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Remote Sensing Application in Agronomy and Crop Management

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Agenda

- Data Collection
  - Drones/UAS/UAV
  - Fixed Wing
    - Light Aircraft
    - High Performance Aircraft
  - Satellite
    - Commercial
    - Micro/Small Sat……
- Imagery
  - Thermal
  - Hyper-Spectral
  - Multi-Spectral
- Agronomy & Crop Management
  - How do you use imagery
  - Examples

Drones

Many Shapes and Sizes

Drones

$700 Mil invested in Drone Companies in 2015-2016, any successes??

I continue to ask three questions:

1. What is their economics of scale?

   200 – 300 acres per day (pilot, observer, pickup)

2. Quality of data?

   Small images that you have to mosaic

   Single CMOS/Interline transfer/frame grabber

   Garbage in-garbage out!! (software does not fix bad imagery)

3. To growers: “do you need another job?”

Drones: GeoG2 Tested

$400K including ITAR flight control

$1.5 Mil ITAR flight control

You can out perform any of these with a Cessna 150 at a fraction of the cost!

Satellite programs (the Littered Field)

Satellite: Commercial Over $3 Billion invested!

Cropix – Dead, Spot imagery too expensive despite government subsidy

R21 – Dead, plan to launch a constellation of satellites for AG, blew through $20+ million

Space Imaging – Lockheed satellite system and yes the target was the AG market.

Digital Globe – Followed Space Imaging, found government markets

Airbus Group - Pleiades & SPOT trying to attract the Ag market

RapidEye – German example of Solyndra, $450M invested sold for $18M to Blackbridge. Then sold to Planet (Labs) for $22 mil. 6-20 meter resolution. Staff of 140 to manage operations.

Satellite: Small/Micro Satellite (another $2.5 Billion invested??)

Planet Labs – Has Rapid Eye and plan to launch a constellation of Satellite (8 lost with SpaceX)

Terra Bella - the old SkyBox, Google is trying to sell it to Planet Labs after $500 mil investment?

Planet IQ – Mostly after weather and climate monitoring

Urthe Cast – Russian group attaching devices to international space station (HD video)

Blacksky – Small Sat, big data, disruptive tech……..seeks government support

Spire – Small Sat, bid data, disruptive tech……..seeks government support

Dauria Aero, Teledyne Brown, Tyuak Nano, Nova Wurks, GeoOptics,……

Satellite basic problem?

- Satellite systems are very expensive to develop, launch, and operate.
- 90% of your money goes into development and launch cost (like farming, mostly sunk cost!!)
- Slow adoption in the Ag Market has killed every program.
- Government has been the only savior!!
- LandSat has been free for 40 years and no one uses it! Macro information in a Micro world.
- 99.9 % of the time they are someplace else

Aircraft Operators

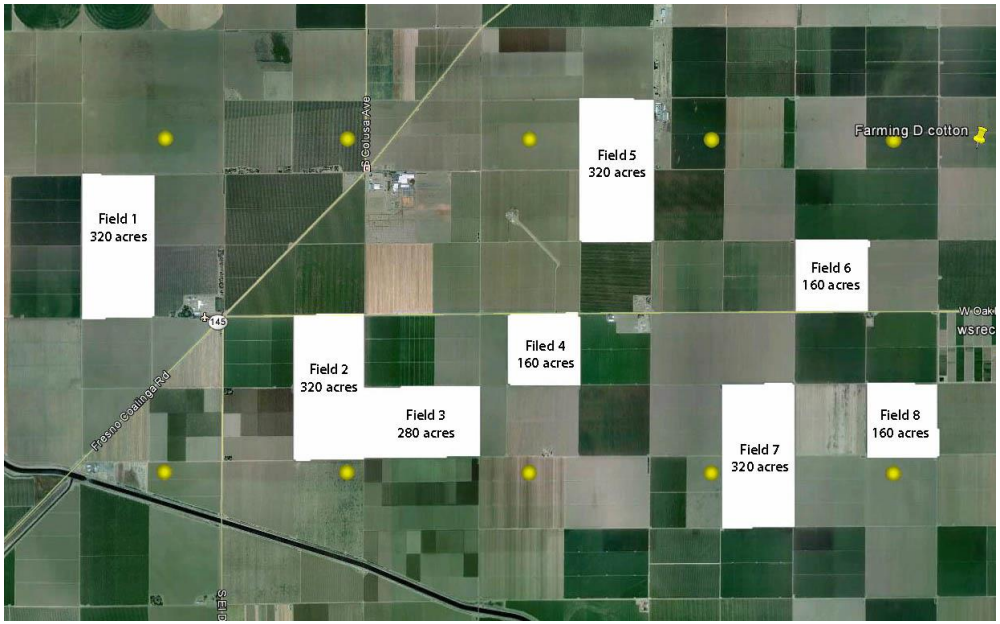
AccuScan – Dead, bunny hop, no profit and slow adoption made TRW quit.
AgRecon – Dead walking, thermal camera system (government support) Dave is still around
I²S (CropImage) – ADAR5500 camera in a light aircraft, my first venture into remote sensing in 1995
TASC (Emerge) – Defense engineers, guild to agriculture remote sensing failure later was rebranded at GeoVantage
Airborne Data System – Still operating with government contracts, mostly non-Ag
Airtime Aviation – First large area coverage operation, "why not to get into a partnership"
GeoVantage Still around, returned to founders after $50+ mil from John Deere
InTime – Individual field images. Died once, dying again, failed in California and has only limited operations in Mississippi
ThirdEye Imaging /Balboa Mapping– Operates R21 camera system in Texas and has partnered with Hemisphere GPS
Ceres: Stanford group flying light aircraft
TerrAvion: trying to decide between drones and fixed wing
MavRX: light aircraft flying individual fields (this may have been tried before??)
Others: **Gray Hawk, VineView, Eagle Digital Imaging, Blue Earth……**

High Performance Aircraft Model

Aircraft: Cessna Conquest II
Operating at 28,000' AGL
1.5-2 mil acres per day

Four 7,218 X 5,412 CCD
Array Cameras
.75 meter resolution
True multi-spectral

Agriculture Imagery Comparison



Sample Farm
2,040 acres
8 fields
24 sq mile area

GeoG2 – 10 images from 2 standard flight lines

Light Aircraft – 132 images from 6 flight lines

UAS – 8 days of flying, 4,230 images, 34 hours of processing

Satellite Pleiades – 1 tasked image 2+ meter resolution <5%clouds

Image Cost Comparison

Cost of raw (registered) imagery

High performance aircraft

Image Cost	$200.00		
Image Processing	$160.00		
Overhead (40%)	$140.00		
Total	$500.00	Cost per acre =	$.25*

Light Aircraft

Image Cost	$ 800.00		
Image Processing	$ 260.00		
Overhead (40%)	$ 424.00		
Total	$1,484.00	Cost per acre =	$.73

UAV

Image Cost (8 days)	$4,000.00		
Image Processing	$ 700.00		
Overhead (40%)	$1,880.00		
Total	$6,580.00	Cost per acre =	$3.23

Satellite –Pleiades (2 + meter resolution)

Image Cost	$3,300.00		
Image Processing	included		
Overhead (40%)	$1,320.00		
Total	$4,620.00	Cost per acre =	$2.26**

*There is an additional 13,320 acres of potential sales

** There is an additional 22,670 acres of potential sales

Agricultural Imagery Market

Who Sells Agriculture Imagery Services

Ag Service Companies
Equipment Dealers
Co-ops
Crop Consultants

Who Buys Agriculture Imagery Services

Growers
Agronomist (Crop Consultants)
Food Processors/Shippers
Real Estate/Lenders/Developers

Agricultural Imaging Adoption

GeoG2 has used two approaches:

Direct Sales: Large growers, usually with their own agronomy staff.

Channel Partners: We work with Ag Service Companies that have extensive sales staff and provide agronomy services to growers.

We have achieved very high repeat sales and slow but steady growth with new customers. I learned a long time ago that **a satisfied customer tells one friend but an unsatisfied customer tells everyone!!**

Agricultural Imagery Adoption

Keys to adoption of technology in AG:

- Seamless and transparent to end users
- Low learning curve, keep it simple
- Grower owns data
- Positive value proposition
- Low Cost (below the noise of production)

GeoG2 Approach to Agricultural Imagery

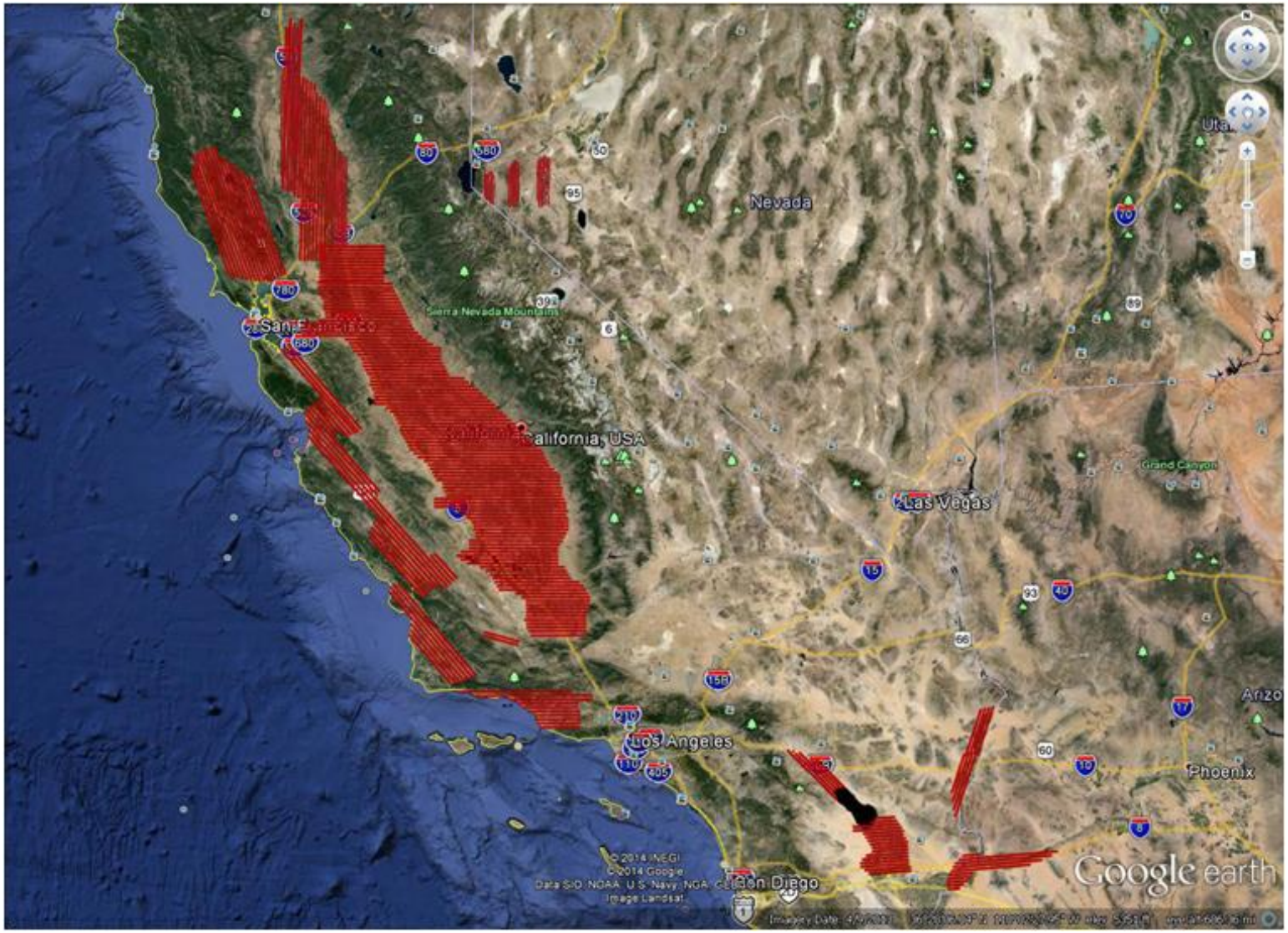
We look at imagery as a commodity and we have three objectives:

<u>Highest quality imagery</u> – To achieve this we built our four camera, full frame CCD array camera system that collects in full 16 bit. We used the largest monochrome CCD that was available in a camera system, continually upgrade system.

<u>Largest area coverage</u> – My philosophy has always been to fly high, fast, and cover the largest area possible. The Cessna Conquest II is one of the most efficient turbo-prop aircraft available.

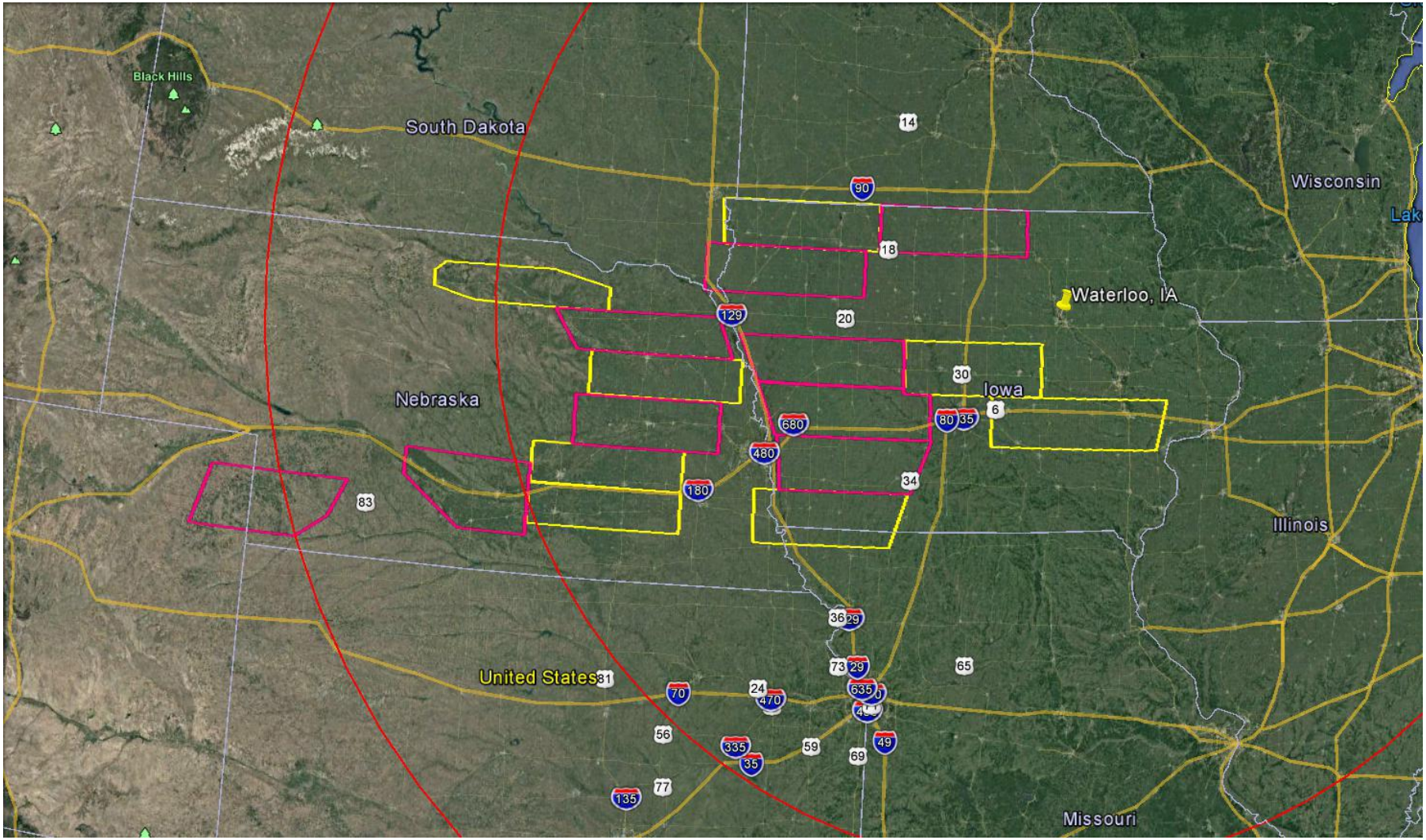
<u>Lowest cost</u> – Growers, like all customers, are looking for the best product and the lowest cost. I believe we have achieved that.

GeoG2 Flight Line California, Nevada & Arizona

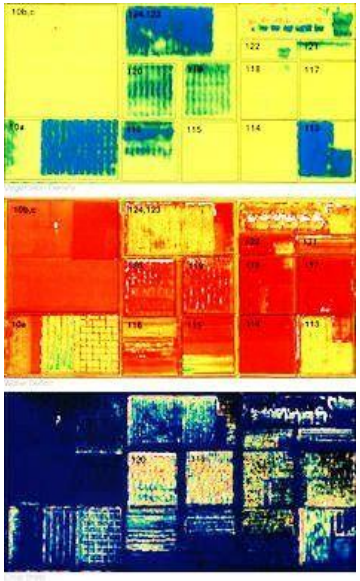


This represents 10 days of flights for GeoG2 Solutions

GeoG2 Flight Line in Mid-West for 2017



Types of Imagery - Thermal



Temperature reflectance of the surface

Sensors are small, the largest commercial are 1300X780 so you give up resolution or efficiency

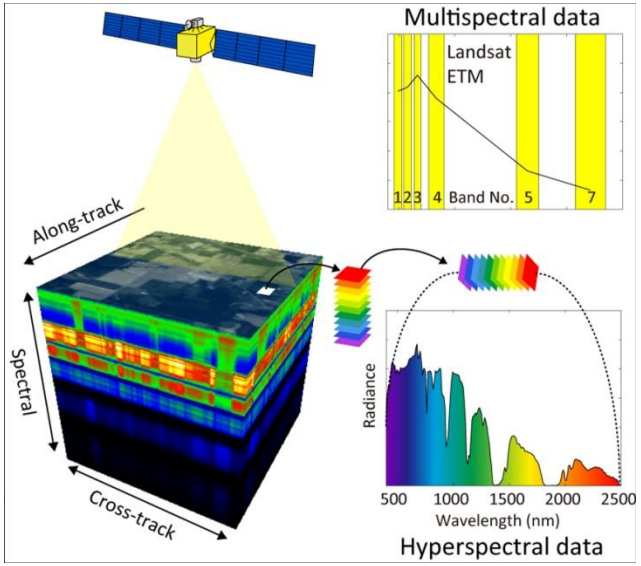
Good at detecting moisture in bare soil, but once you get full canopy you loose that advantage

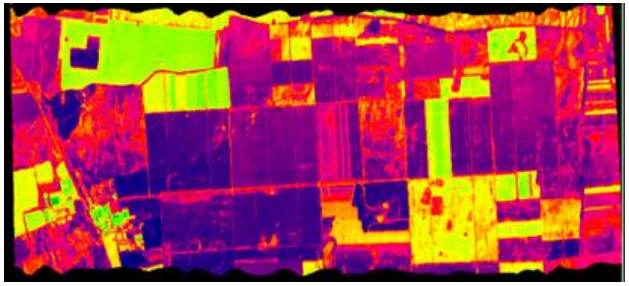
Very difficult to calibrate to specific reflectance

Easily effected by external environmental factors, wind over a field will change surface temperature of the plants

Scientific research and niche market

Hyper-Spectral





Up to 256 bands of reflectance

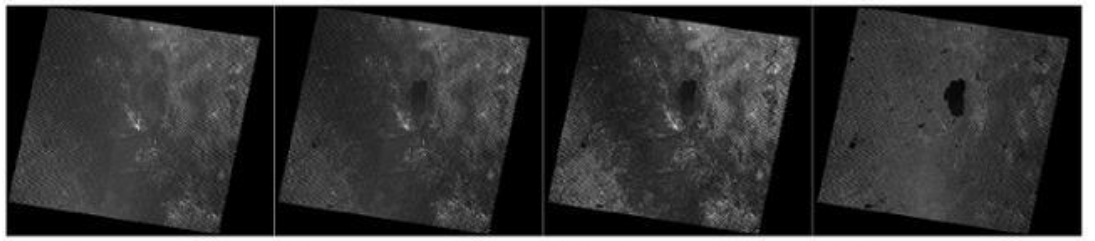
Sensors are line scanners, so they create some distortion that needs to be corrected

Imagery requires intensive post processing that takes computing power and time

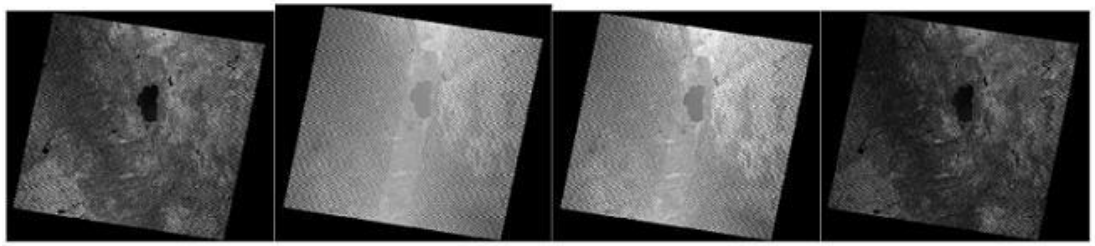
TMI - Information overload

Scientific research is about the only application

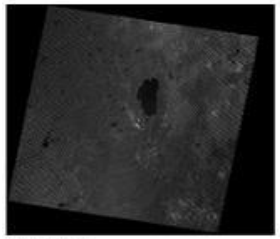
Multi-Spectral



Band 1 Band 2 Band 3 Band 4



Band 5 Band 6(low gain) Band 6(high gain) Band 7



Band 8

Band Properties

Band	Spectral Resolution (µm)	Spatial Resolution (m)
1 (Visible Blue)	.45 - .52	30x30
2 (Visible Green)	.52 - .60	30x30
3 (Visible Red)	.63 - .69	30x30
4 (Near Infrared)	.76 - .90	30x30
5 (Middle Infrared)	1.55 – 1.75	30x30
6L/6H (Thermal Infrared)	10.40 – 12.50	60x60
7 (Middle Infrared)	2.08 – 2.35	30x30
8 (Panchromatic)	.52 - .90	15x15

We have matched LandSat 2,3,4 to create our false color IR imagery

Well researched and proven analysis

Large sensors, we use 7,218 X 5,412 monochrome sensors

Words to be Wary Off

"Single CCD array multi-spectral camera"

"Pan-Sharpened"

"Electronic shutter" (video frame grabber)

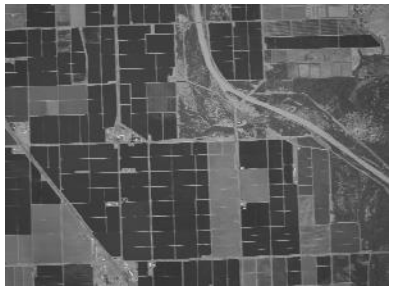
"Mosaic"

Mutton dressed as lamb!!

