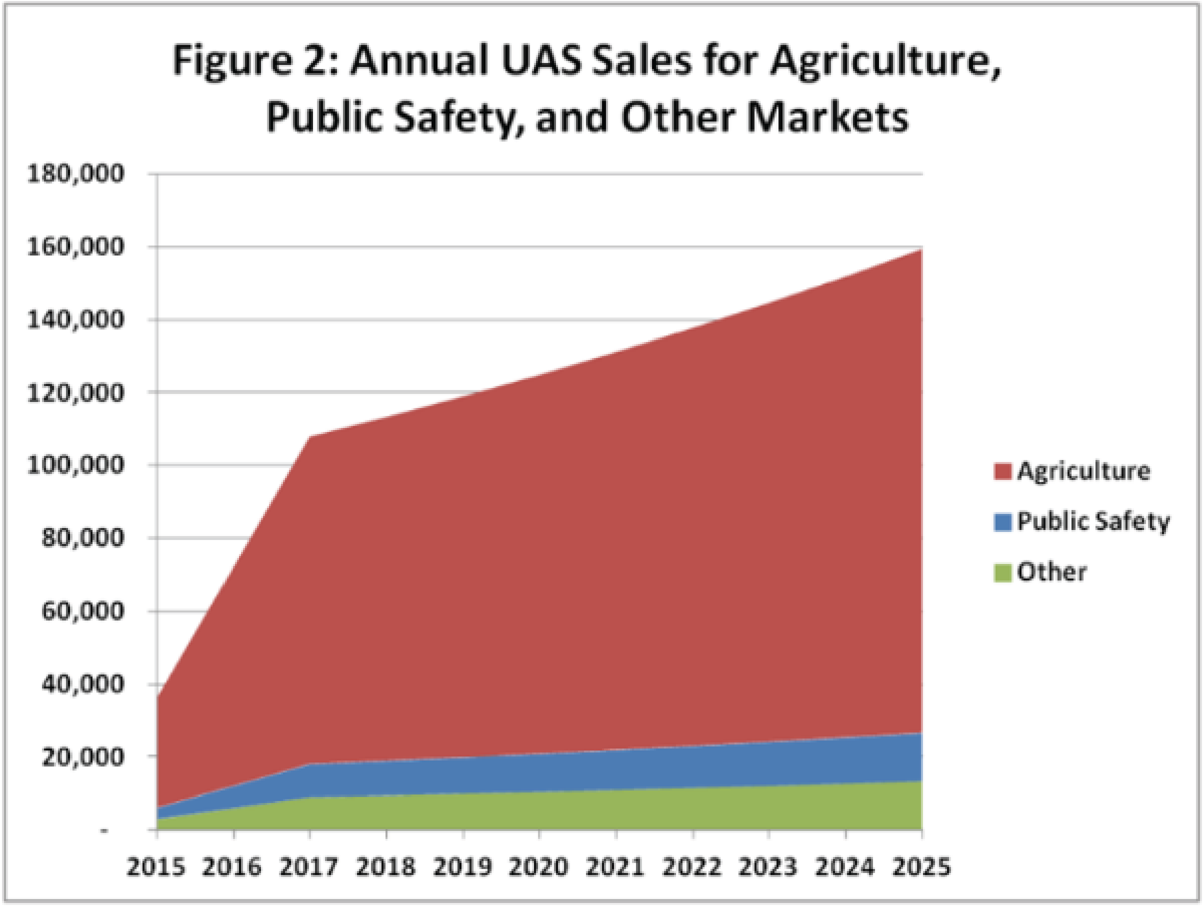
Introduction to Unmanned Aircrafts in Agriculture

Brandon Stark, *Director*
Unmanned Aircraft System Safety
Center of Excellence
University of California

2013 Economic Report, AUVSI



Agricultural Applications = 80% of UAS Industry?

- Remote Sensing
  - Agriculture Decision Support
- Precision Application (Spraying)

Agriculture Decision Support

- Fertilizer Application Decision Support
- Crop Yield Estimation
- Crop Water Stress Prevention
- Crop Health Monitoring
- Optimal Crop Harvesting
- Pest Infestation Mapping
- Post-Storm Damage Assessment
- Fire Damage Assessment
- Irrigation/Canal Leak Detection and Localization
- Soil Moisture
- Plant Species Spatial Distributions
- Invasive Species Monitoring
- Bareground Measurements
- Forage Utilization for Livestock
- 3D Landscape reconstruction
- Soil Erosion Monitoring
- Seasonal Water Feature Monitoring
- Soil Subsidence
- Frost Damage Mitigation
- Soil Salinity
- Bird Control Solution
- Aerobiological Sampling

Precision Application

- Autonomous Spraying for large plots
- Targeted Spraying for Direct Spot Application
- Aerial Application for Irregularly Sized Plots
- Optimal Spraying
- Intelligent Spraying to Counter Wind Drift

Why use UAS?

- Current trend toward optimization
  - A tool that can do specific diagnosis in the early stages
  - Recognize water inefficiencies
  - Reduce pesticide inefficiencies
- UAS can provide high resolution details
  - UAS = 2-5 cm resolution
  - Satellite = 1m to 30m resolution
- UAS can provide almost on-demand imagery
- UAS could replace cropdusting planes

Where are we now?

- Some encouraging results
  - High resolution imagery
  - Some crop dusting capabilities for small farms
  - Drone Regulations

- But still a lot more work needs to be done
  - Remote viewing ≠ remote sensing

Agriculture Decision Support
Remote Sensing

Platforms

Multi-rotor Copters

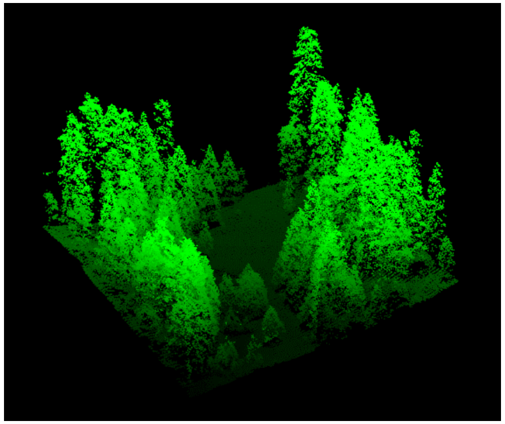
- Generally 20-25 minute flight time with
- Vertical take off and landing
- Typically < 2 pound payload
- Can cover > 50 acres per flight

Fixed-Wing

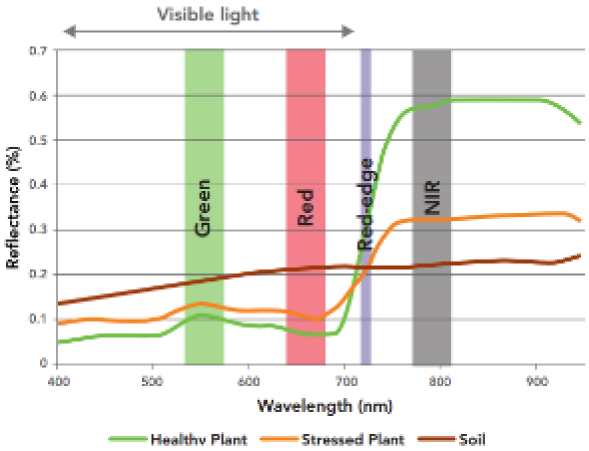
- Longer flight time (> 40 min)
- Moves faster and can cover 100-200+ acres per flight
- Typically more difficult to fly and more difficult to land
- Typically can carry more payload

Payloads

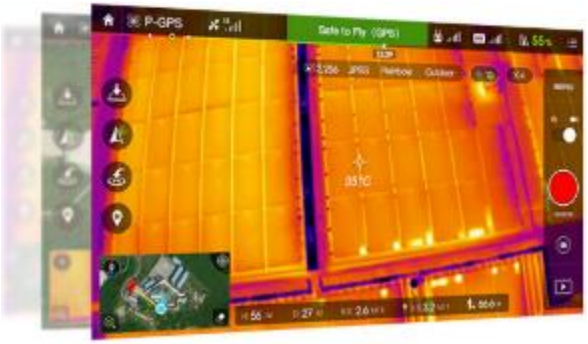
LiDAR



Multispectral



Thermal



Applications

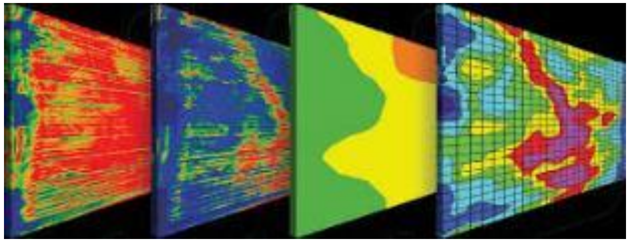
- **Multispectral cameras** currently give you the most bang-for-your-buck for agricultural applications. These instruments typically cost between **$740** and **$3500**

- **LiDAR** technology is best for complex measurements of tree canopy structures. Previously, LiDAR processing software was an issue, now it is the cost of UAS adapted units, which typically start at around **$55,000**.

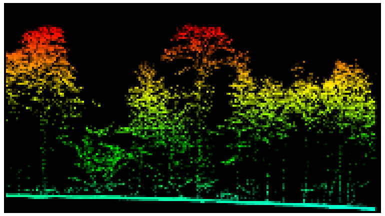
- **Thermal imaging** is particularly suitable for detection of moisture (including water features, irrigation and even evapotranspiration), fire detection (including intensity) and search and rescue. These units typically start at around **$9000** for digital units (if you intend to use it for mapping, don't get a cheaper analog unit).

