

# **CIE5401**

# **GIS and Remote Sensing for**

# **Water Resources Management**

**Lecture 4: Visible Remote Sensing**  
**5 March 2018**  
**Susan Steele-Dunne**

# Course Introduction: Schedule

<b>Lecture Date</b>	<b>Lecture topic</b>	<b>Assignment Due Date</b>
12 February	Introduction to GIS	19 February
19 February	Spatial Analysis in GIS	26 February
26 February	Watershed delineation	5 March
5 March	Visible RS	12 March
12 March	Thermal IR	19 March
19 March	Microwave remote sensing	26 March

# Course Introduction: Schedule

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12 February	Introduction to GIS	19 February
19 February	Spatial Analysis in GIS	26 February
26 February	Watershed delineation	5 March
<b>5 March</b>	<b>Visible RS (Vera Hollander)</b>	<b>12 March</b>
12 March	Thermal IR (NEO)	19 March
19 March	Microwave remote sensing (VanderSat)	26 March

# Acknowledgements

- Prof. Nick van de Giesen
- ESA
- NASA/USGS Landsat

# Why?

# Why?

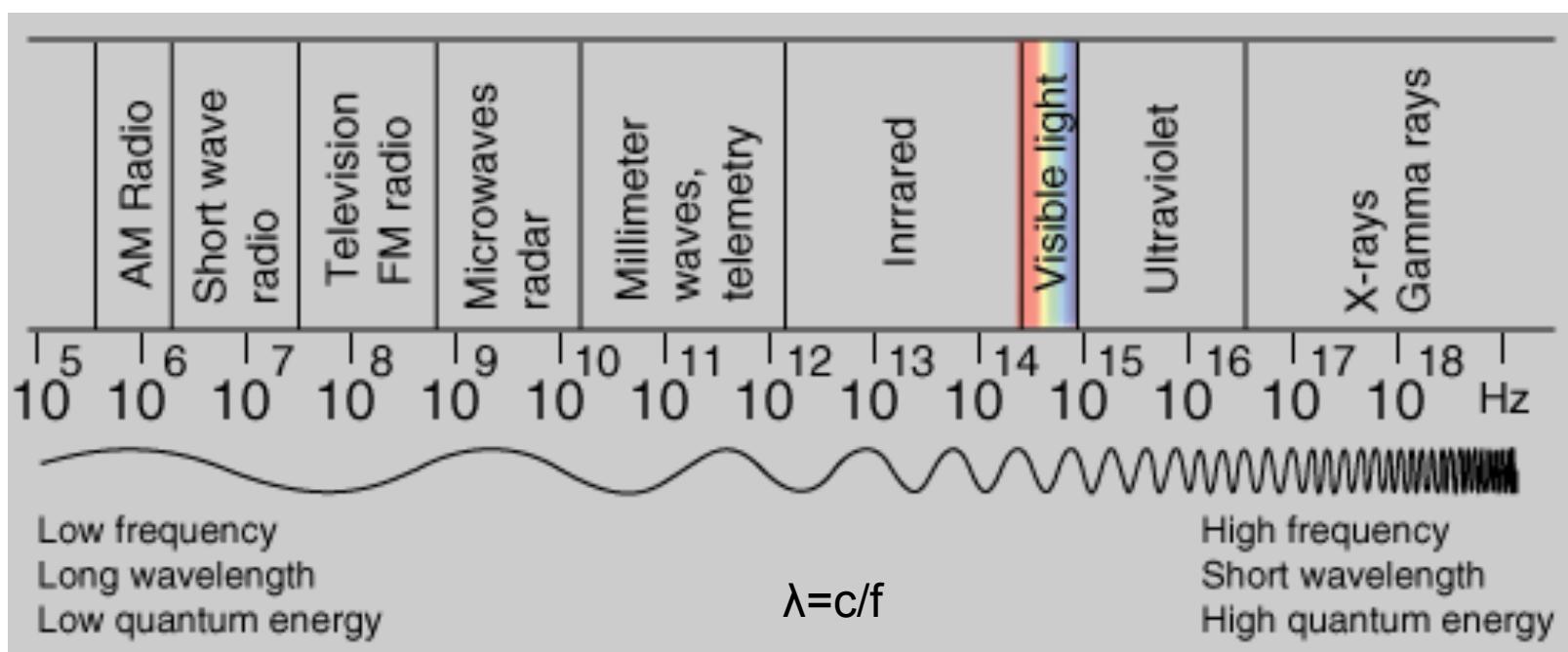
Global coverage

Inexpensive?

Continuous monitoring

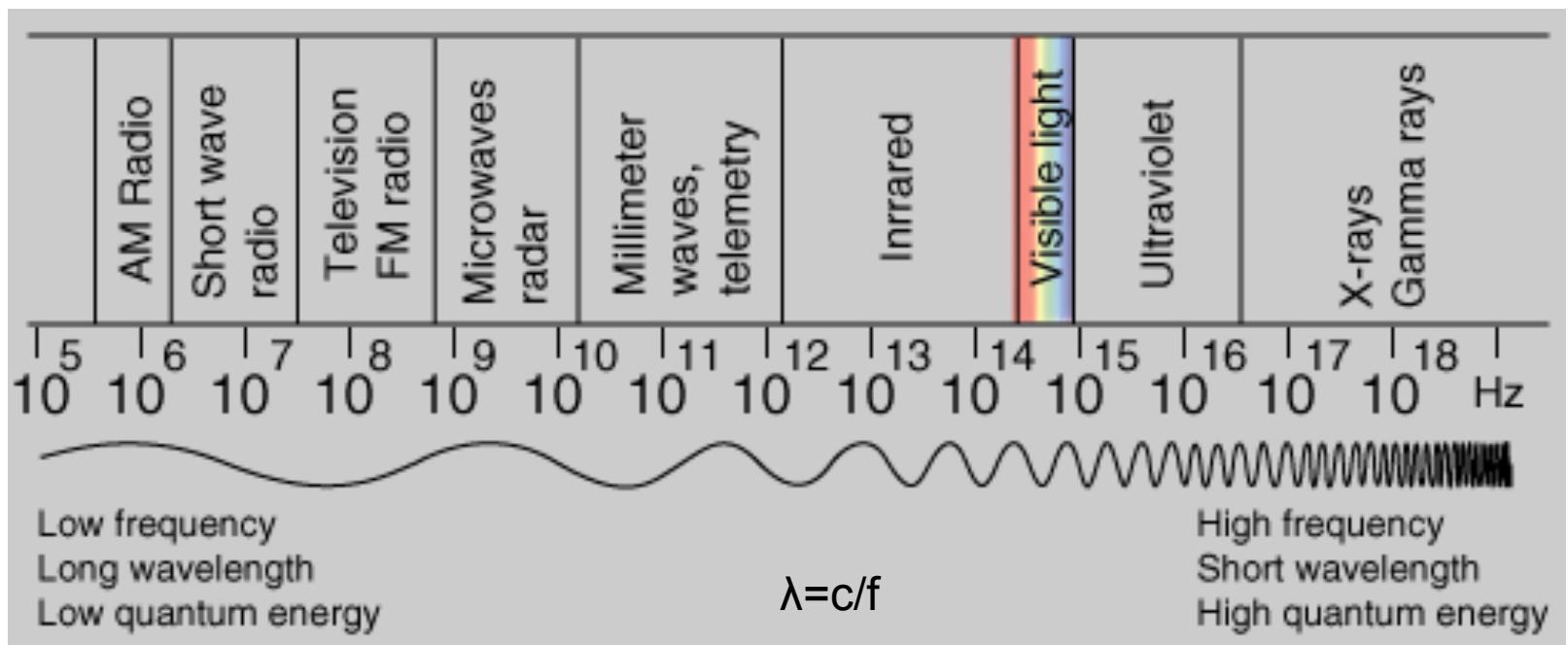
Monitor everywhere ...

# Electromagnetic Spectrum

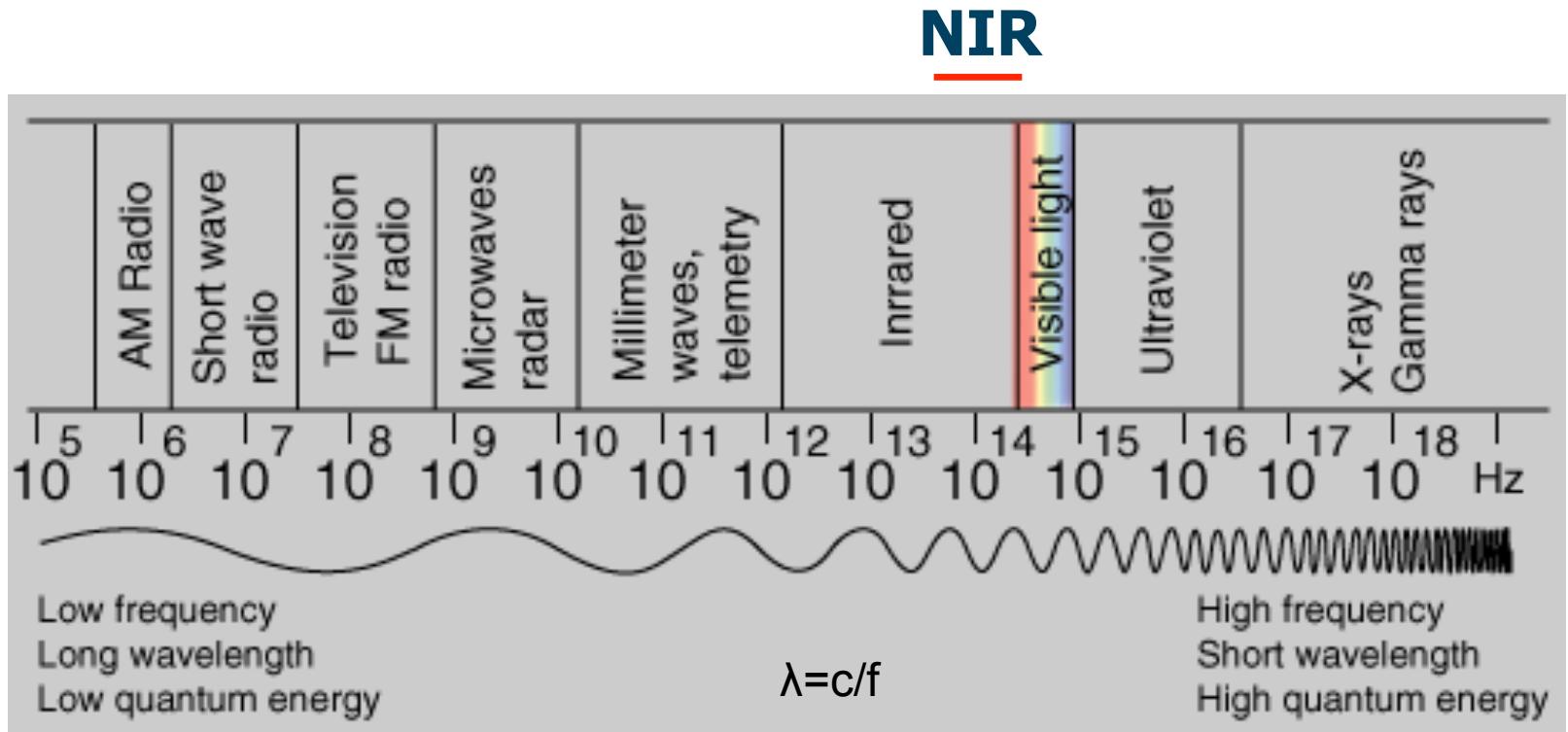


# Electromagnetic Spectrum

**Visible**

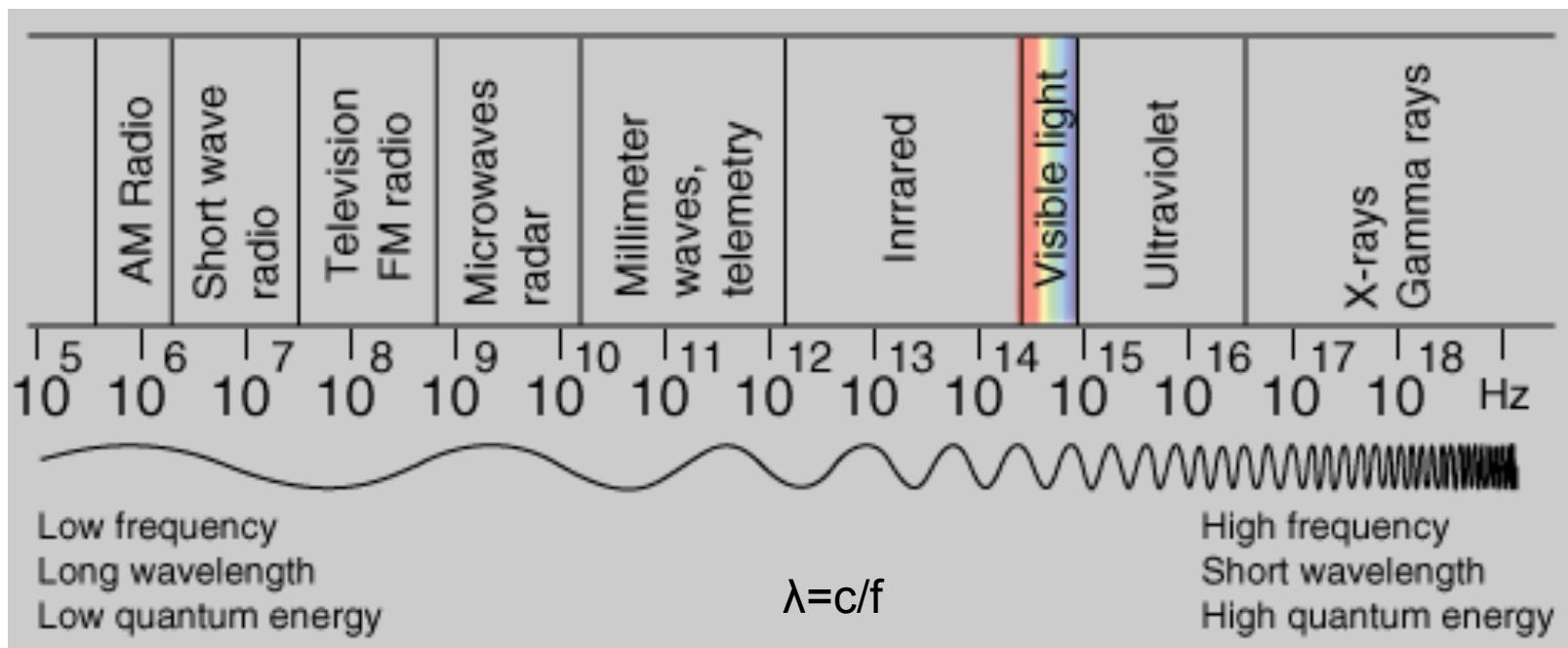


# Electromagnetic Spectrum



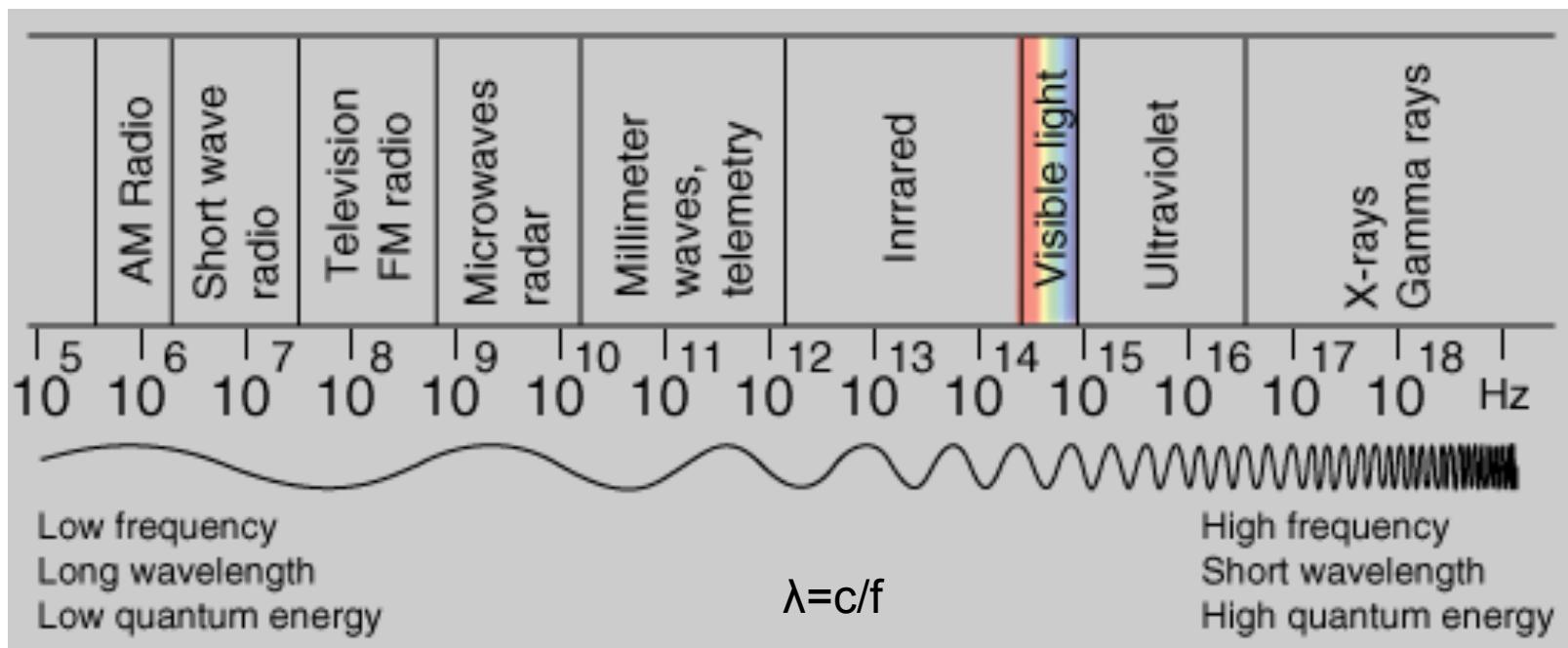
# Electromagnetic Spectrum

## Thermal



# Electromagnetic Spectrum

## Microwave



# Visible: Easy to Interpret

Google Maps!



