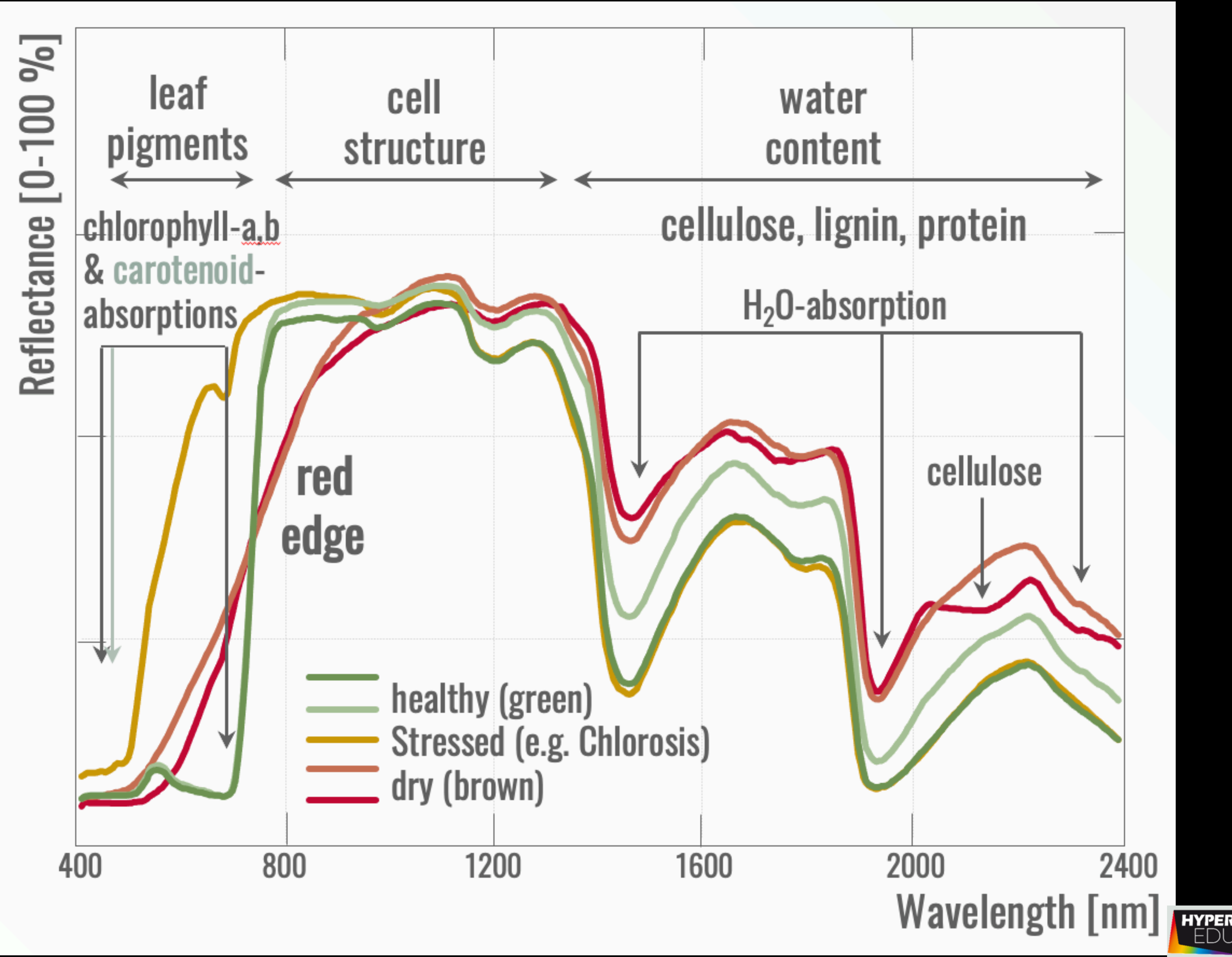
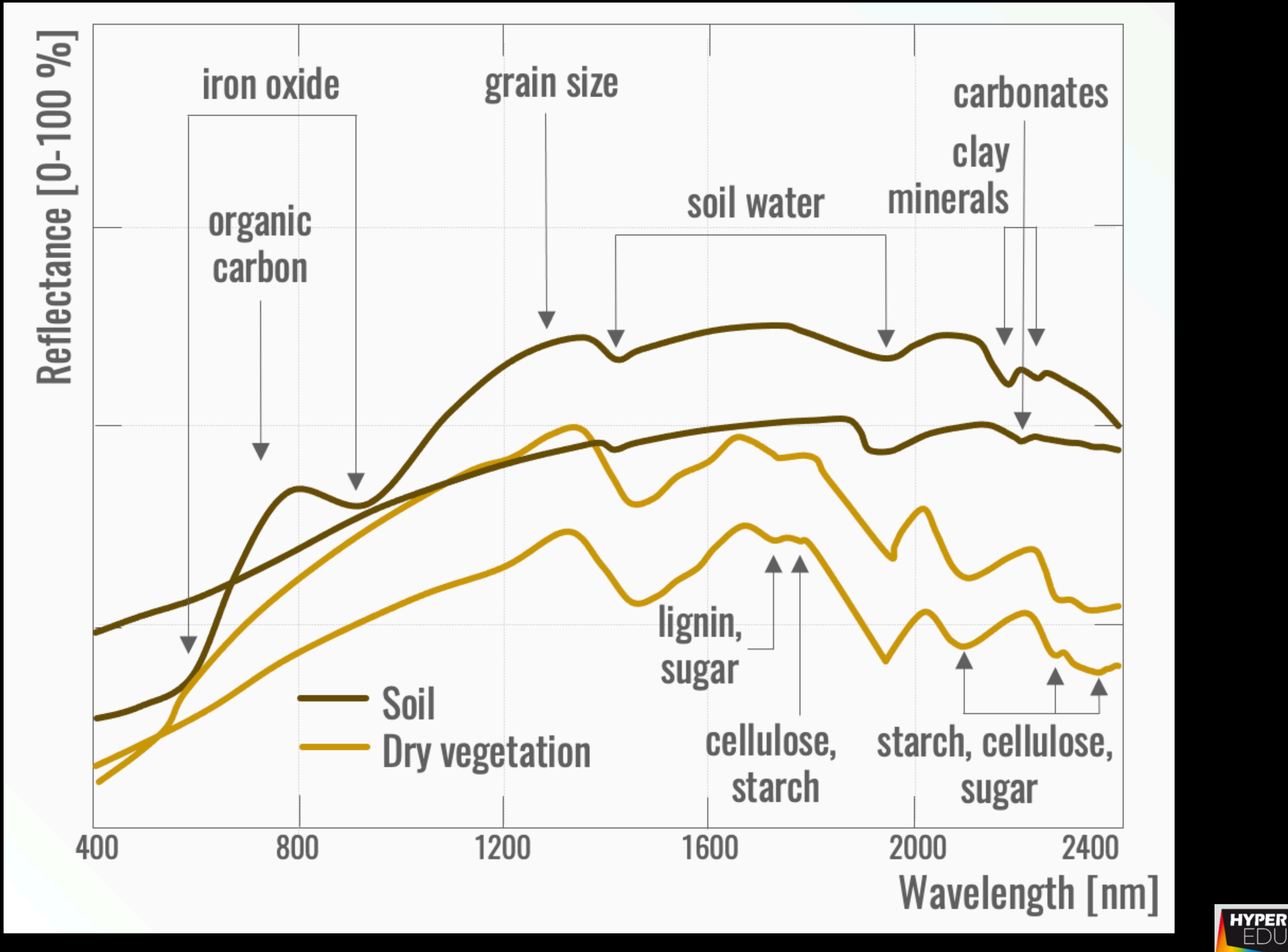


Reflectance [0-100 %]
leaf pigments
cell structure
water content
chlorophyll-a,b & carotenoid-absorptions
cellulose, lignin, protein
H_2O-absorption
red edge
cellulose
healthy (green)
Stressed (e.g. Chlorosis)
dry (brown)
400
800
1200
1600
2000
2400
Wavelength [nm]
HYPER EDU



Reflectance [0-100 %]
iron oxide
organic carbon
grain size
soil water
clay minerals
carbonates
lignin, sugar
cellulose, starch
starch, cellulose, sugar
Soil
Dry vegetation
400
800
1200
1600
2000
2400
Wavelength [nm]
HYPER EDU

Data of the Week

https://eyes.nasa.gov/apps/earth/
https://climate.nasa.gov/images-of-change

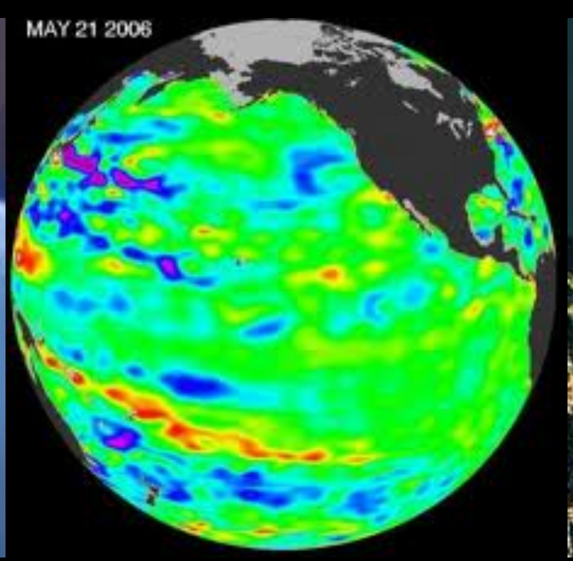




Image Analysis (II)

