DRONES IN MODERN AGRICULTURE

Dr. Kevin Price
Executive Vice President of Research & Technology Development, AgPixel/RoboFlight Systems, LLC
We have our own state of the art computing facilities in Des Moines, Iowa. This also houses our research and development lab.

Presently capable of processing imagery covering ~1.5 million acres per day
Green plants use specialized light capturing organelle called chloroplasts that produce a green pigment called chlorophyll a and b. This pigment captures energy from the sun in the blue and red regions of the electromagnetic spectrum. By a process called photosynthesis, the solar energy is converted for light to chemical energy (sugars, starches, proteins).

NATURAL COLOR IMAGE OF A DISEASED SOYBEAN PLANT GROWING IN A GREENHOUSE

Terminology –
When features are captured on film we call it a picture.

When features are captured in a digital format, we call it an image.
Computing the NORMALIZED DIFFERENCE VEGETATION INDEX (NDVI)

Visible band (usually RED)

\[
\text{NIR} - \text{Visible band (RED)} = \text{NDVI}
\]

NDVI Gray Shade Image

Low NDVI

High NDVI
Redder = Greener

FALSE_COLOR_COMPOSITE

COLORIZED_NDVI

Low NDVI

High NDVI
UNMANNED AIRCRAFT SYSTEMS

Multirotor systems are appropriate for small scale and research operations under 50 acres. The Fixed Wing can cover over 1000 acres at 1.0 inch resolution a day.
RoboFlight RF-70 - True Aerial Mapping System
Manned Aircraft

Our company is committed to collecting and processing quality remotely-sensed data, whether it be from unmanned aircraft, manned aircraft, or satellites. We are platform agnostic.

Cessna pod camera mount

Aerial imagery collection with a Cessna aircraft
Tomatoes
Aerial Image Capture

Color Infrared Orthomosaic

Color Infrared Image showing individual tomato plants
Comparing sUAS with Modified NDVI cameras Values to GreenSeeker NDVI Values

Collecting color infrared imagery using Hexcopter and Canon T4i NDVI camera

Collecting NDVI data using the Trimble® GreenSeeker® crop sensing system

Yellow Arrows: GreenSeeker Row
Green Stars: N Reference Strips
Comparing sUAS with Modified NDVI cameras Values to GreenSeeker NDVI Values

Taking samples to calculate the NDVI values

NDVI map

- **T4i red-NDVI vs. GreenSeeker red-NDVI**
  - $y = 0.0115x - 0.7787$
  - $r^2 = 0.93$

- **T4i green-NDVI vs. GreenSeeker red-NDVI**
  - $y = 0.0142x - 1.1332$
  - $r^2 = 0.91$

- **s100 blue-NDVI vs. GreenSeeker red-NDVI**
  - $y = 0.0182x - 1.733$
  - $r^2 = 0.90$
Using sUAS Imagery and AgPixel to Model Corn Yields

Color Infrared Mosaic of Corn Field

Yield Map

Sandy Soils

Lower Yields

Higher Yields

T4i green-NDVI vs. Corn grain yield

\[ y = 7.8986x - 823.77 \]

\[ r^2 = 0.91 \]

T4i red-NDVI vs. Corn grain yield

\[ y = 6.2546x - 607.85 \]

\[ r^2 = 0.90 \]
SOILS MAP SUPERIMPOSED ONTO AN NDVI MAP

1. Keith silt loam, 3 to 6 % slopes, eroded
2. Keith silt loam, 1 to 3 % slopes
3. Sulco-Ulysses silt loams, 9 to 30 percent slopes, eroded
4. Keith silt loam, 1 to 3 % slopes
5. Keith silt loam, 1 to 3 % slopes, eroded
COMPARISON BETWEEN NDVI AND CROP YIELD MONITOR MAPS FOR CORN

**NDVI Map**
Flown August 1, 2014

**Crop Yield Monitor Map**
Harvested October 16, 2014

2.5 months difference

220 lbs/acre nitrogen

Bushels

<table>
<thead>
<tr>
<th>Lower Yields</th>
<th>0</th>
<th>50</th>
<th>100</th>
<th>150</th>
<th>200</th>
<th>250</th>
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</thead>
<tbody>
<tr>
<td>Low NDVI</td>
<td></td>
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Higher Yields
OUR DATA FEED INTO SST SUMMIT FARM MANAGEMENT SOFTWARE
The Normalized Difference Vegetation Index (NDVI) is useful for identifying problem areas in fields. NDVI is then used to create management zones into which different treatments will be applied. This NDVI Shapefile (SHP) product is compatible with most farm management software packages.