Imagery ©2014 Aerodata International Surveys, Aerodata Survey & Gemeente Westland, Cnes/Spot Image, DigitalGlobe, Landsat, Map data ©2014 Google

# Pigeon photography



1907 Julius Neubronner  
Spy Museum, Washington DC  
[https://en.wikipedia.org/wiki/Pigeon\\_photography](https://en.wikipedia.org/wiki/Pigeon_photography)

# Drones

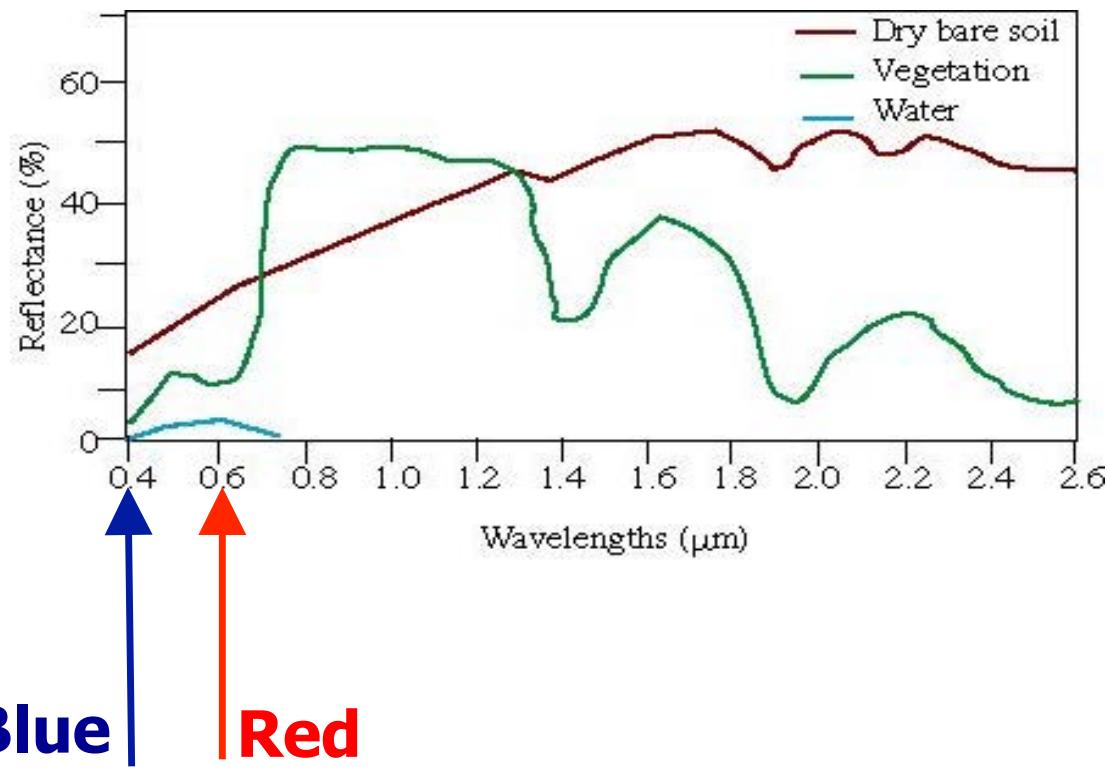


<http://dronecameraworld.com/>

# Optical: Sensitive to Water and Vegetation

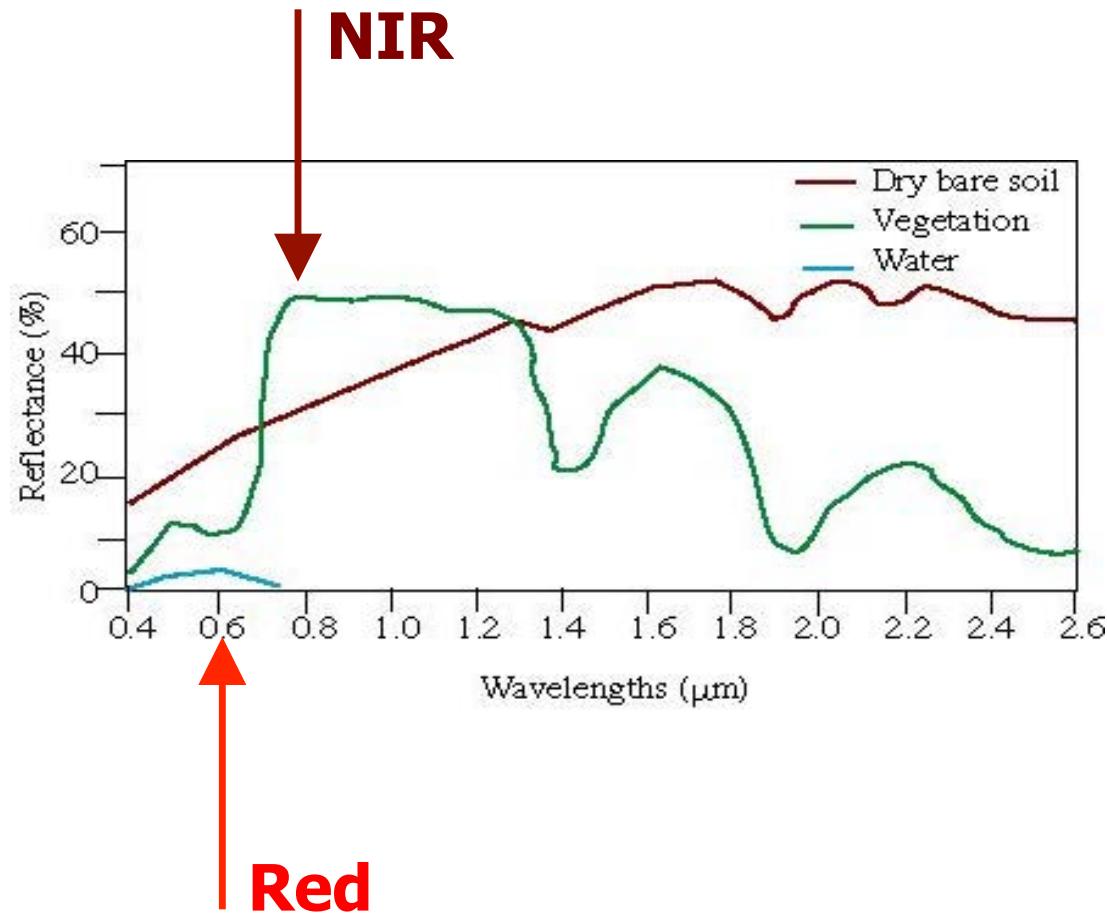


# Vegetation Indices



# Vegetation Indices

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

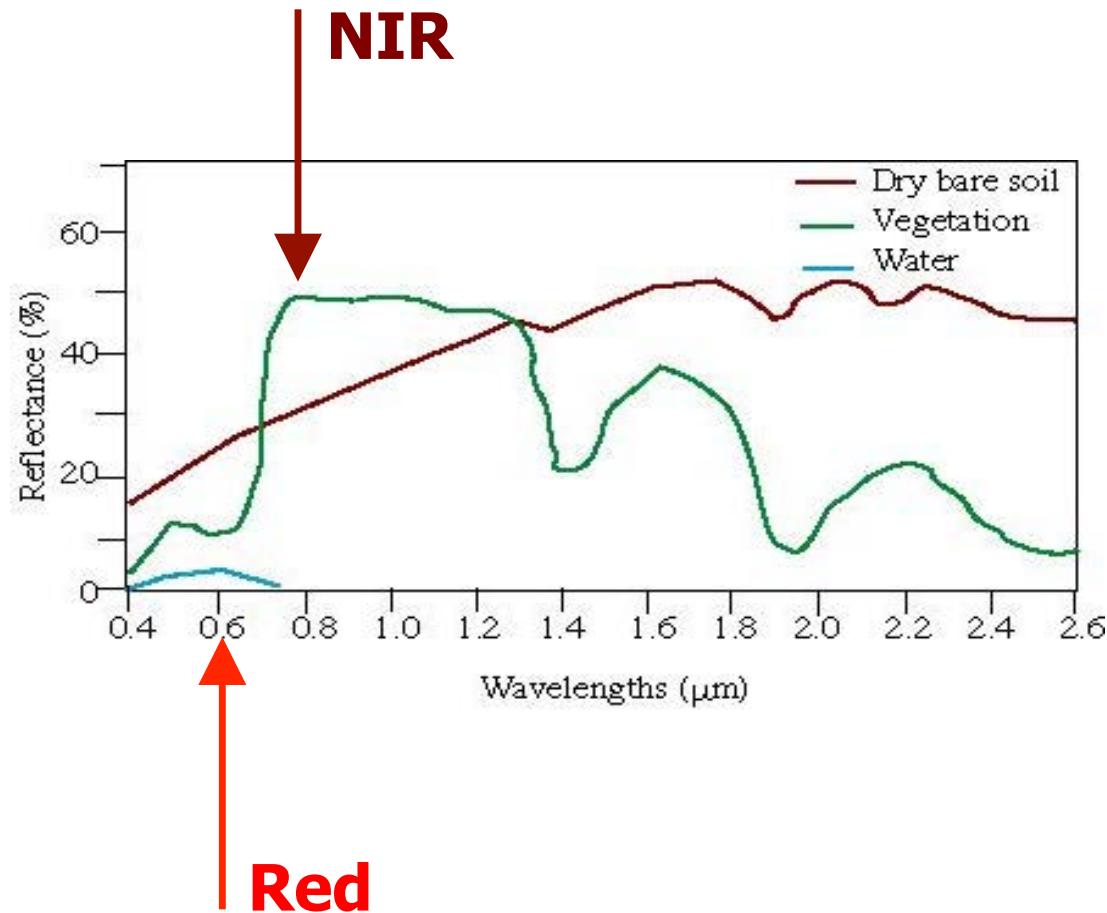


# Vegetation Indices



# Vegetation Indices

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



# Vegetation Indices



<https://www.youtube.com/watch?v=FO6ztYUAvhY>

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

# LandSat (1972 - )



# LandSat Archive on Google Earth Engine



Search anywhere (e.g. "Las Vegas") to see its timelapse...



Earth Engine > Landsat Annual Timelapse 1984-2012



# LandSat Archive on Google Earth Engine



Search anywhere (e.g. "Las Vegas") to see its timelapse...



Earth Engine › Landsat Annual Timelapse 1984-2012



# LandSat Archive on Google Earth Engine



Search anywhere (e.g. "Las Vegas") to see its timelapse...



Earth Engine › Landsat Annual Timelapse 1984-2012

Amazon Deforestation, Brazil



50 km  
20 mi



1984

Fast



1984

Google

2012

# LandSat Archive on Google Earth Engine



Search anywhere (e.g. "Las Vegas") to see its timelapse...



Earth Engine > Landsat Annual Timelapse 1984-2012



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Earth Engine › Landsat Annual Timelapse 1984-2012

Saudi Arabia, Irrigation



Google

?

# LandSat Archive on Google Earth Engine



Search anywhere (e.g. "Las Vegas") to see its timelapse...



Earth Engine > Landsat Annual Timelapse 1984-2012

Saudi Arabia, Irrigation



10 km  
10 mi



2000

Slow

1984

Google

2012



# LandSat Archive on Google Earth Engine



Search anywhere (e.g. "Las Vegas") to see its timelapse...



Earth Engine › Landsat Annual Timelapse 1984-2012

Saudi Arabia, Irrigation



10 km  
10 mi



2011

Slow

1984

Google

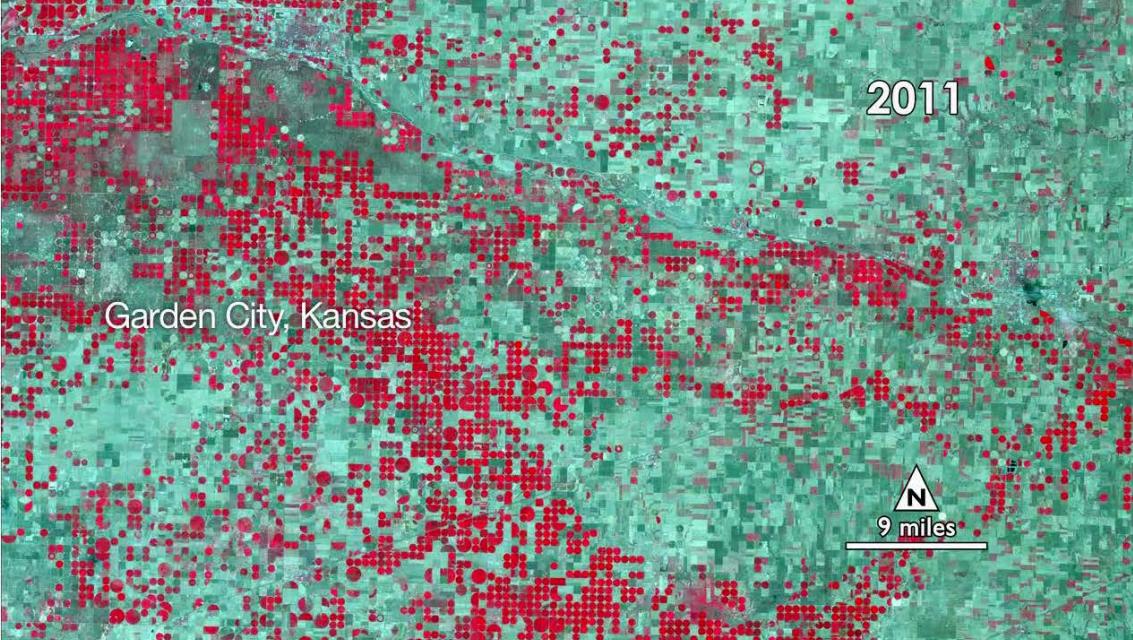
2012



# LandSat8

← → ⌂ Secure <https://www.youtube.com/watch?v=JCzIageDf0k>

YouTube NL Search



Garden City, Kansas

2011

N  
9 miles

Landsat 8: Landsat Data Continuity Mission  
Overview 2013 NASA Goddard Space Flight Center  
LDCM

