UAV use in Agriculture: Practical, Legal, and Technological Considerations

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Why collect field imagery?

Long-term field trends
• Soil properties
• Compaction problems
• Land use history

Short-term conditions or events
• Irrigation problems or inconsistencies
• Nutrient deficiencies
• Application errors
• Weather damage
• Insects*
• Disease*

*May be visible only after the damage is done.
Still better than not knowing!
Why collect field imagery?

• Imagery is collected so a grower can make a *change* to their operation, or so the scouting method can change.

• Are they *willing* and *able* to change how they plant, fertilize, irrigate, spray, or harvest?

• Will the consultant change how they scout the field?
Sources of Imagery

- Satellite
- Manned-Aircraft
- UAV (drone)
Satellite

- Lowest cost source of imagery
- Relatively low resolution
  - 15 foot pixels *at best*
- Unreliable availability
  - Clouds, smoke, and haze
Manned Aircraft

• Higher cost than satellite, but cheaper than UAV imagery.

• Far better resolution than satellite.
  • 1 foot pixels vs 15 foot pixels.

• Much more reliable image capturing than satellite.

• Very scalable for adding more fields.
UAV

- Ultra-high resolution imagery allows for unique products.
  - Weed maps
  - Plant population/stand count maps
  - Canopy closure percentage across the field.
  - Feature training and identification.

- Very expensive (or time consuming) to collect and process at this point.
Terminology

What is a “drone?”
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**UAV** – Unmanned Aerial Vehicle

**UAS** – Unmanned Aerial System

“A UAS is the unmanned aircraft (UA) and all of the associated support equipment, control station, data links, telemetry, communications and navigation equipment, etc., necessary to operate the unmanned aircraft.” – FAA

**sUAS** – A UAS where the aircraft weighs less than 55 lbs.
Is this thing technically a UAV?
Is this thing technically a UAV?

Start

Can you control it from the ground and/or does it have an autopilot?

No

It might just be a paper airplane.

Yes

Does it weigh more than 0.55 lbs?

No

It is too small for the FAA to care about

Yes

Is there a human on board?

Yes

That’s just a normal aircraft

No

It is probably a UAS
Is this thing technically a UAV?
Legal Implications

• What is a commercial use?
  • Selling maps/imagery to growers?
  • Using a UAV to help scout a field?
  • Farmer checking their own pivots?
  • An ag retailer posting video on their Facebook page?
Commercial Restrictions

• Must maintain visual line-of-sight and be ready for manual override.
• Stay below 400 feet above ground level.
• One UAV per operator.
• Operator must take paper test and apply for certification.
• UAV must be registered online.
• Can’t fly at night.
• ... and more! Check online for full details.
Part 107 Rule Changes

• No more pilots license (easier to take test)
• No more secondary “spotter” person
• No more NOTAMs
• No distance buffer around class G (no ATC tower) airports.
• No more 333 exemption, Certificate of Waiver or Authorization (COA,) or paper registration of aircraft required.
So which one should I buy?
Multi-Rotor vs. Fixed-Wing

Multi-Rotor
• *Much* easier to take-off and land
• Capable of lower/slower flight

Fixed-Wing
• Can handle faster wind
• Higher top speed
• Much longer battery life
How are you going to use your UAV?

• The UAS is used as a tool by the person who is already checking the field.

• The imagery sold as a separate service that compliments other agronomic services.
Live Video

Pros

• Faster than flying a whole-field image.
• Useful for identifying equipment problems.
• Is a lot of fun to fly.
• No image processing required.

Cons

• Not as useful for locating or quantifying crop stress areas.
• Can’t easily archive or compare the data for future use.
• Can’t use to create variable-rate prescriptions.
Which camera/sensor?

- RGB
- Multi-Spec
- Filter-swapped “NIR” cameras
- Thermal (?)
Science lesson about light

- Visible light
- Near Infrared
- Long-wavelength Infrared
Visible Light

• “Native” image
• RBG (Red Green Blue) image
• “What you see is what you get.”
Near Infrared (NIR)

- Invisible, reflected light.
- Healthy vegetation reflects it very well.
- Used to calculate vegetative indices like Normalized Difference Vegetative Index (NDVI)
What is a “vegetation index?”
Normalized Difference Vegetation Index (NDVI)
Long-wavelength Infrared

- “Thermal” or “heat” imaging.
- Emitted (glowing), rather than reflected.
- Healthy vegetation is cooler than stressed vegetation.
- Wet soil is cooler than dry soil.
Long-wavelength Infrared
Long-wavelength Infrared
4-channel multi-spectral sensor
4-channel multi-spectral sensor

Green

Red

Red-Edge

Near Infra-Red
Modified RGB to "NIR" camera
Modified RGB to “NIR” camera
Which type of camera/sensor is better?

• A true Multi-Spec camera has *much better* final map quality than a filter swap-job. (Less “noise” and better contrast.)

• Swap-jobs are cheaper and can often cover a larger area (due to a wider field of view.)
Which type of camera/sensor is better?

True Multi-Spec sensor

Filter-swapped “NIR” camera
Why not use a RGB camera for crop health?

• Would you hire a color-blind interior decorator?
• If your camera can’t see NIR, then it’s color-blind!

