UAS in Precision Agriculture: Opportunities for the Eastern Shore

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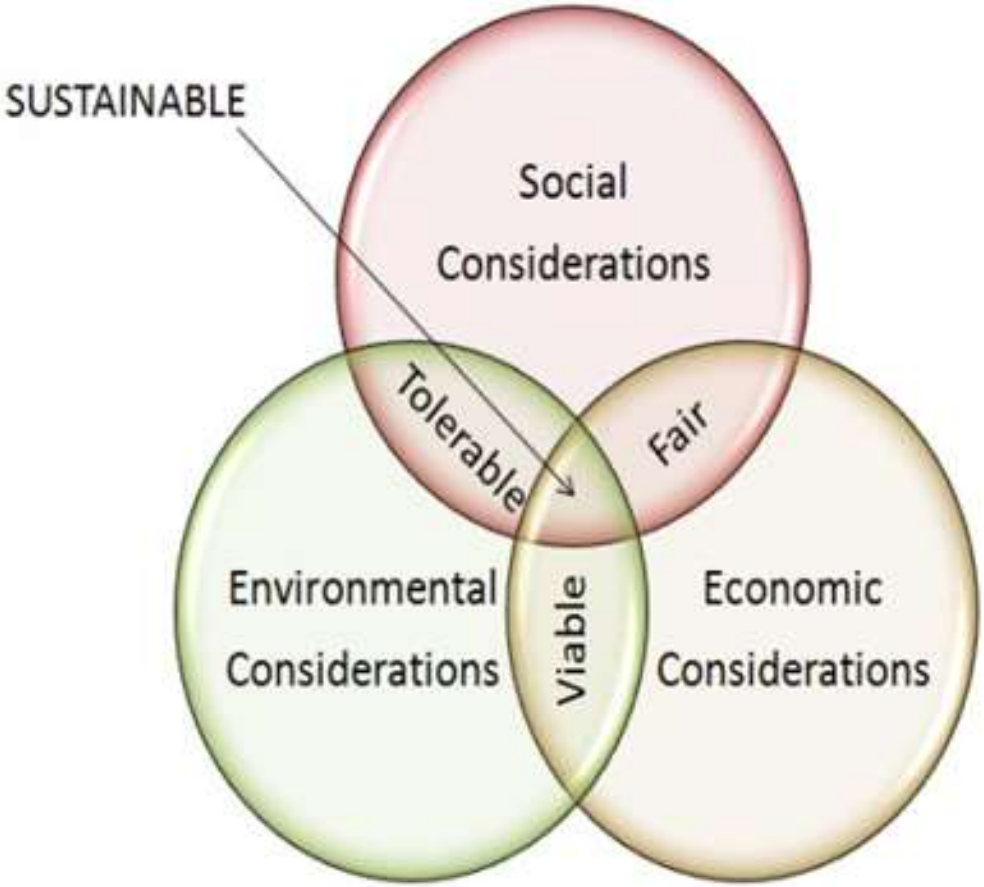
Engineering and Aviation Sciences Department
Chris Hartman, MS, Program Coordinator,
Aviation Science Program

UNIVERSITY of MARYLAND
EASTERN SHORE

Overview

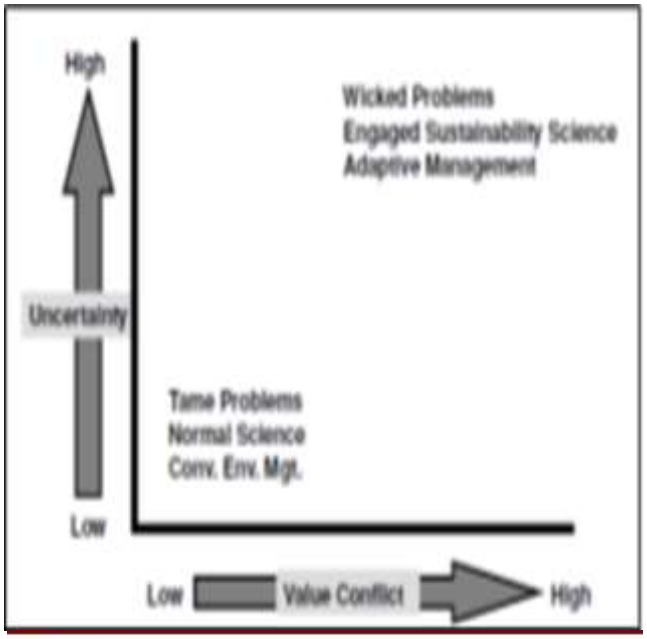
Why precision agriculture?



What is precision agriculture?

- A method of optimizing agricultural inputs to improve economics and minimize environmental impacts.
- Simple definition
  - Right product
  - Right time
  - Right place

WICKED PROBLEM – EASTERN SHORE




The Delmarva Farmer

PMT delays could outlast O'Malley administration

Maryland tops region in ag gains

Final chicken festival a success

PMT delays could outlast O'Malley administration

By BRUCE HOTCHKISS
Senior Editor

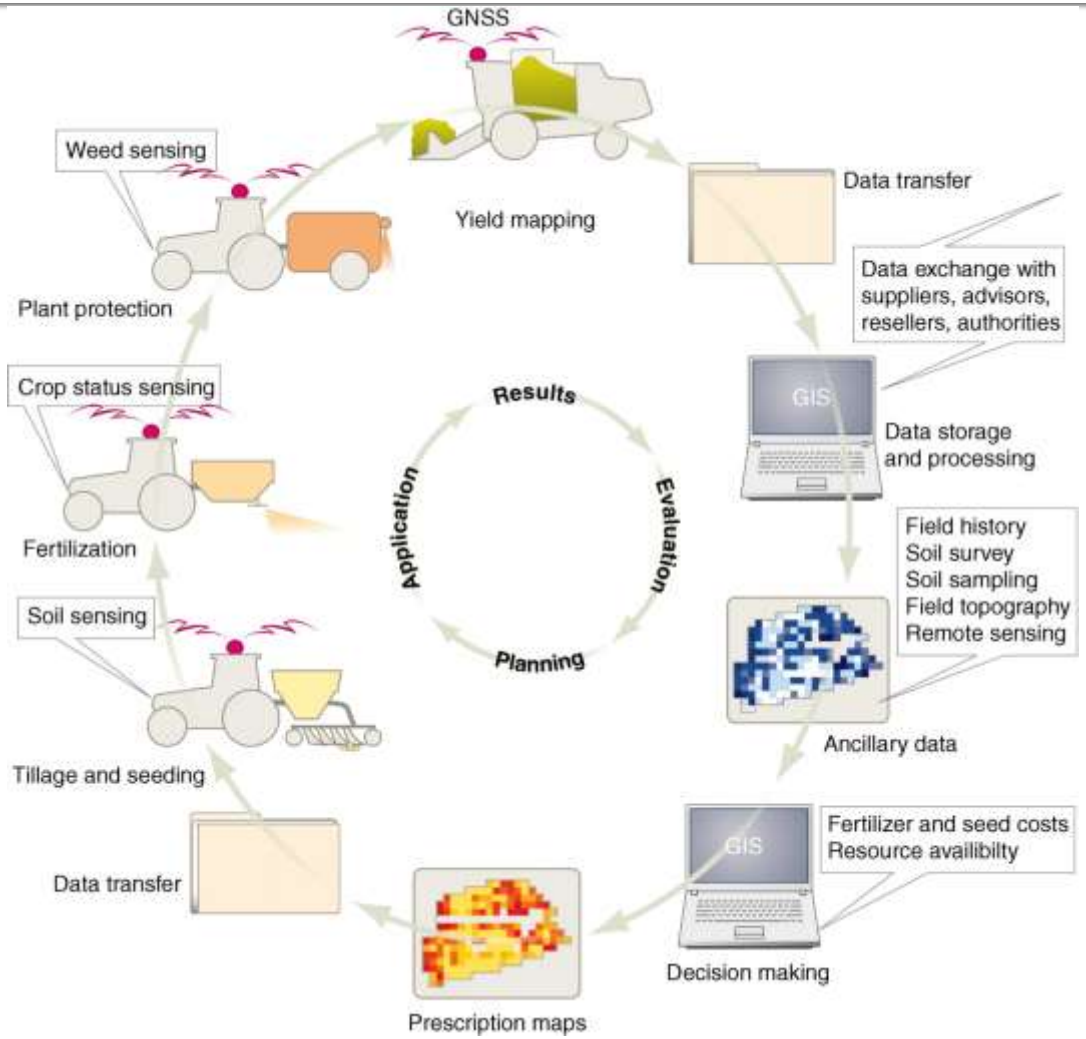
(July 1, 2014) Even as an intricate study continues in Maryland on the economic impact of the proposed Phosphorus Management Tool, it has become apparent that the ultimate implementation of the new nutrient management regulations could be delayed until well beyond the first of the new year. That would put it off until after Gov. Martin O'Malley leaves office. The PMT's importance to the restoration of the health of the Chesapeake Bay and the priority it has received in the affairs of state is providing O'Malley with political ammunition as he treads the path to a bid for national elective office.

DPI lauds contributions of poultry industry

By MICHEL ELBEN
Staff Reporter

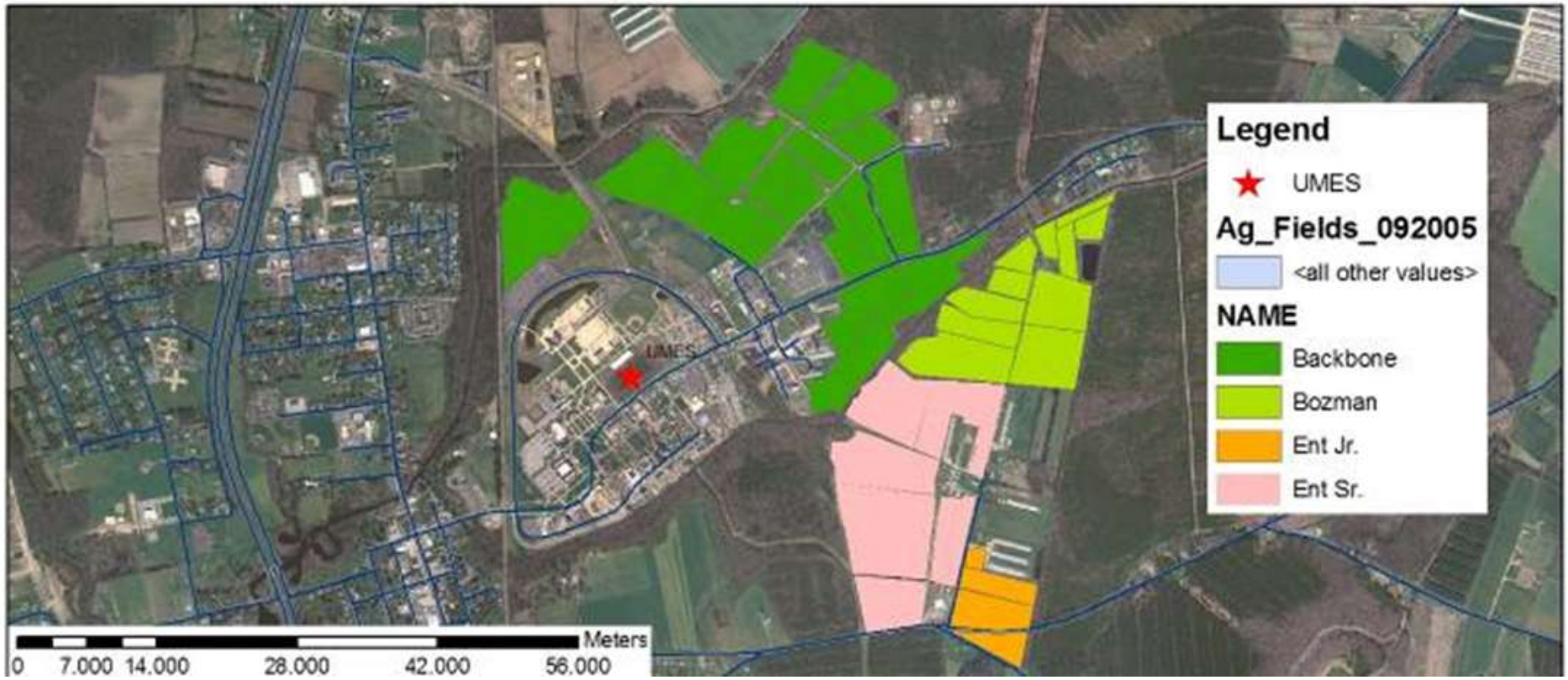
EASTON, Md. —
……."**Thanks to chickens, farmland and farm families remain on Delmarva**," said Jim Smith, DPI president.
"**Delmarva's poultry industry is responsible for nearly 10 percent of Delmarva's jobs."**
Smith said it takes about 73 million bushels of corn and 24 million bushels of soybeans to feed Delmarva's chickens.
"That acreage is larger than Rhode Island," he said.