<https://www.youtube.com/watch?v=JCzIageDf0k>

# ESA's Sentinel-2

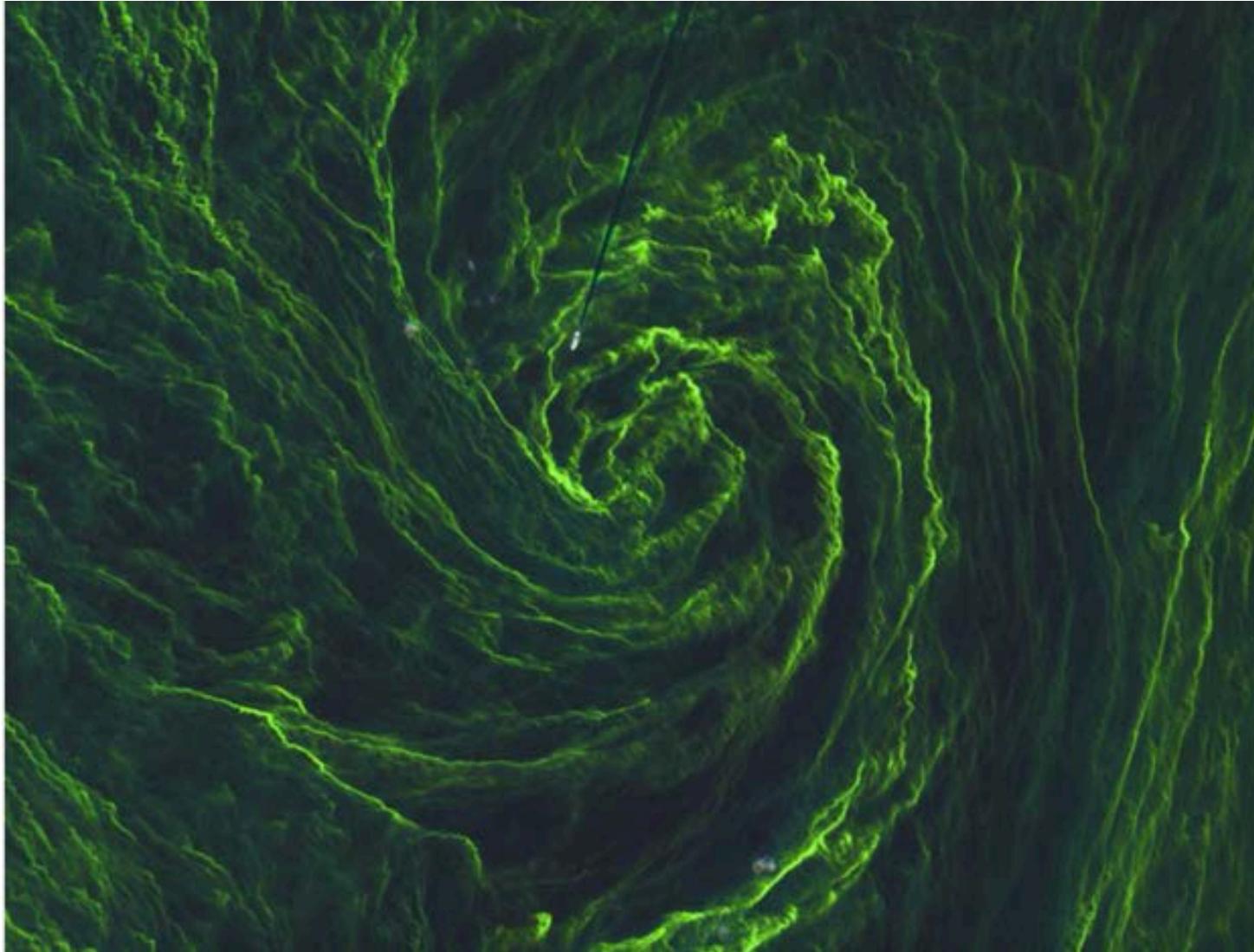


Sentinel-2B liftoff

[Access the video](#)

**SECOND 'COLOUR VISION' SATELLITE FOR COPERNICUS LAUNCHED**

# ESA's Sentinel-2 catches eye of algal storm



[http://www.esa.int/Our\\_Activities/Observing\\_the\\_Earth/Copernicus/Sentinel-2/Sentinel-2\\_catches\\_eye\\_of\\_algal\\_storm](http://www.esa.int/Our_Activities/Observing_the_Earth/Copernicus/Sentinel-2/Sentinel-2_catches_eye_of_algal_storm)

# ESA's Sentinel-2 Agricultural Monitoring in Spain



# ESA's Sentinel-2 Agricultural Monitoring in Spain



June

# ESA's Sentinel-2 Agricultural Monitoring in Spain



# Commercial data

## High Resolution Satellite Images (0.31m - 2m)

2016

Click on any of the following satellite images to view their galleries.

GeoEye-1 (0.5m)



WorldView-3 (0.31m)



WorldView-2 (0.5m)



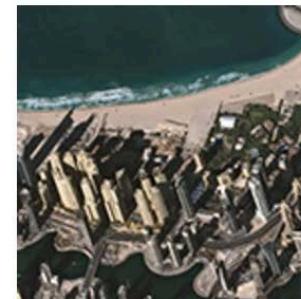
WorldView-1 (0.5m)



Pleiades-1A (0.5m)



Pleiades-1B (0.5m)



# Satellite Data Portal from NSO

www.satellietbeeld.nl

Netherlands Space Office

Nationaal Satellietdataportaal — Voorbewerkte data

Informatie & Ondersteuning  
Web: NSO Satellietdataportaal  
E-mail: NSOportaal@neo.nl  
Download: 6m multi-spectraal

De Heuvel

+ -

Gebruiken

Snel naar een plaats of adres...

+ Filteren

Gefilterd: beek

Voorbeeld

- Gevonden

Opname datum: 24-12-2016

WMS

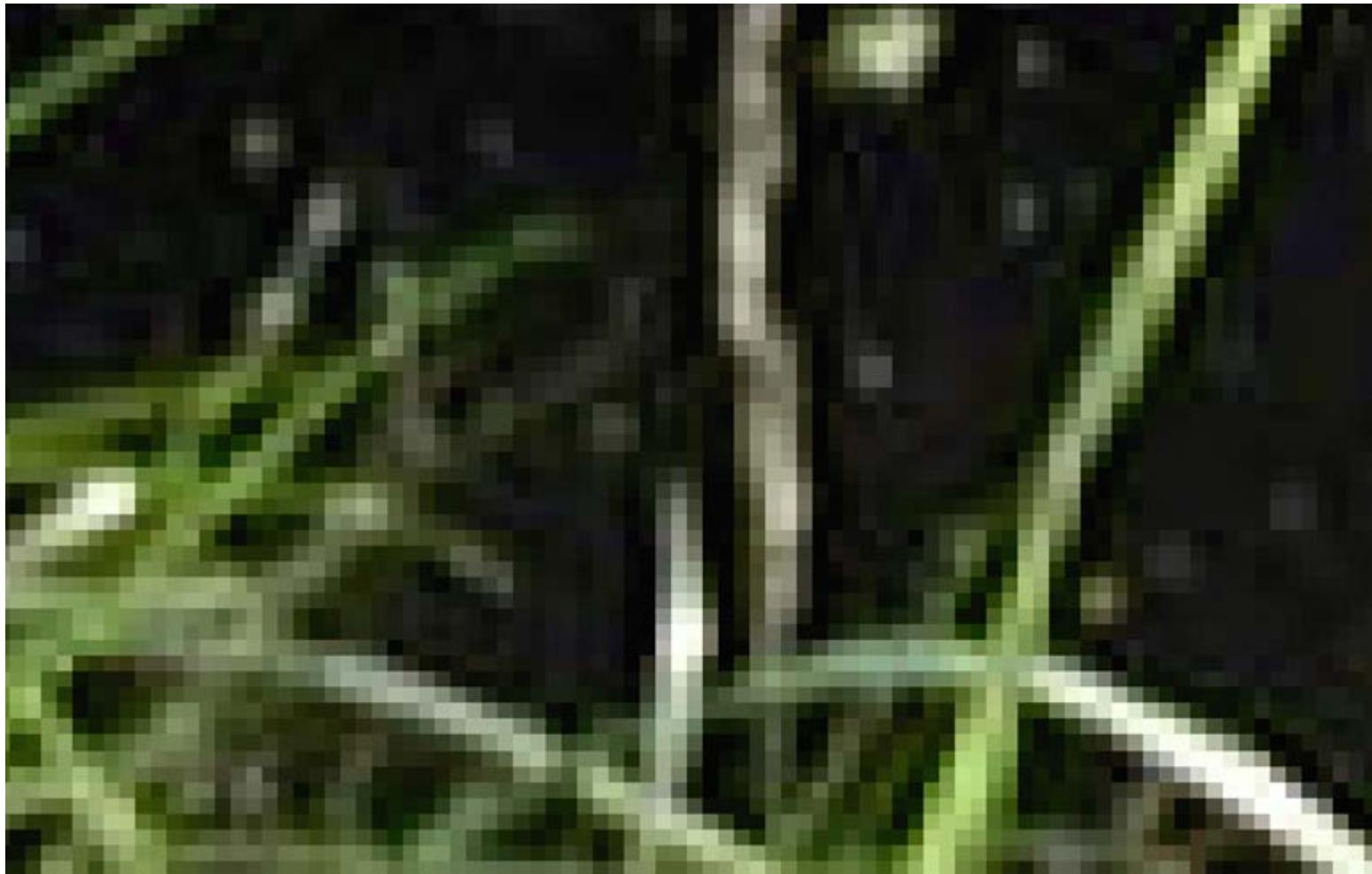
Satellietbeeld: © NEO bv, Amersfoort, © 2014-2017 Airbus Defence and Space. Topografie/Luchtfoto: PDOK

The screenshot shows the National Satellite Data Portal (NSO) interface. At the top, there's a header with the portal's name and a logo of the Netherlands Space Office. Below the header, there's a search bar and a 'Filteren' (Filter) button. A preview window on the left displays a satellite image of the Netherlands, with a specific area over the Randstad highlighted in purple. To the right of the preview is a larger map of the Netherlands with major cities labeled: Groningen, Uithuizen, Hollum, Den Burg, Heerenveen, Alkmaar, Amsterdam, Apeldoorn, Farchede, Rotterdam, Ouddorp, Middelburg, 's-Hertogenbosch, Tilburg, Eindhoven, Venlo, Roermond, and Maastricht. A zoomed-in view of the Randstad area is shown in the bottom right corner, with a yellow box highlighting a specific location labeled 'De Heuvel'. The interface includes various buttons for filtering, zooming, and downloading data.

# Image Analysis



# Image Analysis



# Image Analysis

Image => Matrix

Row => Horizontal line

Column => Vertical line

Entry => Picture element (pixel)



# Image Analysis

## Pre-processing:

- Georeferencing
- Atmospheric correction
- Image enhancement

## Processing

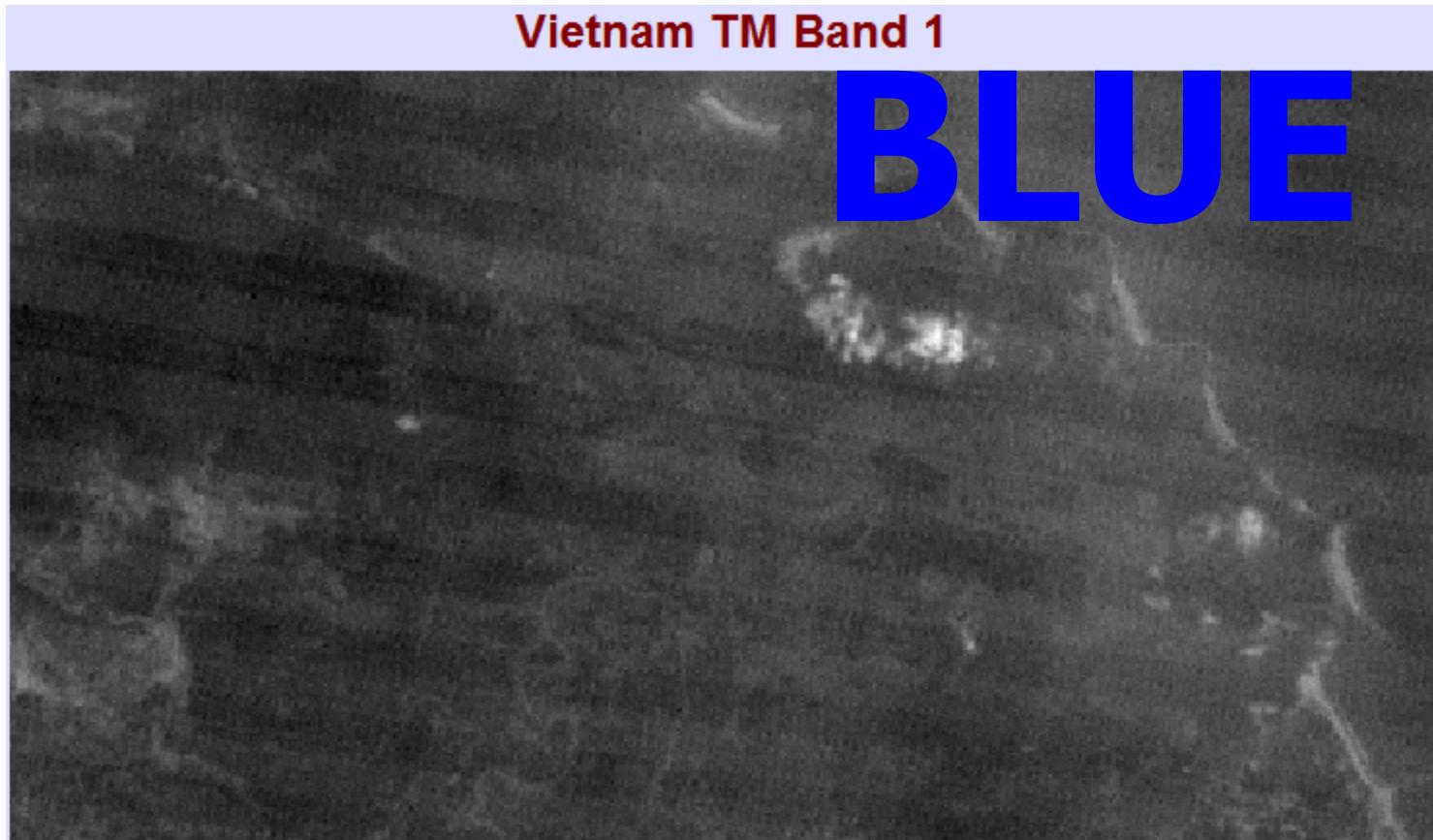
- NDVI
- Surface temperature
- Classification

