Remote Sensing of Vegetation

Part I – theory

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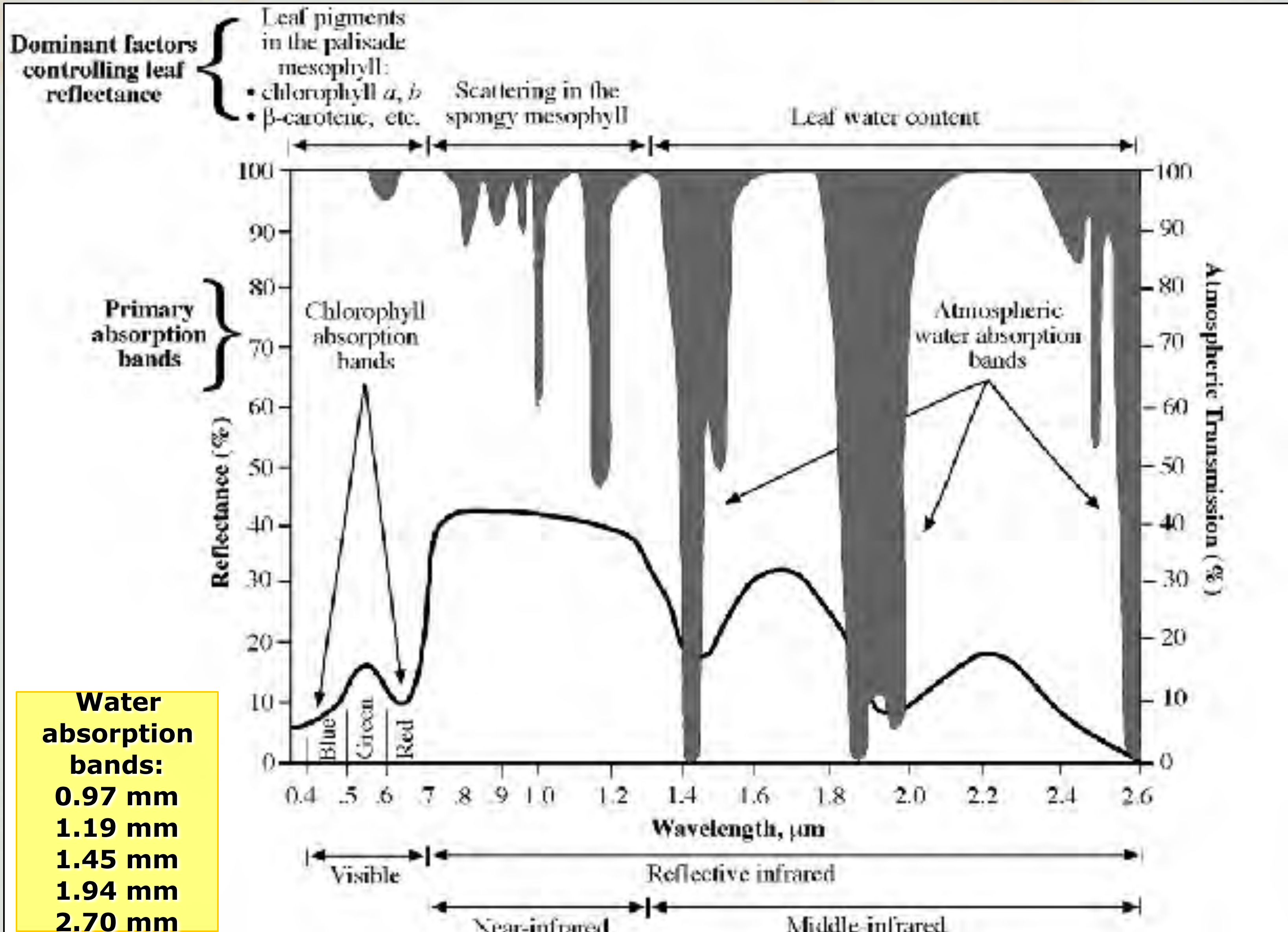
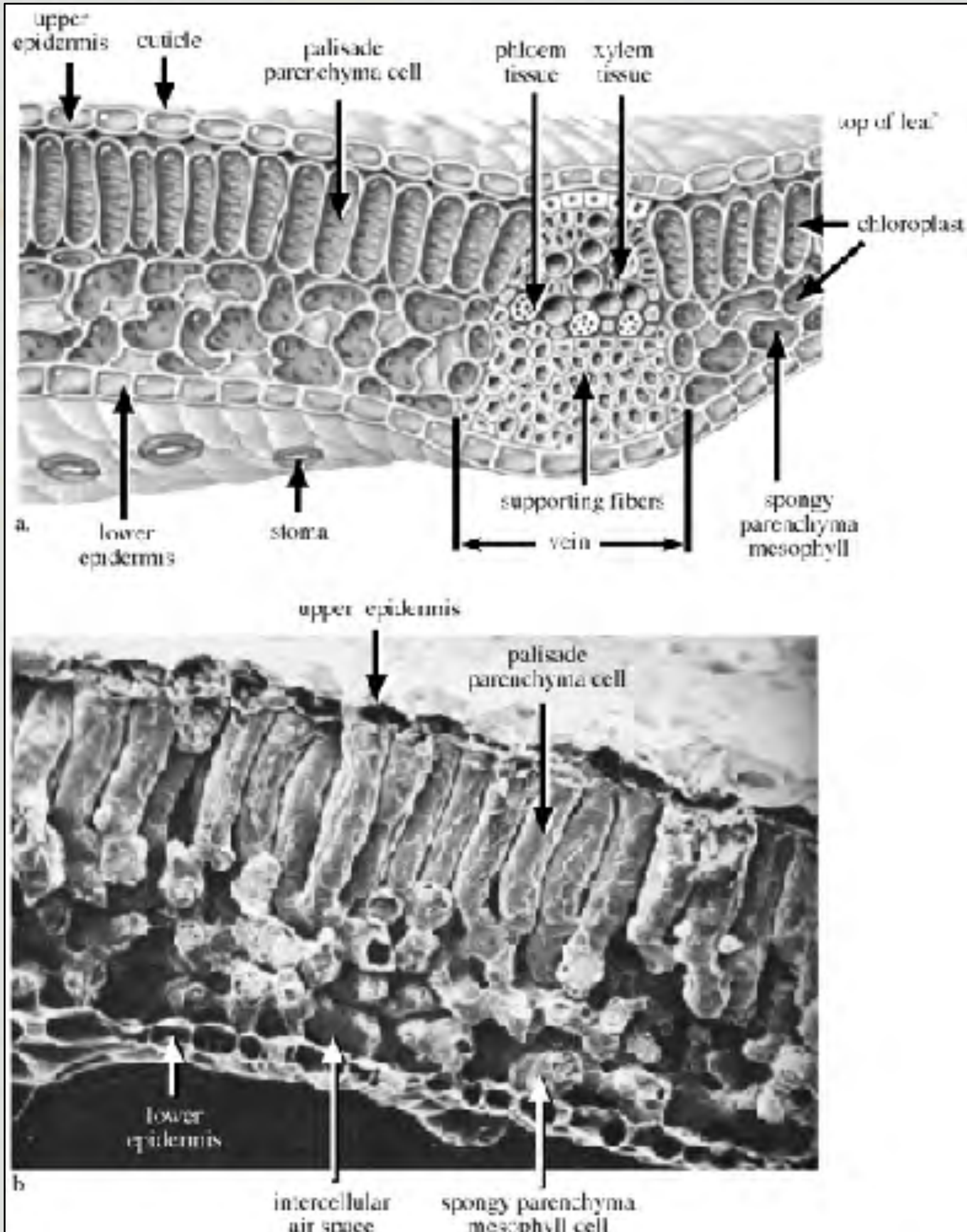
Remote Sensing of Vegetation

Spectral characteristics of vegetation

Factors controlling Leaf Reflectance

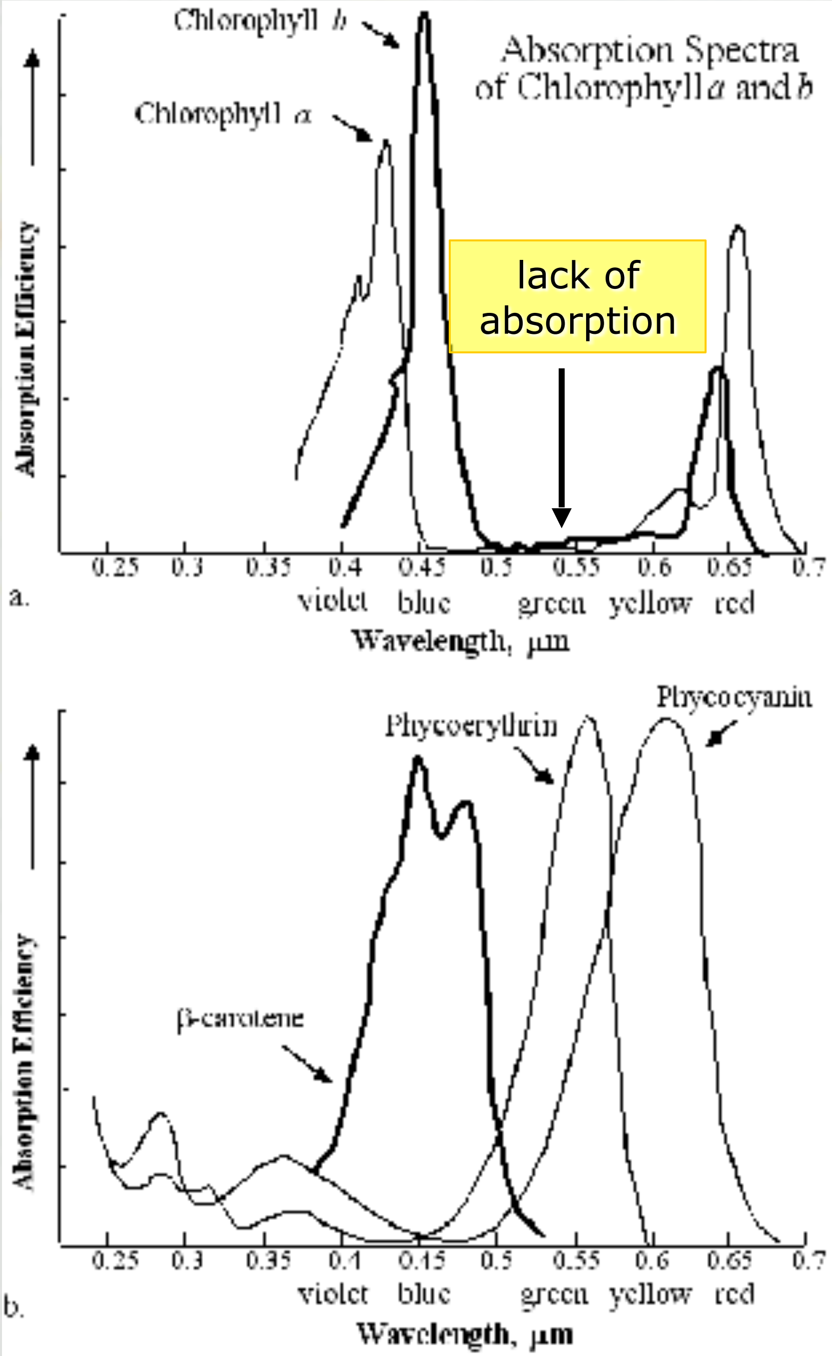


Water absorption bands:
0.97 mm
1.19 mm
1.45 mm
1.94 mm
2.70 mm



Leaf cross-section

Cross-section through a hypothetical and real leaf, revealing the major structural components that determine the spectral reflectance of vegetation



Absorption spectra of chlorophyll

Chlorophyll *a* peak absorption is at 0.43 and 0.66 µm.

Chlorophyll *b* peak absorption is at 0.45 and 0.65 µm.

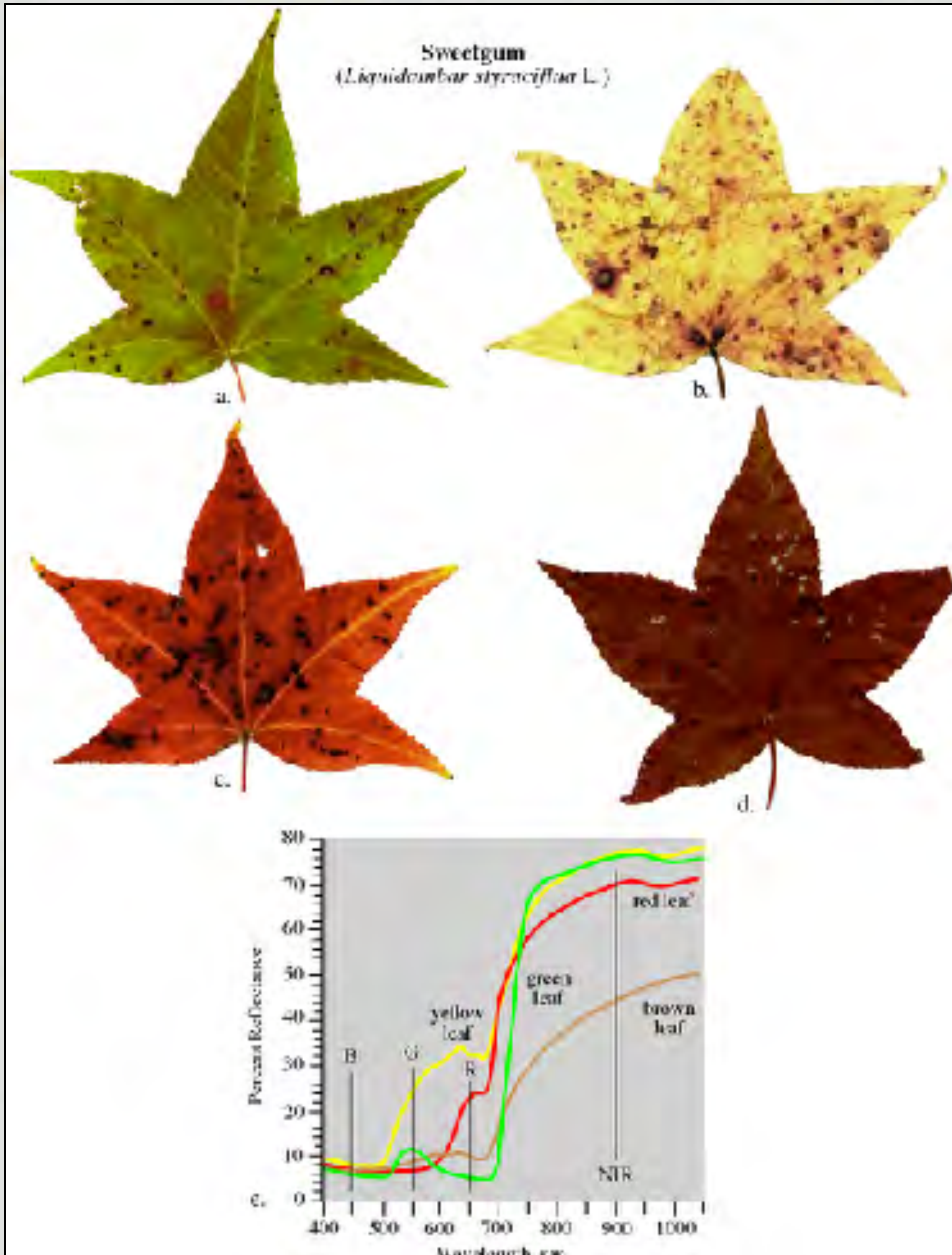
Optimum chlorophyll absorption windows are: 0.45 - 0.52 µm and 0.63 - 0.69 µm

