

# Integration of UAV's for Agricultural Applications: Policy, Research and Commercialization

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- UAV are tools for carrying packages or sensors to places that could not be reached safely in a timely or spatially relevant time period
- Also called UAS – Unmanned Aerial System

Forestry  
Inventory



Yamaha helicopter spraying crops in Japan



Powerline  
Inspection

Actual Photo



# FAA Modernization and Reform Act

- 2012 Federal Aviation Administration Modernization and Reform Act requires the FAA to integrate UAS into civilian airspace by 2015
- FAA has completed 9 of 17 requirements in the Act
- No rule on sUAS yet
  - Small UAV's under 55 lbs.
- Has created 6 test sites
  - Provide data on safe integration of UAS into Airspace

# Test Sites

- 6 test sites approved for research and development



# What are the rules??

- No commercial operations (Civil) of UAV's unless exemption given by FAA (exemption 333)
- Public entities allowed with COA (Certificate of Authorization)
  - Federal, state and local municipalities
  - Scientific Research (public universities only)
- Some private entities have been provided exemptions
  - Called a 333 exemption (no need for airworthiness certificate)
  - Trimble, movie makers, real estate (around 19 total)
  - Over 400 applications as of Jan. 30
  - May still require COA (Certificate of Authorization), within 5 miles of Air Traffic Control
- Various state laws are introduced to curtail the use of UAV's
  - Issue is usually privacy and illegal search and seizure driven

# Status

- Now allow hobby use following hobbyist rules
  - Less than 400 ft
  - More than 5 mile radius from airport
  - Line of sight
- States and local entities setting their own regulations
- NPRM issued soon
  - Approximately 16 months to final rule (late 2016 or early 2017)
  - Concerns that FAA regulation will be too restrictive (autonomy, line of sight, etc..)

# Other Countries

- Japan, UK, Australia, and Canada progressed much further
  - Australia has issued 180 operating certificates
  - Canada issued new regulation exempting UAS 55 lbs or less from needing special approval for flying

## 3/31/2014

So far in 2014, 35 states have considered UAS or UAV (also commonly called drones) bills and resolutions. Two states - **Indiana** and **Utah** - have enacted new laws.

Legend:

- Pending UAS legislation
- Enacted UAS legislation
- Adopted a resolution

Territories: AS, GU, MP, VI, PR





















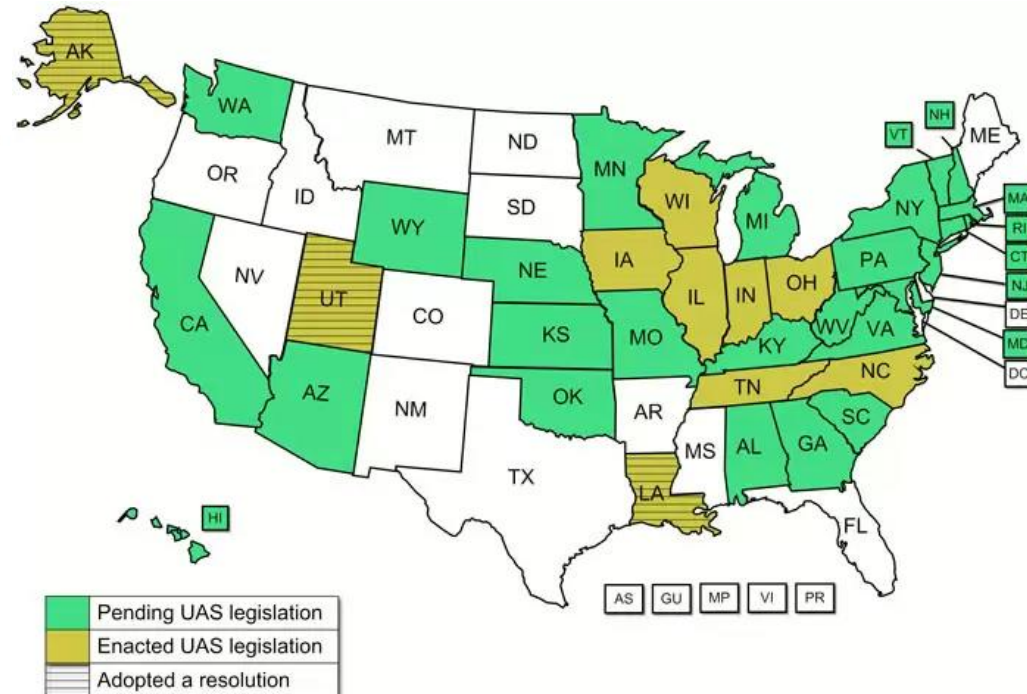










# Latest GA Proposed Regulations

- HB 5
- Misdemeanor for surveillance over someones private property without consent
- Allows use of UAV for specific purposes as long as it is:
  - Limited to 1000 ft above ground level
  - Not Within 5 mile radius of airport
- All law enforcement entities will report every odd year on their use of UAV's
- **Does not** spell out agricultural applications;
  - Does spell out **images allowable**

# Concerns

- Safety
  - Shared Airspace
    - Crop Dusters (NAAA)
  - Loss of control – crash into pedestrians, other vehicles on ground and in air
  - Lack of detect and avoid maneuvers
- Privacy and security
- Search and seizure warrants

# Unmanned Aircraft Systems (UAS)

- Two Primary Flavors, VTOL (Rotor), and Winged
- Vertical Take-off and Landing Systems
  - Quadcopters, octocopters, hexacopter, tricopter, and helicopters
  - Blimp Systems, dirigibles, light than air, etc..
- Winged
  - Hand Launched, catapult launched, Ground Launched
  - Variety of landing
    - Parachute, ground, net