Precision Agriculture is driven by technology and research

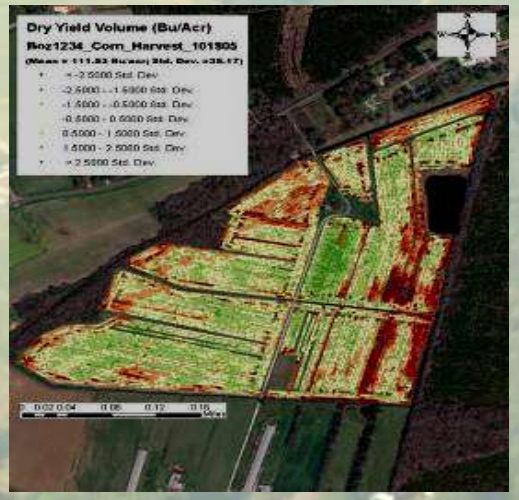


http://www.sciencemag.org/content/327/5967/828/F2.large.jpg

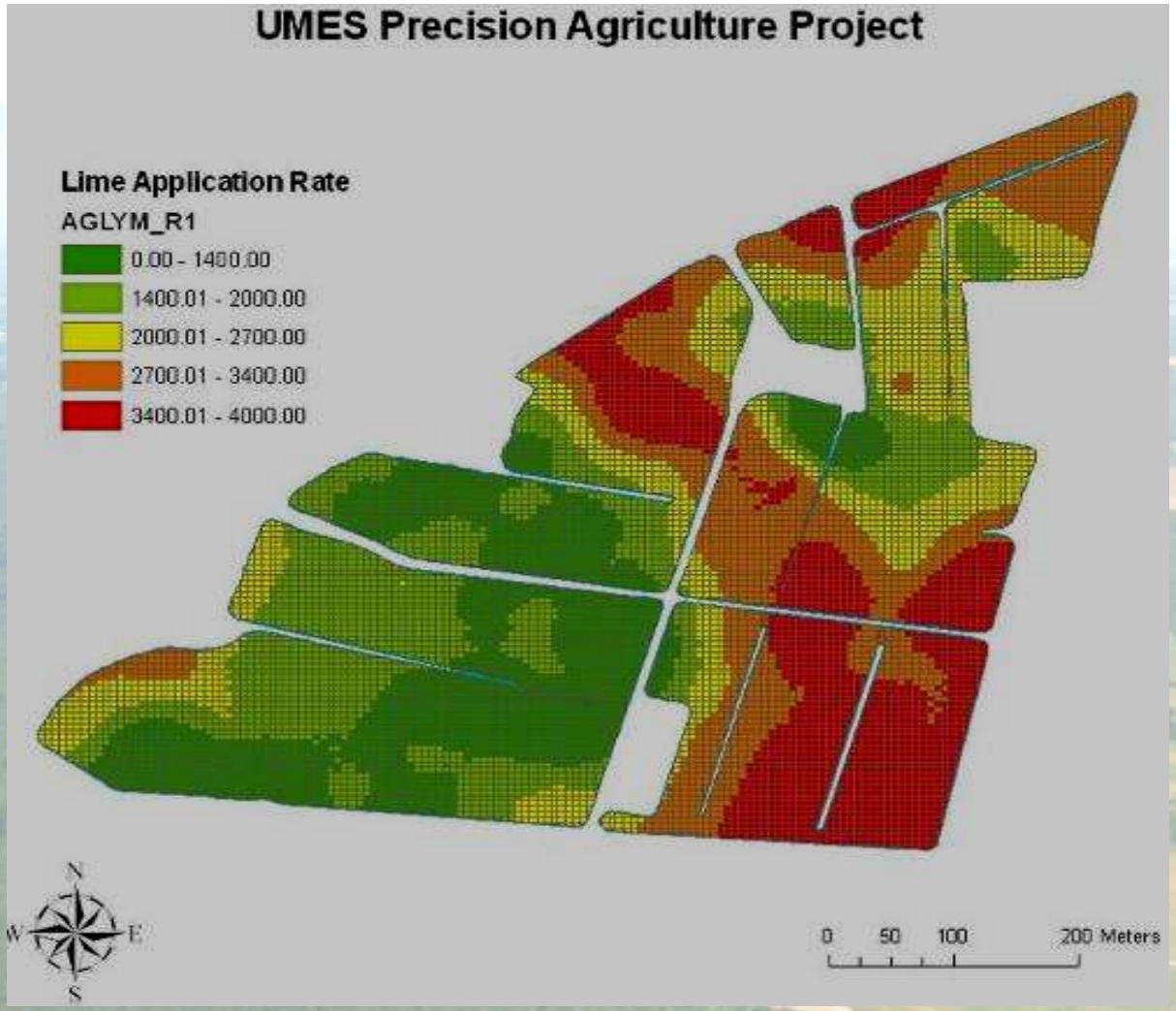
Precision Ag Efforts at UMES



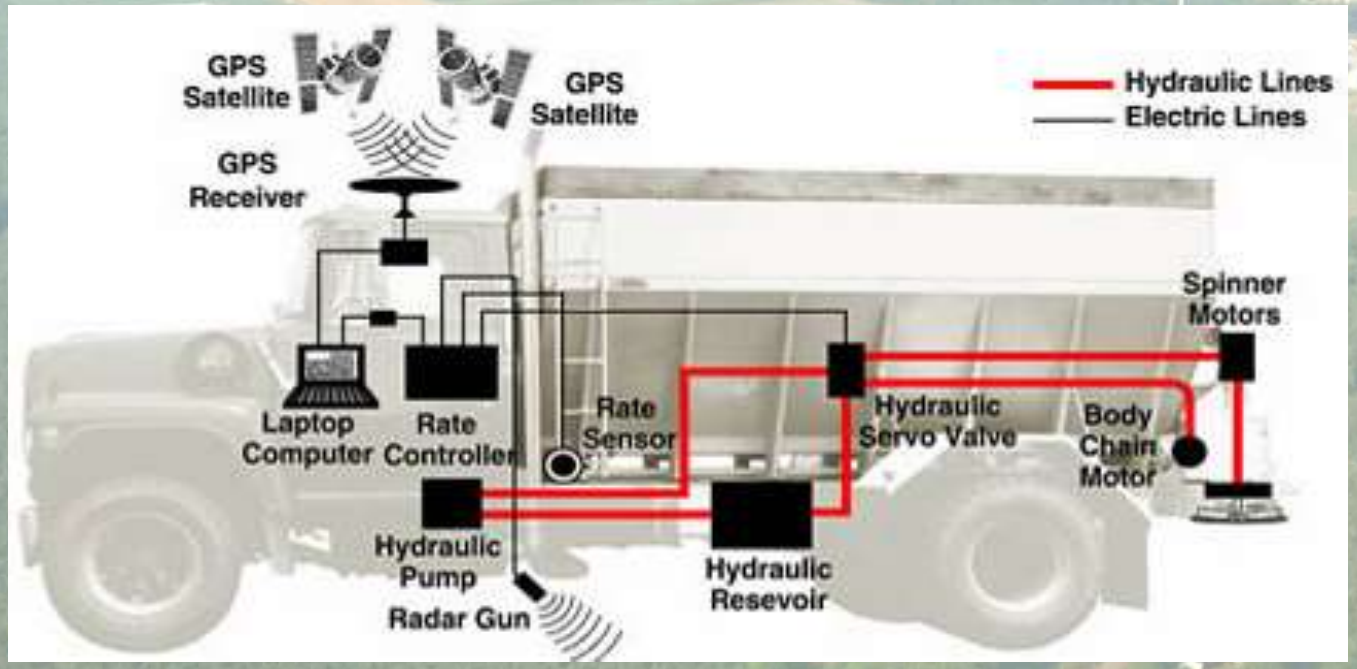
UMES Combine and Yield Monitor

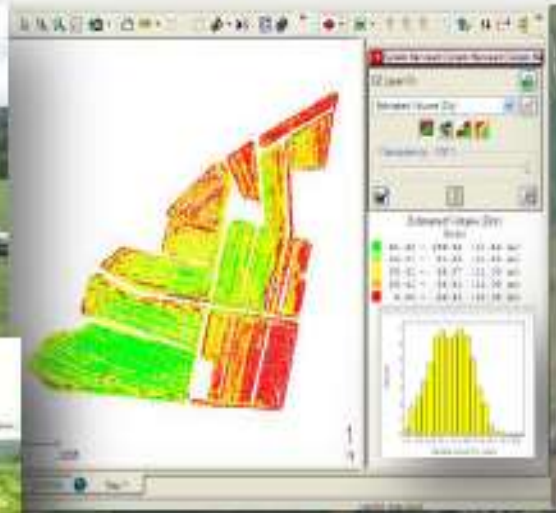


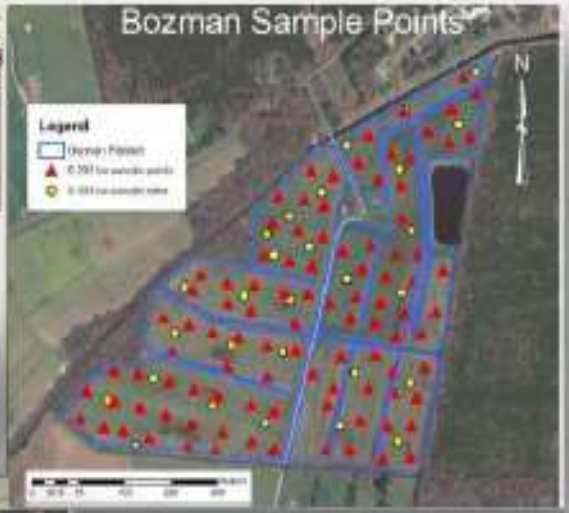
Results from the pH Field Experiment

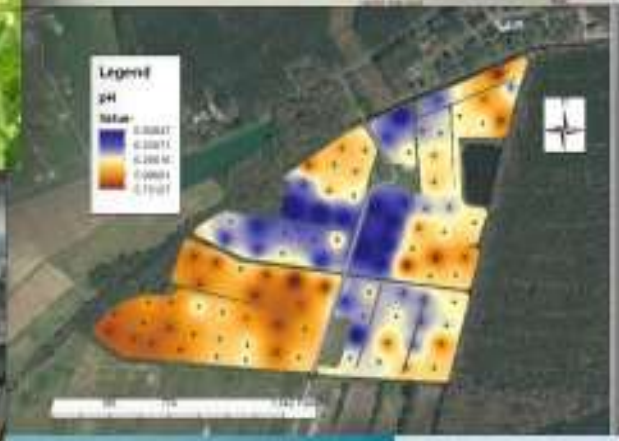


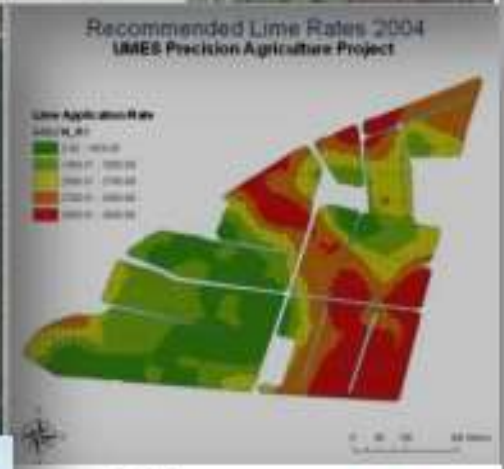
Variable Rate Application of Lime

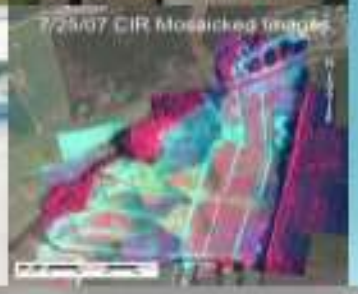


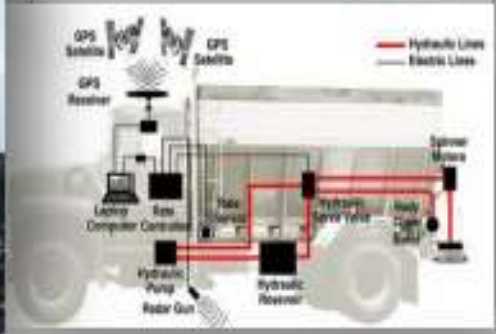



Bozman Sample Points
N
Legend

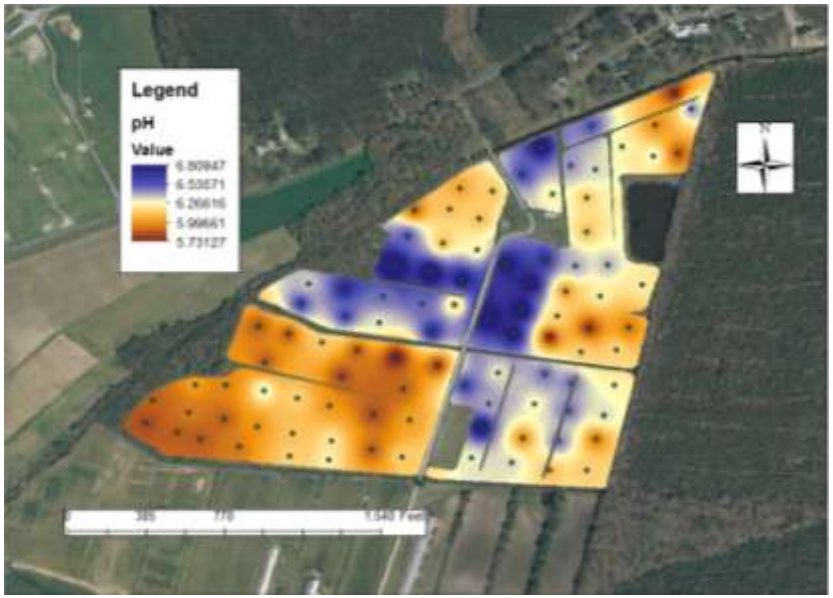

Legend
pH

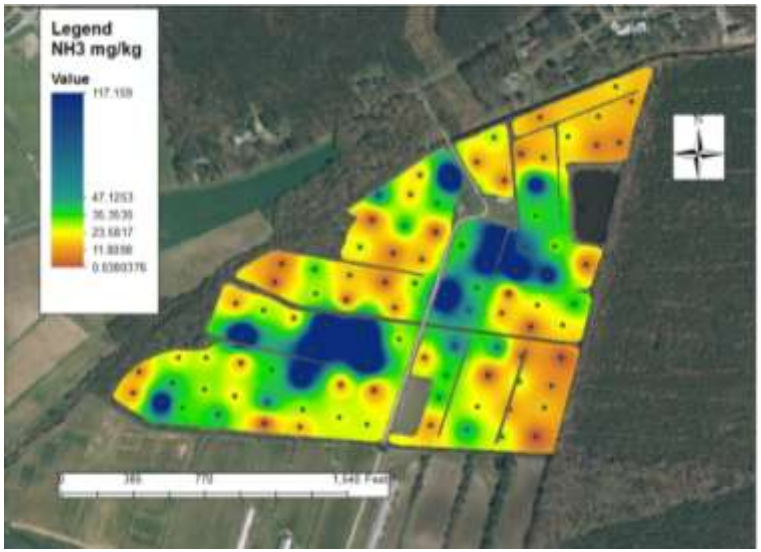

Recommended Lime Rates 2004
IAMES Precision Agriculture Project

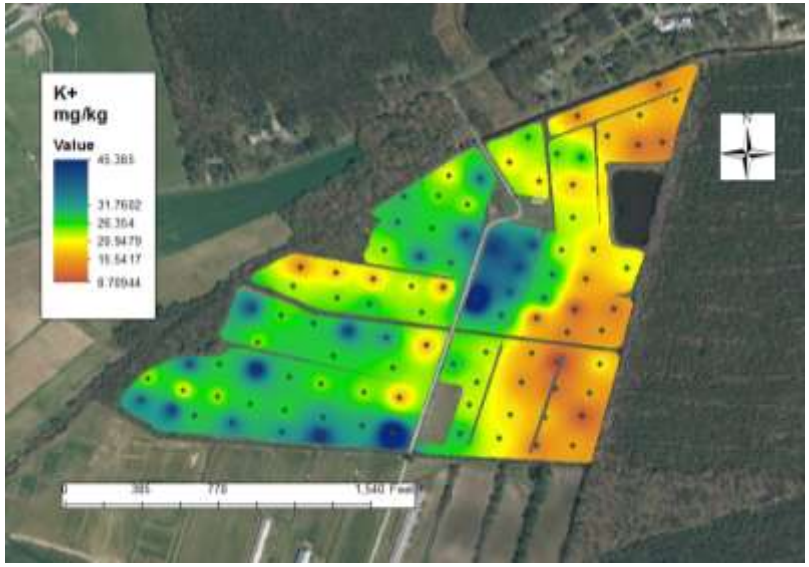

7/25/07 CIR Mosaicked Images

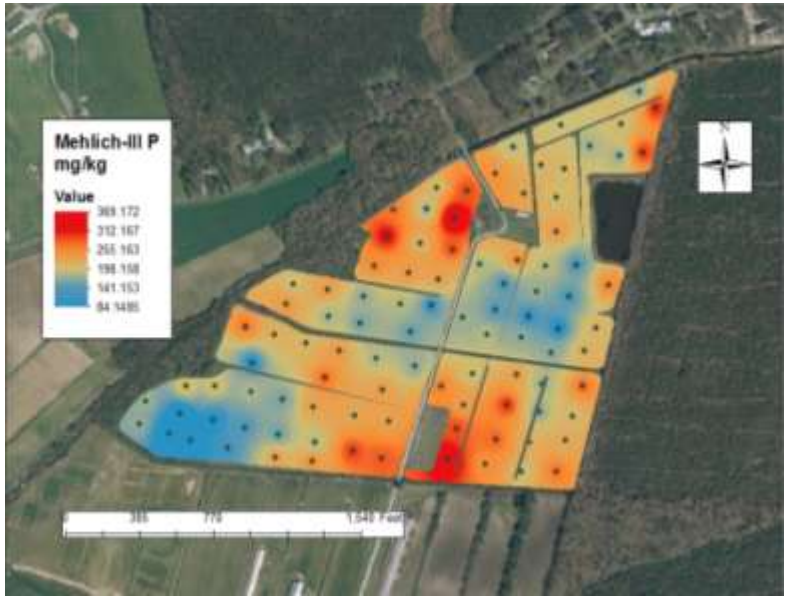

GPS Satellite
GPS Satellite
GPS Receiver
Hydraulic Lines
Electric Lines
Spinner Motors
Hydraulic Pump
Radar Gun
Hydraulic Reservoir

GRID SOIL SAMPLING – SOIL TEST RESULTS ON GIS MAP (BOZMAN FIELD)









Applied Research and Field Experiments utilizing Variable Rate Nitrogen Application, Remote and In Situ Sensing, and Drought Tolerant Corn Seeds

Drought Product Development

- **Identification of rate limiting processes under stress**
  - More stable photosynthesis
  - More aggressive silking
  - More allocation of C and N to ears
  - Maintain green leaf area
  - Better water conservation in canopy
  - Better water uptake from soil

In 11,269 on-farm comparisons with competitive products, 2012 yield data demonstrated an advantage of 8.9 percent with Optimum® AQUAmax™ products in water-limited environments; and a 1.9 percent yield advantage in favorable growing environments at locations harvested.

DuPont Pioneer's Contributions to UMES Project

- Corn seed supply of best suited Optimum® AQUAmax™ products for the eastern shores crop production region.
- Access to DuPont Pioneer personnel (researchers and field agronomists) for advice on executing UMES experimental plan

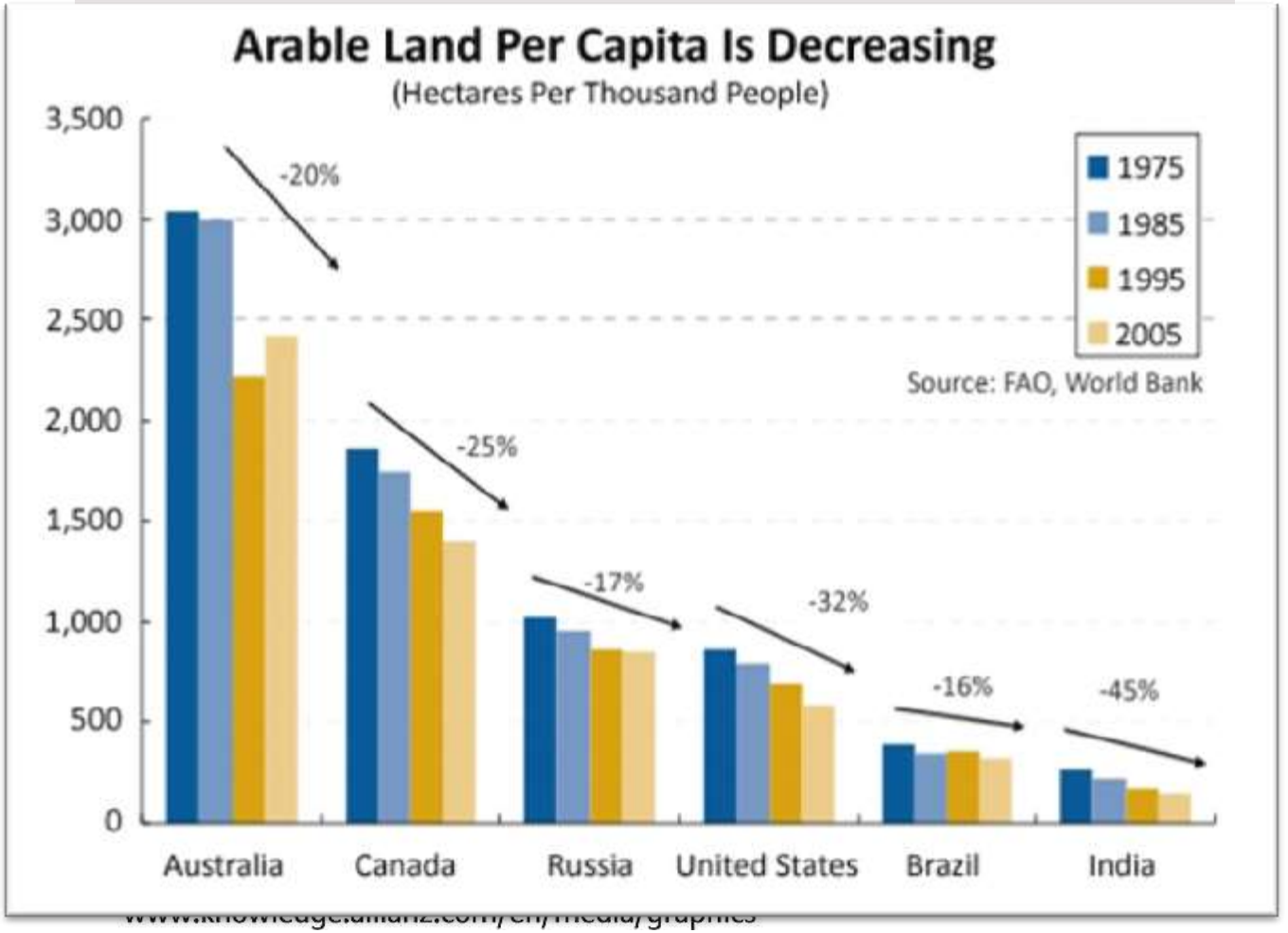
PIONEER. A DuPont Business | Science with Service Delivering Success™ | DUPONT The miracles of science™

PIONEER. A DuPont Business | Science with Service Delivering Success™ | DUPONT The miracles of science™

Why precision agriculture?

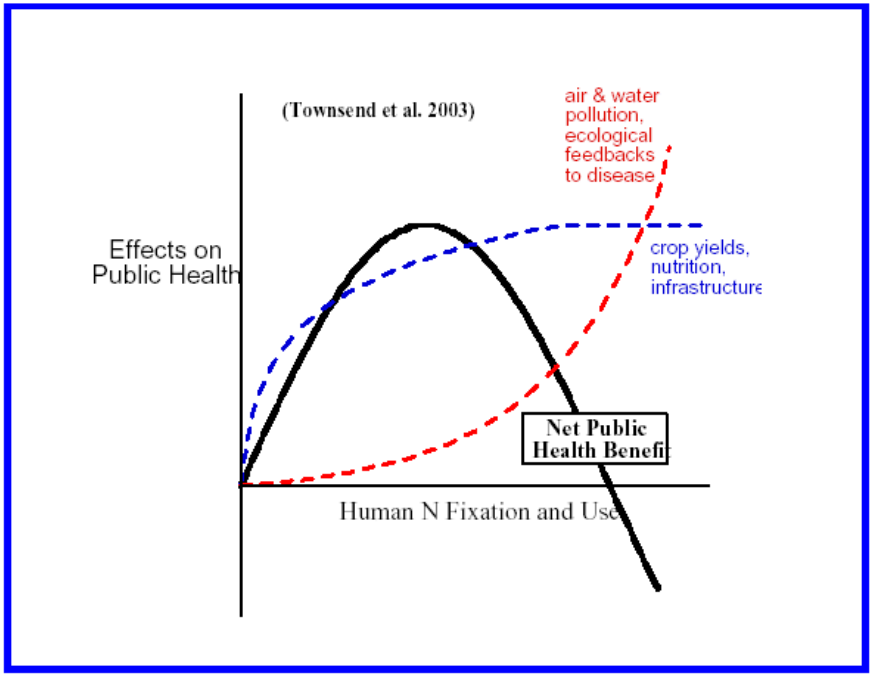
The world population is growing…