Color composites, Uppsala, Sweden

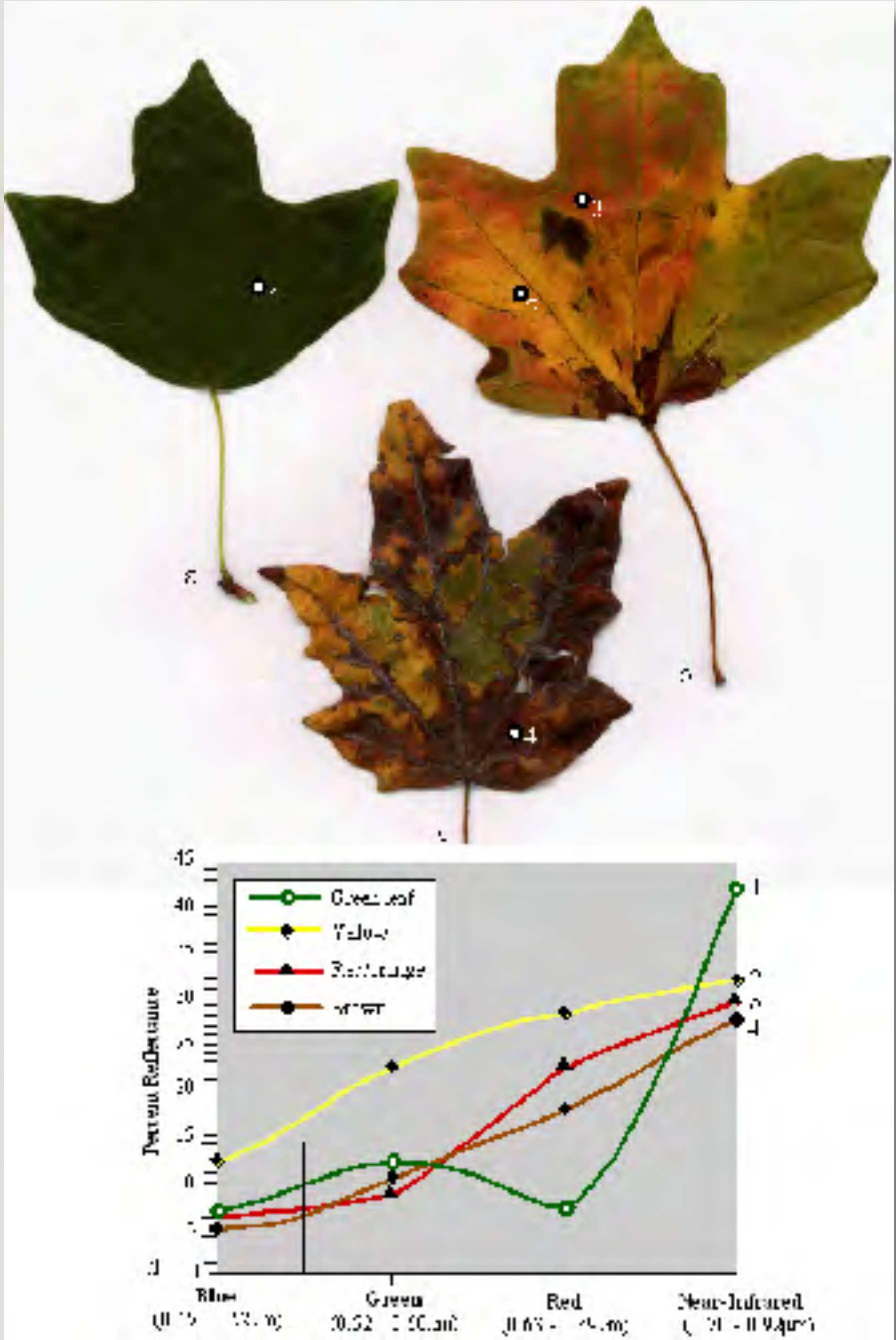
False color composite (NIR,R,G)
Uppsala, Sweden.
Spot5 2002-09-04

False color composite (R,G,B)
Uppsala, Sweden.
Spot5 2002-09-04

Seasonal changes in leaf reflectance



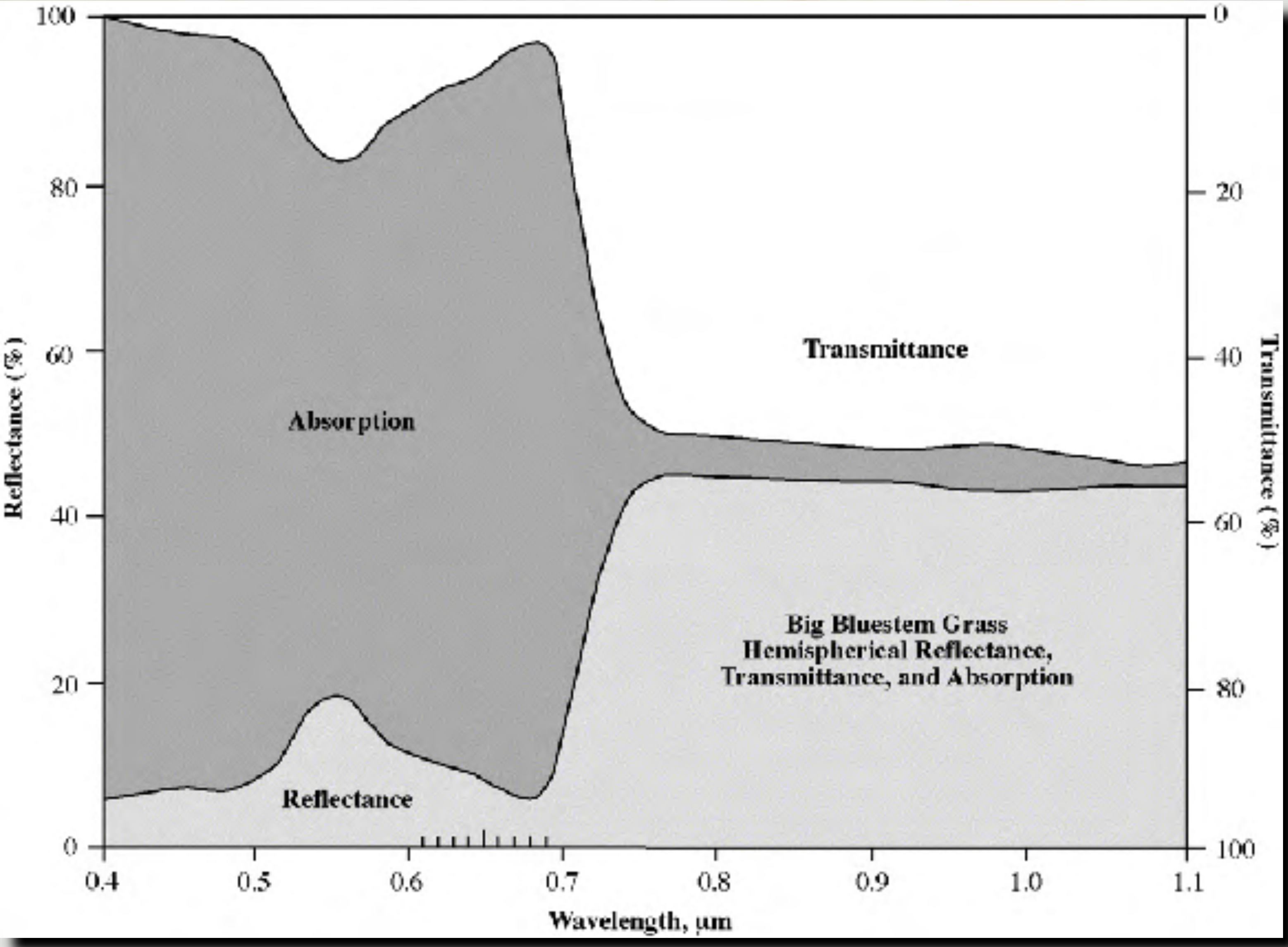
Spectral Reflectance Characteristics of Sweetgum Leaves (*Liquidambar styraciflua* L.)



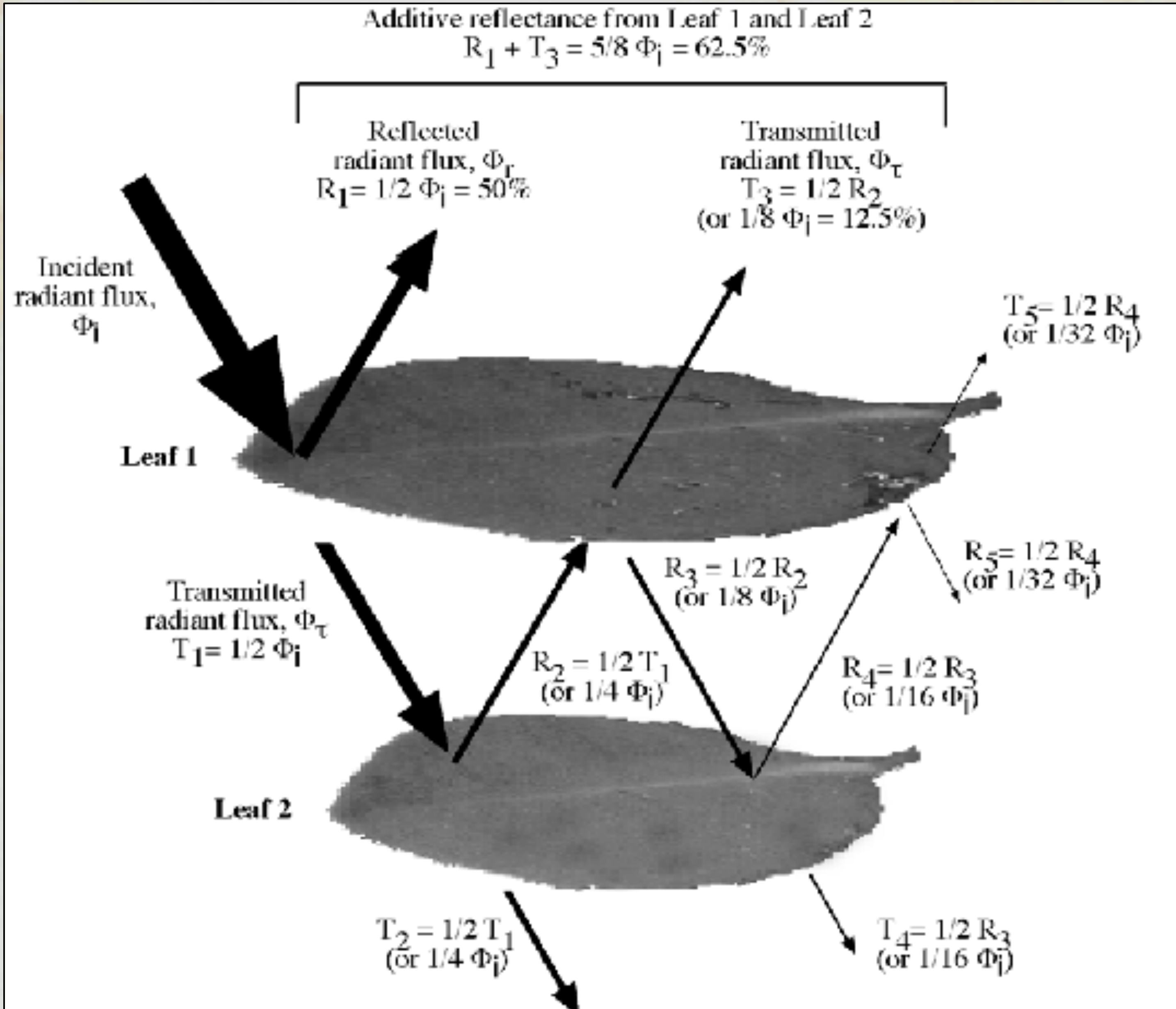
Seasonal changes in leaf reflectance

Spectral Reflectance Characteristics of Selected Areas of Blackjack Oak Leaves

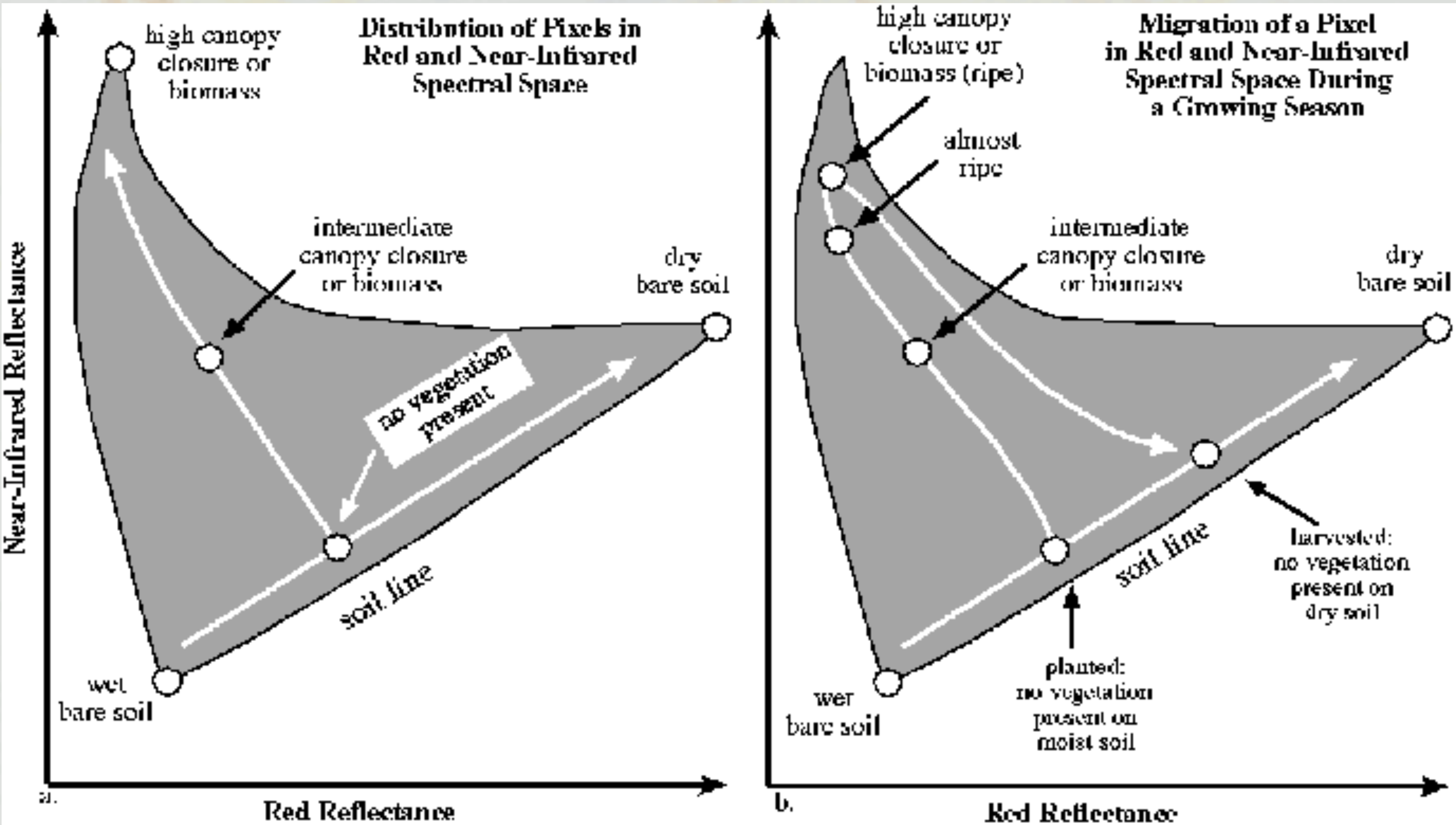
Spectral Characteristics of Big Bluestem Grass