True Multi-Spectral Imagery

Bayer Pattern
True Color

Green

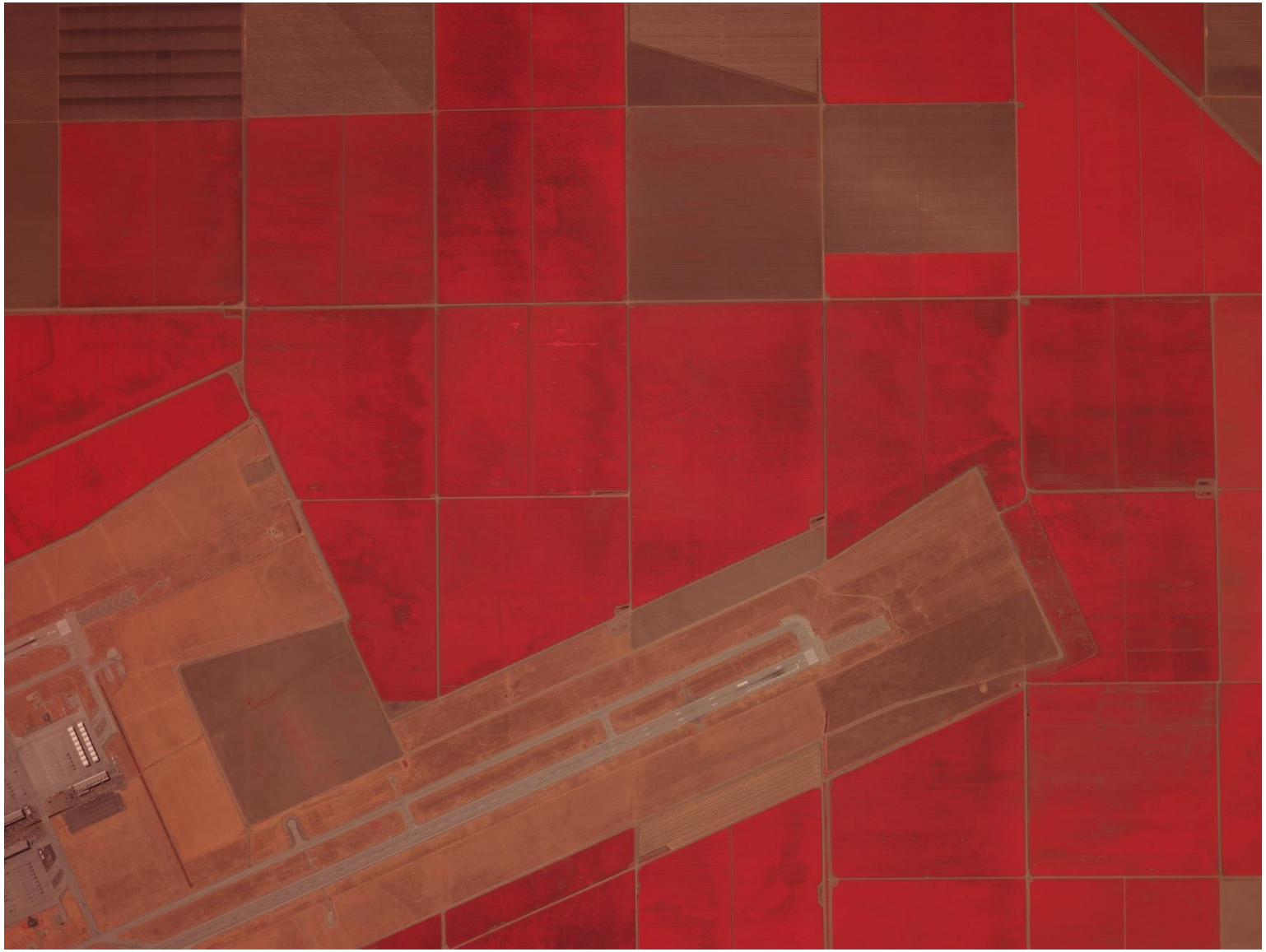


Red

Near IR

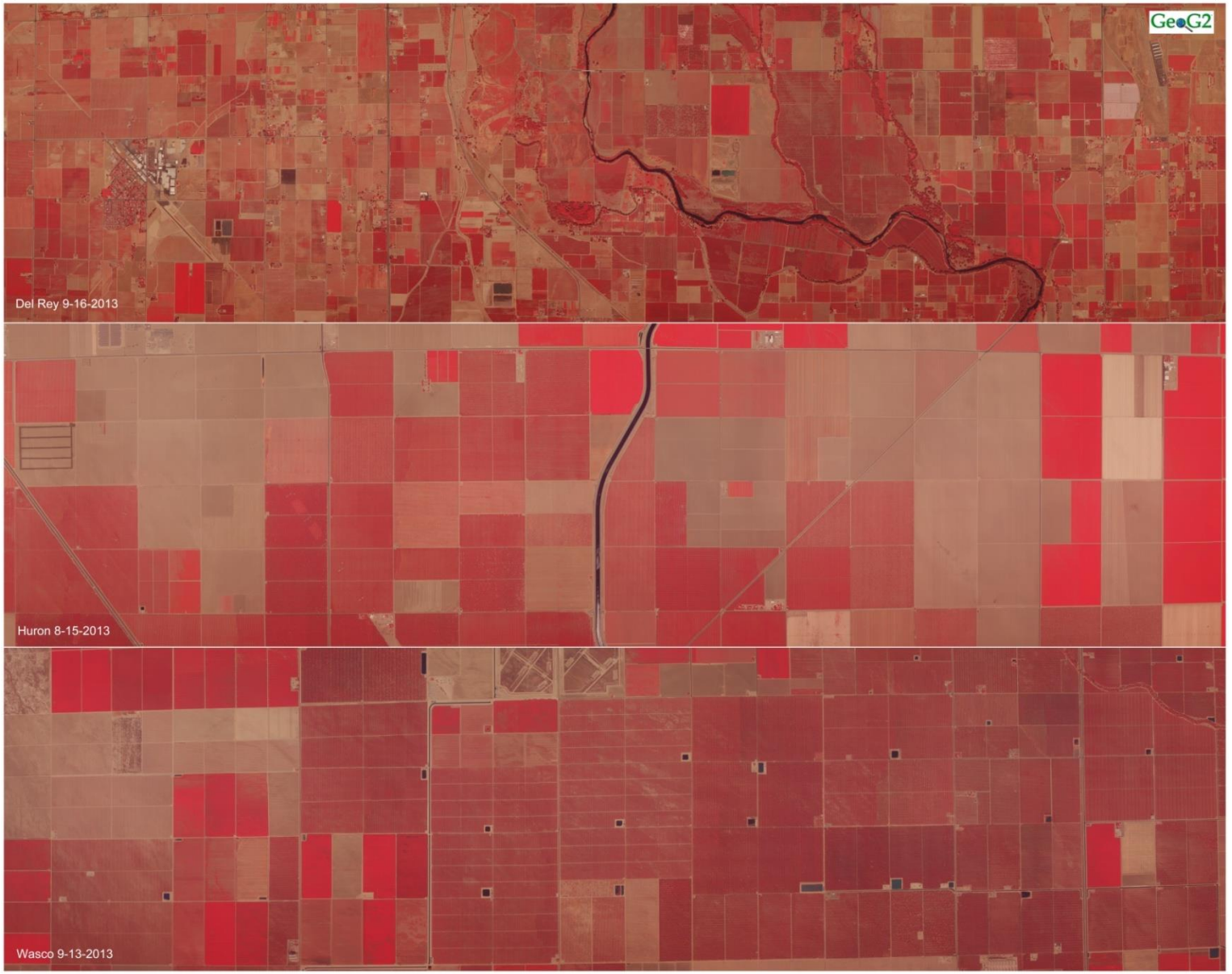
False Color IR
Green > Blue
Red > Green
NearIR > Red

GeoG2 Full Scene Image (3.2 miles X 2.4 miles)

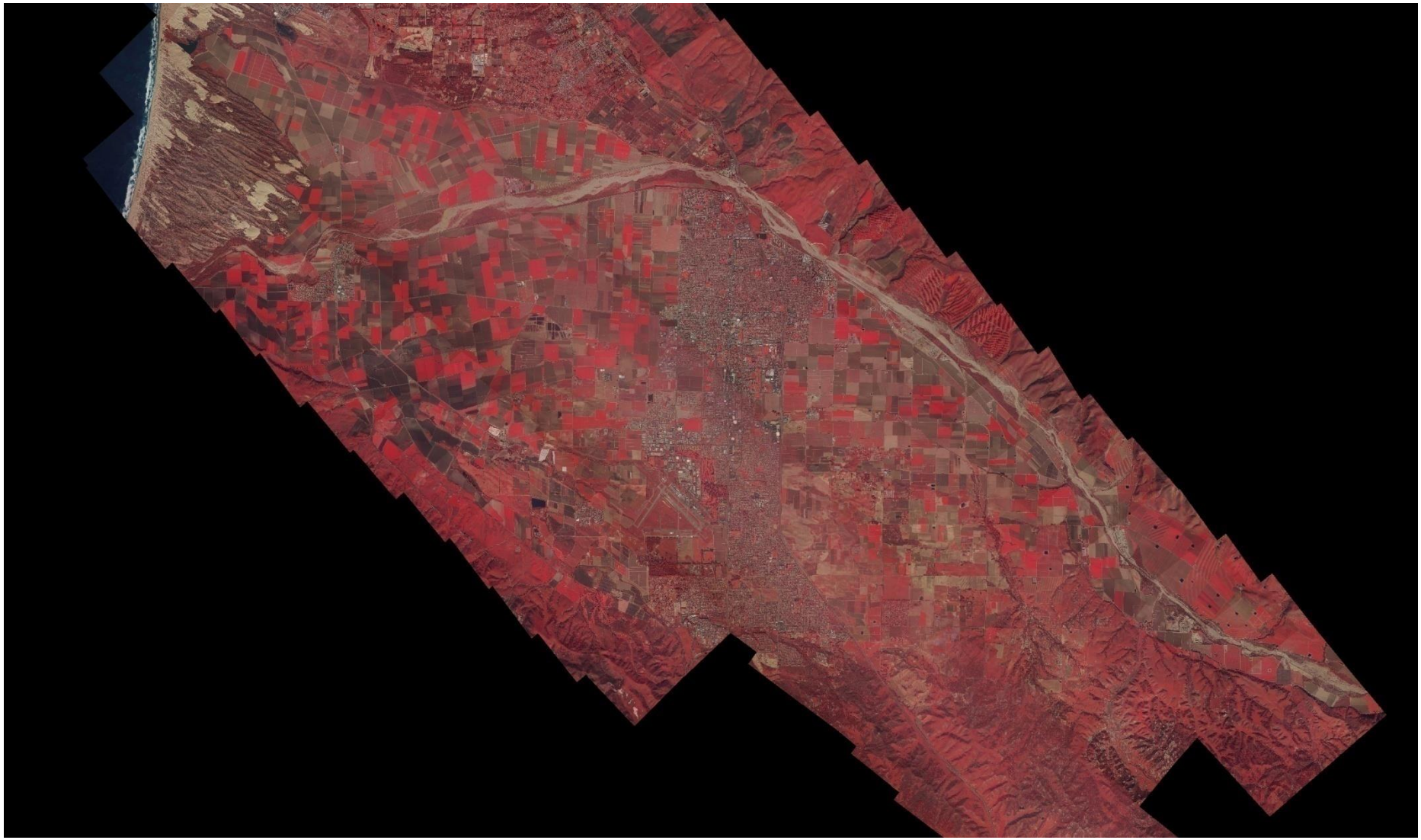


Data Collection (2 min for each line)

9 Miles



GeoG2 Image Geo Referenced and Mosaiced



Santa Maria 2009

Analytical Tools (No Shortage)

GIS

ArcGIS ESRI

Global Mapper

Autodesk

MAGELLAN

PCI Geomatics

MapInfo

Image Processing

Google earth

Adobe Photoshop

erdas The Earth to Business Company

APEX Farm Management Software

CROPLOGIC

Farm Management

SST Software Manage Data. Harvest Information.

FarmSite Management software

FARM WORKS SOFTWARE

ONFARM GROW INFORMED

Farmers Business Network

MapShots

PIONEER. FIELD360

Trimble

Image Analysis Tools

Image enhancement (PhotoShop)

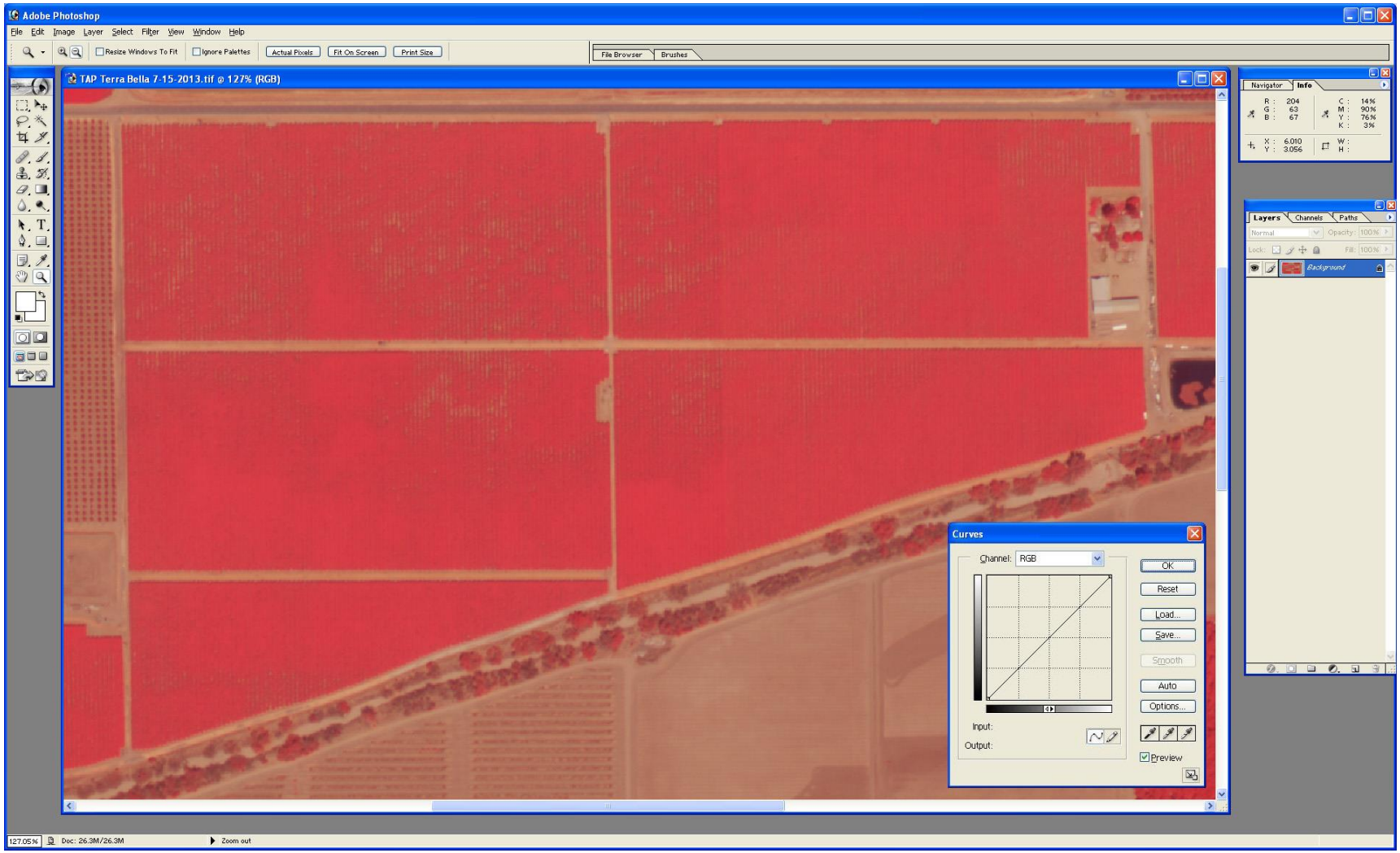


Image Analysis Tools

Image enhancement

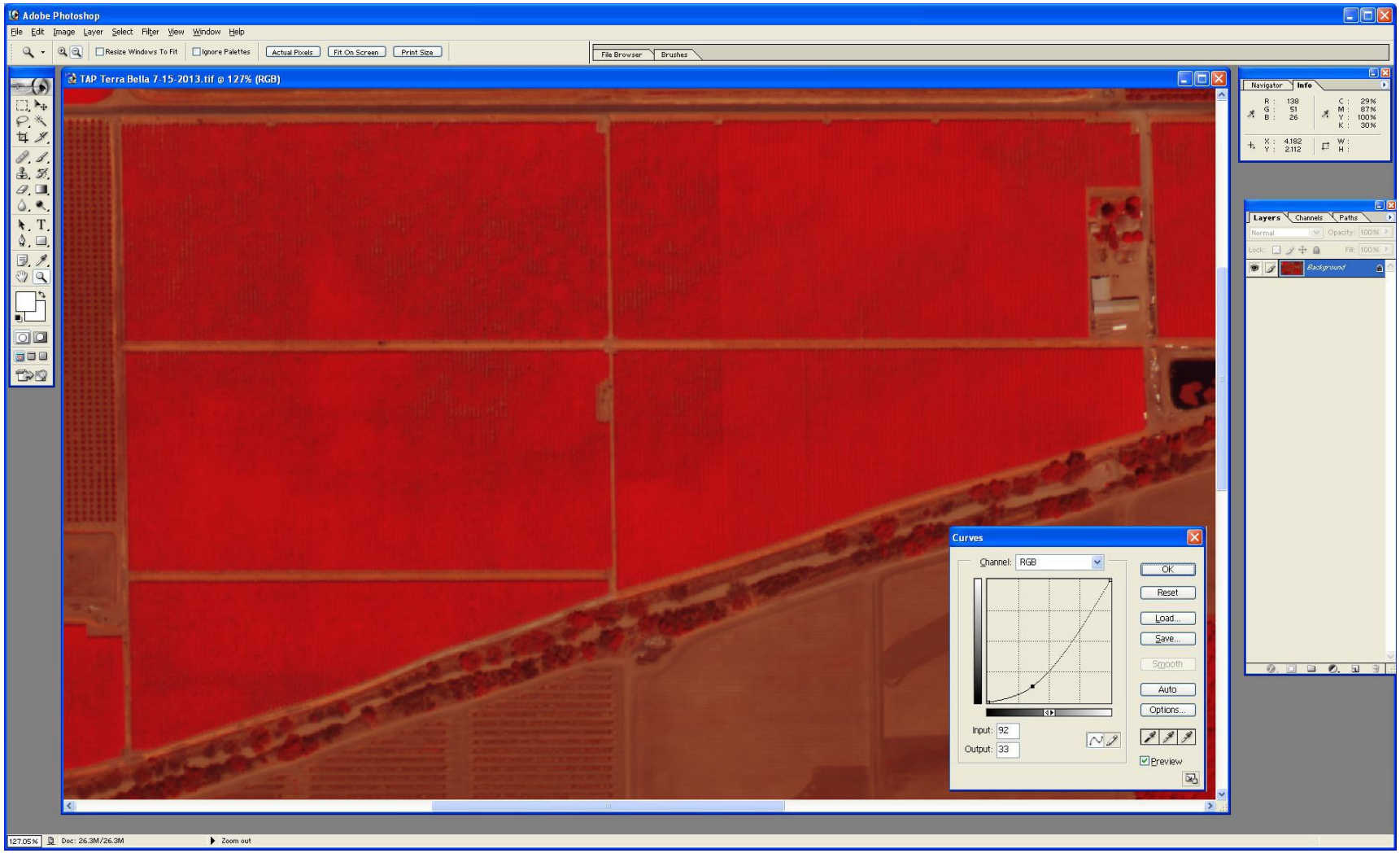
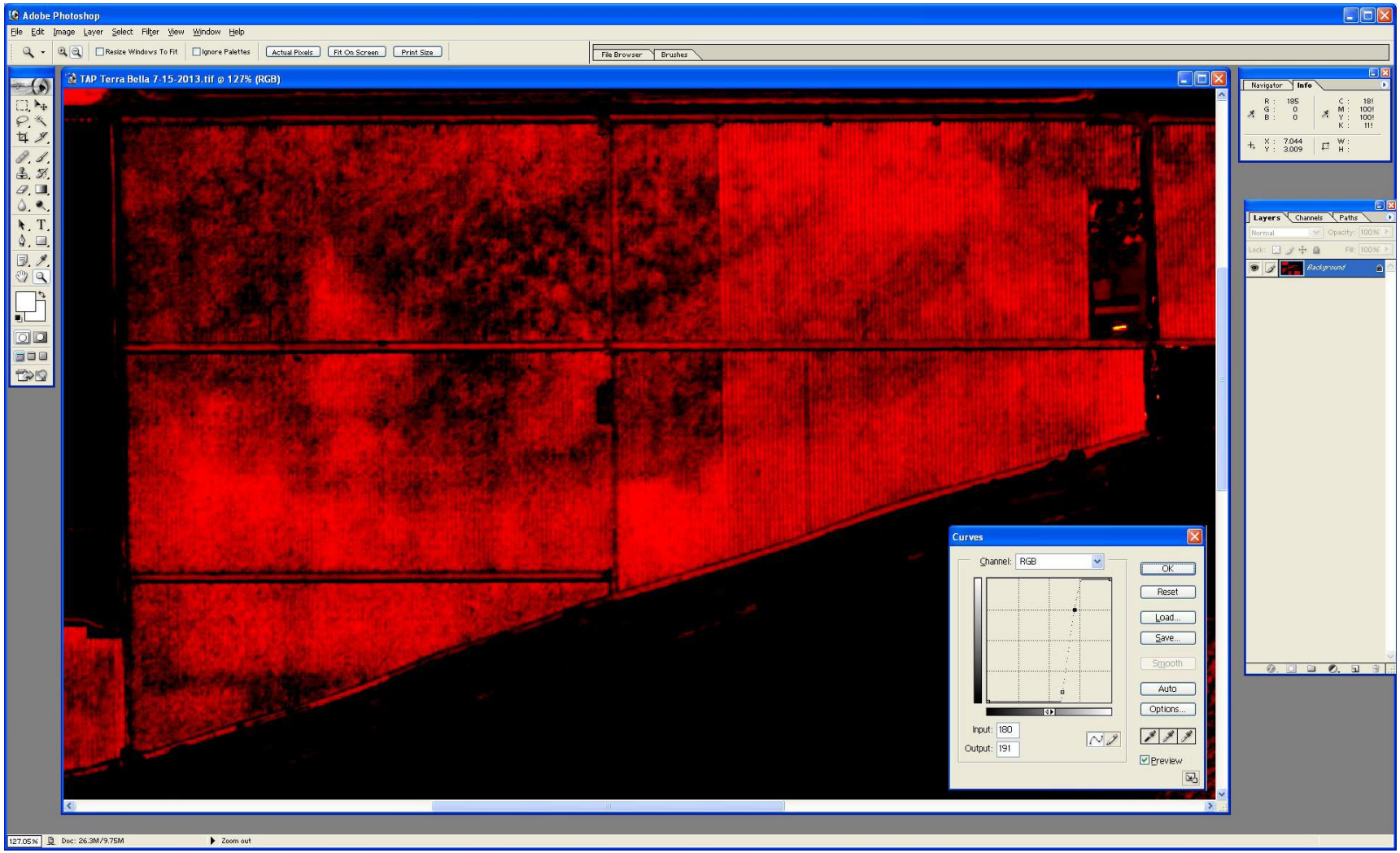


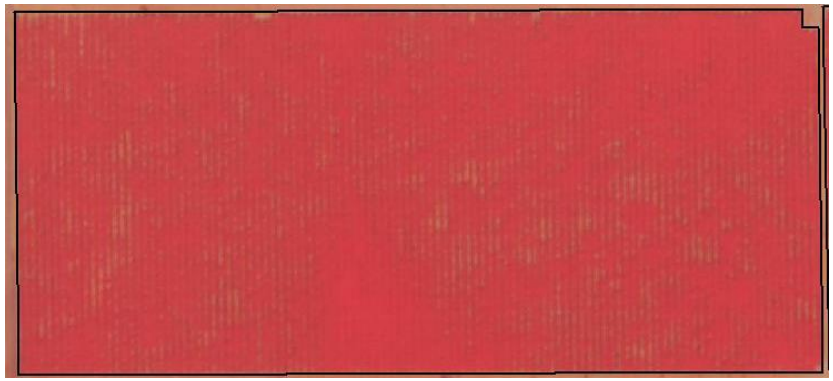
Image Analysis Tools

Image enhancement

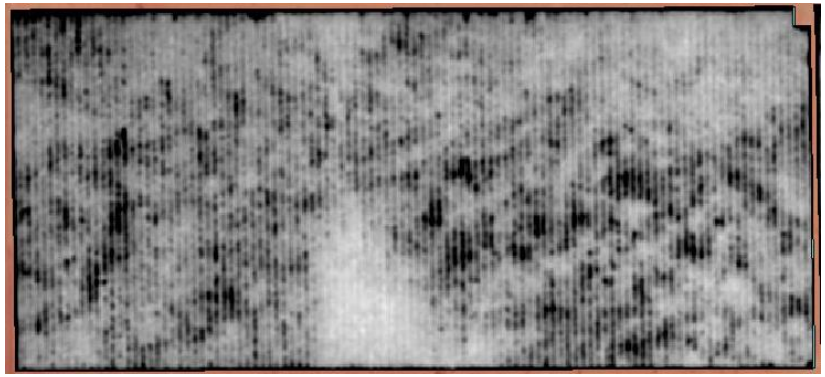


NDVI – Vegetative Index

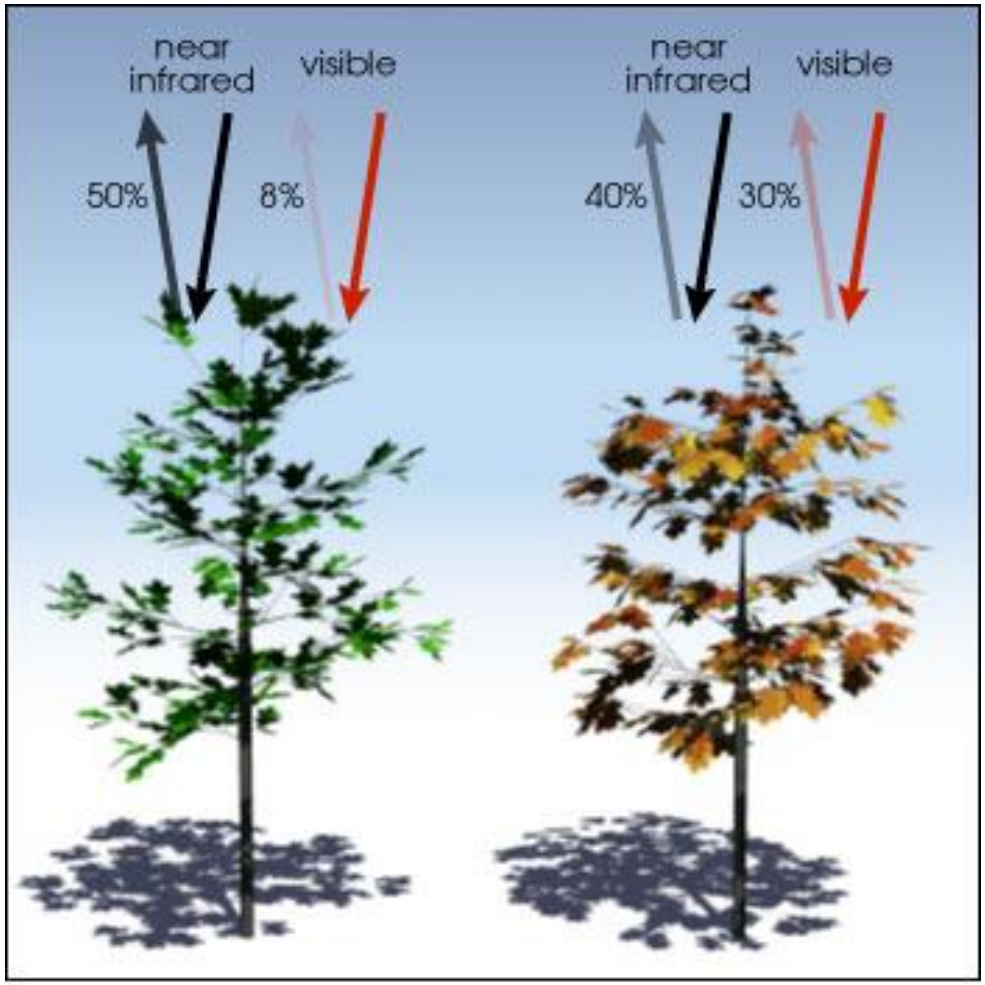
$$NDVI = \frac{(NIR - Red)}{(NIR + Red)}$$