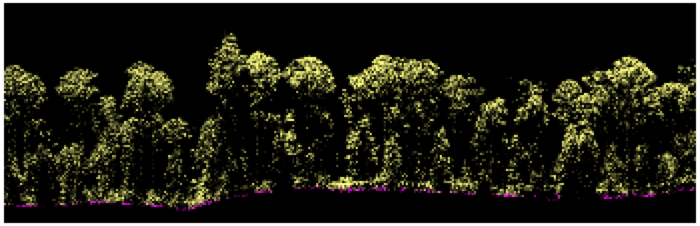
Applications

- For agricultural

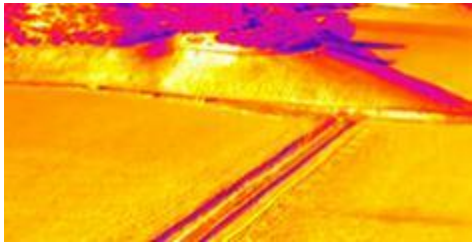


- LiDAR for forestry

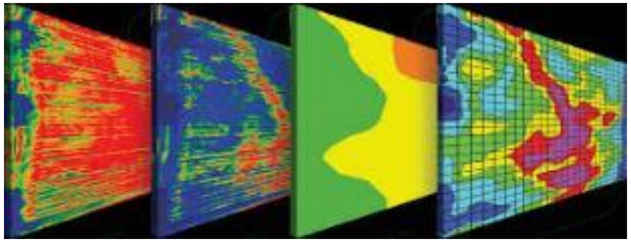


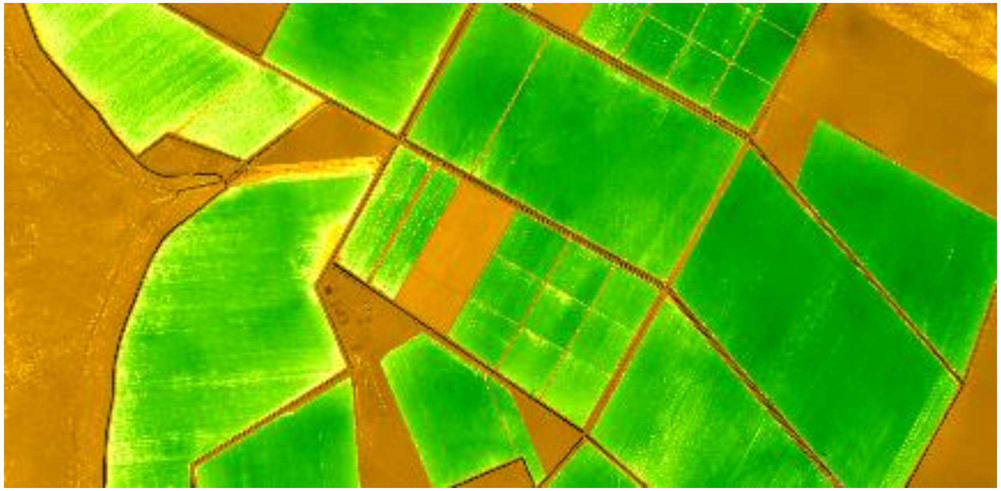


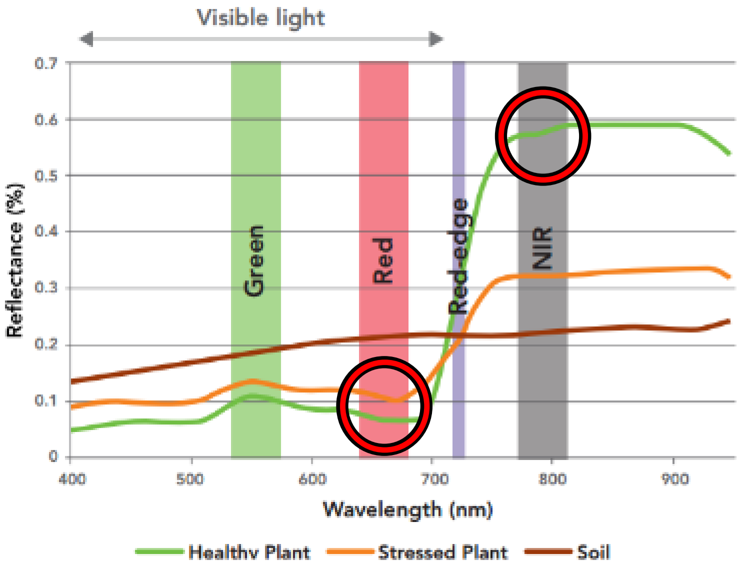
- Thermal imaging for irrigation



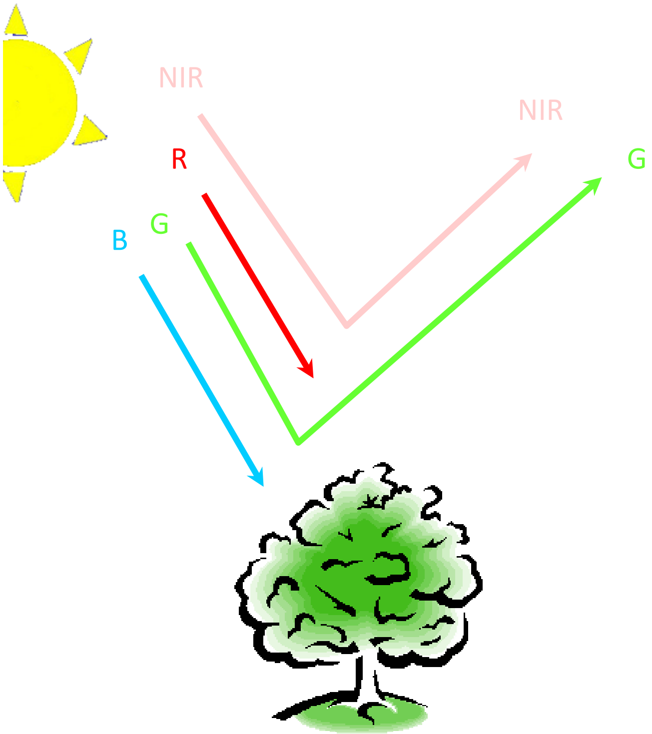
Applications – Crop Health

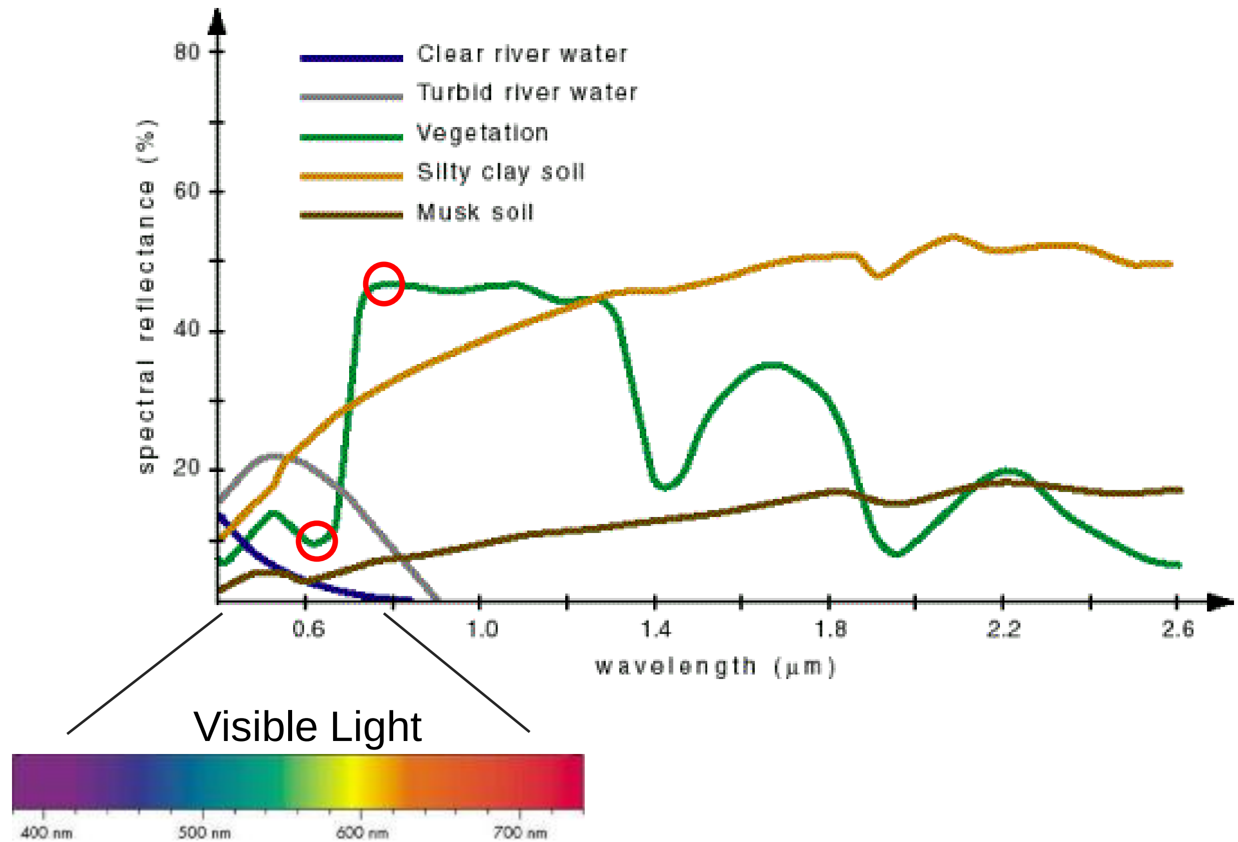




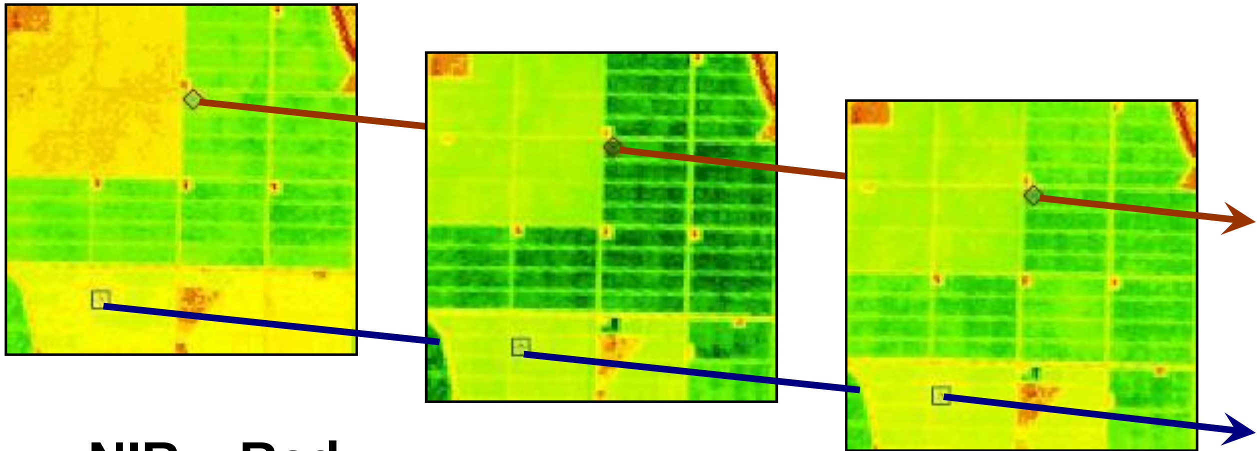


Remote Sensing of Vegetation

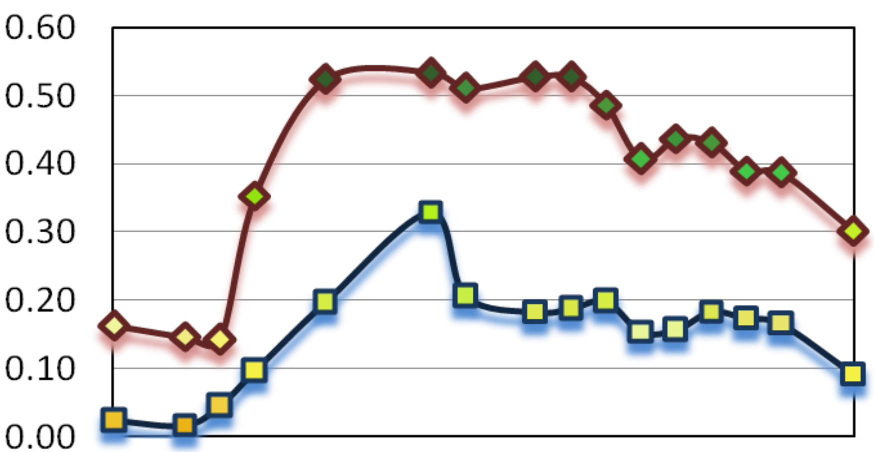


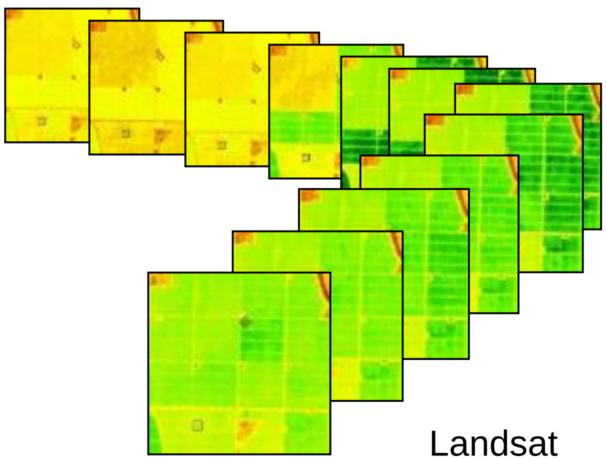


Light reflecting from vegetation…



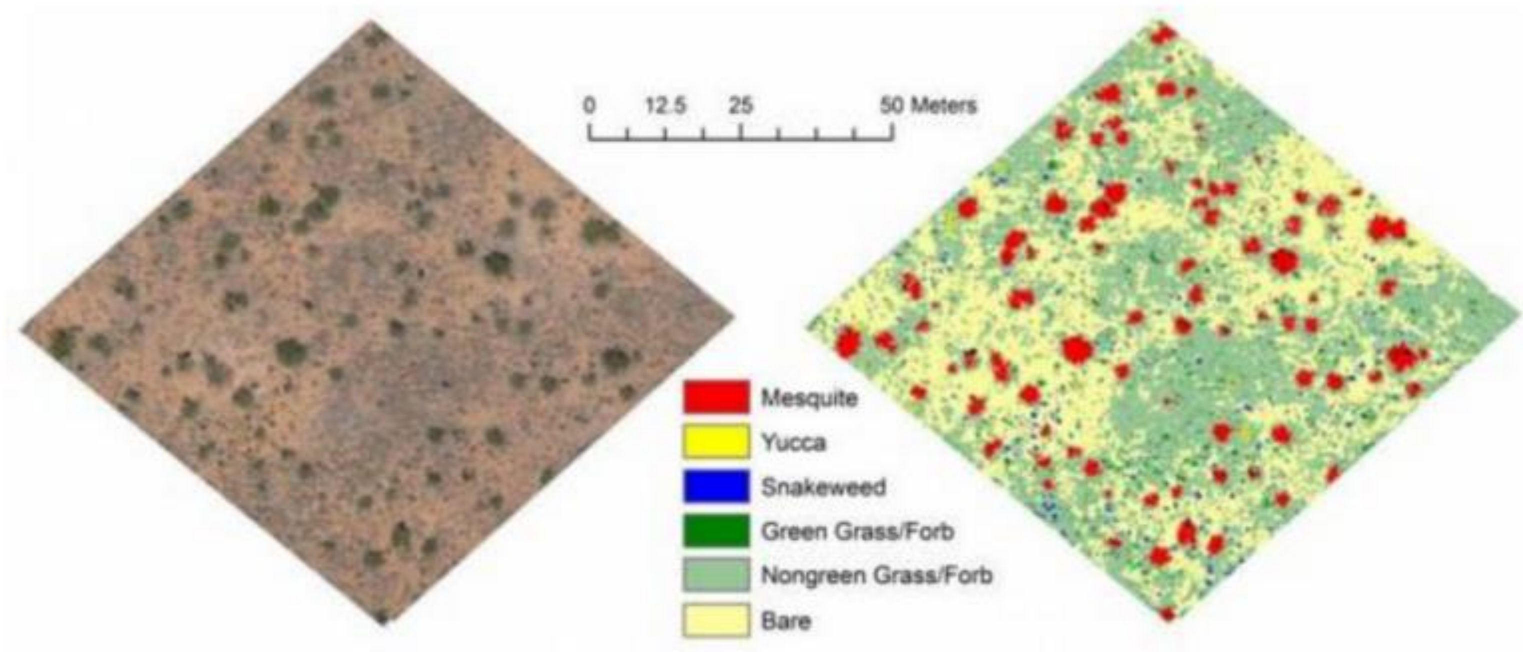
$$NDVI = \frac{NIR - Red}{NIR + Red}$$





Landsat
Every 16 days

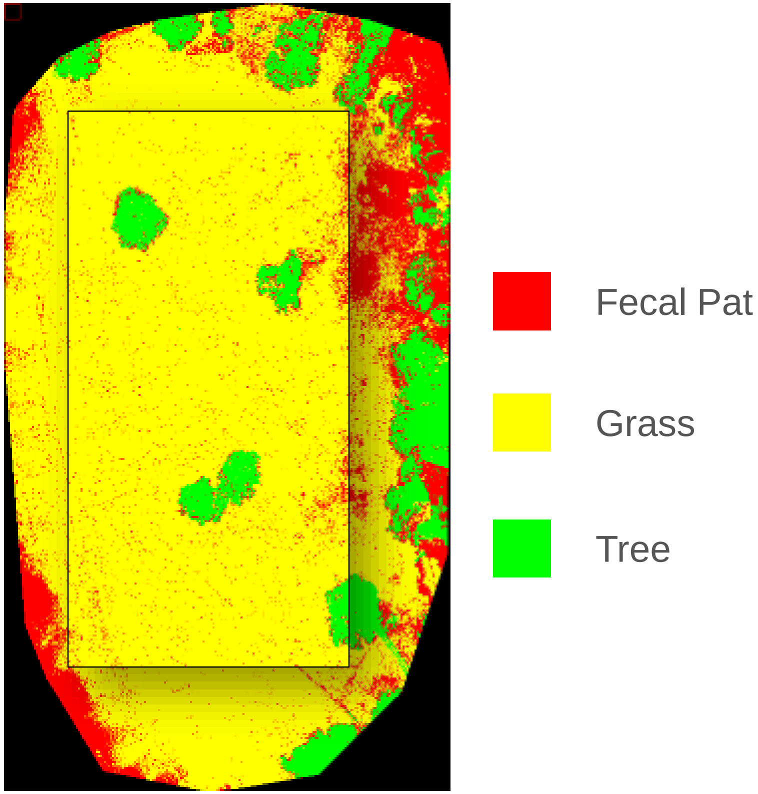
Applications – Rangeland Assessment



UAS image and vegetation classification. This image was acquired from an altitude of 215 m above ground level, and using a Canon SD900 10-megpixel digital camera. The pixel resolution is 6 cm.

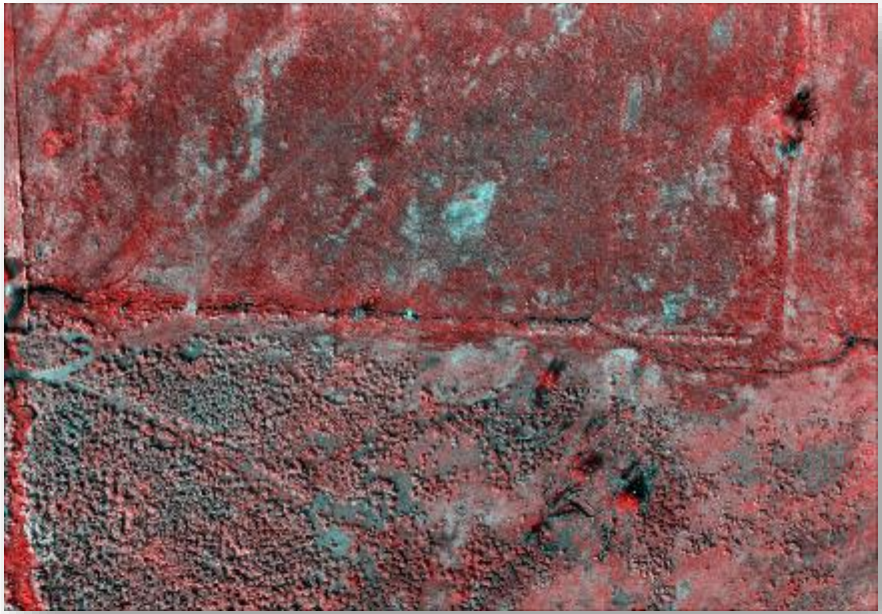