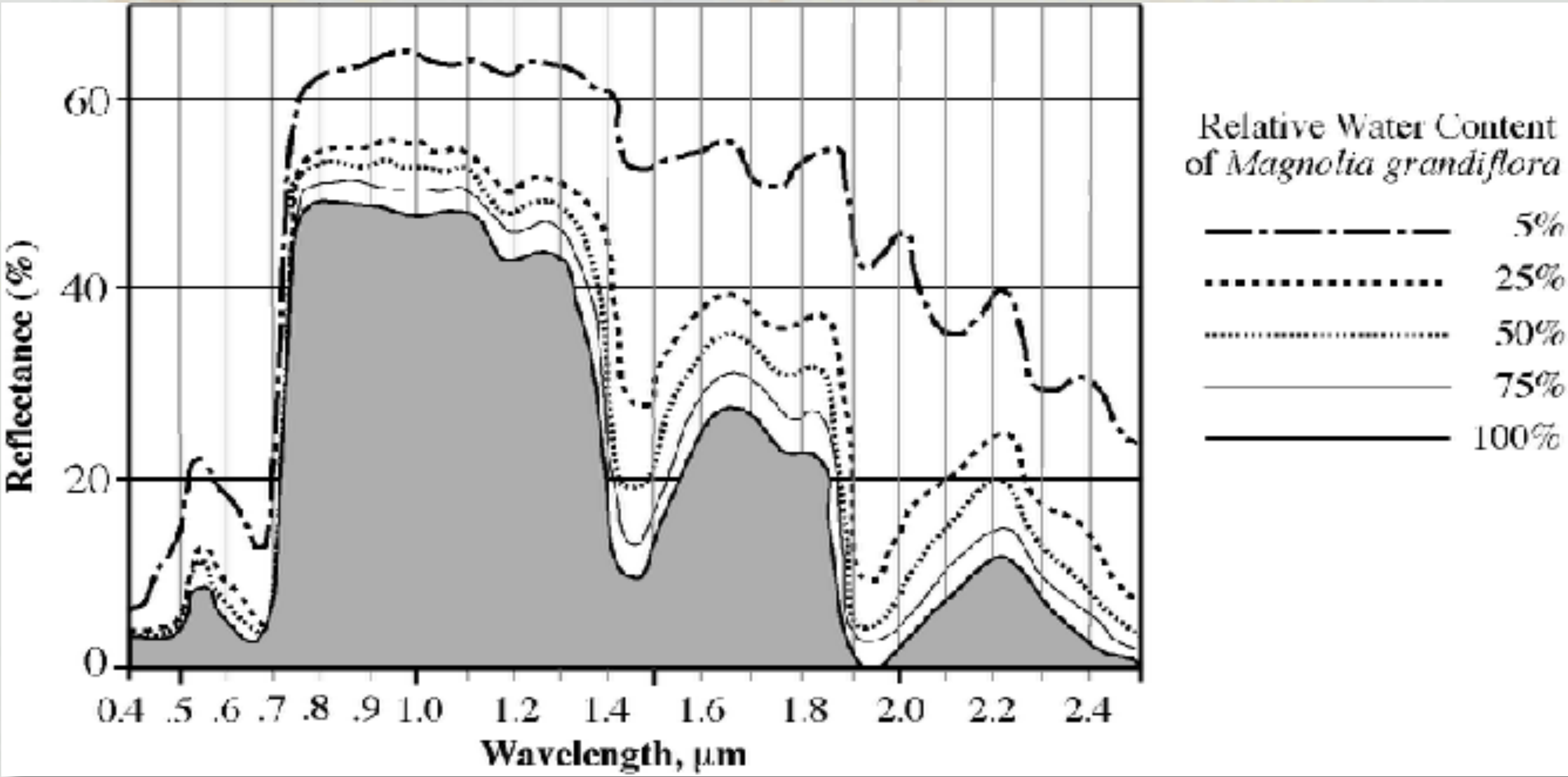
Additive reflectance from canopy with two leaf layers



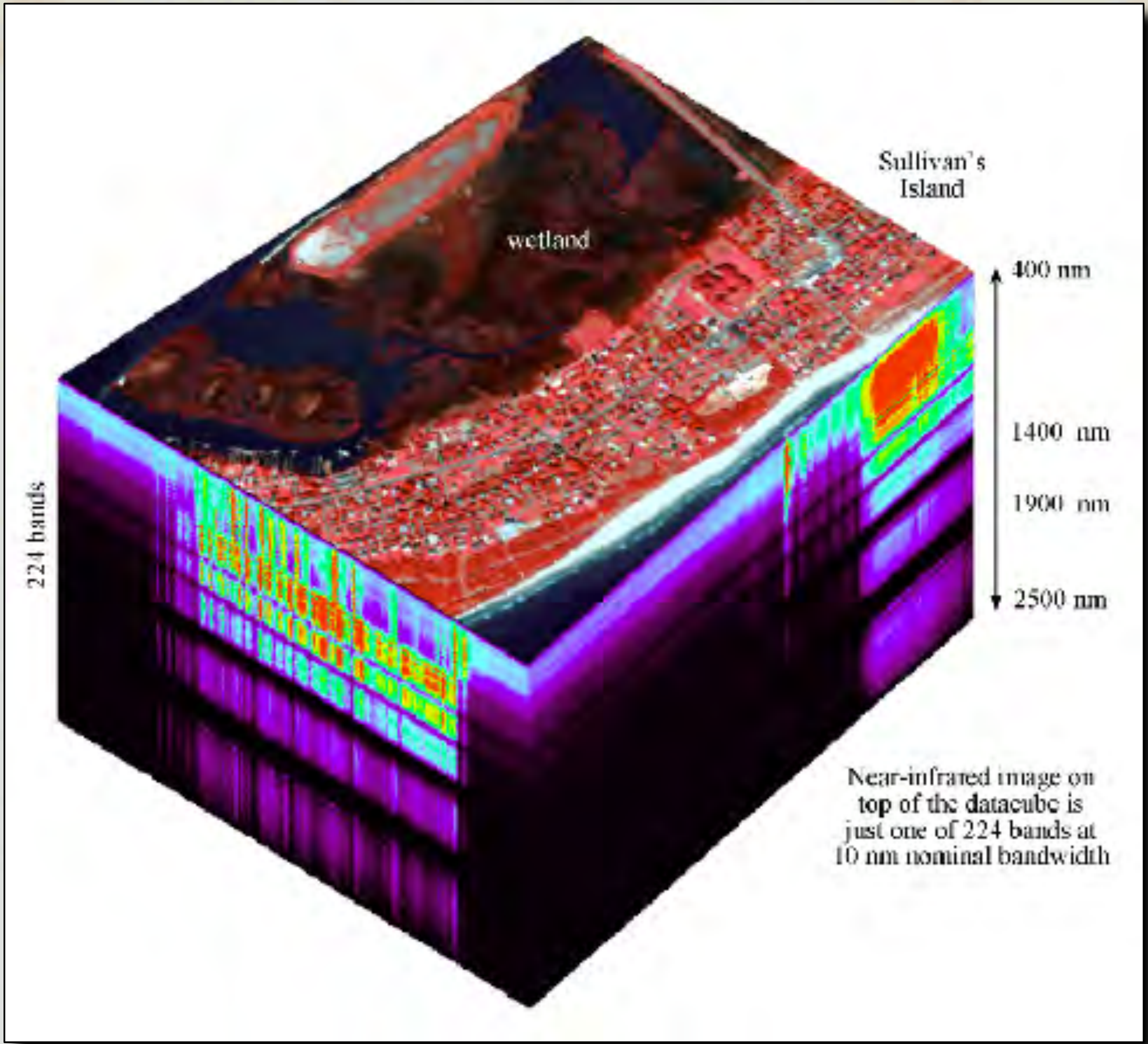
Distribution of Pixels in a Scene in Red and Near-infrared Multispectral Feature Space



Reflectance response of a Magnolia leaf (*Magnolia grandiflora*) to Decreased Relative Water Content

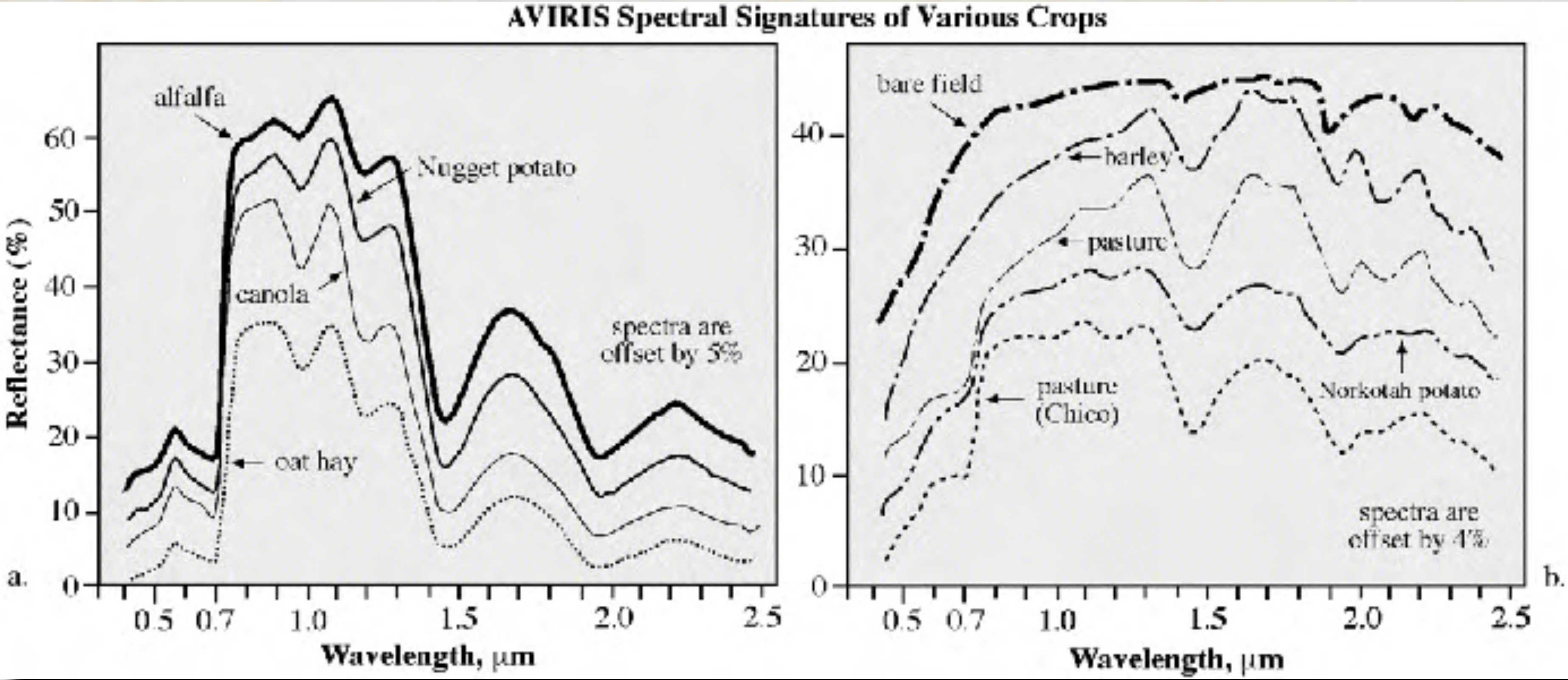


Airborne Visible Infrared Imaging Spectrometer (AVIRIS)



Data cube of Sullivan's Island Obtained on October 26, 1998

Imaging spectrometer data of healthy green vegetation

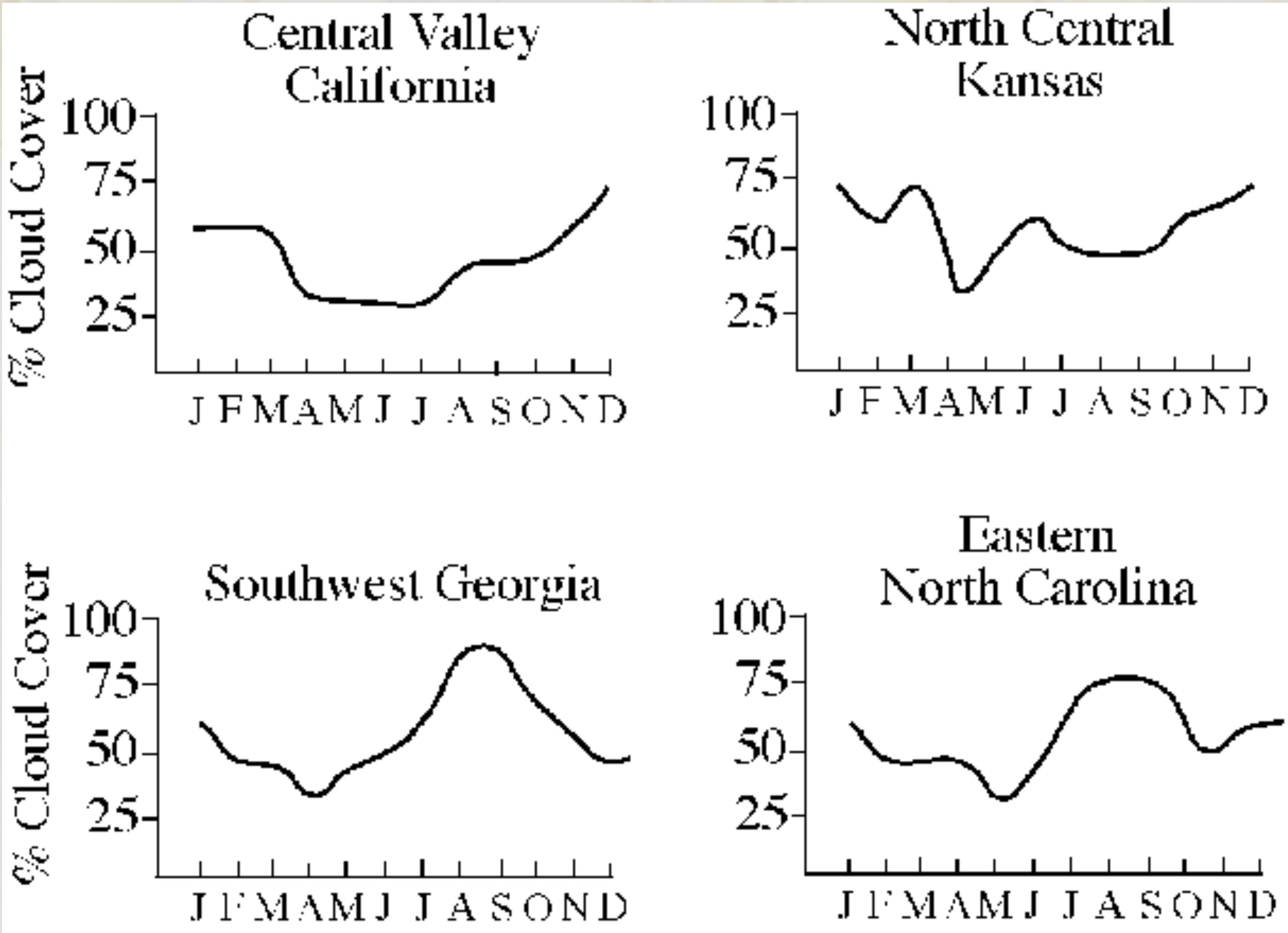


San Luis Valley of Colorado Obtained on September 3, 1993 Using AVIRIS, 224 channels each 10 nm wide with 20 x 20 m pixels