False color IR image

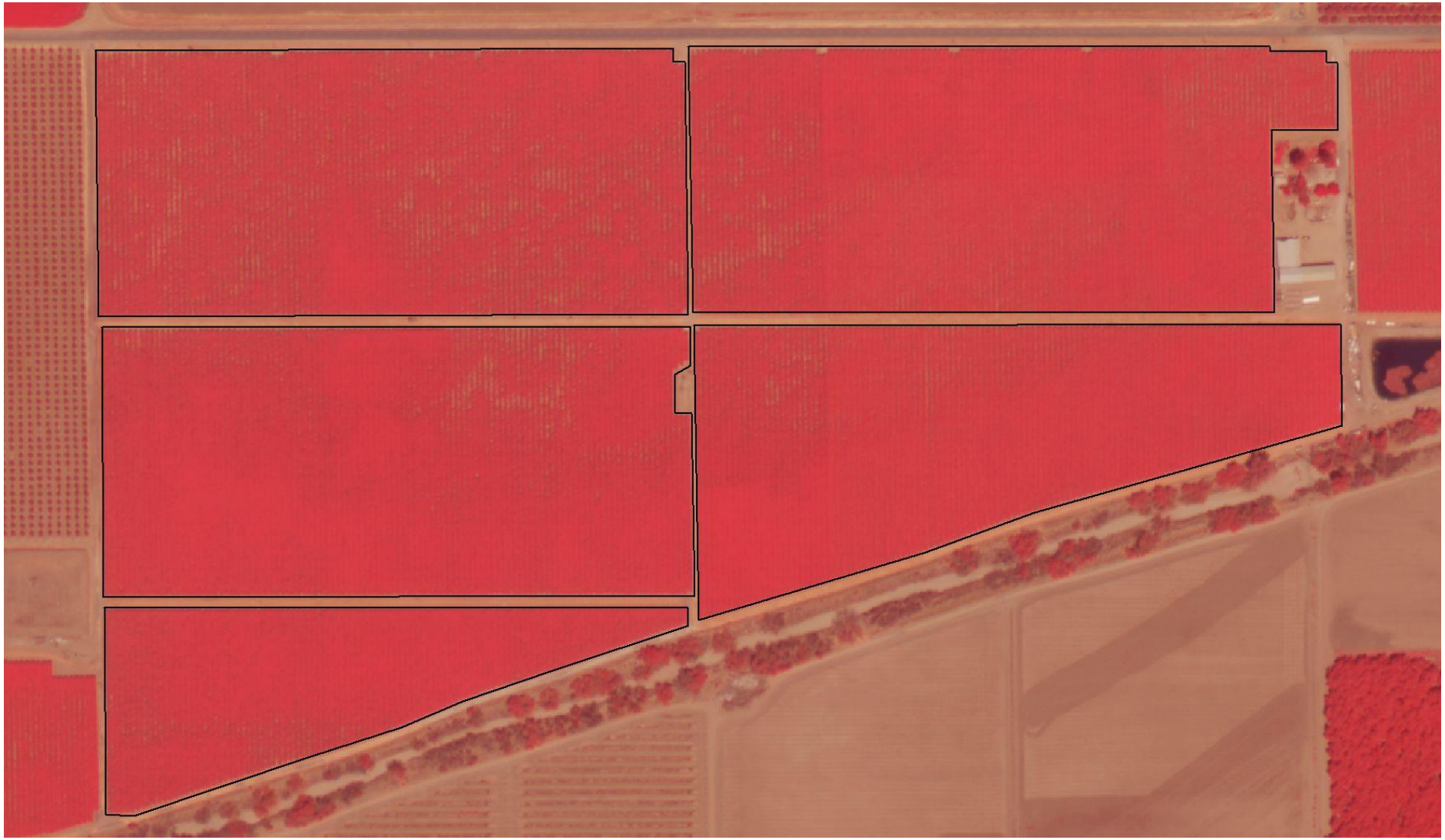


NDVI Gray Scale Image



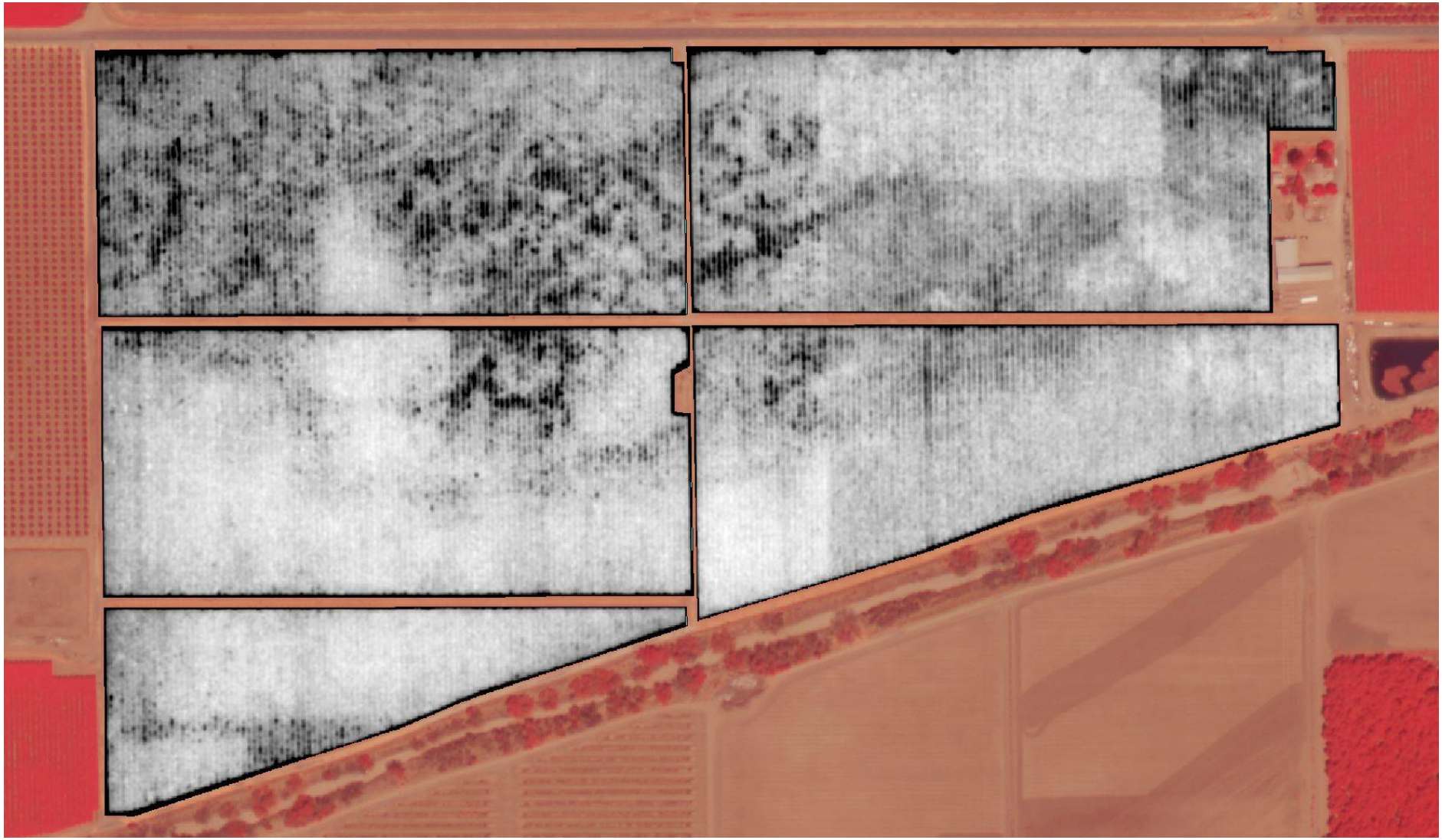
$$\frac{(0.50 - 0.08)}{(0.50 + 0.08)} = 0.72 \qquad \frac{(0.4 - 0.30)}{(0.4 + 0.30)} = 0.14$$

NDVI – Vegetative Index



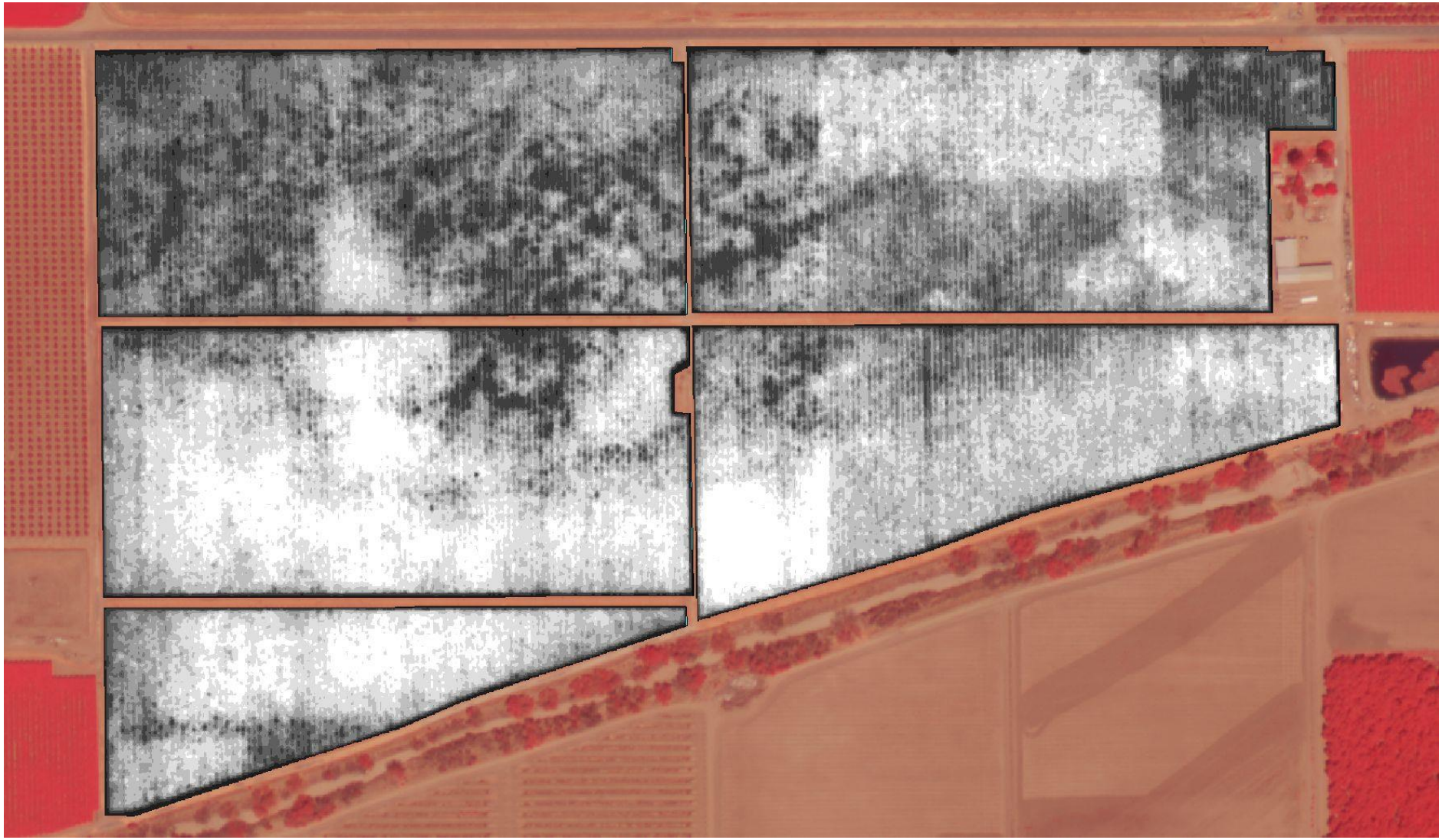
False Color IR Image

NDVI – Vegetative Index



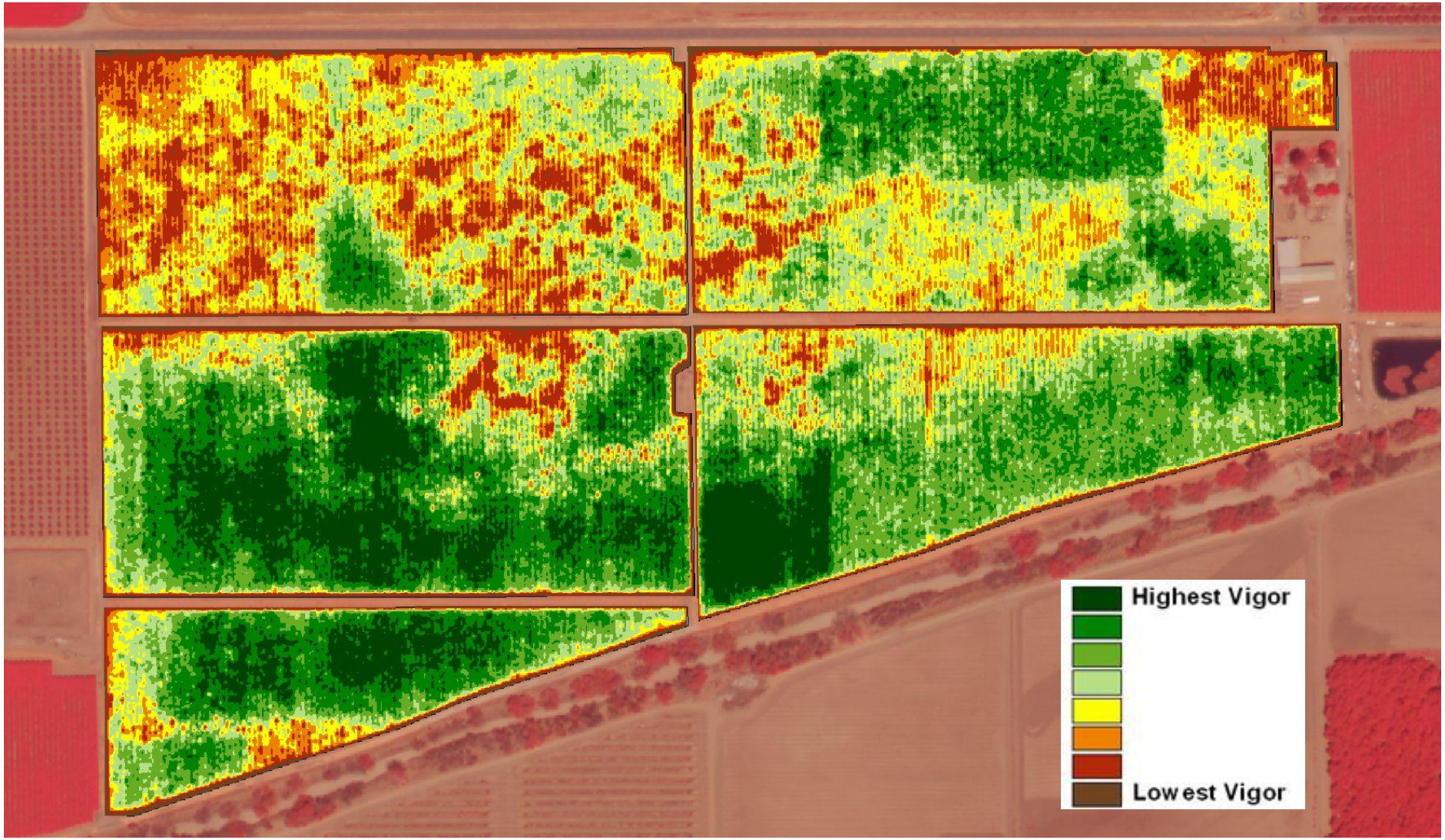
Gray Scale NDVI (256 shades)

NDVI – Vegetative Index



NDVI 8 Class Gray Scale

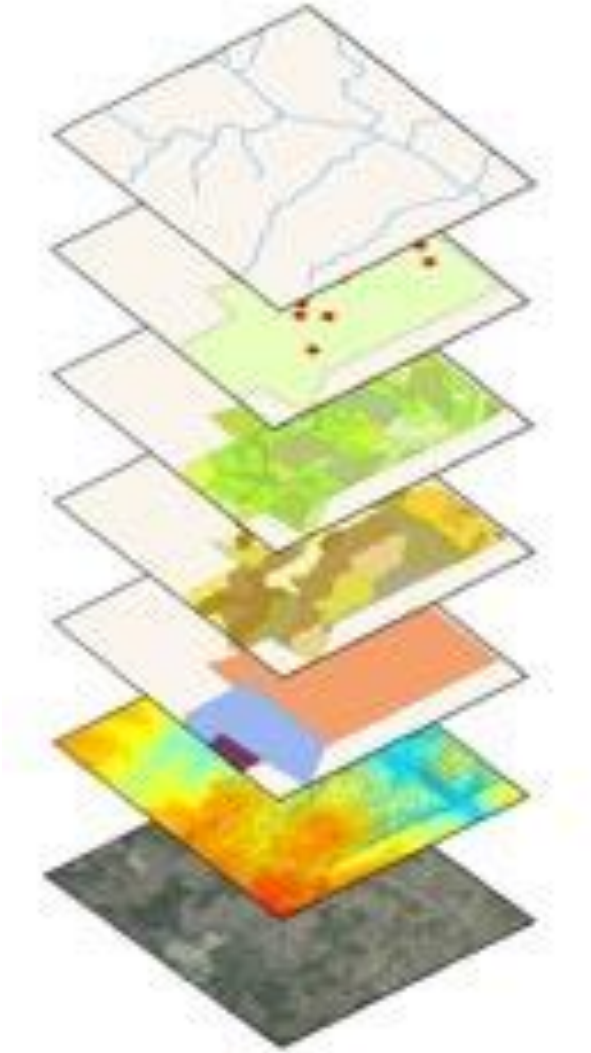
NDVI – Vegetative Index



NDVI 8 Class Colorized

Post Harvest Analysis

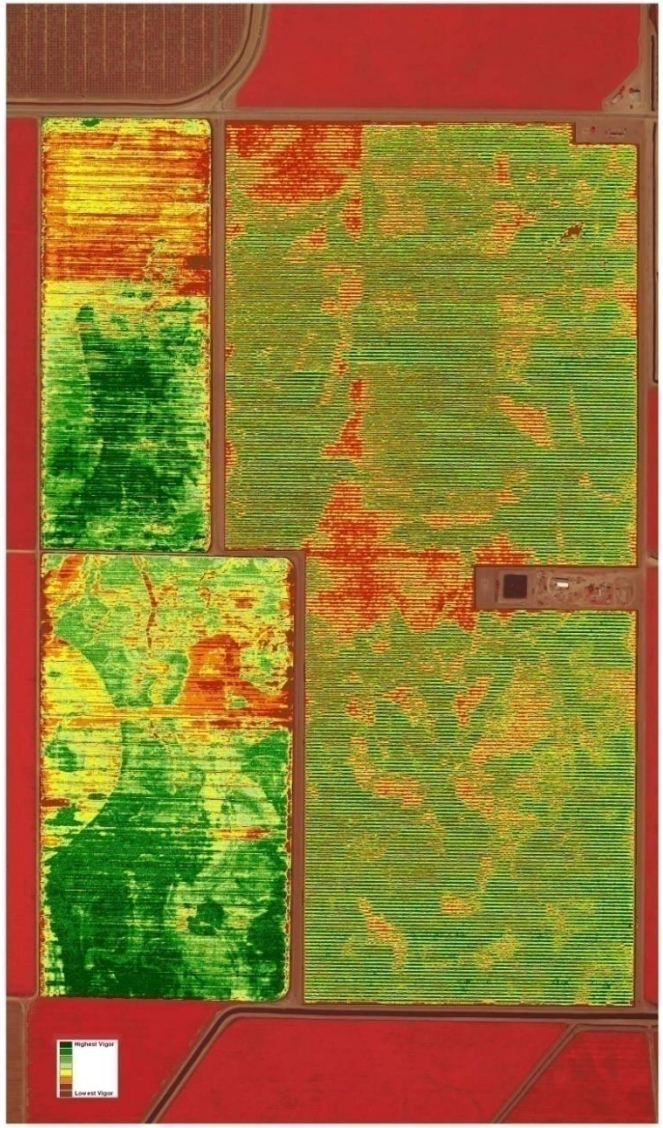
GIS "Geo-Reg Relational Data Base":



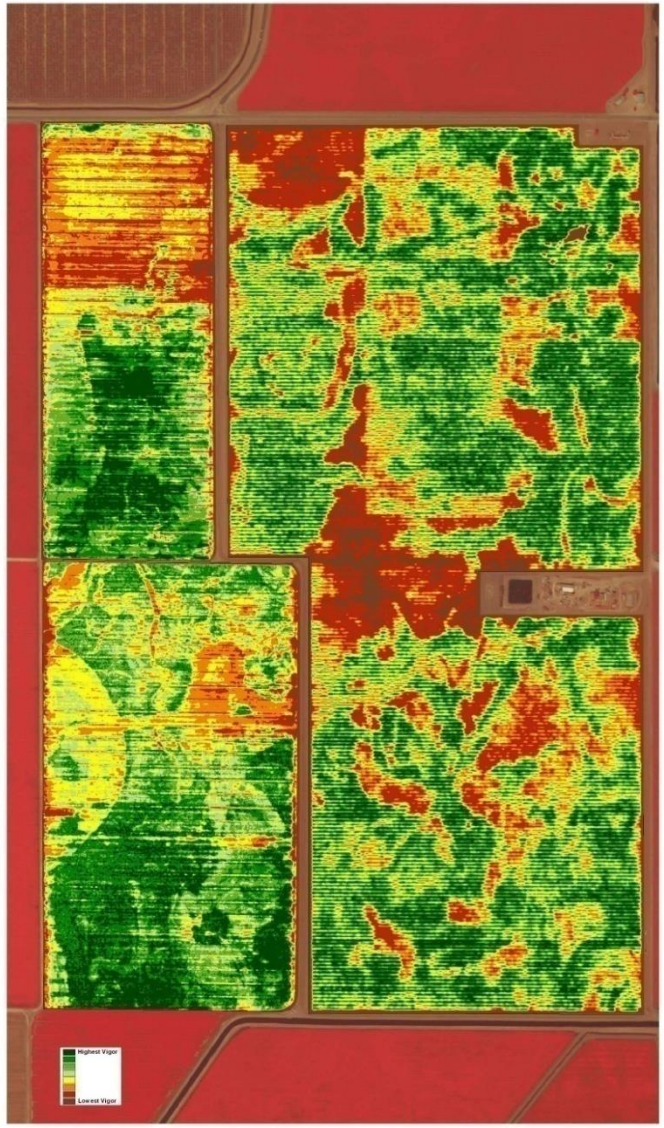
Base Map
Soils
Planting Data
Imagery
Irrigation
Application
Scouting
Yield……

Resolution, Resolution, Resolution to a Point!

12 in. Resolution



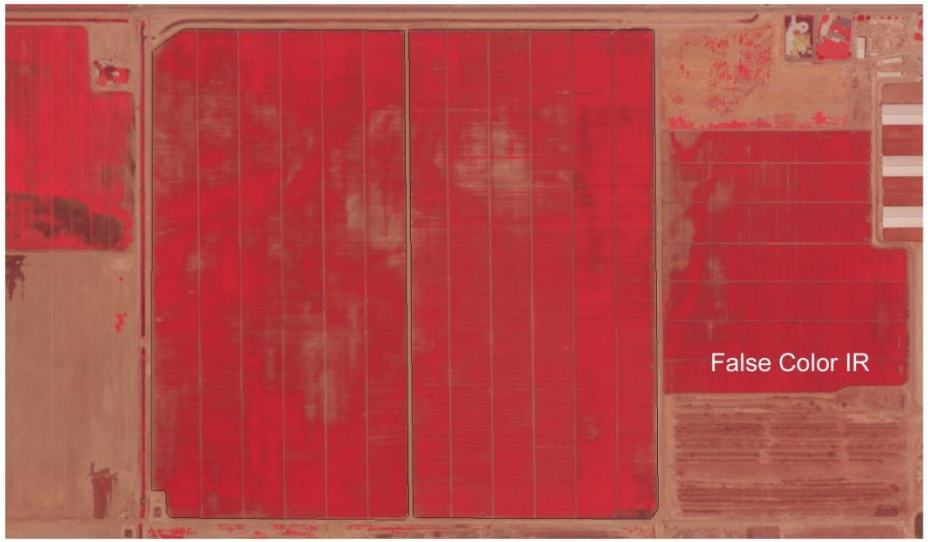
30 in. Resolution

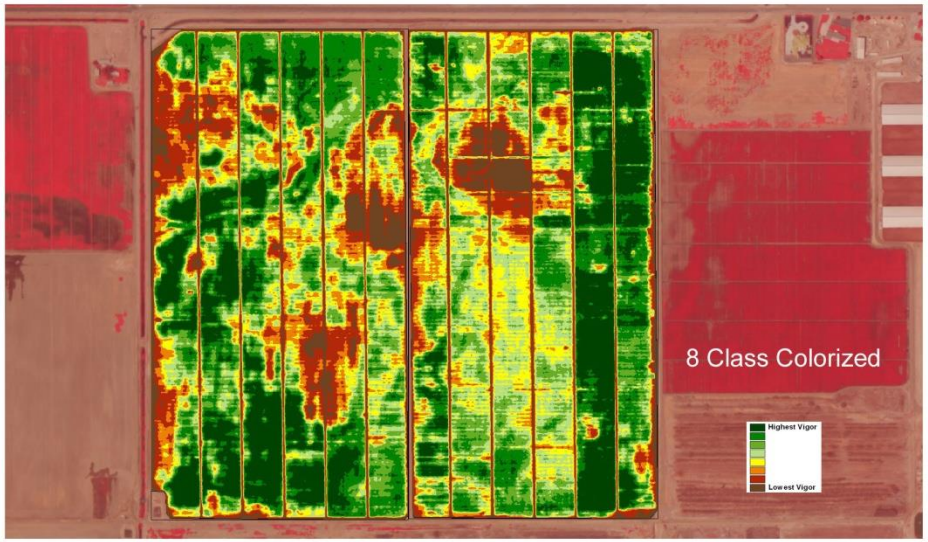


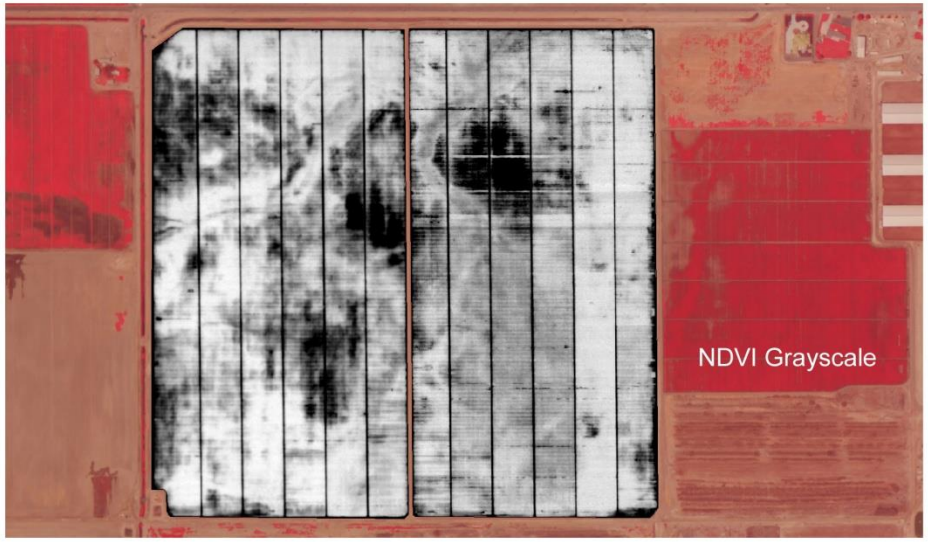
What do you do with the information?