…while land useable for farming is in decline



Another wicked problem

- The imbalance between population and farm land has been overcome by increased efficiency in farm output driven by the use of fertilizers
- Worldwide nitrogen-use-efficiency (NUE) is said to be less than 50 %.
- The remainder of the N is left to enrich the atmosphere as well as ground and surface water.



NATIONAL ACADEMY OF ENGINEERING
OF THE NATIONAL ACADEMIES

CHALLENGES | IDEAS | NEXT STEPS | COMMITTEE

NAE GRAND CHALLENGES FOR ENGINEERING

Grand Challenges

- Introduction
- Make solar energy economical
- Provide energy from fusion
- Develop carbon sequestration methods
- **Manage the nitrogen cycle**
  - Where to reduce nitrogen first?
- Provide access to clean water
- Restore and improve urban infrastructure
- Advance health informatics
- Engineer better medicines
- Reverse-engineer the brain
- Prevent nuclear terror
- Secure cyberspace
- Enhance virtual reality
- Advance personalized learning
- Engineer the tools of scientific discovery

Home > Grand Challenges > Manage the nitrogen cycle

Manage the nitrogen cycle

Engineers can help restore balance to the nitrogen cycle with better fertilization technologies and by capturing and recycling waste.

It doesn't offer as catchy a label as "global warming," but human-induced changes in the global nitrogen cycle pose engineering challenges just as critical as coping with the environmental consequences of burning fossil fuels for energy.

Why is the nitrogen cycle important?

The nitrogen cycle reflects a more intimate side of energy needs, via its central role in the production of food. It is one of the places where the chemistry of the Earth and life come together, as plants extract nitrogen from their environment, including the air, to make food. Controlling the

INTERVIEW CLIPS

Committee members explain how lots of nitrogen can be too much of a good thing.

Nitrogen management enabled the green revolution, but there are side effects.

Excess nitrogren can cause major problems in rivers and coastal waters

WHAT DO YOU THINK? Where do we start?

IMAGE GALLERY

Managing the nitrogen cycle - image gallery

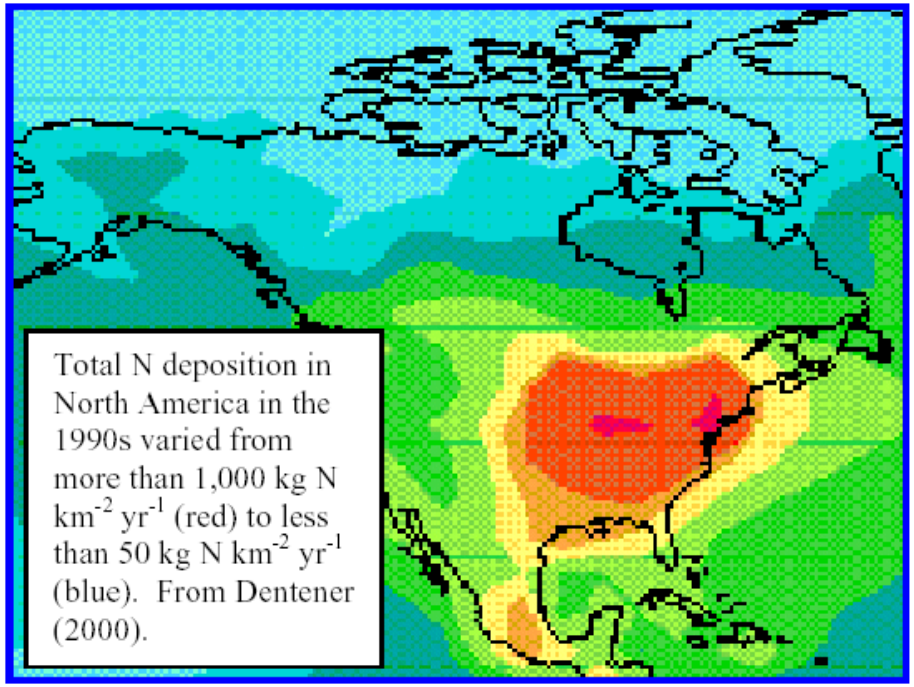
http://www.engineeringchallenges.org/

- The benefits of efficient N application are two-fold:
  - minimize pollution of groundwater
  - optimize profits for producers
- Proper assessment of within–field crop variability is critical for improvement of NUE.