# Image Analysis: Color composite

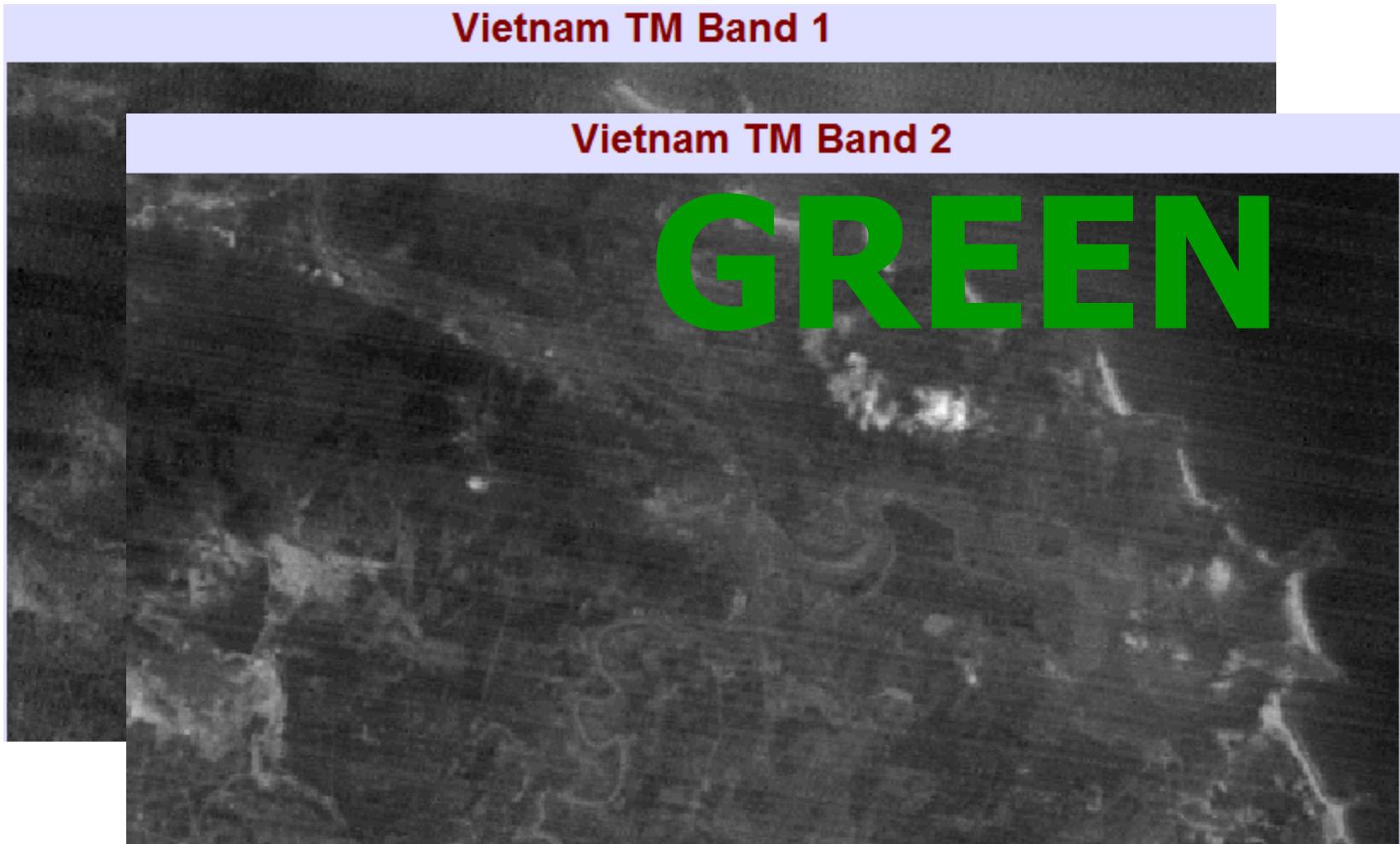
Pixel => Number (DN), greyscale



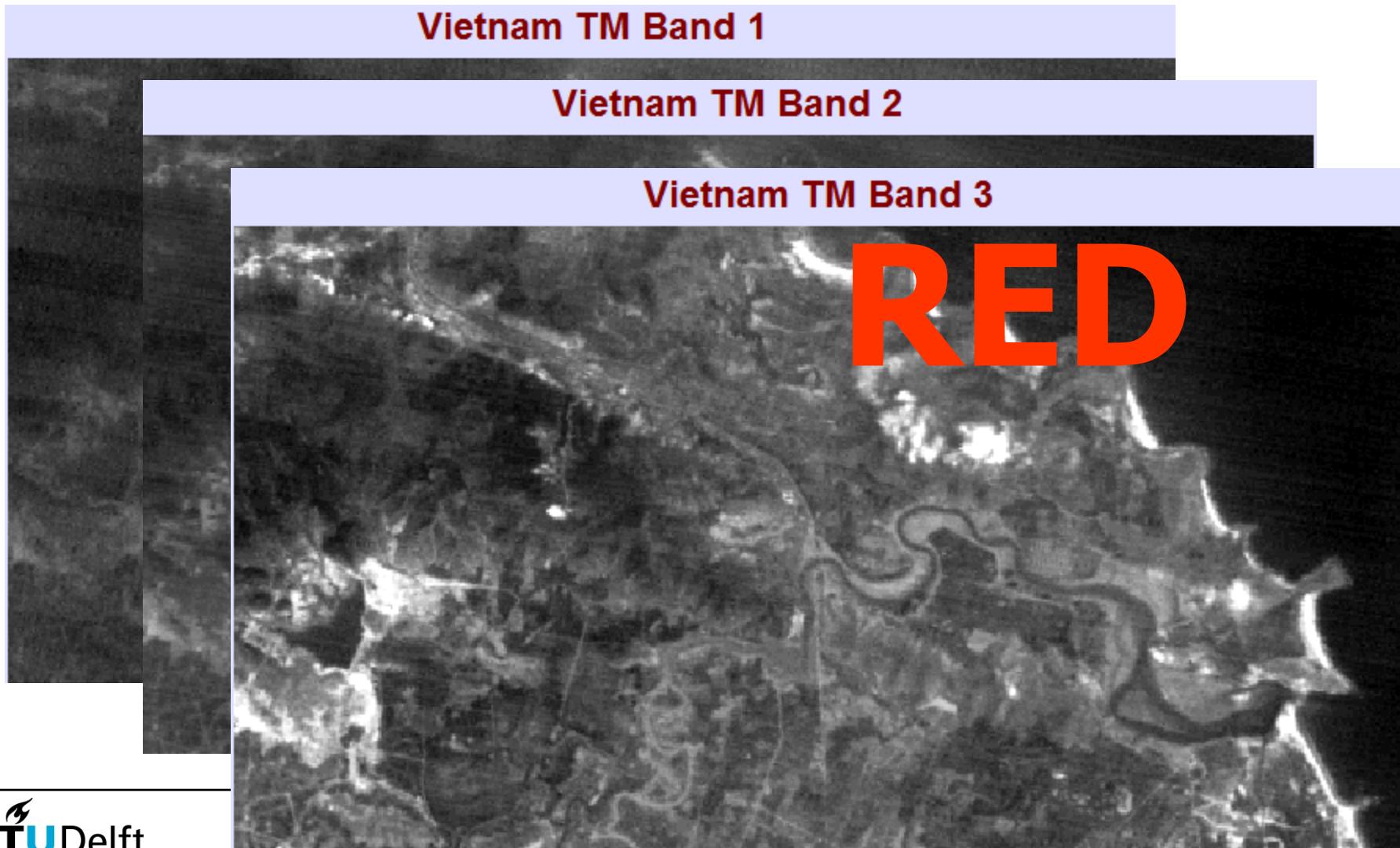
# Image Analysis: Color composite



# Image Analysis: Color composite



# Image Analysis: Color composite

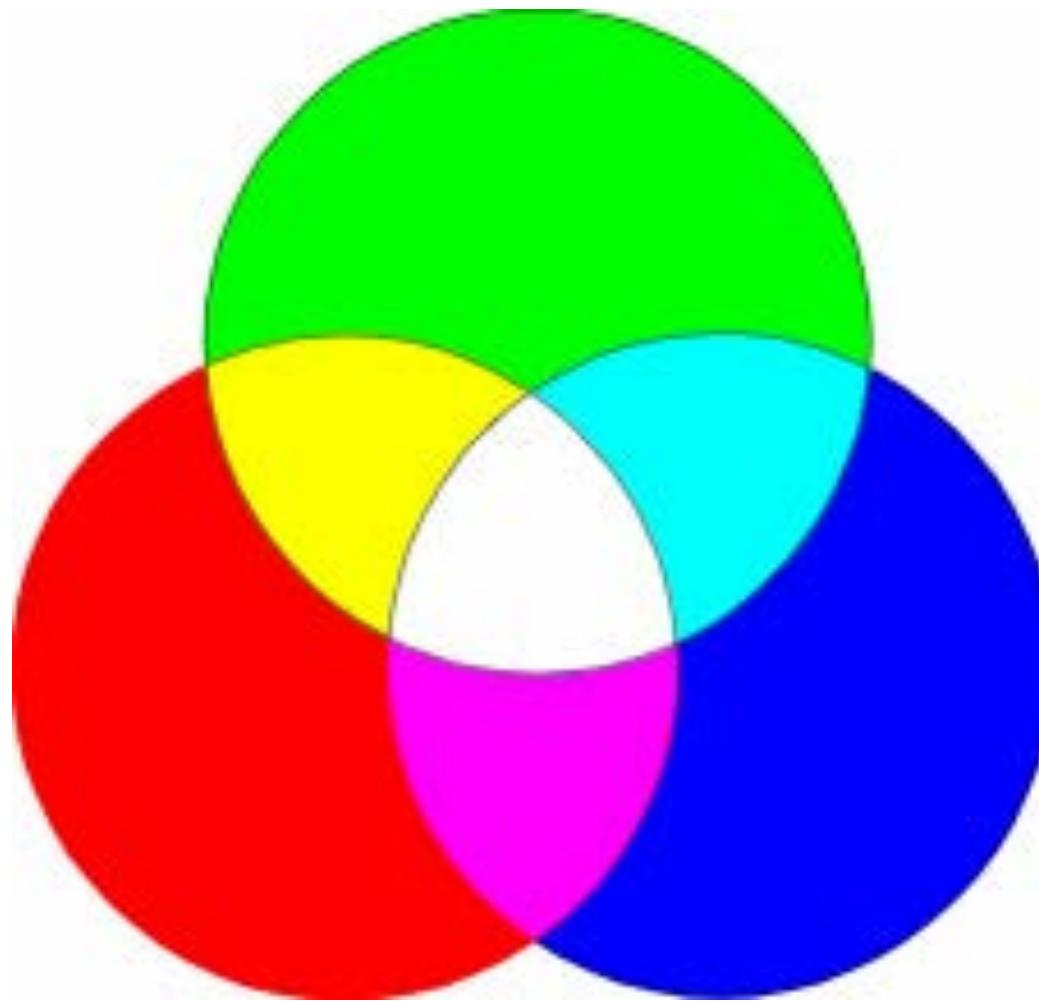


# Image Analysis: Color composite

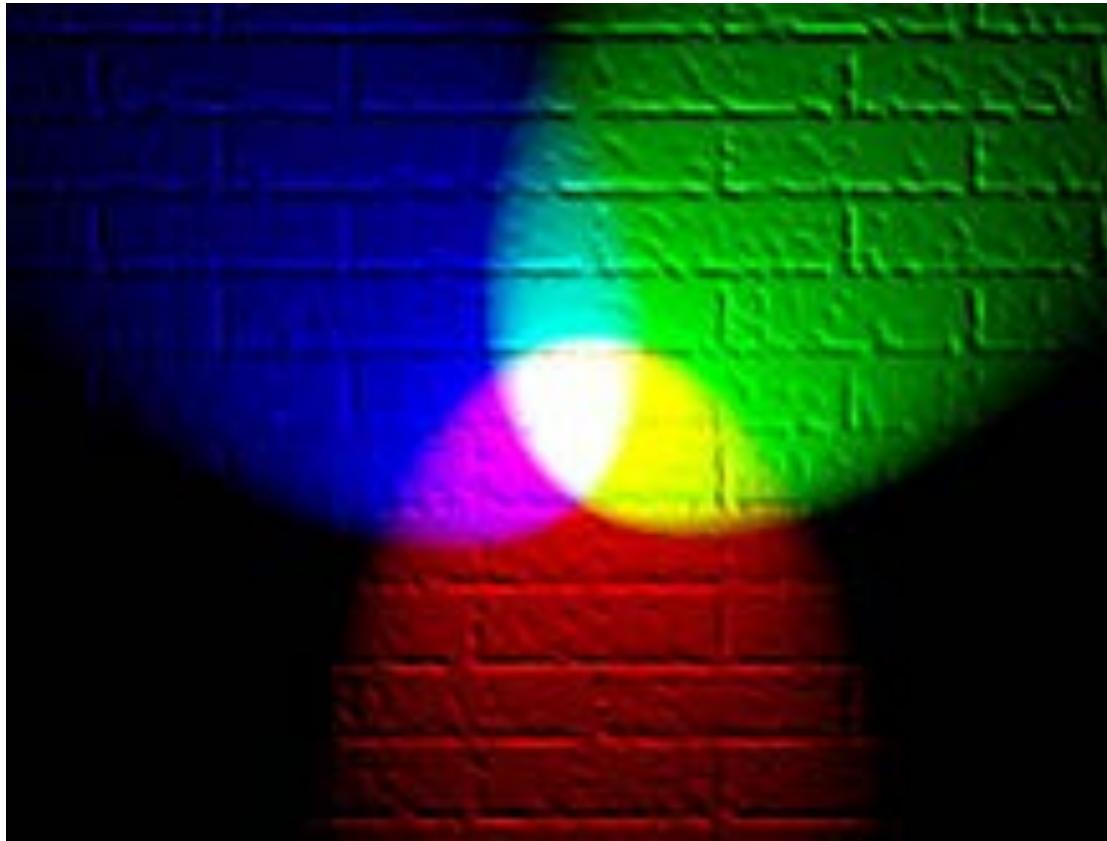
“Natural color”



# Image Analysis: Color composite



# Image Analysis: Color composite



# Image Analysis: Color composite

“Natural color”



# Image Analysis: Color Composites

← → C [https://www.youtube.com/watch?v=YP0et8I\\_bvY](https://www.youtube.com/watch?v=YP0et8I_bvY)

☰ YouTube NL Search

Wavelength( $\mu\text{m}$ ) Band  
0.450 - 0.515 Blue  
0.525 - 0.600 Green  
0.630 - 0.680 Red

Agricultural District

Wavelength( $\mu\text{m}$ ) Band  
0.525 - 0.600 Green  
0.630 - 0.680 Red  
0.845 - 0.885 Near Infrared

Fort Lauderdale

Wavelength( $\mu\text{m}$ ) Band  
0.525 - 0.600 Green  
0.845 - 0.885 Near Infrared  
2.100 - 2.300 Shortwave Infrared

Cypress Forest

NASA | Peeling Back Landsat's Layers of Data

NASA Goddard

[Subscribe](#) 376,809

[13,445 views](#)

# Image Analysis: Color Composites



# Image Analysis: Color Composites

## Landsat 7 (ETM+) bands (wavelengths in micrometers)

Band 1	0.45-0.52	Blue-Green
Band 2	0.53-0.61	Green (often mapped to Blue)
Band 3	0.63-0.69	Red (often mapped to Green)
Band 4	0.75-0.90	Near IR (often mapped to Red)
Band 5	1.55-1.75	Mid-IR
Band 6	10.4-12.5	Thermal IR
Band 7	2.09-2.35	Short Wave IR
Band 8	0.52-0.90	Panchromatic

# Image Analysis: Map Algebra

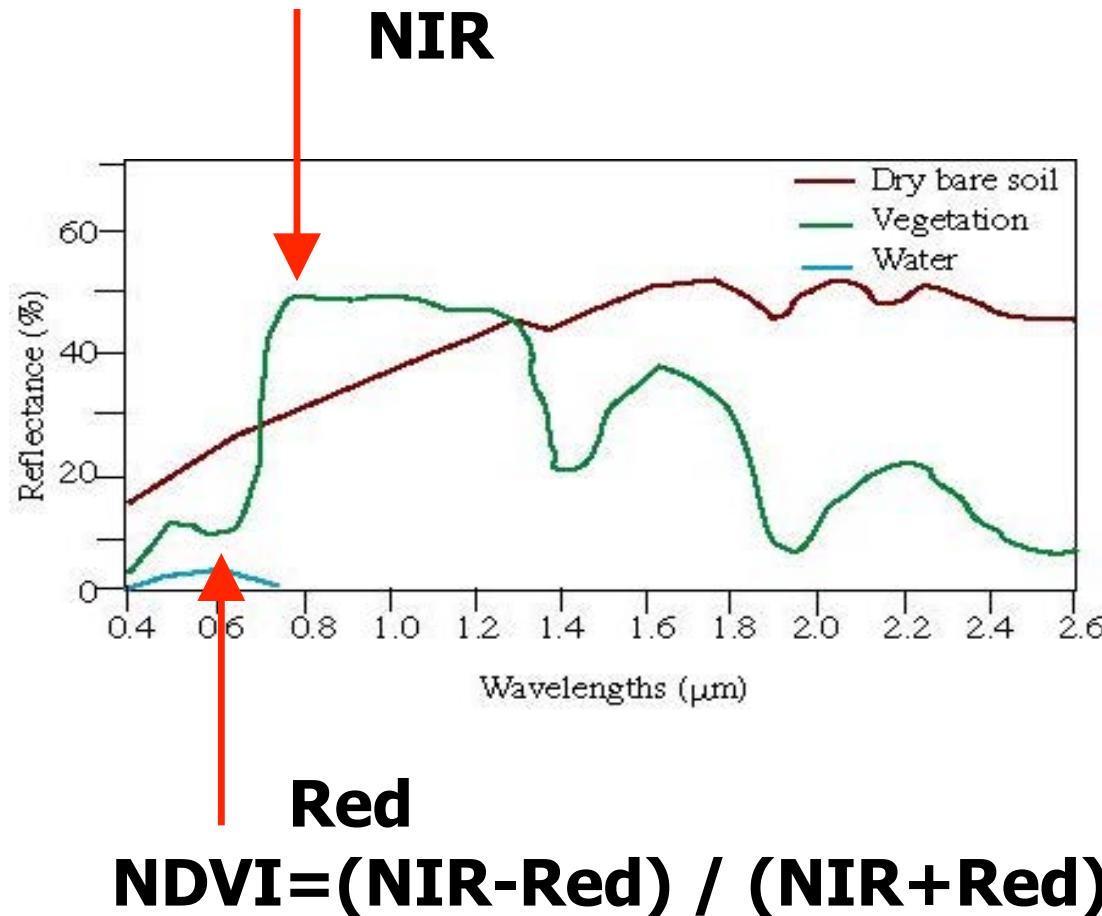
## Operators

Multiply, add, subtract, ...