# Rotary Systems

- Carries a heavier payload
  - Camera, Sensors, Packages (medicine delivery)
- Battery life usually 20-30 minutes
- Cover smaller areas
- Easily controlled with R/C
  - With controller on UAV

# Rotor



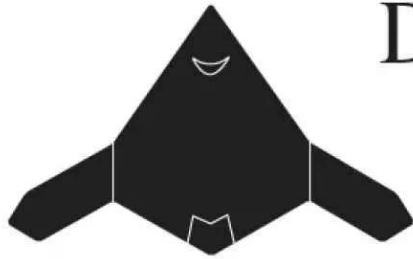
# Winged UAS



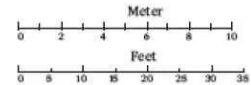
# Military Drones

FOR UNOFFICIAL USE ONLY (FUUO)

## DRONE SURVIVAL GUIDE



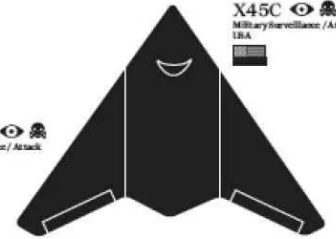
**X47C**   
Military Surveillance / Attack  
USA



**Sentinel**   
Military Surveillance  
USA



**nEUROn**   
Military Surveillance / Attack  
France



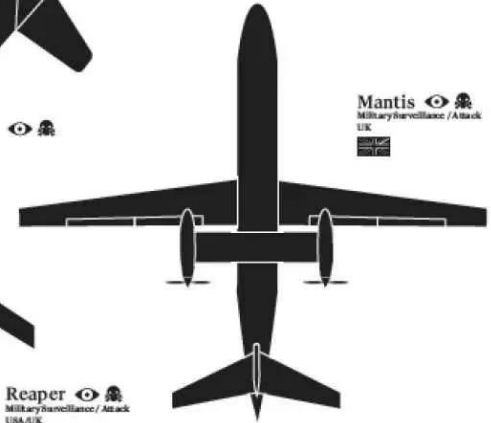
**X45C**   
Military Surveillance / Attack  
USA



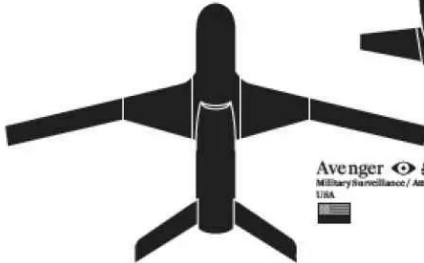
**Global Hawk**   
Military Surveillance  
USA



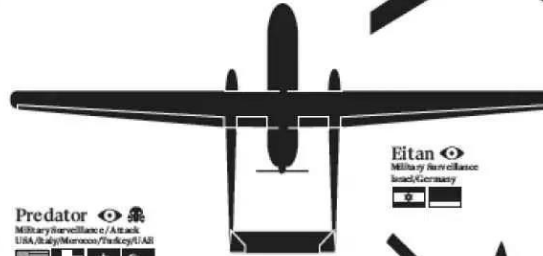
**Soaring Dragon**   
Military Surveillance / Attack  
China



**Mantis**   
Military Surveillance / Attack  
UK



**Avenger**   
Military Surveillance / Attack  
USA



**Eitan**   
Military Surveillance  
Israel/Germany



**Reaper**   
Military Surveillance / Attack  
USA/AUK



**Barracuda**   
Military Surveillance  
France/Germany



**Herti**   
Surveillance  
UK



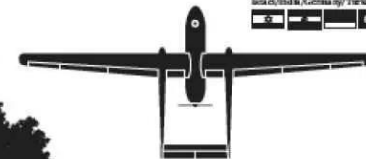
**Predator**   
Military Surveillance / Attack  
USA/Italy/Morocco/Turkey/Algeria



