UNMANNED AERIAL SYSTEMS (UAS) DATA REVOLUTION IN PRECISION AGRICULTURE

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NPUAS Test Site
ND Soybean Council
ND Ag Experiment Station
ND Department of Commerce
Grand Fork EDC
Hillsboro Airport
Halstad, ...
WHY AGRICULTURE?
2 BILLION MORE PEOPLE TO FEED IN 2050

Food security has to be achieved even though people are different owing to their geographic location, economic conditions or food cultures. Let us work to harmonize the differences and pool efforts, so that we will no longer read that food security for the North means eliminating fat and encouraging movement; while for the South, it consists in obtaining at least one meal a day. – Pope Francis (2015)

• What can we do to feed the world?
  • Put more land to agriculture?
  • Grow food in Moon? Mars?
  • Make food production efficient – conserve resources

Use new technology to increase efficiency & sustainability of food production
WHY AGRICULTURE?
MEETING CHANGING NEEDS OF SOCIETY

• UAS will be an $80B industry by 2025
• Over 80% this growth will be in precision agriculture
• Smart agriculture will contribute to sustainability of food production while meeting the food demand
DATA REVOLUTION IN PRECISION AGRICULTURE

Fertilizer Application Map

Weather
Elevation
Soil sensors
Yield

Soil Map

Machinery data

Aerial, Satellite & UAS Imagery

Seeding Application Map
Scouting Map

Chemical Application Map

WINTER SPRING FALL SUMMER
NDSU UAS-PRECISION AG RESEARCH OBJECTIVES

• Evaluate small and large UAS for crop management
  • Weed identification and mapping for site-specific weed management
  • Herbicide injury – glyphosate in wheat, Dicamba in soybean, etc
  • Nutrient management – nitrogen, iron, etc for need-based nutrient management
  • Crop insects and diseases monitoring for managing pesticide application
  • Weather damage assessment for crop insurance, winter kill in alfalfa
  • Yield predictions
  • Soil problems – salinity, drainage channels

• Economic viability of the UAS applications in agriculture
UAS PLATFORMS

- Trimble UX5
- Hermes 450
- 3DR RTF X8
- Altavian
- DJI 100 Matrice
- Phantom 3 & 4
- RF70 - Troybuilt
- DJI 1000A

https://www.ag.ndsu.edu/agmachinery
UAS SENSORS

Cameras
- ICI 9640 S Thermal camera
- Large area scanning EO/IR/NIR camera
- Rikola Hyperspectral sensor
- Ximera Hyperspectral sensor
- MicaSense Rededge
- Sentera dual sensor (4 band)
- Sentera Quad sensor (6 band)
- Slant Range
- Sony NEX-5R camera with NIR
- Tetracam ADC
- GoPro Camera
2016 PROJECT LOCATION – EASTERN ND

Covers 50,000 acres in 1 hour at 8 cm ground resolution

2016: 100,000 acres study area, other small fields

In 2017, Elbit Systems of America expanded their research to 300,000 acres
EXAMPLE APPLICATION - WEED MANAGEMENT FOR SUSTAINABILITY AND INCREASED PRODUCTION EFFICIENCY

- Weeds reduce production efficiency by competing for water, nutrients & sunlight
- Weed resistance to herbicide is major problem

Pesticide usage, 1974-2014 (NASS, USGS, EPA): 67% increase 1607 Million Kg
MAPPING WEED INFESTATION WITH UAS BASED ON COLOR/LOCATION

- Camera
- Near Infrared (NIR) image
- RGB image
- Weed map
WEED MAPPING – INFESTATION, SPECIES & RESISTANCE
BASED ON 3D ANALYSIS OF VISIBLE/NIR + THERMAL DATA
IDENTIFYING HERBICIDE-RESISTANT WEEDS

Ragweed

Potentially significant wavelengths

Reflectance

506 558 610 662 714 766 818 870
Wavelength (nm)

Resistant
Susceptible
Resistant sprayed
Susceptible sprayed

Thermal Signature

\[ \Delta T(\text{Ambient Temp}-\text{Leaf Temp}) \text{ [°C]} \]

Time (h)

Resistant Ragweed
Susceptible Ragweed
IDENTIFYING NOXIOUS PLANTS

UAVs:
- DJI Phantom 3 & 4
- DJI Matrice 100

Cameras:
- Senterra Multispectral Cameras
- Slantrange Multispectral Camera

Spectral signatures of leafy spurge and surroundings

Spectral signatures of purple loosestrife and surroundings

Outside visible range

- Leafy spurge bracts
- Leafy spurge leaves
- Grass
- Background
- Litter
- Soil

Reflectance (%)

Wavelengths (nm)

Reflectance (%)

Wavelengths (nm)

Purple Loosestrife
Grass
Background
Litter
Soil

Wavelengths (nm)

Hermes 450

NDSU Department of Agricultural and Biosoystems Engineering
North Dakota State University, Fargo, ND

Hermes 450
LARGE UAS IMAGERY FOR NITROGEN MANAGEMENT
MAPPING IRON DEFICIENCY CHLOROSIS IN SOYBEANS

Vegetation index
Correlation to IDC

NDVI showing IDC
Trimble with MicaSense Camera
HAIL DAMAGE IN CORN, FROM 4,000’