Increase in nitrogen flux in rivers due to human activities for key contrasting regions of the world:

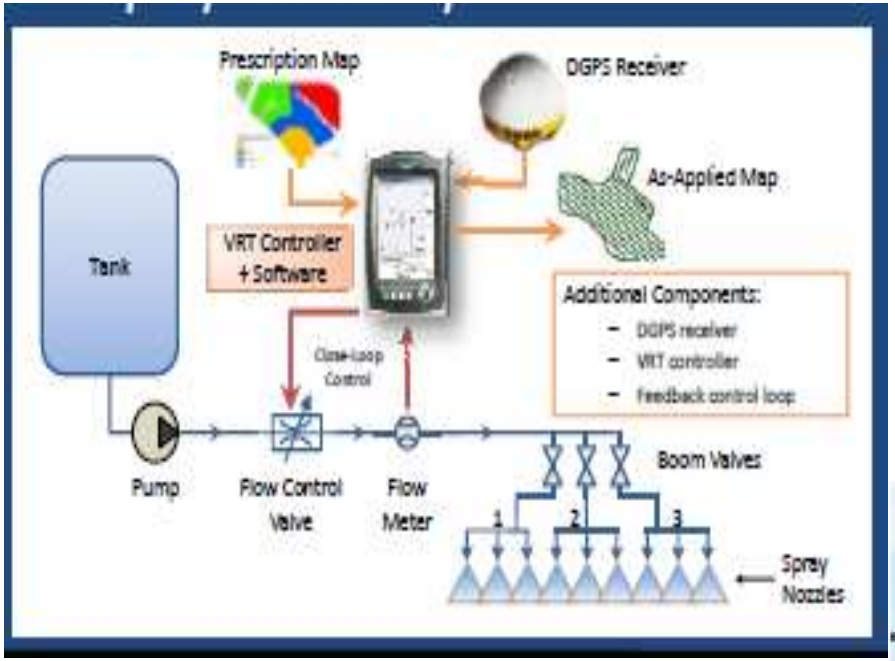
Labrador & Hudson's Bay	No change
Southwestern Europe	3.7-fold
Great Lakes/St. Lawrence basin	4.1-fold
Baltic Sea watersheds	5.0-fold
Mississippi River basin	5.7-fold
Yellow River basin	10-fold
Northeastern US	11-fold
North Sea watersheds	15-fold
Republic of Korea	17-fold

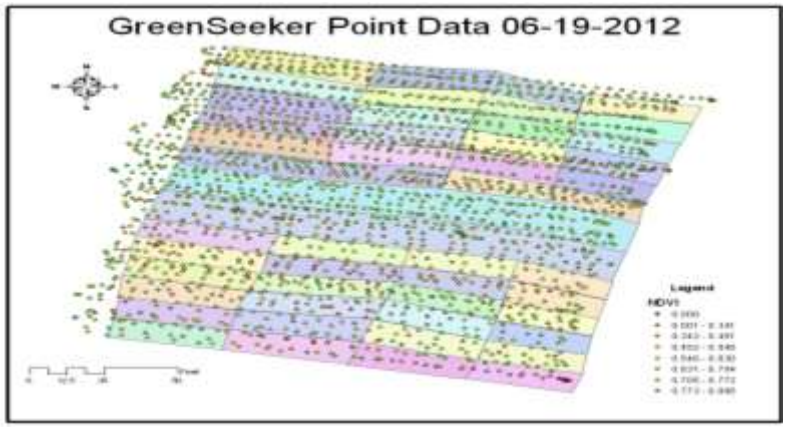
(Regions in North America are in red).
(Howarth 2003)

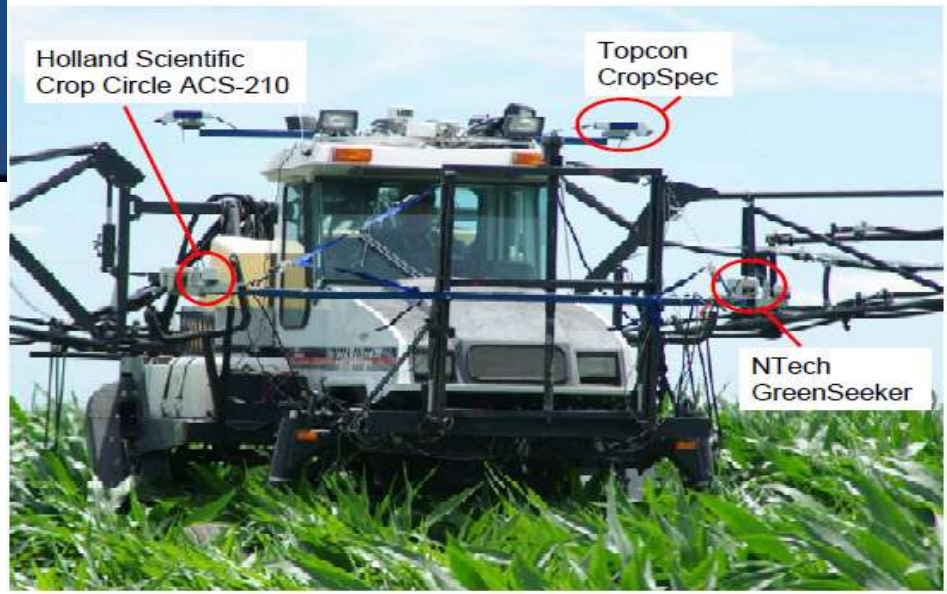


Total N deposition in North America in the 1990s varied from more than 1,000 kg N km^{-2} yr^{-1} (red) to less than 50 kg N km^{-2} yr^{-1} (blue). From Dentener (2000).

Applied Research and Field Experiments utilizing Variable Rate Nitrogen Application, Remote and In Situ Sensing and Drought Tolerant Corn Seeds







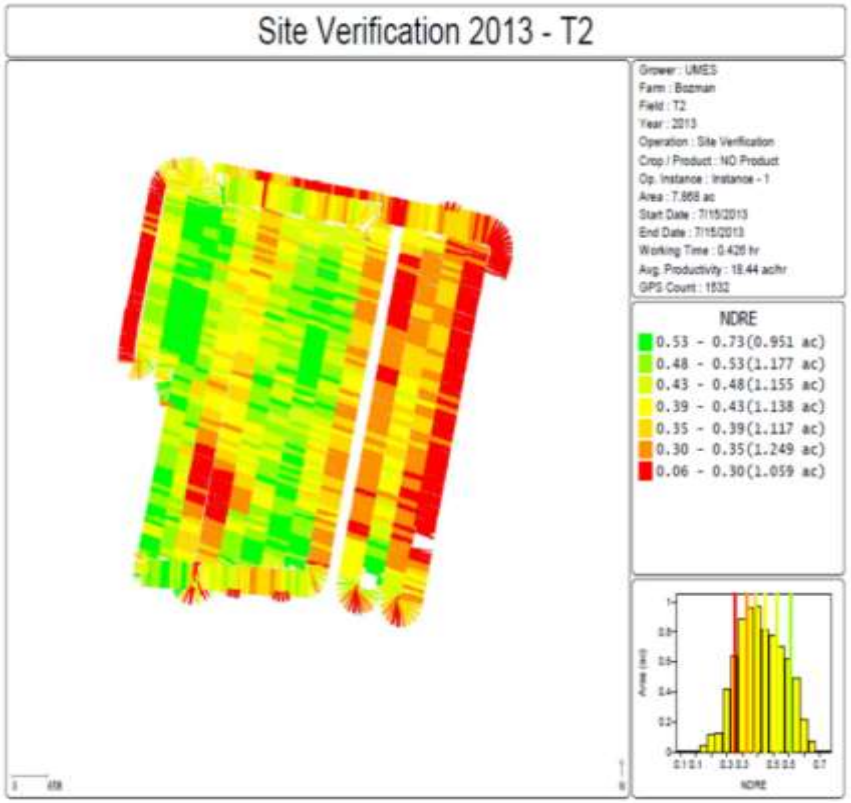
http://ag.topconpositioning.com/sites/default/files/ASABE_1111261_Sudduth_whitepaper.pdf

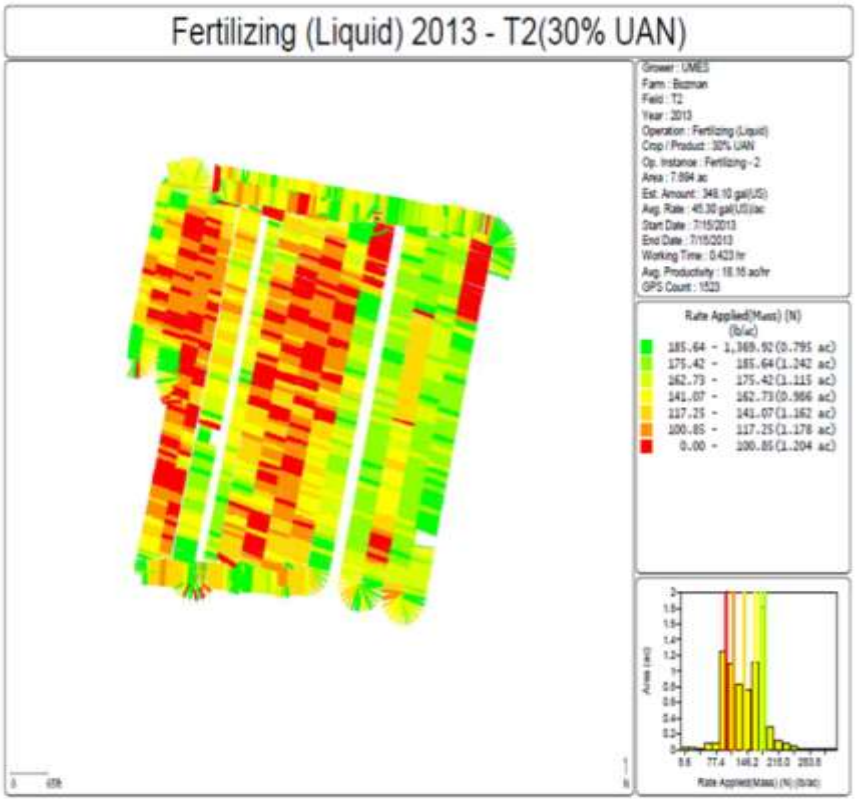
OPTRX SENSORS – VARIABLE RATE SPRAYER

Individual OptRx Active Sensor

OptRx sensors are active sensors that can shine light centered on 670nm (red), 730nm (red_edge) and 780 nm (near-infrared) wavelengths and record reflectance from the crop canopy to determine VIs (vegetation indices) such as NDVI ($\frac{NIR-RED}{NIR+RED}$) and NDRE ($\frac{NIR-RED\_EDGE}{NIR+RED\_EDGE}$) indicative of crop biomass and nutrient stress.

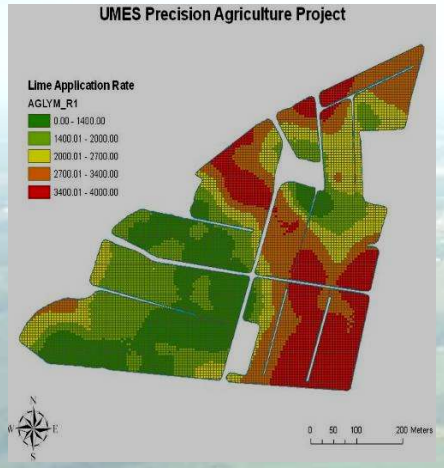
VARIABLE RATE NITROGEN APPLICATION – FIELD TRIAL (2013)