True Multi-Spec sensor  Processed RGB image
Flying the UAV

1. Mission planning
2. Launch
3. Observation
4. Landing and recovery
5. Processing the imagery
Launching by hand
Time to get out the glue!
UAV imagery

Statistics for the image:
- RNDVI threshold: 0.44
- Plant rows: 12
- Row spacing: 56.3 [pixels], sigma: 1.6 [pixels]
- Plant spacing: 98.7 [pixels], sigma: 3.7 [pixels]
- Plant spacing method: cross-correlation
- Plants found: 504
- Weeds found: 13
- Average plant density: 35574 per acre
UAV imagery

Statistics for the image:
- NDVI threshold: 0.42
- Plant rows: 12
- Row spacing: 43.0 pix, sigma 1.0 (pixels)
- Plant spacing: 6.0, sigma 2.0 (pixels)
- Plant spacing method: cross-correlation
- Plants found: 608
- Weeds found: 0
- Average plant density: 25505 per acre
UAV imagery

Statistics for the image:
NDVI threshold: 0.42
Plant rows: 17
Row spacing: 40.9 pix, sigma 17.1 [pixels]
Plant spacing: 6.0, sigma 2.0 [pixels]
Plant spacing method: spot detection
Plants found: 282
Weeds found: 34
Average plant density: 10709 per acre
UAV imagery
UAV imagery
UAV imagery

Weeds (grass in bean field)
UAV imagery

White mold in beans
UAV imagery

Early symptoms of SDS
UAV imagery
Image metadata:
Platform position: lat 41.288692, lon -97.307958, alt 114.98m above ground
Sensor aimpoint: lat 41.288797, lon -97.307976
Sensor orientation: roll 0.00, pitch 0.00, hdg 14.95 deg
Sensor motion: speed over ground 19.03 m/s, course 14.95 deg
Sensor band 0: ADC 947 out of 1070, exposure 2.00 ms
Sensor band 1: ADC 683 out of 780, exposure 1.00 ms
Sensor band 2: ADC 347 out of 400, exposure 3.00 ms
Sensor band 3: ADC 74 out of 90, exposure 1.25 ms
Image metadata:
Platform position: lat 41.292189, lon -97.304882, alt 114.16m above ground
Sensor aimpoint: lat 41.293393, lon -97.304107
Sensor orientation: roll 0.00, pitch 0.00, hdg 12.05
Sensor motion: speed over ground 1.36 m/s, course 12.05 deg
Sensor band 0: ADC 8.47 out of 1070, exposure 2.25 ms
Sensor band 1: ADC 6.08 out of 780, exposure 1.25 ms
Sensor band 2: ADC 30.89 out of 400, exposure 3.30 ms
Sensor band 3: ADC 65 out of 80, exposure 1.25 ms
Image metadata:
Platform position: lat 41.383232, lon -97.465474, alt 91.88m above ground
Sensor aimpoint: lat 41.383222, lon -97.465540
Sensor orientation: roll 0.00, pitch 0.00, hdg 270.73
Sensor motion: speed over ground 15.14 m/s, course 270.73 deg
Sensor band 0: ADC 700 out of 1670, exposure 2.50 ms
Sensor band 1: ADC 512 out of 768, exposure 1.50 ms
Sensor band 2: ADC 256 out of 400, exposure 4.25 ms
Sensor band 3: ADC 60 out of 90, exposure 1.50 ms

brent, 102 acres
Processed 137 acres
13 JUL 2016, 21:47:34 UTC
Good placement for a moisture probe.

Very dry ridge! Consider a drought-resistant hybrid here.

This corner is disked and ridged for pipe.
Moisture stress ahead of the pivot.

Moisture stress in the non-irrigated corner.

Manned-Aircraft Imagery
In-Season Thermal
Moisture stress varies greatly in this field due to soil type and topography. This information can be used to better manage irrigation.
Challenges

What are some challenges with UAV use?
Challenges

What are some challenges with UAV use?

• Safely sharing the air with aerial applicators.

• *Lots* of maintenance and repair.

• Maximizing time/cost efficiency.
  
  • Flying 160 acres may take up to an hour.

• Requires skill, experience, (and a little luck) to operate.

• Weather conditions. (Wind, rain.)
Imagery Problems

- Light angle / time of day effects
- Shadows and uneven “glare”
- Image stitching / overlap errors
- Cloud shadows and changing light conditions
Problem with these fields?
Angle of light causes “glare” in manned aircraft image.
Angle of light causes “striping” effect in image.
Image Stitching

Two main ways to combine many small images into one big image:

1) Tile images based on plane position and orientation.
   • Fairly reliable but never perfect.

2) Stitch images based on overlapping parts of the image.
   • Better final product.
   • Requires more overlap of images.
Tiling based on plane orientation.
Good stitching based on imagery overlap.
Poor stitching based on imagery overlap.
Bad spot due to one faulty picture
Technology Use

None of these technologies are a replacement for regularly checking the field!

- They *do* let you be smarter about where you spend your time.
- They can help you catch problems you may otherwise miss.
- They can create variable-rate prescription maps to allow the smartest use of inputs.
To drone or not to drone?

• Do you need better resolution than manned-aircraft?

• Do you have free time that can’t be profitable otherwise?

• Do you have a very high tolerance for risk and failure?

• Do you want video instead of a field map?
Manned-Aerial
UAV
Manned-Aerial
Questions?

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