**Hummingbird**   
Military Surveillance / Attack  
USA



**Fire Scout**   
Military Surveillance / Attack  
USA



**Heron**   
Military Surveillance  
Israel/India/Germany/Turkey



**Hermes**   
Military Surveillance  
Israel



**Shadow**   
Military Surveillance  
USA/NATO



**Rustom I**   
Military Surveillance  
India



**WASP III**   
Military Reconnaissance  
USA/NATO



**Killer Bee**   
Military  
USA



**Raven**   
Military Reconnaissance  
USA/NATO



**Scan Eagle**   
Military Surveillance  
USA/NATO



**Harpy**   
Military Attack  
Israel



**Air robot**   
Domestic surveillance  
UK



**Aeryon Scout**   
Domestic surveillance  
Canada

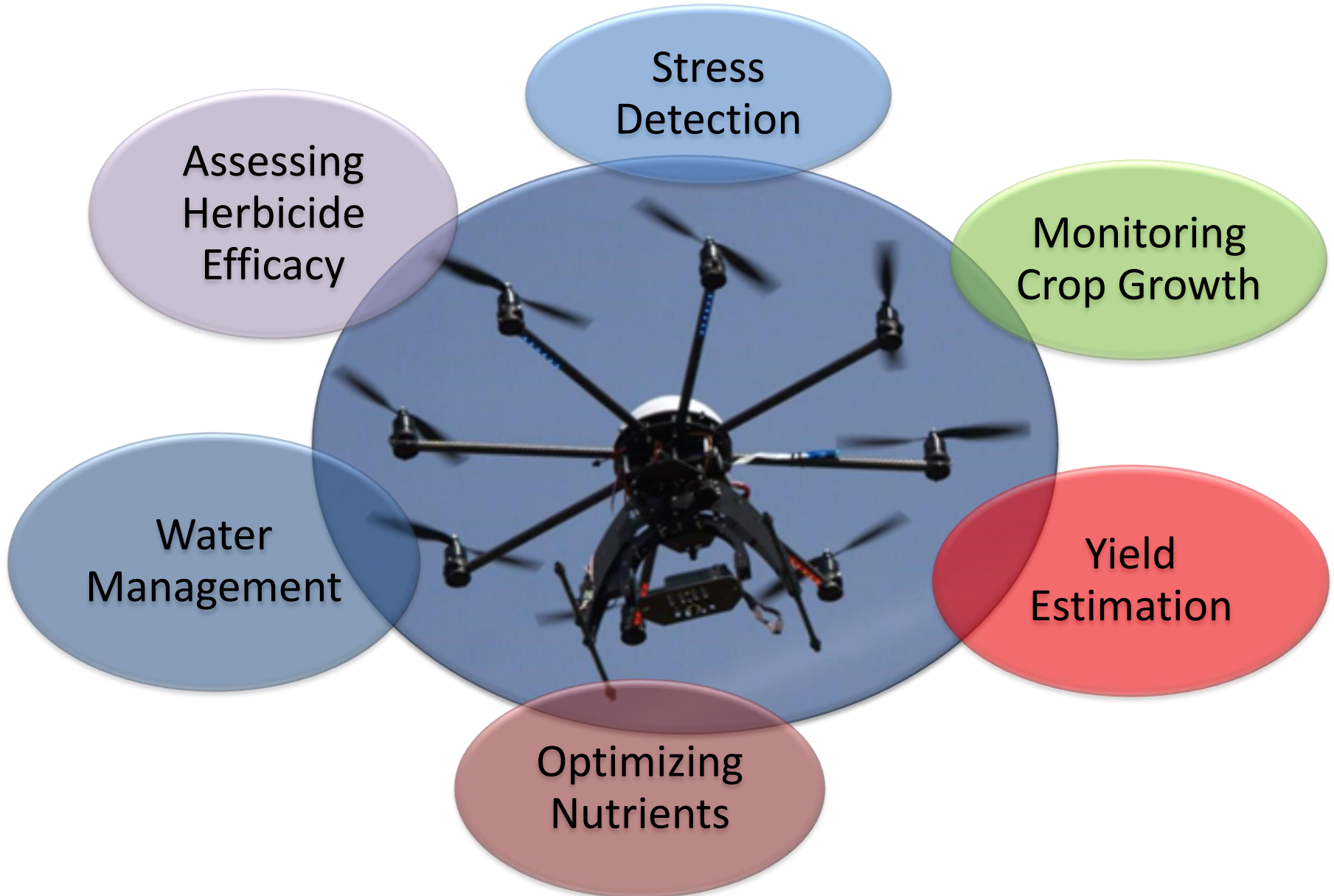


**AR Parrot**   
Consumer photography  
USA

# Winged Aircraft

- Cover larger areas
- In air longer
- Carry lighter loads (in general) for sUAS
- Can be thrown into air, catapulted or take off like passenger aircraft on a landing strip
- Can land using catch net, parachute or landing strip
- Carries cameras or other data collection material