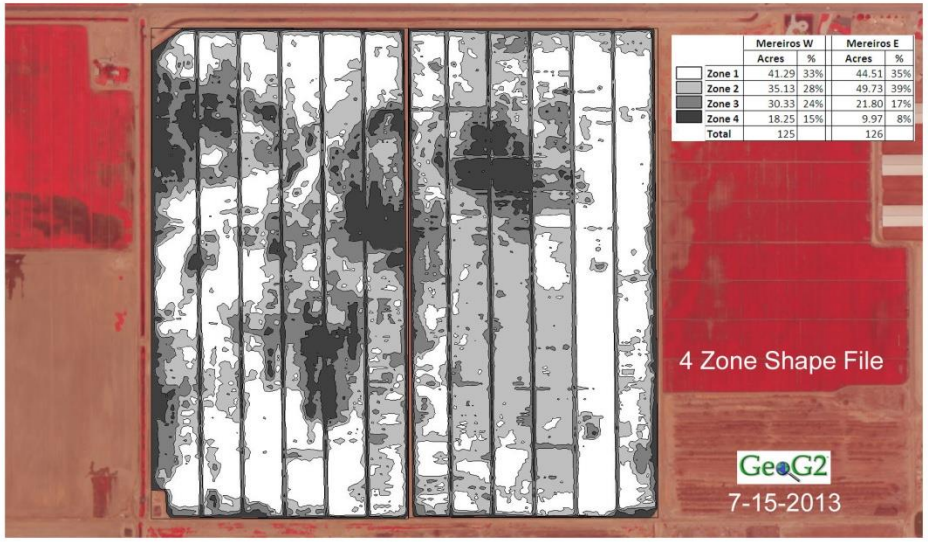
- **Cheat sheet to walk the field**
- **Geo-ref image analysis**
- **Selective Soil Sampling**
- **Damage/problem assessment**
- **Precision application**
- **Harvest estimate**
- **Post harvest analysis**

FCIR > NDVI > 8Class > 4Class Shape Map





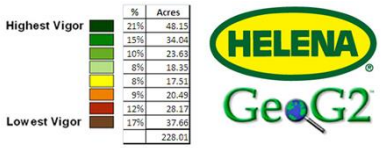




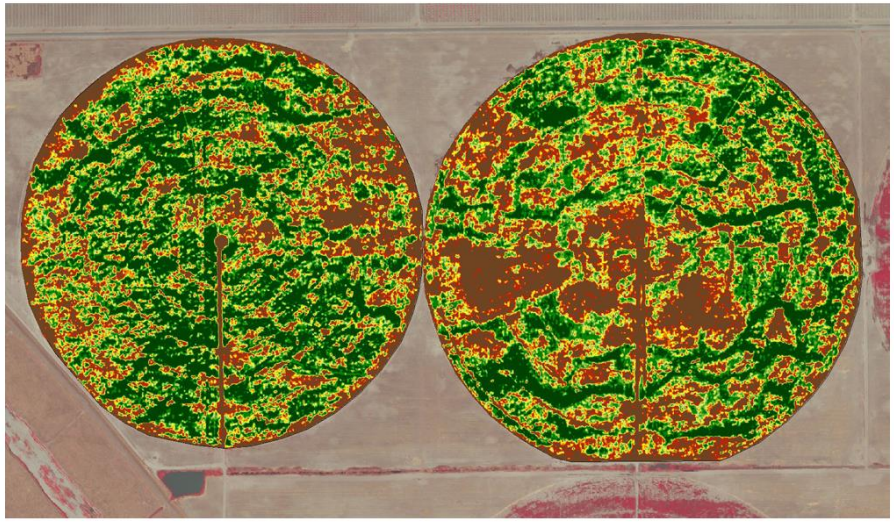
	Mereiros W		Mereiros E	
	Acres	%	Acres	%
Zone 1	41.29	33%	44.51	35%
Zone 2	35.13	28%	49.73	39%
Zone 3	30.33	24%	21.80	17%
Zone 4	18.25	15%	9.97	8%
Total	125		126	

Application of Technology

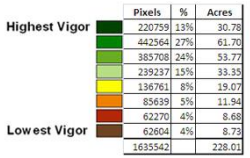
A&E Farming
Field: P6-P7
Date: 8-8-2010



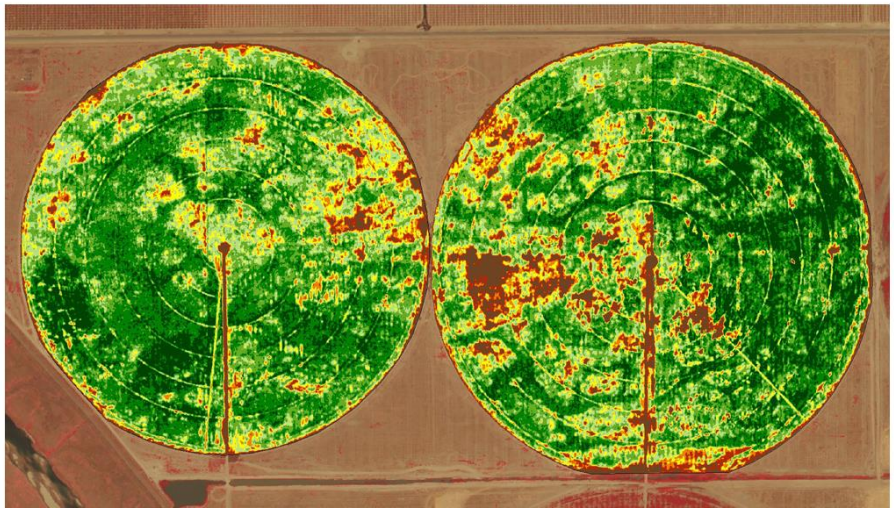
%	Acres
21%	48.15
15%	34.04
10%	23.63
8%	18.35
8%	17.51
9%	20.49
12%	28.17
17%	37.66
	228.01



A&E Farming
Fields: P-6 P-7
Date: 8-16-2011



Pixels	%	Acres
220759	13%	30.78
442564	27%	61.70
385708	24%	53.77
239237	15%	33.35
136761	8%	19.07
85639	5%	11.94
62270	4%	8.68
62604	4%	8.73
1635542		228.01

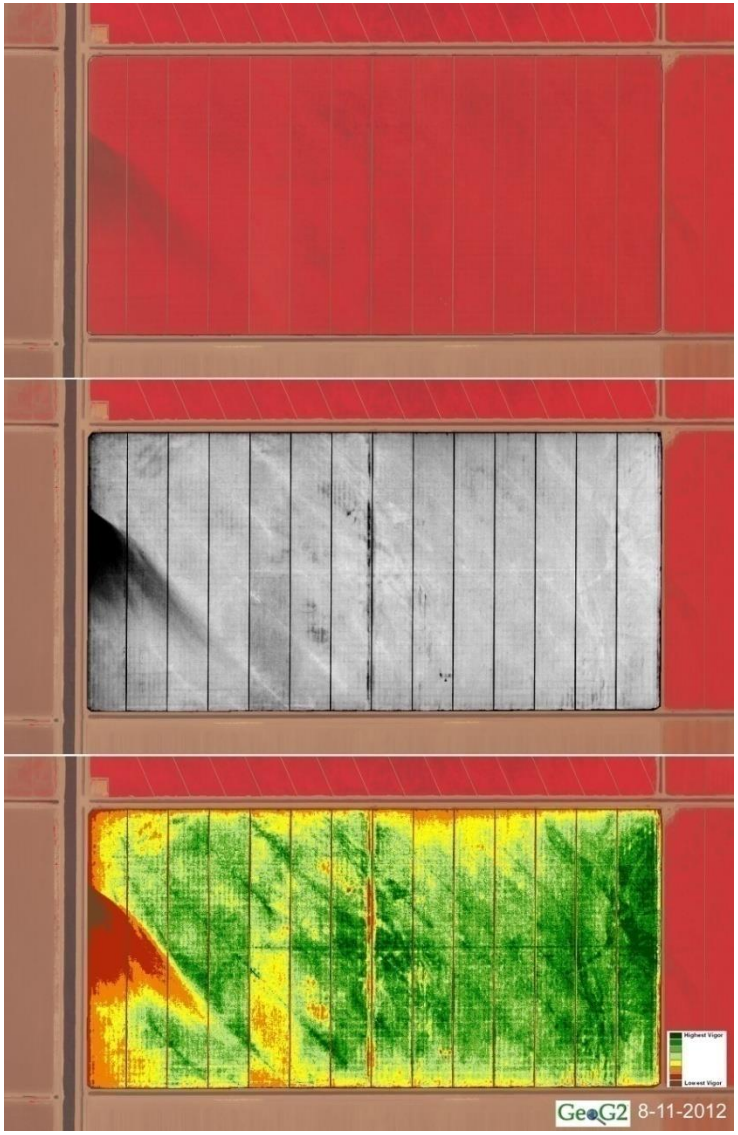


Problem (Left Image): In 2010, GeoG2 imagery was used to identify significant problems in these two corn fields.

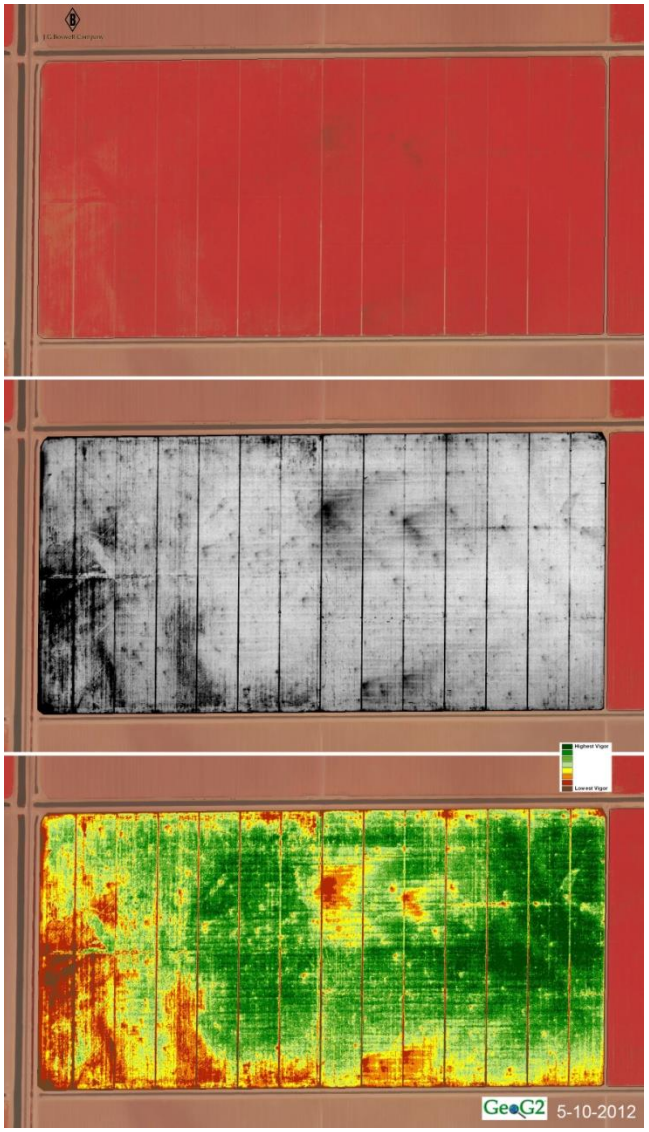
Treatment: The grower, A&E Farming, in conjunction with their chemicals supplier, Helena, used the imagery to direct soil sampling and prescribe a variable rate application treatment.

Results (Right Image): 2011 GeoG2 imagery of improved results.

