos that had been down loaded from a video format (Figures 18 and 19). It is helpful for the individual reviewing the drone photos to be experienced in the identification of trees and other plants. It is also helpful that a zoom effect can be used with drone photos to get a close up of the seedlings. Although a physical inventory is more reliable for seedling identification, a drone inventory is definitely faster for just determining success of a planting. If you have 3 rows of ten seedlings on drone video it takes 4-6 minutes to count, identify and interpret ground cover per row (12-18 min.) You could spend 15 – 20 minutes of office time completing the inventory. If you add 10 minutes for the drone field work for each row the total time spent would be 50 minutes to fly and interpret findings for a 3-5 acre site.

Figure 18. Identification of Black locust in a drone photo.

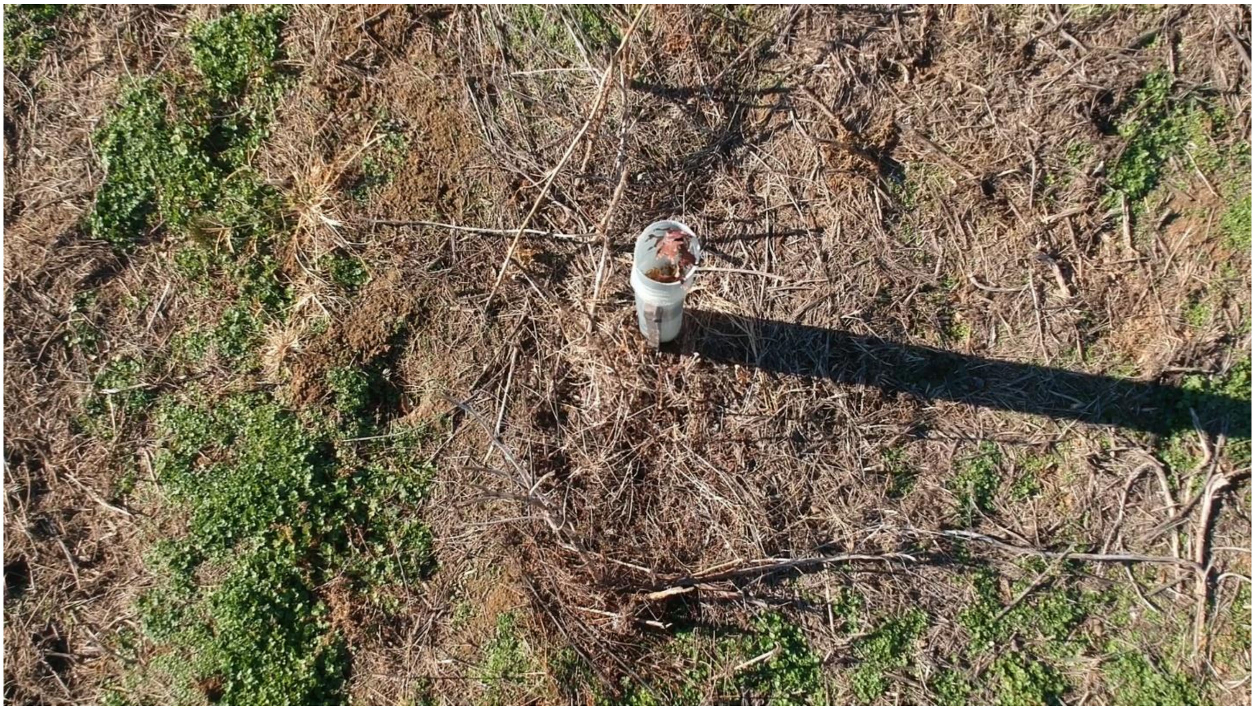

Figure 19. Young Oak identified in this drone photo emerging from a 48-inch shelter.