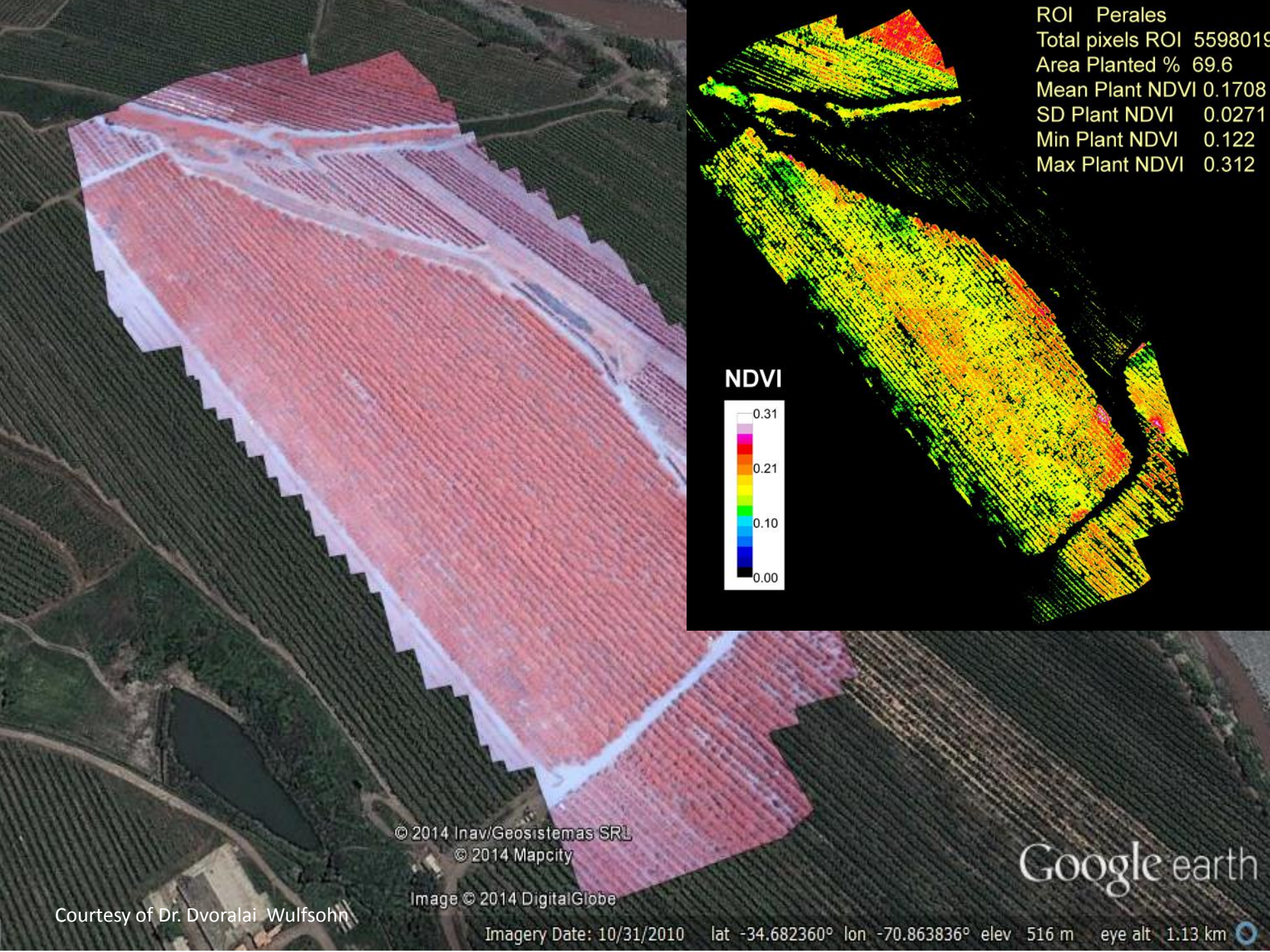
# UAVs in Agriculture



# Agriculture Companies that use UAVs

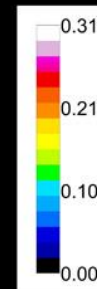
- Precision Hawk
  - Honey Comb
  - Sense Fly
  - Delair Tech
  - Aerial Technology International
  - Ag Eagle
  - Farm Intelligence 2
  - Precision Drone
  - Agri Dotix
  - **VSG – Georgia company**
  - **Guided Systems – Georgia company**
- Specialize in color images and spectral images (calculate vegetative indices)





ROI Perales  
Total pixels ROI 5598019  
Area Planted % 69.6  
Mean Plant NDVI 0.1708  
SD Plant NDVI 0.0271  
Min Plant NDVI 0.122  
Max Plant NDVI 0.312

NDVI



© 2014 Inav/Geosistemas SRL  
© 2014 Mapcity  
Image © 2014 DigitalGlobe

Google earth

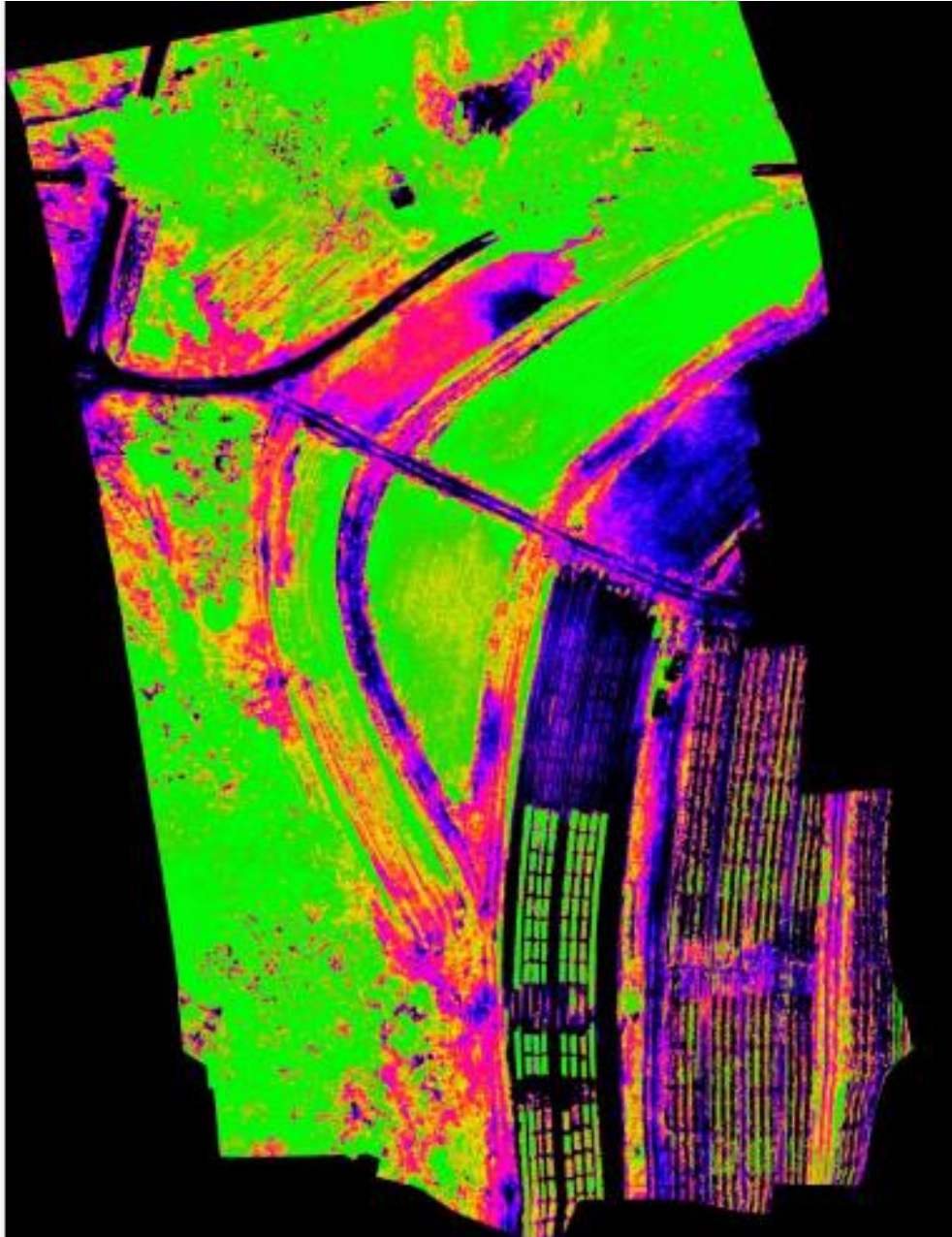
Courtesy of Dr. Dvorlai Wulfsohn

Imagery Date: 10/31/2010 lat -34.682360° lon -70.863836° elev 516 m eye alt 1.13 km