Example: Drift and Disease

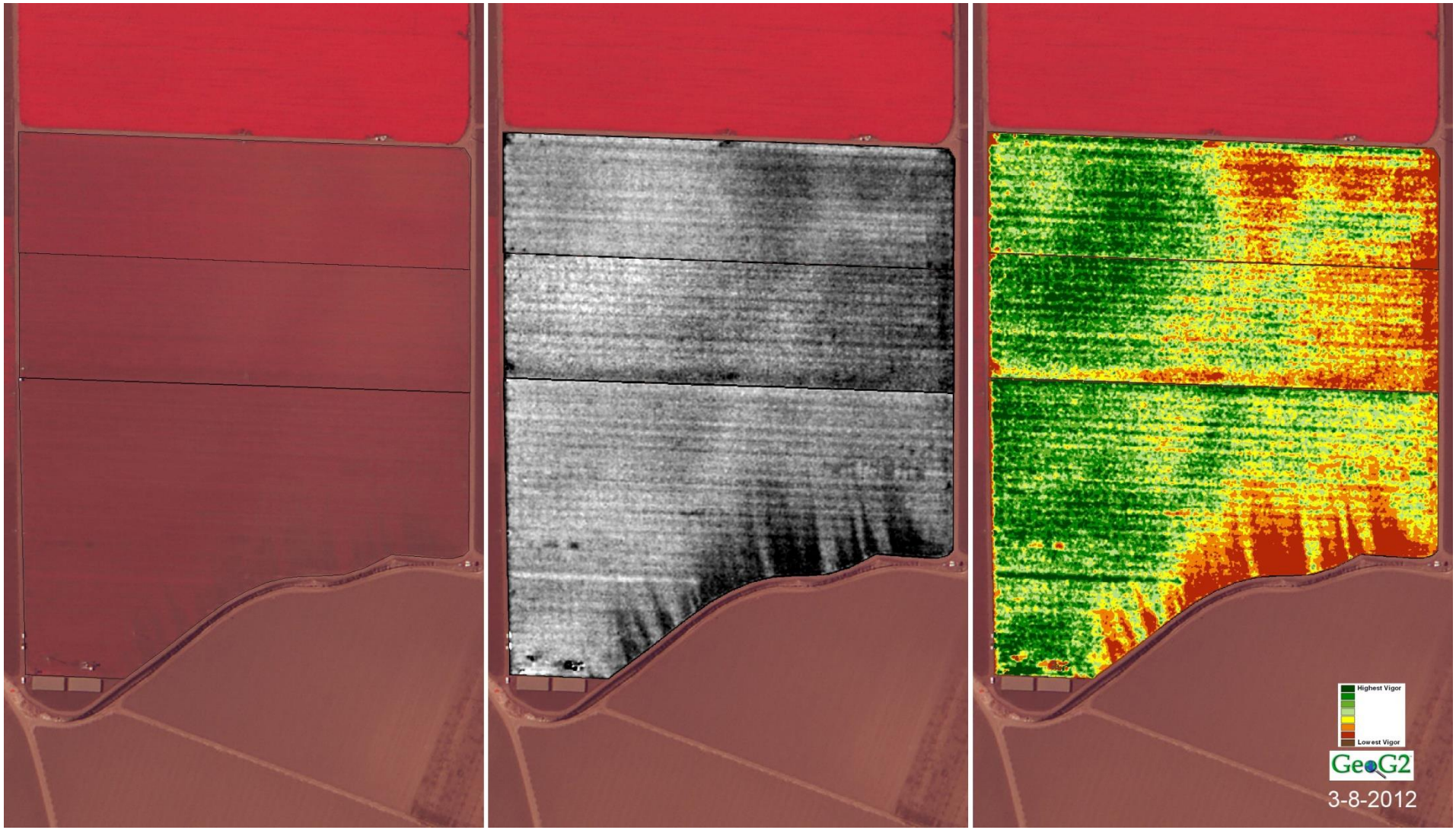


Chemical Drift

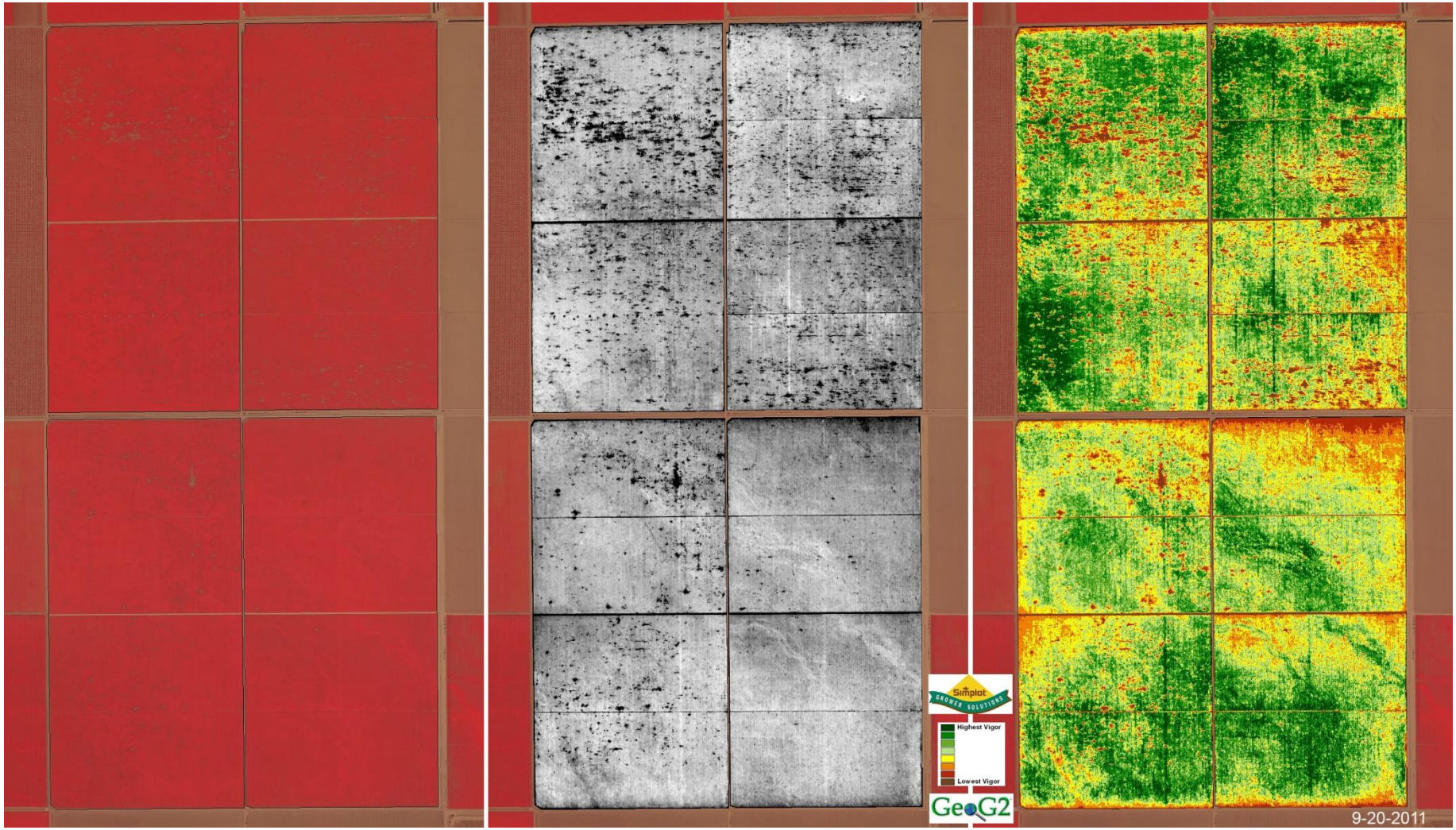


Rust in Wheat

Example: Drift In Broccoli

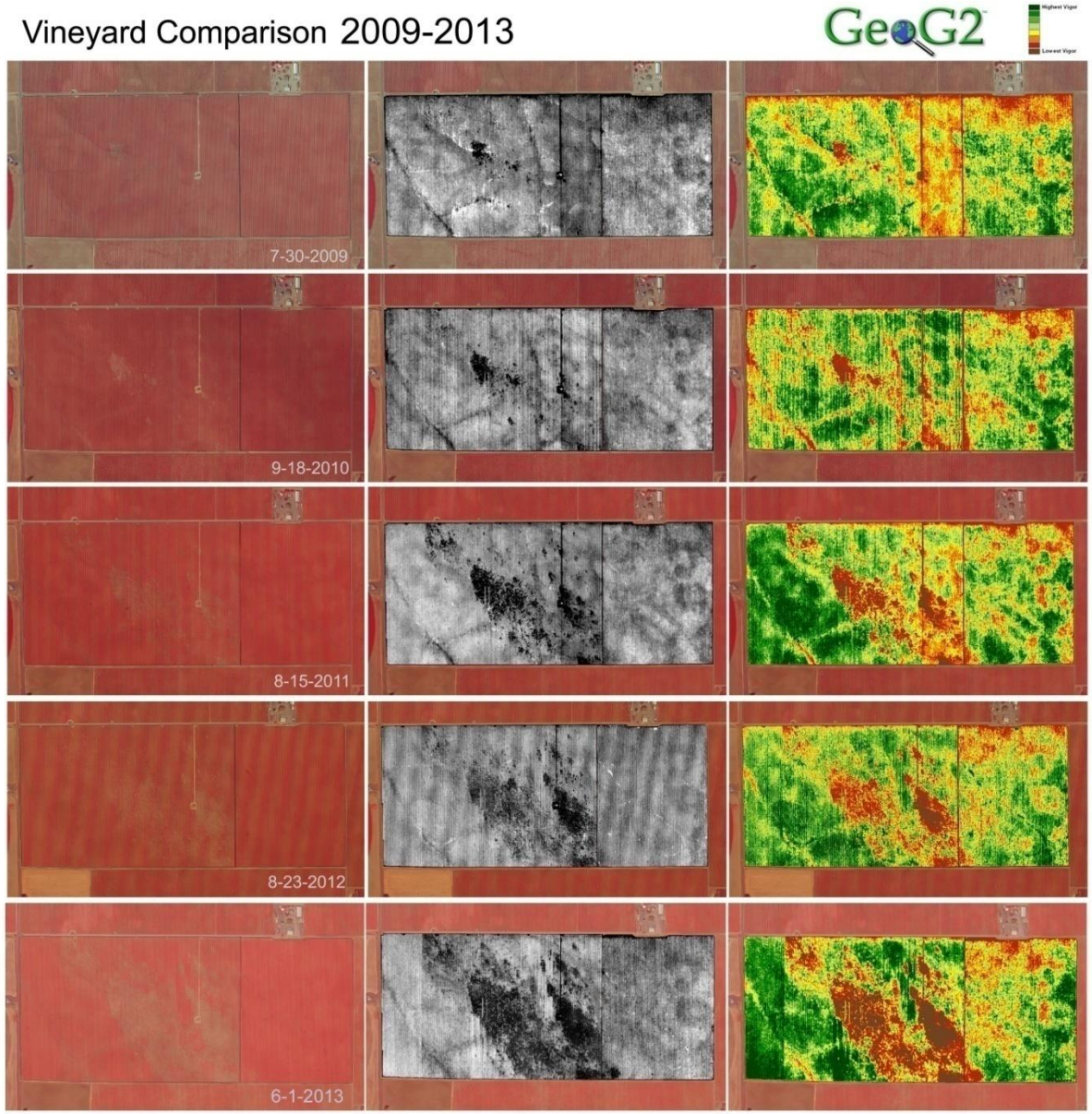


Example: Disease Fusarium race4

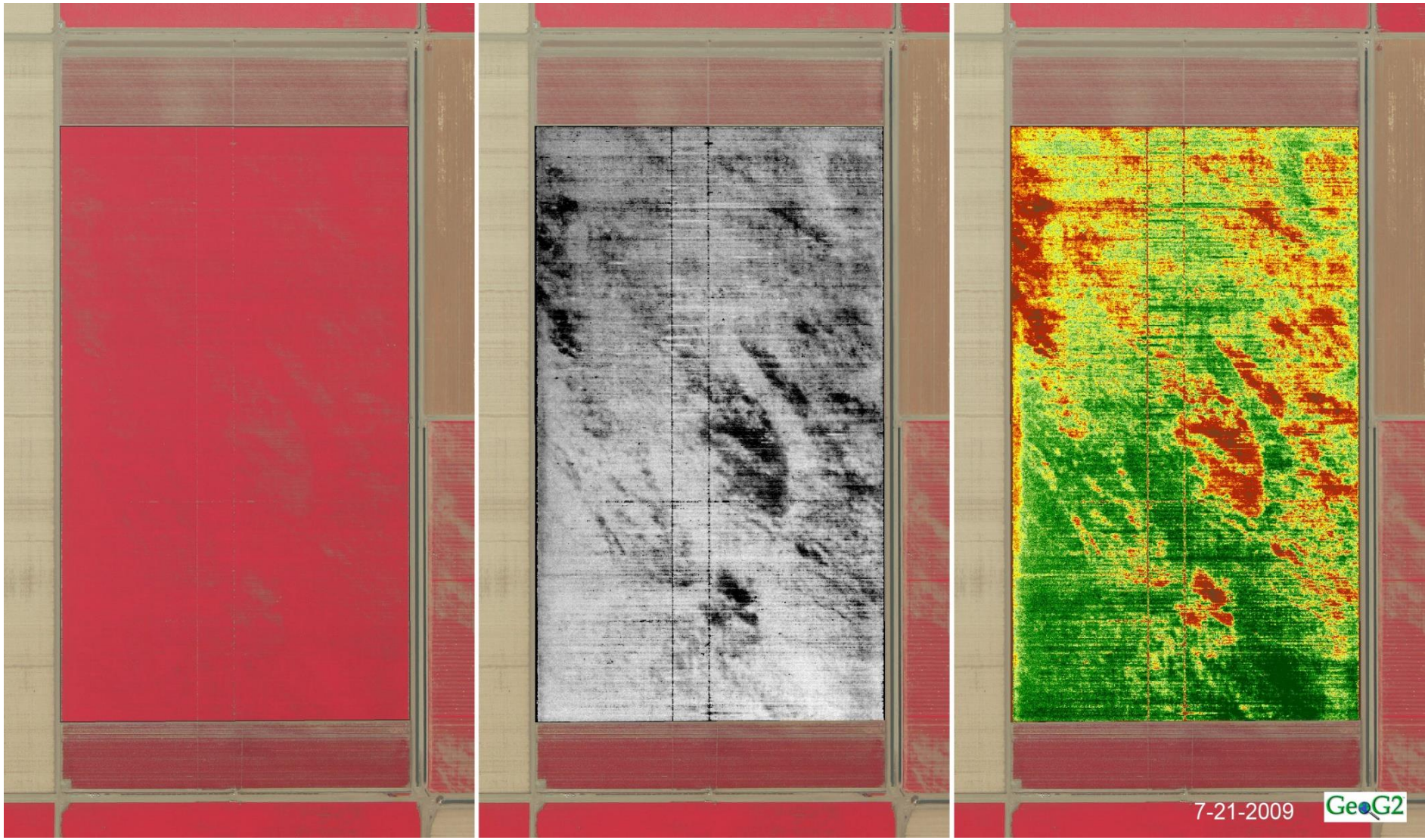


Fusarium Race4 in Cotton

Example: 5 Year Comparison

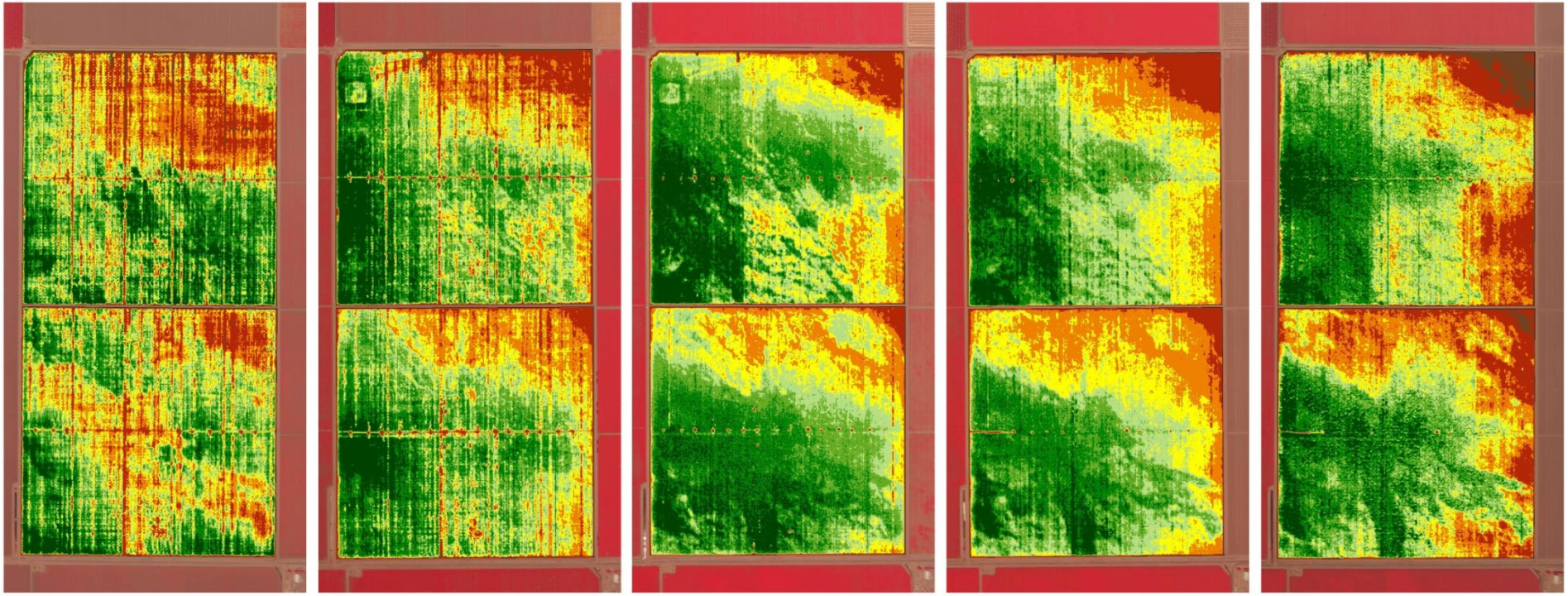


Example: Processing Tomatoes Huron, CA



Example: Cotton Growth Cycle

Cotton Growth Cycle
8Class Colorized NDVI
2013

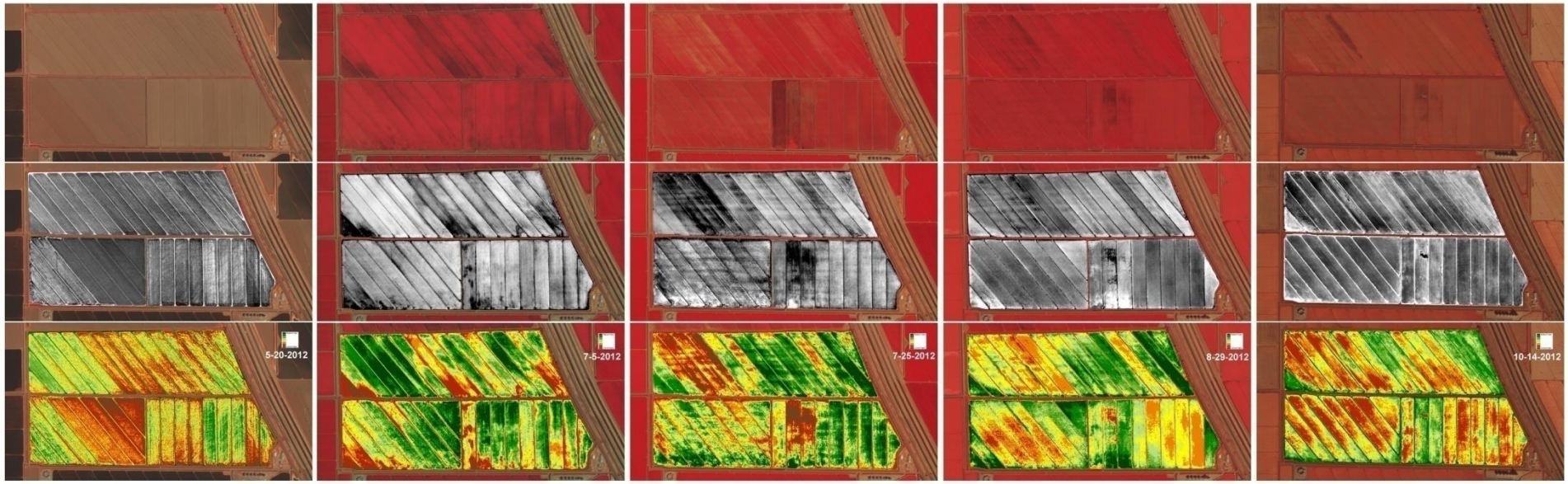


5-14-2013 6-17-2013 7-15-2013 8-15-2013 9-14-2013

Example: Rice Growth Cycle

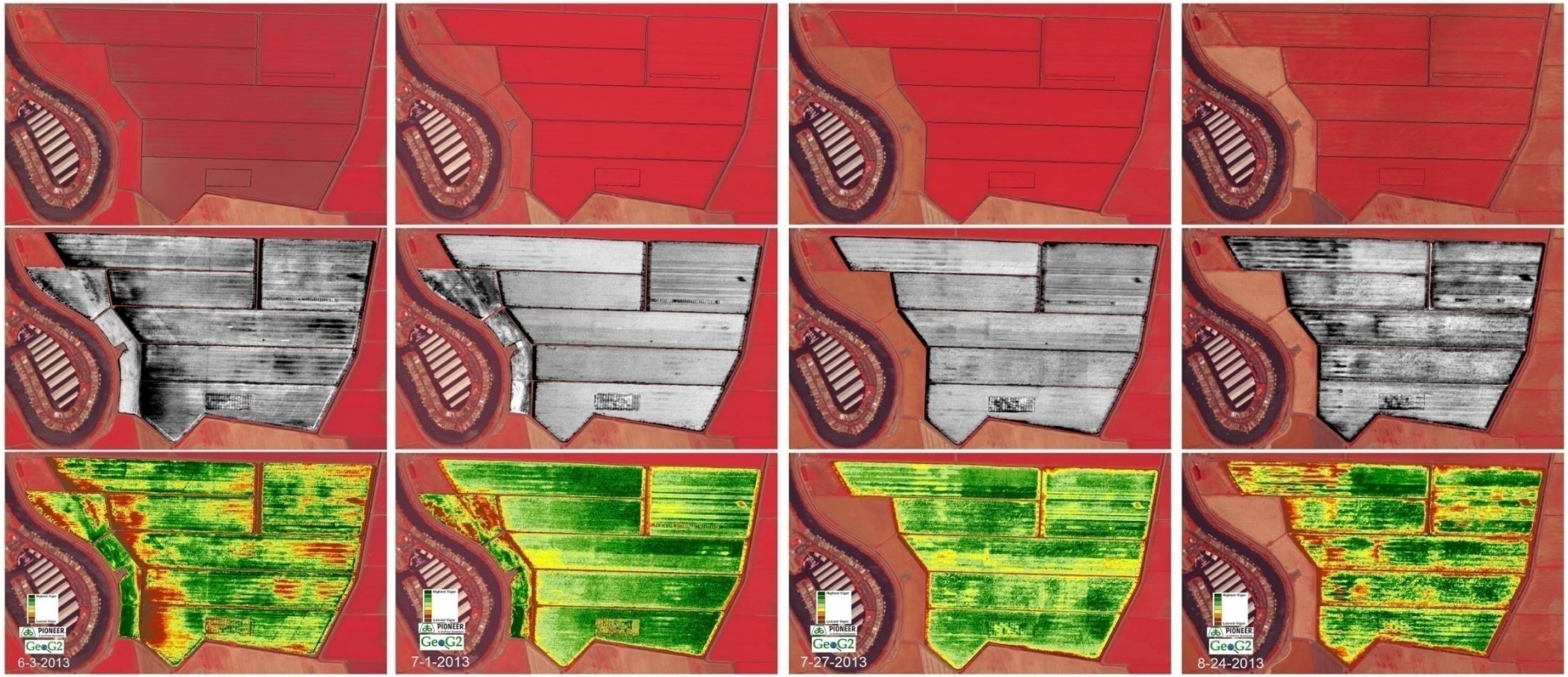
Haas Rd, Williams, CA

GeoG2

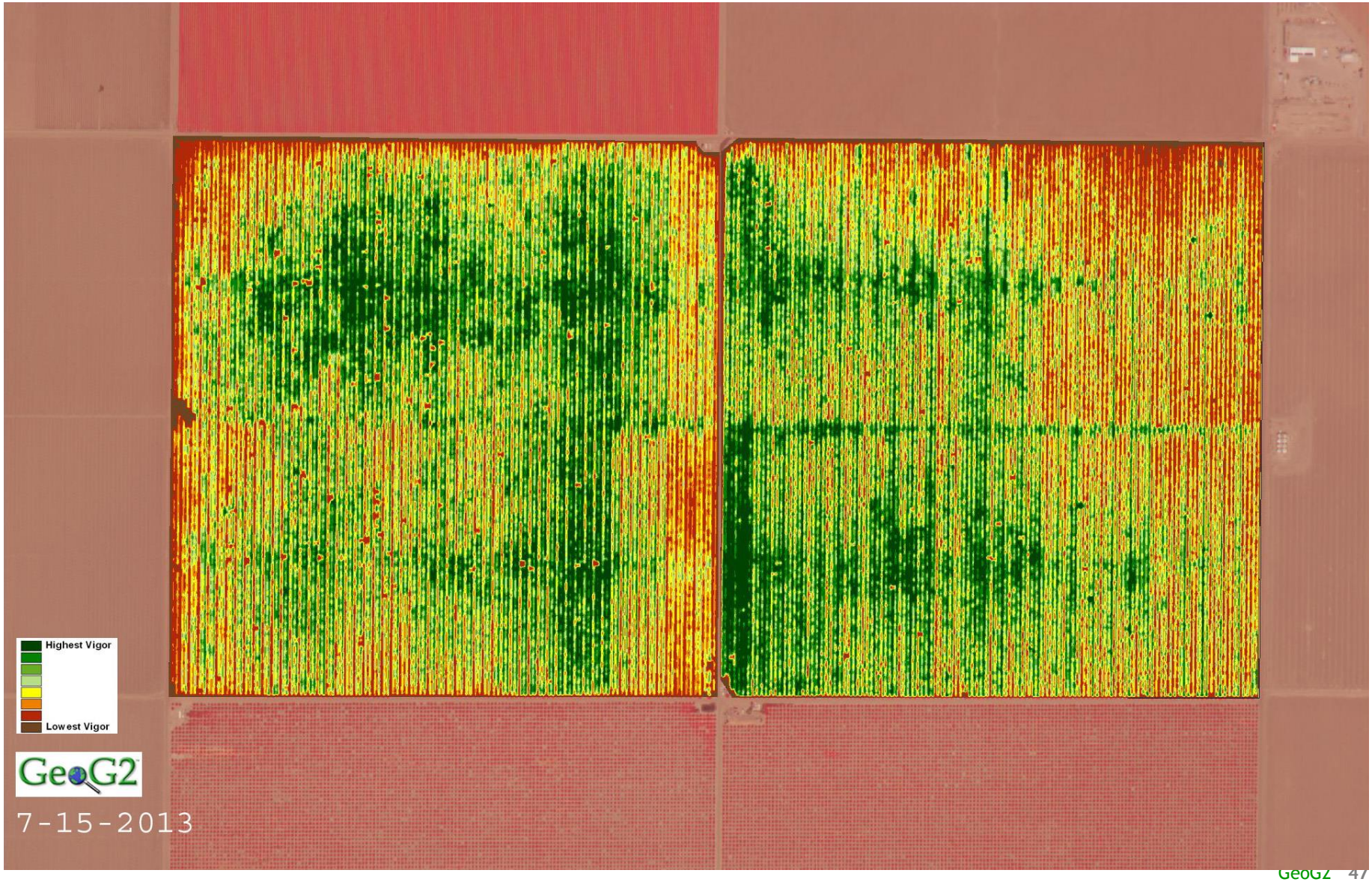


Example: Corn Growth Cycle

