



transforming the way the world works



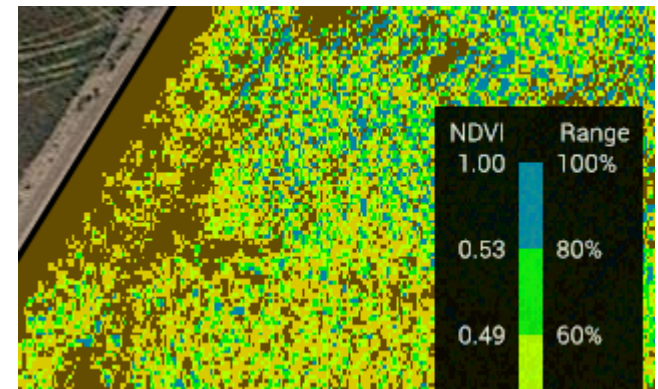
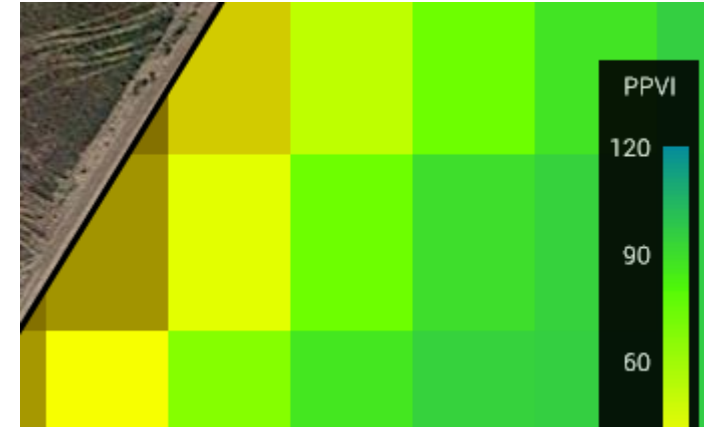
Trimble Aerial Imaging

John Curry

Jerome Coonen and Jim Quaderer

Three takeaways

1. Calibrated vegetation and chlorophyll indexes from satellite imagery
2. Uncalibrated NDVI from UAV imagery
3. Fertile arena of aircraft, sensors, processing, indexes, applications, and *integration*