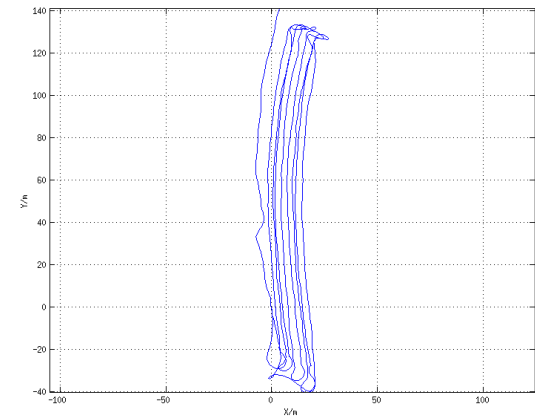
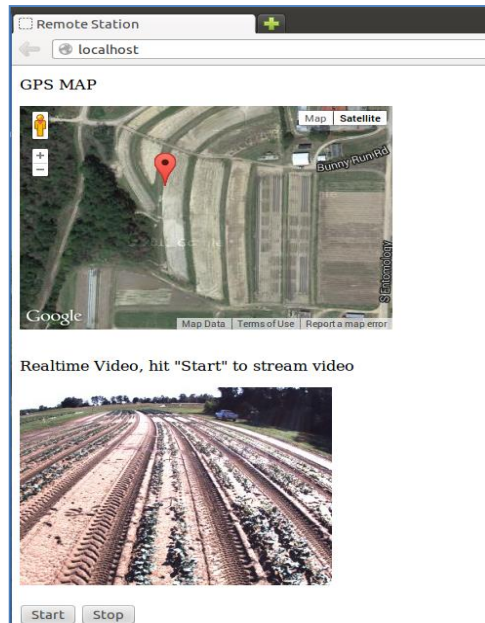


The effect of  
different  
experimental  
treatments in  
an apple  
orchard

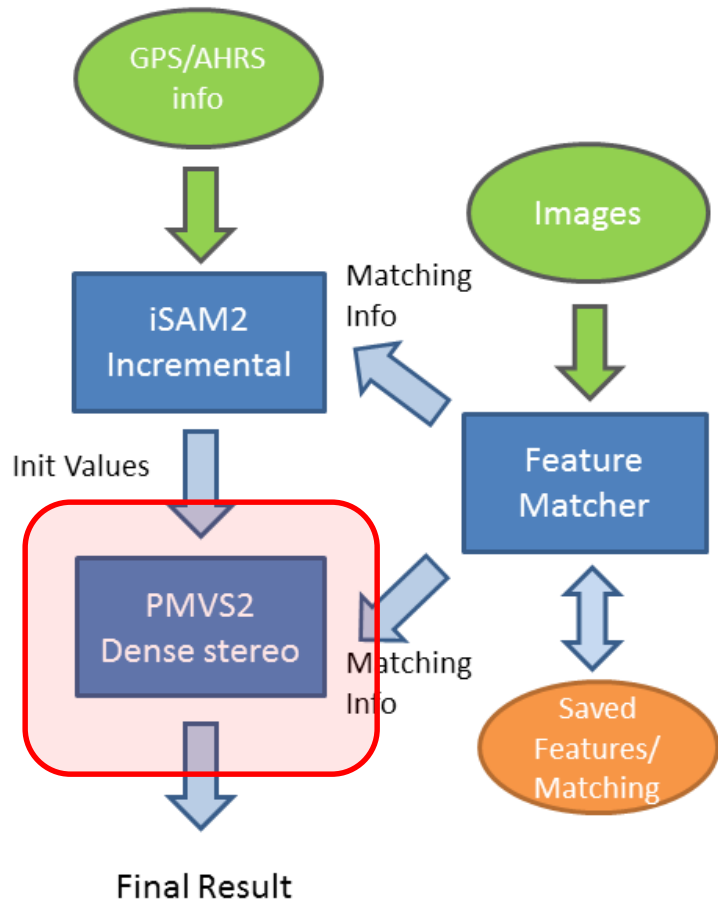
# NDVI (Tifton Research Field)



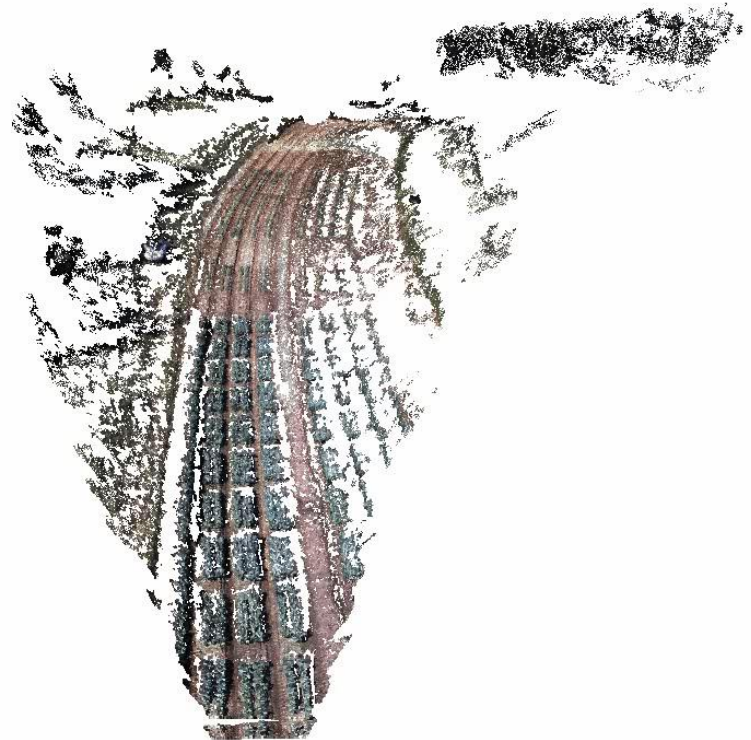
# Low-Altitude



# Software pipeline



- PMVS2 dense reconstruction
- Provide better reconstruction result, more details shown.