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EVSC 4010/7010 Week 7

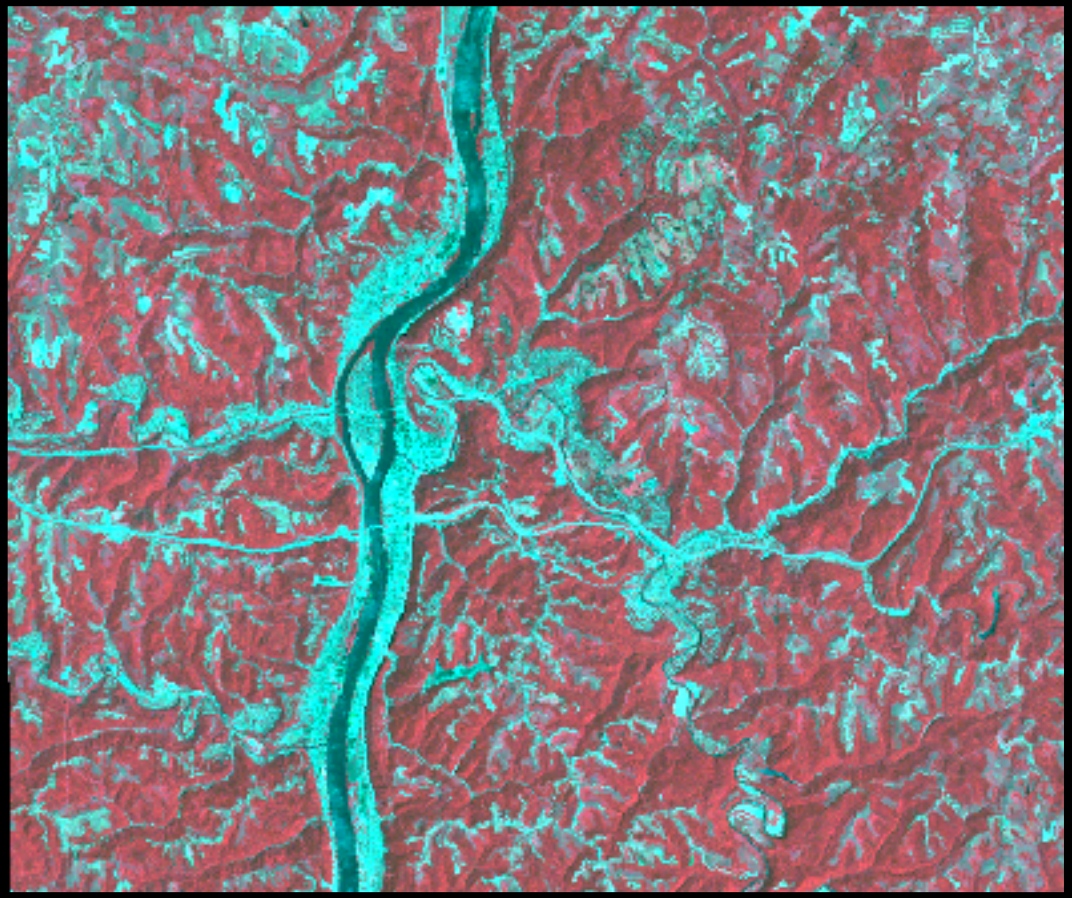
Week 6 & 7 Outline

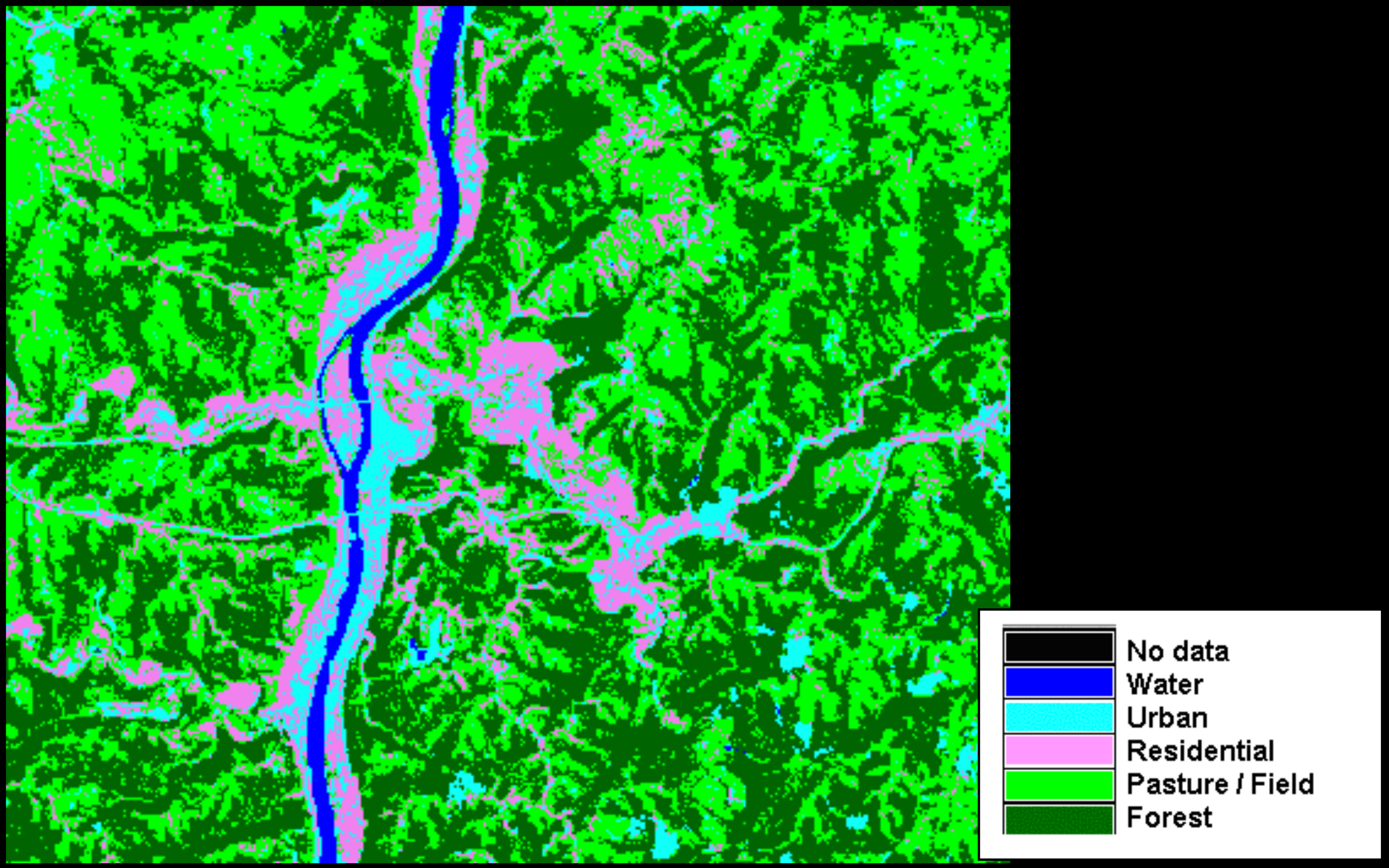
- Methods for data analysis — Tasseled Cap and PCA
- Spectral Mixture Analysis (SMA)
- Land cover land use classification
- Change detection and time-series analysis

What is land cover?

Natural Vegetation	
Forest	
Evergreen Needleleaf	Dominated by woody vegetation with a cover >60% and height > 2 m. Almost all trees remain green all year. Canopy is never without green foliage.
Evergreen Broadleaf	Dominated by woody vegetation with a cover >60% and height > 2 m. Most trees and shrubs remain green year round. Canopy is never without green foliage.
Deciduous Needleleaf	Dominated by woody vegetation with a cover >60% and height > 2 m. Seasonal needleleaf communities with an annual cycle of leaf-on and leaf-off periods.
Deciduous Broadleaf	Dominated by woody vegetation with a cover >60% and height > 2 m. Broadleaf tree communities with an annual cycle of leaf-on and leaf-off periods.
Mixed Forest	Dominated by trees with a cover >60% and height > 2 m. Communities with interspersed mixtures or mosaics of the other four forest types. None of the forest types exceeds 60% of landscape.
Shrubland, Grasslands, and Wetland	
Closed Shrublands	Woody vegetation <2 m tall and with shrub canopy cover >60%. The shrub foliage can be either evergreen or deciduous.
Open Shrublands	Woody vegetation <2 m tall and with shrub canopy cover between 10% and 60%. The shrub foliage can be either evergreen or deciduous.
Woody Savannas	Herbaceous and other understory systems, and with forest canopy cover between 30% and 60%. The forest cover height >2 m.
Savannas	Herbaceous and other understory systems, and with forest canopy cover between 10% and 30%. The forest cover height >2 m.
Grasslands	Lands with herbaceous types of cover. Tree and shrub cover is <10%.
Permanent Wetlands	Lands with a permanent mixture of water and herbaceous or woody vegetation. Vegetation can be present in salt, brackish, or fresh water.
Developed and Mosaic Lands	
Agriculture	
Croplands	Lands covered with temporary crops followed by harvest and a bare-soil period (e.g., single and multiple cropping systems). Perennial woody crops are classified as the appropriate forest or shrub land-cover type.
Cropland/Natural Vegetation Mosaic	
Cropland/Natural Vegetation Mosaic	Mosaic of croplands, forests, shrubland, and grasslands in which no one component comprises > 60% of the landscape.
Urban	
Built-up	Land covered by buildings and other human-made structures.
Nonvegetated Lands	
Barren	
Barren or Sparsely Vegetated	Exposed soil, sand, rocks, or snow and ≤10% vegetated cover during the year.
Snow and Ice	
Snow and Ice	Lands under snow/ice cover throughout the year.
Water	
Water	Oceans, seas, lakes, reservoirs, and rivers. Can be fresh or salt water.

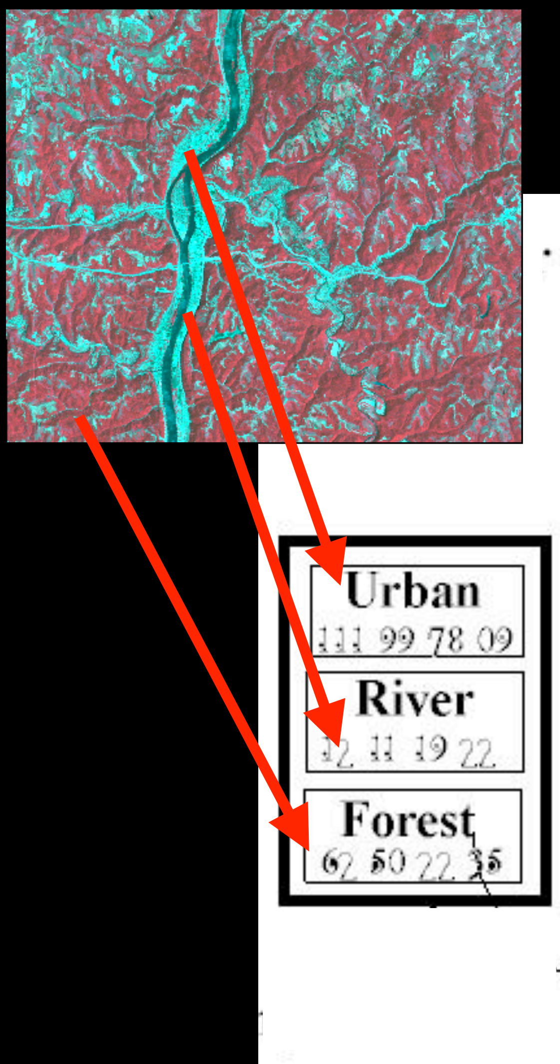
Why classification?

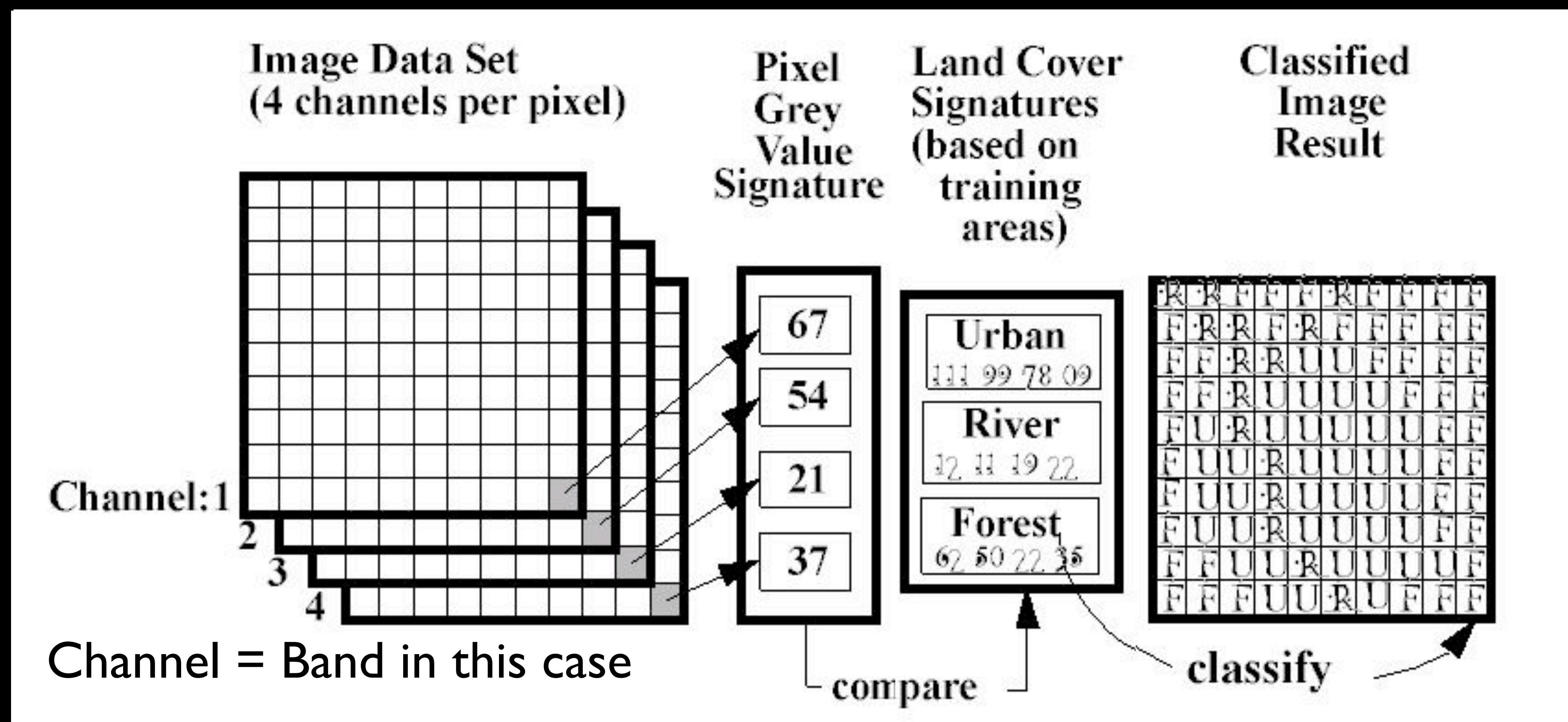




- Anthropogenic impact on the environment
- Ecology
- Climate change
- Urban planning