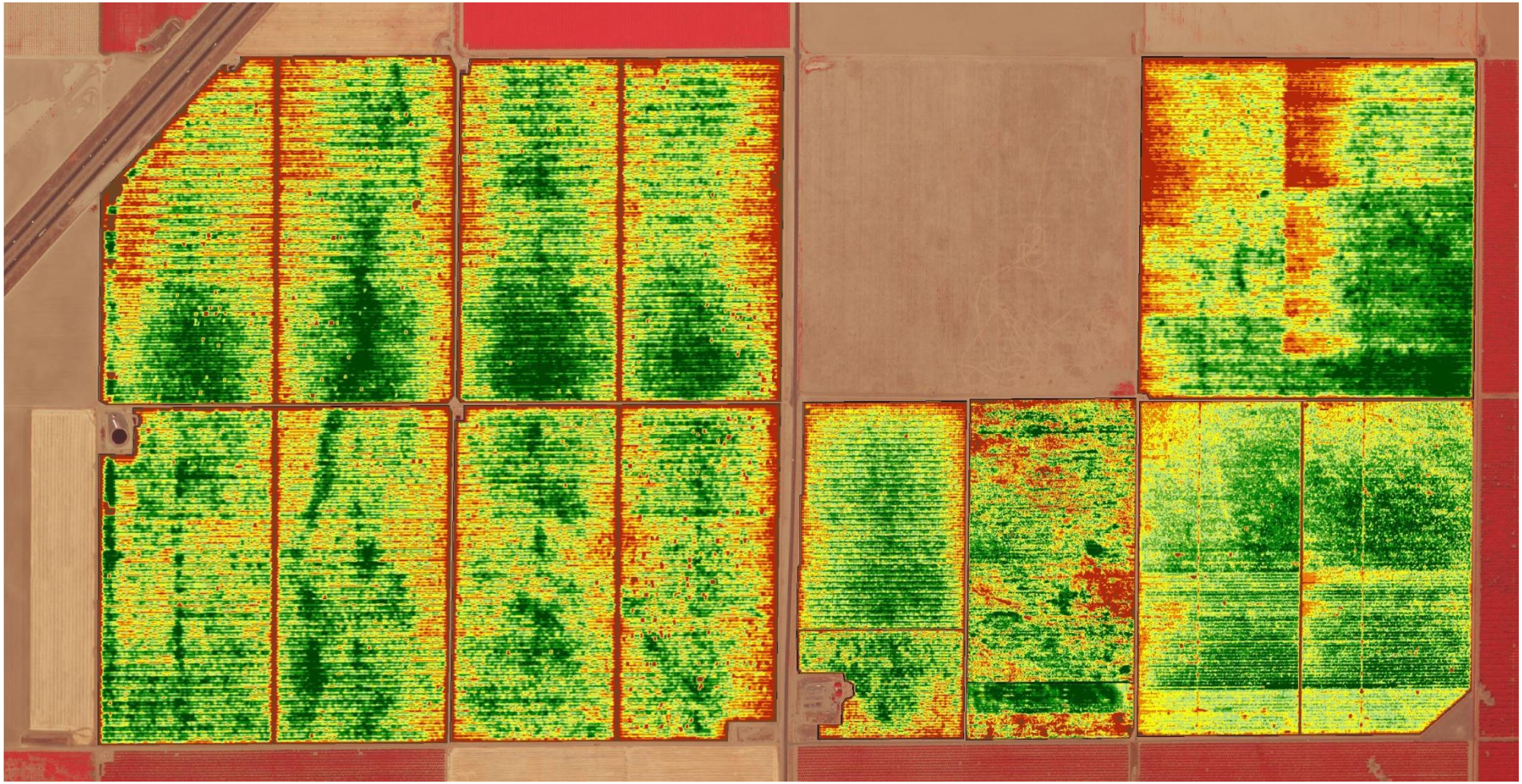
Tyler Island 2013 Imagery



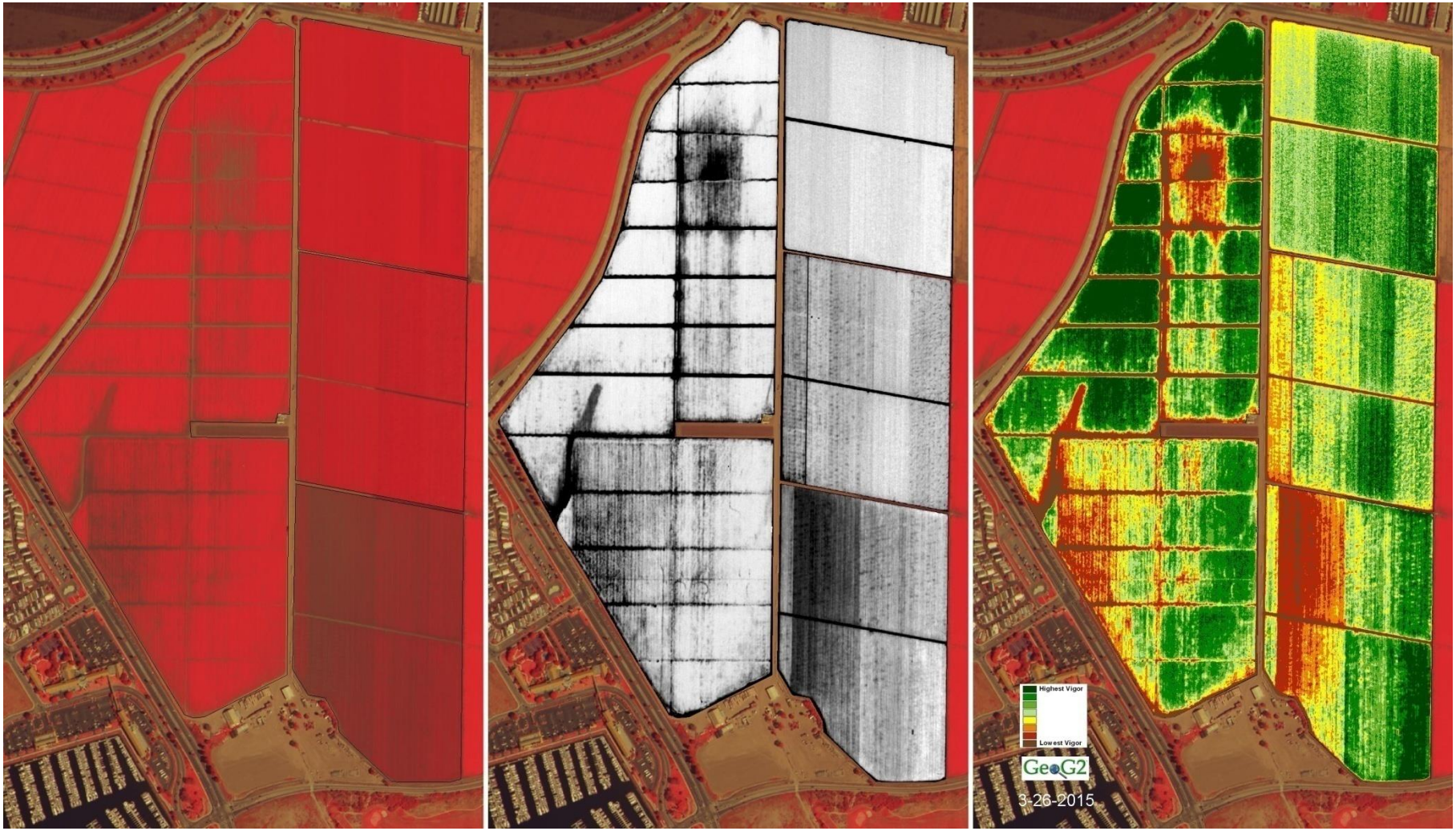
Example: Irrigation Issues



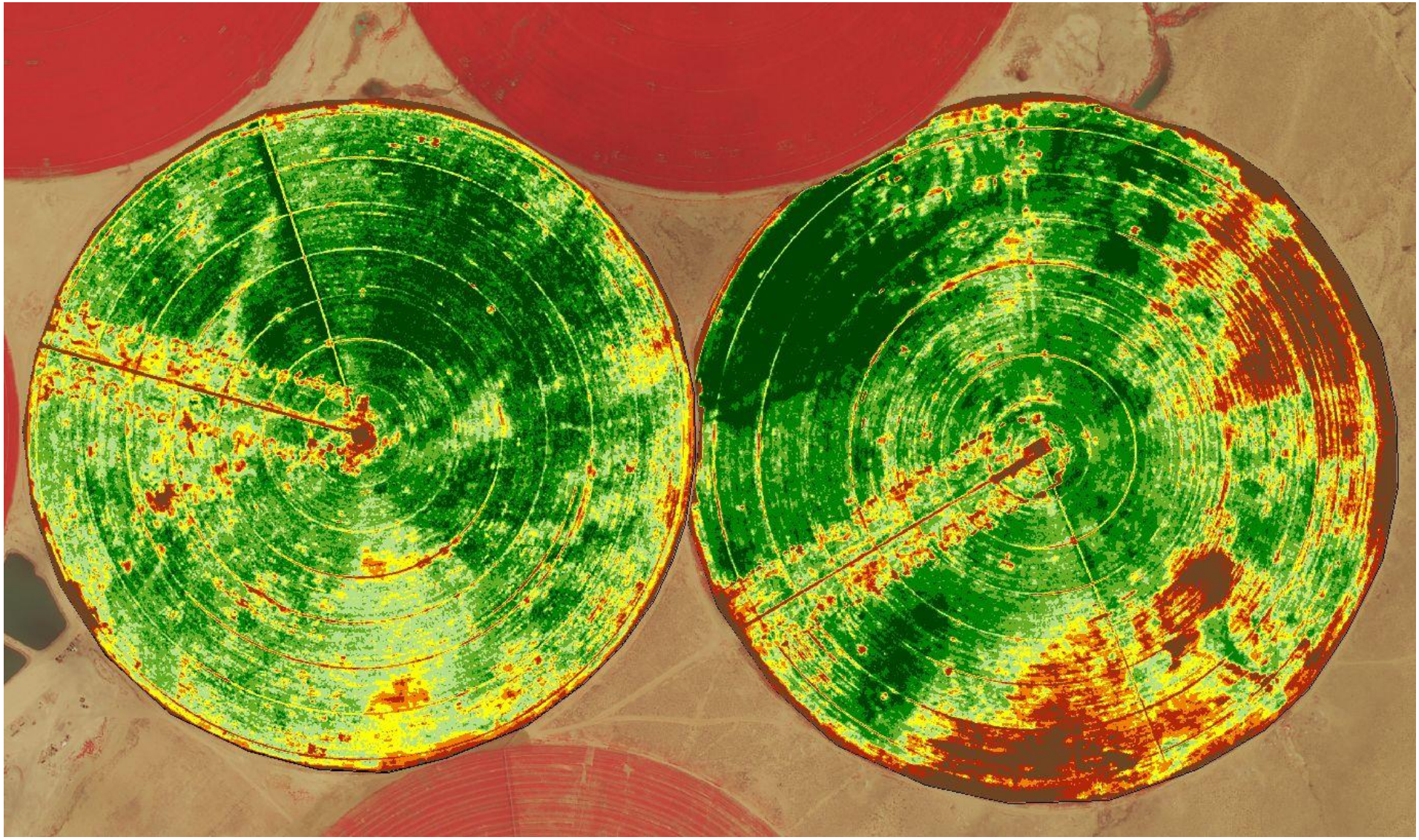
Example: Irrigation Issues



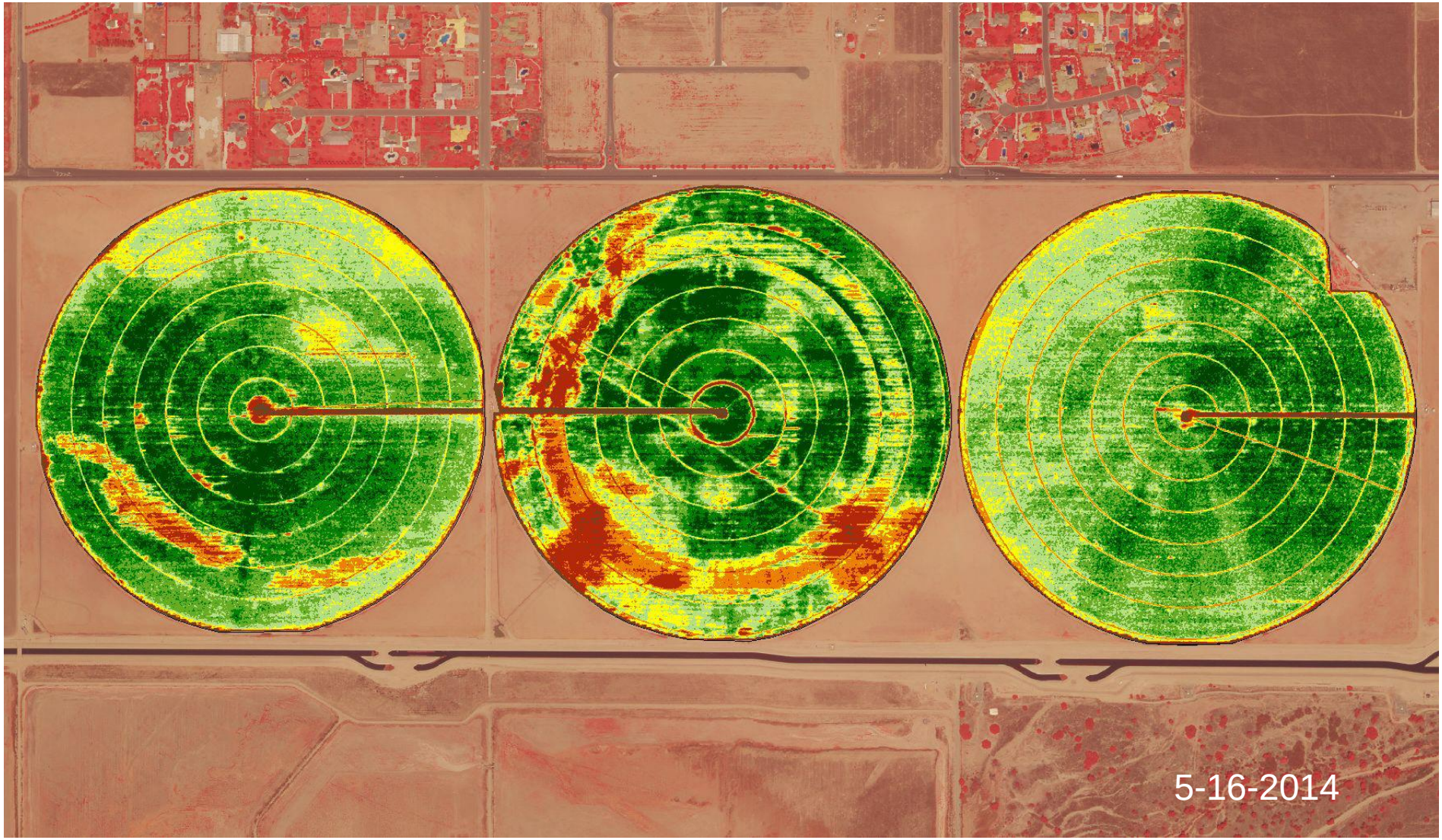
Example: Oxnard Strawberries & Lettuce



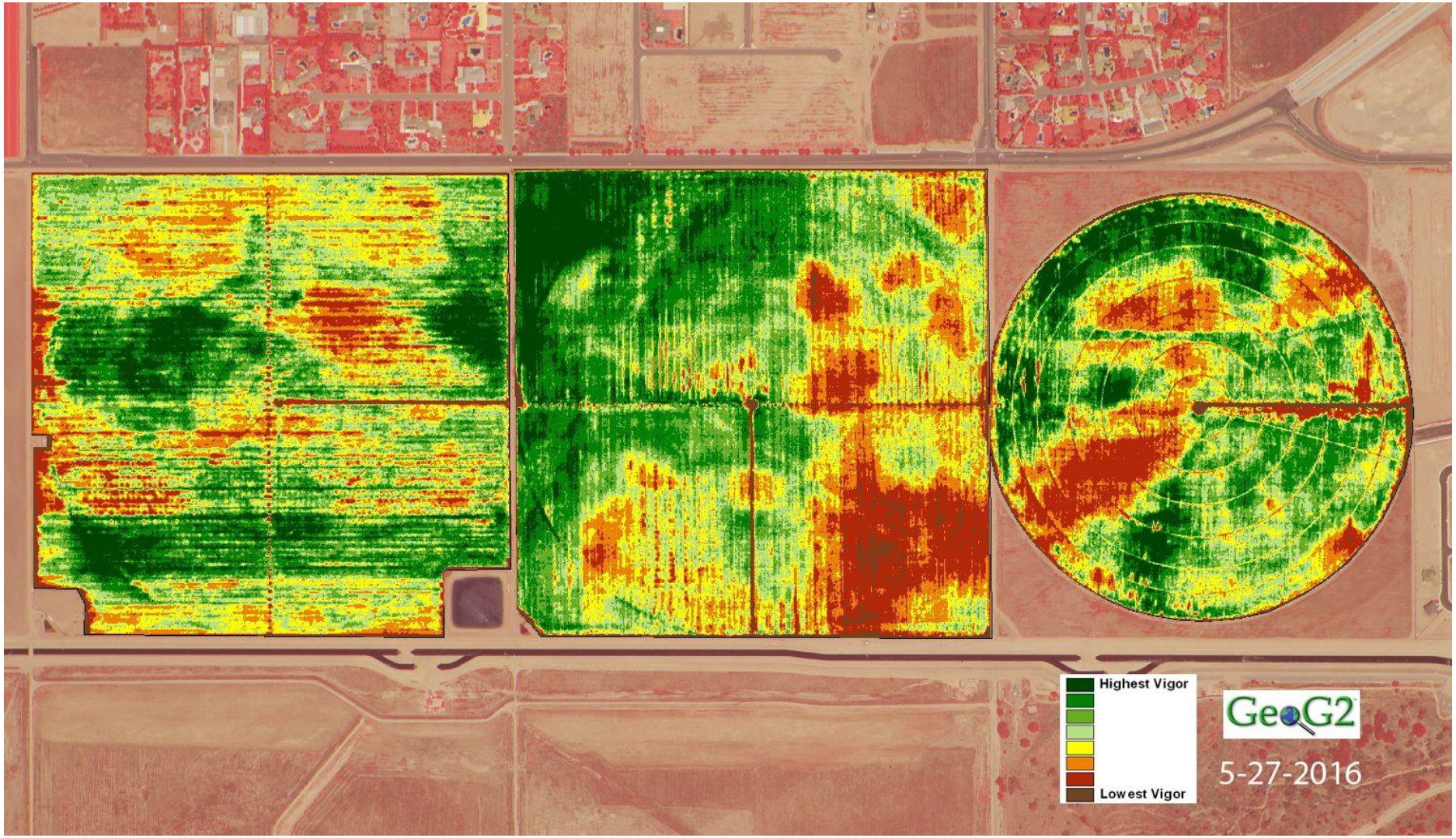
Example: Potatoes in Idaho



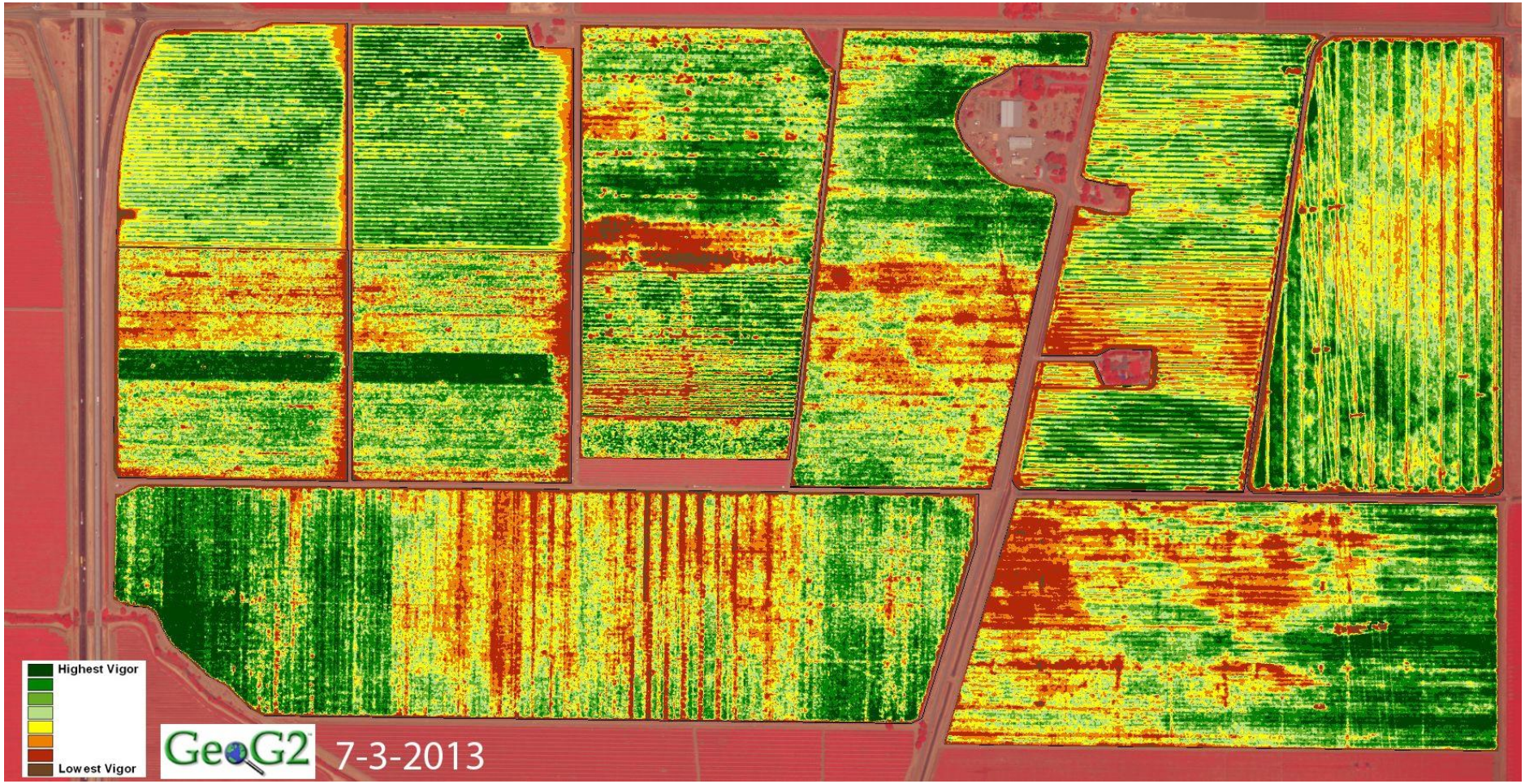
Example: Potatoes in California



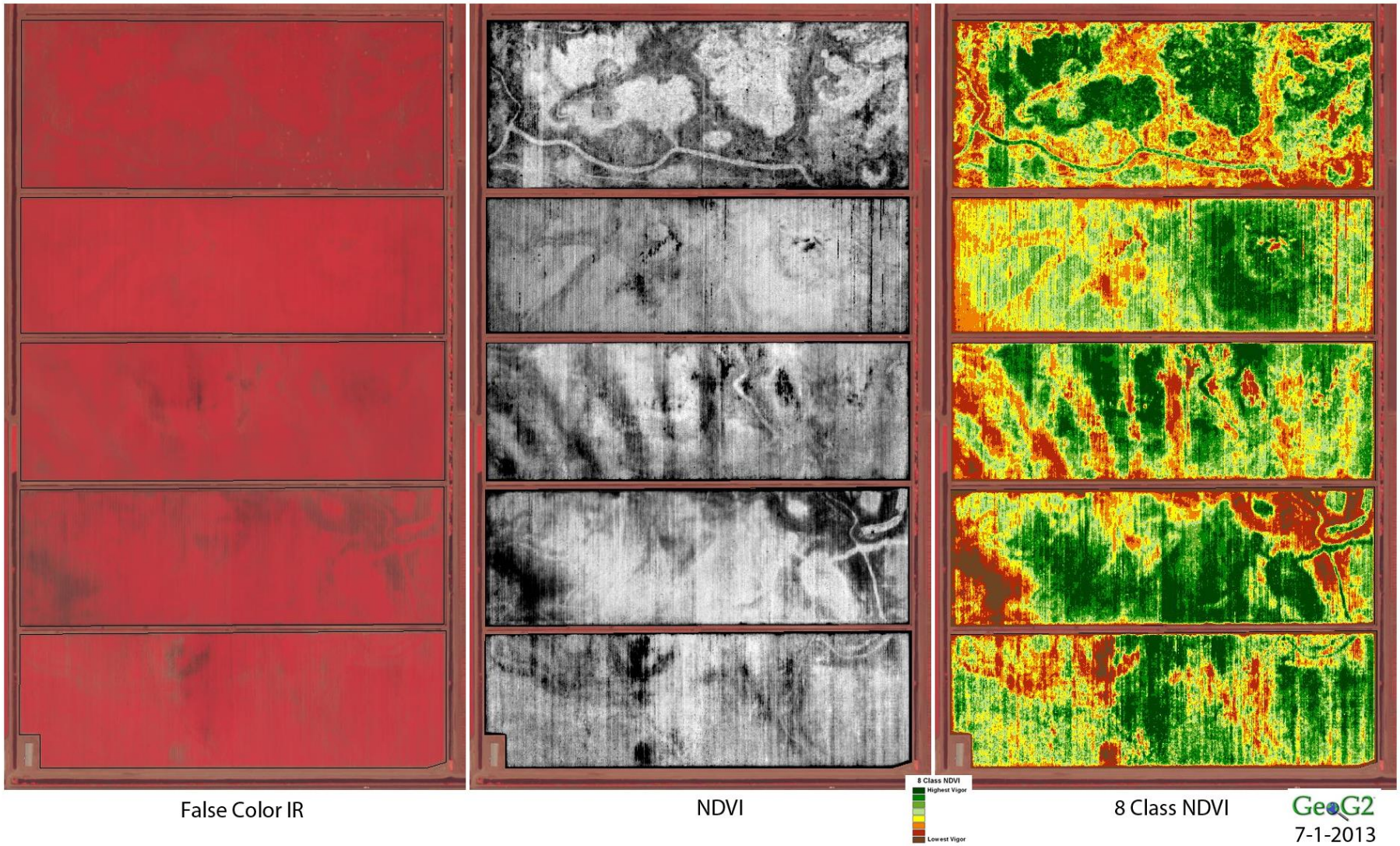
Example: Potatoes in California



Example: Winters,CA Field Crops



Example: Delta Asparagus



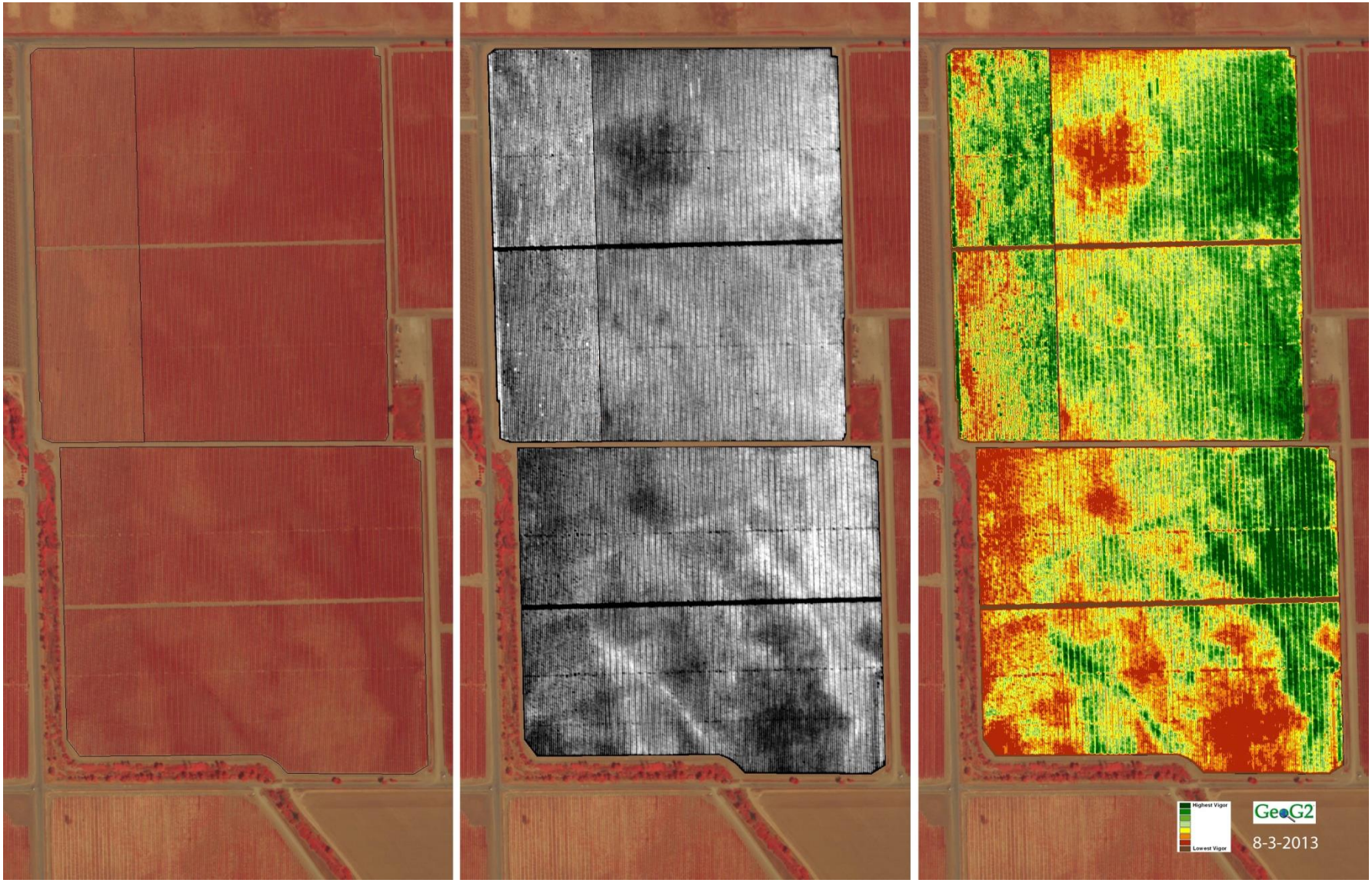
False Color IR

NDVI

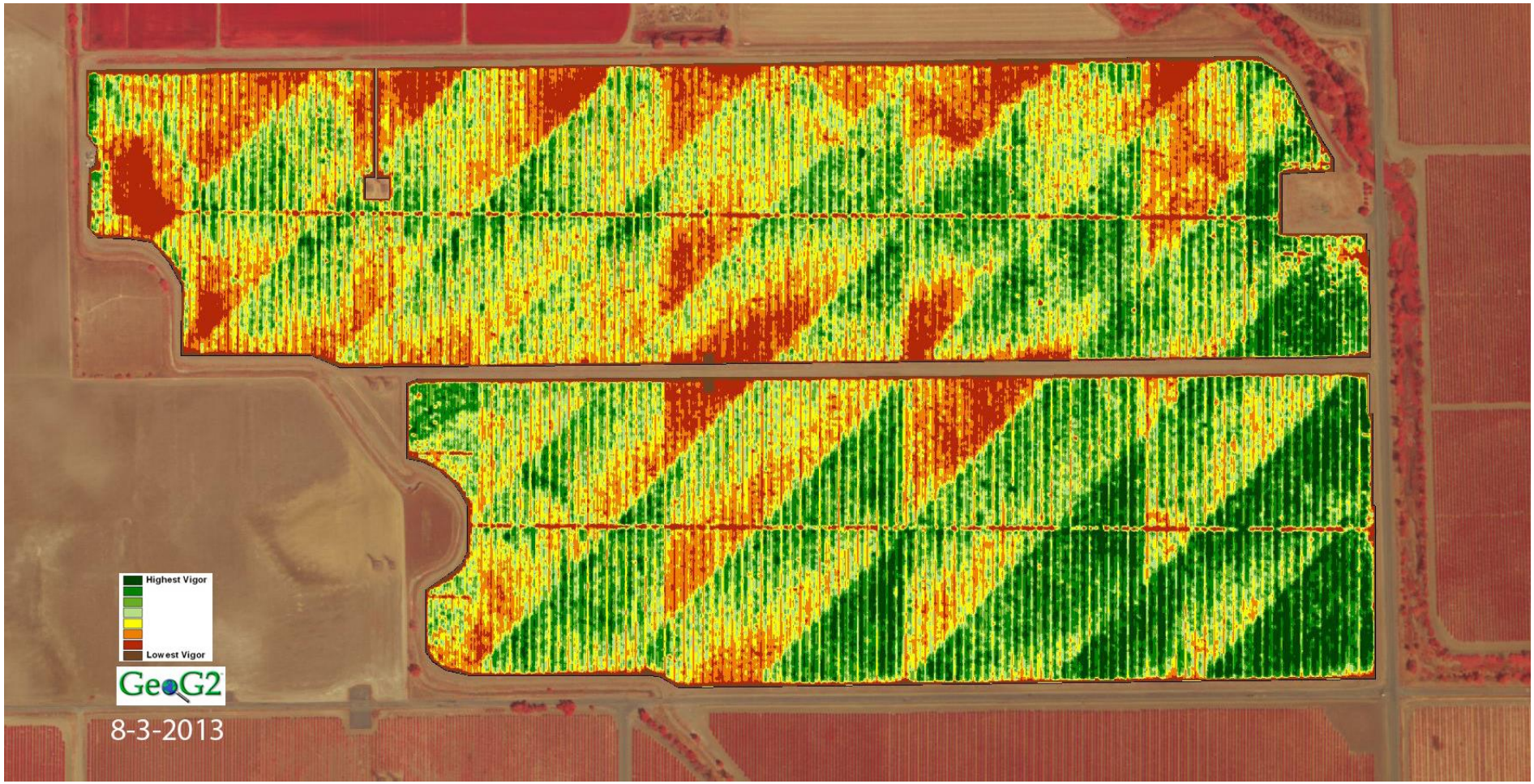
8 Class NDVI

GeoG2
7-1-2013

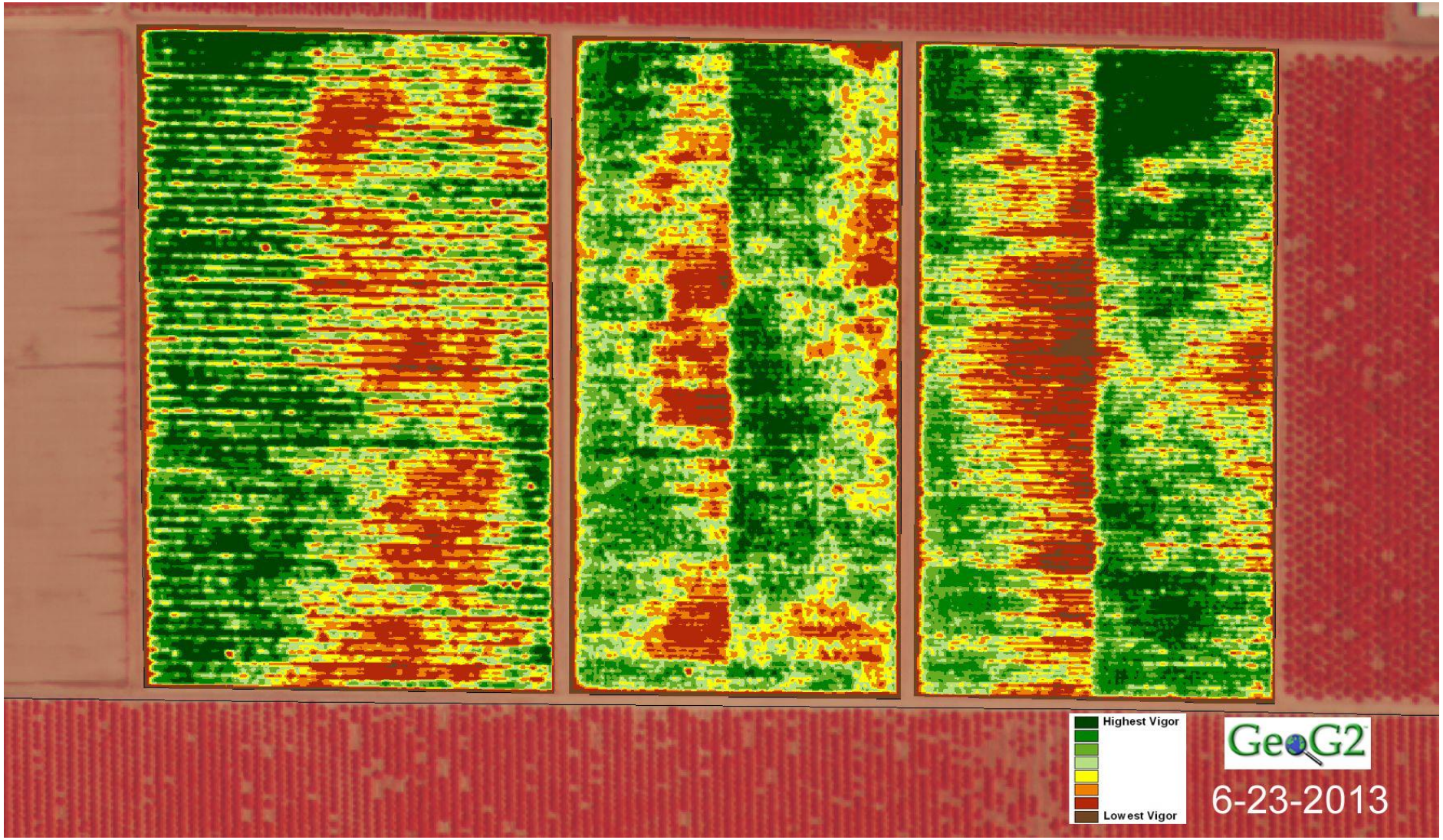
Example: Williams Orchard



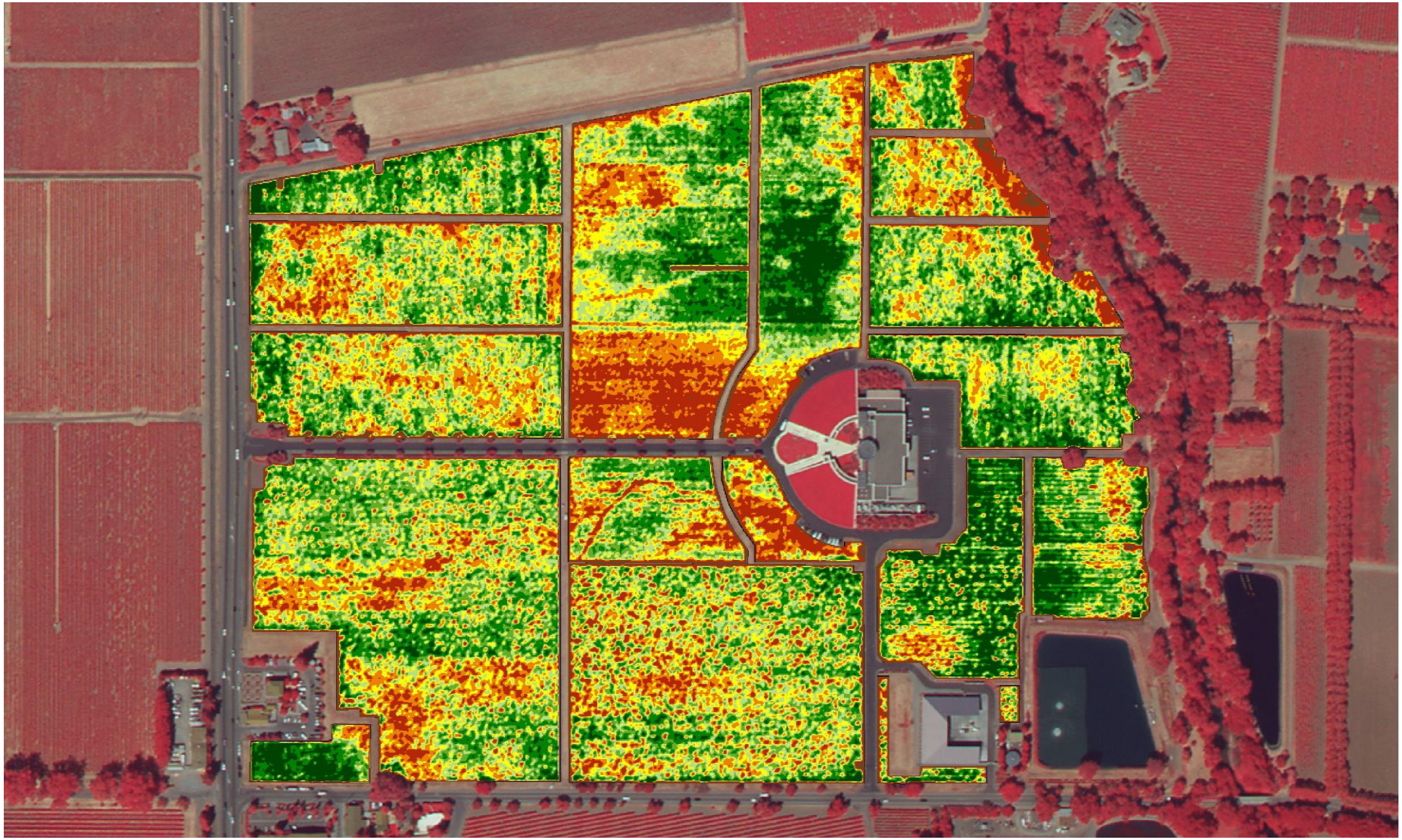