Image courtesy of the USDA-ARS Jornada Experimental Range

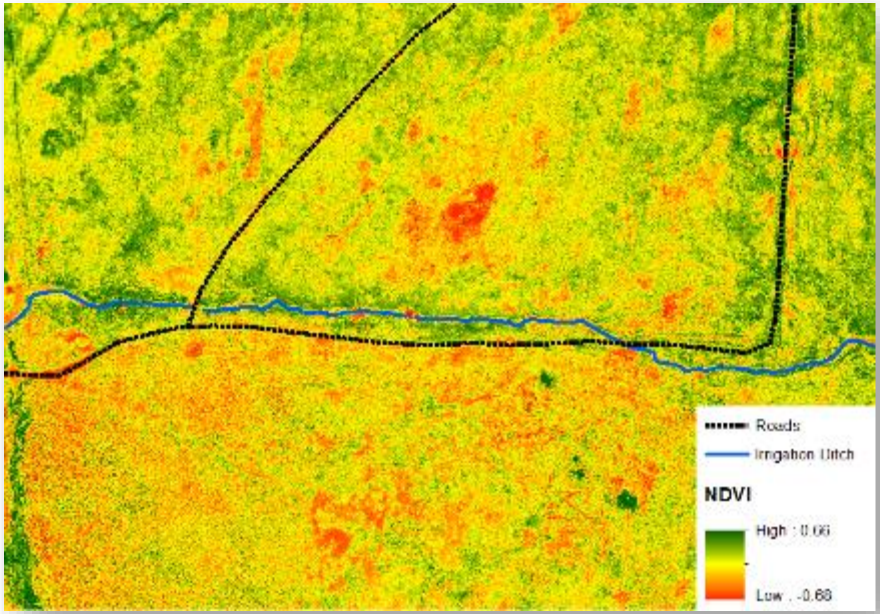
Applications – Rangeland Assessment



UAS color image mosaic (left) and maximum likelihood land cover classification (right) from the region of Lake Berryessa CA. The image was acquired from an altitude of 100 feet above ground level, and using a GoPro 12-megpixel digital camera. The pixel resolution is approximately 0.8 inches over 18 acres. Note – The peripheral area not directly underneath the flight lines are frequently misclassified.

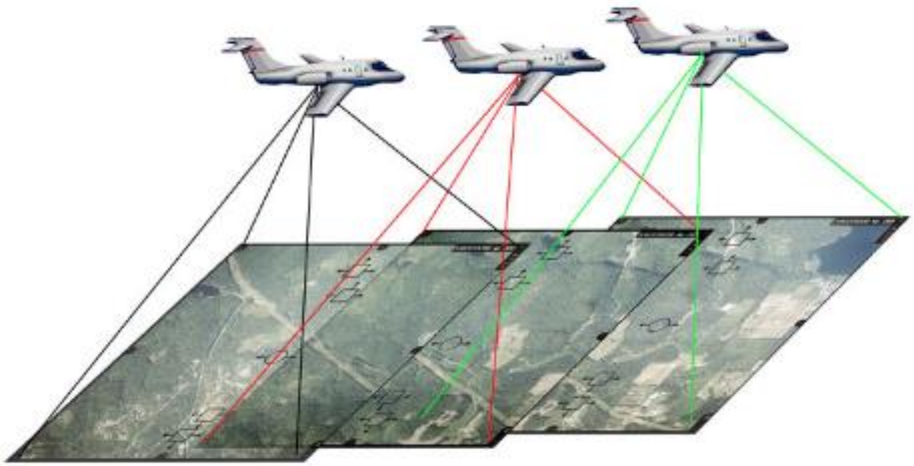
Applications – Rangeland Assessment

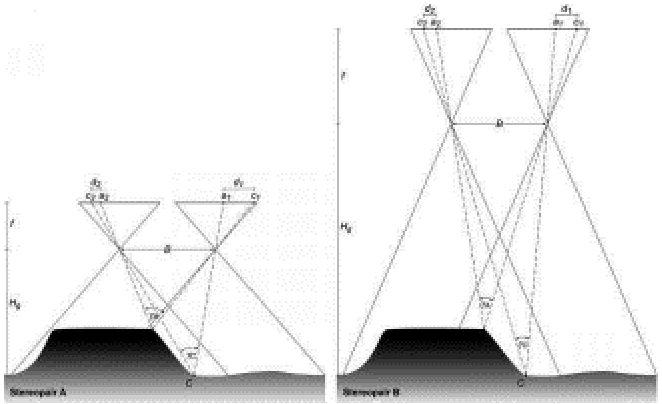


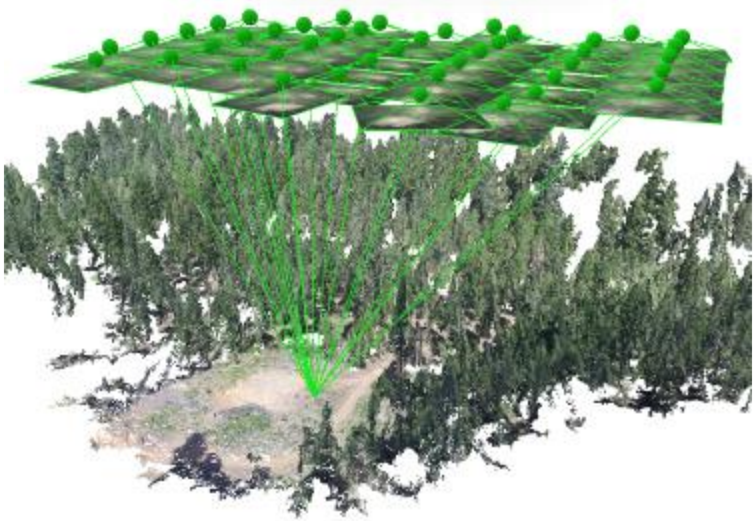


Color infrared image (left) and normalized difference vegetation index (right) from a UAS image mosaic collected in the Bishop CA area. This image was acquired from an altitude of 100 feet above ground level, and using a 1.2 megapixel Micasense Sequoia camera. The pixel resolution is approximately 1.45 inches, over approximately 10 acres.