Two phases of classification

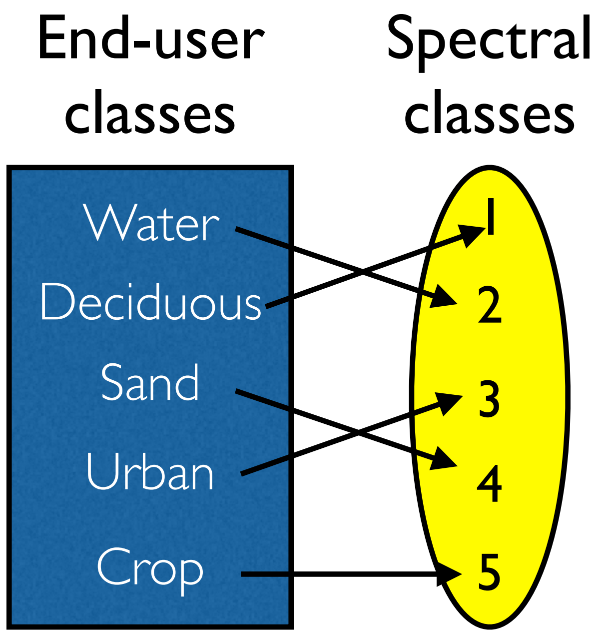


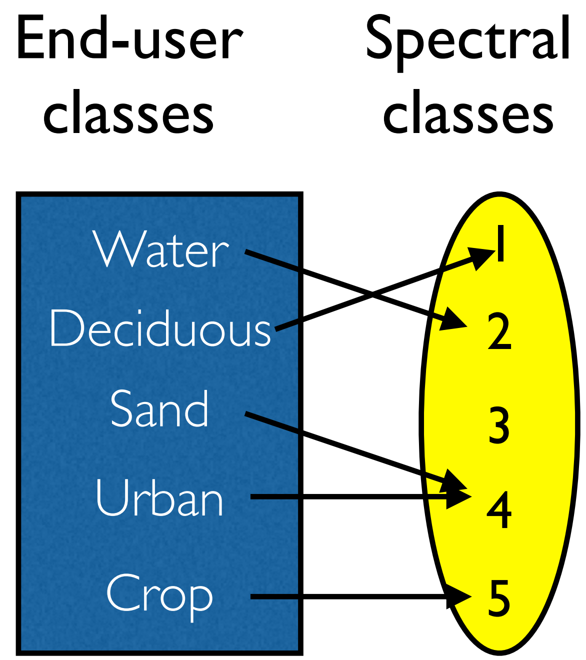


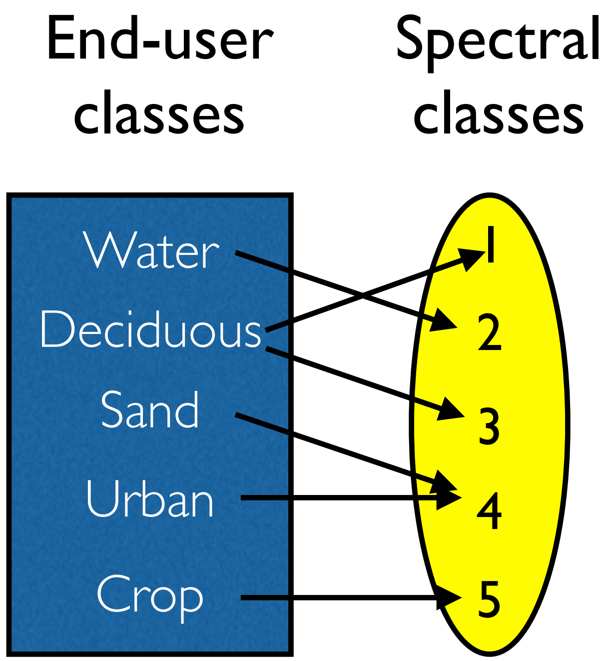
- Training phase
  - ✳ Supervised
  - ✳ Unsupervised

Assignment phase

Training phase: Determine the number/type of classes





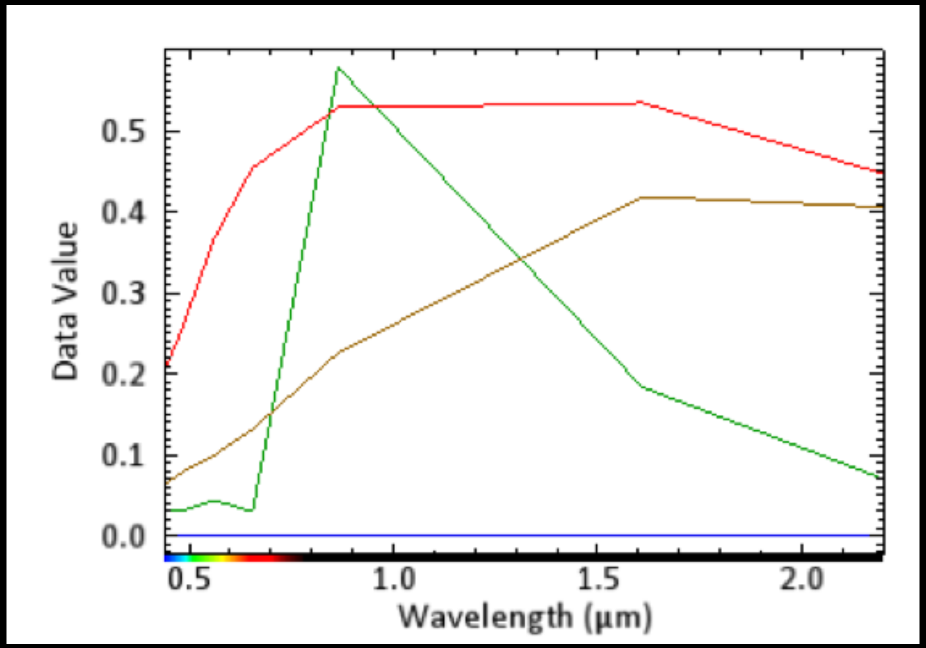


Examples:

1) Deciduous tree in the sun-facing slope vs. shade-facing slope;
2) Water with different depths and turbidity;
3) Bare ground and urban areas.

Training phase: Supervised Classification

Supervised classification assumes knowledge of some parts of the study area ("training fields") is acquired by external sources or fieldwork.
The accuracy of supervised classification depends on the quality of these "training fields".



Known optical properties

Field observations

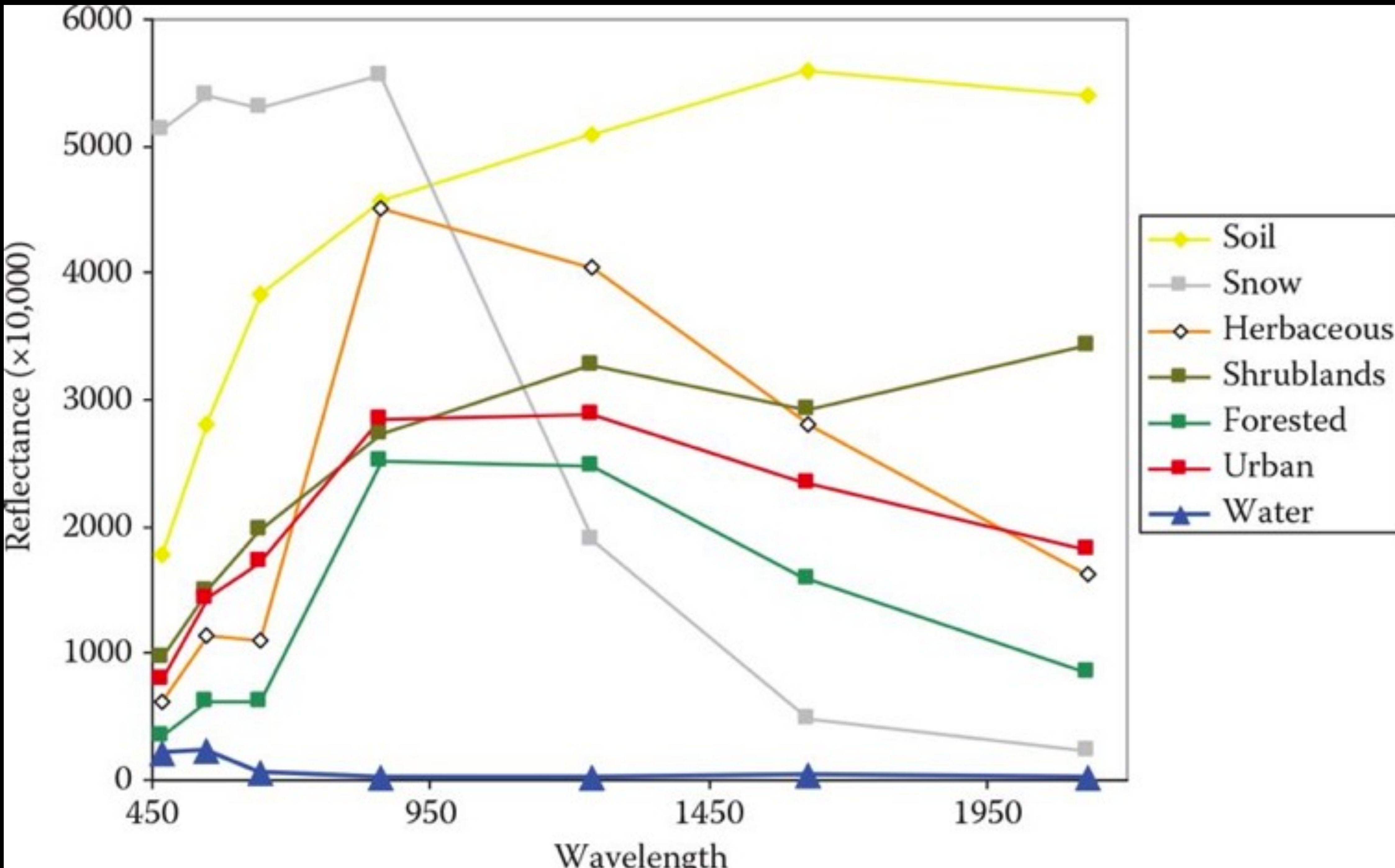
Aerial maps

Training phase: Supervised Classification

- Select the training fields in homogenous areas, and avoid transitional areas. On the other hand, select pixels of the same category in different locations.

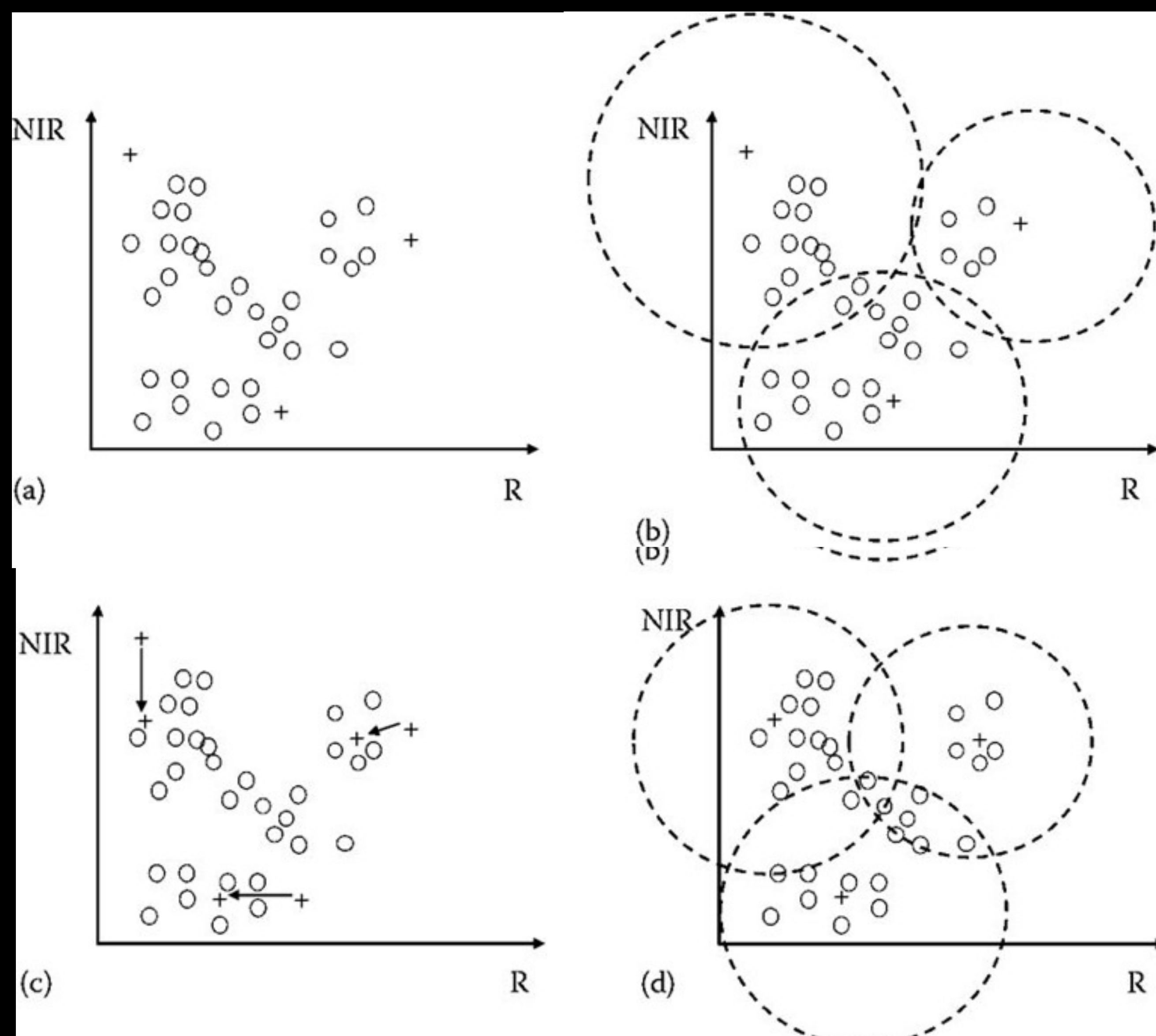
- The size of training fields: how many pixels? Spatial distribution?
  - Size: 10*m ~ 100*m, where m is the number of bands
  - Spatial distribution: choose many small patches instead of one single large field.