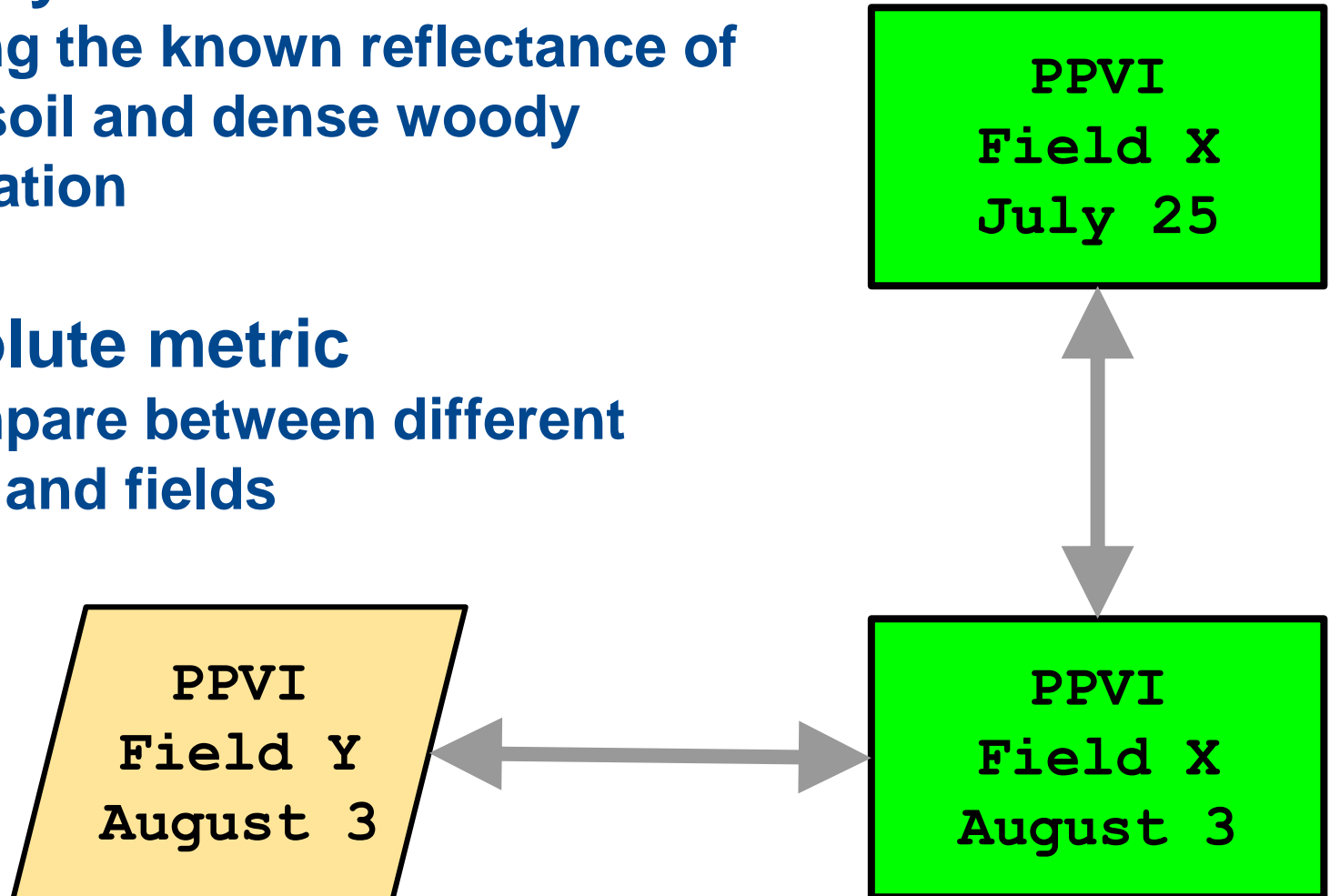
PurePixel™

- **Refined over four decades since Landsat 1**
 - **Resolution -- 15 m**
 - **Timing -- 16 days between updates**
 - **Clouds**
 - **Errors from shadows, soil color & moisture**

- **Calibrated indexes exploiting 3 bands**
 - **Vegetation -- PPVI**
 - **Chlorophyll -- PPCI**

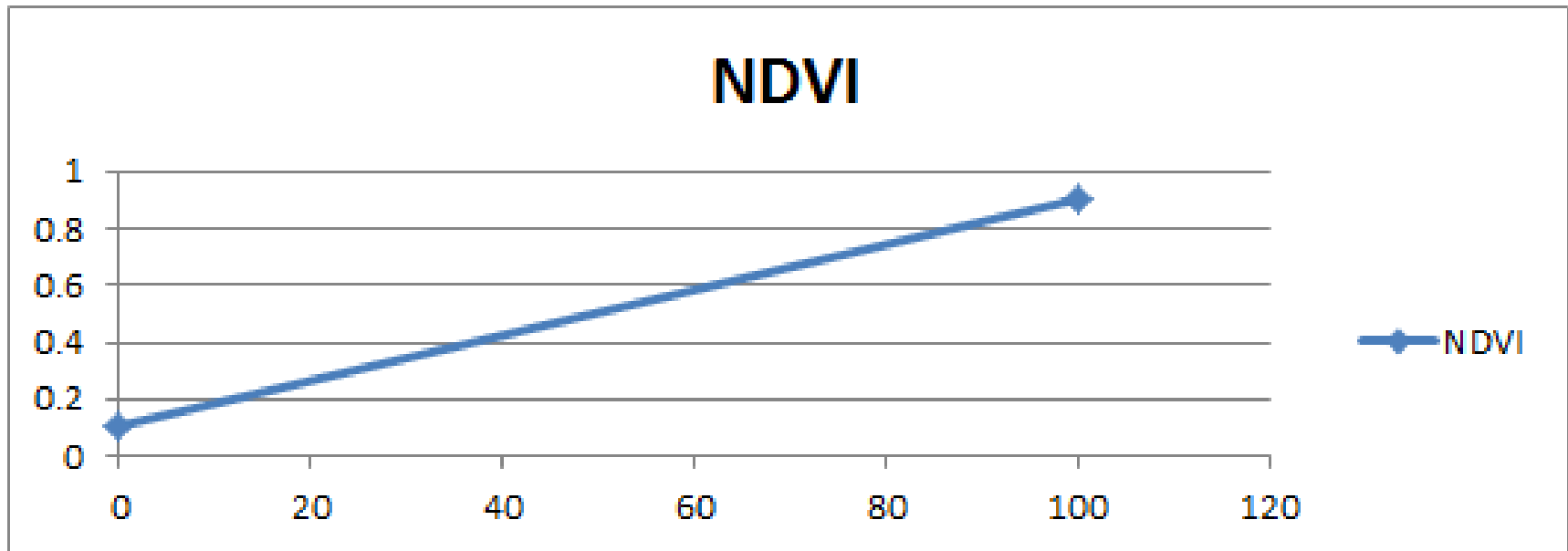
Calibrated imagery

- **Biophysical calibration**
...using the known reflectance of bare soil and dense woody vegetation
- **Absolute metric**
...compare between different dates and fields



