DRONES IN MODERN AGRICULTURE

Dr. Kevin Price

Executive Vice President of Research & Technology Development, RoboFlight Systems, LLC
EDUCATIONAL BACKGROUND

**BRIGHAM YOUNG UNIVERSITY**
- Bachelor and Master of Science
- Department of Botany and Range Science, College of Agriculture

Thesis: *Habitat and Community Relationships of Cliffrose (Cowania mexicana var. stansburiana) in Central Utah*

**UNIVERSITY OF UTAH**
- Ph.D. in Geography
- Specialty in biogeography, remote sensing, GIS

Dissertation: *Detection of Soil Erosion With Thematic Mapper (TM) Satellite Data Within Pinyon – Juniper Woodlands*
PROFESSIONAL BACKGROUND
Working in the Rocky Mountains presented a unique challenge with what is called the topographic effect.

TOPOGRAPHIC EFFECT

White Sands, New Mexico
In 1989, I found a solution to the topographic effect when I moved to Kansas.
PROFESSIONAL BACKGROUND

University of Kansas (KU)  
1989 – 2008  
Professor Geography  
Associate Director of the Kansas Applied Remote Sensing Program

Kansas State University (KSU)  
2008 – 2014  
Professor, Agronomy  
Director of the Ecology and Agricultural Spatial Analysis Laboratory (EASAL)
ABOUT ROBOFLIGHT SYSTEMS

“RoboFlight Systems assists our clients in acquiring, processing, analyzing, and managing remotely sensed data in order to make intelligent precision agriculture management decisions.”

RoboFlight™ turns your aerial imagery into actionable intelligence. Our expert team is able to collect, process, analyze, and manage data from a variety of sources, including:

- Unmanned aerial systems (UAS)
- Piloted aircraft
- Satellite imagery services

View your business from a new perspective. Contact us for more information.
SOME EXAMPLES OF WHAT WE DO WITHIN ROBOFLIGHT/AGPIXEL
Orthomosaic  NDVI Map  NDVI Management Zone

**GEORECTIFIED ORTHOMOSAIC OF SURVEY ZONE**

Map quality image products that allow agronomists and farmers to identify problem areas in their fields, such as diseases, insect infestations, nutrient deficiencies, and water stress. These images can also be used to identify areas where replanting is necessary early in the growing season.

**GEORECTIFIED NDVI MAP OF SURVEY ZONE**

The Normalized Difference Vegetation Index (NDVI) is useful for identifying problem areas in fields, often with better contrast than a color infrared image.

**NDVI MANAGEMENT ZONES**

NDVI is used to create management zones into which different treatments will be applied. The Shapefile format is compatible with most farm management software packages.

<table>
<thead>
<tr>
<th>SPATIAL RESOLUTION (PIXEL SIZE):</th>
<th>10 inches</th>
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<tbody>
<tr>
<td>FILE FORMAT: GeoJPEG/GeoTIFF</td>
<td></td>
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<tr>
<td>OUTPUT PRODUCTS: Natural Color (Red, Green, Blue) or Color Infrared (Near-Infrared, Green, Blue) Image</td>
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<td>OUTPUT PRODUCTS: NDVI Image (Single Band)</td>
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<tr>
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<tr>
<td>OUTPUT PRODUCTS: NDVI Management Zones in Shapefile Format</td>
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We have our own state of the art computing facilities in Des Moines, Iowa. This also houses our research and development lab.
I was introduced last week at the Produce Marketing Association’s International Conference in Santiago, Chile as working in a “Disruptive Technology.” Other disruptive technologies include PC, Internet, Smart Phone, etc.

**Agricultural Drones**

Relatively cheap drones with advanced sensors and imaging capabilities are giving farmers new ways to increase yields and reduce crop damage.
ECONOMIC IMPACT

- More $13.6 billion in the first three years
- $82.1 billion between 2015 and 2025
- More than 34,000 manufacturing jobs
- More than 70,000 new jobs in the first three years
- An anticipated 103,776 new jobs by 2025
- Tax revenue to the states exceeding $482 million in the first 11 years following integration (2015-2025)
- Every year that integration is delayed, the United States loses more than $10 billion or $27.6 million per day that UAS are not integrated into the NAS.

Statistics per Association of Unmanned Vehicle Systems International (AUVSI) 2013 Report
ECOnomic impact

There are 10 times more sUAS applications in agriculture than any other area.