Training phase: training sites



Training phase: Unsupervised Classification

Unsupervised classification identifies spectral classes in the image by finding clusters of pixels with similar pixel values.



Training phase: Mixed methods

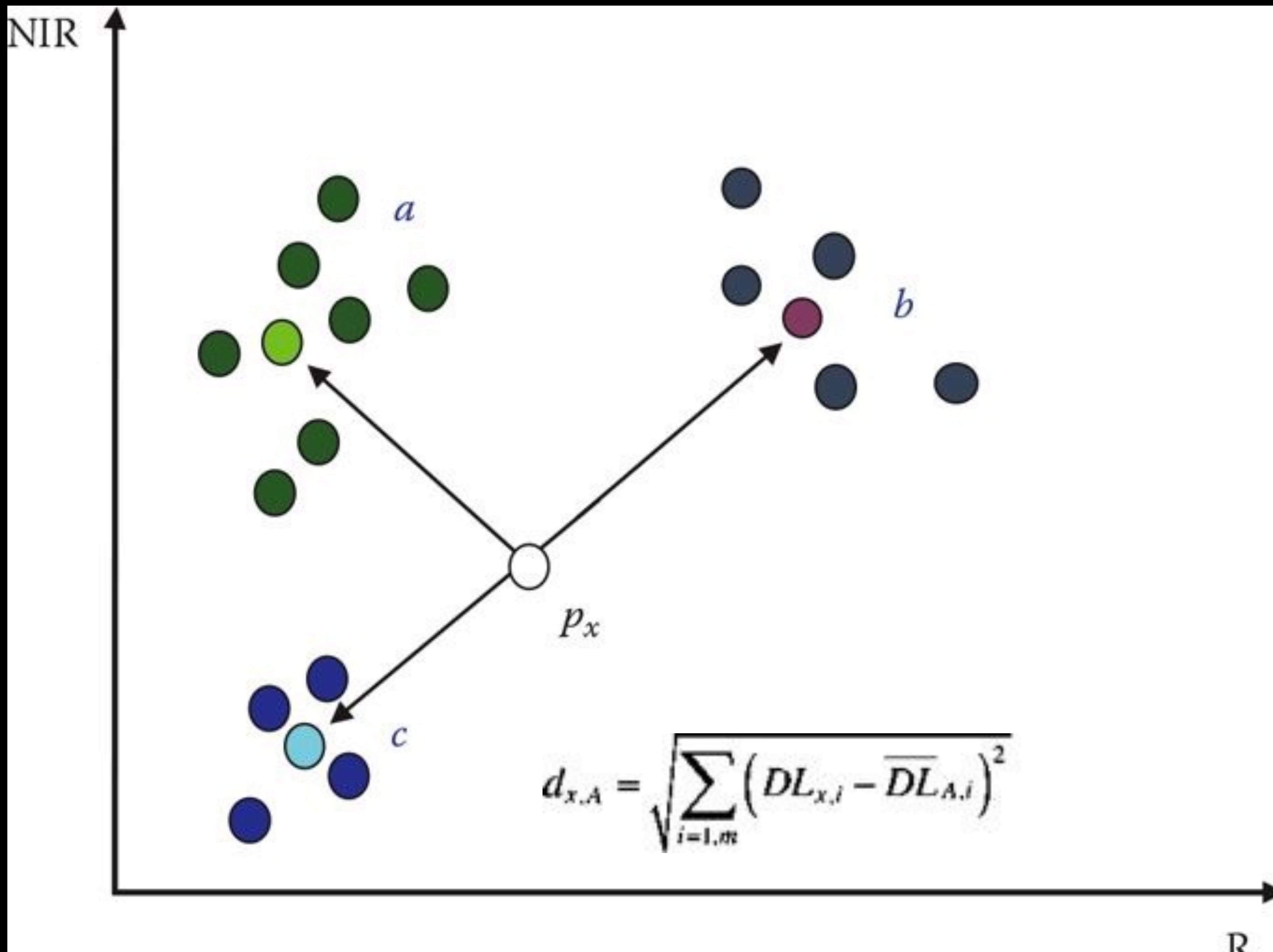
- Supervised and unsupervised methods both have advantages and disadvantages.
  - The former is often biased because the user decides *a priori* categories without considering the spectral variability in the image;
  - The latter does not guarantee the output has a meaning for the end users.
- We can combine the supervised and unsupervised methods.
  - Use supervised method to "guide" the unsupervised.

Assignment phase: find the best algorithm

This phase aims to classify the whole image by **assigning each pixel to one of the previously selected categories**. This categorization is carried out on the basis of the values of each pixel (DN or reflectance), for all input bands selected by the user.

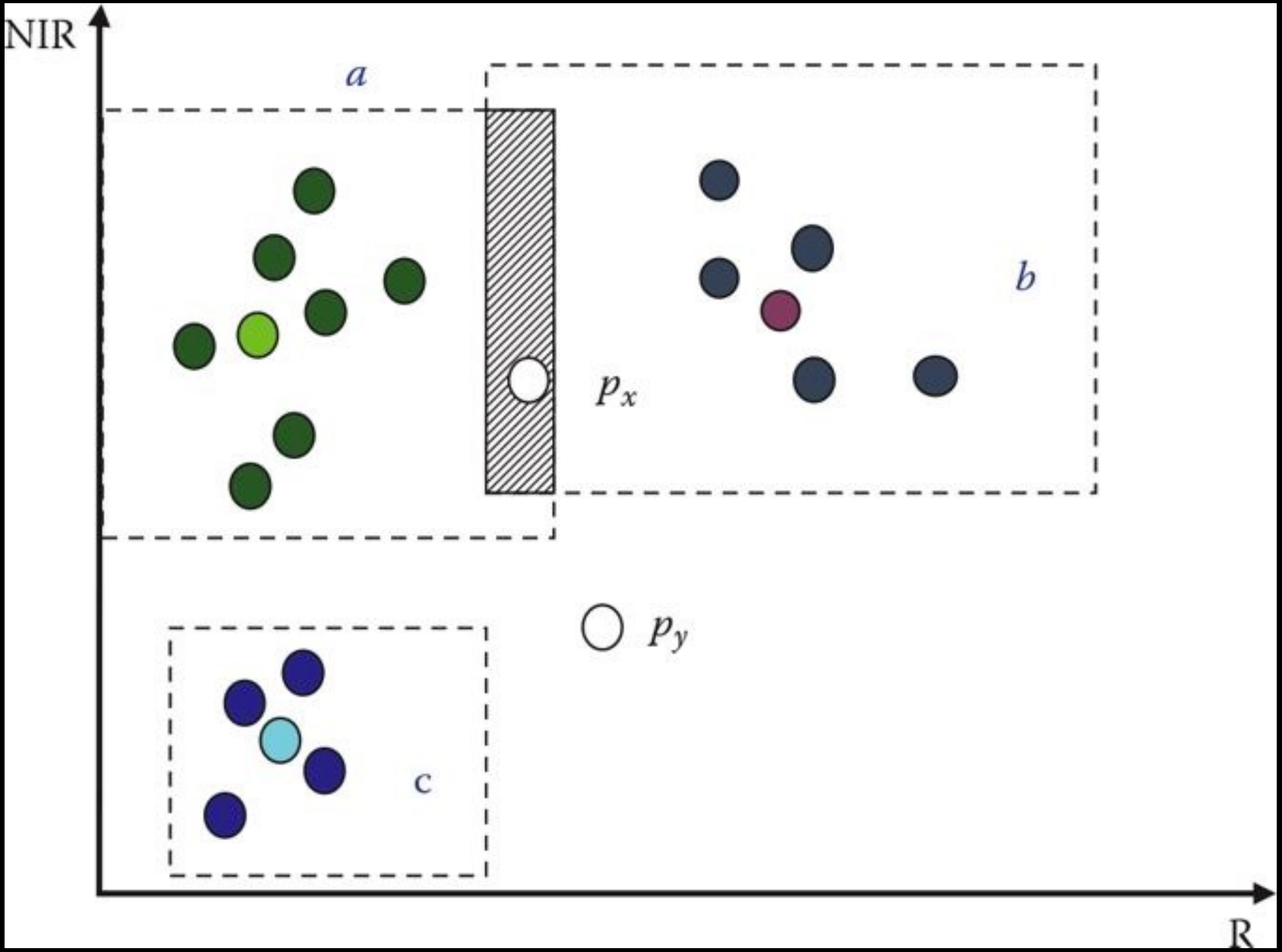
- Minimum-Distance Classifier (Nearest Neighbor)
- Parallelepiped Classifier
- Maximum Likelihood Classifier
- Decision-Tree Classifier

Minimum Distance Classifier

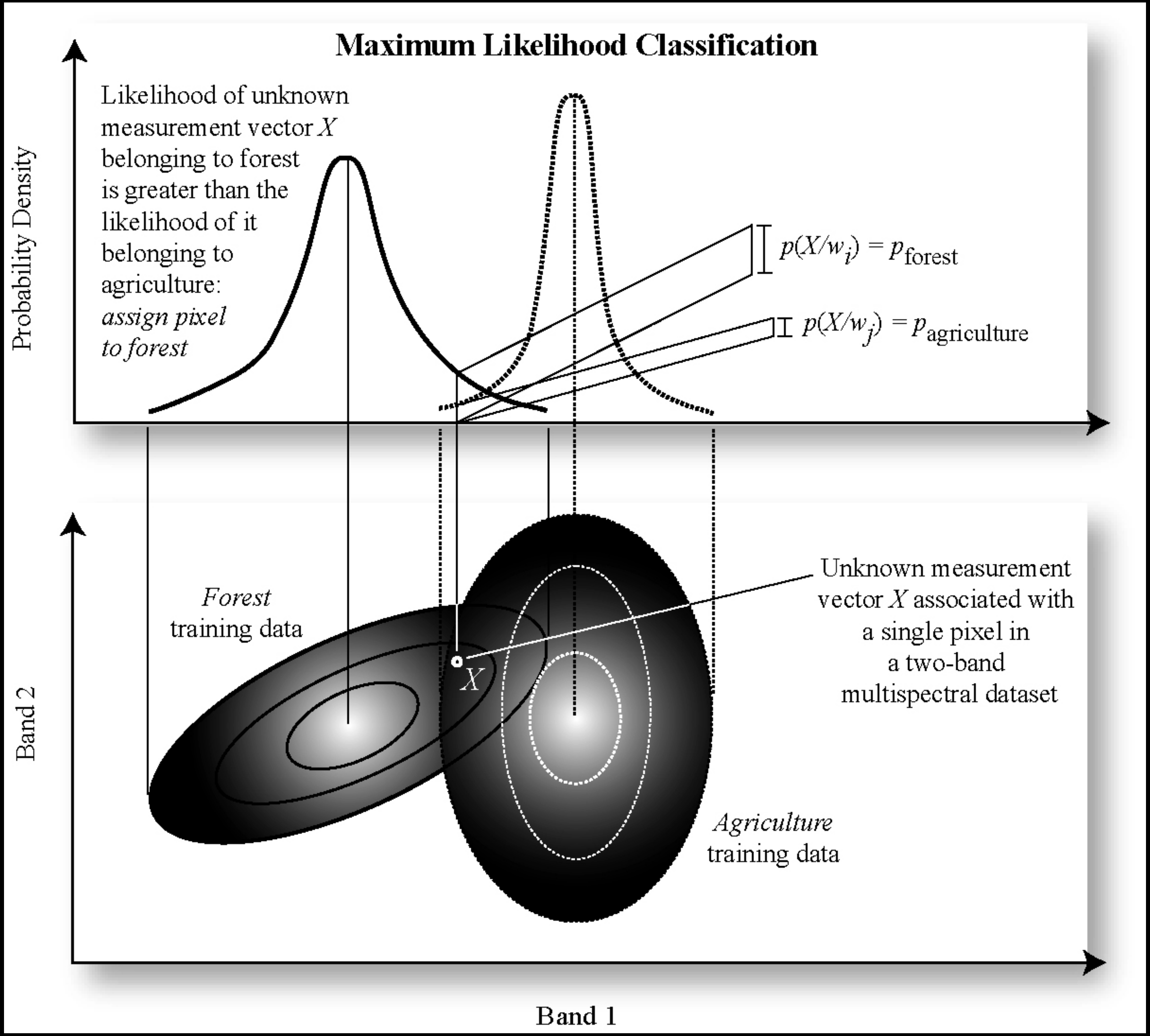


$d_{x,A}$ is the distance between the pixel x and the category A
$DL_{x,i}$ is the value of the target pixel in the band i
$\overline{DL}_{A,i}$ is the mean DL of category A in the same band
m is the number of input bands