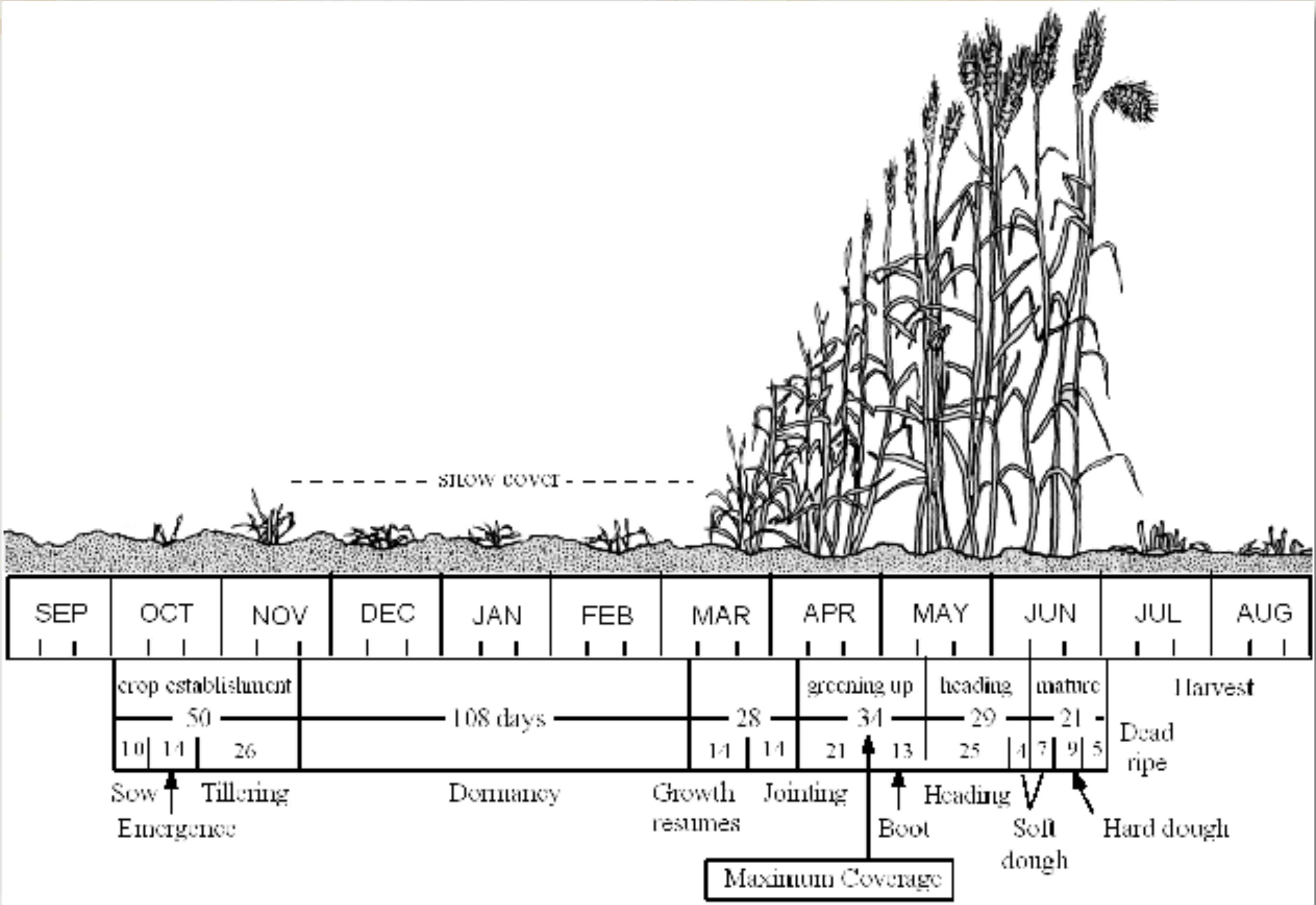
Remote Sensing of Vegetation

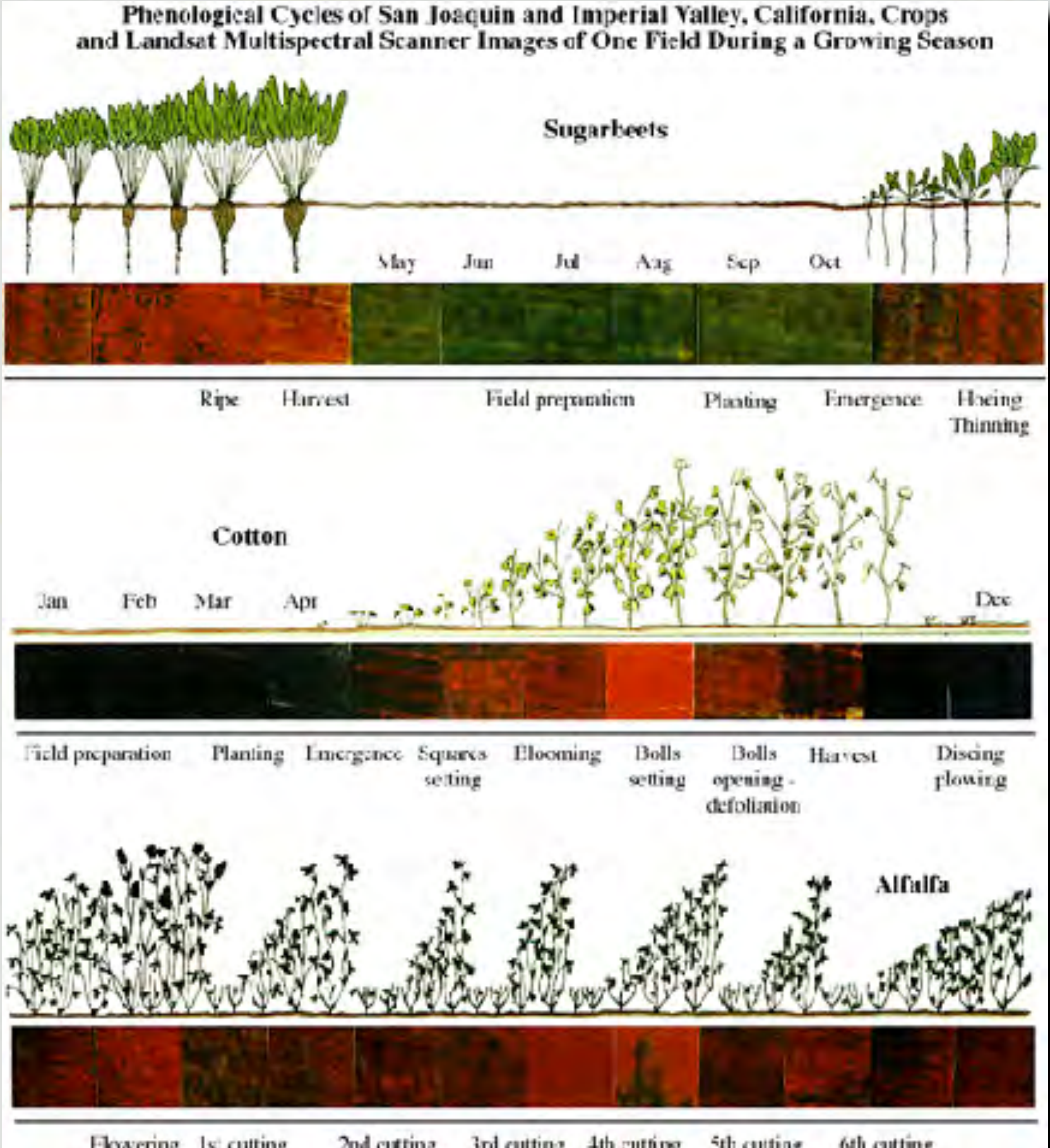
Phenological
(temporal)
characteristics

Cloud Cover in Four Areas in the United States

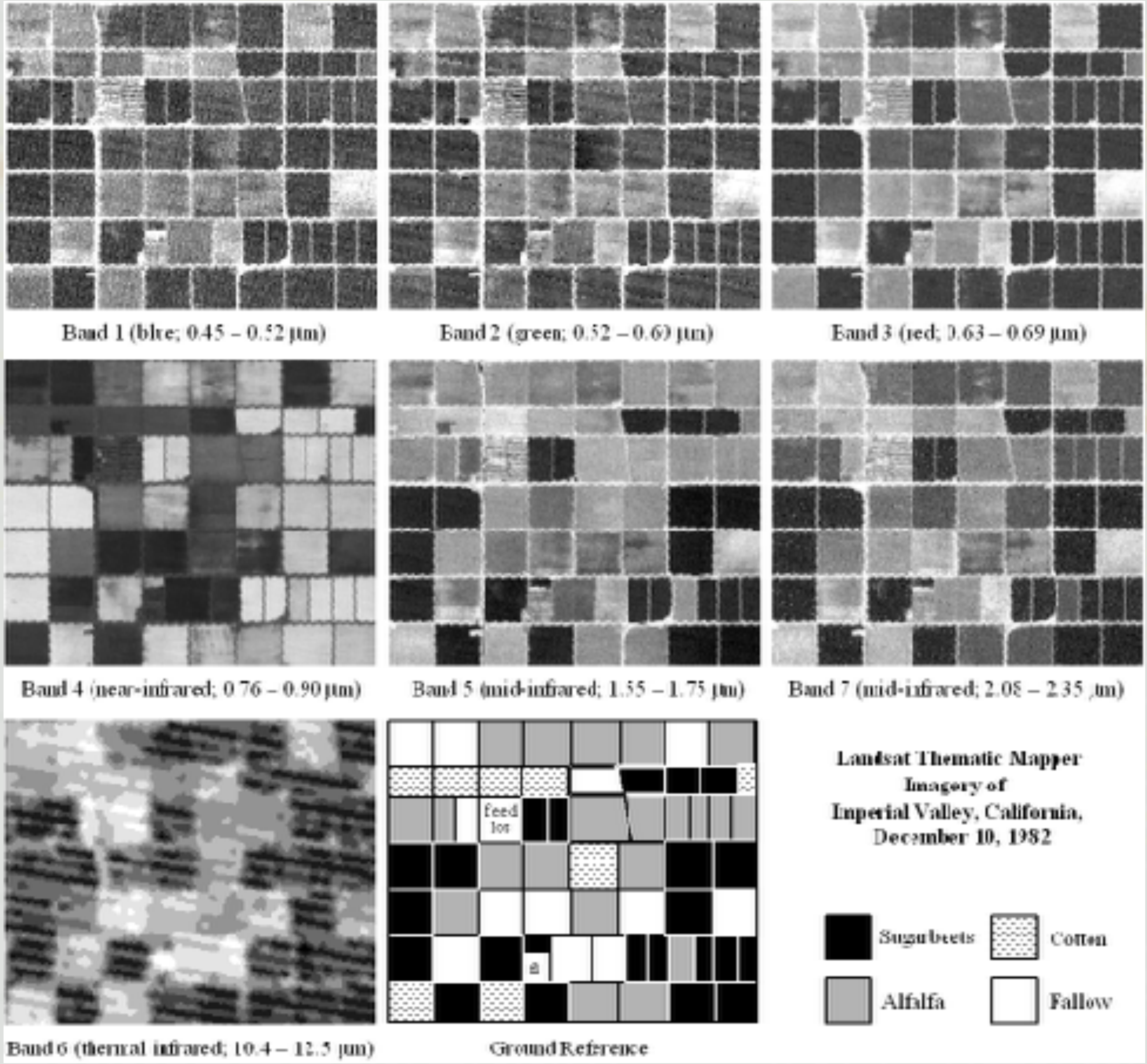


Phenological Cycle of Hard Red Winter Wheat in the Great Plains, USA



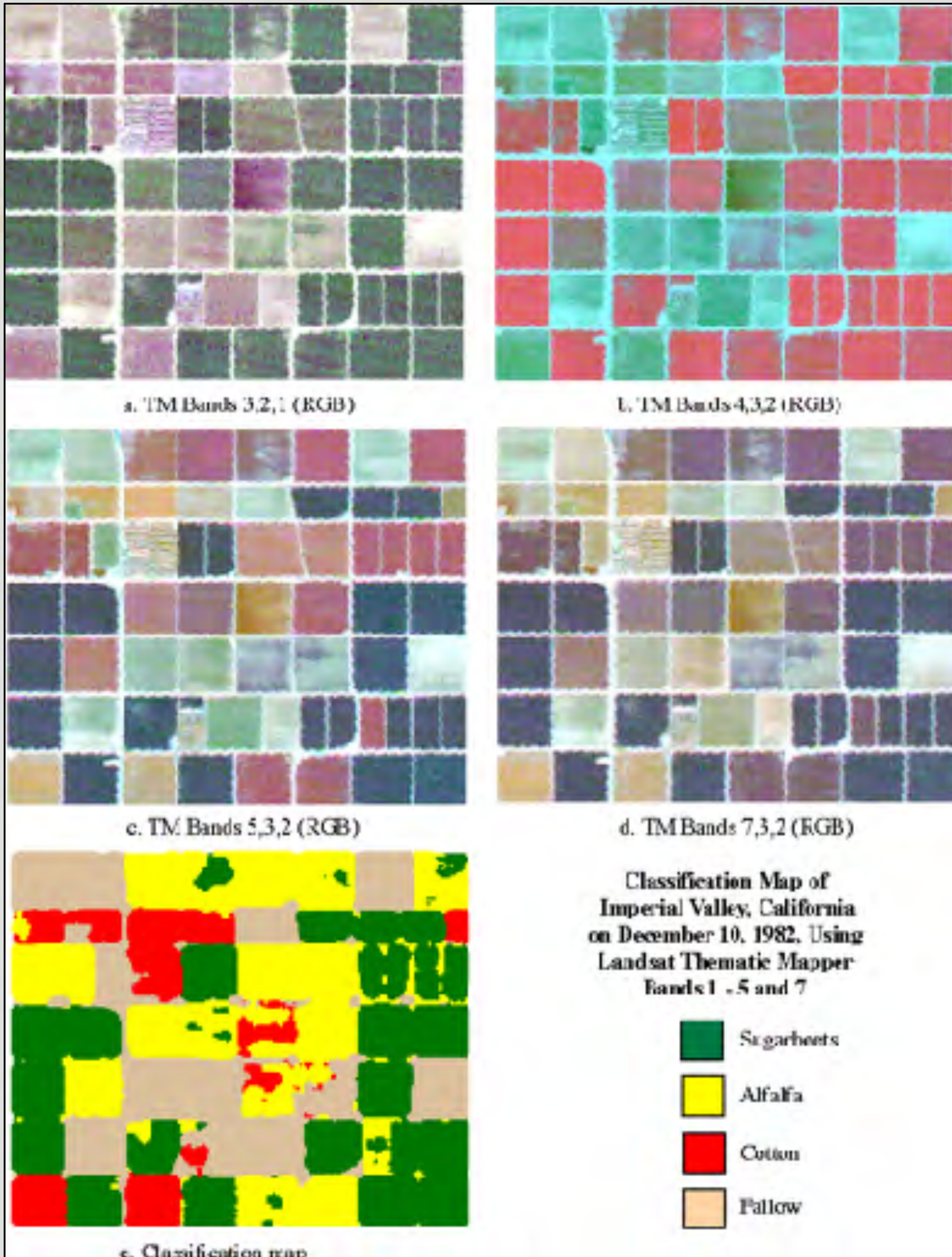


Phenological Cycles of San Joaquin and Imperial Valley, California Crops and Landsat Multispectral Scanner Images of One Field During A Growing Season