80% of the economic impacts of sUAS will be in agriculture.
Martha Stewart: Why I Love My Drone

Because it's a useful tool. And imagine what Louis XIV could have accomplished at Versailles if he'd had one.

There's been a lot of discussion and a tremendous amount of speculation lately about the nature of drones and their role in our society as useful tools and hobbyist toys.

Last year, while celebrating my birthday in Maine, I was given a drone fitted with a high-definition camera. After a quick introduction to the mechanics of operating the contraption and a few words about its idiosyncrasies, I loaded the appropriate app on my iPad and went down to the beach.

In just a few minutes I was hooked. In near silence, the drone rose, hovered, and dove, silently and surreptitiously photographing us and the landscape around us. The photos and video were stunning. By assuming unusual vantage points, the drone allowed me to “see” so much more.
A SHORT LESSON ON REMOTE SENSING AND SPECTRAL REFLECTANCE CHARACTERISTICS OF PLANTS
WHAT IS REMOTE SENSING?

BASIC PRINCIPLES OF REMOTE SENSING

How does remote sensing apply to sUAS and precision agriculture?

You are remote sensing right now.
When visible and near infrared (NIR) light interacts with green (photosynthetically active) plant tissue it is differentially absorbed, reflected and transmitted depending on wavelength and plant tissue characteristics.
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).

This graph illustrates visible and NIR light interacting with a green plant leaf cross section and this light from the sun being either absorbed, reflected or transmitted.

Graph after: http://www.seos-project.eu/modules/agriculture/agriculture-c01-s01.html
While blue and red light are absorbed by chlorophyll in the plant leaf, approximately 50% of the NIR light is reflected and 50% transmitted through the leaf. Transmitted NIR that interacts with lower leaf layers is likewise reflected or transmitted resulting in a magnification of NIR light recorded by the sensor. More leaf layers = more NIR reflectance.

Additive reflectance from Leaf 1 and Leaf 2

\[ R_1 + T_3 = \frac{5}{8} \Phi_1 = 62.5\% \]

Reflected radiant flux, \( \Phi_r \)

\[ R_1 = \frac{1}{2} \Phi_1 = 50\% \]

Transmitted radiant flux, \( \Phi_T \)

\[ T_3 = \frac{1}{2} R_2 \]

(or \( \frac{1}{8} \Phi_1 = 12.5\% \))

Near IR

The effects of increasing plant canopy layers is illustrated in the spectral response curve below that shows the reflectance of NIR energy increasing with increasing cotton leaf layers. Notice that the visible light (0.5 to 0.73) shows little change in reflectance with increasing leaf layers. This is because these wavelengths have been mostly absorbed and there is little light reflected.

BASIC PRINCIPLES OF REMOTE SENSING

Natural color image of soybean

HEALTHY

UNHEALTHY
BASIC PRINCIPLES OF REMOTE SENSING

Examples of blue, green, red and near infrared (NIR) wavelength images.

NIR cannot be seen with our eyes, but it can be detected with sensors.
Creating a Normalized Difference Vegetation Index (NDVI)

\[
\text{NIR} - \text{Red\ Wavelength} = \text{NDVI}
\]
NIR, red and green false color composite

NDVI with red = high values, blue = low values
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.
Disadvantage is one cannot cover larger areas (10 to 50 acres).

An Advantage is you can have gimbals and carry heavier payload.
UNMANNED AIRCRAFT SYSTEMS
RF70 Fixed Wing Unmanned Aircraft
Designed as a mapping aircraft that is significant step above the hobbyist aircraft, but under military aircraft level.
Can fly for 45 to 120 minutes on single battery charge.
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.
Tomatoes
Aerial Image Capture

Color Infrared Orthomosaic

Color Infrared Image showing individual tomato plants
Tomatoes
Crop Density Assessment

Within the accuracy assessment areas:
2,335 plants delineated
10.5% less than capacity
Crop Yield Potential
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 (0-200) 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

Graphs showing:
- T4i green-NDVI vs. Corn grain yield
  - $y = 7.8986x - 823.77$
  - $r^2 = 0.91$

- T4i red-NDVI vs. Corn grain yield
  - $y = 6.2546x - 607.85$
  - $r^2 = 0.90$

- Lower Yields
- Higher Yields
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)

Very Low  Low  High  Very High

SOIL MAP (Previous Year)

NITROGEN REQUIREMENTS:

Low  Medium  High  Very High

Crop management zones can assist agronomists in mapping nutrient prescriptions, yield forecasting, and many other precision farming applications.
Assessing crop yield potential 2.5 months ahead of harvest
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

220 lbs/acre nitrogen

2.5 months difference

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>
</tr>
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<tbody>
<tr>
<td>Low NDVI</td>
<td></td>
<td></td>
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</table>

Higher Yields

<table>
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<tr>
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<th>50</th>
<th>100</th>
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Rice fields near Yangzhou, China.