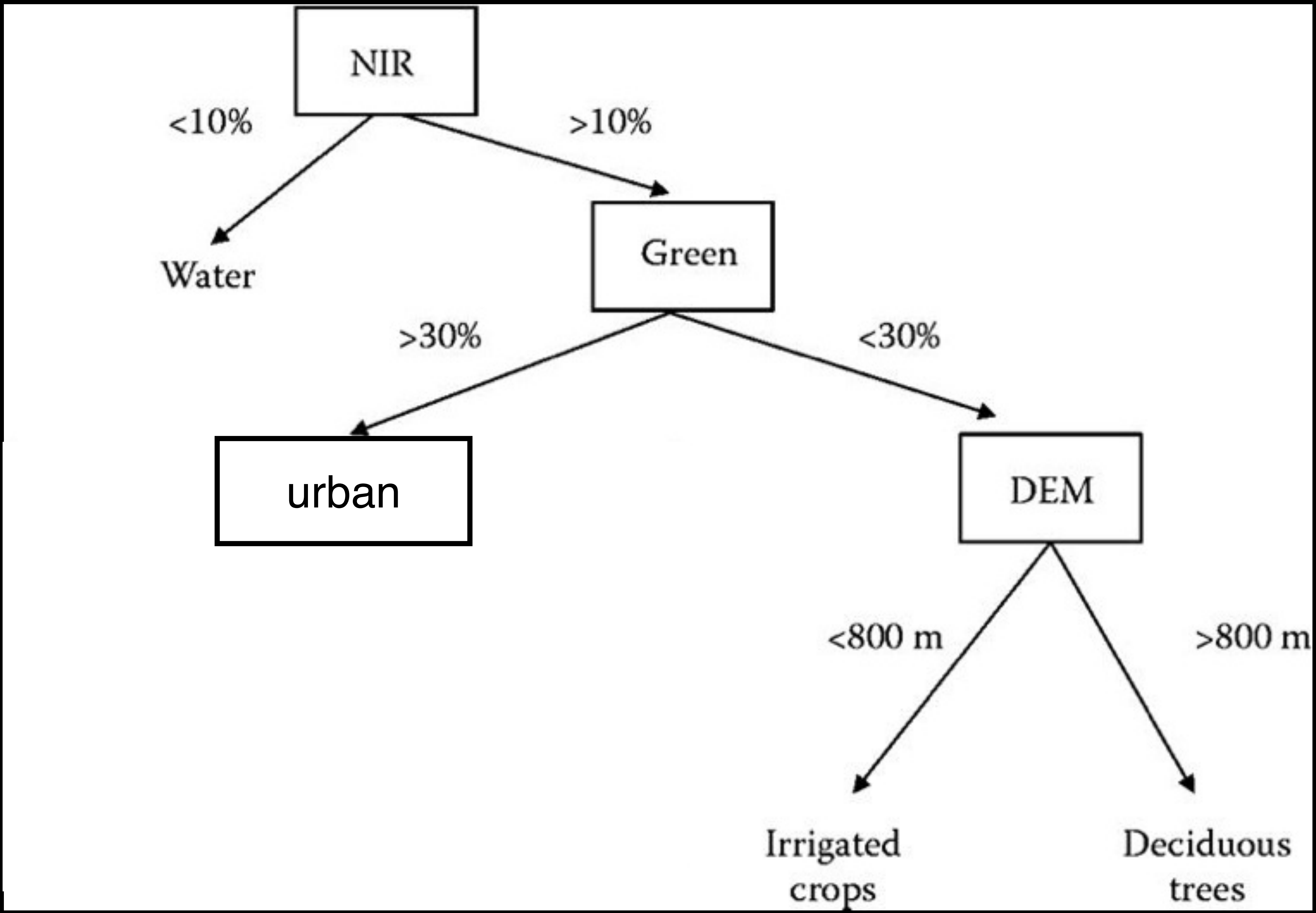
Parallelepiped Classifier



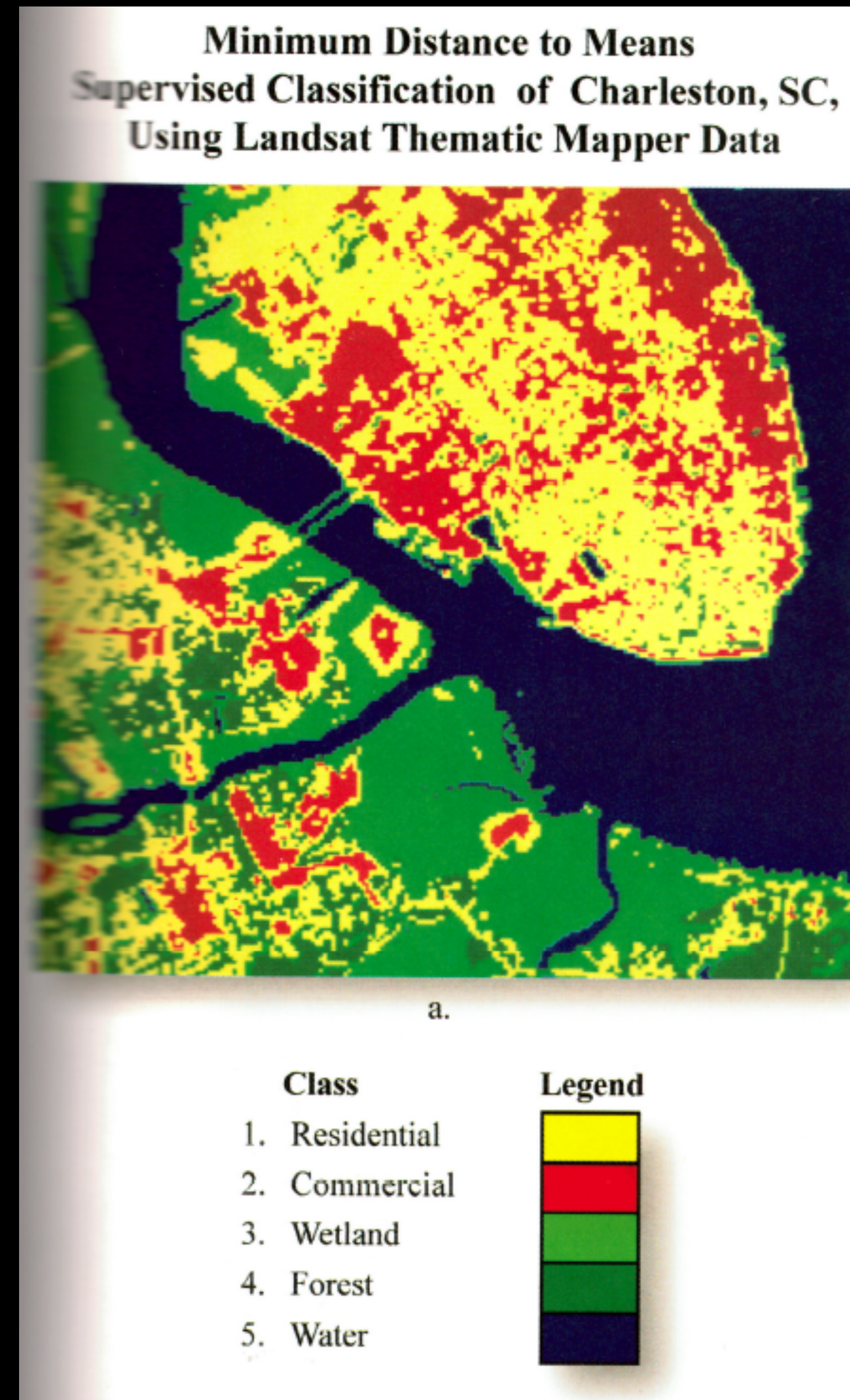
Maximum Likelihood Classifier



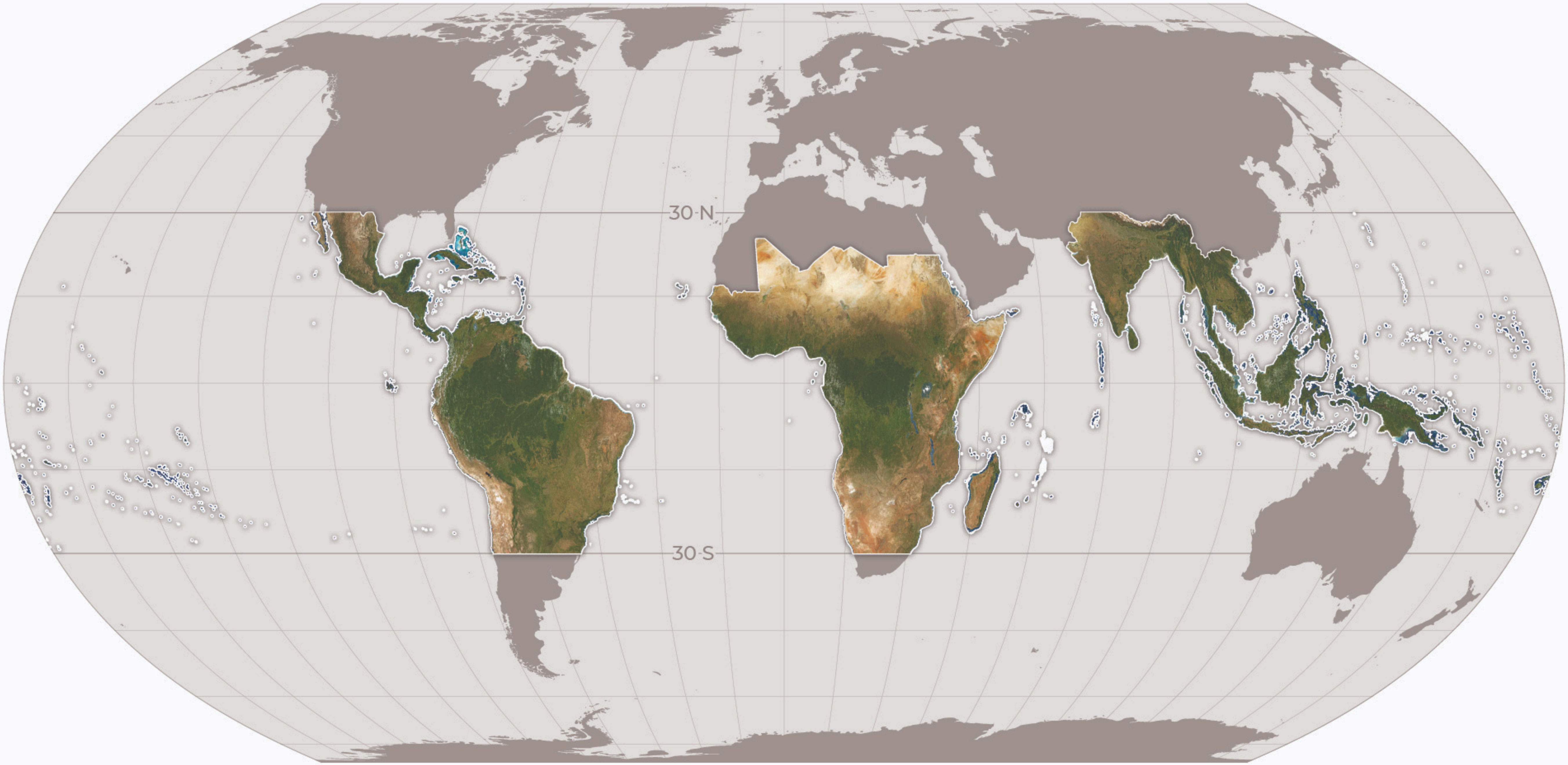
Decision Tree Classifier



Minimum-Distance Classification Result



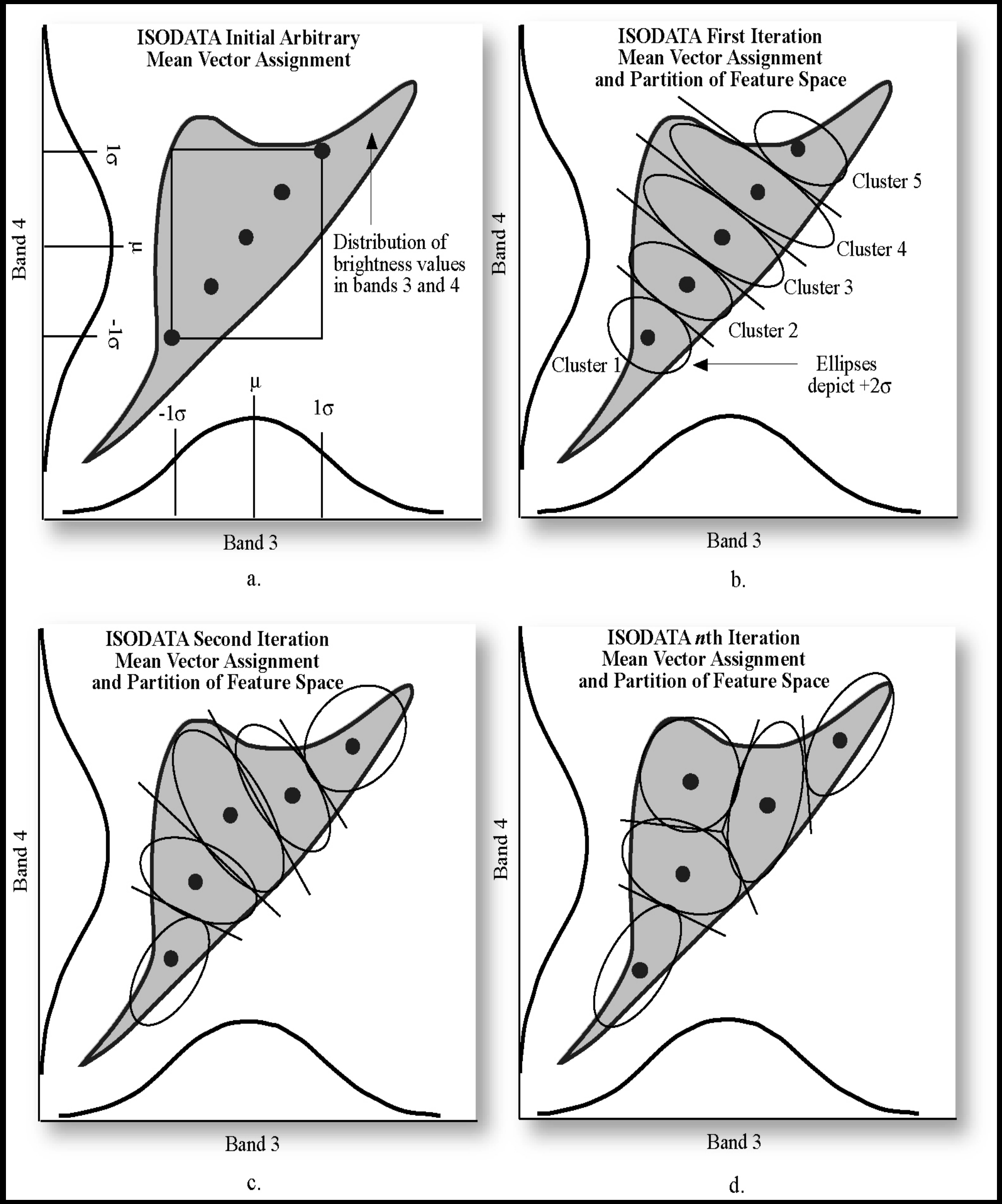
Data of the Week



https://www.planet.com/pulse/planet-ksat-and-airbus-awarded-first-ever-global-contract-to-combat-deforestation/

ISODATA

The Iterative Self-Organizing Data Analysis Technique (ISODATA) algorithm

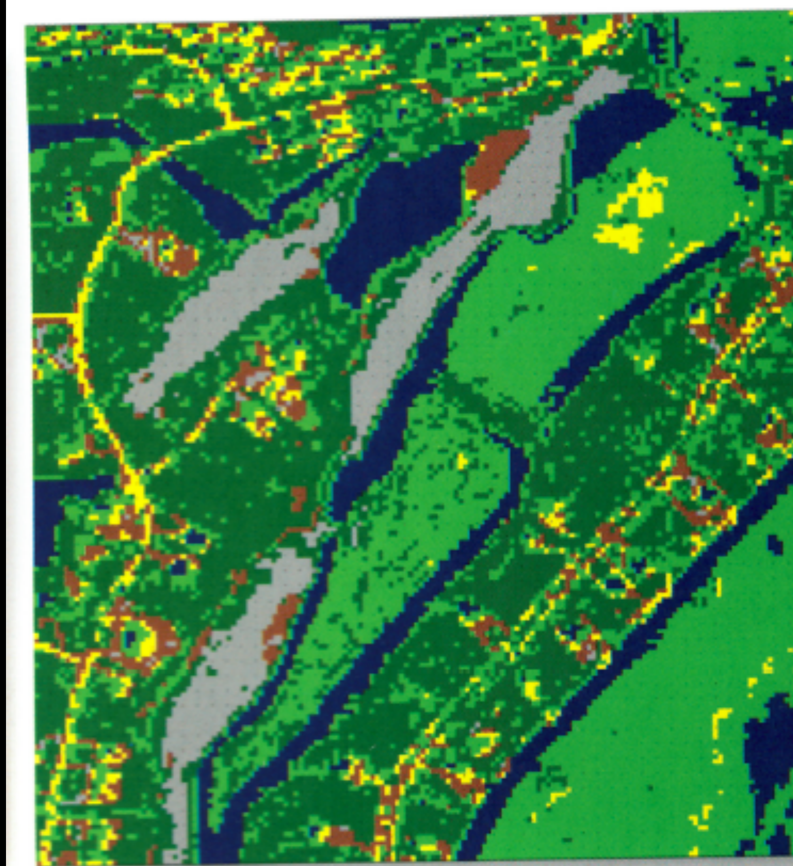


1. A series of cluster centers are initiated.
2. The pixels of the image are assigned to the cluster with the closest center, following the distance criterion previously selected.
3. Once the first iteration is completed, the class centers are recalculated,
4. A second iteration starts. Again, all pixels are classified under the nearest center class.
5. The centers are recalculated. The process continues until the number of pixels that changed categories from one iteration to the previous one is below a certain threshold indicated by the interpreter.

ISODATA result

a. Color composite of HyMap data.

b. Final location of 10 ISODATA mean vectors after 10 iterations.



c. Classification map derived from 10 ISODATA clusters.

Class	Legend
1. Water	
2. Wetland	
3. Wetland	
4. Roof/asphalt	
5. Forest	
6. Wetland	
7. Forest	
8. Bare soil	
9. Forest	
10. Fairway	

Original false color