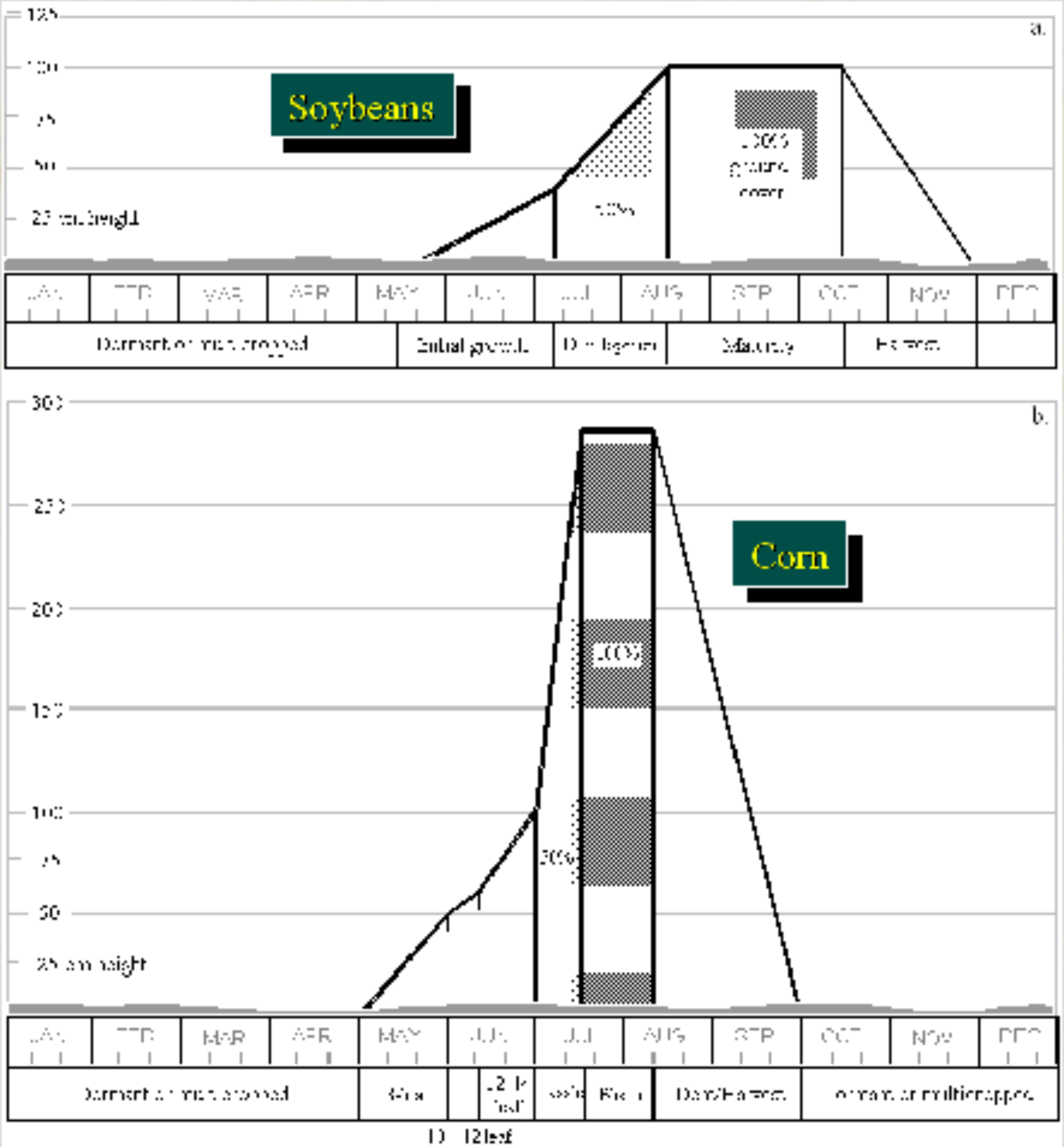


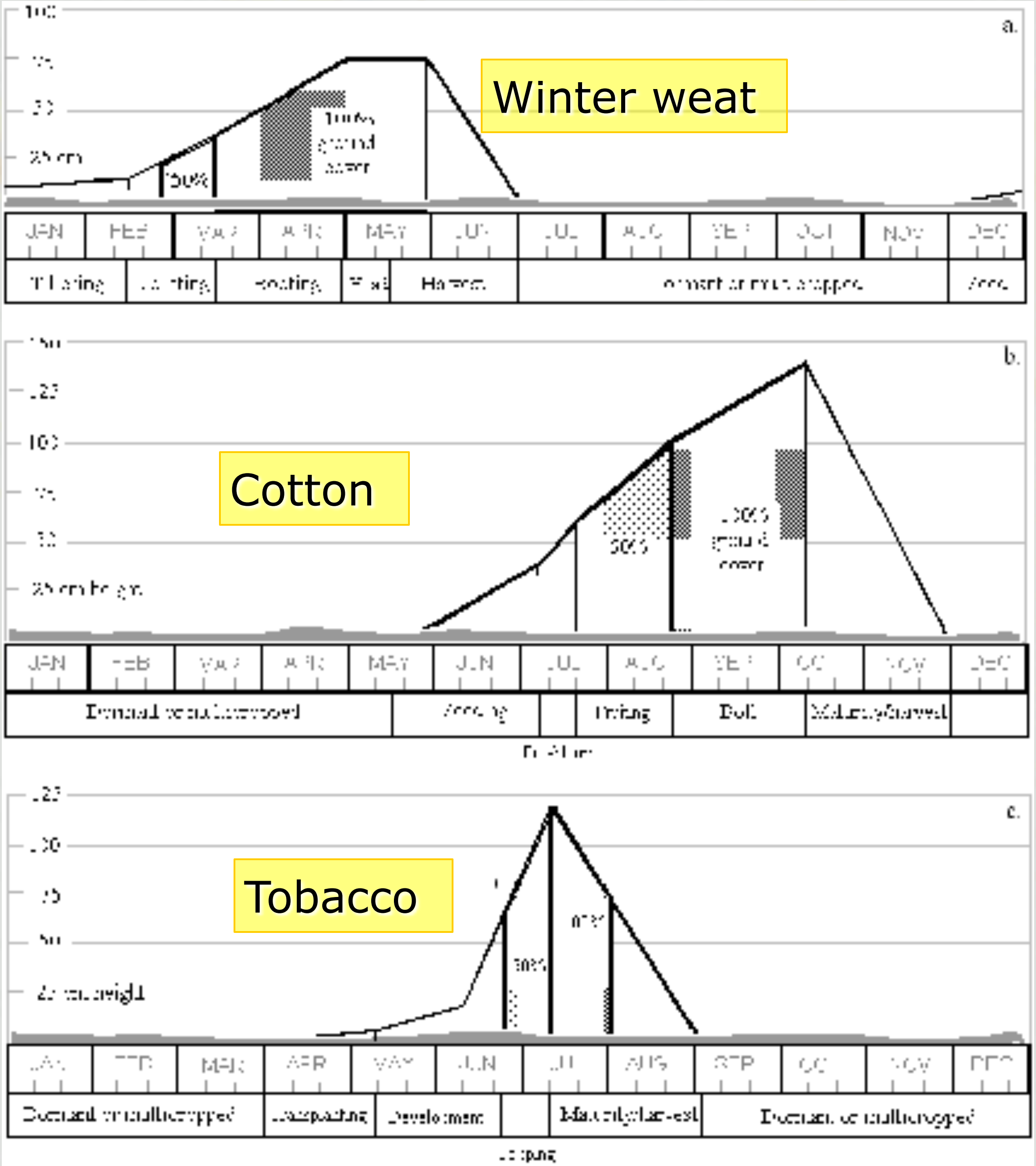
Landsat Thematic Mapper Imagery of the Imperial Valley, California Obtained on December 10, 1982

Landsat Thematic Mapper Color Composites and Classification Map of a Portion of the Imperial Valley, California



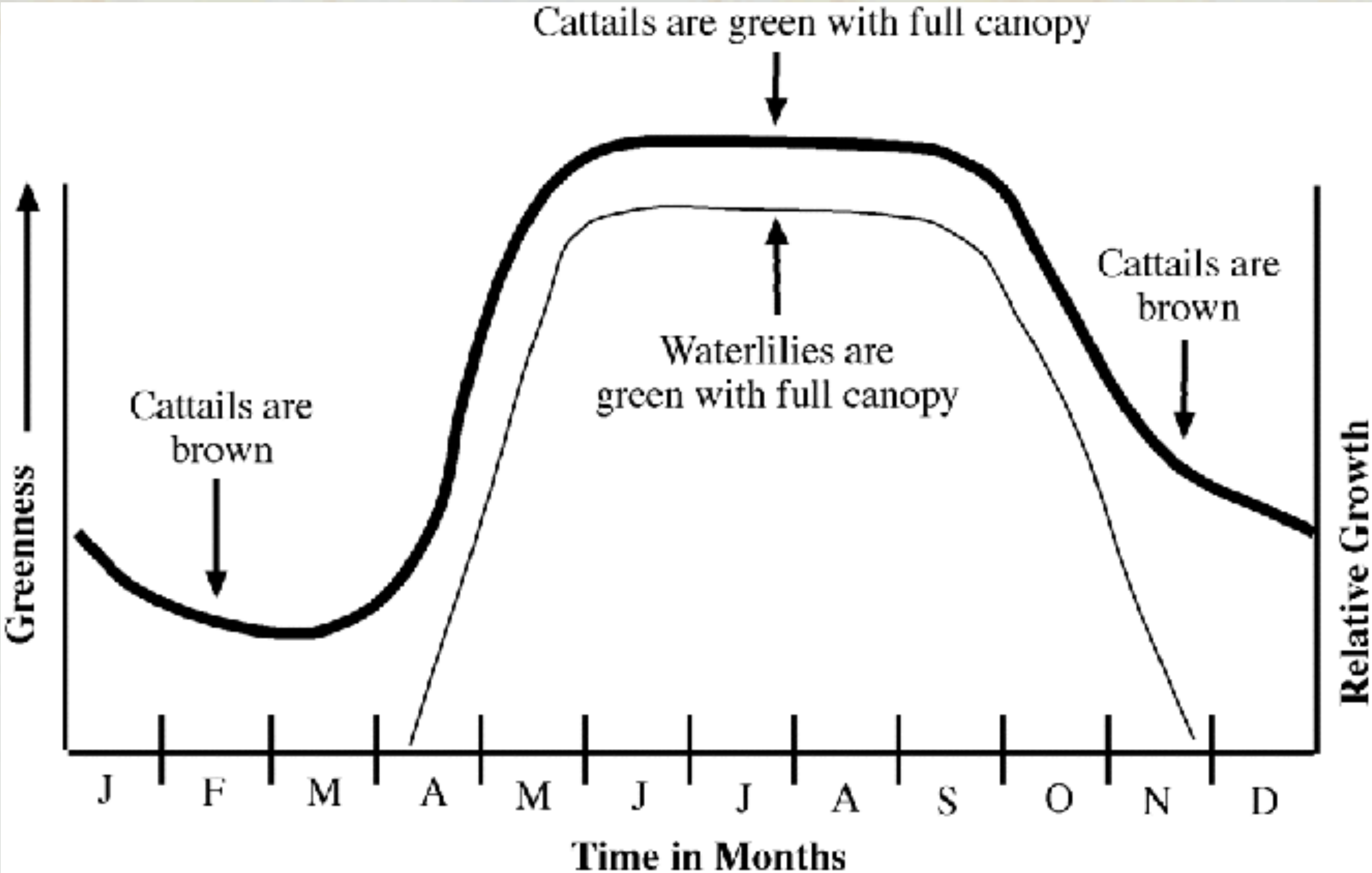
Phenological Cycles of Soybeans and Corn in South Carolina





Phenological Cycles of Winter Wheat, Cotton, and Tobacco in South Carolina

Phenological Cycle of Cattails and Waterlilies in Par Pond, S.C.



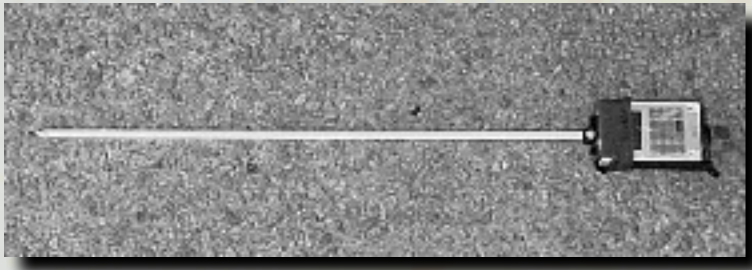
Remote Sensing of Vegetation

Ground based measurements (Ground truthing)

Goniometer, bi-directional reflectance measurements

The Sandmeier Field Goniometer; A measurement Tool for Bi-directional reflectance.

In Situ Ceptometer Leaf-Area-Index Measurement



LAI may be computed using a Decagon Accupar Ceptometer™ that consists of a linear array of 80 adjacent 1 cm^2 photosynthetically active radiation (PAR) sensors along a bar.

Incident sunlight above the canopy, Q_a, and the amount of direct solar energy incident to the ceptometer, Q_b, when it was laid at the bottom of the canopy directly on the soil is used to compute LAI.

In Situ Ceptometer Leaf-Area-Index Measurement

Hemispherical photographs

Remote Sensing of Vegetation

Algorithms

Infrared/Red Ratio Vegetation Index

The near-infrared (NIR) to red simple ratio (SR) is the first true vegetation index:

$$SR = \frac{NIR}{red}$$

It takes advantage of the inverse relationship between chlorophyll absorption of red radiant energy and increased reflectance of near-infrared energy for healthy plant canopies.

Normalized Difference Vegetation Index

The generic normalized difference vegetation index (NDVI):

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

has provided a method of estimating net primary production over varying biome types, identifying ecoregions , monitoring phenological patterns of the earth's vegetative surface, and of assessing the length of the growing season and dry-down periods.

Infrared Index

An Infrared Index (II) that incorporates both near and middle-infrared bands is sensitive to changes in plant biomass and water stress.

$$II = \frac{NIR_{TM4} - MIR_{TM5}}{NIR_{TM4} + MIR_{TM5}}$$

Healthy, mono-specific stands of tidal wetland such as *Spartina* often exhibit much lower reflectance in the visible (blue, green, and red) wavelengths than typical terrestrial vegetation due to the saturated tidal flat understory. In effect, the moist soil absorbs almost all energy incident to it.

Moisture Vegetation Index

Moisture Stress Index (MSI):

$$MSI = \frac{MidIR_{TM5}}{NIR_{TM4}}$$

based on the Landsat Thematic Mapper near-ifnrared and middle-infrared bands

Soil Adjusted Vegetation Index

Improved vegetation indices take advantage of calibrated hyperspectral sensor systems such as MODIS. The improved indices incorporate a *soil adjustment factor* and/or a *blue band for atmospheric normalization*. The soil adjusted vegetation index (SAVI) introduces a soil calibration factor, *L*, to the NDVI equation

$$SAVI = \frac{(1 + L)(NIR - red)}{NIR + red + L}$$

An *L* value of 0.5 minimizes soil brightness variations and eliminates the need for additional calibration for different soils.