PurePixel PPVI vs. NDVI

- PPVI -- no bias from dark soil background
- PPVI -- no saturation at full canopy
- $NDVI = 0.008 * PPVI + 0.1$



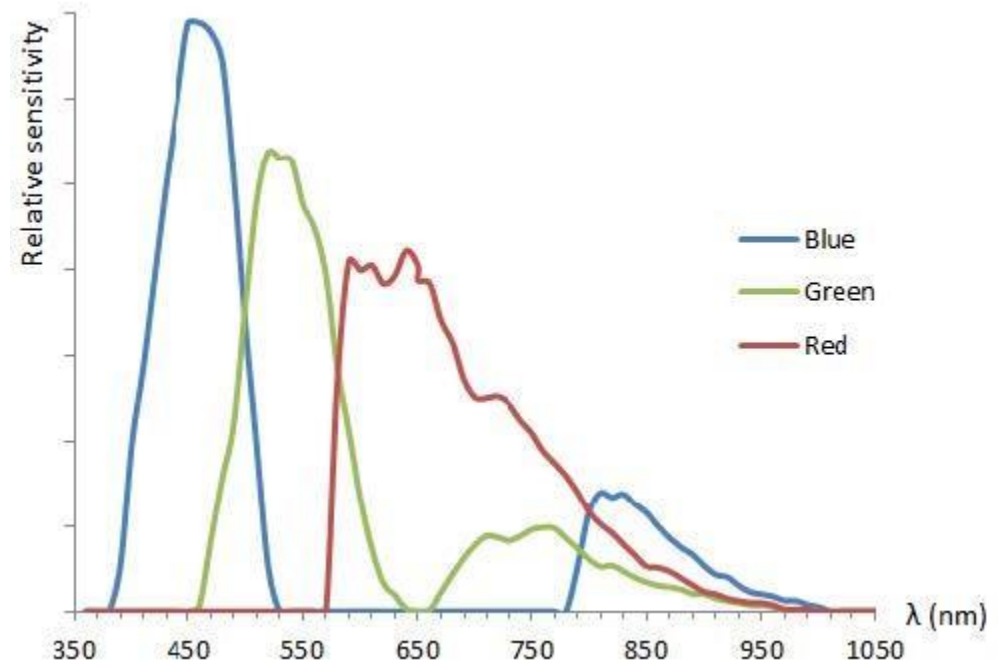
Color infrared imagery

- **May 2015 potatoes**
- **Captured R-G-NIR on Sony camera**
- **Displayed as NIR-R-G**