Isodata

Jensen 2008

Classification accuracy

- Ground truth: from geolocated field observations; aerial survey; other data sources.

- Two types of errors:
  - Omission Error (“false negative”, OE): the number of unassigned pixels / total number of pixels in that category.

  - Commission Errors (“false positive”, CE): pixels that are included in a given category when they are not in fact part of that category.

- Two types of accuracies:
  - Producer Accuracy (PA): 1-OE
  - User Accuracy (UA): 1-CE.

Confusion Matrix

	Reference											
Classification	**1**	**2**	**4**	**5**	**6**	**7**	**9**	**A**	**B**	**Total**	**User's Accuracy**	**Commission Error**
1	927	49	63		42		5	87		1173	79	21
2	35											
4	6											
5												
6	11											
7												
9	99											
A	70											
B												
Total	1148											
Producer's Accuracy	80.7											
Omission Error	19.3											

- Omission Error ("false negative", OE): the number of unassigned pixels / total number of pixels in that category.
- Commission Errors ("false positive", CE): pixels that are included in a given category when they are not in fact part of that category.
- Producer Accuracy (PA): 1-OE
- User Accuracy (UA): 1-CE.

$$OE_i = \frac{X_{+i} - X_{ii}}{X_{+i}}$$

$$PA_i = \frac{X_{ii}}{X_{+i}}$$

$$CE_i = \frac{X_{i+} - X_{ii}}{X_{i+}}$$

$$UA_{u,i} = \frac{X_{ii}}{X_{i+}}$$

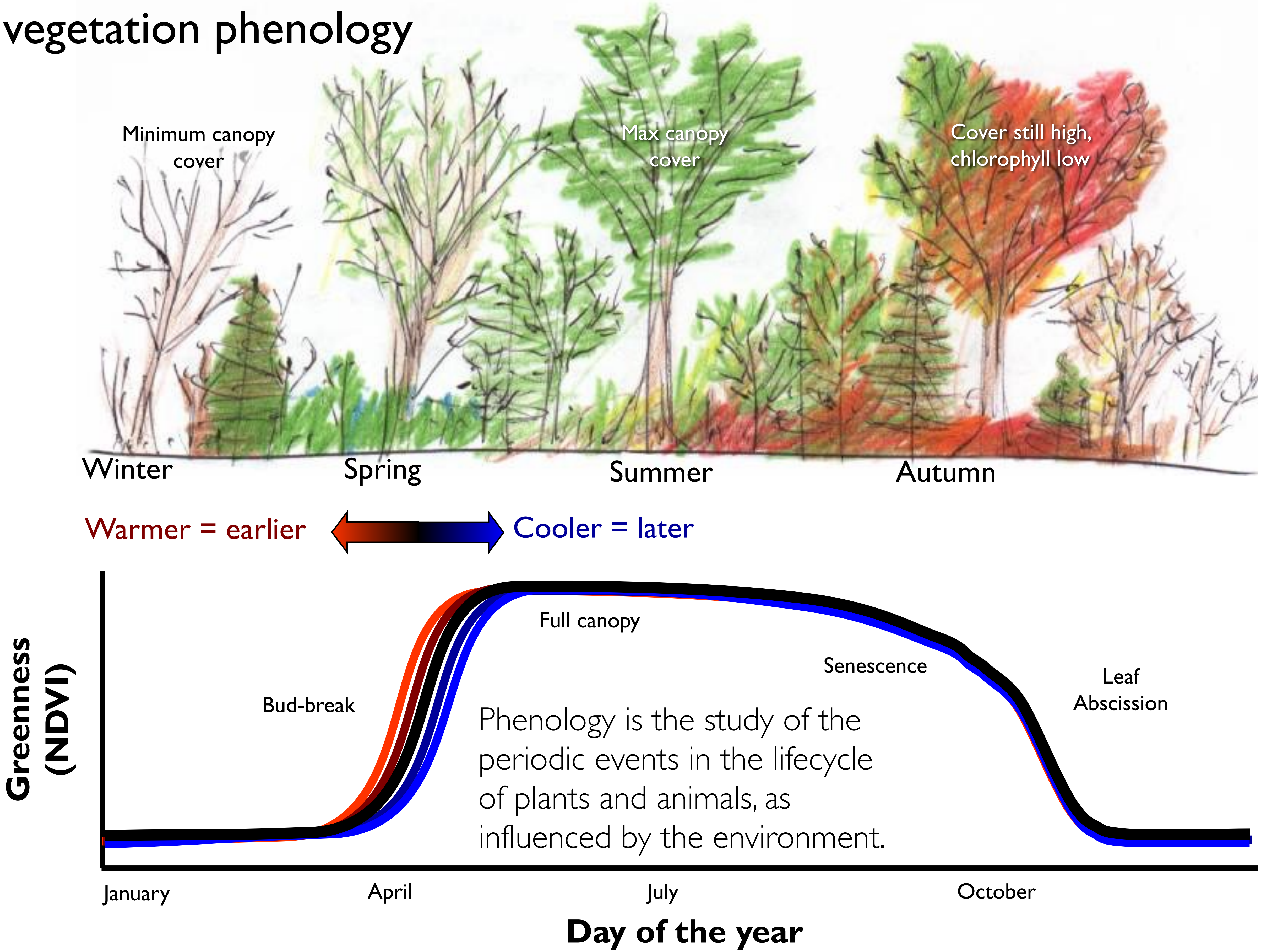
Overall Accuracy (OA):