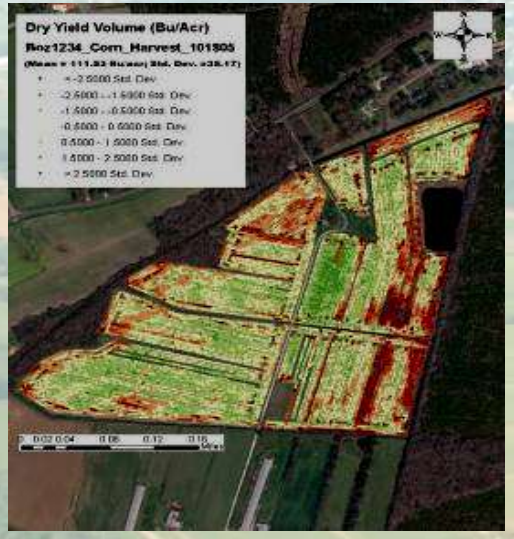


Sensed NDRE (left) and applied N maps (right) using Ag Leader SMS software

Aerial Image and Yield Map

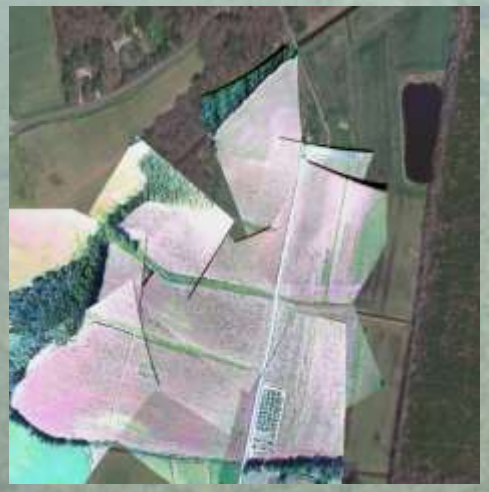


Bozman



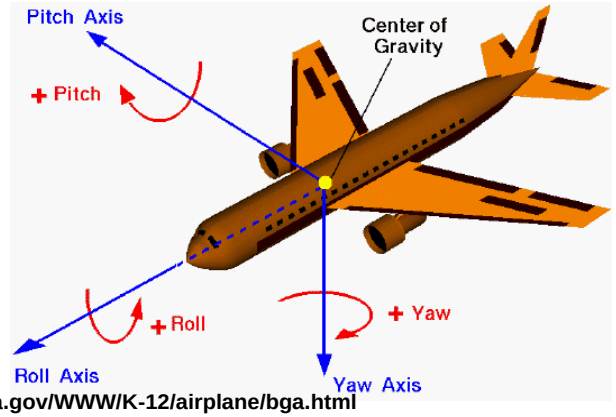
Bozman -Corn

Ent Farm



Principles of Aerial Imagery

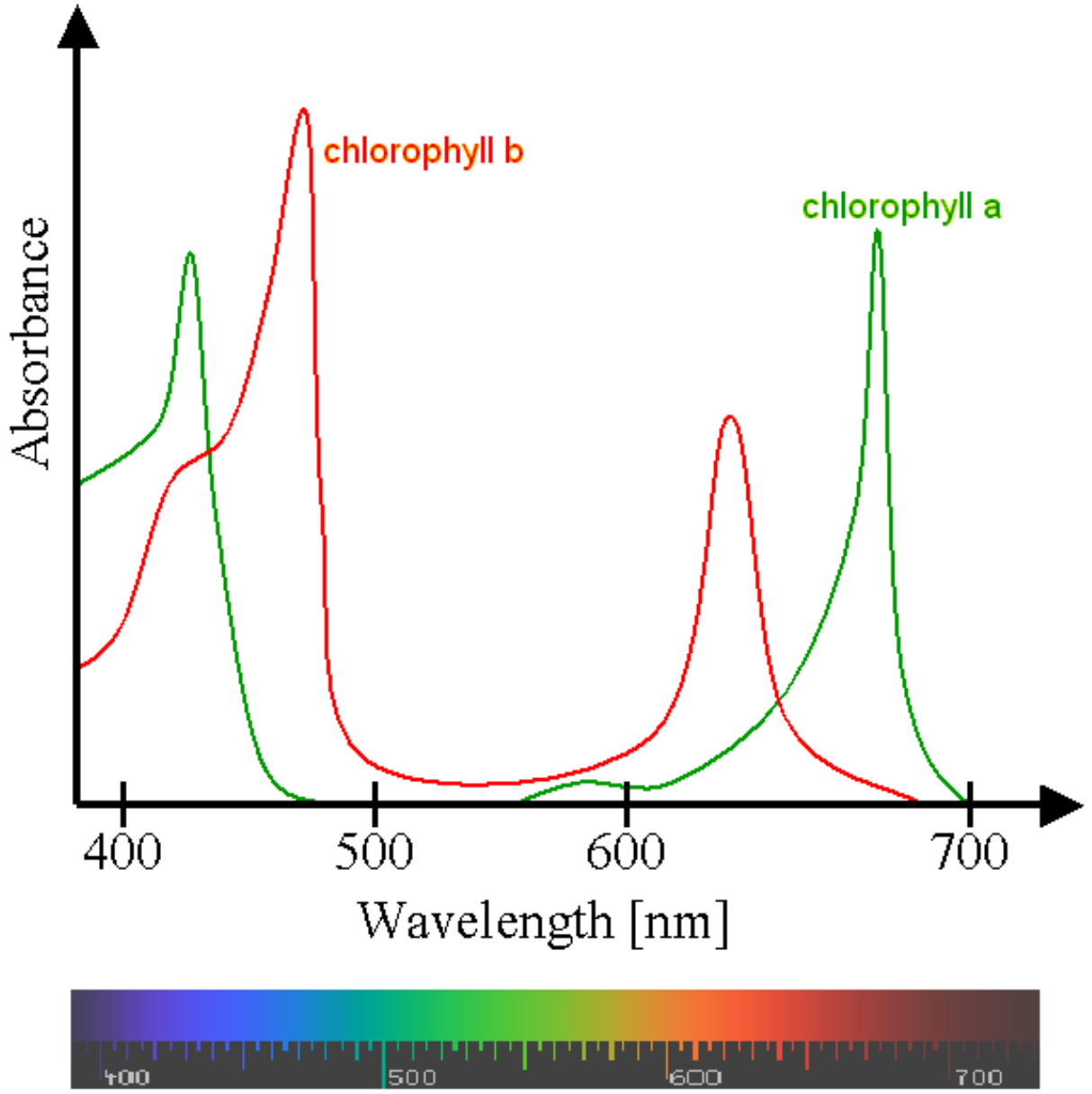
- Fly aircraft over areas of interest with a nadir view camera
- Bodies in flight are not always level
- Induced error from motion in:
  - Pitch
  - Roll
  - Yaw



http://www.grc.nasa.gov/WWW/K-12/airplane/bga.html

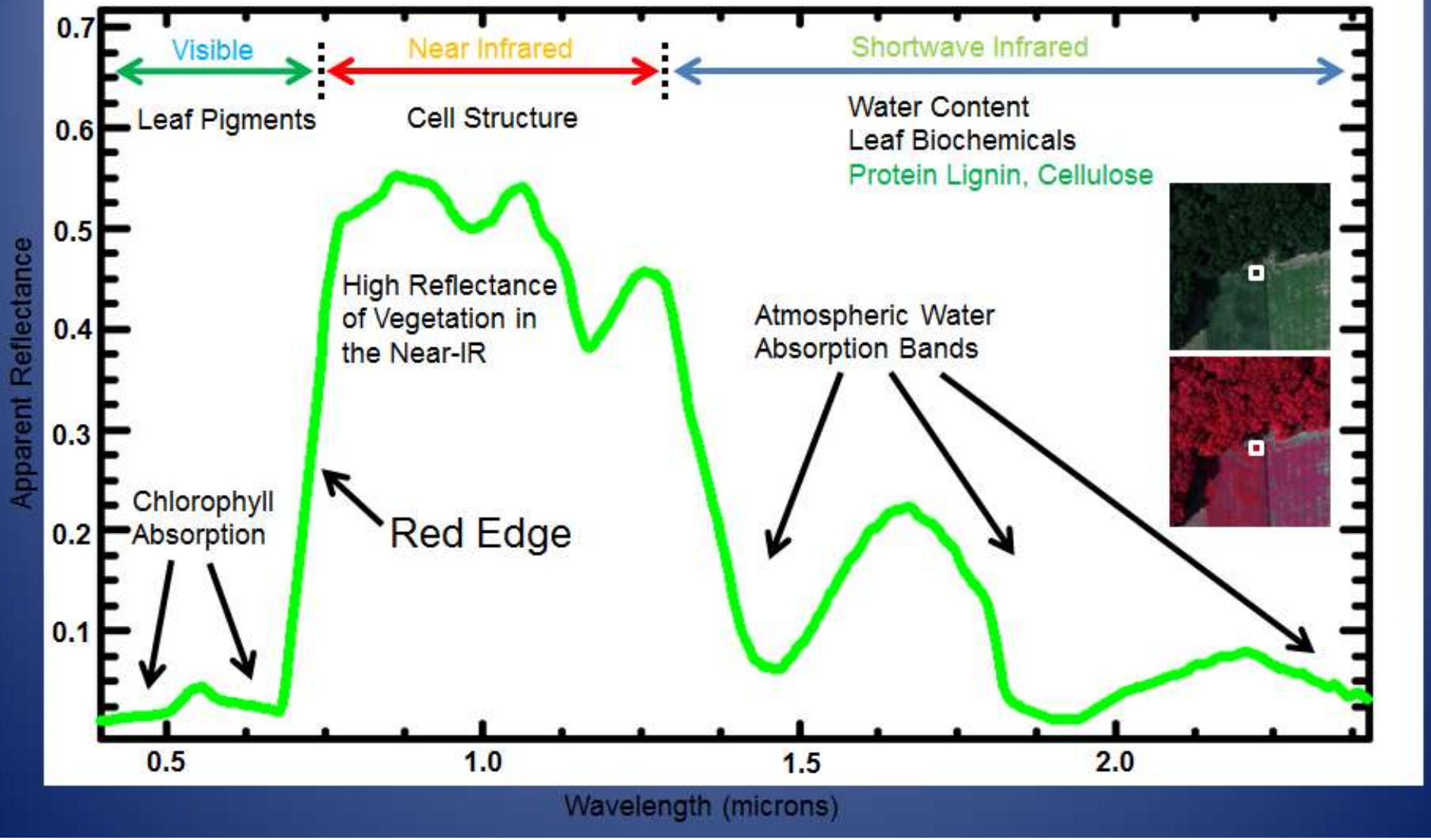
Relevance of Aerial Imaging in Precision Agriculture

•Aerial Imagery provides users with insight into crop health studies, yield estimates, land use patterns studies.



http://www.open-terrain.org/uploads/LibGrid/Chlorophyll-Spectra.png

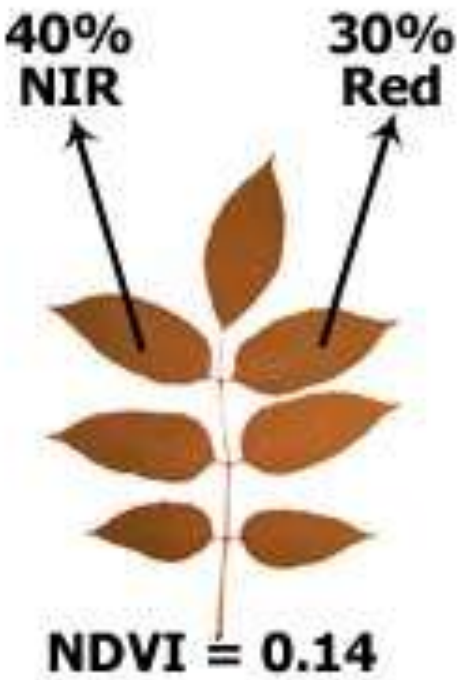
The Vegetation Spectrum in Detail



http://www.markelowitz.com/Vegetation-Spectrum.png

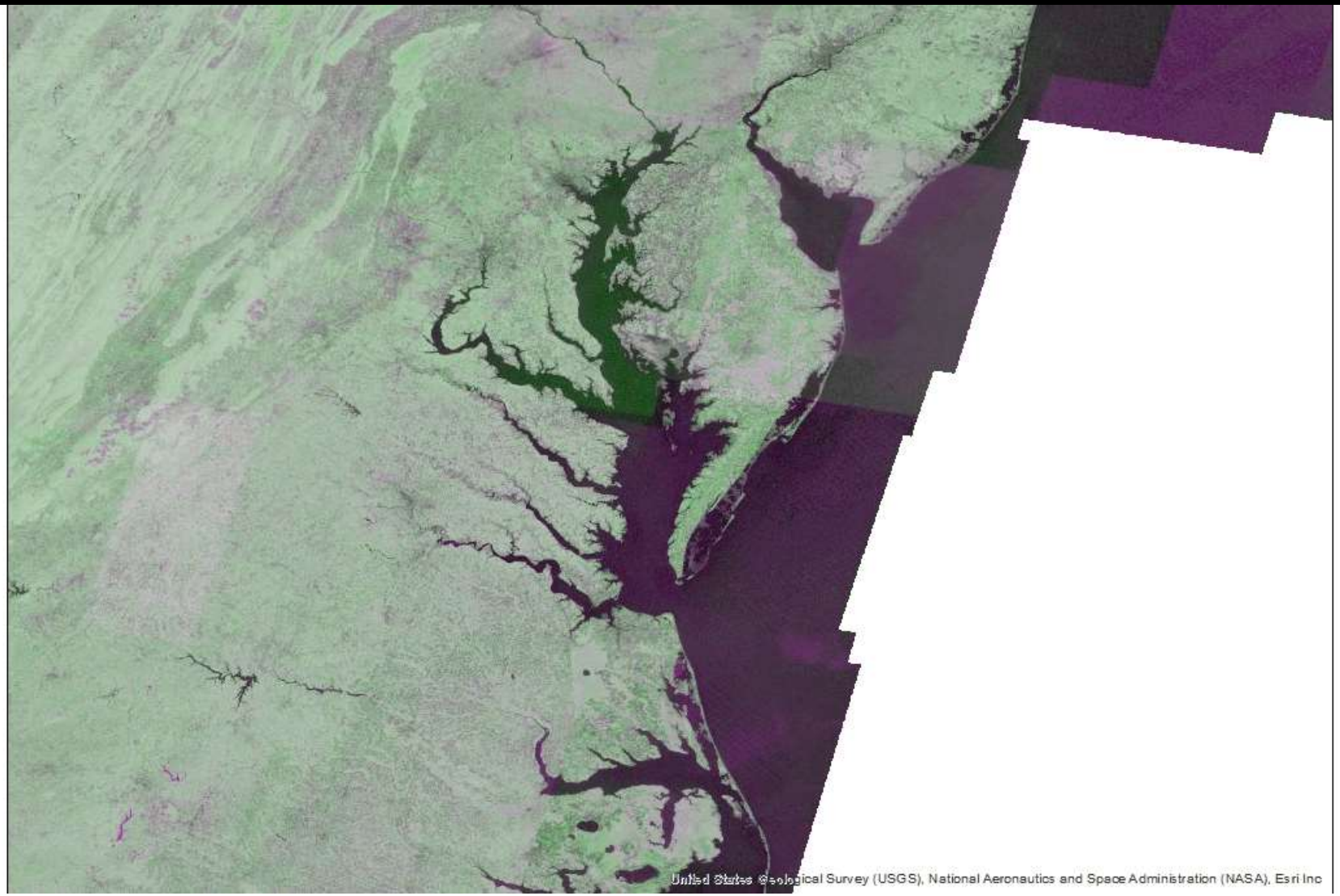
Heathy Vegetation Reflectance

Stressed Vegetation Reflectance



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

Landsat NDVI Change 1975-2005



Areas that show up green were brighter in 1975 (meaning more vigorous vegetation), while areas that show up in magenta were brighter in 2005 than 1975.