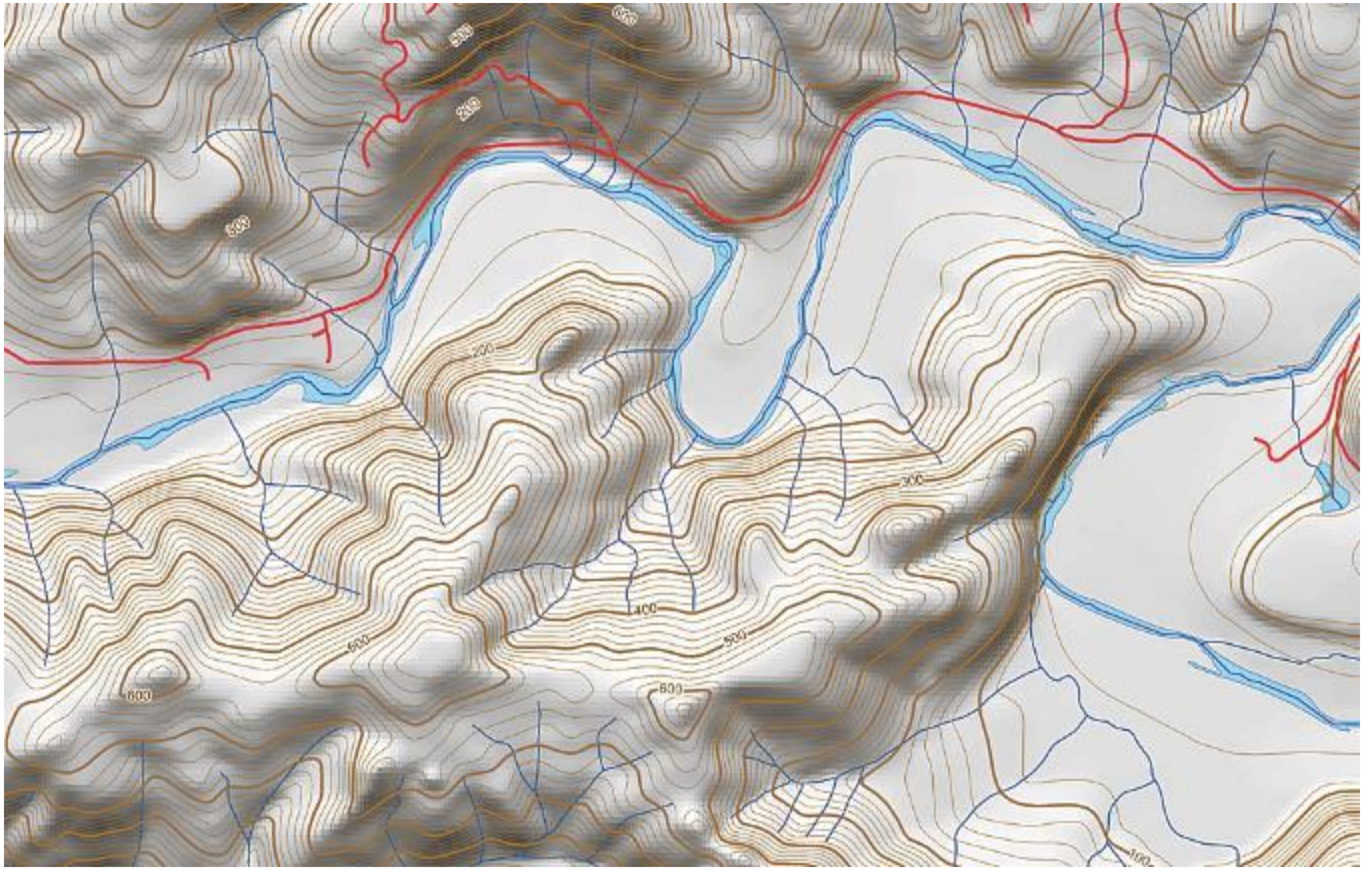
Photogrammetry







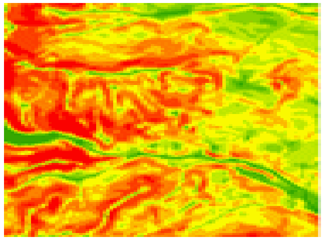
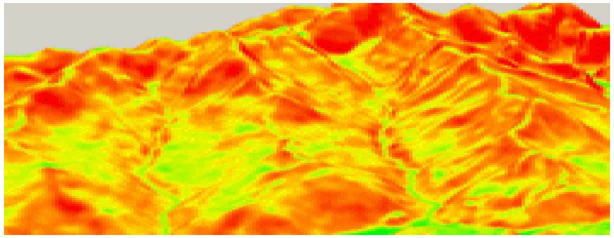
Digital Terrain Modeling (DTM)



Digital Terrain Modeling

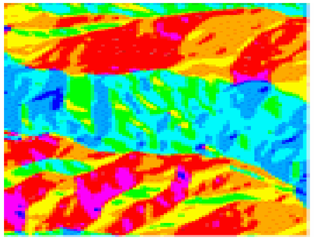
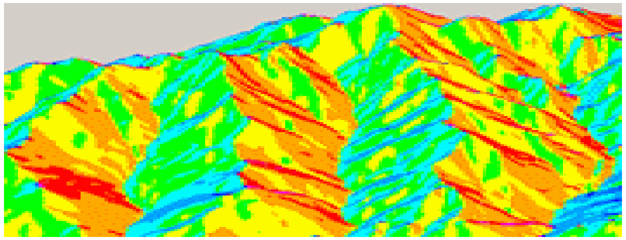
Elevation


Slope

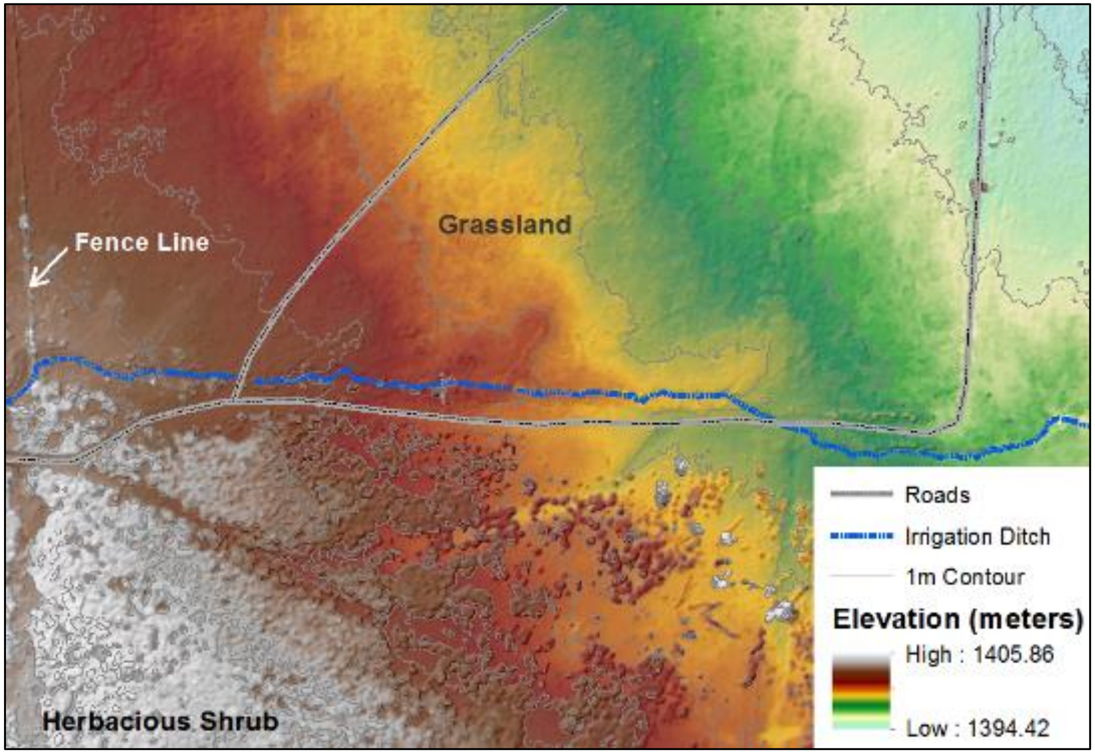



Aspect

Aspect usually results in degrees 0-360

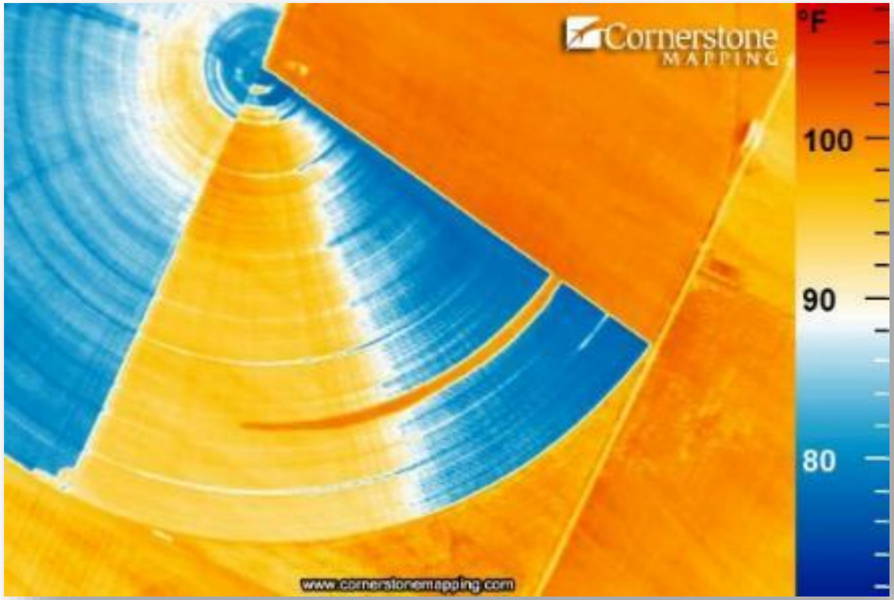



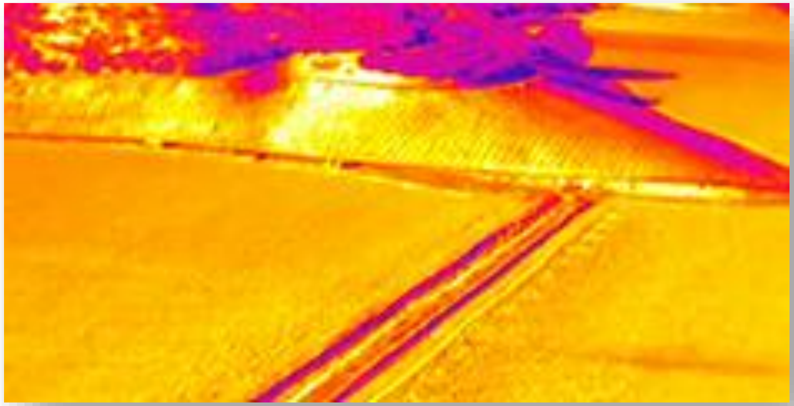
DTM Applications for Rangelands



A digital terrain model derived from a UAS image mosaic in the Bishop Ca. area. The image was acquired from an altitude of 100 feet above ground level, and using a GoPro 12-megpixel digital camera. The pixel resolution is approximately 0.8 inches over approximately 12 acres.