$$\widehat{OA} = \frac{\sum_{i=1,n} x_{ii}}{\sum_{i=1,n} \sum_{j=1,n} x_{ij}}$$

Multi-temporal analysis and change detection

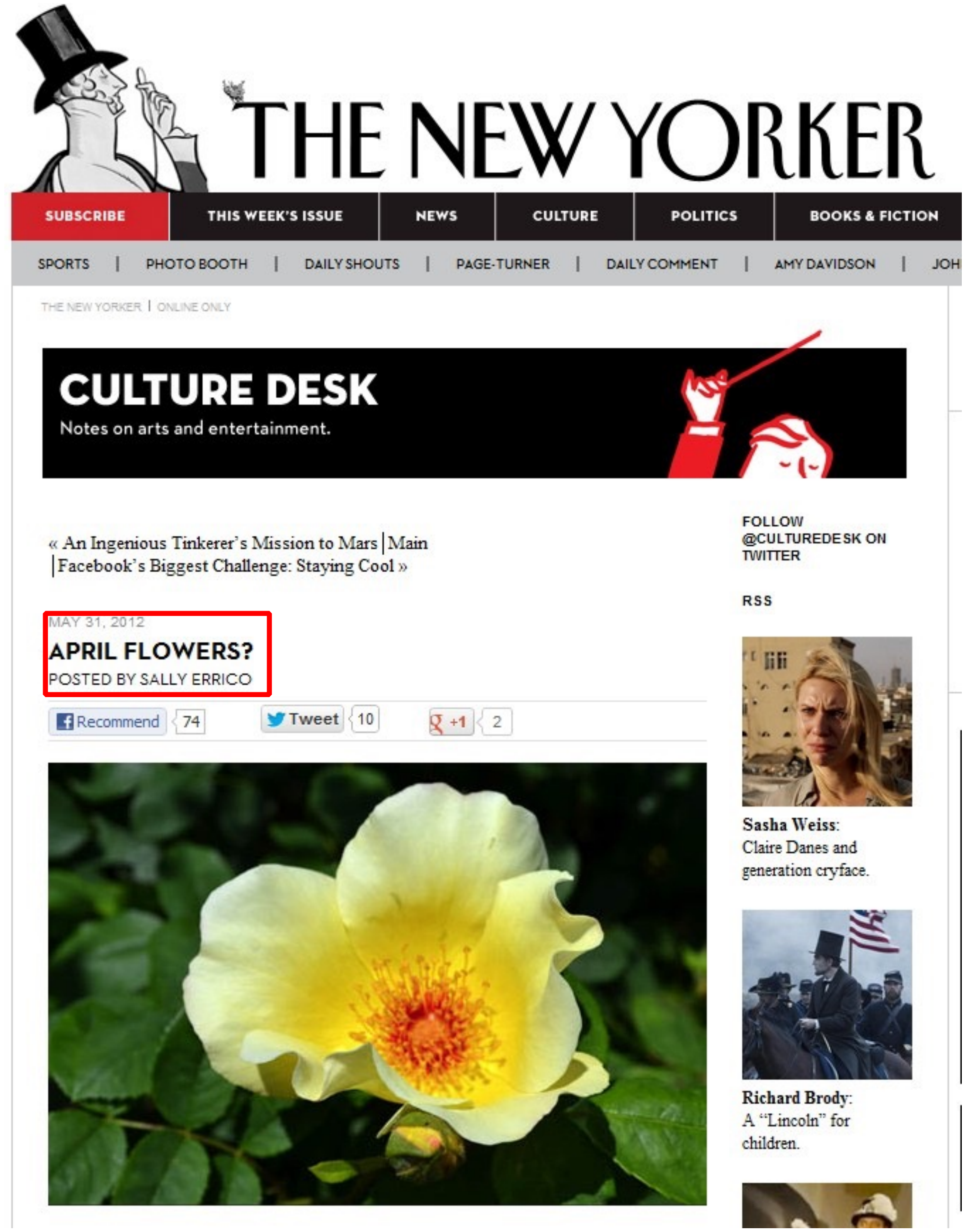
- Multi-temporal analysis: an example of vegetation phenology
- Change detection

Multi-temporal analysis: an example of vegetation phenology



Modified from Jeremy Fisher

In the News: Early Spring



- Horticulture and gardening
- Public Health: pollen allergy
- Cherry blossom viewer in DC

"spring phenology + climate change"

In the News: Early/Late Fall?


USA TODAY | Weather
Home | News | Travel | Money
Weather: Weather Now | Maps | Storm Center | Weather/Climate Science | Photo Gal

Is climate change affecting fall foliage?

Comment 332 | Recommend 1 | Tweet 45 | +1 1

PORTLAND, Maine (AP) – Clocks may not be the only thing falling back: autumn change in leaf colors may be drifting further down the calendar.

Scientists don't quite know if global w the signs of fall like it already has wit spring. They're turning their attention hopes of determining whether climate to a later arrival of autumn's golden, hues.

Studies in Europe and in Japan alrea are changing color and dropping late reason that it's happening here as we Primack, professor of biology at Bost

INTERACTIVE: Fall colors depend on

Tom Hindman, AP

The colors of autumn are reaching their peak this week along the Highland Scenic Highway in Pocahontas County, W.Va.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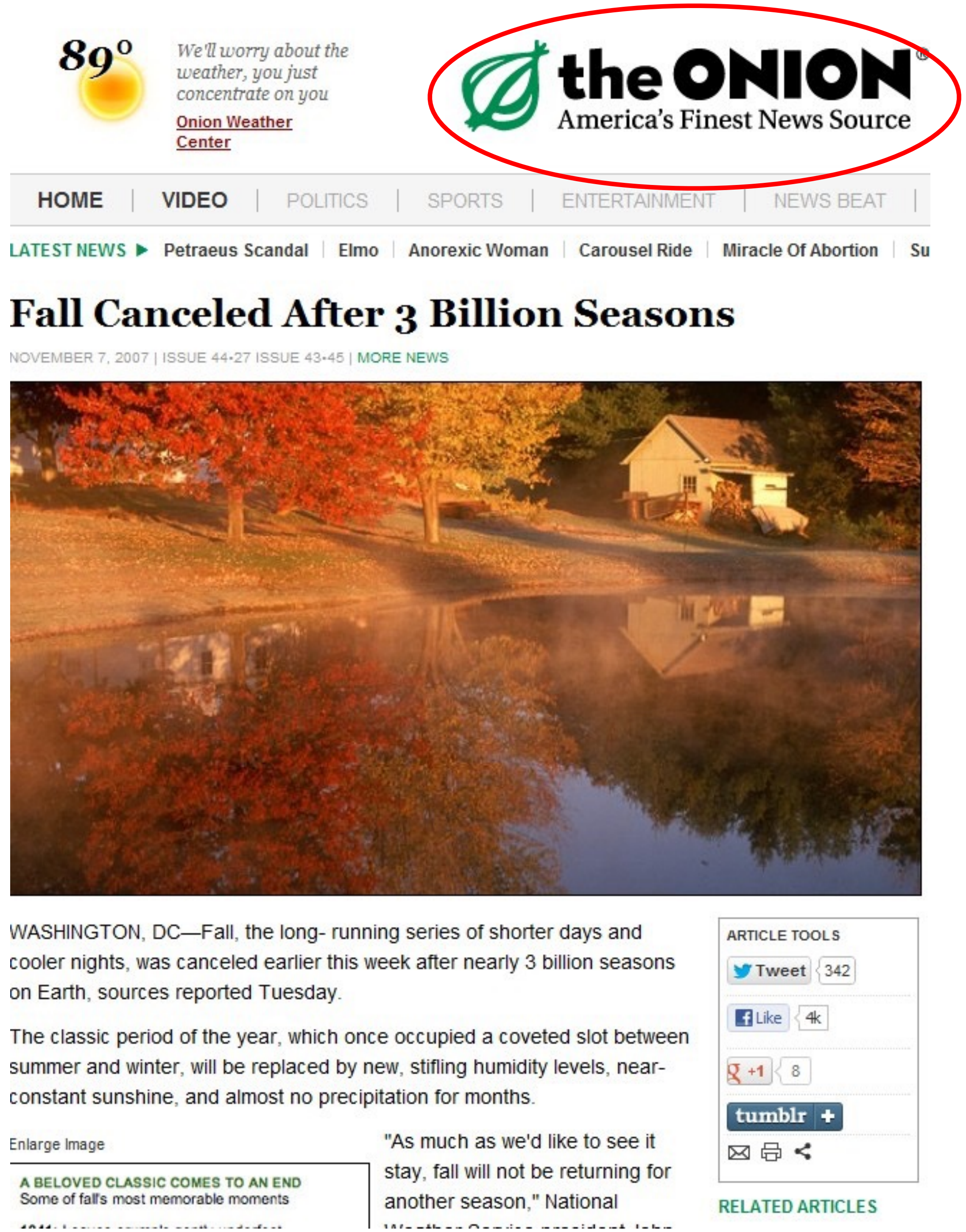
Climate Change Could Delay Fall Foliage Colors [Video]

By Mark Fischetti | October 2, 2012 | 1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Fall Canceled After 3 Billion Seasons

NOVEMBER 7, 2007 | ISSUE 44•27 ISSUE 43•45 | MORE NEWS

WASHINGTON, DC—Fall, the long- running series of shorter days and cooler nights, was canceled earlier this week after nearly 3 billion seasons on Earth, sources reported Tuesday.

The classic period of the year, which once occupied a coveted slot between summer and winter, will be replaced by new, stifling humidity levels, near-constant sunshine, and almost no precipitation for months.

Enlarge Image

A BELOVED CLASSIC COMES TO AN END
Some of fall's most memorable moments

"As much as we'd like to see it stay, fall will not be returning for another season," National

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- Aesthetically
- Economically

"fall phenology + climate change"

