The Use of UAS in Teaching Research and Service at Stephen F. Austin State University

David Kulhavy, Daniel Unger, I-Kuai Hung and Yanli Zhang
Arthur Temple College of Forestry and Agriculture
Stephen F. Austin State University

“Society-ready Foresters”

Producing ‘Society-ready’ Foresters:
A Research-based Process to Revise the Bachelor of Science in Forestry Curriculum at Stephen F. Austin State University

Steve Bullard, Dean Coble, Theresa Coble,
Ray Darville, Laurie Rogers, and Pat Stephens Williams

ATCOFA Monograph 1.2014 • February 2014
“Our overall goal in the Bachelor of Science in Forestry (BSF) degree program at Stephen F. Austin State University (SFASU) is to produce foresters who are ‘society ready,’ i.e., capable of dealing effectively with the complex economic, ecological, and social issues involving forest resources today.”

“Our BSF graduates must be prepared to effectively enhance the integrity, stability and health of the environment through sustainable management, conservation, and protection of forests and natural resources.”
### Importance to Forestry (5.00 most important)

<table>
<thead>
<tr>
<th>Importance</th>
<th>Mean Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Understand the ecological functioning of natural systems, including competition, plant succession, nutrient cycling and population dynamics.</td>
<td>4.46</td>
</tr>
<tr>
<td>2. Apply analytical skills to measure and predict, knowing how to measure land areas, conduct forest inventories, and project future growth.</td>
<td>4.36</td>
</tr>
<tr>
<td>3. Manage forest resources at the stand, forest and landscape levels, to meet ecological, economic and social needs.</td>
<td>4.37</td>
</tr>
<tr>
<td>4. Sustainably manage working forest systems, through the application of silvicultural and other available tools.</td>
<td>4.34</td>
</tr>
<tr>
<td>5. Be able to develop management plans, to maintain the productivity, biodiversity and resilience of public and private forests.</td>
<td>4.30</td>
</tr>
<tr>
<td>6. Use geospatial technologies, to collect, analyze and convey spatial data in multiple formats.</td>
<td>4.22</td>
</tr>
</tbody>
</table>

Kulhavy, Unger, Hung, and Zhang, College of Forestry and Agriculture, Stephen F. Austin State University
5. Apply analytical skills to measure and predict, knowing how to measure land areas, conduct forest inventories, and project future growth.

12. Use geospatial technologies to collect, analyze and convey spatial data in multiple formats.
**Unmanned Aerial Systems: Where do we begin?**

- Training under FAA 336 for teaching/demonstrations
  - Fly under 400 feet
  - Line of sight
  - Pilot in Command and Visual Observer
  - Daytime
  - Student involvement
- Training course for FAA UAS Pilot Exam
  - FAA 107 rule for UAS license
  - 60 question test at FAA site; vetting by TSA

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**Horizontal Perspective**

**Stem analysis: from ground to crown. Hazard Rating**
## Vertical Perspective

<table>
<thead>
<tr>
<th>Old School</th>
<th>Drone Nadir</th>
<th>Drone Off-Nadir</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSS – 79 meters</td>
<td>Drone – ≥ 2.25</td>
<td></td>
</tr>
<tr>
<td>TM – 30 meters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>QB – 2.44 meters</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Arthur Temple College of Forestry and Agriculture, Stephen F. Austin State University

## Why SFA? Why Arthur Temple College of Forestry and Agriculture?

- B.S. in Spatial Science
- B.S.F. in Forestry
- B.S. in Environmental Science

Integration of GIS across the entire curriculum. SFA has the “ATCOFA Drone Squad”.

Meets ACTOFA mission statement of:
- Make a difference,
- Work outdoors, and
- Use high-end technology.

Arthur Temple College of Forestry and Agriculture, Stephen F. Austin State University
The Fleet of UAS at SFA Forestry, Environmental Science, Spatial Science

- AR.Drone 2.0 (Parrot) (tree hazard rating)
- Bebop UAS (Parrot) (tree hazard rating, trail condition, non-nadir)
- DJI Phantom 3 (tree hazard rating, height validation, lps and pine mortality)
- DJI Phantom 4 (programmed flight, Drone2Map ArcGIS software)
- DJI Spark (hazard ration, urban forestry)

Drone2Map for ArcGIS

- Orthomosaics
- Digital surface models
- 3D points clouds
- 3D meshes
Make it fly, safety, preflight check, log in flight

- Planning and executing a flight plan; A to Z DJIGO Pix4D apps

Programmed flight, Pix4D, download to Drone2Map into ArcGIS 10.5.2 in the GIS Laboratory

