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

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Servi-Tech Expanded Premium Services
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
Why collect field imagery?

Fix something this year.

Improve how I farm next year.
Washed-out and replanted areas.

Skip in the anhydrous ammonia application.

Gully erosion in field due to steep slopes and rainfall.

Single pass of downed corn because of a green-snap susceptible hybrid.
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?

• Do you just need a really cool looking image?
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.
Sources of Imagery

• Satellite

• Manned-Aircraft

• UAV (drone)
Satellite

• Lowest cost source of imagery
• Relatively low resolution
  • 15 foot pixels \textit{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.
• You don’t have to rely on someone else to collect it.
• Very expensive (or time consuming) to collect and process at this point.
• Can provide instant feedback about the field.
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

• **Yield to other aircraft!**
• 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.
  • How much time will it add/save to the field check?

• The imagery sold as a separate service that compliments other agronomic services.
  • Will the customer pay enough to make it worth your time?
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?”

It’s a comparison between visible light and NIR light.
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

Irrigation patterns and soil moisture show up better in Thermal than in Native Color.
Long-wavelength Infrared
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.)
Modified RGB to “NIR” camera
Modified RGB to “NIR” camera
4-channel multi-spectral sensor
4-channel multi-spectral sensor
<table>
<thead>
<tr>
<th>Sensor Package</th>
<th>Good/Bad</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unmodified RGB</td>
<td>✅ Good for taking “Glamour shots” &lt;br&gt;✅ Checking equipment or “drone scouting” &lt;br&gt;x Can’t do NDVI mapping</td>
<td>$</td>
</tr>
<tr>
<td>One-camera “NIR” filter modification.</td>
<td>✗ NDVI maps have poor reliability and quantitative value. &lt;br&gt;✗ Bad compromise between better alternatives.</td>
<td>$$</td>
</tr>
<tr>
<td>Two-camera system. (RGB &amp; NIR)</td>
<td>✗ Bulkier than single camera. &lt;br&gt;✅ Production-grade NDVI maps.</td>
<td>$$$</td>
</tr>
<tr>
<td>“True” multi-spectral sensor system.</td>
<td>✗ Research-grade maps and NDVI plot measurements. &lt;br&gt;✗ Narrow field-of-view and complex software makes data collection/processing more difficult. &lt;br&gt;✗ Low sensor resolution requires lower-altitude flights.</td>
<td>$$$$$</td>
</tr>
</tbody>
</table>

**Price**
- $: Low <br>
- $$: Medium <br>
- $$$: High
Is “true multi-spec” worth it?

True Multi-Spec sensor  Filter-swapped “NIR” camera
Why not use an 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
It’s not rocket science...

...rockets are easier!
Launching by hand
Time to get out the glue!
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 41.288840, lon -97.307908, alt 114.98m above ground
Sensor aimpoint: lat 41.288840, lon -97.307908
Sensor orientation: roll 0.00, pitch 0.00, hdg 149.95
Sensor motion: speed over ground 10.03 m/s, course 149.95 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 247 out of 400, exposure 3.00 ms
Sensor band 3: ADC 74 out of 90, exposure 1.25 ms

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40aking the Planet more Productive
Image metadata:
Platform position: lat 41.292189, lon -97.304082, alt 114.16m above ground
Sensor aimpoint: lat 41.292233, lon -97.304107
Sensor orientation: roll 6.89, pitch 0.00, headings 12.85
Sensor motion: speed over ground 1.35 m/s, course 12.85 deg
Sensor band 0: ADC 847 out of 1070, exposure 2.25 ms
Sensor band 1: ADC 609 out of 780, exposure 1.25 ms
Sensor band 2: ADC 399 out of 400, exposure 3.50 ms
Sensor band 3: ADC 65 out of 90, exposure 1.25 ms

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40 MAKING THE PLANET MORE PRODUCTIVE
Image metadata:
Platform position: lat 41.383236, lon -97.486552, alt 91.83m above ground
Sensor aimpoint: lat 41.383222, lon -97.486540
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 1070, 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 1.25 ms
Sensor band 3: ADC 64 out of 90, exposure 1.50 ms
UAV imagery – counting plants and weeds
UAV imagery – counting plants and weeds

Statistics for the image:
- RNDVI 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: 606
- Weeds found: 0
- Average plant density: 25505 per acre
UAV imagery – counting plants and weeds

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: 292
- Weeds found: 34
- Average plant density: 10709 per acre
Very dry ridge! Consider a drought-resistant hybrid here.

Good placement for a moisture probe.

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

Moisture stress in the non-irrigated corner.
Moisture stress varies greatly in this field due to soil type and topography.

This information can be used to better manage irrigation.
Manned-Aircraft Imagery
In-Season Thermal

Sometimes thermal doesn’t tell you much!
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.
   • Reliable but never “clean and 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
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?
To drone or not to drone?

• Do you need ultra-high detail imagery of a small plot, or “good enough” imagery of many acres?

• Do you need **absolute control** over when the field is flown, or can you rely on another group to fly within a range of dates?

• Do you need *exact* NDVI values or just a good idea of where the crop is healthy or not?
Manned-Aerial
Manned-Aerial
UAV
Questions?

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