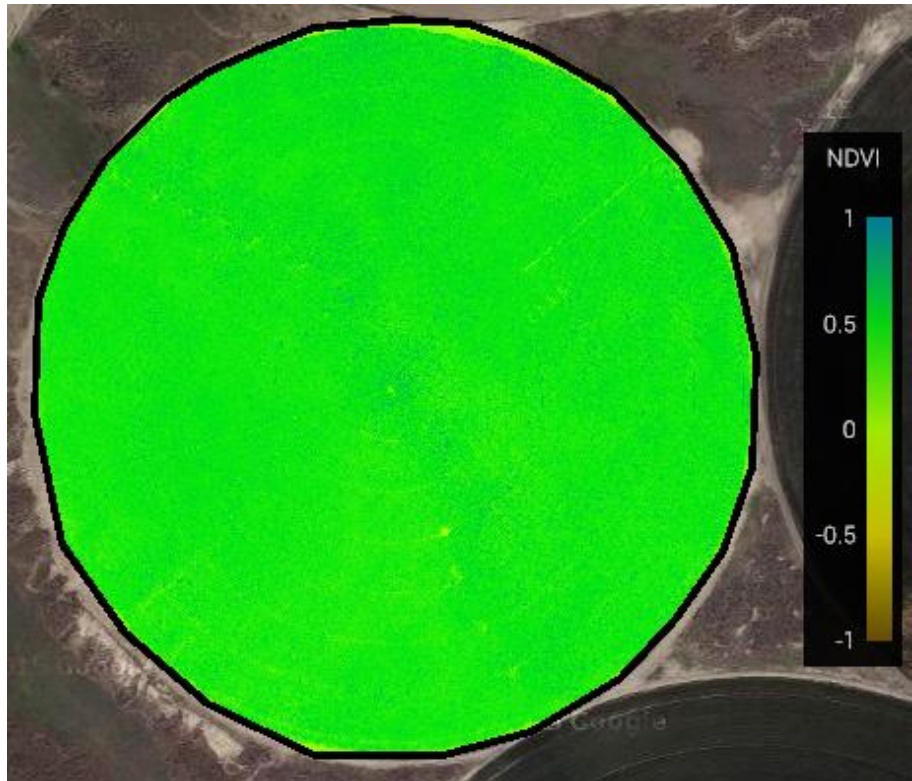
Off-the-shelf solution

- **Sony sensor**
- **Remove NIR filter**
- **Add blue filter**
- **Out-of-band radiation**



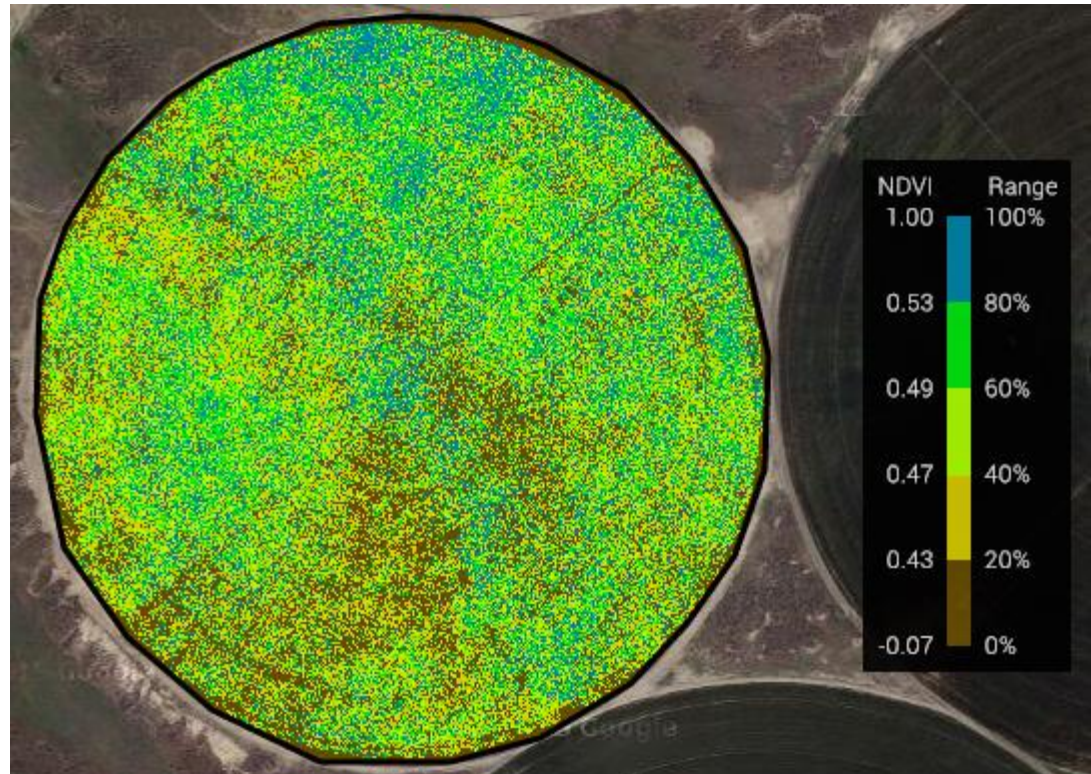
Aerial NDVI today

- Uncalibrated view of the canopy
- Gamma “distortion”
- Limited range
- Cloud shadows
- Soil noise



Exaggerating the NDVI range

- Five quantiles
- Out-of-band radiation
- 0.43 -- 0.53



Leveraging a low-res calibrated map

Given a 5 cm NDVI map and a 15 m PPVI map:

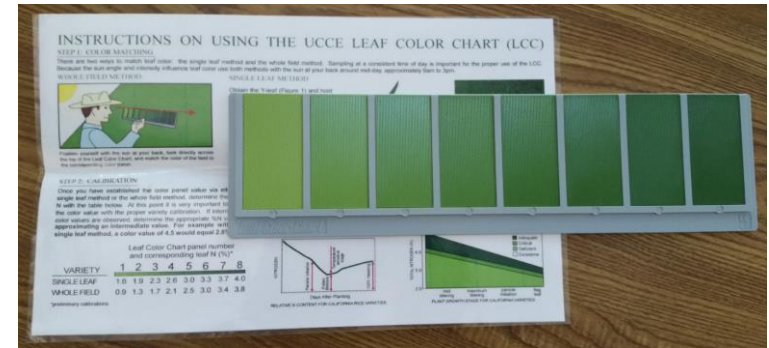
1. Resample the UAV map out to 15 m by averaging the NDVI values
2. Find k , the best fit ratio of $f(\text{PPVI}) / \text{NDVI}$ across the maps, where $f: \text{PPVI} \rightarrow \text{NDVI}$
3. Apply the scale factor k across the original 5 cm UAV map

Sensor directions

- **Multispectral -- a tradeoff of**
 - **Number of bands -- 4, 16, ??**
 - **Resolution -- 1 MP, 2 MP, ??**
 - **Bandwidth -- 10 nm, 50 nm, ??**
- **Hyperspectral**
 - **Registration**
 - **Redundancy**
- **Thermal**
 - **Low resolution backed by panchromatic**

Benefit to growers

- N prescription maps -- the holy grail
 - rice
- Potential / actual yield
 - corn
- Pest detection
- Water stress



Connected Farm

6/11/2014



Connected Farm

7/16/2014



Connected Farm

Fields // Field | Connected

https://field.connectedfarm.com/#fields/53059/cropImagery

ConnectedFarm Dashboard Fleet Field New! Robert Taylor robert_taylor@trimble.com Select Language File Sync

Fields / South of I-85

South of I-85 Edit

Crop: N/A	Tillable Area 21.00 Acres	Boundary Area 21.01 Acres	Client: Auburn University	Farm: Old Barn Field
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- Boundary
- Crop Season
- Crop Imagery**
- Task History
- Rainfall

Crop Season: 2014 Corn, Seed, Hybrid

[Add Crop Season](#)

Purchased	Available	Unavailable
07/16/2014 15M		Download

Imagery

ON OFF Vegetation Index – Natural

ON OFF Vegetation Index – Clustered

pVVI 1 5 17 38 59 67

Range 0% 20% 40% 60% 80% 100%

Map Satellite

Google

Map data ©2014, Google Imagery ©2014, DigitalGlobe, USDA Farm Service Agency Terms of Use Report a map error

Windows taskbar: 1:19 PM

Connected Farm

The screenshot displays the Connected Farm web interface. At the top, the browser address bar shows the URL <https://field.connectedfarm.com/#fields/53059/rainwave/data>. The application header includes the Connected Farm logo, navigation tabs for Dashboard, Fleet, and Field (selected), and the user name Robert Taylor. Below the header, the page title is "Fields / South of I-85".

The main content area features a summary table with the following data:

Crop:	Tillable Area	Boundary Area	Client:	Farm:
N/A	21.00 Acres	21.01 Acres	Auburn University	Old Barn Field

Below the summary table is a large map of the field. A legend indicates "Rainfall (in)" with a color scale from 1.28 in (blue) to 1.6 in (red). The map shows a field boundary with a color gradient representing rainfall intensity. A detailed "Husker Harvest Days RainGraph" is overlaid on the map, showing a bar chart of incremental rainfall (yellow) and a line graph of cumulative rainfall (blue) over time. The graph shows a significant peak in rainfall on 09/12/2013 at 1:38 AM, with an incremental amount of 0.034220 inches. The x-axis labels include 09/11/2013 12:20 PM, 09/11/2013 3:15 PM, 09/11/2013 8:28 PM, 09/12/2013 1:38 AM, and 09/12/2013 3:38 AM. The y-axis labels range from 0.0000 to 0.0300 for incremental rainfall and 0.0 to 2.4 for cumulative rainfall.

At the bottom of the interface, there are navigation buttons for "Map" and "Graph", a date range selector set to "Monday, Sep 1, 2014" to "Thursday, Sep 18, 2014", and a time series selector with options for "Today", "1D", "3D", "1M", "3M", "6M", "1Y", and "Crop Season". The Windows taskbar at the bottom shows the system clock at 1:21 PM on September 1, 2014.

Three-and-a-half takeaways

1. **Calibrated vegetation and chlorophyll indexes from satellite imagery**
 2. **Uncalibrated NDVI from UAV imagery**
 3. **Fertile arena of aircraft, sensors, processing, indexes, applications, and *integration***
- 3.5 Connected Farm has many solutions like PurePixel and RainWave to provide better data to make better decisions**

Questions?