CORN PIVOT STUDY:
August 2014

COLORIZED NDVI MAP

COLOR INFRARED ORTHOMOSAIC

YIELD MAP (Previous Year)

SOIL MAP (Previous Year)

NITROGEN REQUIREMENTS:
Low Meduim High Very High

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Rice fields near Yangzhou, China (July 2013) with professors and students flying a DJI S800 Hexcopter equipped with Color IR Camera (blue, green & NIR band sensitive)

The hexcopter can be seen in the upper middle of the image about 150 feet above the field.

Notice that variation in rice vigor and planting density is not obvious from this vantage point.
Rice fields in Color Infrared image taken from 150 m above ground. Notice the color and textural variation in image that are indicative of variations in crop vigor, plant density and growth stages.
I was standing right here
WEED MANAGEMENT

Canada Thistle (Cirsium arvense)

Uninfested Corn

Canada Thistle
Canada Thistle Mapping
1.0 inch pixel sizes
Canadian Thistle Study: Herbicide Application

- Cost for single rate treatment: $3,931.13
- Estimated cost for data collection, processing, and spot treatment: $506.63
- Total herbicide savings: $3,424.50

Only 0.6 acres affected of 120 acre pivot
Green Snap of corn (stock broken off)
• Lost 55 acres of corn due to green snap

• At 200 bushels/acre: 10,960 bushels lost

• At 2014 price of $3.50 per bushel: Loss = $38,360

Total loss due to herbicide over use, green snap – cost of overflight

$38,360 + $3,425 = $41,784

Does not include equipment use and labor to spray entire field
Where is Canadian Thistle?

1.5 inch pixels

1.0 m pixels

5.0 m pixels

Weeds

Weeds?

Weeds?
NDVI of Corn Field with Thistle

1.5 inch pixels

1.0 m pixels

5.0 m pixels

Weeds

Weeds?

Weeds?
Weeds
What level of detail do you need?

Double planted wheat in areas throughout the field. One of the worst weeds one can have is one of the same species. It is the best at competing for resources and cannot be controlled by herbicides without killing the same species.
Or do you need this level of detail? This is the level of detail available from a small unmanned aircraft system with a good camera flying at 400 feet above the ground.

Do you want to count wheat tillers?
Weeds missed by the sprayer in a new seedling emerging winter whet field
Nutrient issues, double planting, soil erosion, poor emergence

Not enough nitrogen

- Soil erosion
- Double planting
The green areas are where the person laying down the winter wheat double planted. Without sufficient soil moisture and nutrients these areas will most likely produce very poorly.

Lots of variation in this field showing effects of current and past management practices.
# Winter Wheat (UAS vs Cessna vs Satellite)

<table>
<thead>
<tr>
<th>1.0 inch pixels</th>
<th>10.0 inch pixels</th>
<th>5.0 m pixels</th>
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<tbody>
<tr>
<td>Color infrared</td>
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<tr>
<td>NDVI</td>
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Low NDVI | High NDVI

- **Color infrared**: Images showing the color infrared spectrum for different pixel resolutions.
- **NDVI**: Images showing the Normalized Difference Vegetation Index (NDVI) for different pixel resolutions.

The NDVI scale ranges from low NDVI (green) to high NDVI (red) for the 1.0 inch pixels, 10.0 inch pixels, and 5.0 m pixels.
Classification of Winter Wheat Emergence

Where are the corn plants and weeds?
Corn root lodging caused by wind at Iowa State University Genetic Breeding Plots (Picture taken Sept. 3, 2014)
Corn Root Lodging comparison between 2.5 inch and 5.0 m resolution

Cessna Color IR Imagery
2.5 inch pixels

Same image resampled to 5.0 meter. Where is the root lodging?

Corn root lodging
50,000 seed/acre
32,000 seeds/acre

If one is missing something as obvious as the root lodging above, what else is being missed using satellite imagery?

5.0 meter pixels
NOTICE THAT THE SEEDLINGS ARE EASIER TO SEE IN THE COLOR IR IMAGE

Newly emerged soybean seedlings (Natural Color)

Newly emerged soybean seedlings (Color IR (red edge))

Soybean seedlings

Weed (prickly lettuce)
Soybean Emergence

230 feet above the ground

Color Infrared image with seedlings and crop residue visible in the image
COLOR INFRARED ORTHOMOSAIC
Pixels resampled to 2.5 inch pixels (simulated altitude of 1,150 feet)
2.5 inch pixels resolution with vector polygons from 0.5 inch classification map superimposed (As you can see, the pixel classification and vector polygons still align very well telling us that we have not lost much classification accuracy by increasing pixel size by a factor of 5 times
CONSIDERATIONS FOR POTENTIAL UAS OWNERS

• Rapidly-developing technology and constant improvements

• Declining cost as technology becomes widely available

• Potential for inaccurate results without proper aircraft and training

• Research is ongoing and now is the time to ask questions

• Dealing with all the data coming at you will be a challenge.

Can process 1.5 million acres per day and turn it around in 24 hours or less
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