Undergraduate Multidisciplinary Earth Science Airborne Instrumentation Research

UMES-AIR

Collaboration with the University of Maryland Eastern Shore

Student UAVS

Introductory Trainer

Primary Trainer

Remote Sensing
(Visible-Video) UAV

Remote Sensing (Vis/NIR) and
Atmospheric Profiling (T/RH/P) UAV

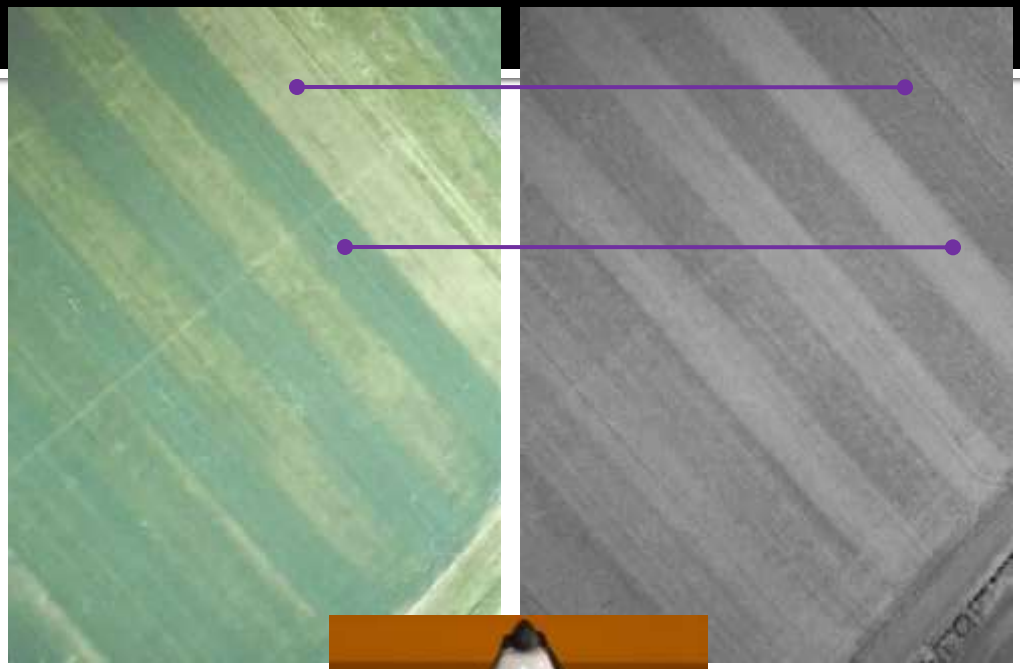
Intermediate Trainer

Advanced Trainer

Aerial Imaging Platforms

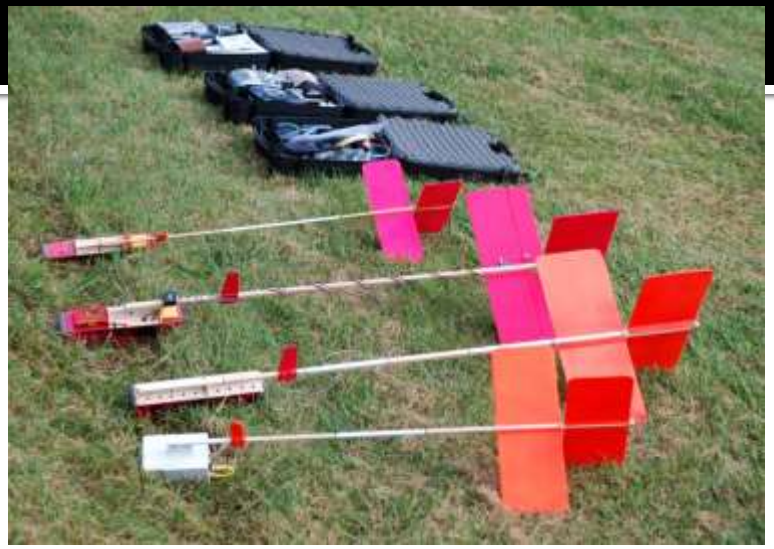
- Rotomotion Robotic Helicopter
- ImageAire Lite II
- RC Light Trainer
- TerraHawk Equipped Cessna 172F
- TwinCam

TwinCam



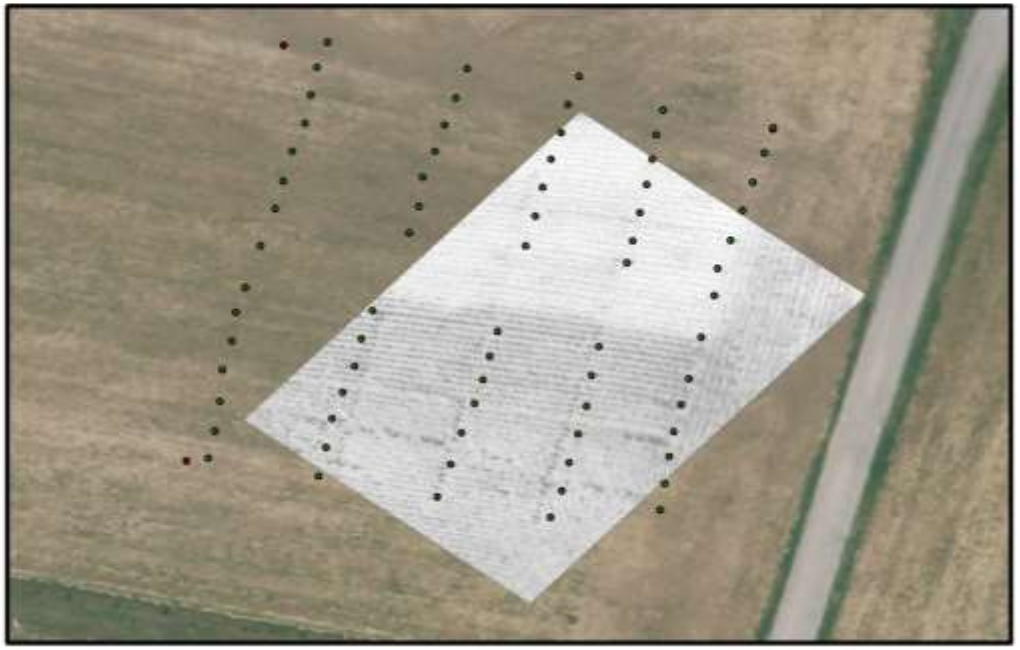
- Low-Cost Video Cameras: Color and Near-Infrared for Normalized Difference Vegetative Index (NDVI)
- With UMES Natural Sciences & Engineering and Aviation Sciences Departments

AEROKATS



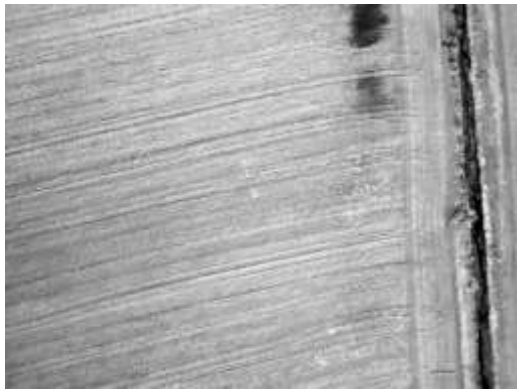
With *AIRSPACES* – MD Space Grant, USDA project: Dr. Nagchaudhuri, et al

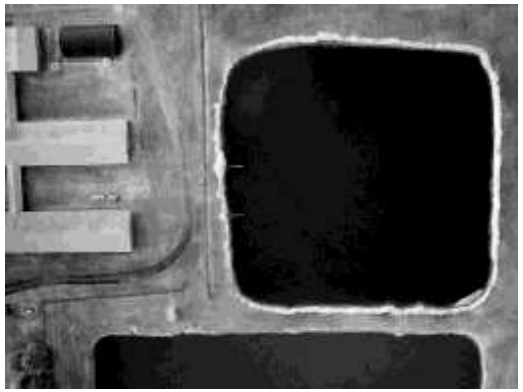
NDVI image acquired with kite-based TetraCam
July 18, 2012



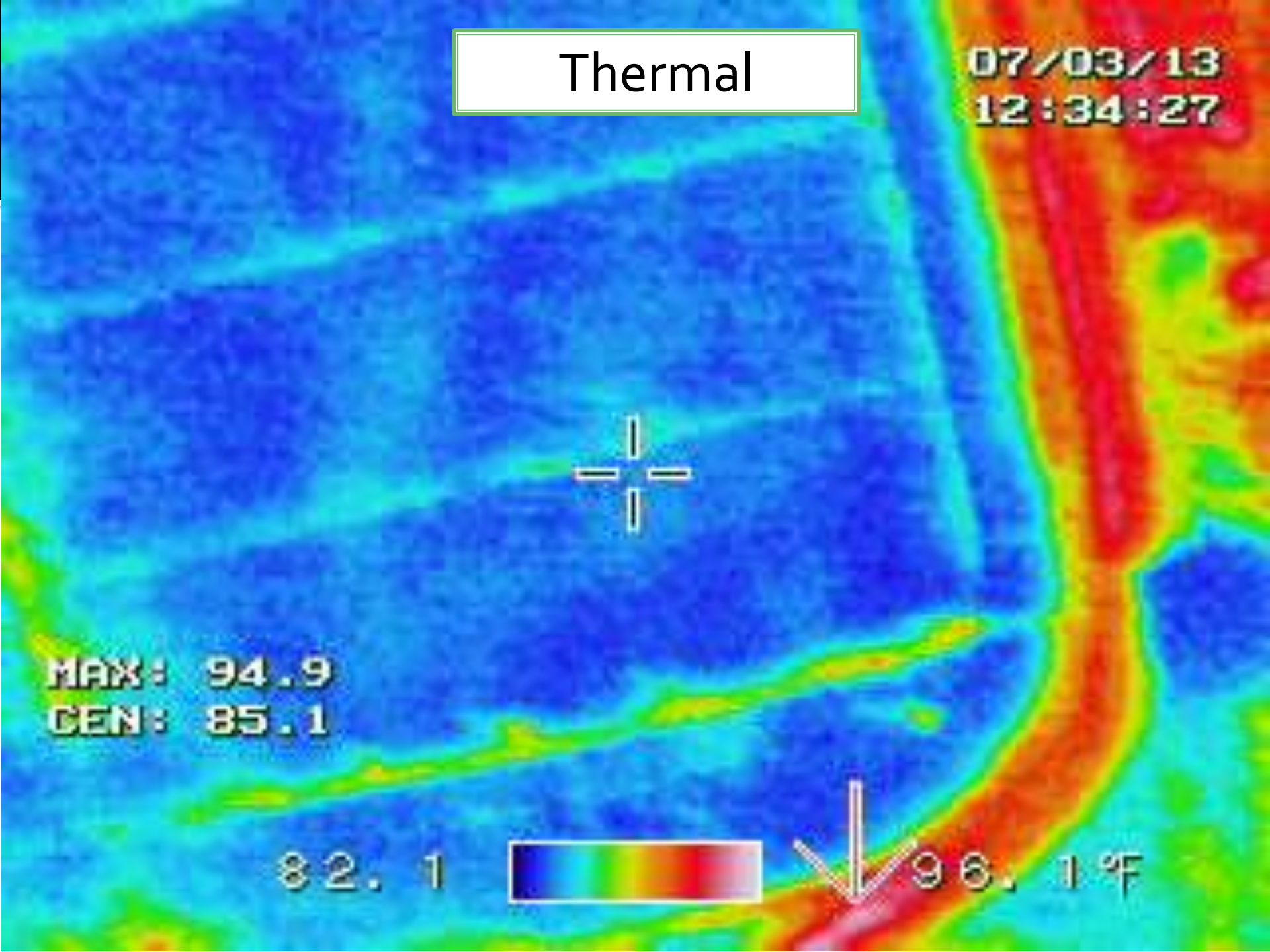
Visible Image acquired with kite-based OmniCam
June 28, 2012

The New *TwinCam*






Visible

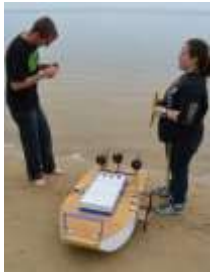

Thermal
07/03/13
12:34:27
MAX: 94.9
CEN: 85.1
82.1
96.1 °F

Remotely Operated Vehicle for Environmental Research

ROVER

(Bland, Miles/610.W)

- Multidisciplinary Project with the University of Maryland Eastern Shore (UMES) Engineering & Aviation Sciences, Biology, Computer Science Students and Faculty
- Fabrication and Instrumentation Classroom Activities
- Deployments to Chincoteague and Chesapeake Bays



NASA

UNIVERSITY of MARYLAND EASTERN SHORE

GIS, GPS, Precision Ag & Remote Sensing

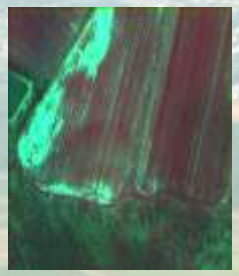
- Geographic Information System (GIS)
  - Geospatial Data Management, Display and Analysis Software
- Global Positing System (GPS)
  - Constellation of 24 Satellites that transmits signal to ground based receivers

GPS Satellite (Courtesy of NASA)

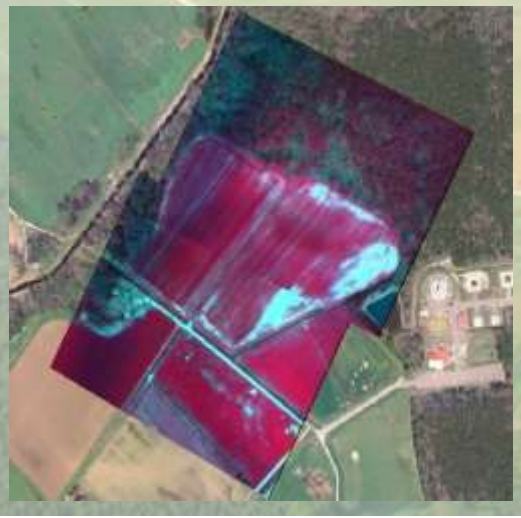
GPS Receiver

GIS Map of GPS points

AERIAL IMAGING USING – TERRAHAWK CIR CAMERA SYSTEM



NDVI = (NIR – RED)/(NIR + RED)