Soil and Atmospherically Adjusted Vegetation Index

SARVI integrates the *L* function from SAVI and a blue-band normalization to derive a soil and atmospherically resistant vegetation index (SARVI) that corrects for both soil and atmospheric noise:

$$SARVI = \frac{p^*nir - p^*rb}{p^*nir + p^*rb}$$

where

$$p^*rb = p^*red - \gamma(p^*blue - p^*red)$$

The technique requires prior correction for molecular scattering and ozone absorption of the blue, red, and near-infrared remote sensor data, hence the term *p**.

Enhanced Vegetation Index

The MODIS Land Discipline Group proposed the *Enhanced Vegetation Index* (EVI) for use with MODIS Data:

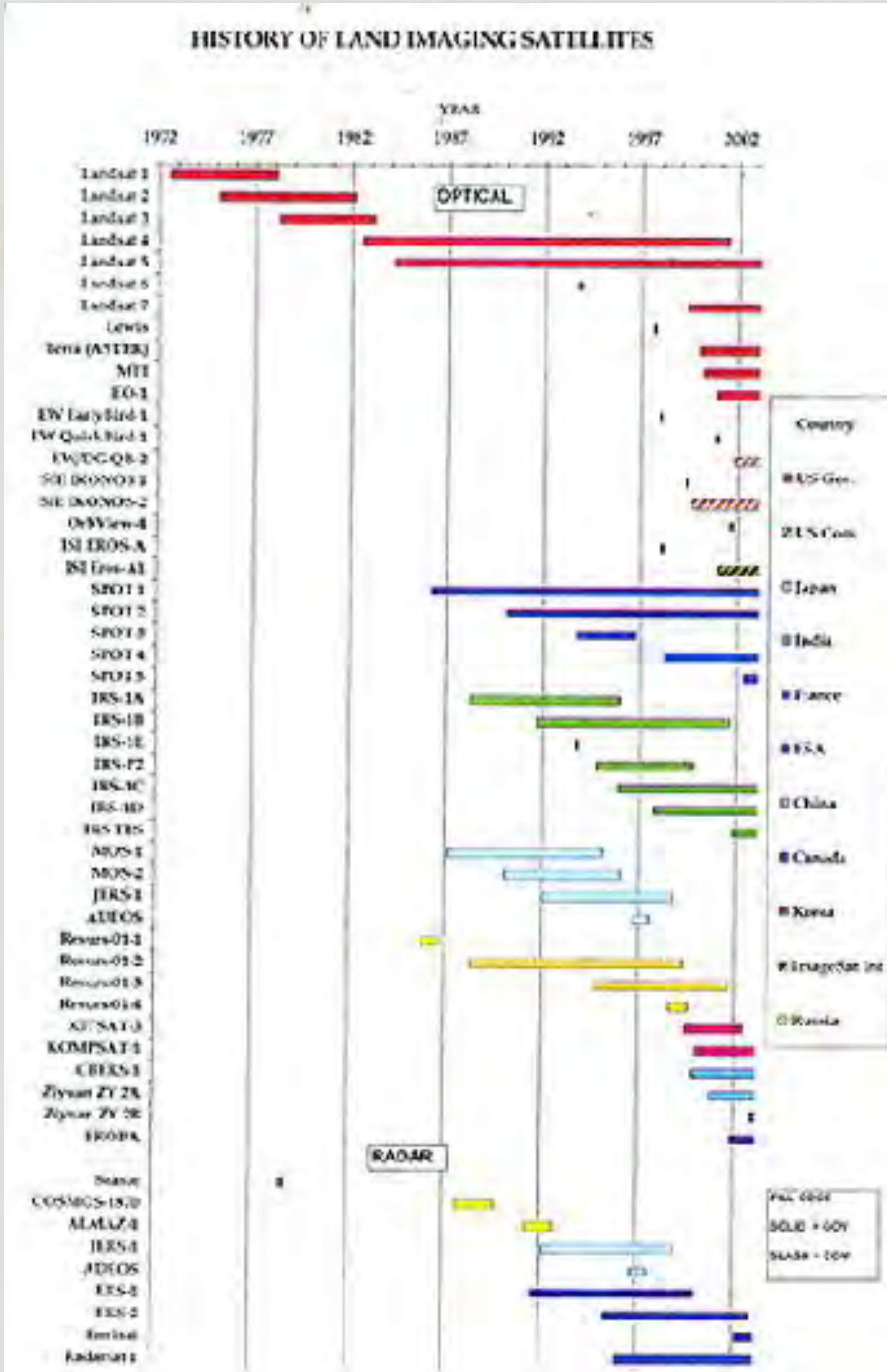
$$EVI = \frac{p * nir - p * red}{p * nir + C_1 p * red - C_2 p * blue + L}$$

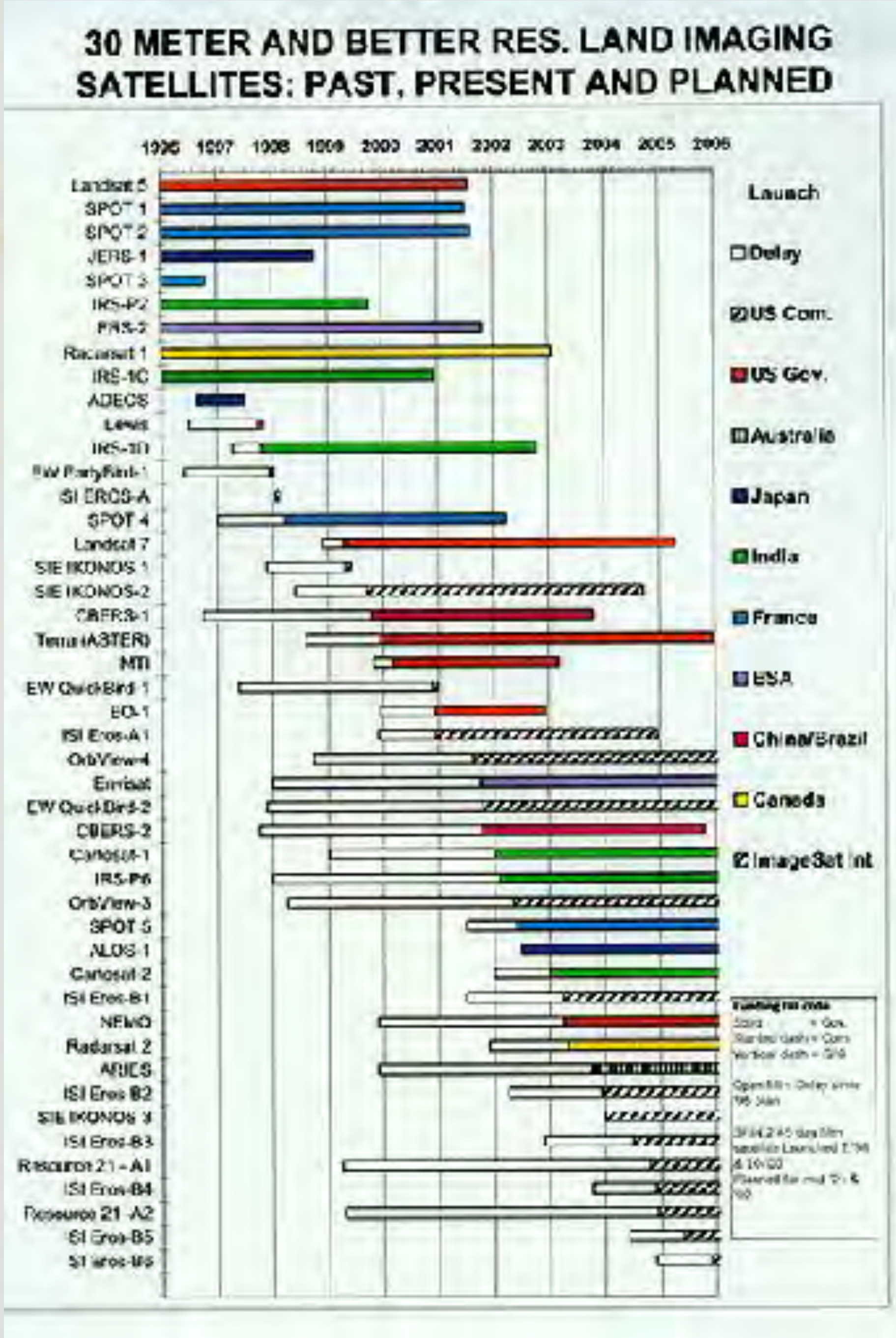
The EVI is a modified NDVI with a soil adjustment factor, L, and two coefficients, C_1 and C_2 which describe the use of the blue band in correction of the red band for atmsoperhic aerosol scattering. The coefficients, C_1 , C_2 , and L, are empirically determined as 6.0, 7.5, and 1.0, respectively. This algorithm has improved sensitivity to high biomass regions and improved vegetation monitoring thorugh a de-coupling of the canopy background signal and a reduction in atmospheric influences.