- 80 percent endlap
- 60 percent sidelap
- Set flight speed
- Two pass flight
- Download to Drone2Map
- Can view individual frames
  - at 2.25 inch resolution from 400 feet
  - 1 inch resolution at 200 feet
Get the hands on and see from above and the side

- Demonstrations for Forestry
- Spatial Science
- Environmental Science
- High Schools

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DJI Phantom 4
View Pine Forest

DJI Phantom 4
Taking images and video for a visual assessment

Video

Monitor timber harvest operation, landscape ecology (patch, corridor, matrix, ecotone)
Visual identification of *Ips* beetle damage, drought, fire, pines, hardwoods, Forest Management Plans
UAS Mosaic

Imagery acquired for forest management capstone course using DJI Phantom 3 and DJI Phantom 4

400 acres flown with four flights of 14 minutes per flight.

Flight height of 390 feet.

Imagery downloaded and mosaicked using Drone2Map.

Spatial resolution of 2.25 inches.

Implications and Questions

Improved visualization of insect damage assessments.

Identification of individual trees affected.

Improved monitoring and tracking of infestation spread.
Measure building height with drone point cloud and Pictometry Spatial Science capstone course

- On-screen height measurement on 30 buildings
- Different methods compared
  - Pictometry 4 inch resolution
  - Drone point cloud as LAS in LP 360
  - Drone point cloud in ArcScene
  - Ground truthing with height pole
- Compare accuracy of building height measurement between different methods

On Screen Building Height, Drone Point Cloud, ArcScene
Mosaic and georeference drone (UAS) aerial images

- Flight line for mosaic
- SFA Children’s Garden
- Used for mosaic, building height, accuracy study of UAS, and surveying with total station

Hazard Rating for Litter Using the DJI Phantom 3
Landscape Ecology—Environmental Science

- 50 square foot grid block for litter estimation
- Red block, high litter
- Orange block, moderate litter
- Yellow block, light litter
- DJI Phantom 3
- 390 feet in height, 2.19 in resolution
- Can assist in planning litter pick up
- Flight time 20 minutes
Port Jefferson History & Nature Center, Jefferson, TX
Forest Management Plans

- Core Area, Port Jefferson History & Nature Center for gardens
- Monarch butterfly gardens with milkweed and pollination plants
- Threatened Neches River rose mallow gardens
- Planning and restoration with Collins Academy and Arthur Temple College of Forestry and Agriculture, DJI Phantom 3 and 4
Measure height with DJI Phantom 3
Spatial Science Capstone Course

- Heights measured at 2, 5, 10 and 15 meters above ground on a height pole
- Drone settings
  - Continuous w/ GPS
  - Continuous w/o GPS
  - Reset w/ GPS
  - Reset w/o GPS
- Assess accuracy of height measurement by drone

How do we measure height?

- Eye ball
- Yardstick (hypsometer)
- Height pole
- Clinometer
- Relaskop
- Laser rangefinder

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A loblolly pine stands at 114 feet tall. Dying...
The drone used for this project - DJI Phantom 3 Standard

- **Aircraft**
  - Weight: 1,216 g
  - Diagonal size: 350 mm
  - Max speed: 16 m/s
  - Max tilt angel: 35º
  - Max service ceiling 6,000 m MSL
  - Max flight time: 25 min
  - **GPS and barometer**
    - Hover accuracy: vertical 0.5 m, horizontal 1.5 m
- **Camera**
  - Sensor: 12 M pixels
  - Lens: FOV 94º, f/2.8
  - Still photo: up to 4,000x3,000
  - Video: up to 1,280x720

- **Gimbal**
  - Stabilization: 3-axis (pitch, roll, yaw)
  - Controllable range: Pitch: -90° to +30°

- **Remote controller**
  - Max transmission distance: FCC 1,000 m, CE 500 m
  - Mobile device holder: tablets and smart phones with built-in WiFi

How does a drone measure height, and **how accurate** is that?

- **Sonar**: calculate time a sound signal travels
- **Radar**: measure frequency shift dependent on distance traveled by radar wave
- **GPS**: trilateration of satellite signals referenced to geoid
- **Barometer**: measure atmospheric pressure referenced to the ground

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Now we have UAS, unmanned aerial system

- “An unmanned aircraft system (UAS), sometimes called a drone, is an aircraft without a human pilot onboard – instead, the UAS is controlled from an operator on the ground.” – FAA
- An aerial vehicle, a ground-based controller, and a system of communications

Timber!!!