# Cross-time correspondence

- Current status: manual match
- Future works: to cross-time corresponding automatically

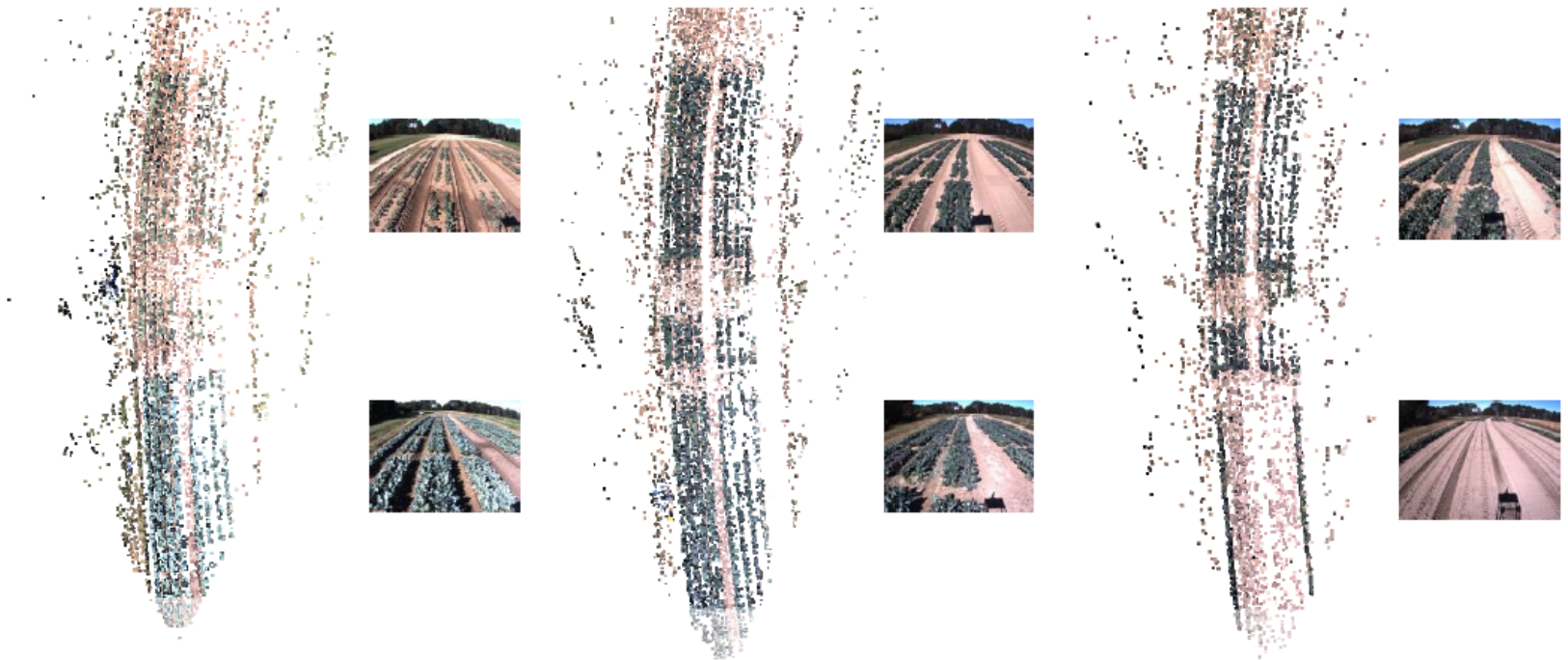
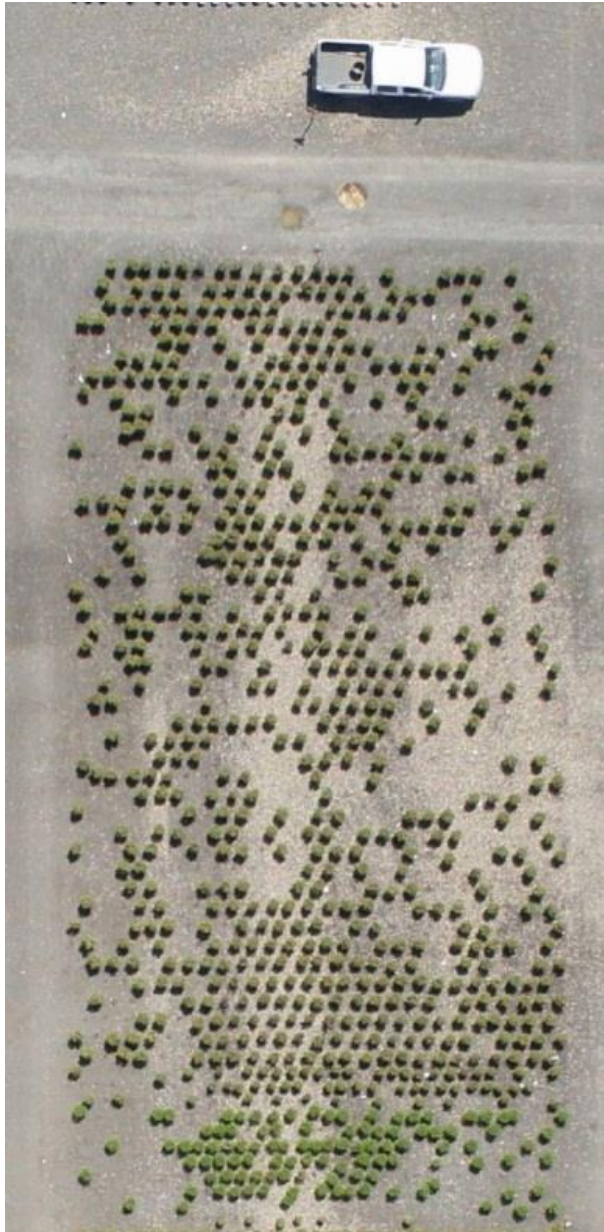