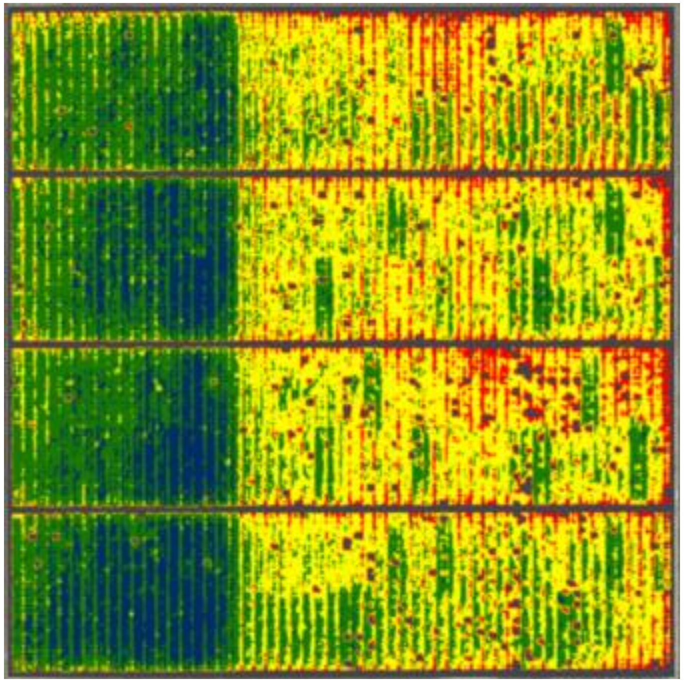
Applications - Irrigation





Applications - Irrigation

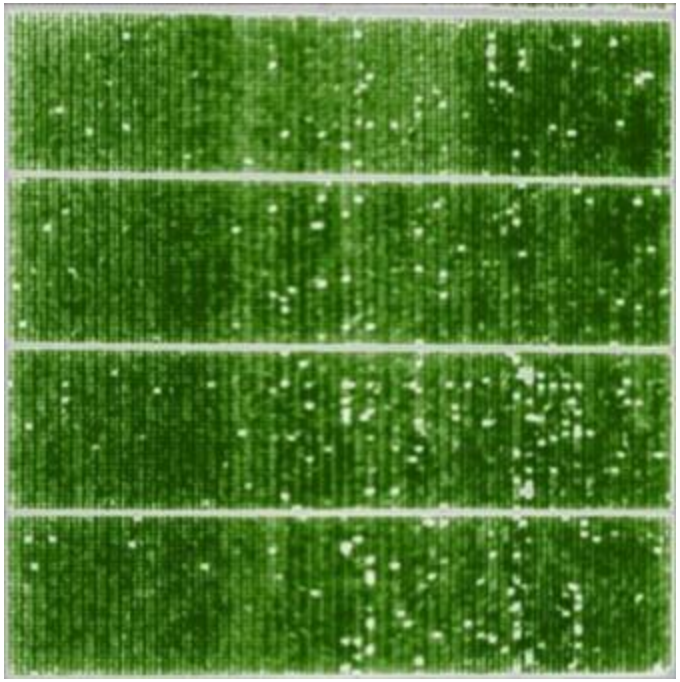
Water Stress Level



High | Moderate | Low | Unstressed

ceresimaging

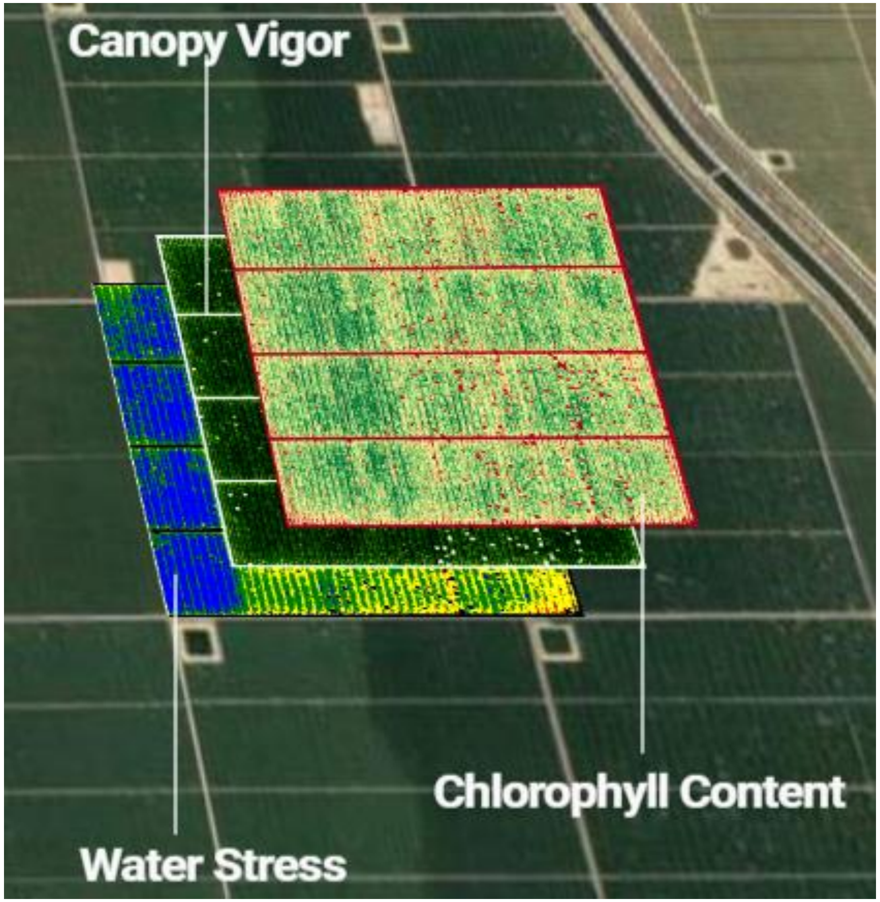
NDVI - Canopy Vigor



Low Vigor ↔ High Vigor

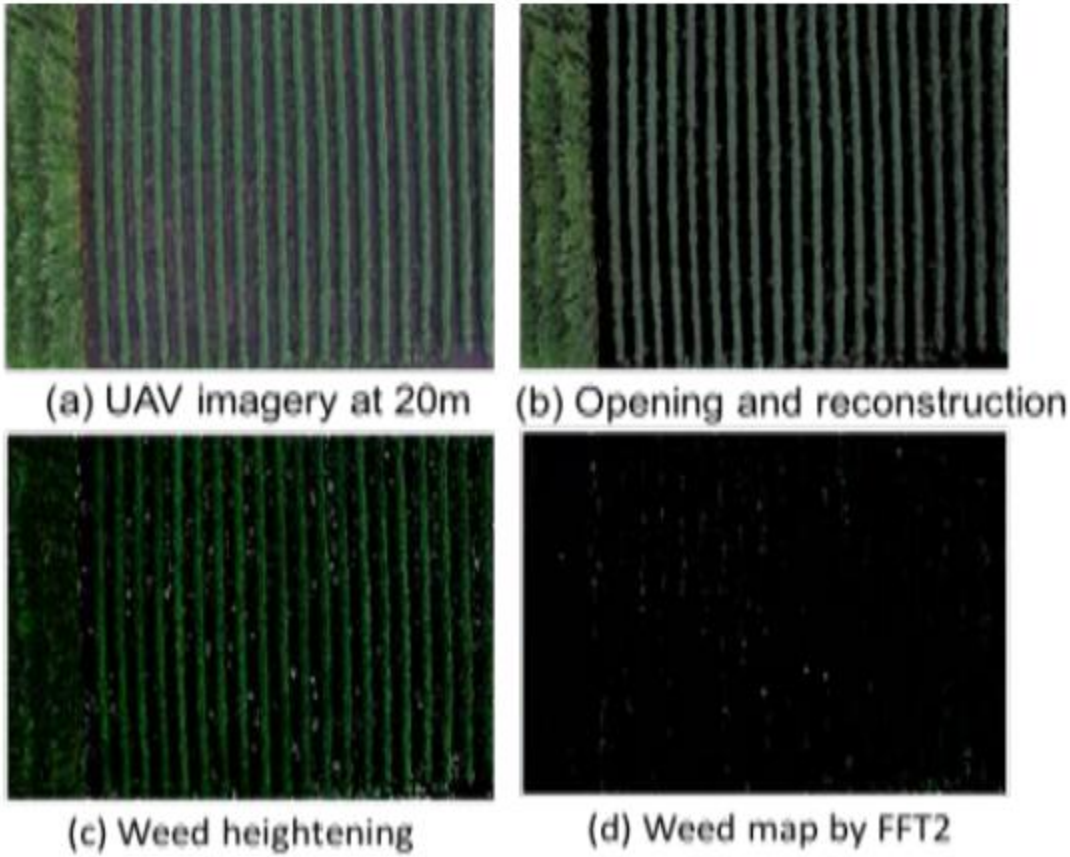
https://tomkat.stanford.edu/ceres-imaging-spotlight

Applications - Interpretation



http://www.ceresimaging.net/

Weed Detection



[18]

[13]

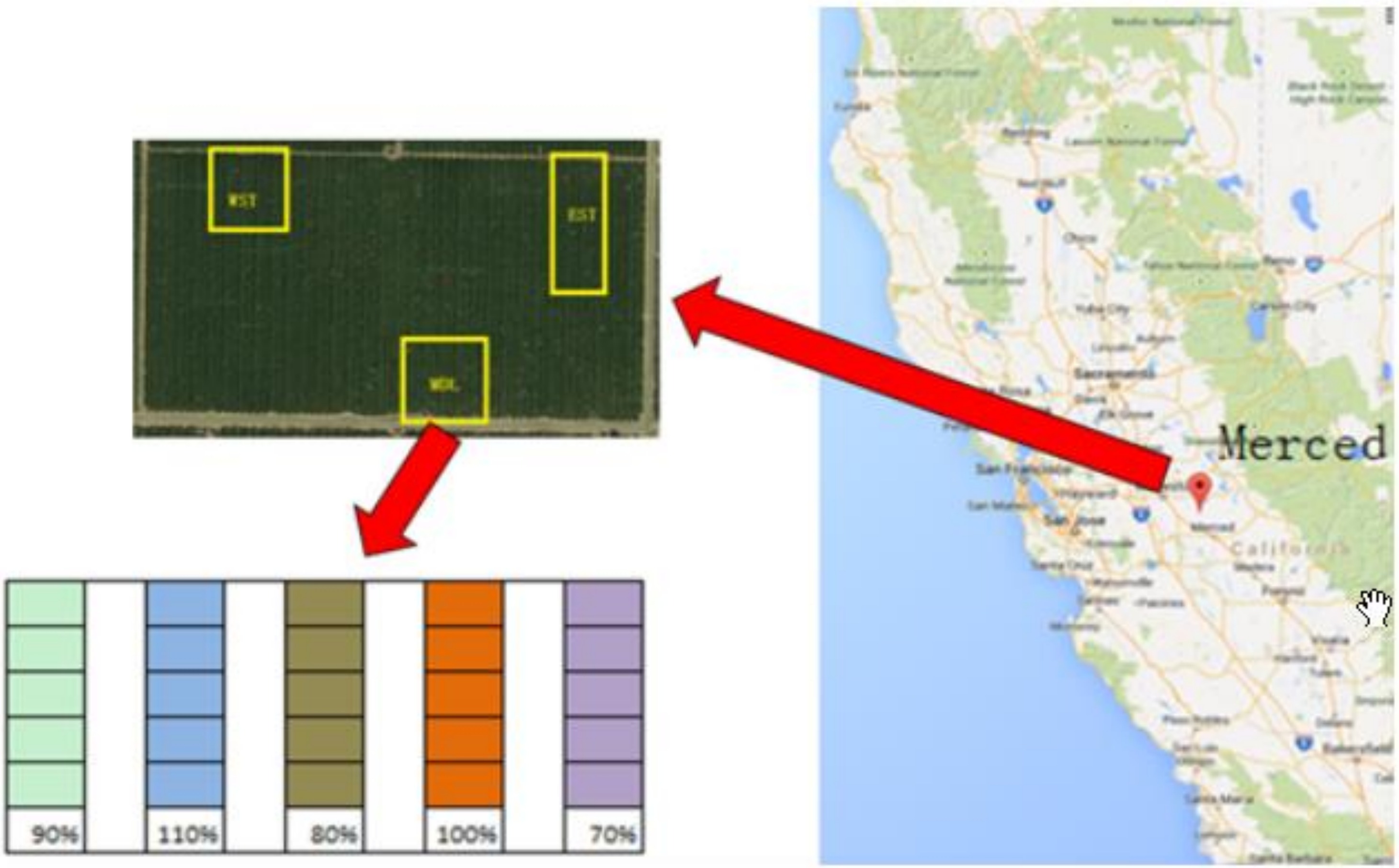
Nitrogen status detection

- The required N rates usually vary with rainfall, soil type, irrigation and plant growth [7]
- Real-time estimation of N status is necessary for minimizing over- and under- application of nutrients
- Red vegetation index (RVI) is proved to estimate N status of winter wheat, while insensitive to growth stages and crop varieties [8]
- NDVI is calculated as reference for nitrogen estimation for the wheat [9]