Example: Artois Olive Orchard



Example: Fresno Vineyard

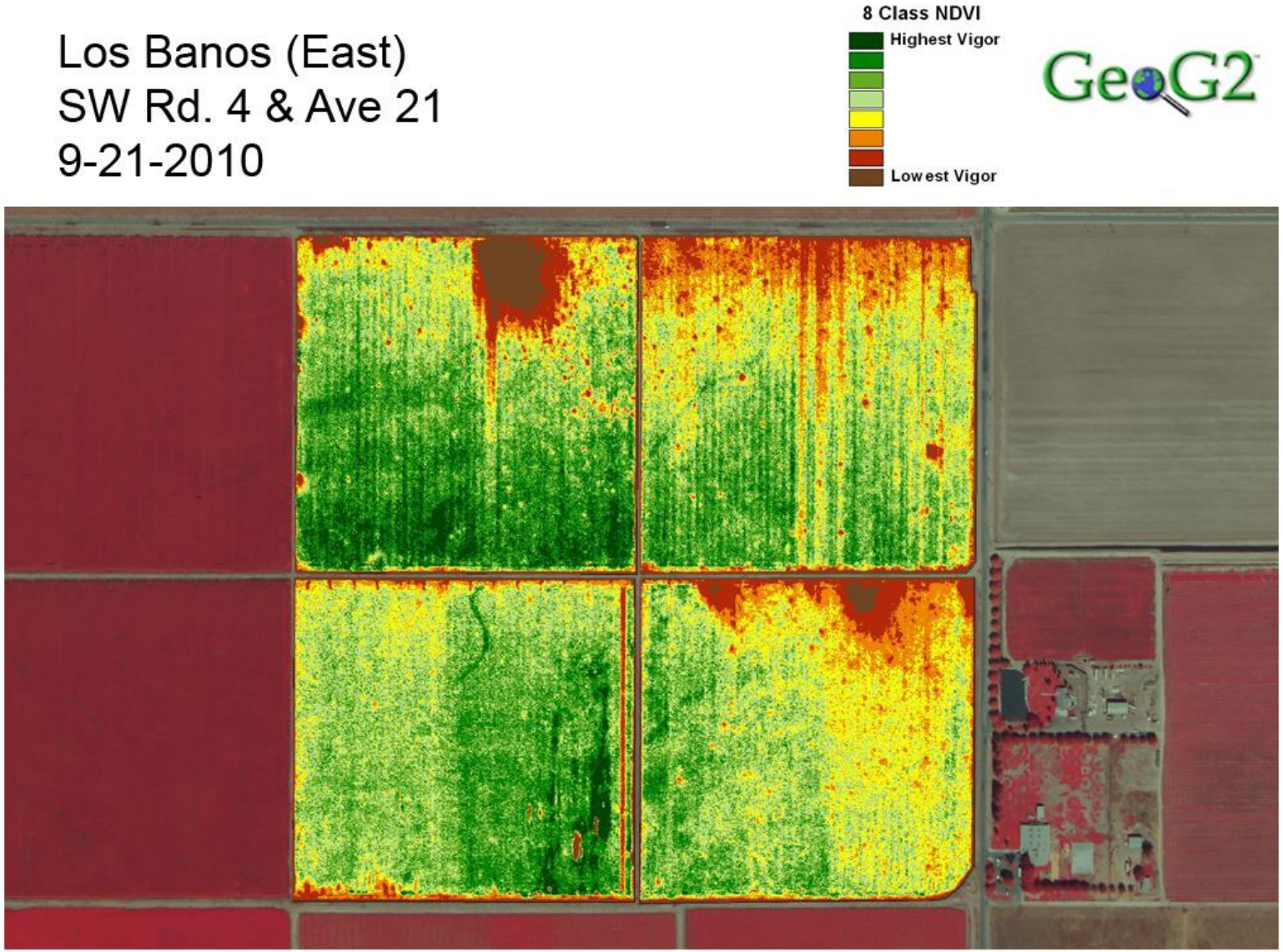


Example: Vineyard Oakville, CA



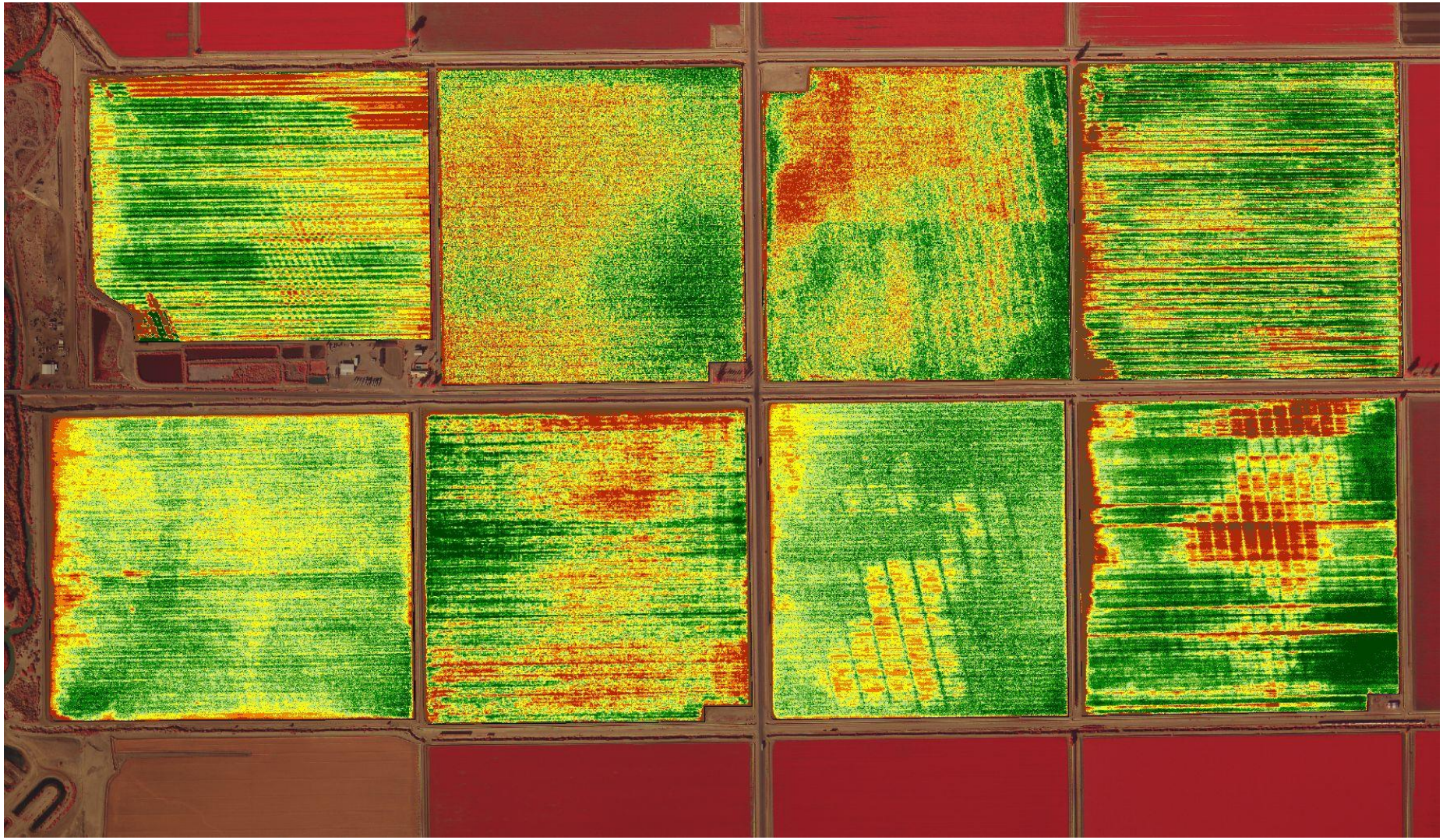
Example: Field Corn Los Banos, CA

Los Banos (East)
SW Rd. 4 & Ave 21
9-21-2010

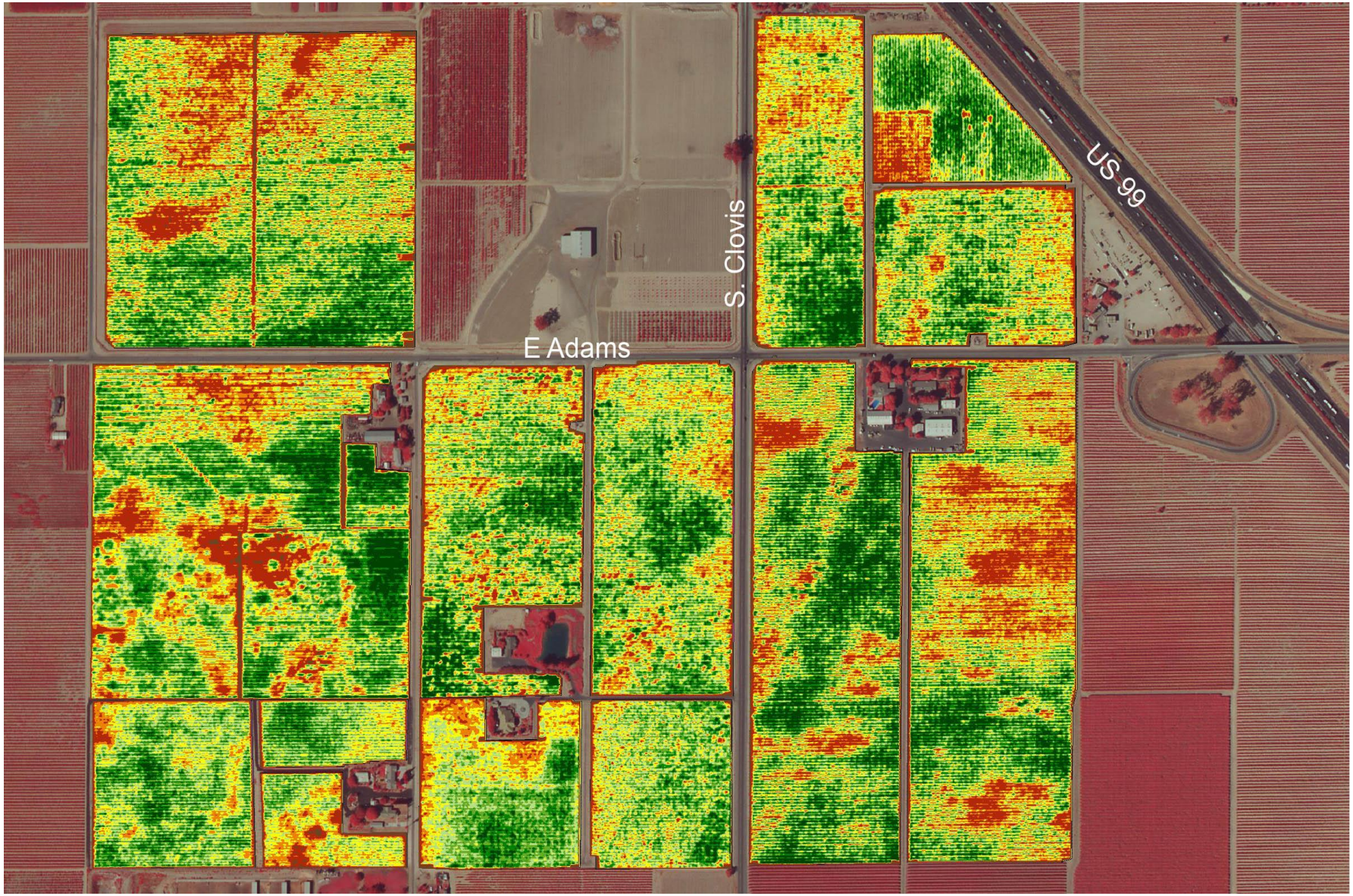


Field Corn

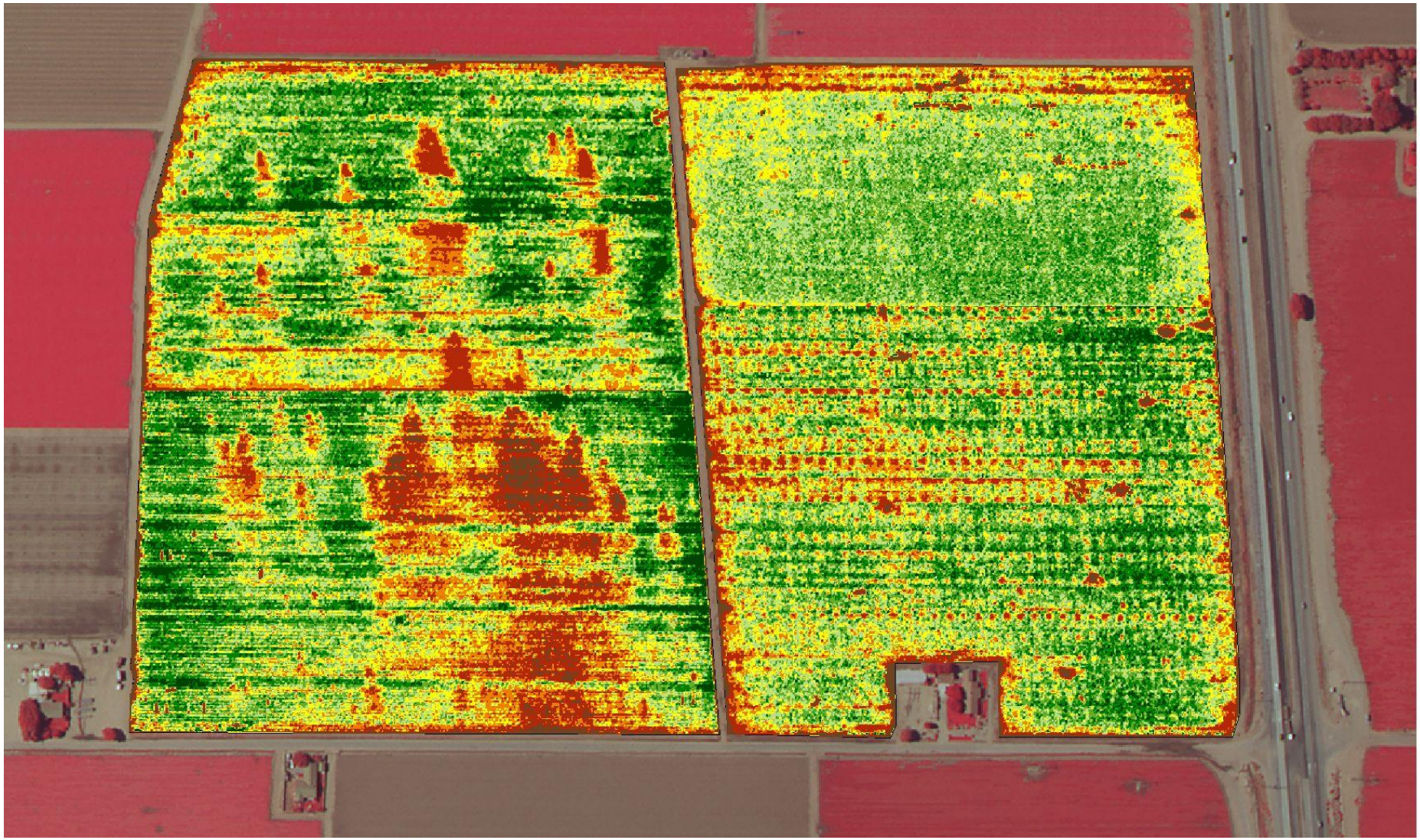
Example: Alfalfa Fields Brawley, CA



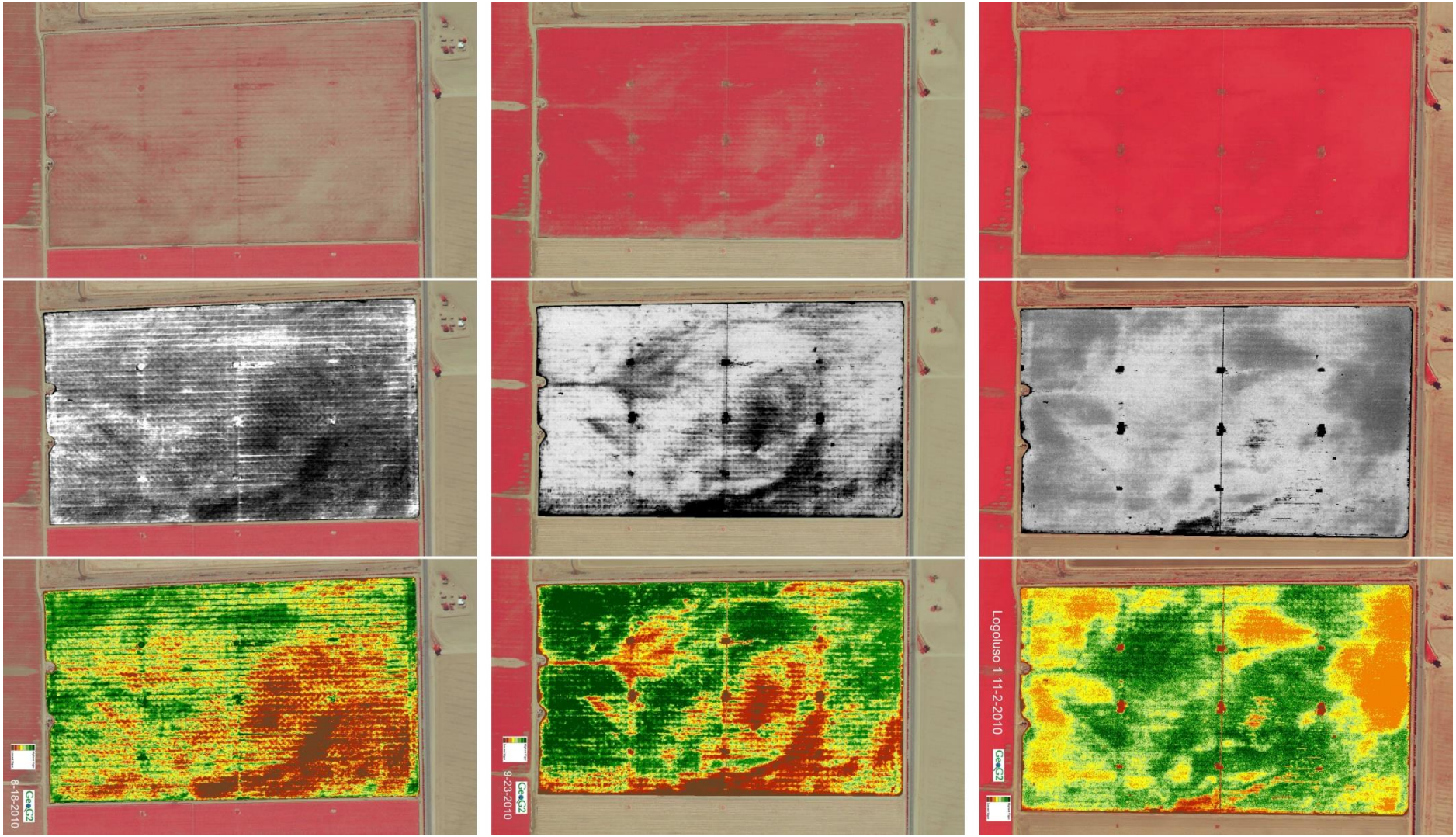
Example: Table Grapes in Fowler, CA



Example: Pepper and Broccoli Salinas, CA

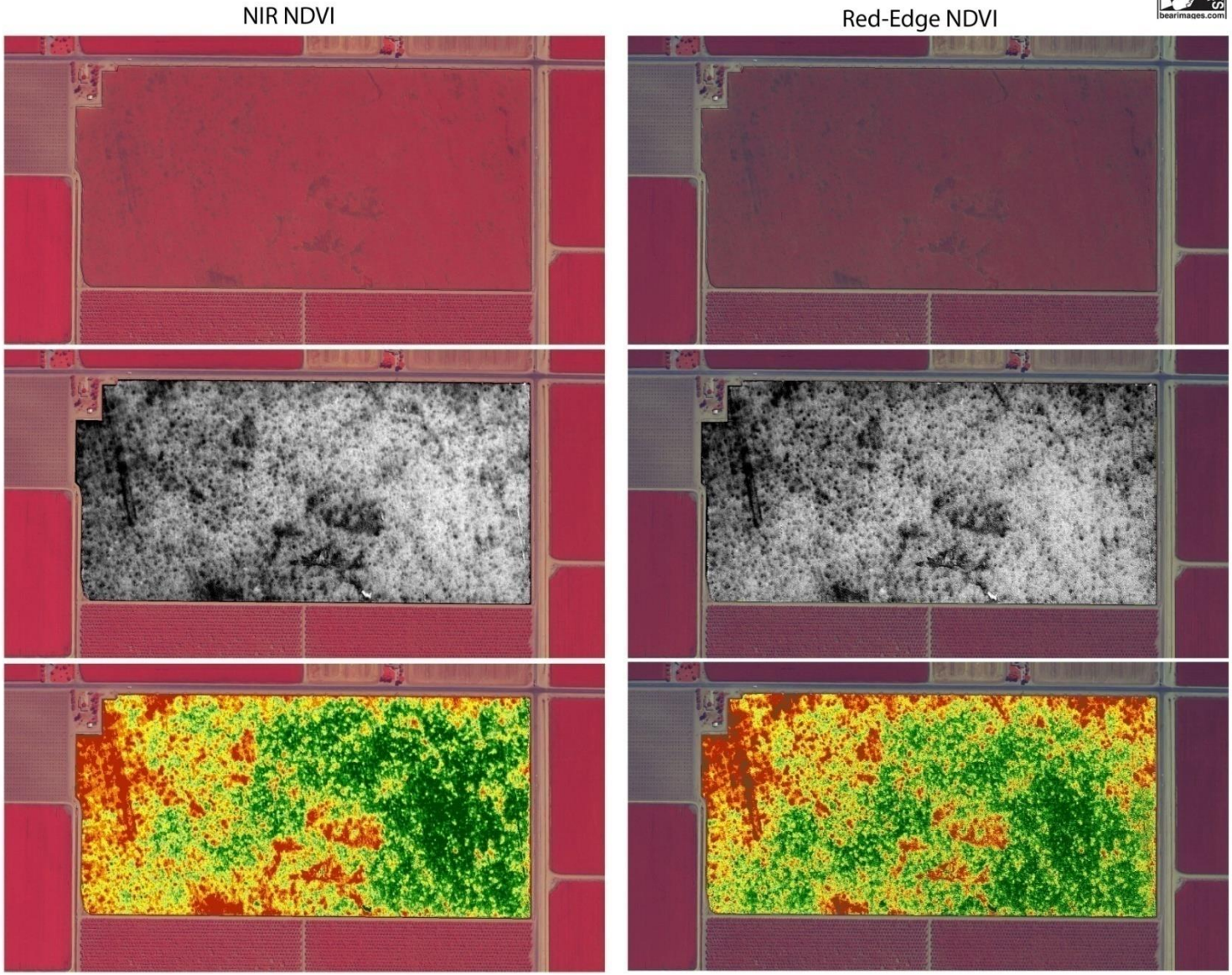


Example: Growth curve in Carrots



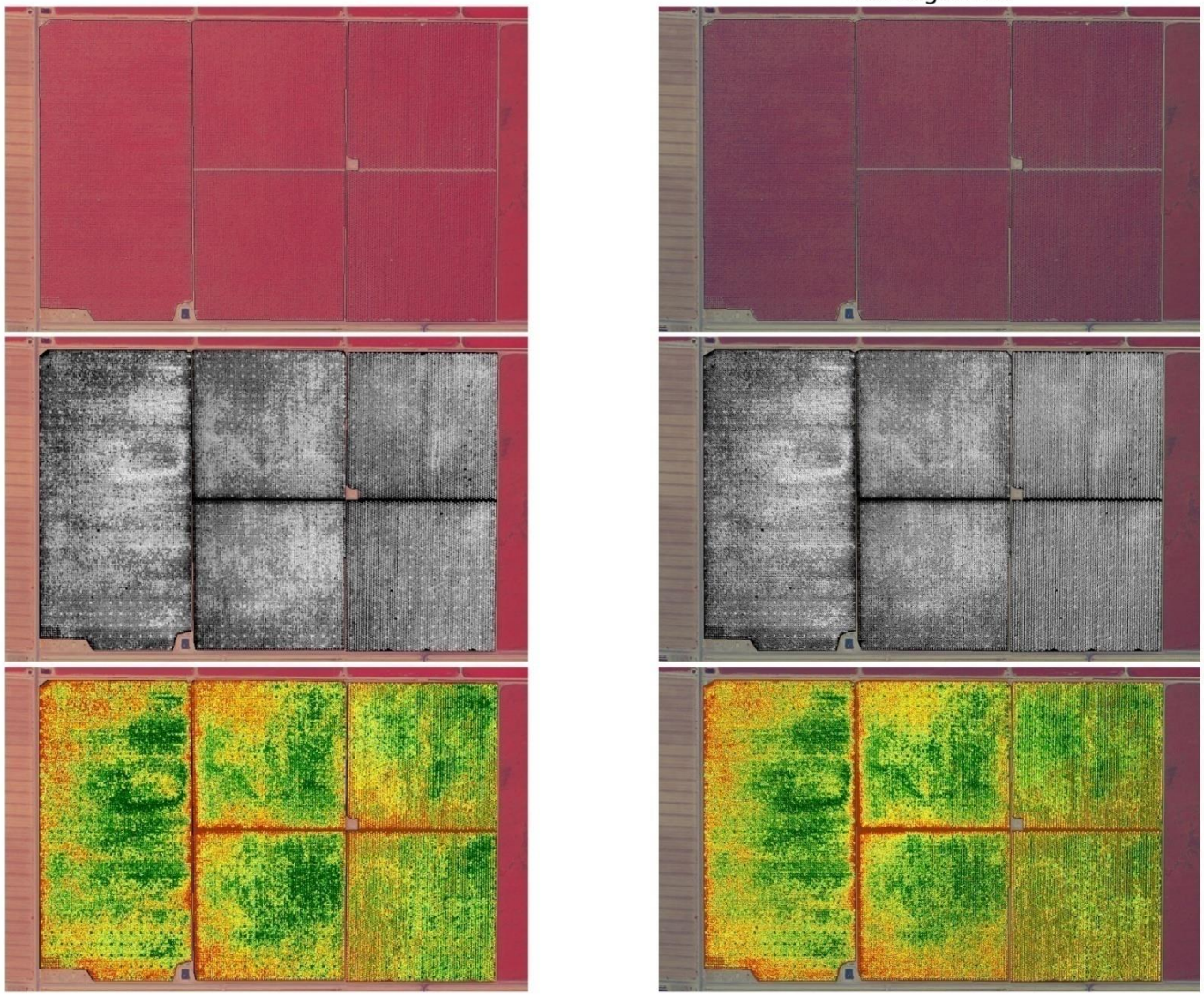
Example: Red-Edge Comparison

Corn 8-17-2016 Comparison NIR NDVI to Red-Edge NDVI

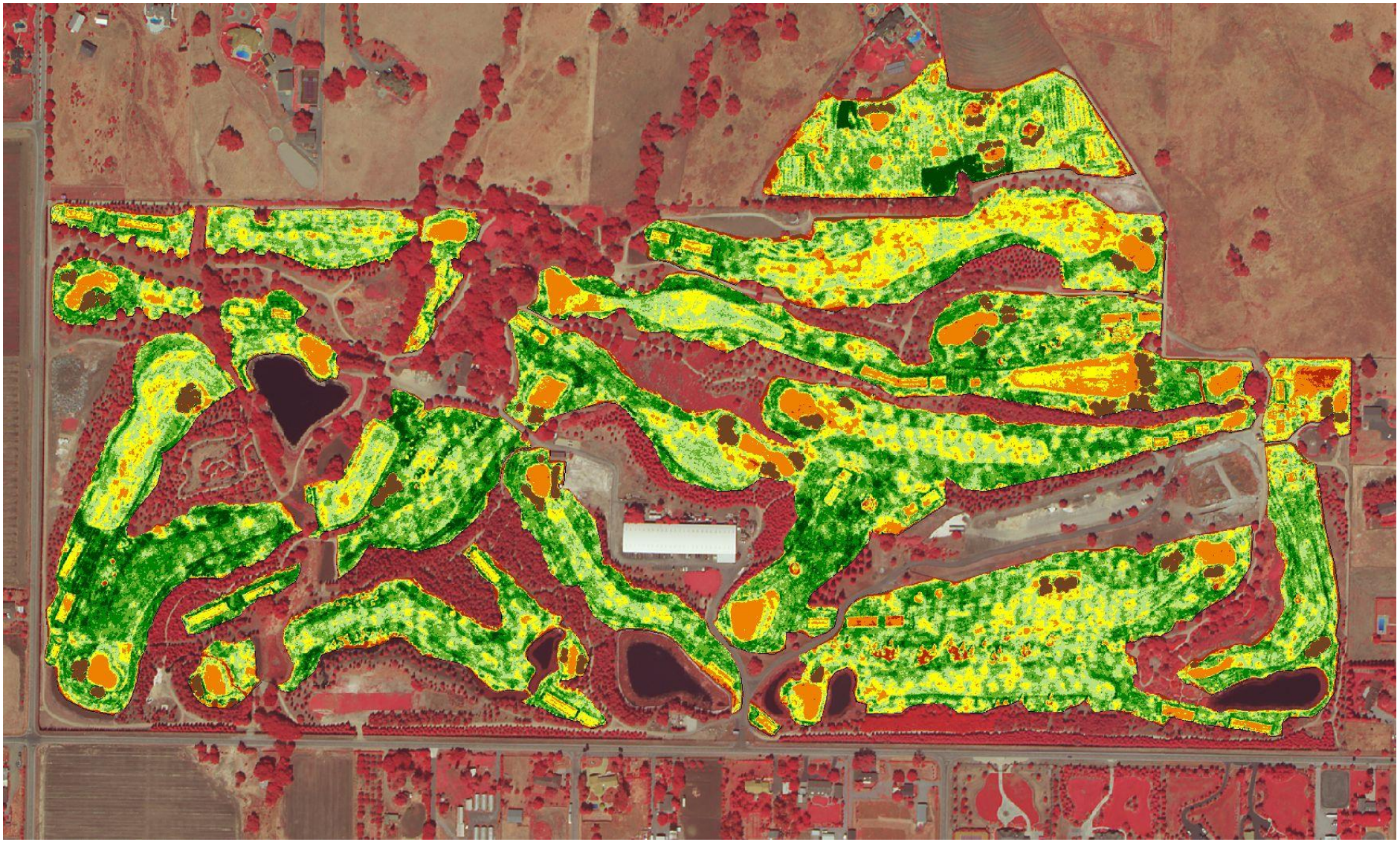


Example: Red-Edge Comparison