Phenology Observation

Traditional Observation

Source: USANPN

Small sample size,
time consuming

Digital repeat photography

Yang *et al.* 2014

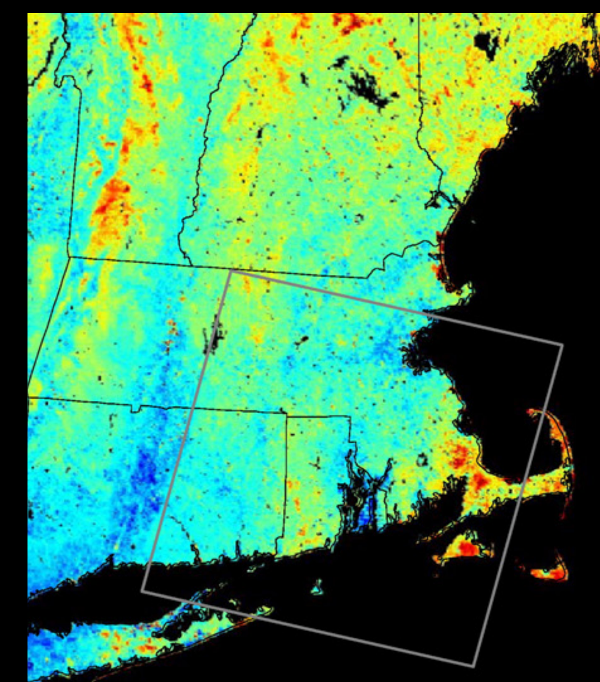
Medium sample size,
automated

Drones

Yang *et al.* in prep

Large sample size,
mostly automated

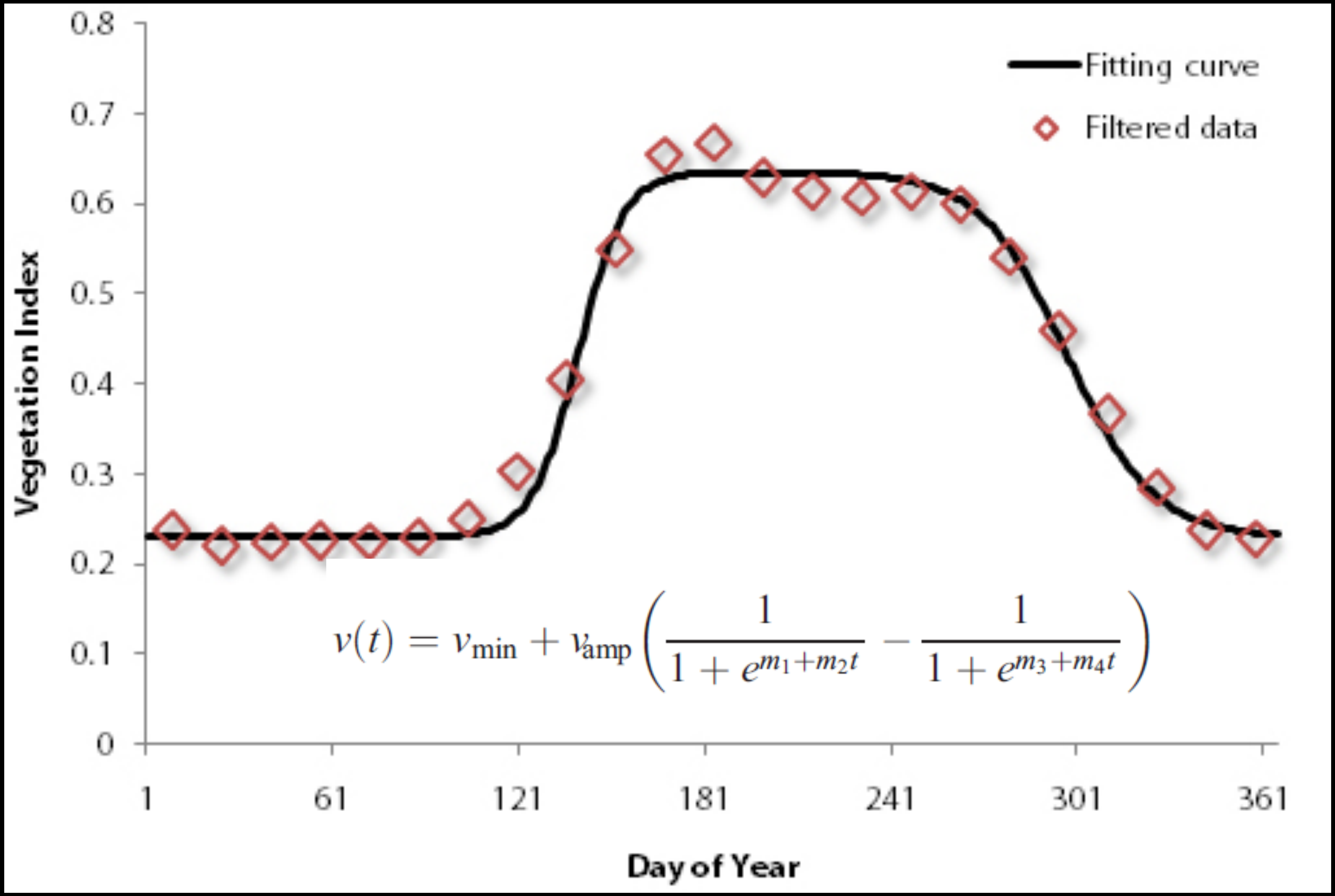
Remote Sensing



Fisher, J. *et al.* 2007; Yang *et al.* 2012

Coarse resolution

The seasonality of EVI



$$v(t) = v_{\min} + v_{\text{amp}}\left(\frac{1}{1+e^{m_1+m_2t}} - \frac{1}{1+e^{m_3+m_4t}}\right)$$

$v(t)$ is the vegetation index at a specific pixel/time;
v_{min} is the minimum vegetation index; v_{amp} is the amplitude.
m_1,m_2,m_3,m_4 are the parameters controlling the shape of the curve.

Phenology of North America

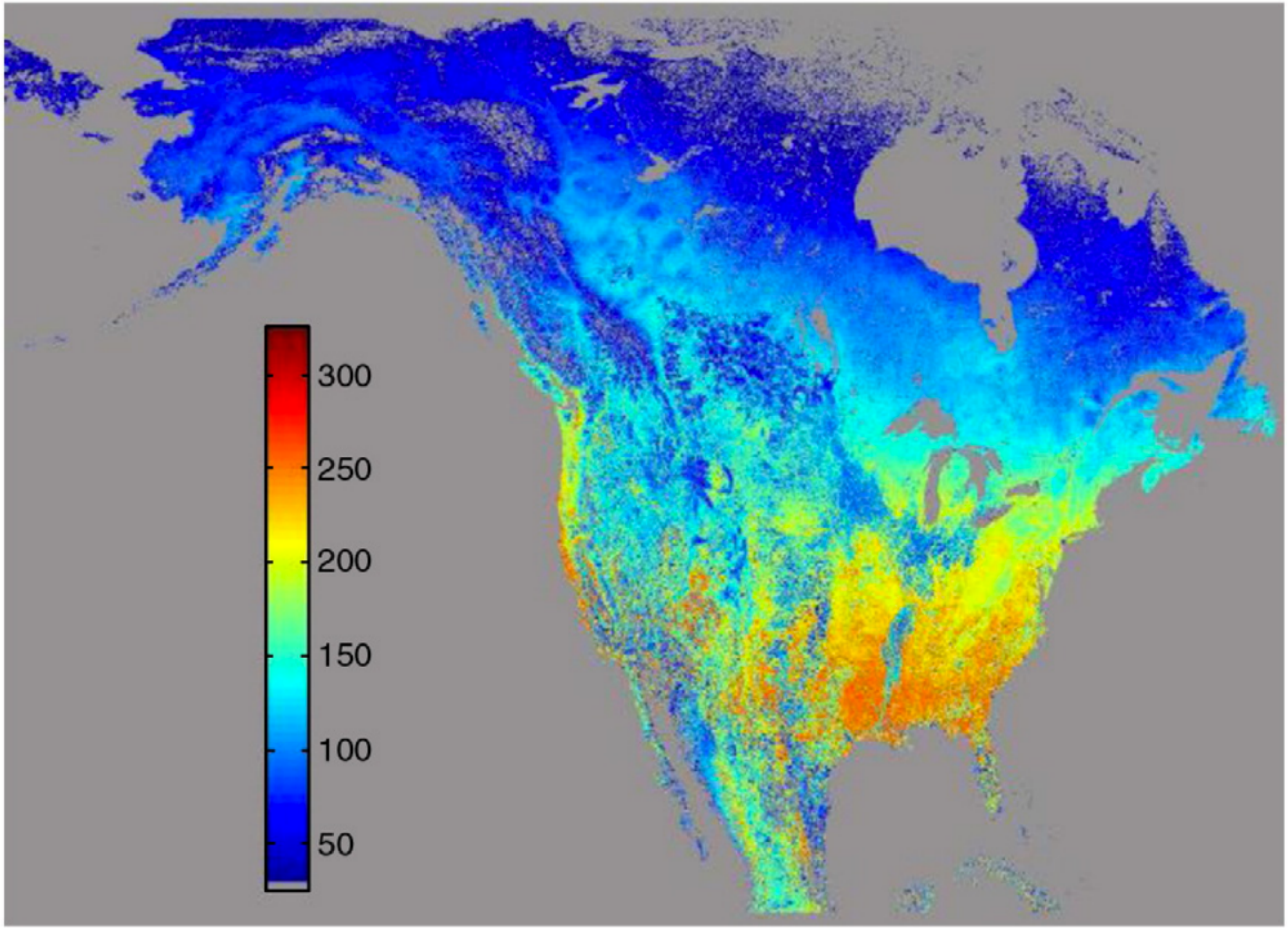


Fig. 1. Mean growing season length in days for North America for the period 2001–2006 derived from the MLCD product.

Change Detection

To use remote sensing, the change must be detectable through the measurement of electromagnetic radiation

- Spectrally: radiance (temperature), others?
- Spatially: generally, grain size of change event >> pixel size

What constitutes a suitable source of data:

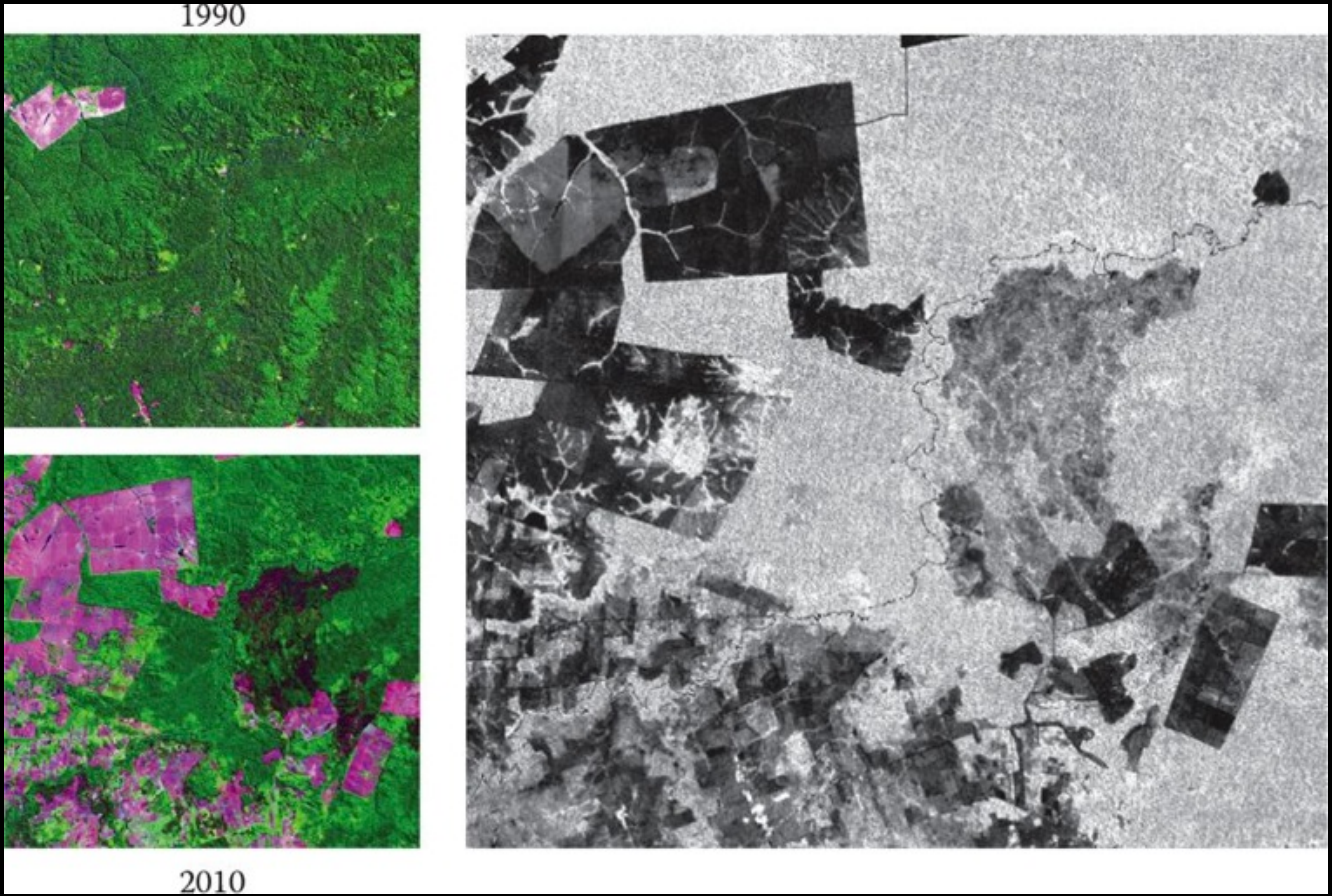
Repeat frequency, spectral range and resolution, IFOV and FOV

What potential “changes” would be interesting and/or important to observe with remote sensing?

Avoid “uninteresting” changes.

- Sun-angle effects: radiometric calibration; or use data from multiple days/ months with different sun-angles.
- Atmospheric effects: radiometric calibration
- Geometric effects: ensure highly accurate registration

Change Detection: Image Differencing



Change Detection: multitemporal color composites