If ..., then ... (Boolean)

Convolution / filters

# Image Analysis: Map Algebra



# Image Analysis: Map Algebra

Red

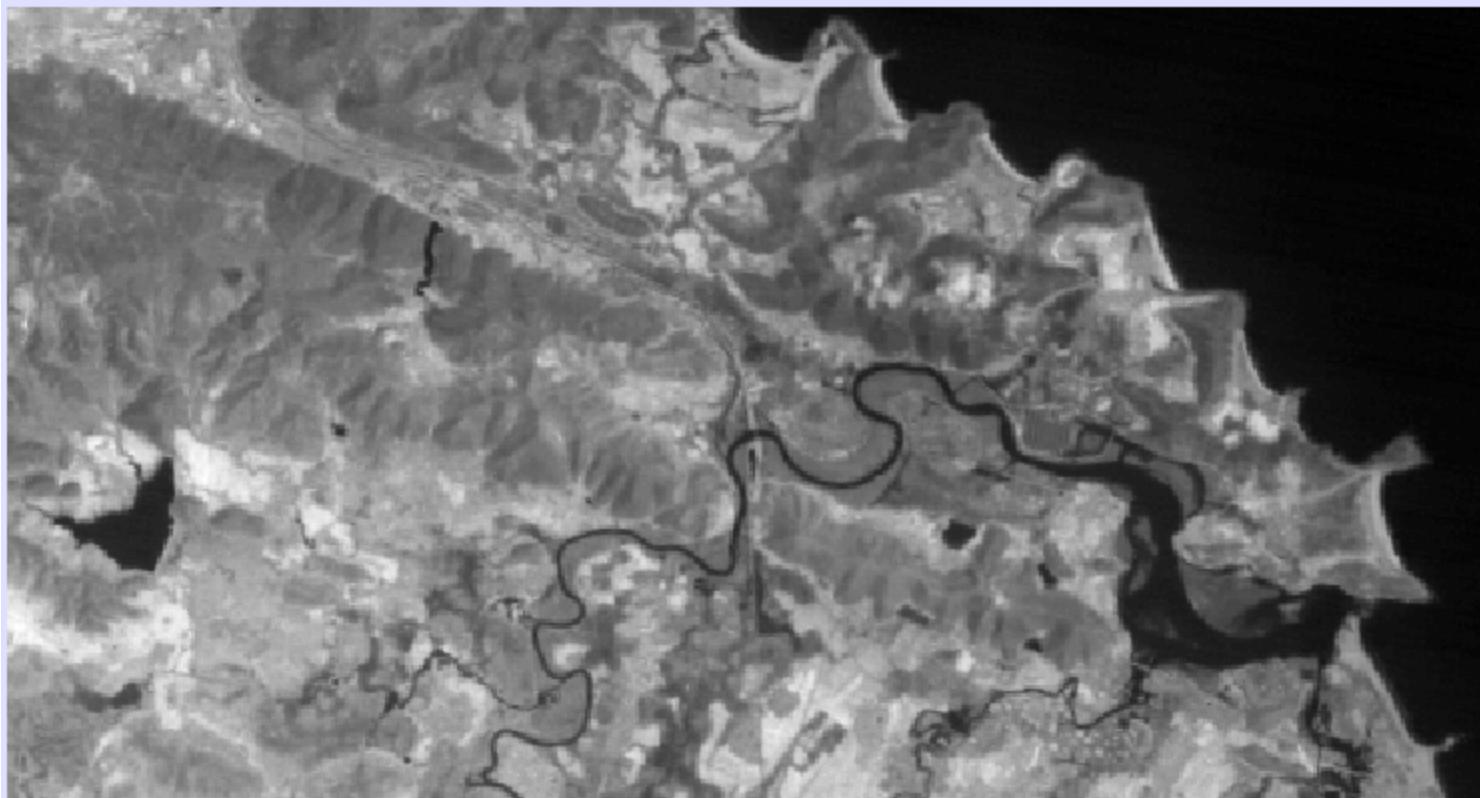
Vietnam TM Band 3



# Image Analysis: Map Algebra

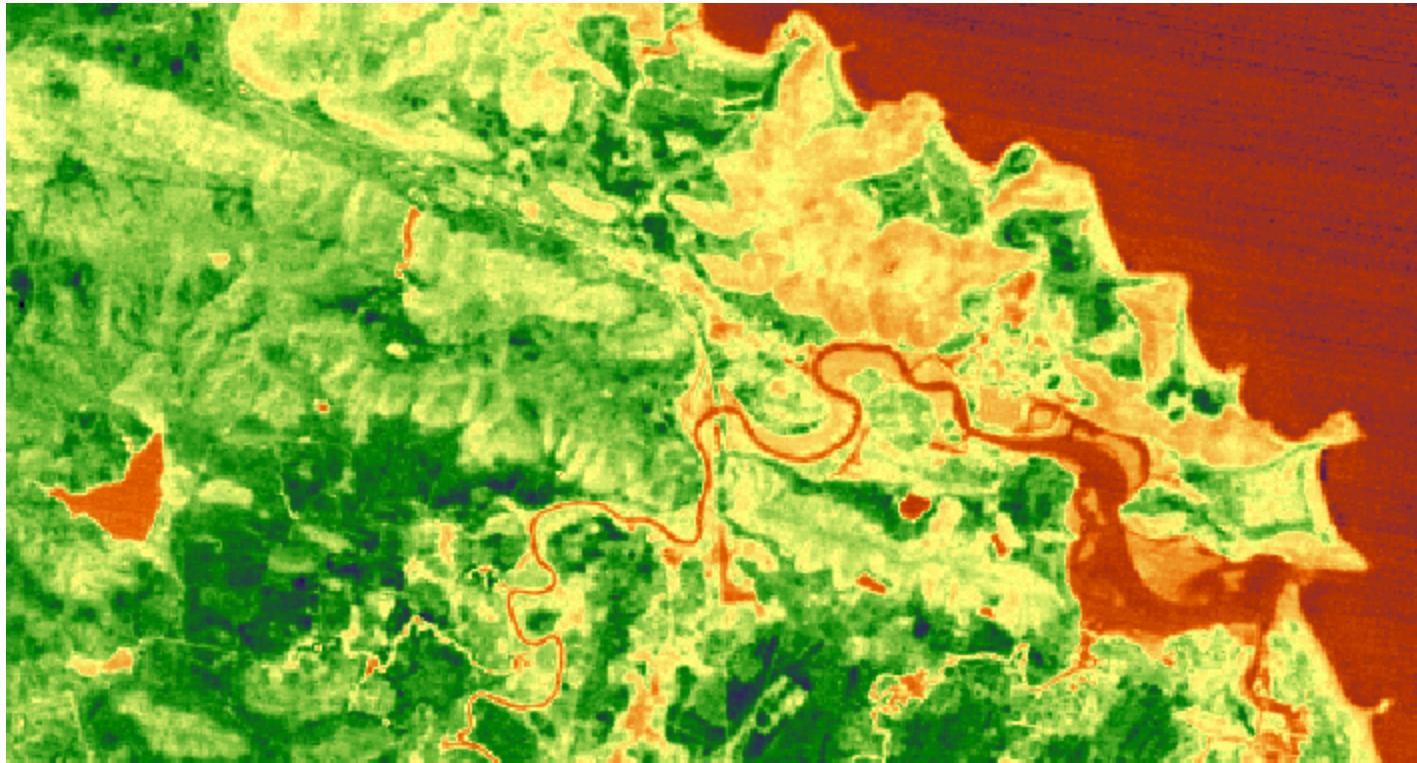
Near Infrared (NIR)

Vietnam TM Band 4



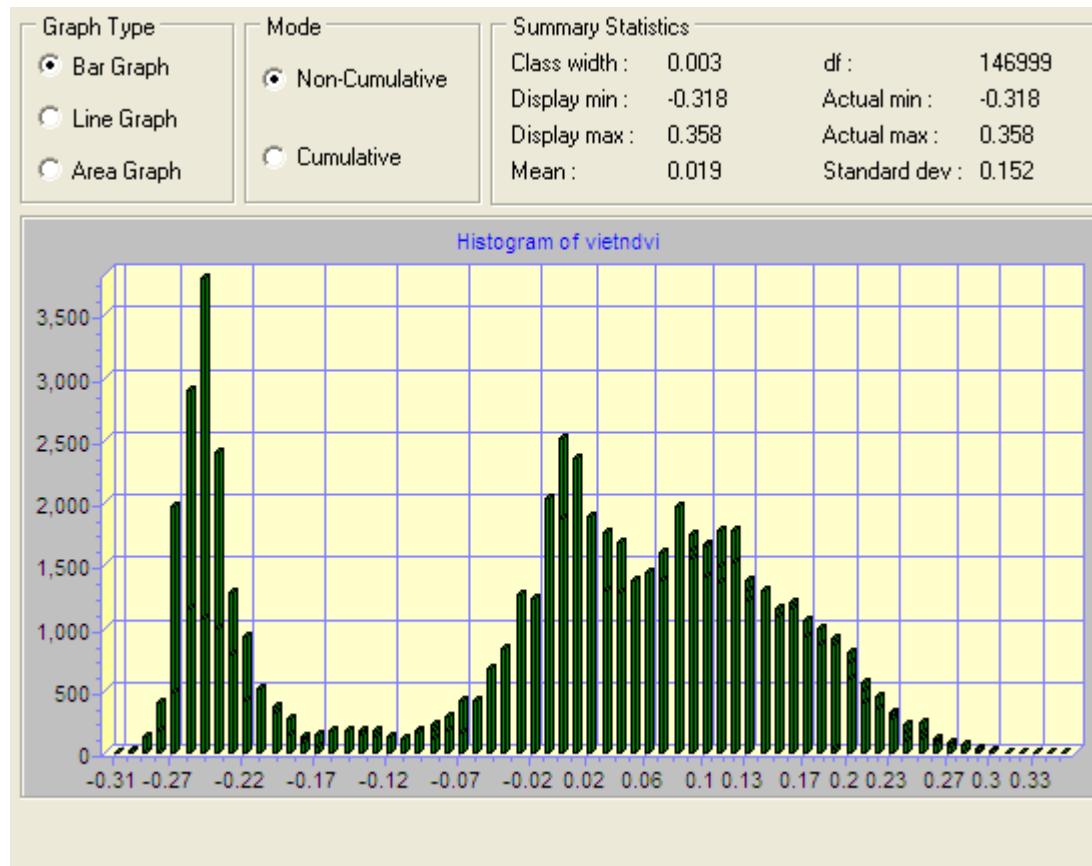
# Image Analysis: Map Algebra

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



# Image Analysis: Map Algebra

## Density Slice Classification

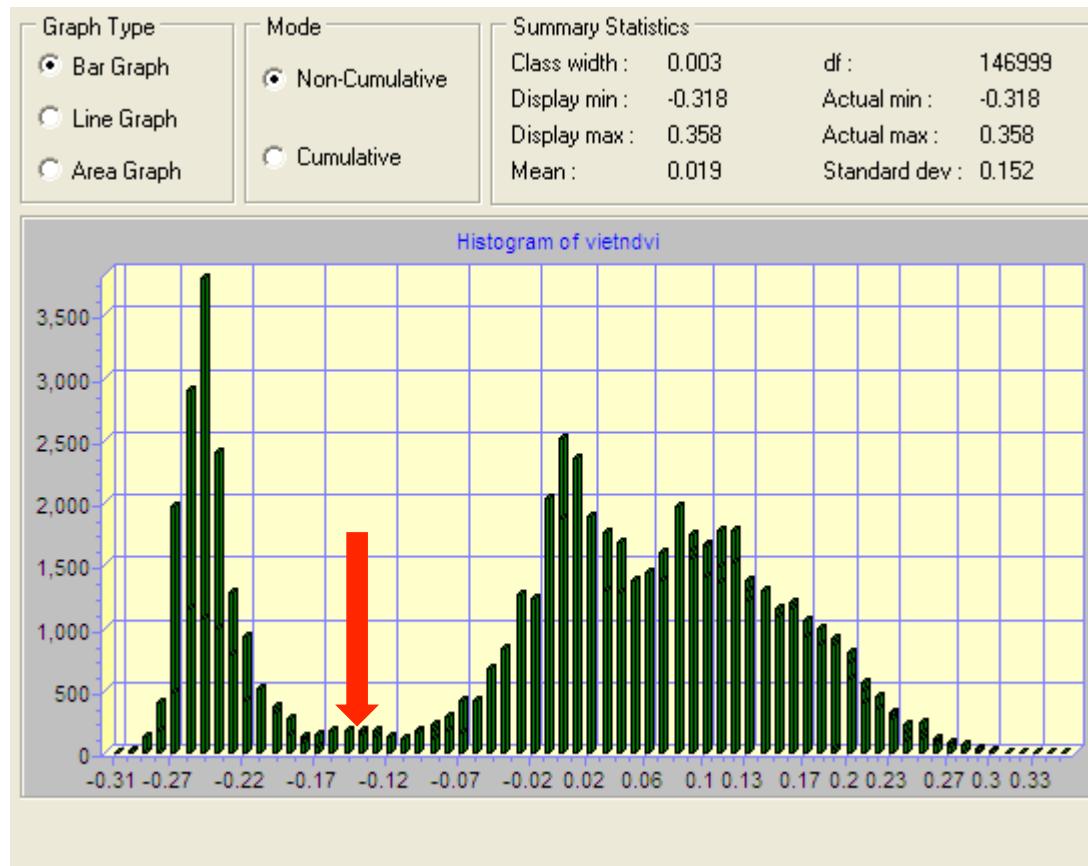


# Image Analysis: Map Algebra

## Density Slice Classification

NDVI<-0.15 => Water

NDVI>-0.15 => Other

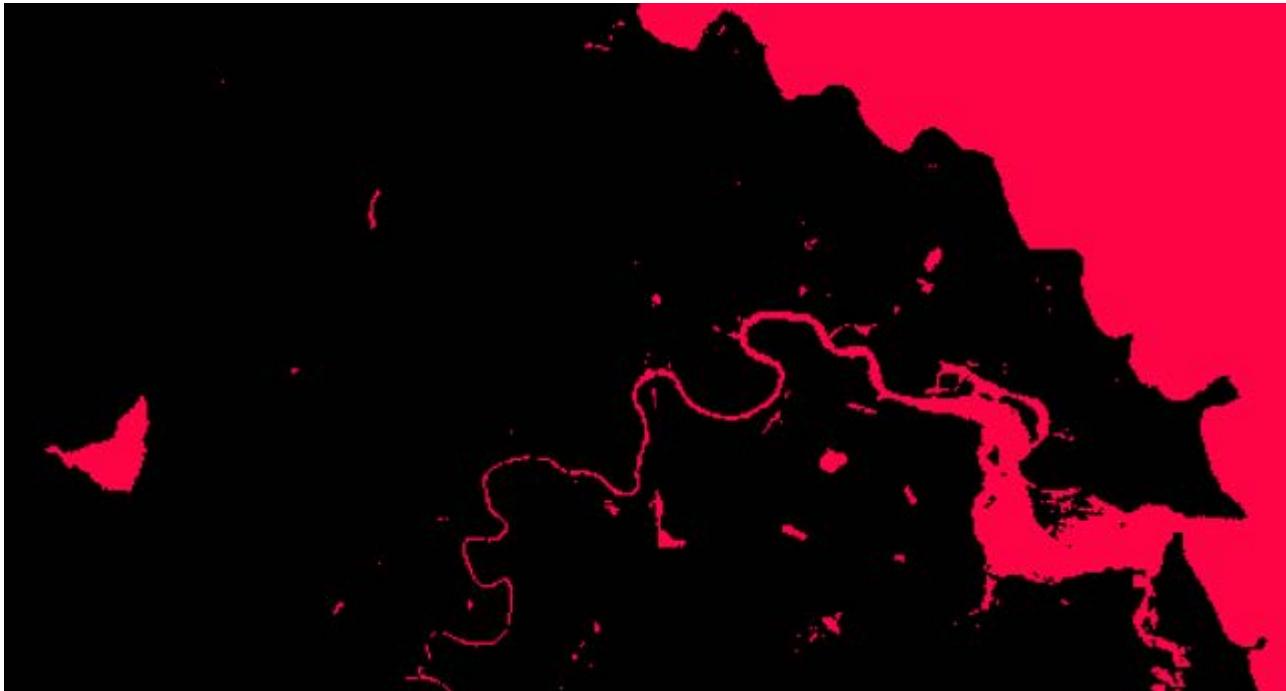


# Image Analysis: Map Algebra

## Density Slice Classification

NDVI<-0.15 => Water (Red)