Remote Sensing of Vegetation

Sensors

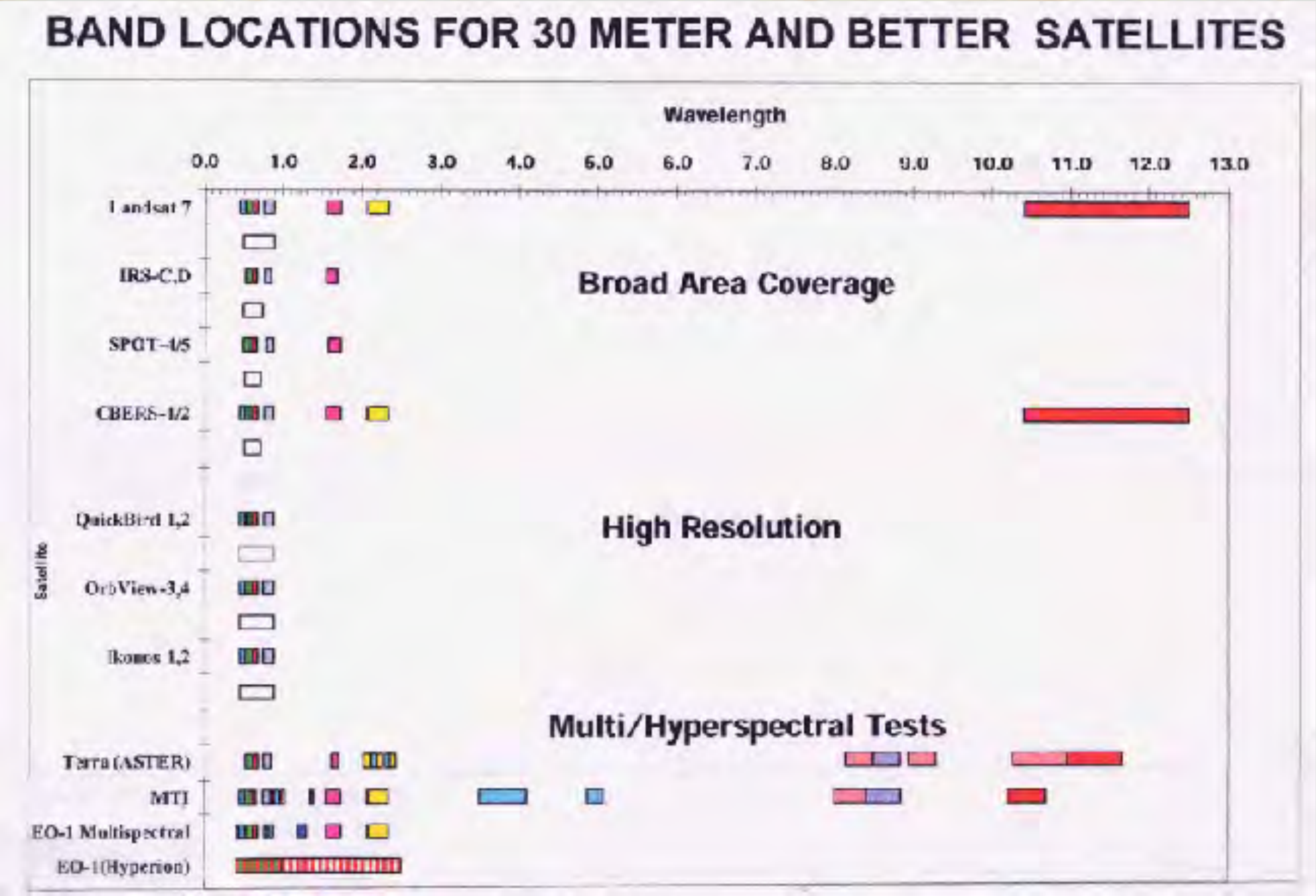
History of land imaging satellites



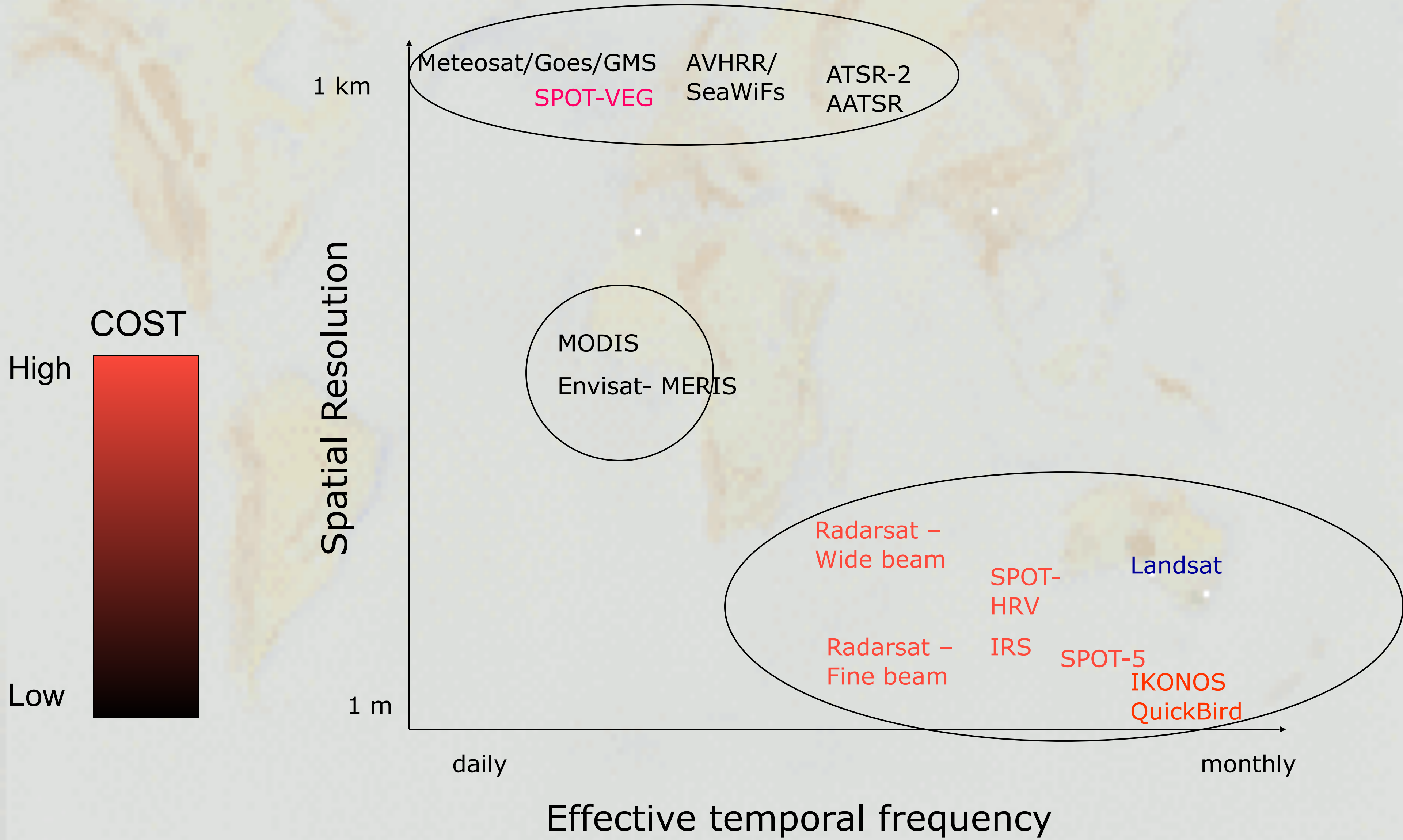


Present and planned imaging satellites

Band locations



Spatial Resolution vs Temporal Resolution



NOAA-AVHRR

Available as time series starting 1981

Daily coverage

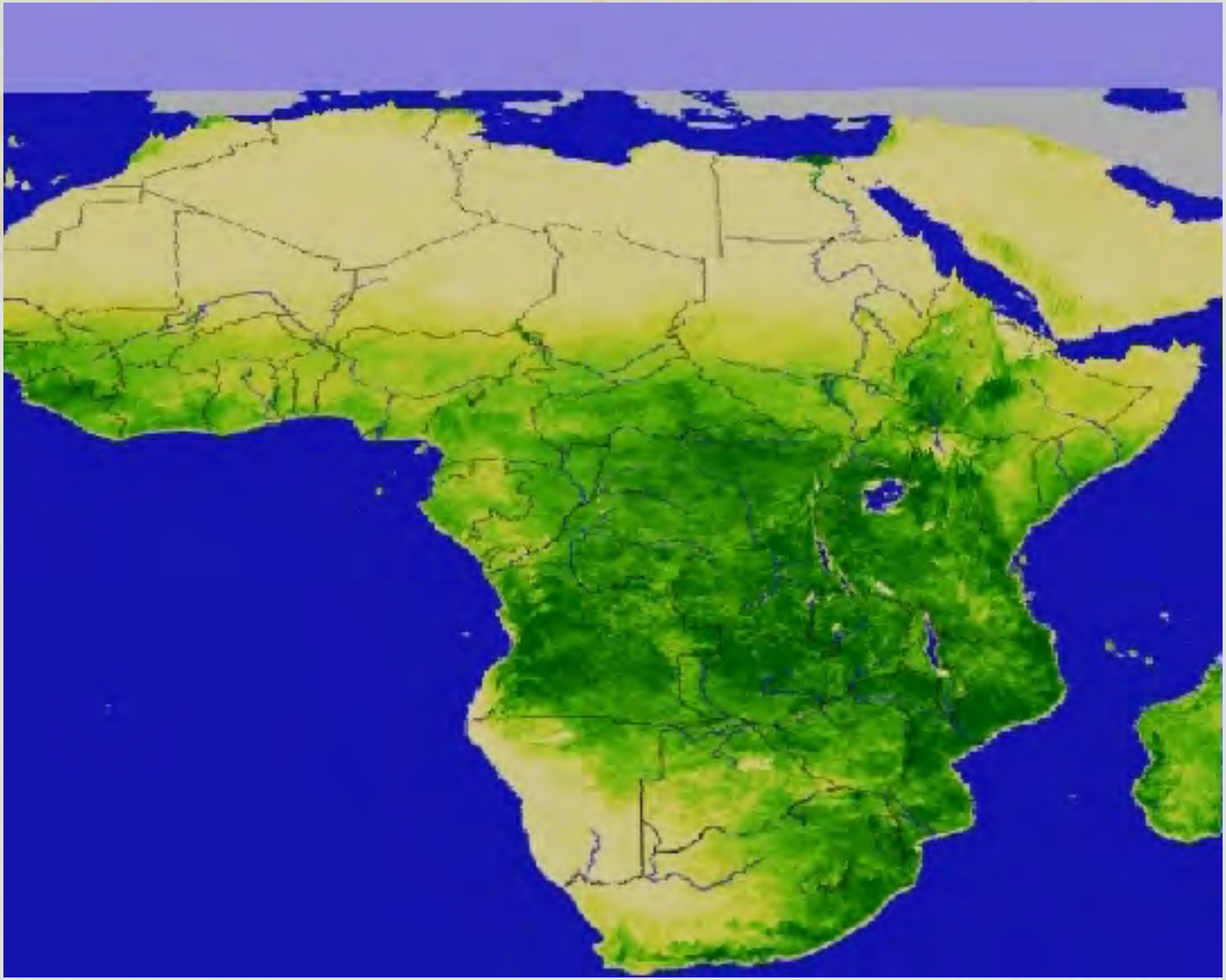
5 bands

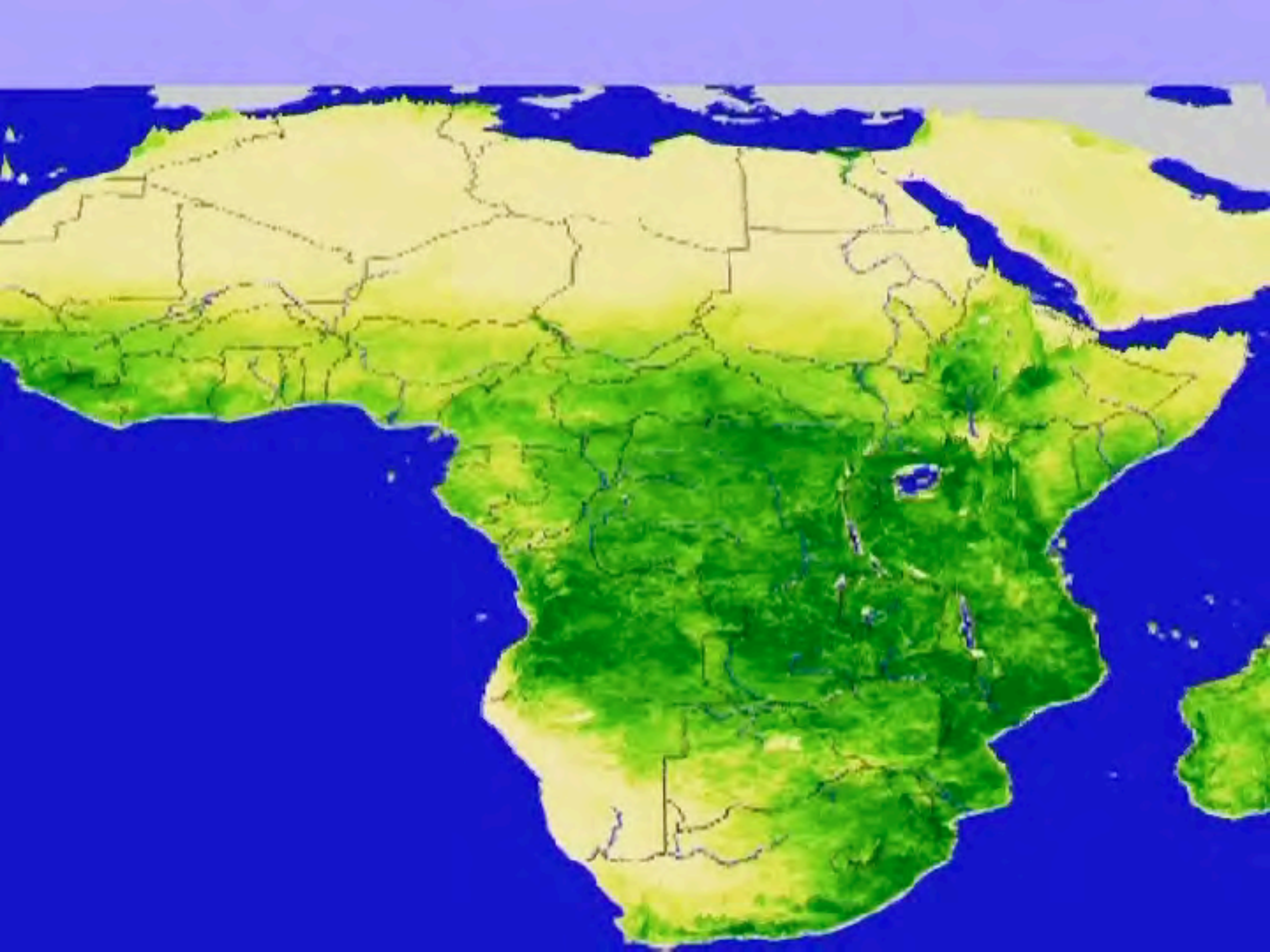
Local Area Coverage (LAC)

Global Area Coverage (GAC)