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Drone measured heights by different flight settings

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Average measured height (m)

<table>
<thead>
<tr>
<th>Flight Setting</th>
<th>2-m</th>
<th>5-m</th>
<th>10-m</th>
<th>15-m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous-GPS</td>
<td>4.05</td>
<td>6.98</td>
<td>11.88</td>
<td>16.81</td>
</tr>
<tr>
<td>Continuous-NonGPS</td>
<td>3.73</td>
<td>6.71</td>
<td>11.61</td>
<td>16.50</td>
</tr>
<tr>
<td>Reset-GPS</td>
<td>2.26</td>
<td>5.20</td>
<td>10.28</td>
<td>15.39</td>
</tr>
<tr>
<td>Reset-NonGPS</td>
<td>1.91</td>
<td>4.88</td>
<td>9.99</td>
<td>14.96</td>
</tr>
</tbody>
</table>

Precision of height measurement by different flight settings

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SD of measured height (m)

<table>
<thead>
<tr>
<th>Flight Setting</th>
<th>2-meter</th>
<th>5-meter</th>
<th>10-meter</th>
<th>15-meter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous-GPS</td>
<td>1.42</td>
<td>1.40</td>
<td>1.40</td>
<td>1.36</td>
</tr>
<tr>
<td>Continuous-NonGPS</td>
<td>1.20</td>
<td>1.21</td>
<td>1.19</td>
<td>1.17</td>
</tr>
<tr>
<td>Reset-GPS</td>
<td>0.22</td>
<td>0.28</td>
<td>0.30</td>
<td>0.40</td>
</tr>
<tr>
<td>Reset-NonGPS</td>
<td>0.14</td>
<td>0.21</td>
<td>0.25</td>
<td>0.24</td>
</tr>
</tbody>
</table>
### Drone measured heights by flight different settings

![Graph showing drone measured heights by flight different settings](image)

### Errors of drone measured heights by different flight settings

<table>
<thead>
<tr>
<th></th>
<th>2-meter</th>
<th>5-meter</th>
<th>10-meter</th>
<th>15-meter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous-GPS</td>
<td>2.48</td>
<td>2.41</td>
<td>2.33</td>
<td>2.25</td>
</tr>
<tr>
<td>Continuous-NonGPS</td>
<td>2.09</td>
<td>2.08</td>
<td>1.99</td>
<td>1.89</td>
</tr>
<tr>
<td>Reset-GPS</td>
<td>0.34</td>
<td>0.34</td>
<td>0.41</td>
<td>0.55</td>
</tr>
<tr>
<td>Reset-NonGPS</td>
<td>0.17</td>
<td>0.24</td>
<td>0.25</td>
<td>0.24</td>
</tr>
</tbody>
</table>

![Bar chart showing errors of drone measured heights](image)
Landing drone before each height measurement is more accurate, while GPS does not play a role.

<table>
<thead>
<tr>
<th>Mean absolute error of measurement (m)</th>
<th>2-meter</th>
<th>5-meter</th>
<th>10-meter</th>
<th>15-meter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous-GPS</td>
<td>2.05</td>
<td>1.99</td>
<td>1.90</td>
<td>1.82</td>
</tr>
<tr>
<td>Continuous-NonGPS</td>
<td>1.73</td>
<td>1.71</td>
<td>1.62</td>
<td>1.52</td>
</tr>
<tr>
<td>Reset-GPS</td>
<td>0.26</td>
<td>0.24</td>
<td>0.31</td>
<td>0.45</td>
</tr>
<tr>
<td>Reset-NonGPS</td>
<td>0.15</td>
<td>0.18</td>
<td>0.21</td>
<td>0.19</td>
</tr>
</tbody>
</table>

All 2-way ANOVA analyses found significant on landing setting, but not GPS; while there is no interaction between the two factors.

Faculty Led Service Learning to Quantify Height

Integrating Faculty Led Service Learning Training to Quantify Height of Natural Resources from a Spatial Science Perspective

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Figure 3. Measuring in situ height with a telescopic height pole

Figure 4. Estimating in situ height with a clinometer

Figure 5. Estimating height onscreen within the Pictometry online web interface
“Using spatial science technology senior undergraduate students under the direction of spatial science faculty learned how to accurately measure the height of vertical features in a landscape that could be used for observation and decision making purposes. This project allowed students not only to collect real-world data using different methods, but also learn how to analyze the collected data and interpret the outcome properly.”
“The results from the study and the students’ ability to acquire multifaceted spatial science information validate the hands-on instruction methodology employed in the spatial science curriculums within ATCOFA at SFASU. The results also reinforce ATCOFA’s mission by empowering students with the capability of employing sophisticated remote sensing technology to accurately quantify, qualify, map, and monitor natural resources.”