Rice Fields
No obvious variation in crop vigor and plant density 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.
Hypothetical map of forecasted bushels per acre of rice

50 bushel per acre

45 bushel per acre

25 bushel per acre
WHAT CAN WE SEE AND HOW CAN WE USE THE IMAGERY?

SELECTED APPLICATIONS
We are partnering with CropQuest to develop methods for delineating weed patches in crop fields.
Canada Thistle Mapping
1.0 inch pixel sizes
Canadian Thistle Study: Herbicide Application

Only 0.6 acres affected of 120 acre pivot

- 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
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?
WHAT CAN YOU SEE IN THE IMAGES
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.

Litter

Do you want to count wheat tillers?
Weeds missed by the sprayer in a new seedling emerging winter whet field
Weeds Everywhere
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 Color Infrared Orthomosaic
1.0 inch resolution (UAS (drone))
Winter Wheat Color Infrared Orthomosaic
10.0 inch resolution (Cessna)
Winter Wheat Color Infrared Orthomosaic
5.0 m resolution (Satellite)
Winter Wheat (UAS vs Cessna vs Satellite)

1.0 inch pixels
- Color infrared
- NDVI

10.0 inch pixels
- Color infrared
- NDVI

5.0 m pixels
- Color infrared
- NDVI

Low NDVI
High NDVI
Classification of Winter Wheat Emergence

1.0 inch Color infrared

Low Density Seedlings

5.0 m Color infrared

Weeds

Classification Maps

Where are the corn plants and weeds?
Patterns (spatial arrangement) or context is critical for accurate image interpretation. Below are two weed types with different spatial arrangements that are key to proper identification.

- **Random Pattern**: Annual life form, seeds are scattered by the wind.
- **Clustered Pattern**: Creeping perennial that reproduces from vegetative (rhizomes or stolens).
Crop Damage Assessment
Wet areas
Red and yellow areas of the NDVI image are associated with the springtail damage.
Hail damage event took place June 21, 2014 in a soybean field near Hillsboro, North Dakota. Field was flown on July 16, 2014.
Crop scout or insurance adjuster’s view from outside the corn field.

Crop scout or insurance adjuster’s view from within the corn field.
Root-Lodged Corn With Range of Severity for Root Damage

EXAMPLE OF CORN ROOT LODGING CAUSED BY WIND

https://www.pioneer.com/home/site/mobile/grow/corn/mid-season-lodging/
Corn Genetics susceptible to root lodging

Color Infrared (Cessna 2.5 inch pixel resolution)

Natural Color Oblique

Corn Root Lodging in University Genetic Breeding Plots

NDVI

Severe

Less Severe

Less Severe

Severe

Severe
Corn Root Lodging comparison between 2.5 inch and 5.0 m resolution

Cessna Color IR Imagery
2.5 inch pixels

Corn root lodging by genetic types

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

If one is missing something as obvious as the root lodging above, what else is being missed using satellite imagery?
Crop Breeding
Differences in corn phenotypes (2.5 inch pixel size)

Darker plots matured sooner
Sorghum Field (Biofuel Applications)

Color Infrared Orthomosaic

1 cm UAS data
09/18/2014
Sorghum Field: Image Detail

Color Infrared

bare soil

covered seed heads
Sorghum Canopy Geometry
Visualization and quantification of relative visible leaf surface area and orientation

Sorghum Canopy Upper Tier Classification of Leaf Area Contiguity for Select Plots

Less Contiguity  |  More Contiguity  |  Most Contiguity

Area (m²)

23  |  24  |  27  |  30

Likely more erect

Likely more decumbent
Sorghum Canopy
Step 5: Seed head mapping (plots 20-34) from landscape metrics-based classification

Upper Tier Leaf Area
- Seed Heads
- Less Contiguous
- More Contiguous
- Most Contiguous
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
Dr. Kevin P. Price
Executive Vice President –
Research & Technology Development

kevin@roboflight.com
(785) 393-5428 (cell)