Figure 8. The 4D reconstruction results of 1st week, 4th week and 8th week. The field contains two subfields and have planted broccoli unsynchronized. The small subfigures show the snapshots of the corresponding subfield. The upper subfield has broccoli continuing to grow, shows in the point cloud as a darker color; the lower subfield has broccoli planted earlier that in the 8th week has already been harvested. (Best viewed in color)

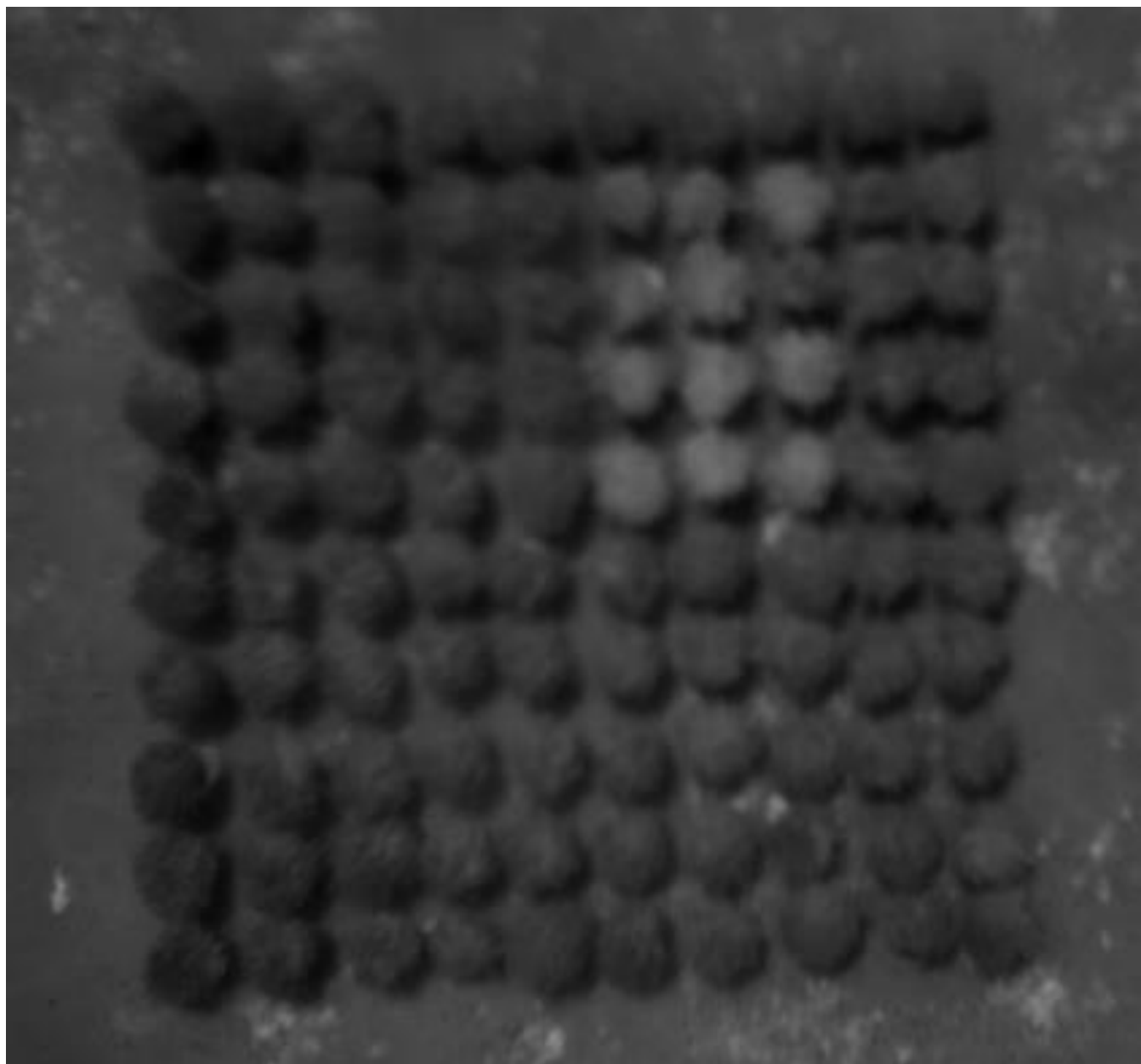
# Inventory



Counting overlapping plants in containers

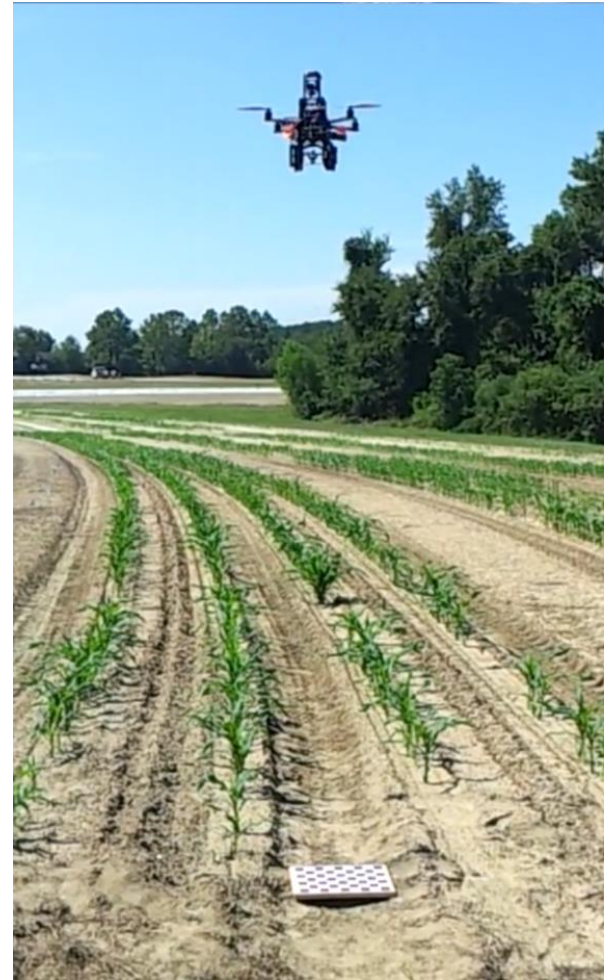






# Surveillance

- Identification of stressed or diseased plants on large scale
- Scouting of individual plants for pests and diseases
- Weed detection
- Monitoring field workers



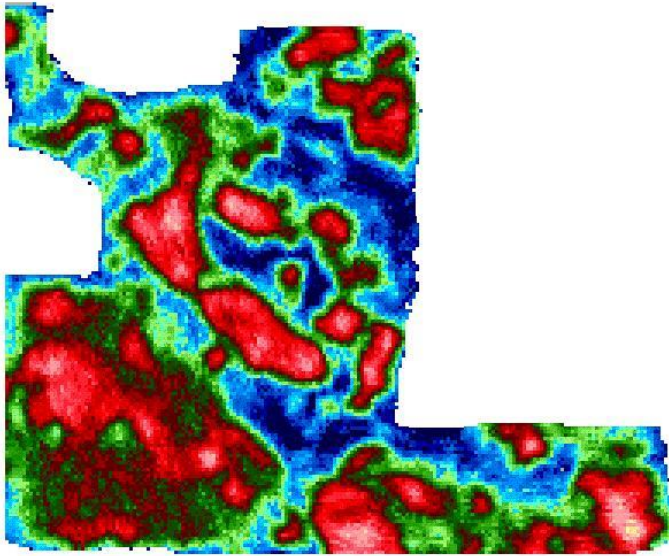
# Interventions

- Repelling and detection of large pests such as birds and feral hogs