Dekadal NDVI data from GIMMS

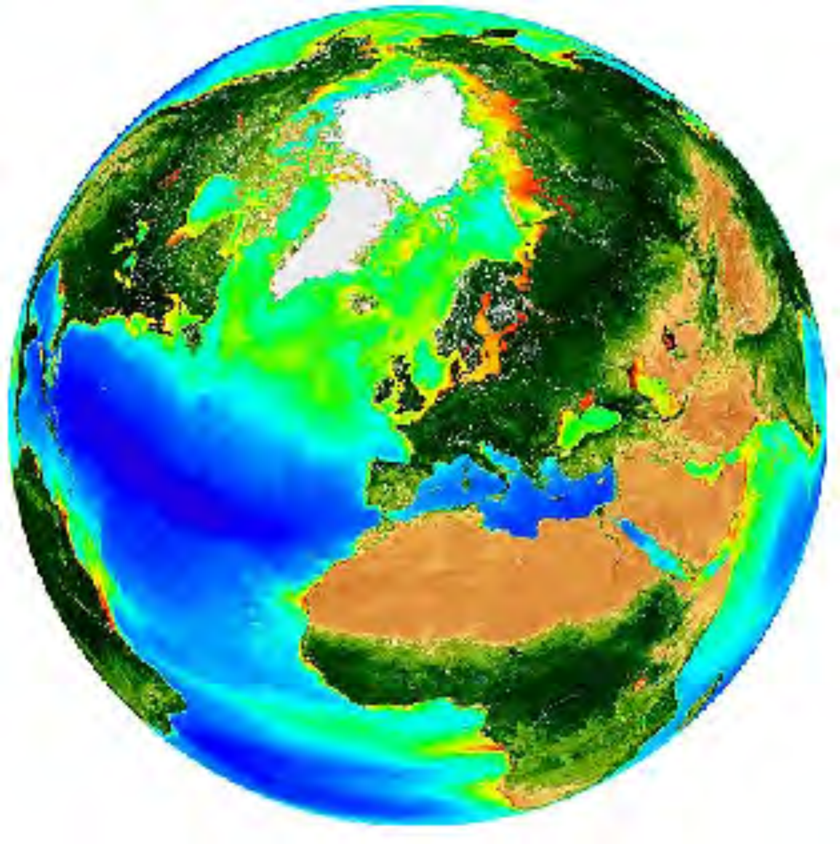
NOAA-AVHRR

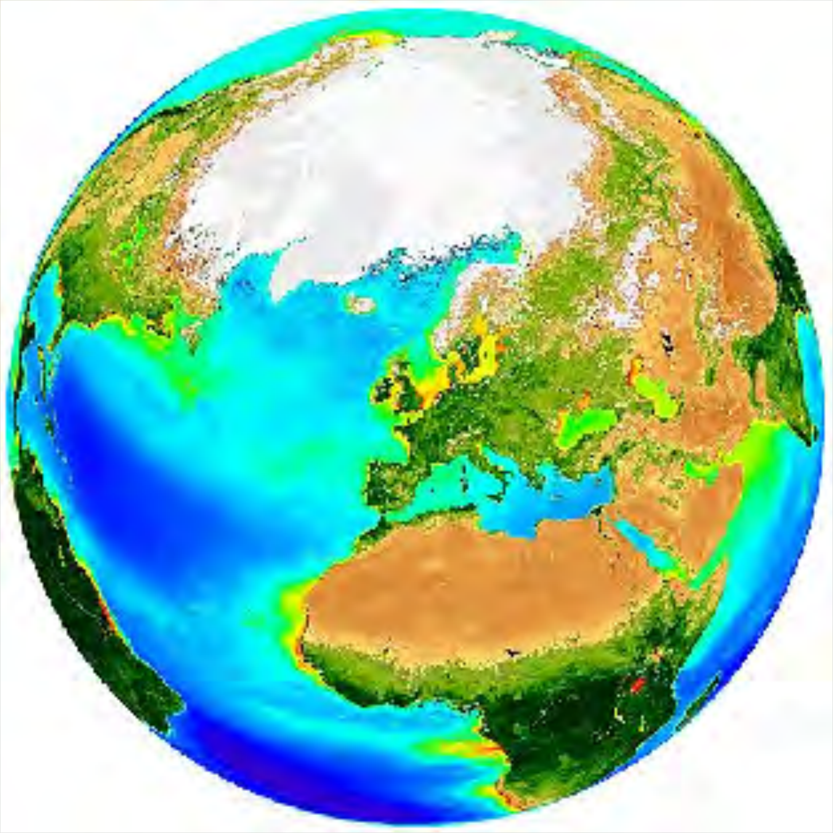




Remote Sensing of Vegetation

SeaWifs





MODIS

Available as time series starting 2000

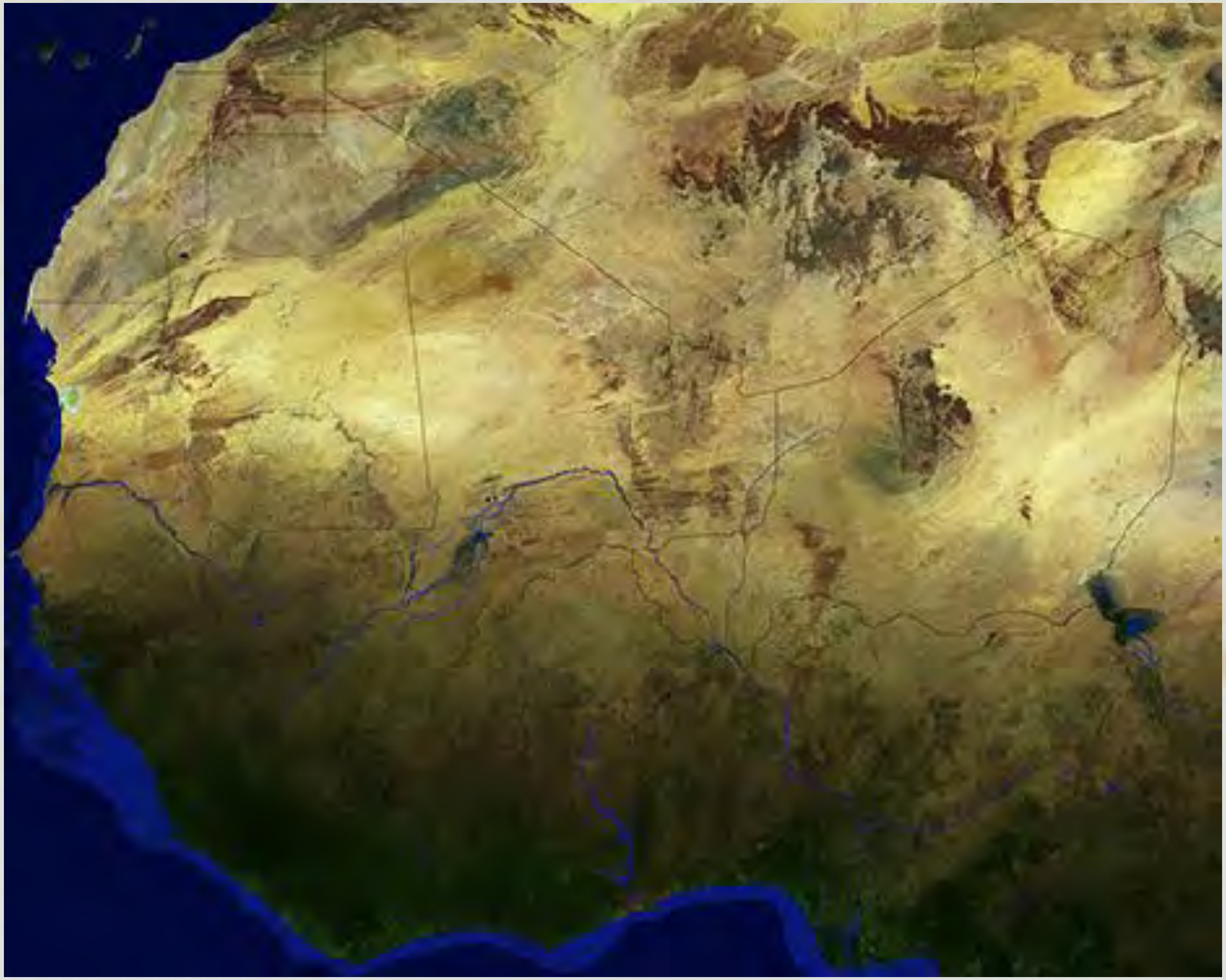
Daily coverage

36 bands

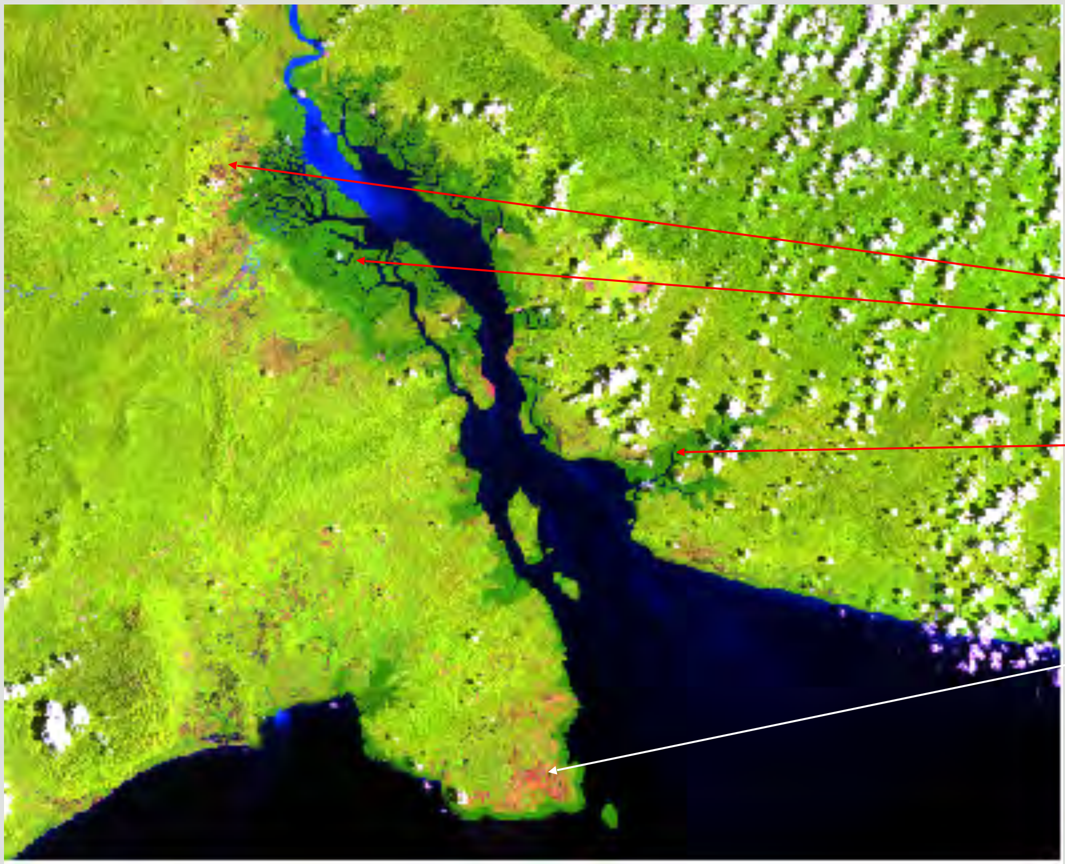
250m – 1000m resolution

Tasseled cap for Brightness, Greenness, Wetness
NDVI

MODIS



Landsat and MODIS



ETM+ February 2001

MODIS Composite, Feb-Mar 01

Spot

SPOT 4

10 m PAN, 20 m MS, SWIR band

SPOT Vegetation (similar to the AVHRR but with much better geolocation)

Recently used to update vegetation cover for Africa

SPOT 5

2.5 m PAN, 10 m MS, 20 m SWIR

Spot

False color composite (NIR,R,G)
Uppsala, Sweden.
Spot5 2002-09-04

False color composite (R,G,B)
Uppsala, Sweden.
Spot5 2002-09-04

Aster

Advances Spaceborne Thermal Emission and Reflection Radiometer

15 m resolution (VIS-NIR)

30 m resolution (SWIR)

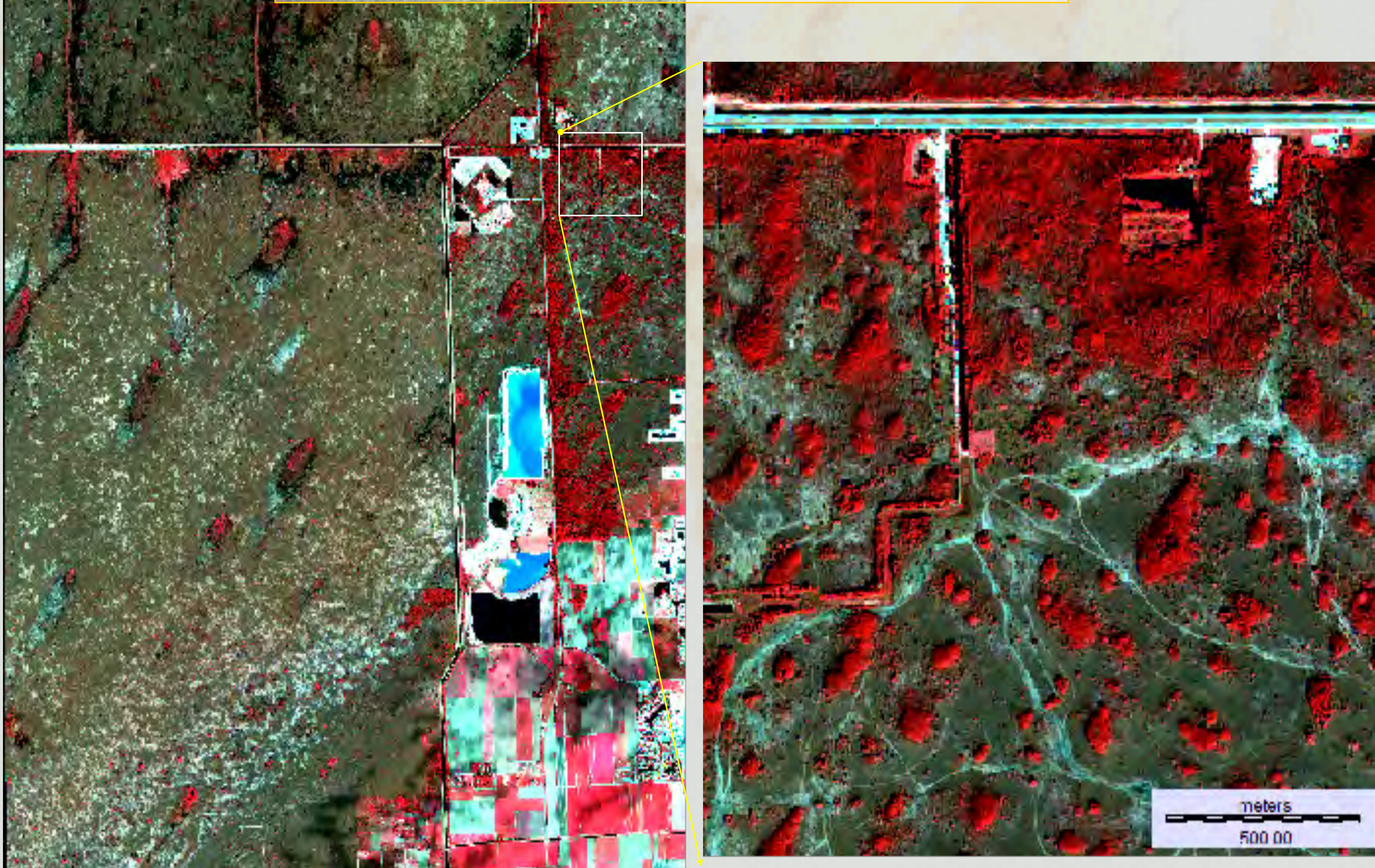
90 m resolution (Thermal)

14 channels

Scene size the same as SPOT

Pointable

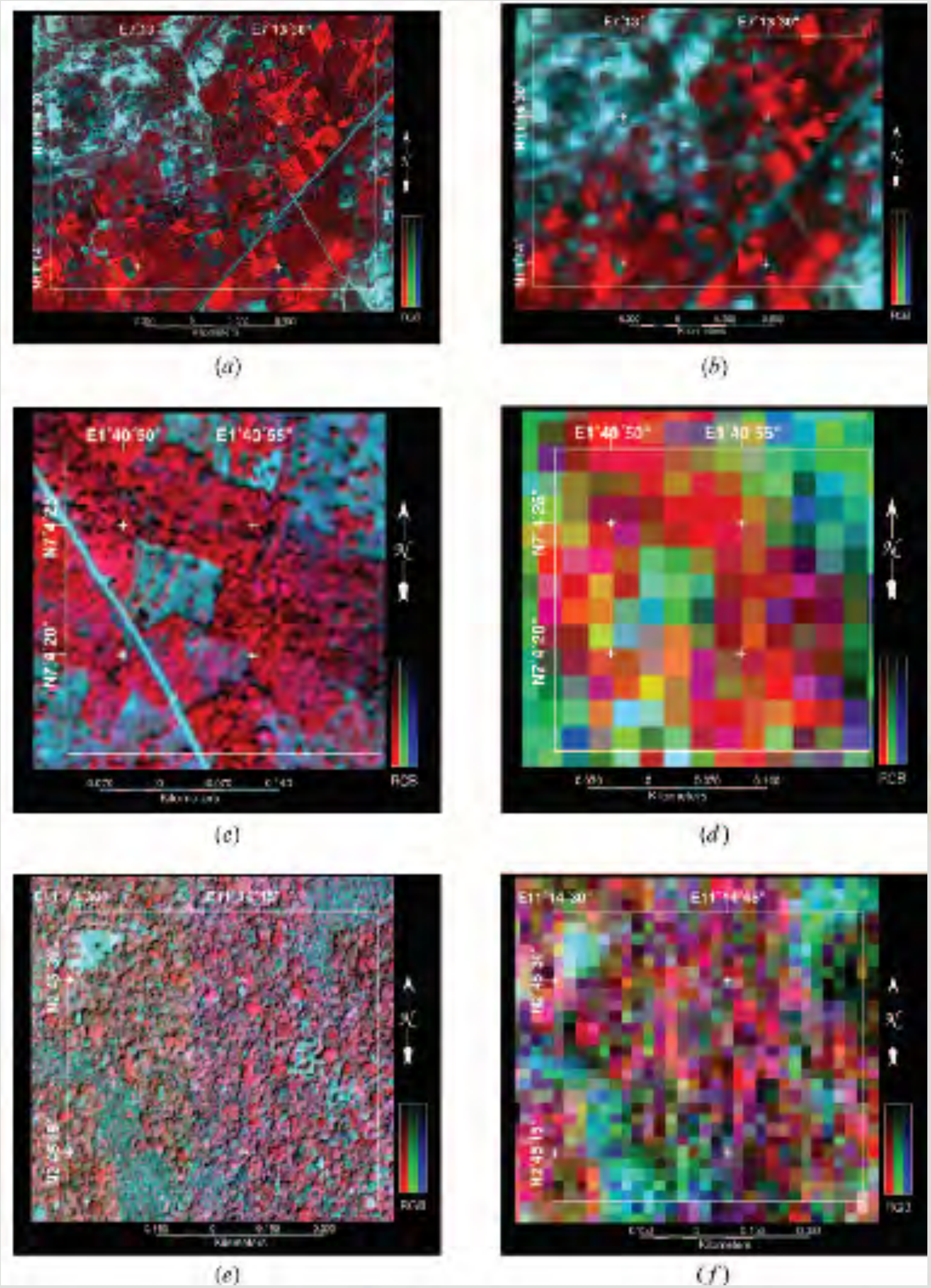
Ikonos



Ikonos

Table 2. IKONOS and Landsat-7 characteristics. Characteristics of IKONOS and Landsat-7 ETM+ multispectral and non-thermal bands used in this study.

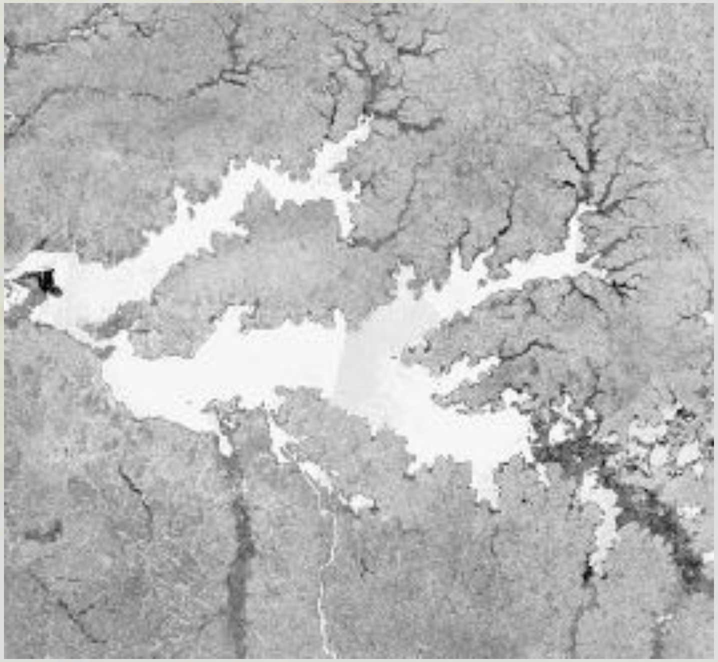
Ecoregion	Spatial	Spectral	Radiometric	Number of bands used	Band range (nm)	Band centres (nm)	Bandwidths (nm)
IKONOS	4 m	4	11-bit	4	445 516	480	71
					506 595	550	89
					632–698	664	66
					757–853	805	96
Landsat-7 ETM+	30 m	6	8-bit	6	450–515	482	65
					525 605	565	80
					630 690	660	60
					750–900	825	150
					1550 1750	1650	200
					2090–2350	2220	260



Ikonos
vs
Landsat

Quickbird

Radar vs Landsat



The future