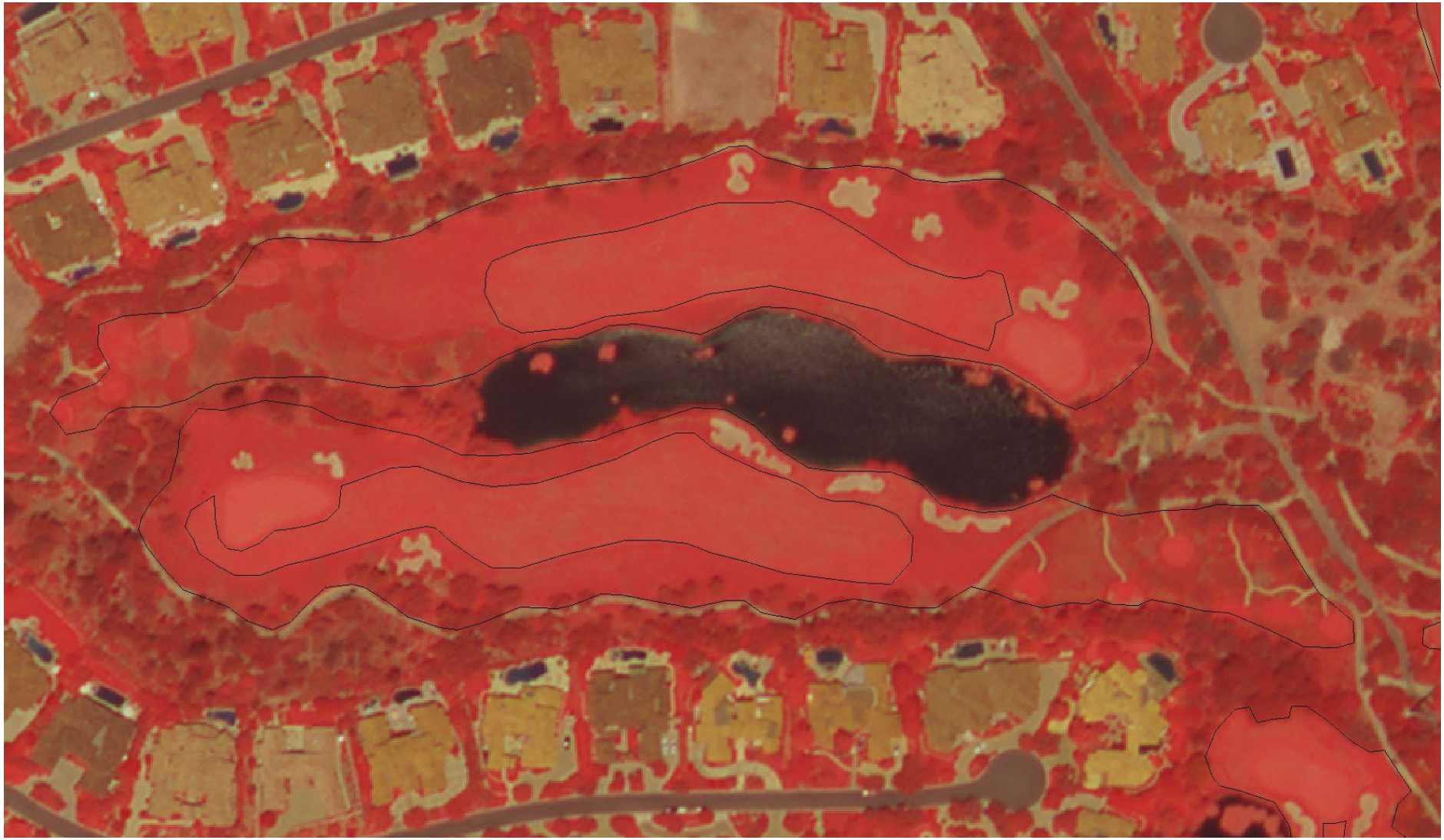
Pistachios 8-17-2016 Comparison NIR NDVI to Red-Edge NDVI



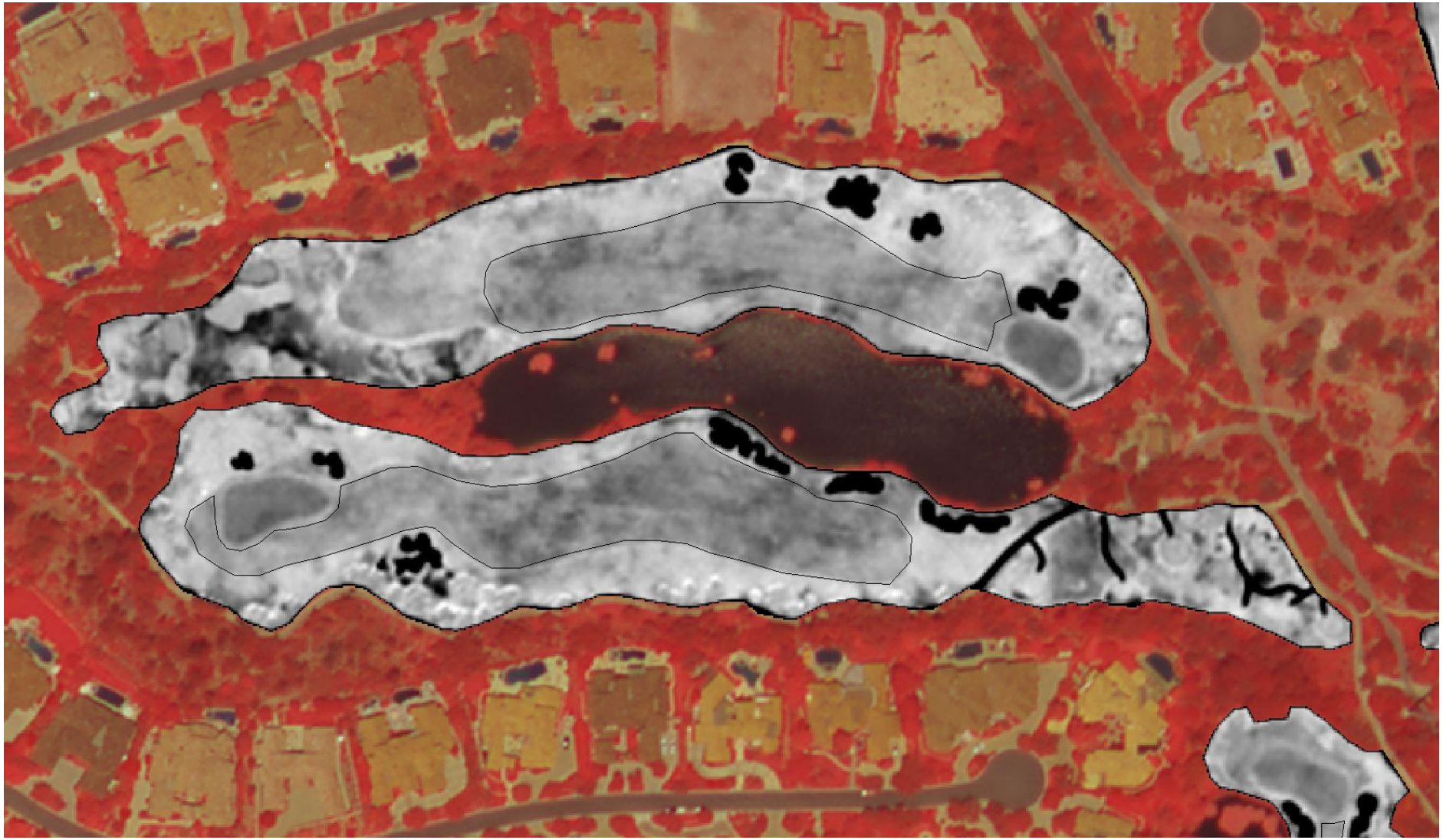
Example: Golf Course San Martin, CA



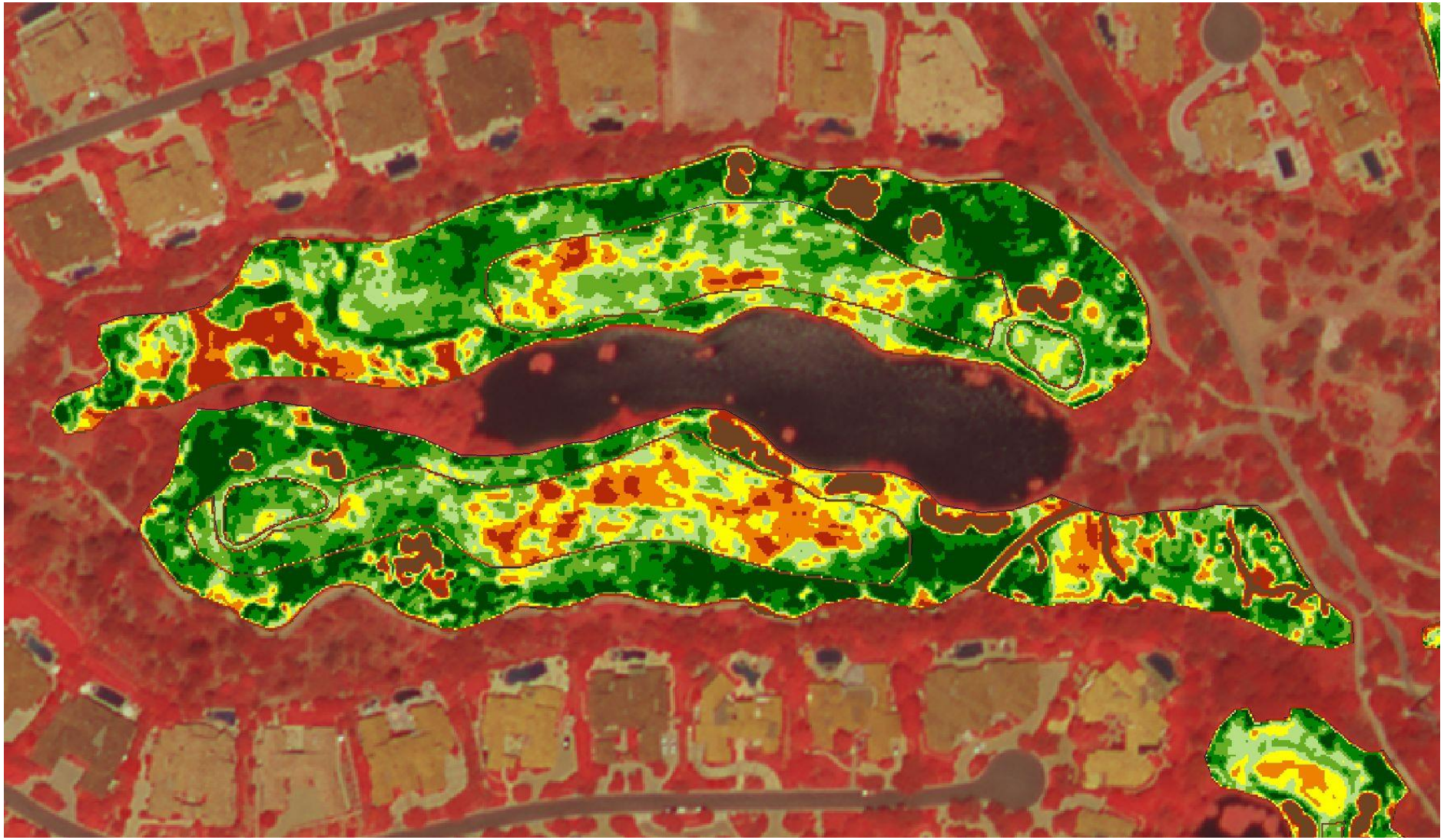
Southern Cal Golf Course FCIR



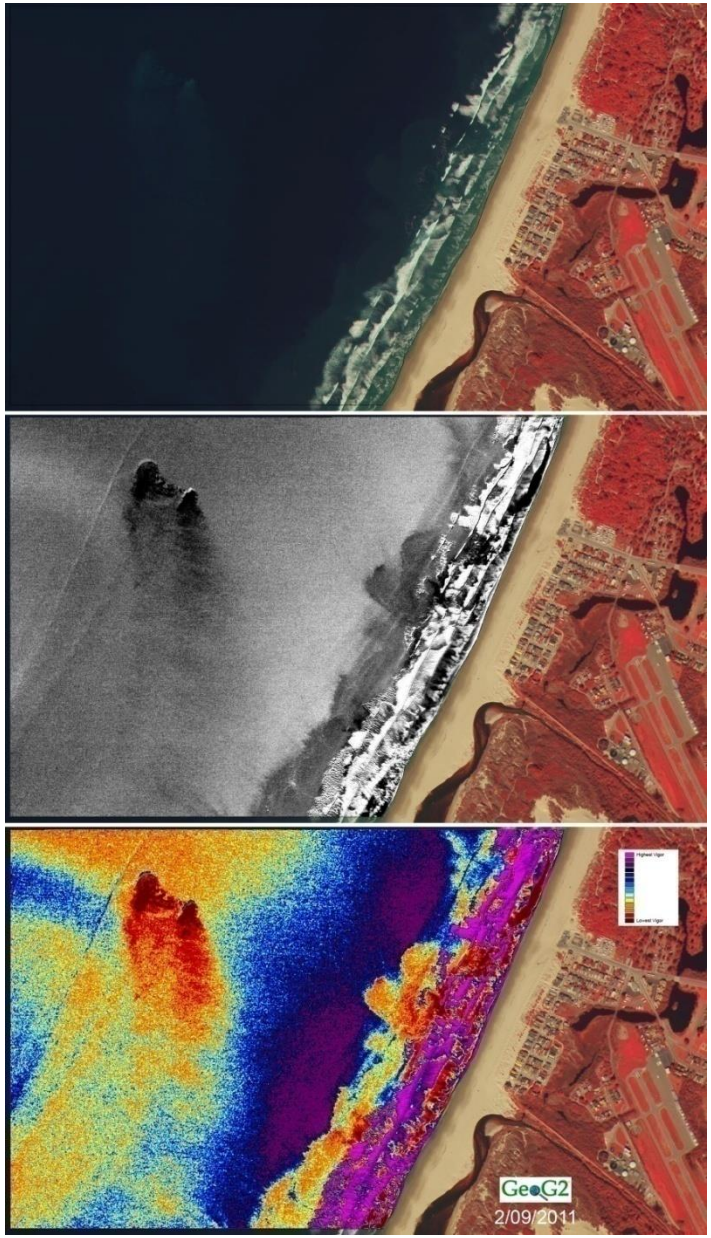
Southern Cal Golf Course NDVI



Southern Cal Golf Course 8Class

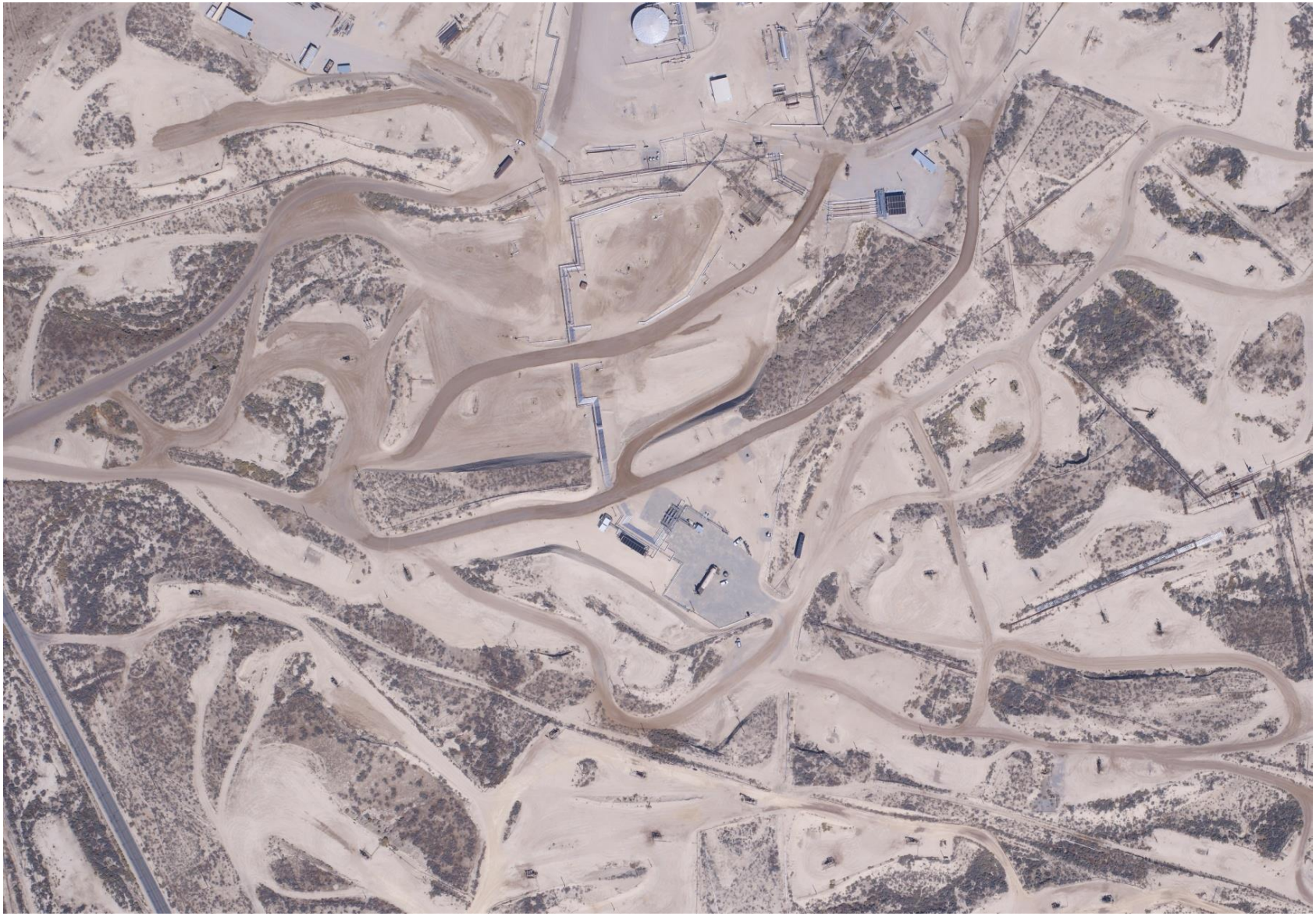


Example: Environmental

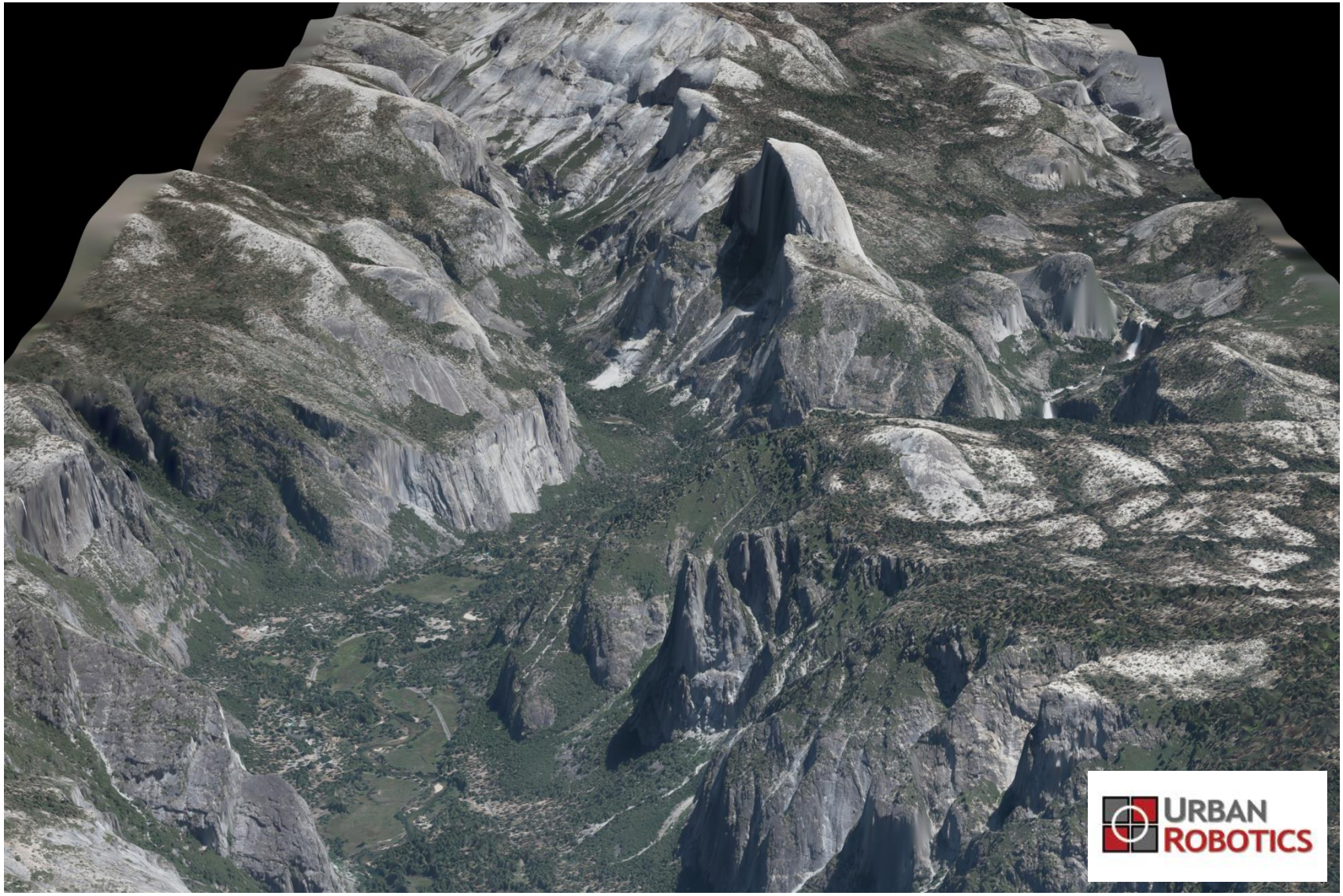


Sewage Discharge off the coast in Grover Beach, CA

Example: Oil field 6” resolution Taft, CA



Example: 3D Modeling



3D Point Cloud Extraction from Nadir Imagery

Example: Disaster Response

San Bruno pipeline explosion taken 10:30 AM the following morning

Conclusion

Thank you
Questions?

1661

Bonus!