Irrigation management

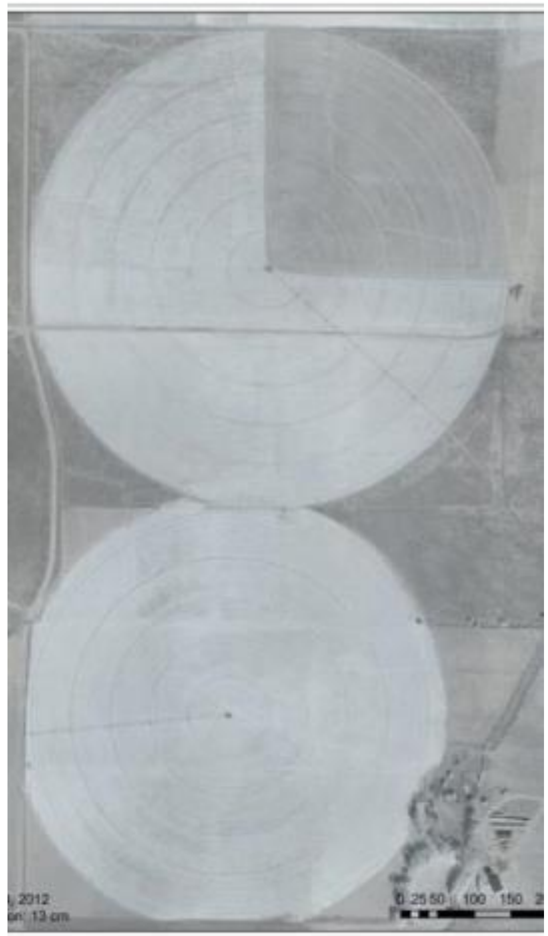
- Water stress monitoring should be conducted to fine tune irrigation applications
- For drip irrigated field, water stress monitoring should be as frequently as one a day [7]
- Crop water stress index (CWSI) has been shown to assess melon water stress and predict its yield with reasonable accuracy [10]

Water stress detection

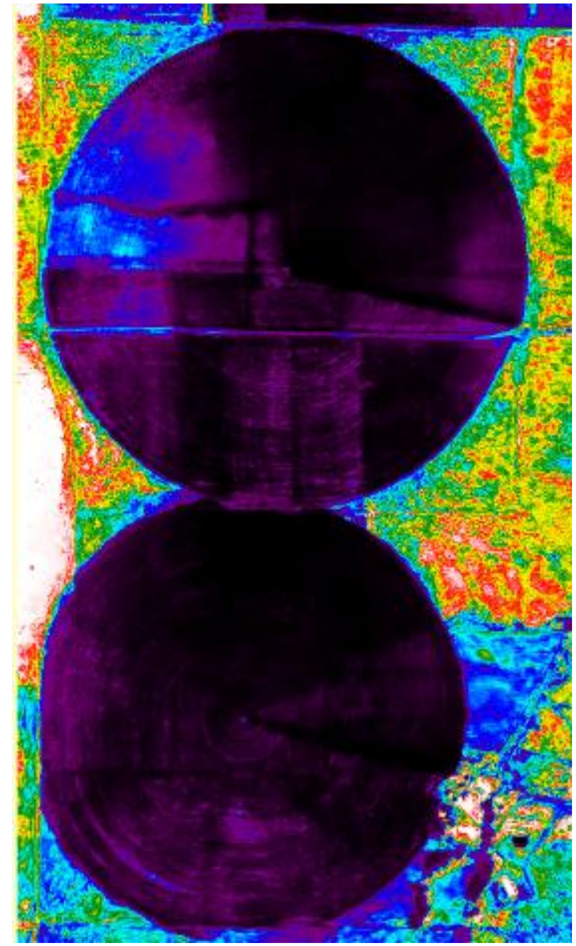


Water content

RGB



NIR



Thermal

Counting trees and measuring canopy size

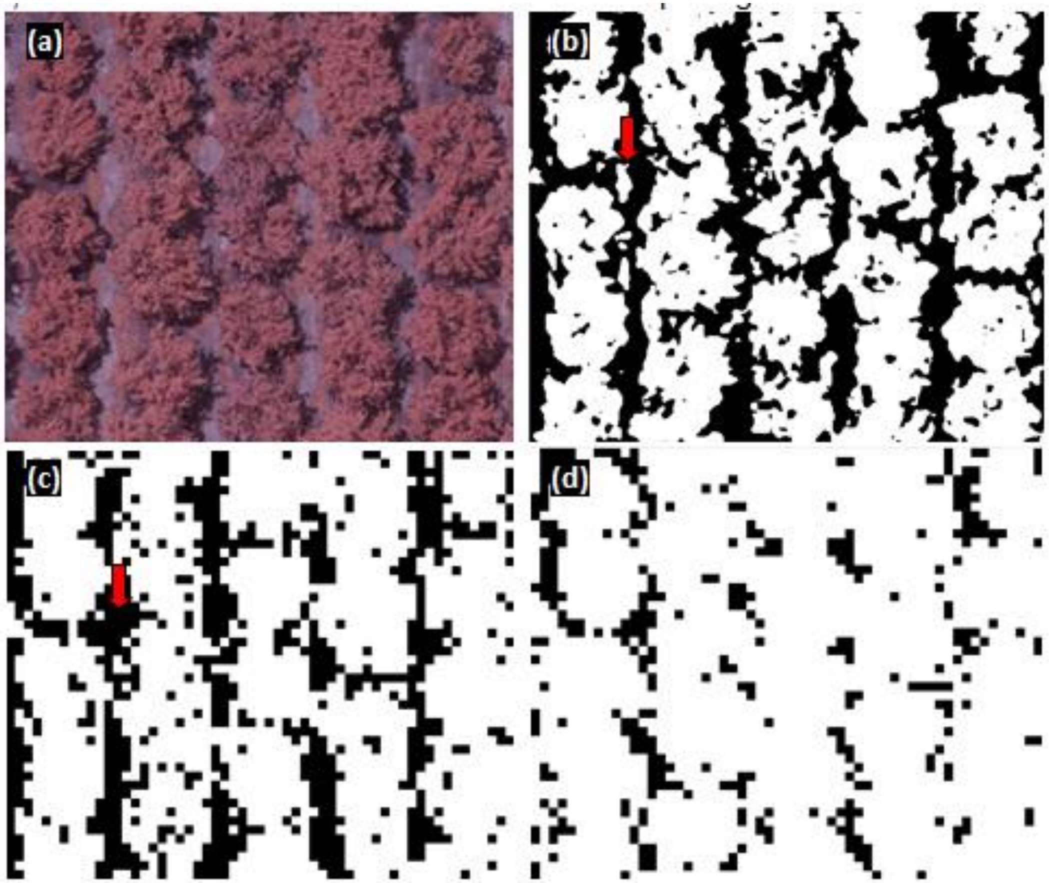


Fig 2. (a) Original image. (b) Binary image with Ostu method. (c) Binary image with HSV method. (d) Binary image with HSV combined with GLCM method. Tree canopy is white and others are black.

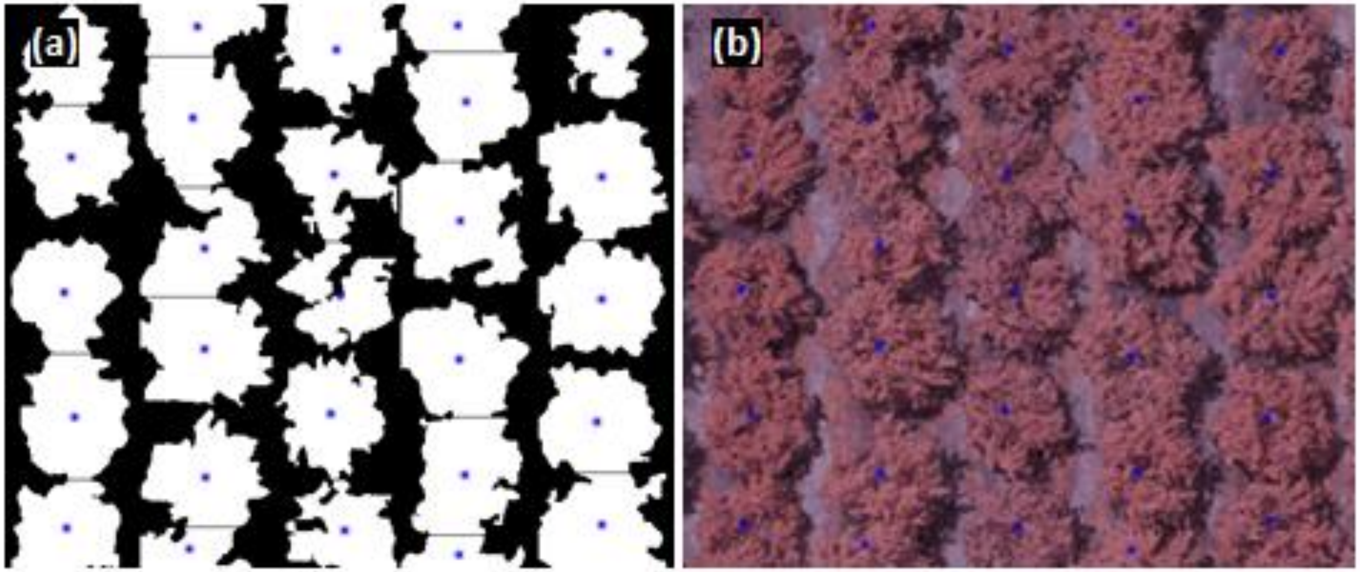
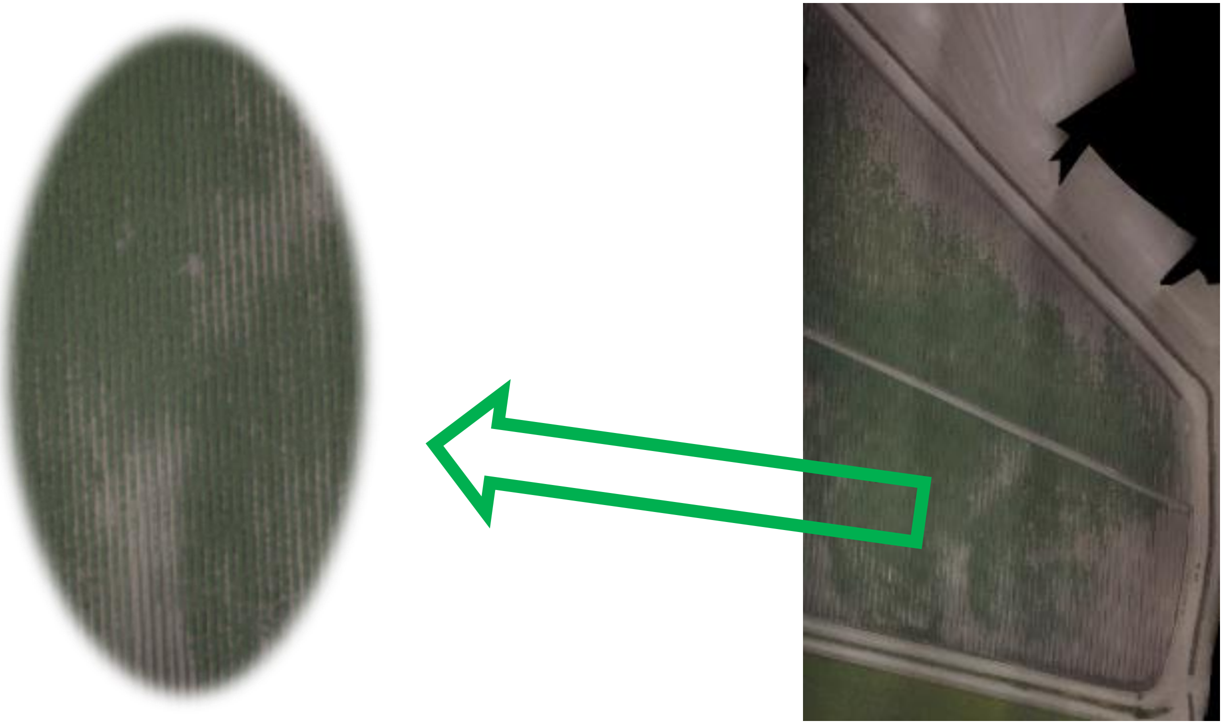


Fig 7. (a) Each tree is separated and its centroid is marked in the binary image. (b) The centroid of each tree is marked in the original image.