NDVI>-0.15 => Other(Black)

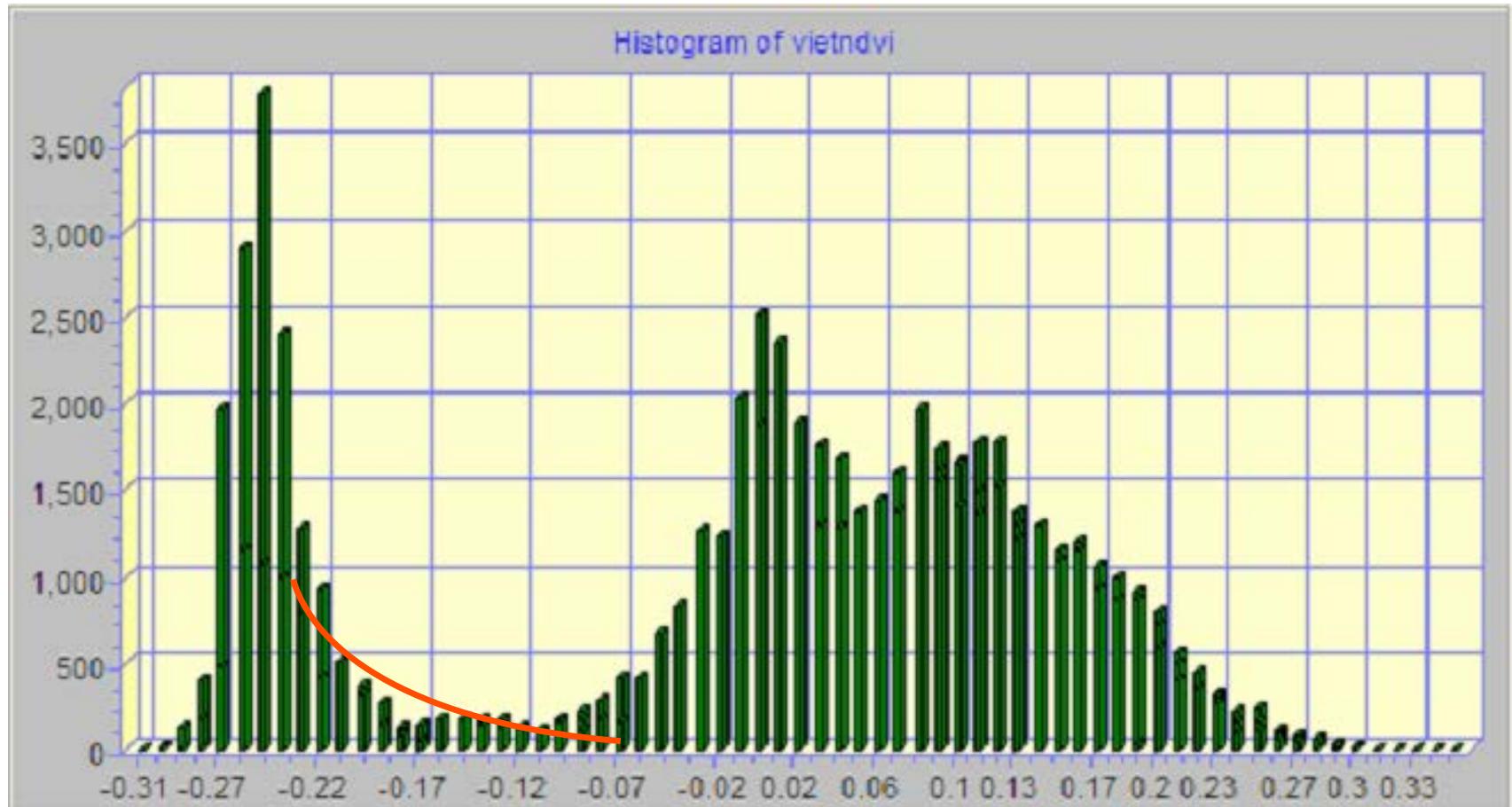


# Image Analysis: Classification

- Automatic (cluster analysis)
- **Supervised**
  - Parallelepiped
  - Minimum distance
  - **Maximum Likelihood**

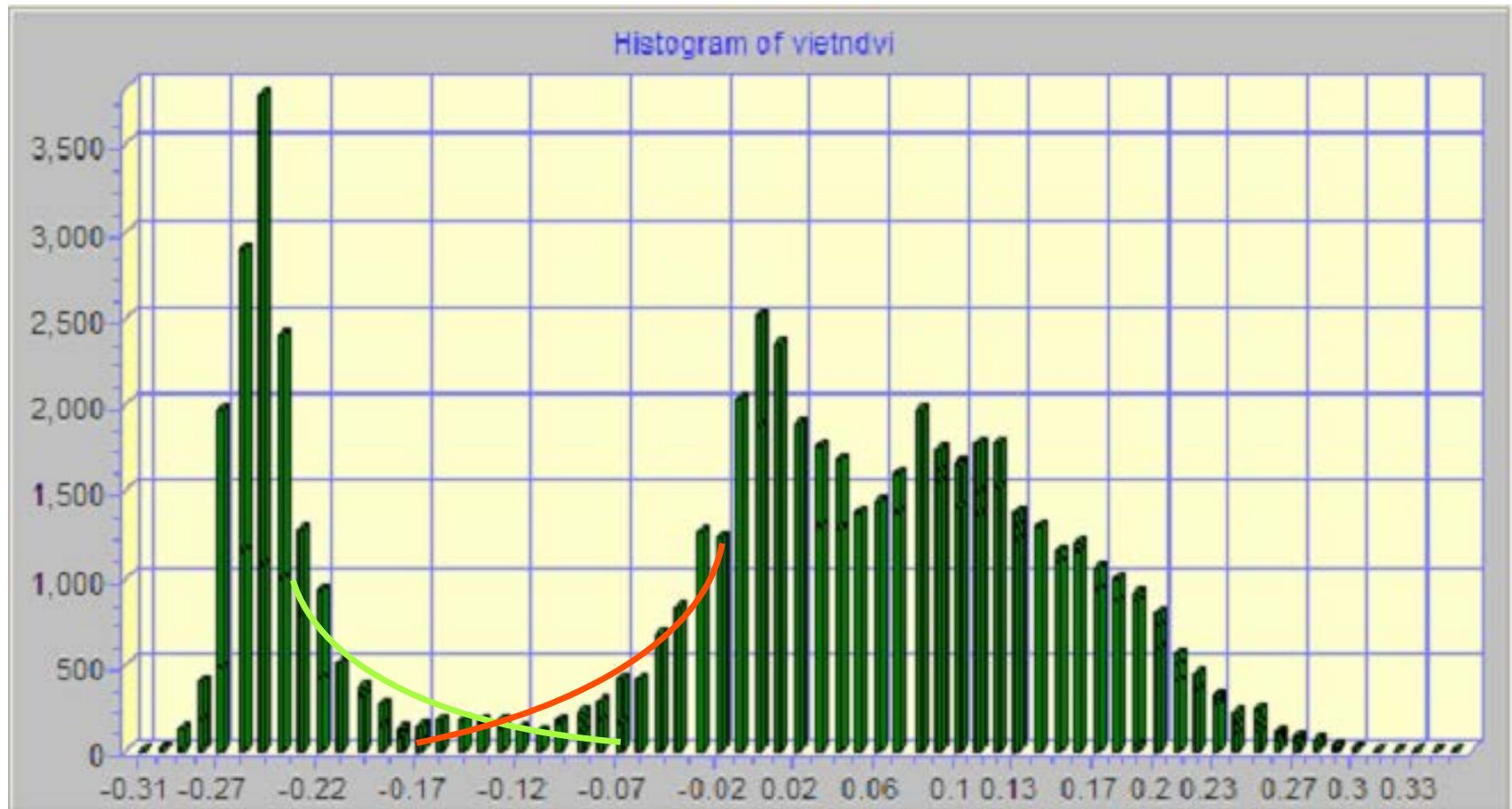
# Image Analysis: Classification

## Maximum Likelihood Classification



# Image Analysis: Classification

## Maximum Likelihood Classification



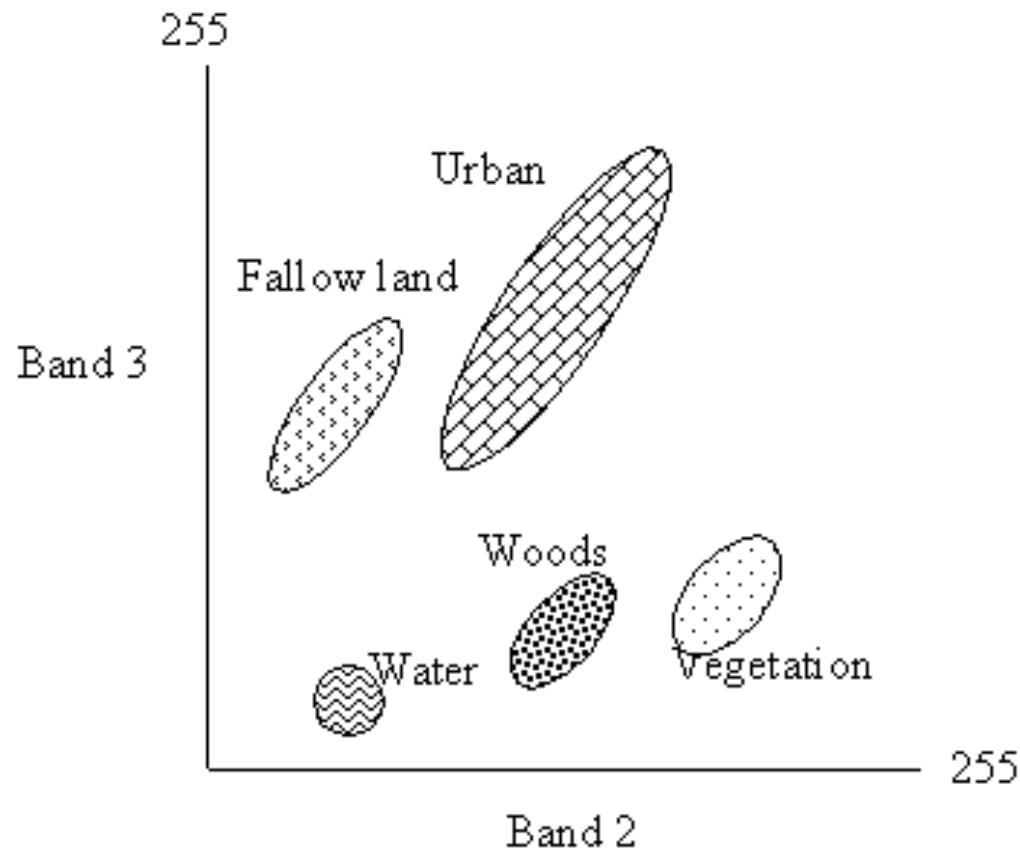
# Image Analysis: Classification

## Maximum Likelihood Classification

- Multi-band analysis
- Assume normal distribution
- Use training sets => avg, sd, cov
- Determine likelihoods per class (take max)
- Some pixels may remain undetermined