- Application of pesticides
- Application of pollen or biocontrol materials

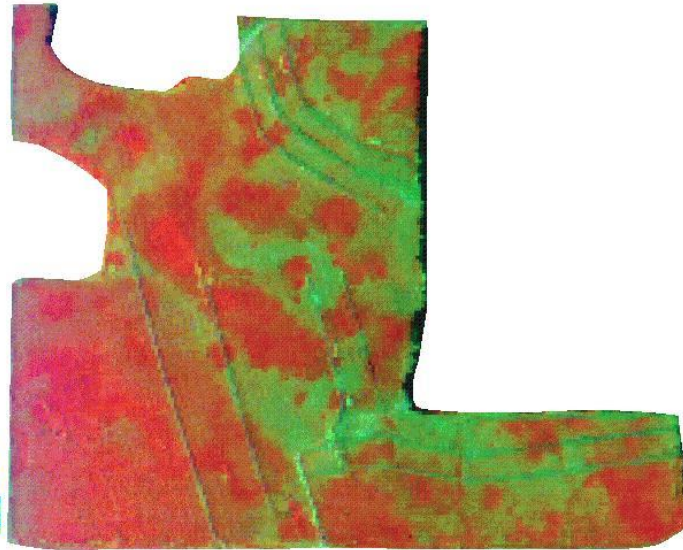


# Data Analysis

- Yield estimation
- Crop maturity estimation



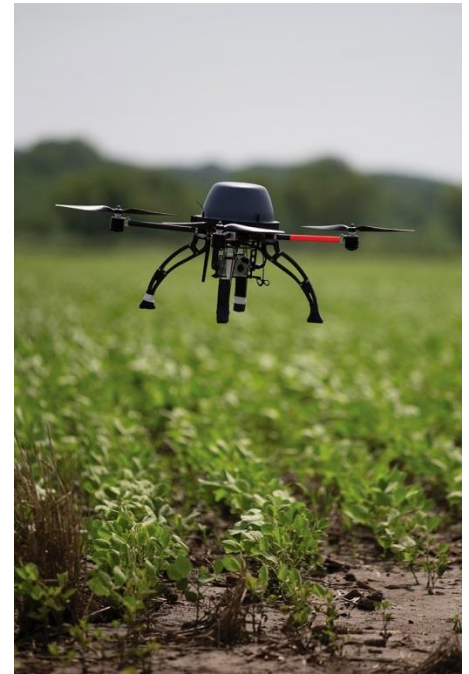
Actual yield measurements



Predicted yield measurements

# Swarming Robotics

- 10 to 100 or 1,000 robots per acre
- Cost of each robot - \$1-\$2
- Not all robots have same sensor payload
- Very close up view of each plant or tree
- Data collection
  - Land on leaf or plant to collect data
  - Land on soil to take measurements
  - Pathogen detection



# Extreme Data Collection

- Develop 4D model of plant or tree
- Collect and integrate data over entire life cycle of plant/tree
  - Rate of growth of plant and fruit
  - Location of blooms that lead to fruit for yield estimation and harvesting
  - Tree architecture for trimming and pruning
  - Multi-sensor approach