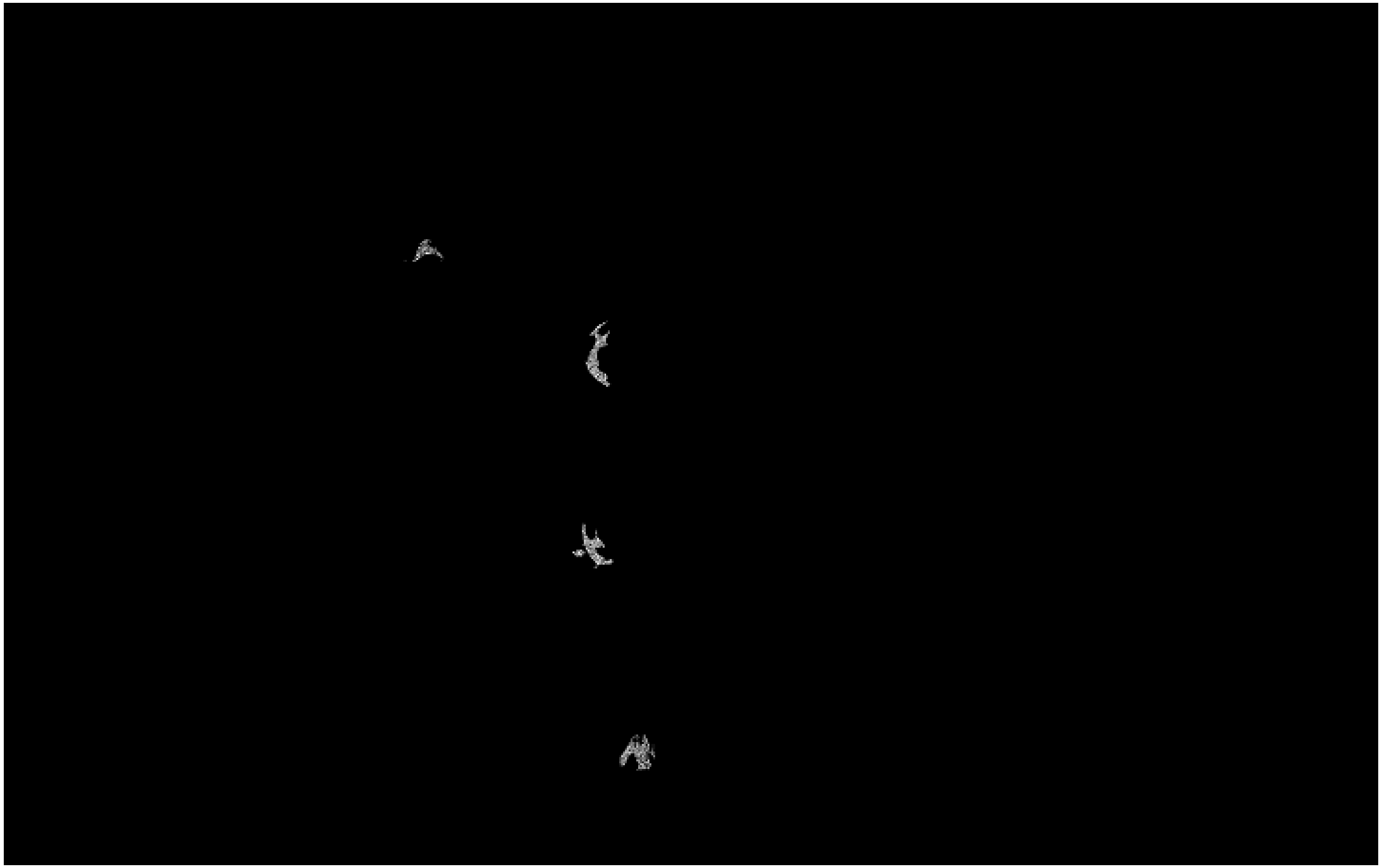
Smart melon drone

- Crop density evaluation for variable rate fertilizer application
- Yield prediction



Can you count the melons?

Machine Vision



What makes AgDrones so hard?

Remote Viewing

- Seeing plants
- High resolution imagery
  - Plenty of existing systems available
- Easy
- As useful as walking around the field
- Not always economically valuable

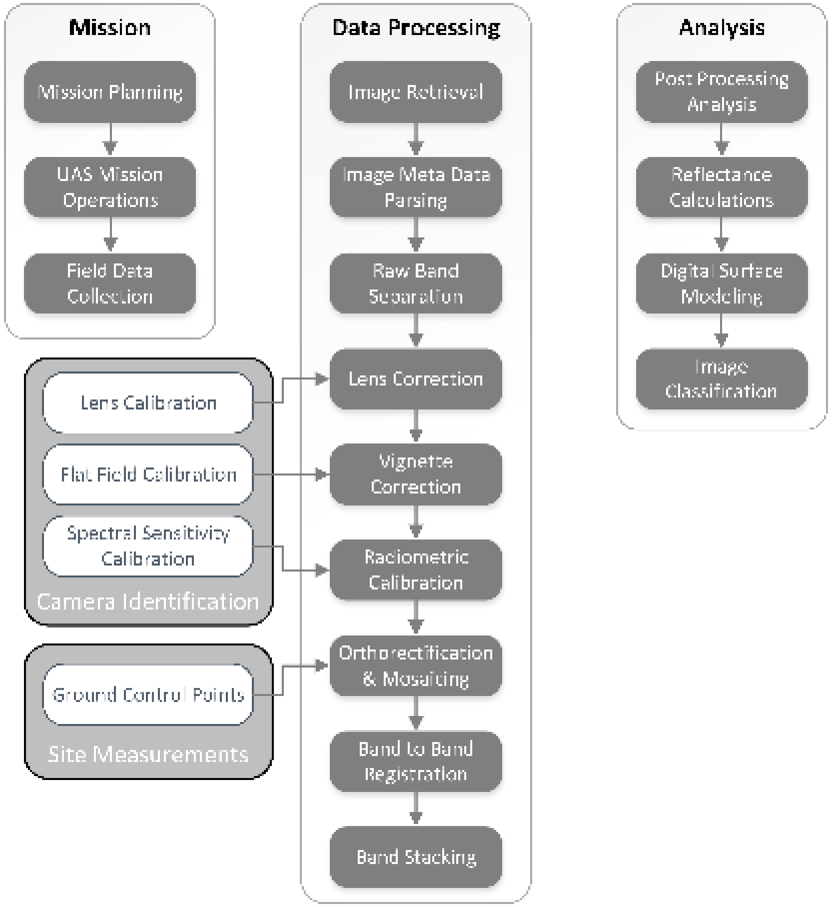
Remote Sensing

- Measuring plants
- Radiometrically calibrated high resolution imagery
  - Starting to be available
- Increased complexity
- Goal: Specific diagnostics

Challenges

- Reflectance
  - Dependent on
    - Illumination wavelengths
      - Function of time of day, location, weather conditions
    - Vegetation structure
    - Angle of incident
    - Other scattering
- Shadowing
  - Shaded areas are not suitable for analysis
- Spectral response information is not always known
  - Hyperspectral indices not immediately usable

Challenges



- Lots of potential for error
- Significant inefficiency in data management and workflow

Precision Application
Drone Spraying



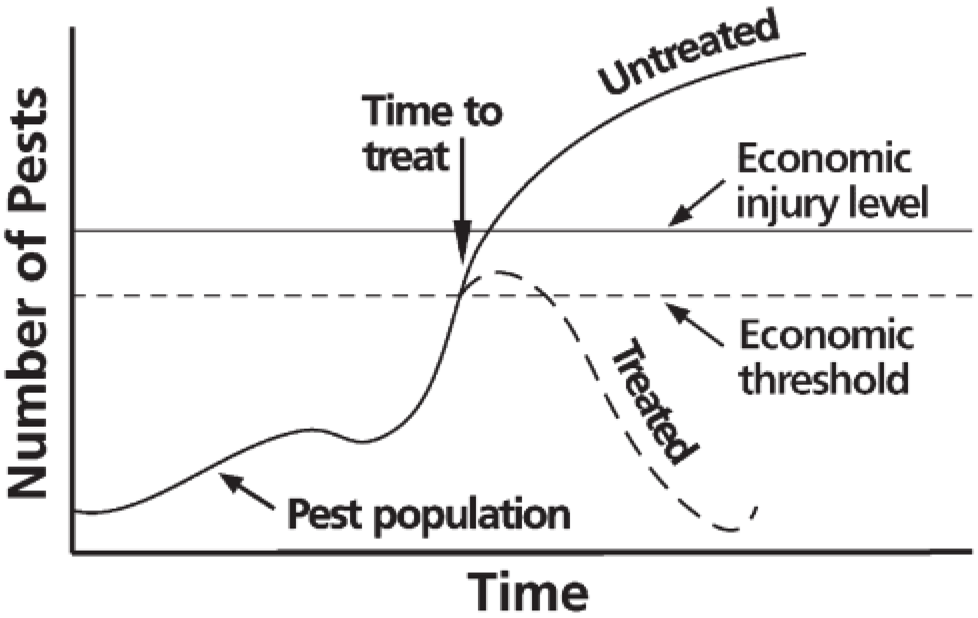

Drone spraying

- By October 2001 1,565 unmanned crop dusters were in use in Japan
- Yamaha accounts for 80% of unmanned crop duster sales with the R-50 and RMAX helicopter systems
- There are currently more than 2,500 RMAX helicopters active in Japan accounting for spraying 40% of the nation’s farmland

Benefits

- Small size allows for low altitude, low speed flights reducing spray drift
- Allow for autonomous precision spraying, reducing the amount of pesticide required
- Lowered risk of damage of property from crashes due to the small size and low speed, no pilot risk
- Smaller landing and take-off area requirements.
- Relatively low cost
- Reduce human contact with the chemicals, which helps to preserve human health
- Avoid the presence of chemicals outside designed areas, which helps to preserve neighborhood fields, preserve nature areas or water sources

Make Decisions



To make a control practice profitable, or at least break even, it is necessary to set the economic threshold (ET) below the economic injury level (EIL). Graphic: *National Pesticide Applicator Certification Core Manual*, NASDARF