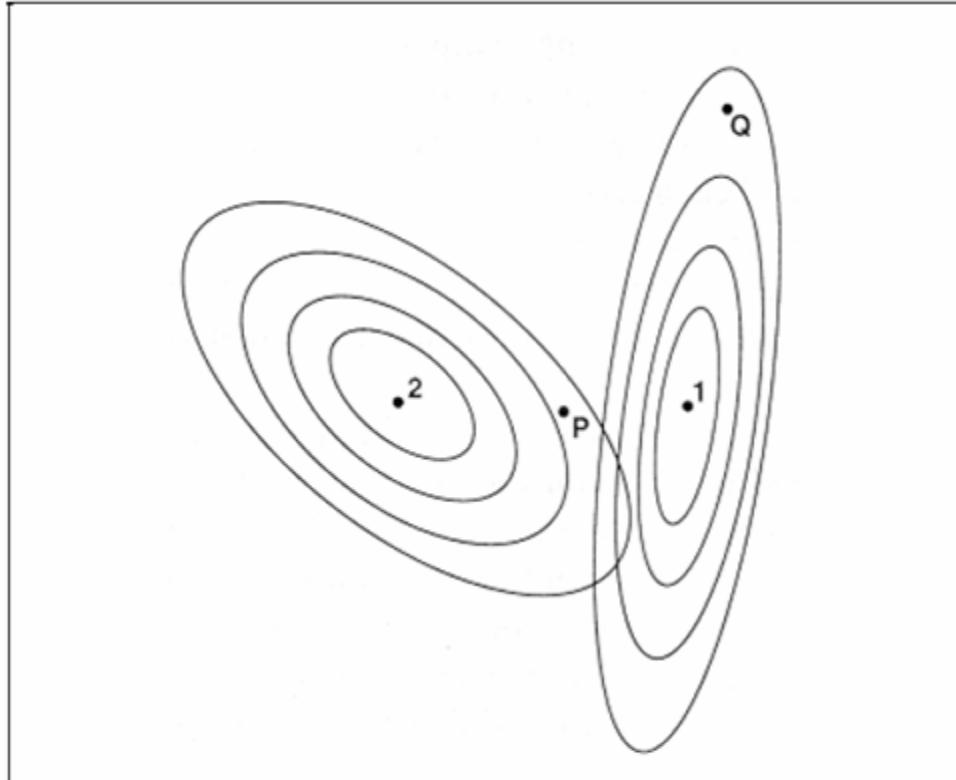
# Image Analysis: Classification

## Maximum Likelihood Classification



# Image Analysis: Classification

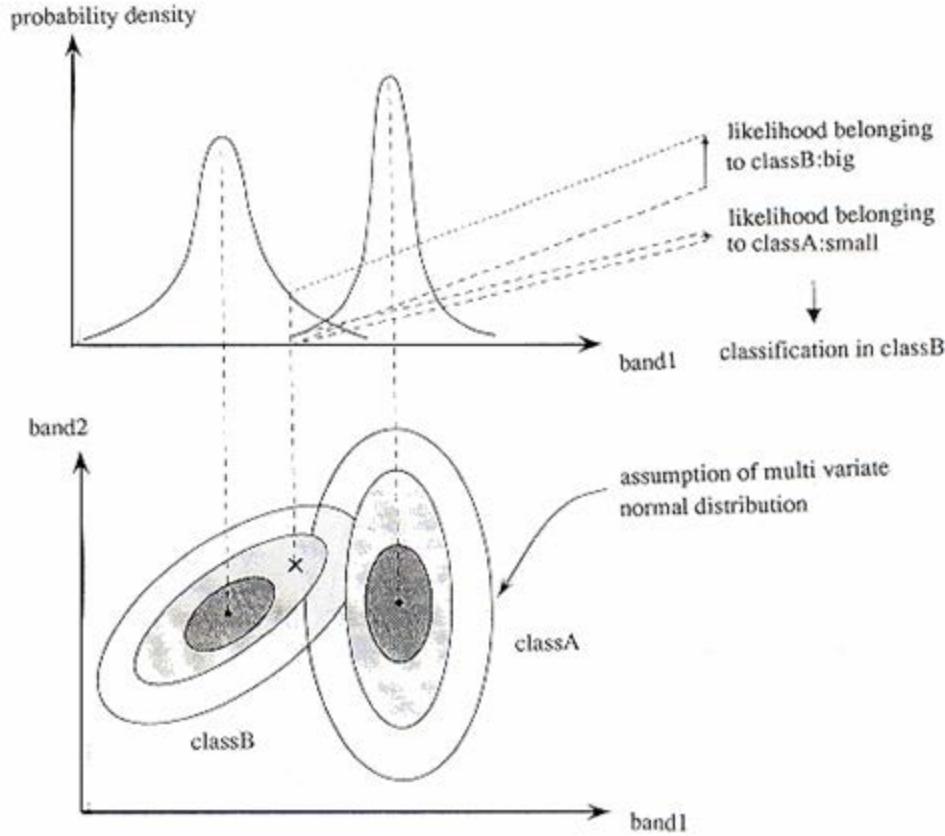
## Maximum Likelihood Classification



Equi-probability contours as used in  
Maximum Likelihood classification

# Image Analysis: Classification

## Maximum Likelihood Classification



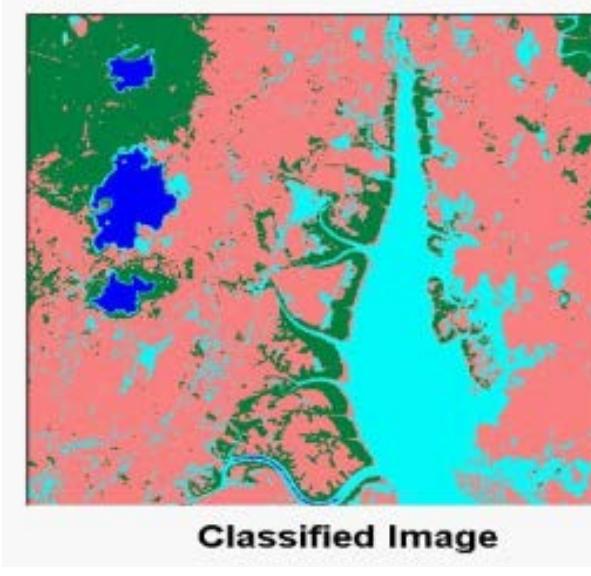
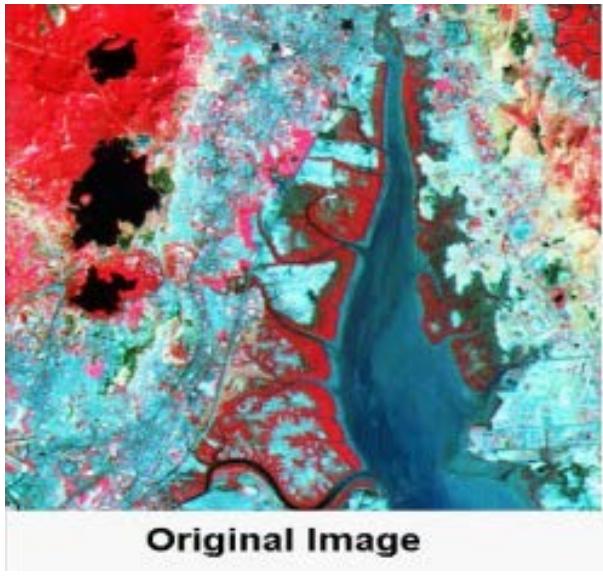
Concept of Maximum Likelihood Method

# Image Analysis: Classification

## Maximum Likelihood Classification

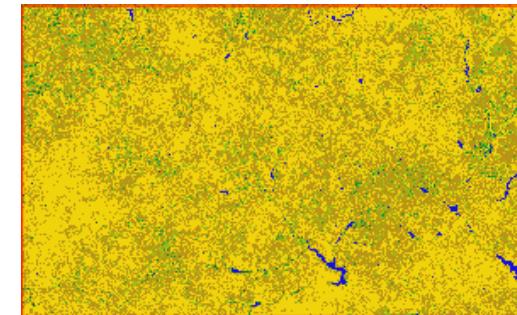
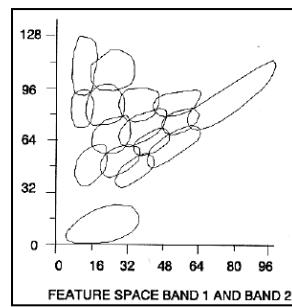
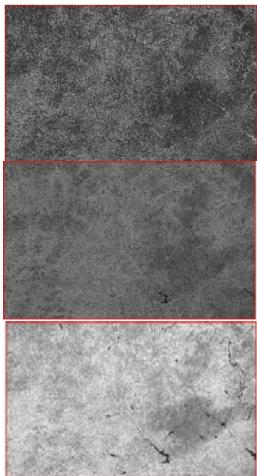
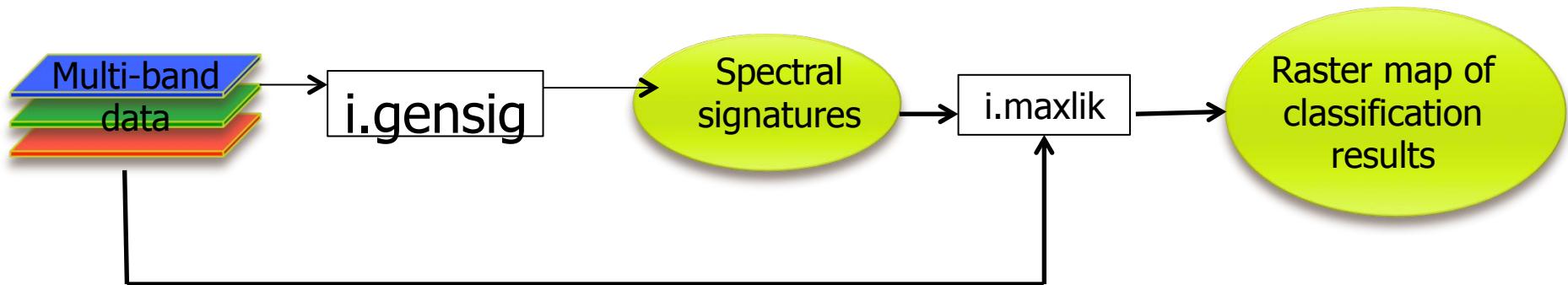
**Steps:**

1. Select test sets
2. Determine statistics
3. Classify complete image



# Classification using GRASS

**i.gensig** is a non-interactive tool for supervised classification, which is just what we need!



# Classification using GRASS Step-by-step

Multi-band  
data



QGIS create  
polygon layer.  
Draw polygons

Raster Training  
Map

i.gensig

Spectral  
signatures

i.maxlik

Raster map of  
classification  
results



# Assignment 4: Small Reservoirs

[www.smallreservoirs.org](http://www.smallreservoirs.org)



# Assignment 4: Small Reservoirs

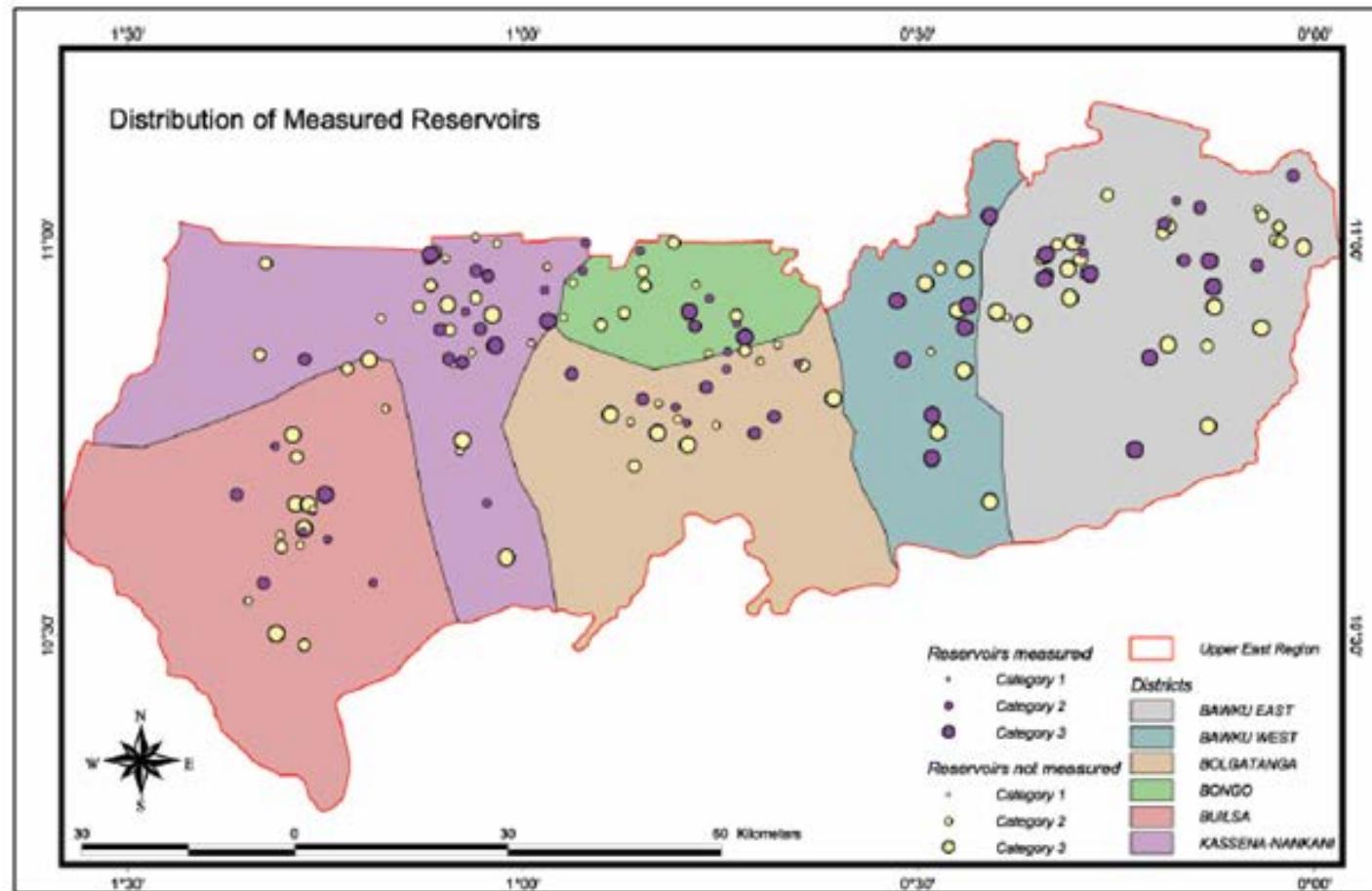
Small Reservoirs in Burkina Faso

Reading: Jens Liebe's Thesis



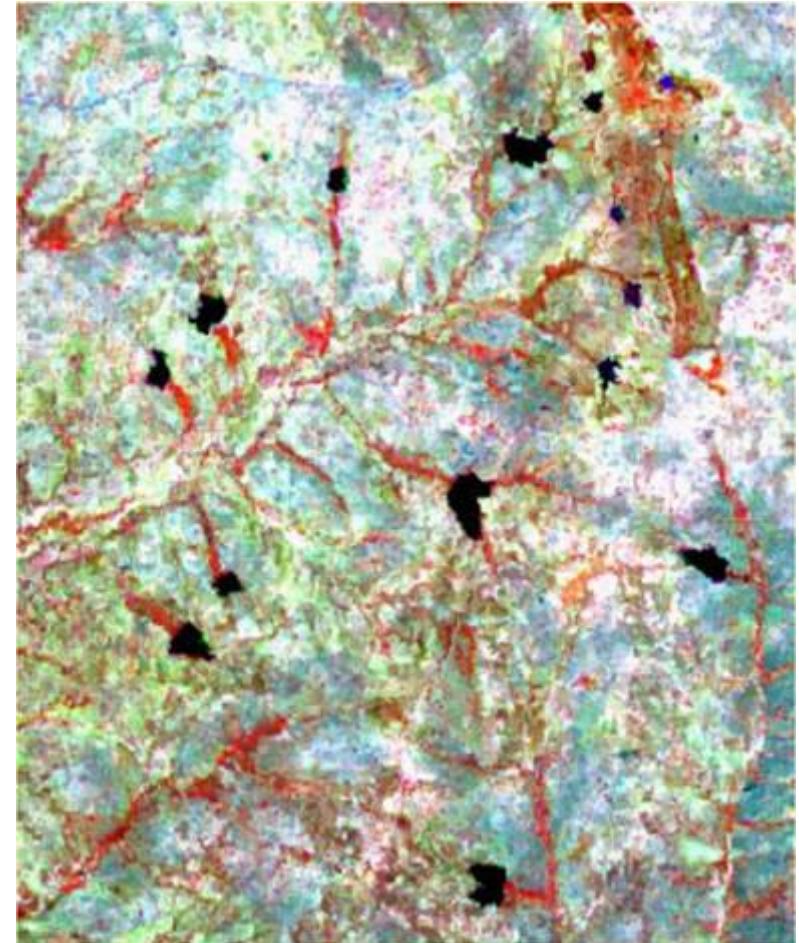
# Assignment 4: Small Reservoirs

## Reading: Jens Liebe's Thesis



# Assignment 4: Small Reservoirs

Lots of shapes and sizes!