“Students learned that by integrating research into a hands-on senior level undergraduate spatial science course that knowledge and cognitive retention increases along with improved insights into spatial science applications within a natural resource context.”
“The integrated of the DJI Phantom 3 drone into the education process enhanced the ATCOFA message of work outdoors, make a difference and use high-end technology as active learners. The direction provided by the MUGS program reinforced higher order thinking skills and student achievement by integrating on-screen Pictometry measurements with in situ drone measurements compared to traditional height measurement techniques.”

Assess positional accuracy of drone derived aerial images

- 35 ground control points surveyed with total station for each geographic coordinates
- Corresponding geographic coordinates attained on-screen based on drone orthomosaics
- Assess positional accuracy of drone orthomosaics
Rate tree condition with AR.Drone2.0

- 52 urban trees measured on campus and city parks, AR.Drone2.0
  - DBH: 10-40 in.
  - HT: 40-100 ft.
  - Geographic coordinates recorded
- Traditional CTLA (Council of Trees and Landscape Appraisers) rating conducted on site
- Drone flown and video recorded
- CTLA rating based on recorded video
- Compare rating results between traditional CTLA and drone video
High correlation on overall tree condition ratings between traditional CTLA and drone

- American Elm
- Box Elder
- Green Ash
- Live Oak
- Loblolly Pine
- Magnolia
- Maple
- Pear
- Pecan
- Red Oak
- Shortleaf Pine
- Sugarberry
- Sweetgum
- Water Oak
- Winged Elm

\[ R^2 = 0.96 \]

A total of 52 trees measured

A tree with the possible highest overall rating

Total Condition = 26 (100%)
No difference on tree condition ratings between traditional CTLA and drone

<table>
<thead>
<tr>
<th></th>
<th>Trunk Condition</th>
<th>Growth</th>
<th>Crown Structure</th>
<th>Insect and Disease</th>
<th>Crown Development</th>
<th>Life Expectancy</th>
<th>Total Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTLA</td>
<td>2.50 (1.47)</td>
<td>1.85 (1.03)</td>
<td>2.52 (1.61)</td>
<td>1.67 (1.03)</td>
<td>2.79 (1.38)</td>
<td>2.79 (1.61)</td>
<td>54.4 (29.7)</td>
</tr>
<tr>
<td>Drone</td>
<td>2.54 (1.59)</td>
<td>1.71 (0.91)</td>
<td>2.48 (1.56)</td>
<td>1.71 (1.04)</td>
<td>2.71 (1.38)</td>
<td>2.71 (1.55)</td>
<td>53.4 (29.3)</td>
</tr>
<tr>
<td>t-value</td>
<td>1.27</td>
<td>2.00</td>
<td>0.57</td>
<td>0.81</td>
<td>0.72</td>
<td>1.27</td>
<td>1.20</td>
</tr>
<tr>
<td>P</td>
<td>0.210</td>
<td>0.051</td>
<td>0.567</td>
<td>0.420</td>
<td>0.472</td>
<td>0.210</td>
<td>0.240</td>
</tr>
<tr>
<td>α = 0.05</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

(mean and standard deviation shown for both CTLA and Drone, n = 52)
Errors of building height measurement with drone point cloud and Pictometry

Distribution of height measurement errors

Method

Drone point cloud is not as accurate as Pictometry in building height measurement

SUMMARY

<table>
<thead>
<tr>
<th>Groups</th>
<th>Count</th>
<th>Sum</th>
<th>Average</th>
<th>Variance</th>
<th>Tukey</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pictometry</td>
<td>30</td>
<td>1.38</td>
<td>0.0460</td>
<td>0.000756</td>
<td>A</td>
</tr>
<tr>
<td>LAS</td>
<td>30</td>
<td>5.08</td>
<td>0.1693</td>
<td>0.012413</td>
<td>B</td>
</tr>
<tr>
<td>ArcScene</td>
<td>30</td>
<td>3.74</td>
<td>0.1247</td>
<td>0.007315</td>
<td>B</td>
</tr>
</tbody>
</table>

ANOVA

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>P-value</th>
<th>F crit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>0.233947</td>
<td>2</td>
<td>0.116973</td>
<td>17.13092</td>
<td>5.33E-07</td>
<td>3.101296</td>
</tr>
<tr>
<td>Within Groups</td>
<td>0.594053</td>
<td>87</td>
<td>0.006828</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>0.828</td>
<td>89</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Absolute building height measurement errors in meters