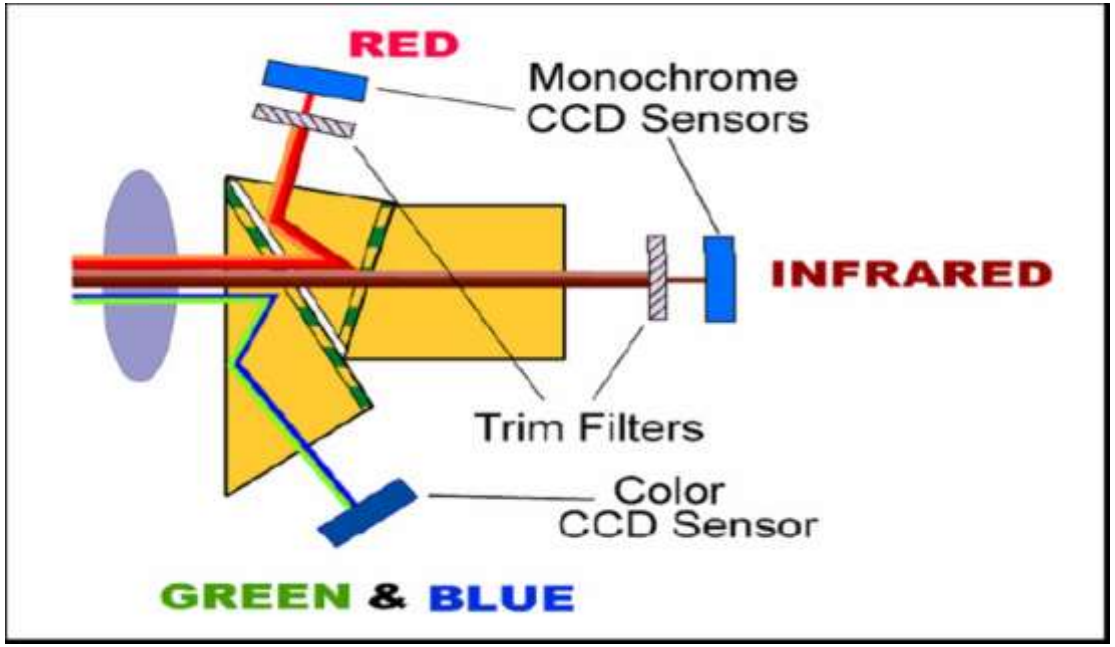


Manned Aircraft

Cessna 172 modified for carrying the TerraHawk Aerial Imaging system

Fig. 1 System Layout

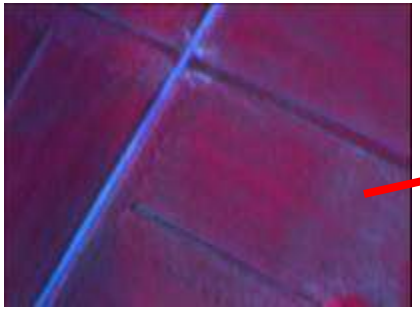
Fig. 2 Computer Port Panel




N
W
E
S
0
0.1
0.2
0.4 Miles

Image Processing

- Georeferenced
- Mosaicked
- Color balanced

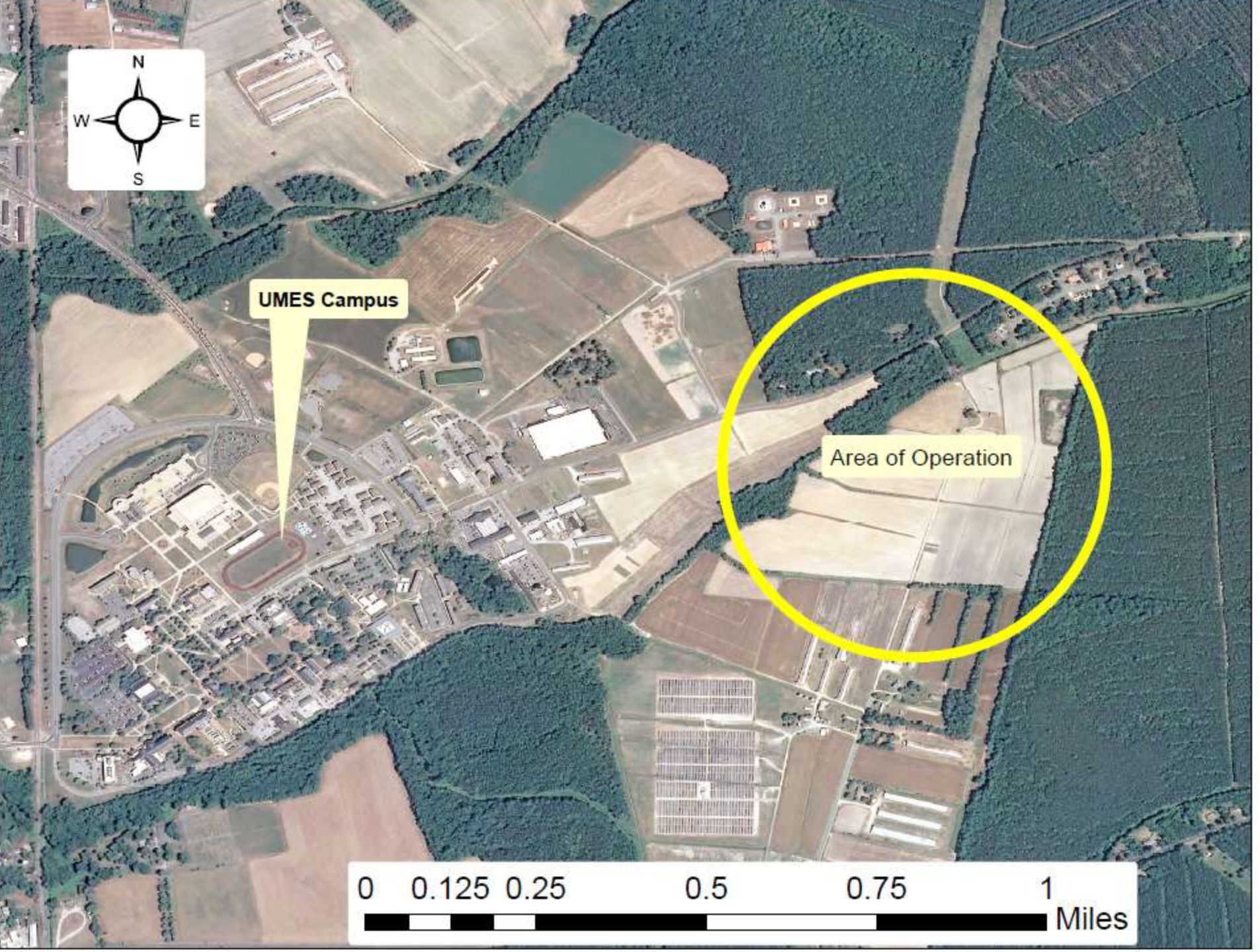


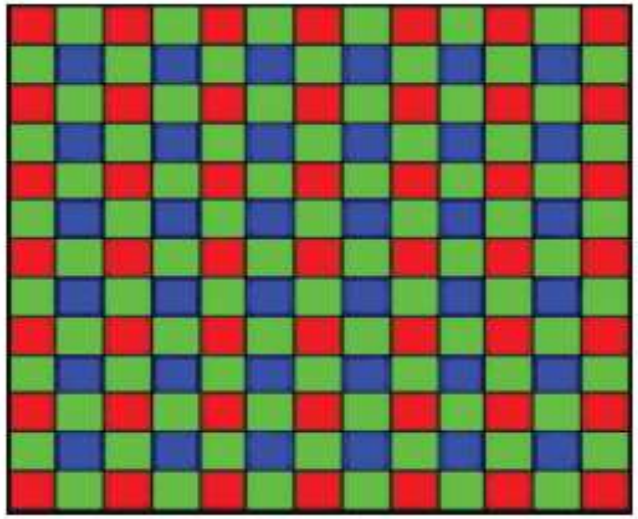
RECTIFICATION AND GEOREFERENCING

- **Software tools : ARCGIS and MATLAB**

3DRobotics X8

- FAA COA approved July 1, 2014
- 3DRobotics X8 with Tetracam ADC Lite
- Series of test flights with first data acquisition on July 10