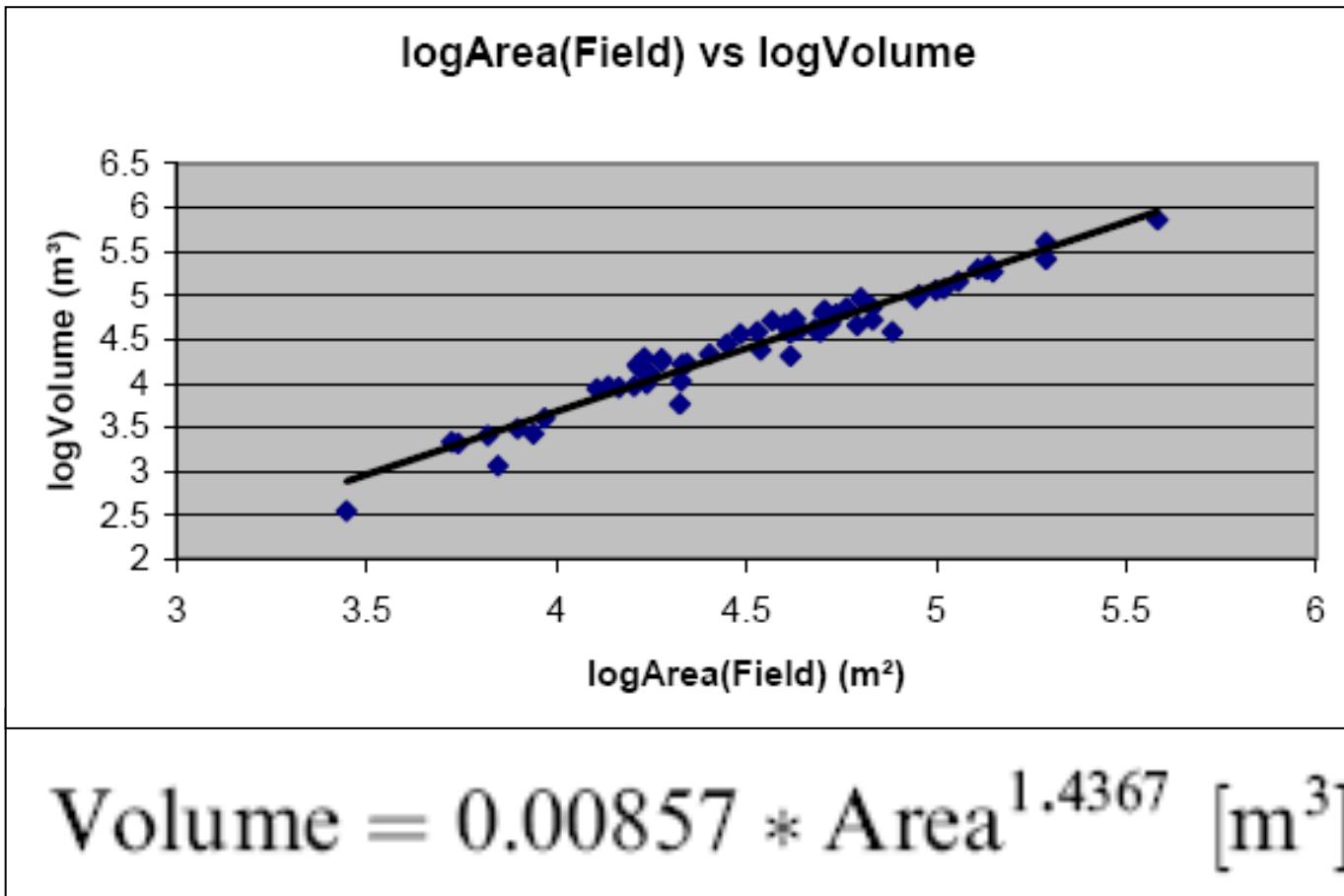
# Assignment 4: Small Reservoirs

Bathymetric survey of sixty reservoirs



# Assignment 4: Small Reservoirs

Many shapes... one equation!

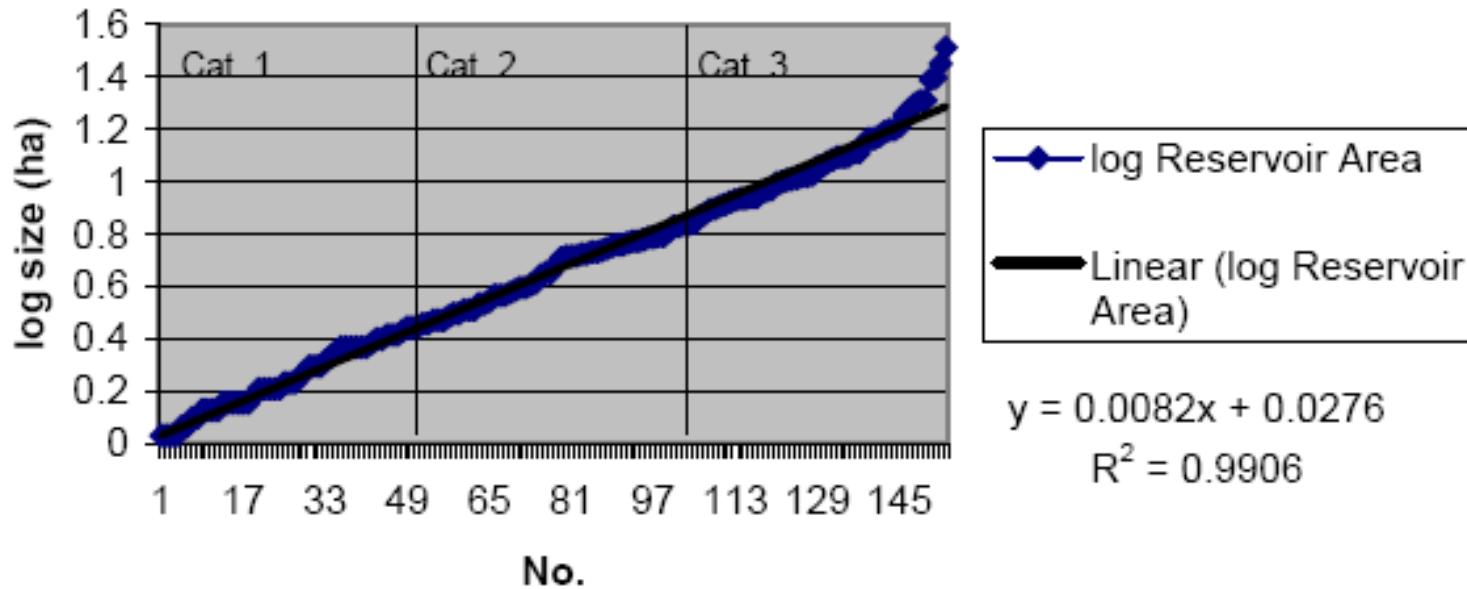




## Exercise

### Mapping small reservoirs in Burkina Faso

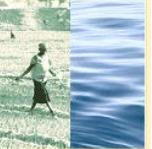
Reservoir Size Distribution  
(> 1ha, w/o Tono & Vea)



# Assignment 4: Small Reservoirs

## How to map open water?

- Color composite
- Training map (many classes!)
  - Maximum Likelihood
    - Contiguity
    - Hand check...



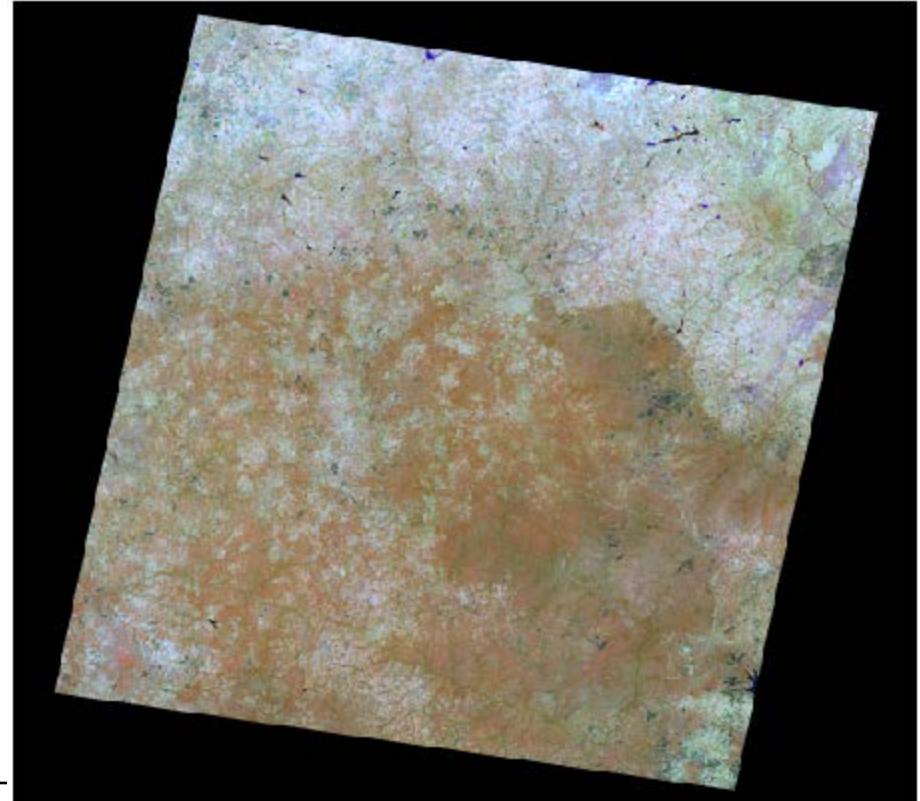
## Exercise

How to map open water?

### Color composite

- Band 4 => Blue
- Band 5 => Green
- Band 3 => Red

(Windows)



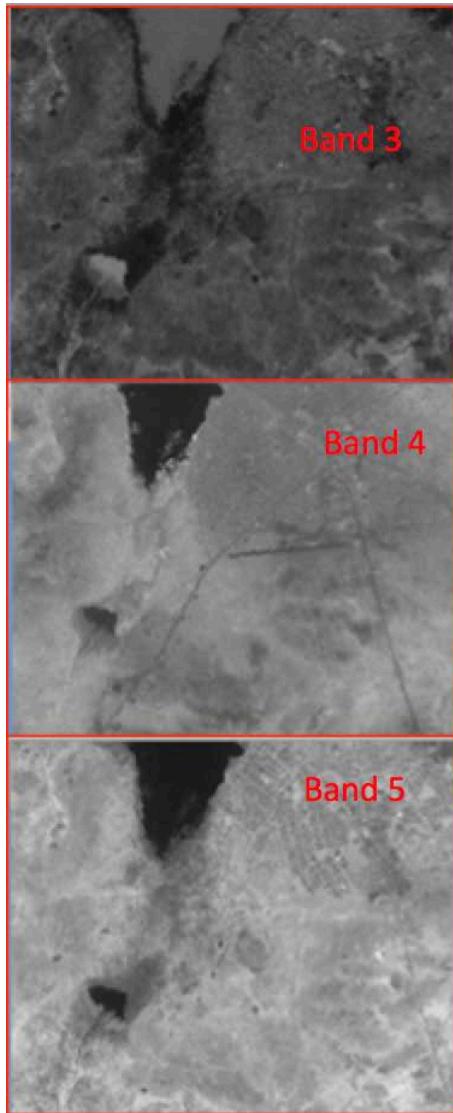
# Assignment 4: Small Reservoirs

## Training map:

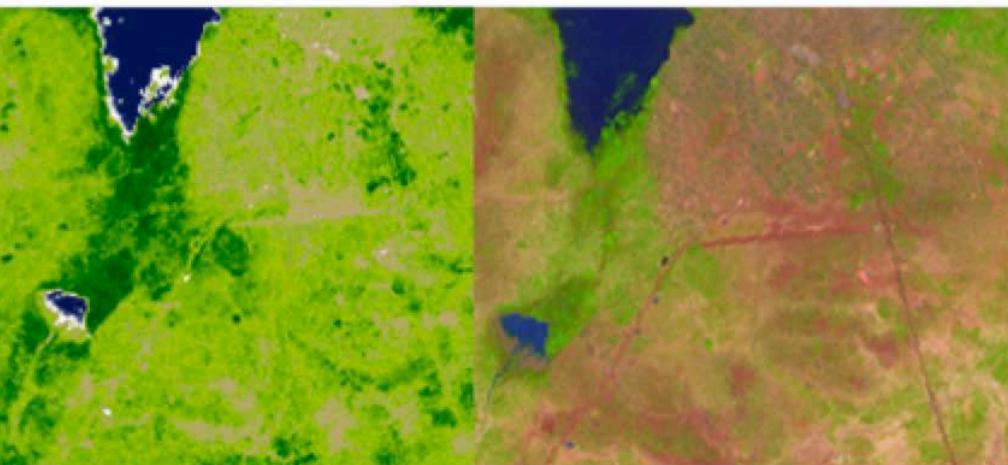
- Sediment
- Clear water
- Non-water!
- Shades & burn scars



# Assignment 4: Small Reservoirs



Use NDVI, individual bands and composite to identify classes:

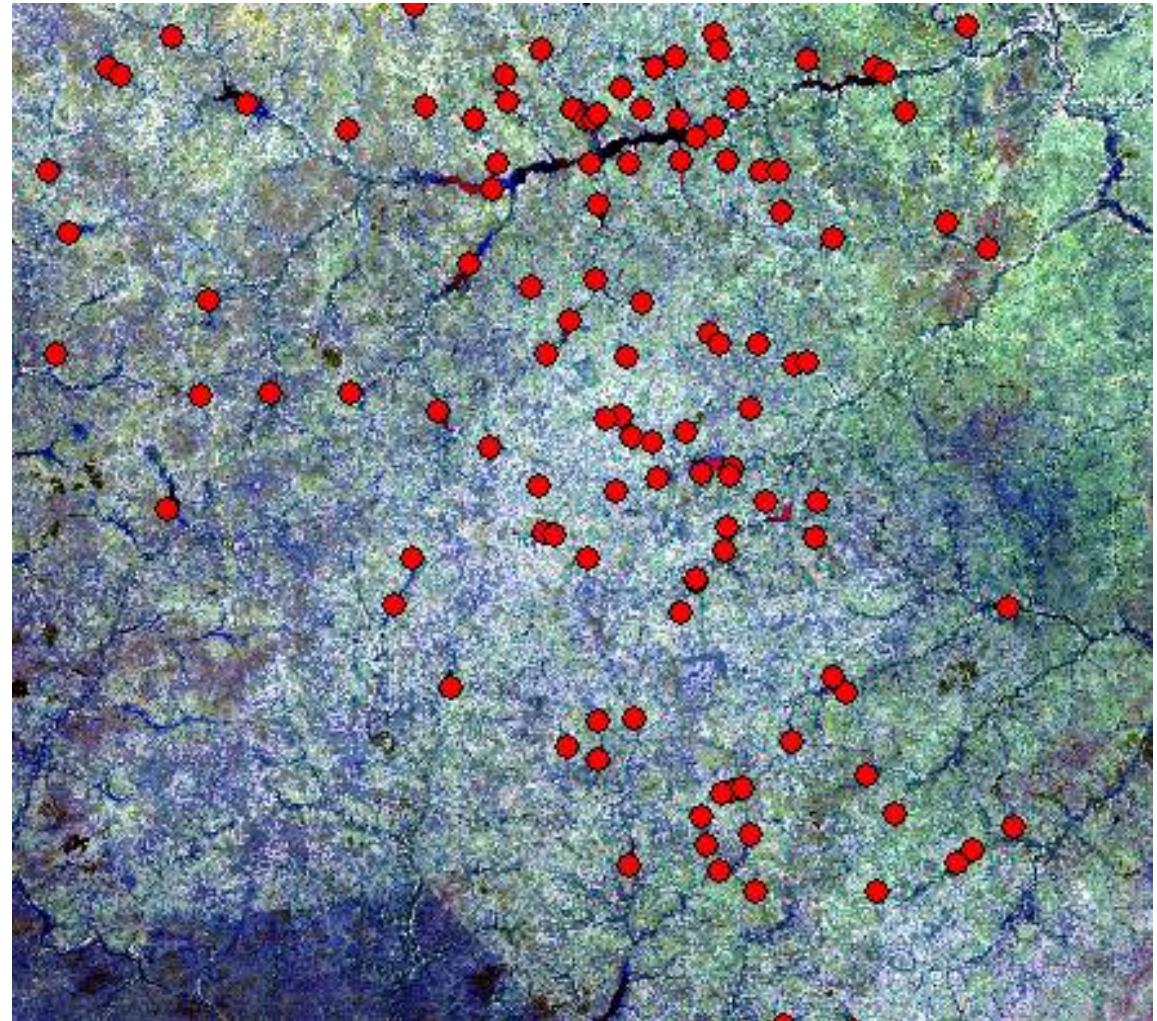


Some features are clearer looking at one of the bands than the composite or NDVI!

# Assignment 4: Small Reservoirs

Check against  
ground data:

**reservoirs.shp**



# Assignment 4: Small Reservoirs

- 1) Maximum Likelihood classification
- 2) Identify real small reservoirs:

Find contiguous sets of water pixels and group them into single objects

- 3) Hand check results:

i.e. check that the “reservoirs” you’ve identified really look like reservoirs.

A single pixel reservoir? => Noise => remove!

River classified as reservoir => remove!

Reservoirs “cut” in two? => Make them a single object

Check that your reservoir is not a burn scar (dark objects)