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Comparison of LaNana Creek 1939 to November 2017
Dylan Coleman, GIS 420, GIS 410, Spatial Science

1939 2017

FAA UAS Pilot Exam

60 question exam; 70 percent correct to pass

Background check by FAA and Homeland Security Good for two years

Six students passed the exam after
18 hours of training and up to 5 practice tests plus UAS flying
Take exam at FAA approved test site
(e.g. LeTourneau University, Cleveland Airport, Just Fly! Flight Training)
Remote Pilot – Small
Unmanned Aircraft Systems
Study Guide

Guidebook used for student training
Reviewed topics for 18 hours of meetings with up to 5 practice tests
Scheduled FAA exam at approved site

Flew UAS (DJI Phantom 3 and DJI Phantom 4) for test flights with review of safety procedures, flight plan using snapshots, video and programmed flights (Pix4D), Drone2Map and ArcGIS 10.5.2
UAS Flight Log

- Each flight should be recorded in a personal flight log
  
  Pre-flight check
  Pilot in Command, Visual
  Observer
  Location of flight
  Type of Flight (video, pictures, programmed flight)
  Safety, Safety Briefing

UAS Flight Log Details

- FLIGHT LOG DETAILS
- Pilot in Command, Date, ACN (UAS registration number)
- Mission Objective
- Mission Location
- Weather
- Flight Codes

![UAS Flight Log Details Table]
UAS Flight Log Details

Completed before each flight
Completed after flight

(remove battery, turn off controller, make sure batteries are turned off, secure UAS, complete log book)

Mike Walker Property flown June 9, 2017

- DJI Phantom 4, Programmed Flight, 80 Percent Endlap, 60 Percent Sidelap, Double Flightline
- 10 acres, 4 minutes, 120 meters (390 feet)
- Pilot in Command, Visual Observer
- Line of Site
- Favorable Weather Conditions
- Status of UAS Checked Prior to Flight (Battery Status, Visual Check of UAS, Propellers Properly Installed, Synchronized with Controller and UAS, Clean Take Off and Landing Area)
- Synchronized Imagery (15 minutes)
- Download Individual Images, Video, Programmed Flight (30 minutes)
- Available to Landowner with Orthomosaic
Missions, Mike Walker Property, flown June 8, 2017

Download to Drone2Map software into ArcGIS 10.4
Three Products: Orthomosaic, Hillshade, Elevation Model

Create New Project, Drone2Map
Mike Walker Property, flown June 9, 2017, Double Flight Line (Blue Dots, Photo, Programmed Flight
FEATURE

ATCOFA's spatial science program leads natural resource management into the future

The subtle whir of an unmanned aircraft system, commonly known as a drone, may not be the first thing one expects to hear when visiting a forested tract of land managed by the ATCOFA, but the use of such technology in natural resource management is becoming more commonplace. Natural resource professionals with high-resolution images and precise GPS coordinates that can be used to make management decisions.

Kulhavy, Unger, Hung, and Zhang. College of Forestry and Agriculture, Stephen F. Austin State University

ATCOFA

make a difference • work outdoors • use high-end technology

A forestry student collects data for a research project to determine the accuracy of drones in measuring tree height.

Kulhavy, Unger, Hung, and Zhang. College of Forestry and Agriculture, Stephen F. Austin State University
“Global positioning systems, aerial measurements and drones are the wave of the future,” said Dr. Daniel Unger, professor of remote sensing of natural resources in the college. “The key is its high spatial resolution, its detail, and you can fly it whenever you want the imagery taken.”

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Questions?
The Use of UAS in Teaching Research and Service at Stephen F. Austin State University

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Arthur Temple College of Forestry and Agriculture
Stephen F. Austin State University
Acknowledgement

- The Spatial Science team at the College of Forestry and Agriculture at Stephen F. Austin State University
- McIntire-Stennis funds

Regional and National Scale Analysis

Wildlife Impacts
- Temple Fork, UT

Ecosystem Evaluation
- Kamiak Butte, WA

Recreation Planning
- Scenic Beach State Park, WA

Range Assessment
- Uinta-Wasatch-Cache National Forest, UT
Local Scale Analysis

Urban Trail Assessment
Lanana Creek Trail, TX

Urban Forestry
Ips Beetle Tree Removal, TX

Forestry Outreach
ATCOFA FFA Demonstration, TX

Counting Turtles
Lanana Creek, TX

Boy Scout Eagle Project, Labyrinth

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