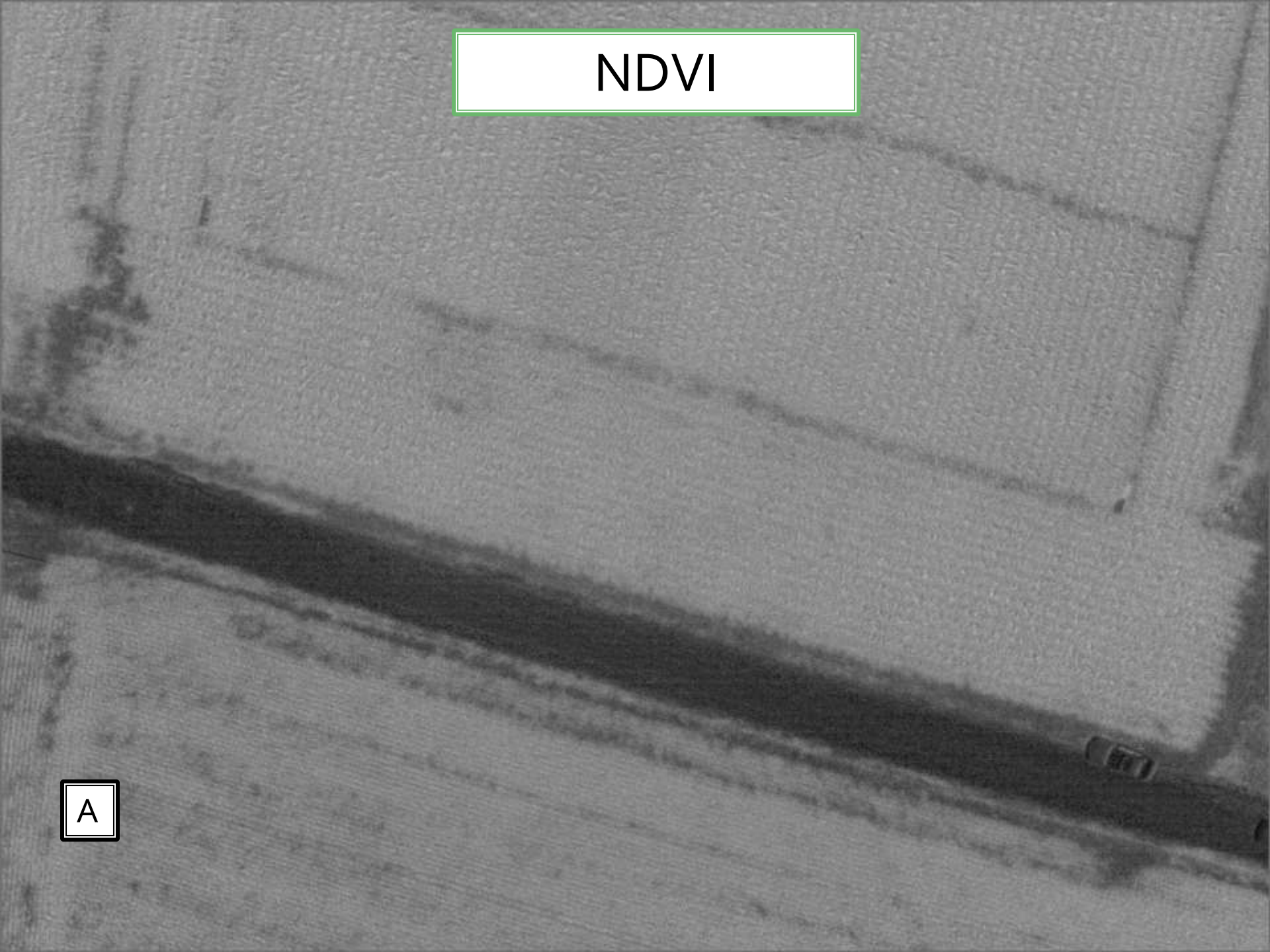

N
W
E
S
UMES Campus
Area of Operation
0 0.125 0.25 0.5 0.75 1
Miles

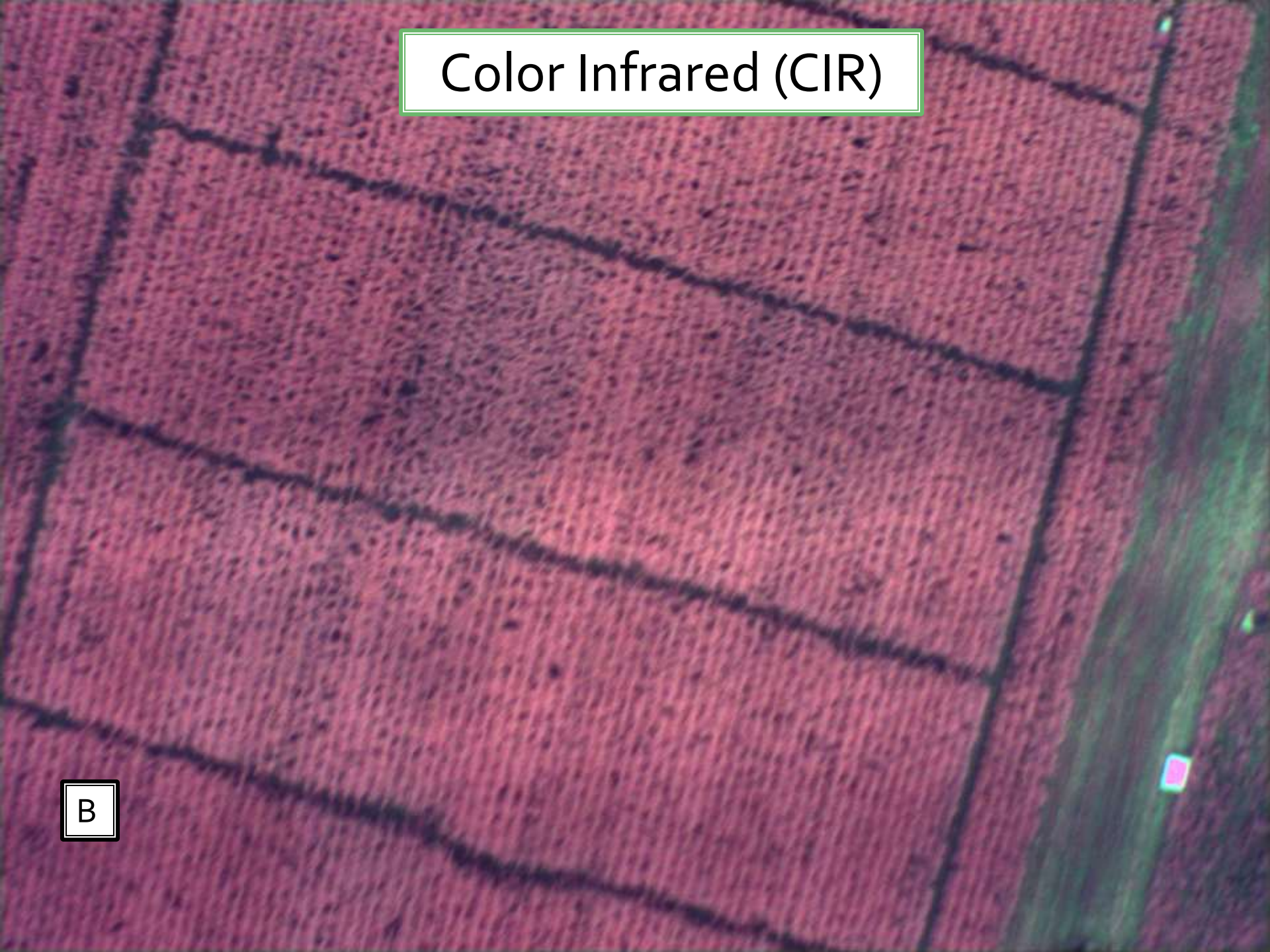


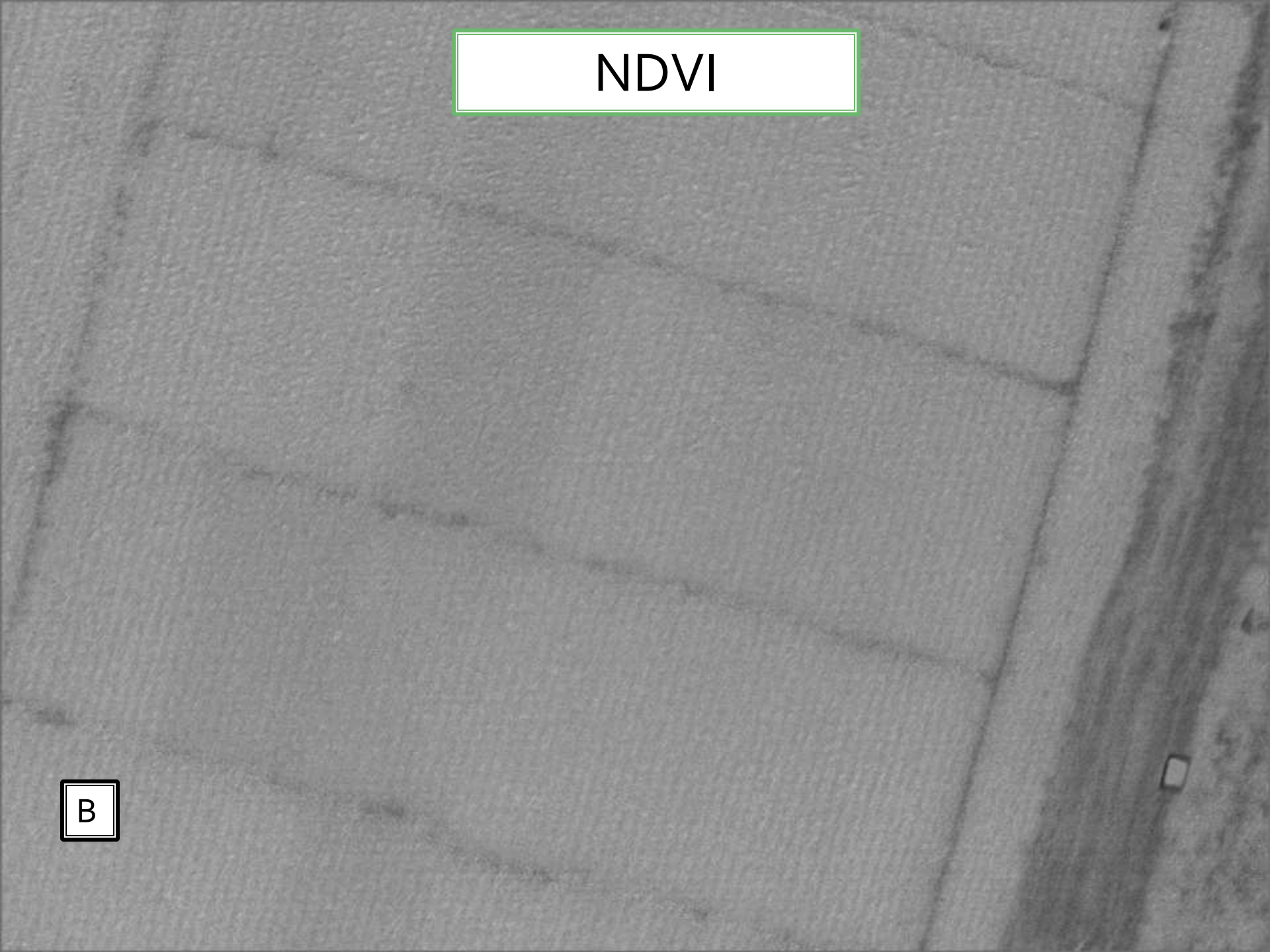
Bayer interpolation. A mosaic of tiny filters is placed over the array of detectors. Each pixel receives NIR, RED or Green (shown for RGB) light in the pattern shown.

The ADC Lite contains a single 3.2 megapixel Complementary Metal Oxide Semiconductor (CMOS) sensor (single array with Bayer pattern filters)optimized for capture of visible light wavelengths longer than 520 nm and near-infrared wavelengths up to 920 nm.

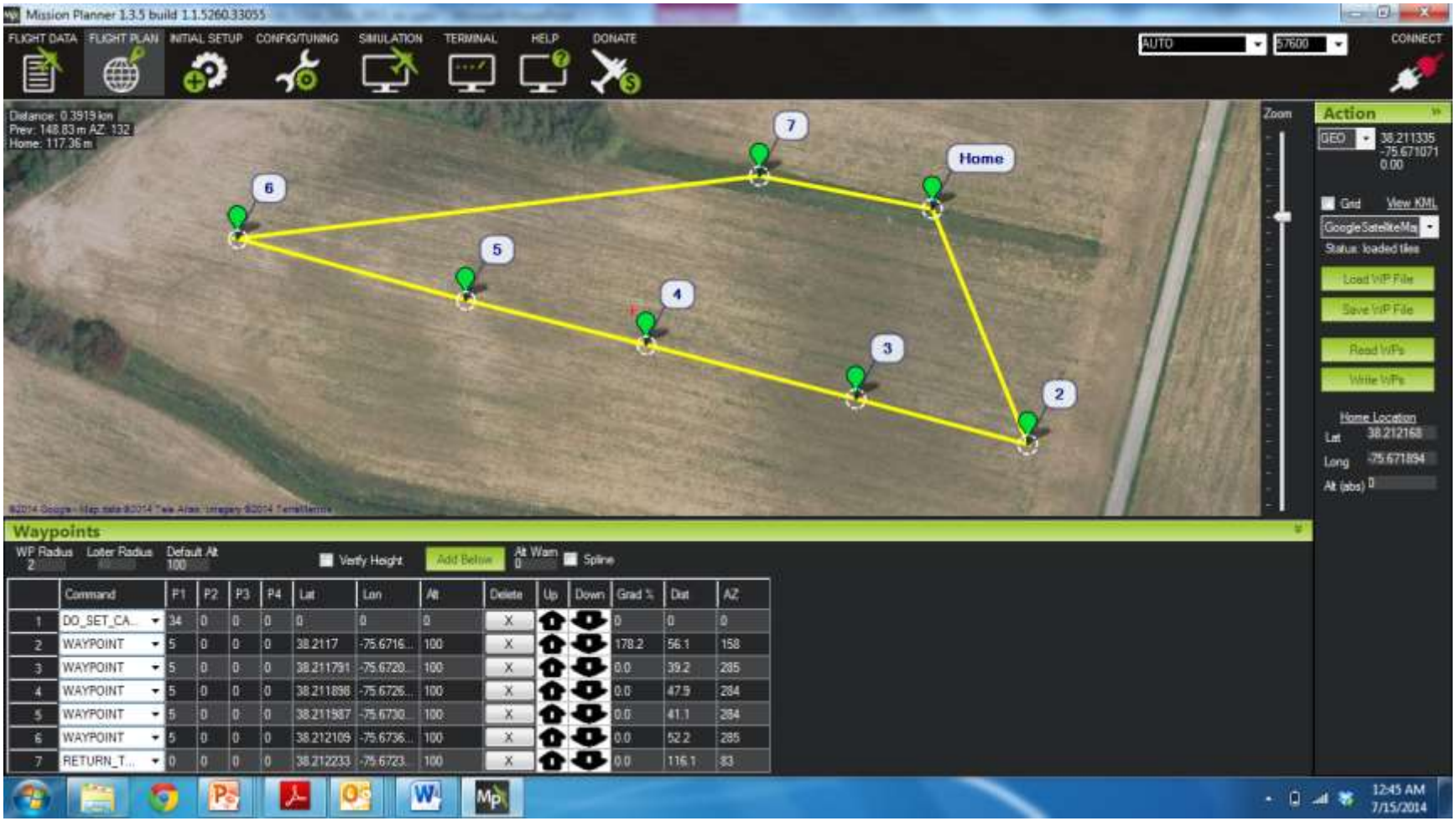

Color Infrared (CIR)
A


NDVI
A

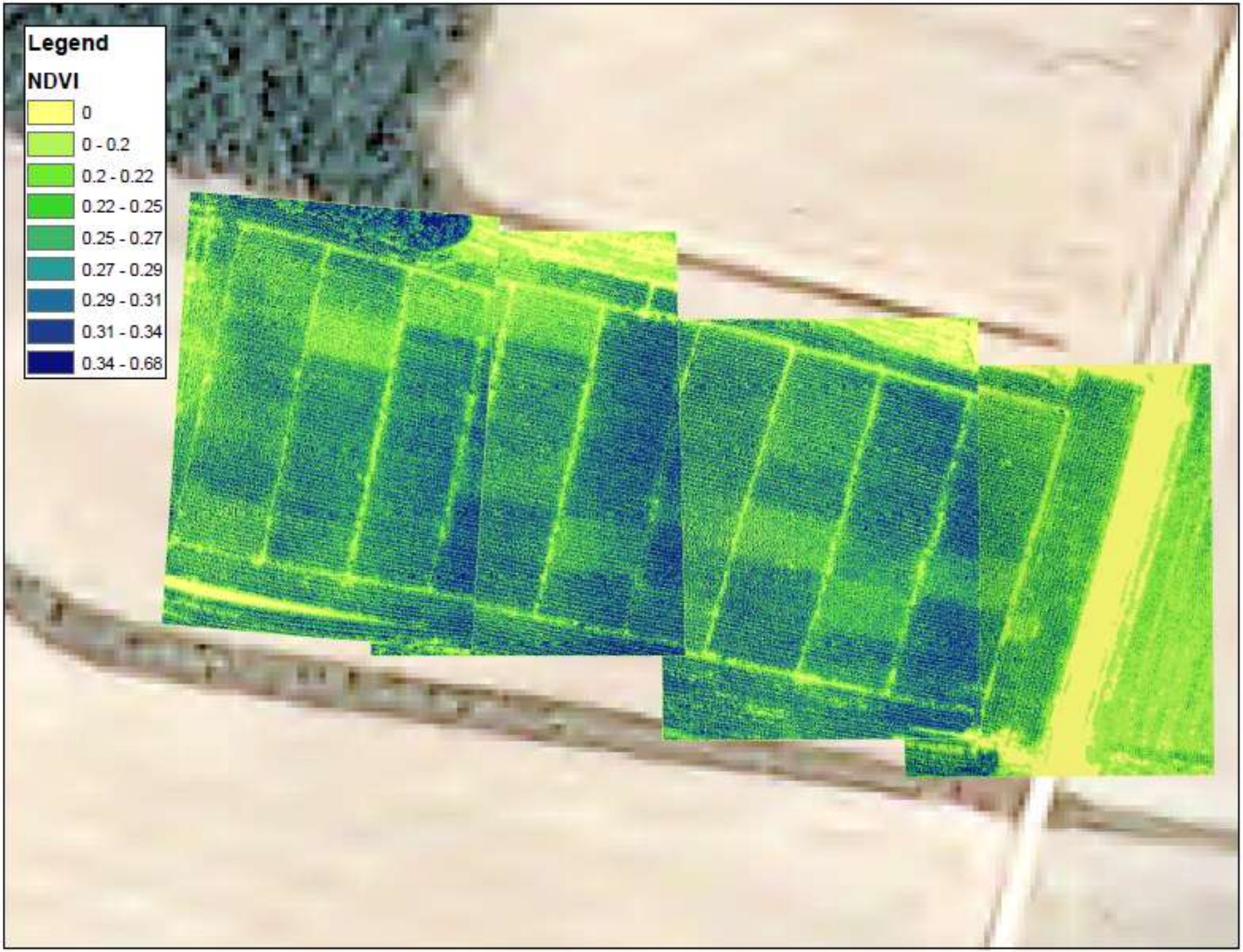

Color Infrared (CIR)
B


NDVI
B

Mission Planner




6
7
Home


Legend
NDVI
0
0 - 0.2
0.2 - 0.22
0.22 - 0.25
0.25 - 0.27
0.27 - 0.29
0.29 - 0.31
0.31 - 0.34
0.34 - 0.68

Opportunities and Challenges

- Safe and efficient data collection
  - Aviation Program
    - Procedures, mission planning, resource management
  - Agriculture and Environmental Sciences
- Data processing to create meaningful and actionable products to end users at a marketable price
  - Increase productivity
  - Drive down the cost of utilization
- Compliance with FAA requirements

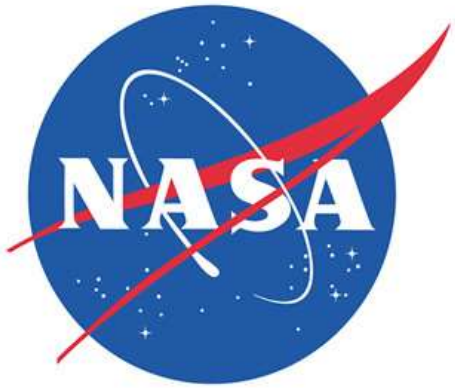
Train the Pilot

- 1972
  - Commercial Pilots – 196K
  - Private Pilots – 320K
- 2011
  - Commercial Pilots – 123K
  - Private Pilots – 195K

- Source : AOPA

Acknowledgements

- USDA Capacity Building Grant
- MDSGC
- Geoff Bland and Ted Miles of NASA
- Dr. Craig Daughtry of USDA



Questions/Discussion

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