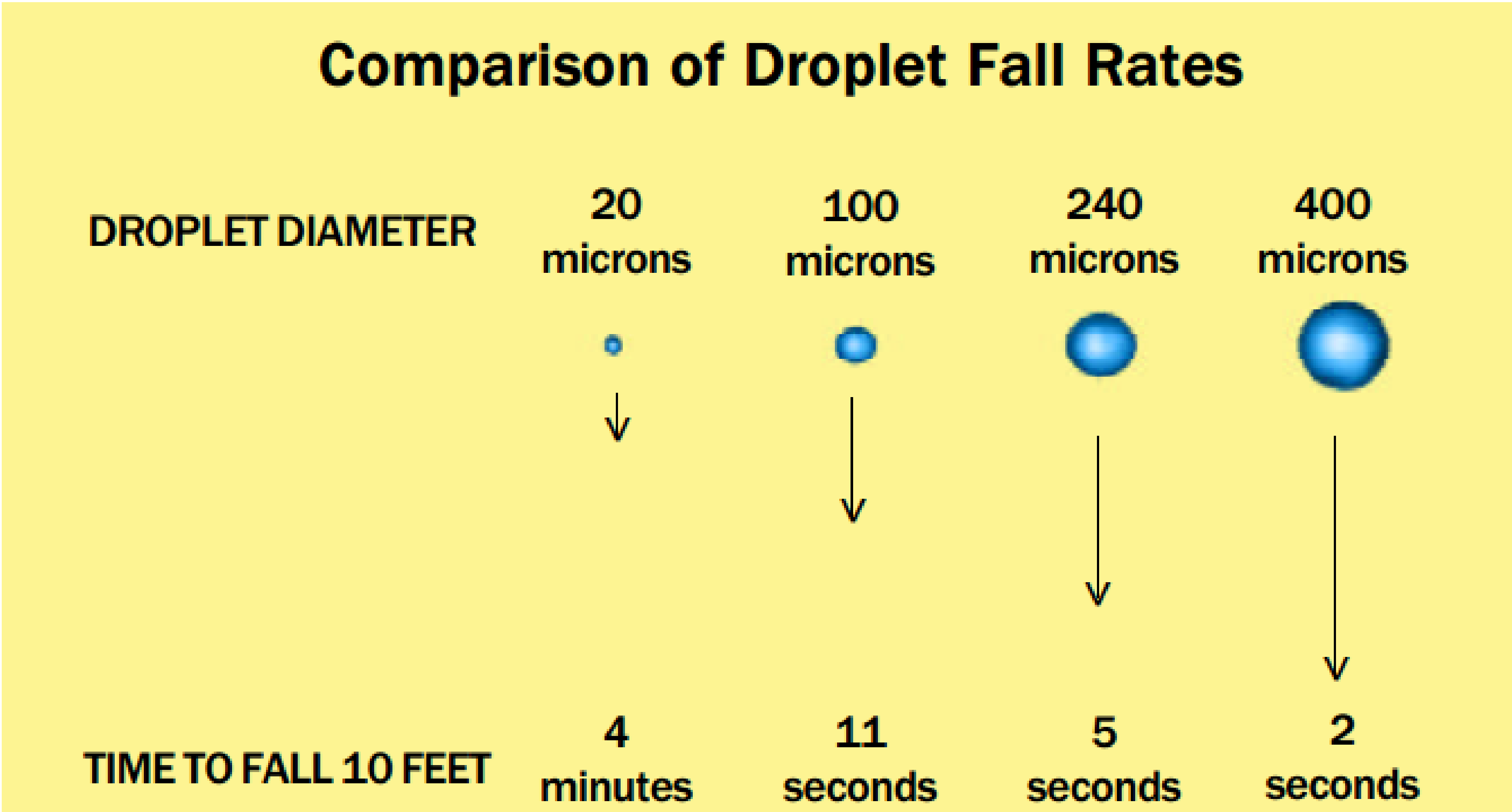
Pesticide Application

Yamaha RMAX - Weighs about 141 pounds empty and can carry a load of fertilizers and pesticides that weigh up to 61 pounds

https://www.buzzfeed.com/mbvd/the-future-of-farming-us-approves-drones-for-crop-dusting?utm_term=.qrEjjzl3pz#.wmqkkWJE2W

Pesticides in Air

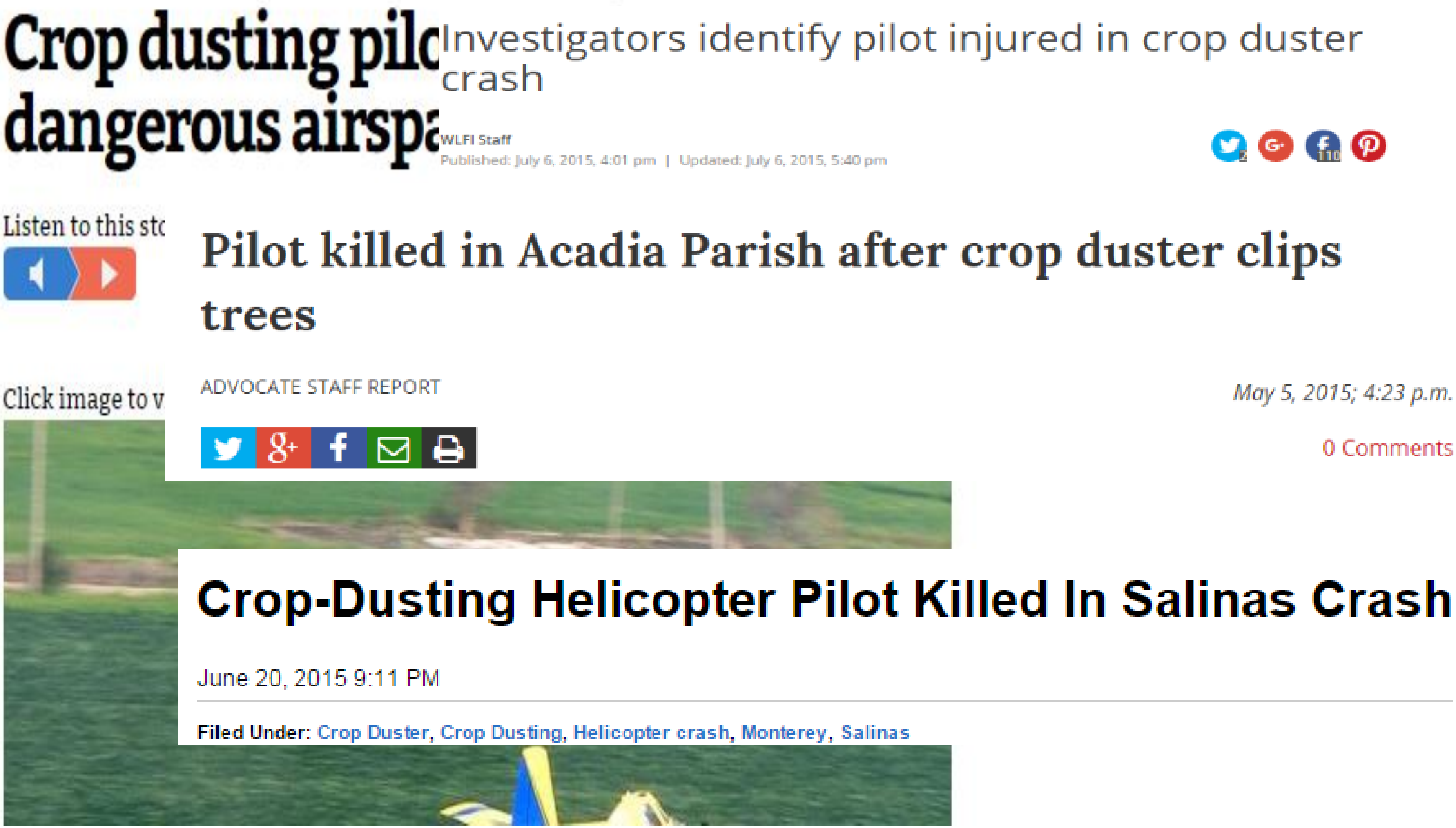
- 80-90 percent of certain compounds can be lost within a few days of application through this process.
- Even in the Arctic and Antarctic pesticides are found in the air, snow, people and animals. The extent of atmospheric contamination has not been adequately studied [11]


Comparison of Droplet Fall Rates
DROPLET DIAMETER
20 microns
100 microns
240 microns
400 microns
TIME TO FALL 10 FEET
4 minutes
11 seconds
5 seconds
2 seconds

Advantages of aerial application

- The adverse ground conditions that could impede ground equipment, like
  - soil too wet for supporting ground equipment
  - fields with obstacles such as levees
  - props for supporting tree limbs
  - low-hanging tree limbs
- High speed
- Large swath capabilities
- Accounts for 18-20 percentage of cropland

Are Drones Worth it?



Crop dusting pilo
dangerous airspa

Listen to this sto

Click image to v

Investigators identify pilot injured in crop duster crash

WLFI Staff
Published: July 6, 2015, 4:01 pm | Updated: July 6, 2015, 5:40 pm

Pilot killed in Acadia Parish after crop duster clips trees

ADVOCATE STAFF REPORT

May 5, 2015; 4:23 p.m.

0 Comments

Crop-Dusting Helicopter Pilot Killed In Salinas Crash

June 20, 2015 9:11 PM

Filed Under: Crop Duster, Crop Dusting, Helicopter crash, Monterey, Salinas

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UAS Regulations

Remote Pilot Certificate with SUAS Rating

- Civil License for "Non-Recreational" purposes (includes research, promotional activity for non-profits, etc)

- How to obtain
  - Operators must pass an Aeronautical Knowledge Test at an FAA-approved knowledge testing center.
  - Knowledge exam is $150 and is allotted for 2 hours
- Responsibilities
  - Make available to the FAA, upon request, the small UAS for inspection or testing, and any associated documents/records required.
  - Report an accident to the FAA within 10 days of any operation that results in injury or property damage.

Details in a separate presentations

Not Allowed

- Does not permit flying over people or near people in a manner that puts them at risk
- No flying above 400 ft
- No flying beyond line of sight or at night

New with Part 107

- International students may not operate for commercial gain or for employment
  - Certain research projects are allowed (see cheat sheet)

When do you **not** need a SUAS Certificate?

- Model Aircraft Operations
  - Recreational **Purposes**
    - ‘For fun’
  - Specific Educational **Purposes**

The separation between regulations is defined by **PURPOSE**, not entity

Recreational Purposes

- Cannot receive money or compensation
- Cannot be used in furtherance with a business or official duty regardless of compensation
- Must be operated within a community-based set of safety guidelines and within the programming of a nationwide community-based organization

If it is plausible that someone would pay for a UAS to do it, then it is not recreational

What does this mean for drones in Ag?

- Commercial flights are now allowed
- The remote pilot certificate is now affordable and achievable
- Drones can weigh up to 55lbs

- But… we’re still not quite there yet

What does this mean for drones in Ag?

- Precision spraying can be done with drones under 55 lbs
  - But who can afford them?
  - Prohibition on beyond line of sight flying limits coverage

- Remote sensing of agriculture is now easier legally
  - But most off-the-shelf platforms are only suitable for small areas (< 50 acres) per flight
  - The 400 ft ceiling limits larger platform coverage
  - Technology is more available, but still expensive

- The new laws enable precision agriculture with drones, but aircraft technology, sensor technology and analysis techniques are still not quite there yet.

The Present & Future

- Remote Sensing
  - Vegetation Indices (RVI, NDVI, PRI) developed from satellite imagery
    - Newer VIs specific for UASs just now starting to be developed
  - Other Indices (CWSI) based on in-field measurements
    - Just now starting to be converted for UAS use
- Precision Application
  - UASs already in use in Japan/Europe
  - Optimal spraying algorithms just now starting to be developed
- UAS Agricultural Applications are just getting started
  - Still a steep learning curve, but it'll mature

My Recommendations

Short Term

- Buy a drone to fly for fun or for visual inspections,
- Don’t expect significant returns on your investment

5-10 Years down the road

- Keep an eye out for new developments
- Data mining and analysis is the future of drone’s applicability

Questions?

Email: bstark2@ucmerced.edu
UASSafety@ucmerced.edu
http://tinyurl.com/UC-UAS-COE
http://uassafety.ucmerced.edu/

Phone: (209) 201 - 2051

Facebook page:
https://www.facebook.com/UC.UAS.Safety/

Please sign up for the UC UAS Listserves if you'd like to be kept in the loop of the latest developments

Other Presentations:
UAS Safety Management System
SUAS Remote Pilot Certificate Exam
Drones for Student Clubs
Drones for Researchers
Drones for Staff

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