17 Acres out of 67 acres
ALFALFA WINTERKILL

Causes
- Lack of protection
- Adverse weather
- Late cuttings

Importance
- Evaluations are time consuming and difficult for inexperienced crop scouts
- Areas are hard to map/quantify
- Producers need to know if alfalfa stands are will produce adequate tonnage

Reclassification based on Ground cover
Nursery plot experiments

Rhizoctonia, Cercospora & Fusarium infestation
ROBOTIC DROP DOWN PROBE
3D MODELING EXAMPLES - REPROJECTION ERROR:
LOCATION: CARRINGTON, ND

<table>
<thead>
<tr>
<th>Test area</th>
<th>Sensor size</th>
<th>Pixel size</th>
<th>Images</th>
<th>Flying height</th>
<th>Flying Mode</th>
<th>Image overlaps</th>
<th>Ground resolution</th>
<th>Reprojection error</th>
<th>Process time (h)</th>
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</thead>
<tbody>
<tr>
<td>125m²</td>
<td>1&quot;</td>
<td>2.53*2.53μm</td>
<td>42</td>
<td>5.59m</td>
<td>Automatic</td>
<td>80%</td>
<td>1.47 mm/pix</td>
<td>2.3112 pix</td>
<td>0.78</td>
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<tr>
<td>871m²</td>
<td>1&quot;</td>
<td>3.75*3.75μm</td>
<td>166</td>
<td>9.58m</td>
<td>Automatic</td>
<td>70%</td>
<td>5.82 mm/pix</td>
<td>11.6677 pix</td>
<td>1.33</td>
</tr>
<tr>
<td>6.48m²</td>
<td>1&quot;</td>
<td>1.56*1.56μm</td>
<td>24</td>
<td>2.5m</td>
<td>Manual</td>
<td>80%</td>
<td>0.908 mm/pix</td>
<td>31.5288 pix</td>
<td>0.67</td>
</tr>
</tbody>
</table>

1. Model parameters: High Res & Low error
- Tie Points: 66,703
- Total points: 42,862,147
- Point density: 34.2897 points/cm²

2. Model parameters: Low res, low error
- Tie Points: 168,647
- Total points: 9,014,460
- Point density: 1.0349 points/cm²

3. Model parameters: High res, high err
- Tie Points: 208,800
- Total points: 8,104,609
- Point density: 47.6867 points/cm²
BIG FARM DATA COLLECTION

Area: 125m²
Number of images: 42
Single Image storage size: 6.79MB
Total storage size: ~286MB

Reprojection error: 2.3112 pix
Point density: 34.2897 points/cm²

Area: 2000 acres
Number of images: 2.72e+6
Image storage size: 6.79MB
Total storage size: ~19TB
DATA MANAGEMENT

Large UAS – Entire Corridor Each Date in 2016

<table>
<thead>
<tr>
<th>Date</th>
<th>May 23-27</th>
<th>June 20-24</th>
<th>July 18-22</th>
<th>August 15-19</th>
</tr>
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<tbody>
<tr>
<td>Altitude</td>
<td>4,000’</td>
<td>6,000’</td>
<td>6,000’</td>
<td>4,000’</td>
</tr>
<tr>
<td></td>
<td>6,000’</td>
<td>8,000’</td>
<td>8,000’</td>
<td>8,000’</td>
</tr>
<tr>
<td>Image Quantity</td>
<td>2.0 TB</td>
<td>1.5 TB</td>
<td>1.5 TB</td>
<td>2.0 TB</td>
</tr>
<tr>
<td></td>
<td>1.5 TB</td>
<td>0.5 TB</td>
<td>0.5 TB</td>
<td>0.5 TB</td>
</tr>
<tr>
<td>Total Size</td>
<td>4.0 TB</td>
<td>2.0 TB</td>
<td>2.0 TB</td>
<td>2.5 TB</td>
</tr>
</tbody>
</table>

Total Quantity of Imagery Collected during the Project: **10.5 TB**

Plus Small UAS Imagery, plus ground data
Plus Image Analyses
Transfer Time from NDSU Secure File Site
2 minutes – Grand Forks Courthouse – Wired Connection
4 minutes – Fargo Home – CableOne & Wireless
7 minutes - Fargo Home – CableOne & Wireless
9 minutes – Carrington Home – Cable & Wireless
10 minutes – Cass County Courthouse – Wireless
27 minutes – Richland County Courthouse
53 minutes – Griggs County Courthouse
1 hour and 10 minutes – NDSU CREC
• By nature, production ag occurs in rural / remote areas, likewise the data for initiatives like this will originate in those same locations.

• To use the data for analysis, discovery and innovation, the data must travel or at least be accessible to experts from a distance.
DATA PRIVACY AND SECURITY ~

- **Grower privacy** protect the grower’s crop production and business related data while ensuring timely access to key research data sets by partners.

- **Intellectual Property** allow universities to patent research discoveries and transfer the patent to the private sector.

- **Research transparency and replicability** ensure attention to data privacy concerns is rigorous, but does not stifle progress of public/private research initiatives intended to benefit global society and economy.
TAKE AWAY

• UAS will have many more applications in agriculture
• Smart farming will be the future of food production
• Issues on data management, data infrastructure, privacy & ownership needs to be resolved

Thank You!