In summary, from this project a tree seedling planting project inventory by use of a drone can be completed satisfactorily to determine success or failure of the project. Individual elements that can be determined are:

- Seedling mortality
- Vegetative competition (native/non-native plants)
- Maintenance practices
- Shelter conditions (damage or need removal particularly nets)
- Estimate of seedling height from known shelter height
- Natural regeneration at the site
- Possible species identification

Comments on Drone Operation

The following guidelines are offered based on experience gained in the four trials reported here.

- Preparing and operating the drone for buffer inventory
    - Horizontal and vertical controls are essential to efficiently capture images of the trees to be inventoried; therefore, the operator should gain experience with the drone, the remote controller, smart phone and drone software prior to conducting the inventory
    - Use the drone's video camera to capture images of all trees in the sample area
    - Begin and end a drone flight for each sample and be sure the camera is activated for each sample. This will produce a separate data file for each sample area, which aids in review and documentation of results
    - Fly slowly so the image of each tree can be clearly seen
    - Fly at a height of 3 to 4 feet above the highest trees in the sample area to capture a detailed view of each tree; this will also provide a view of ground cover immediately adjacent to each tree and show presence of possible regeneration and vegetative competition
    - A separate flight at a somewhat higher elevation may be desirable to capture a broader view of regeneration and invasives in the overall buffer area
- Reviewing the image files
    - Download and save the resulting files to a desktop or laptop computer for viewing and to preserve a record of the inventory.
    - The computer used to save files should have some type of video playback software. Computers that use either the Apple or Microsoft operating systems generally include software that will handle most video files produced by drones.
    - Load each inventory file separately, play the video, and pause at each tree

    - Examine the image to determine status (dead or alive), evidence of surrounding regeneration and invasives or other factors that may affect buffer longevity and success

- While some public agencies and private sector organizations may already have a professional grade drone available, many consumer-grade quadcopter drones are satisfactory for use in forest buffer inventories. The suggested minimum requirements are:
    - 12-megapixel camera on a controllable and stabilized 2-axis gimbal capable of capturing still images and 1080p video
    - GPS
    - On-board image storage device (e.g., Micro SD card)
    - Wireless remote controller with 4-way control (up-down, turn left-turn right, fly left-fly right, forward-reverse)
    - Wireless link to smart phone loaded with compatible software with these capabilities:
        - Real-time view of the drone's camera image
        - Audio and visual obstacle warning
        - Low battery warning
        - Warning of proximity to a restricted flight area; e.g., airport control zone
    - At least two batteries
- Compliance with federal, state, and local requirements
    - Ensure that the drone and drone operator comply with FAA regulations as described on page 2 of this report.
    - Review the location for restricted areas including an air traffic control zone or critical infrastructure facilities such as railroads and facilities involved in the production of electricity, oil, and natural gas, including their respective distribution networks
    - Check for and comply with any local restrictions on drone operations established by local units of government and/or individual property owners
    - Conform to policies for drone operations established by the responsible agency of organization

References Cited

Banu, T.P., G.F. Borlea and C. Banu. 2016. *The Use of Drones in Forestry.* Journal of Environmental Science and Engineering B 5 557-562.

Hassaan, O. A.K. Nasir, H.Roth, M.F. Khan. 2016. *Precision Forestry: Trees Counting in Urban Areas Using Visible Imagery based on an Unmanned Aerial Vehicle.* IFAC PapersOnLIne 49-16 016-021.

Shahbazi, M., J. Theau, and P. Menard. 2014. *Recent Applications of Unmanned Aerial Imagery in Natural Resource Management.* GIScience and Remote Sensing 51(4): 339-65.

Tech Specs: DJI Spark User's Manual V1.6 (2017) http://www.dji.com/spark

U.S. Department of the Interior. 2020. *Unmanned Aircraft Systems (UAS) Program Use Report*, www.doi.gov/sites/doi.gov/files/fy20-doi-uas-flight-use-report-final.pdf

https://enterprise.dji.com/surveying/natural-resource-management

https://www.faa.gov/uas/recreational _fliers/

https://www.faa.gov/uas/commercila _ operators/ or https://faadronezone.faa.gov/#1

https://www.dof.virginia.gov