Mon. Apr. 16, 2018

- Vegetation (for Wed.'s alternate lab)

- Sabins Chapter 10 Sudan and Central Arabian Arch (Oil)
  - Most will probably be covered Wednesday

- Reading:
  - Skim/Review Chapter 10 – Sabin's Older Petroleum case histories
    - I'll just briefly review the Sudan and Central Arabian Arch cases
  - Skim/Review Chapter 11 Sabin's Mineral Exploration.
    - We've actually covered most of this in labsSabins Ch. 10 (Oil exploration in Sudan and central Saudi Arabia)

Vegetation Overview

- References:

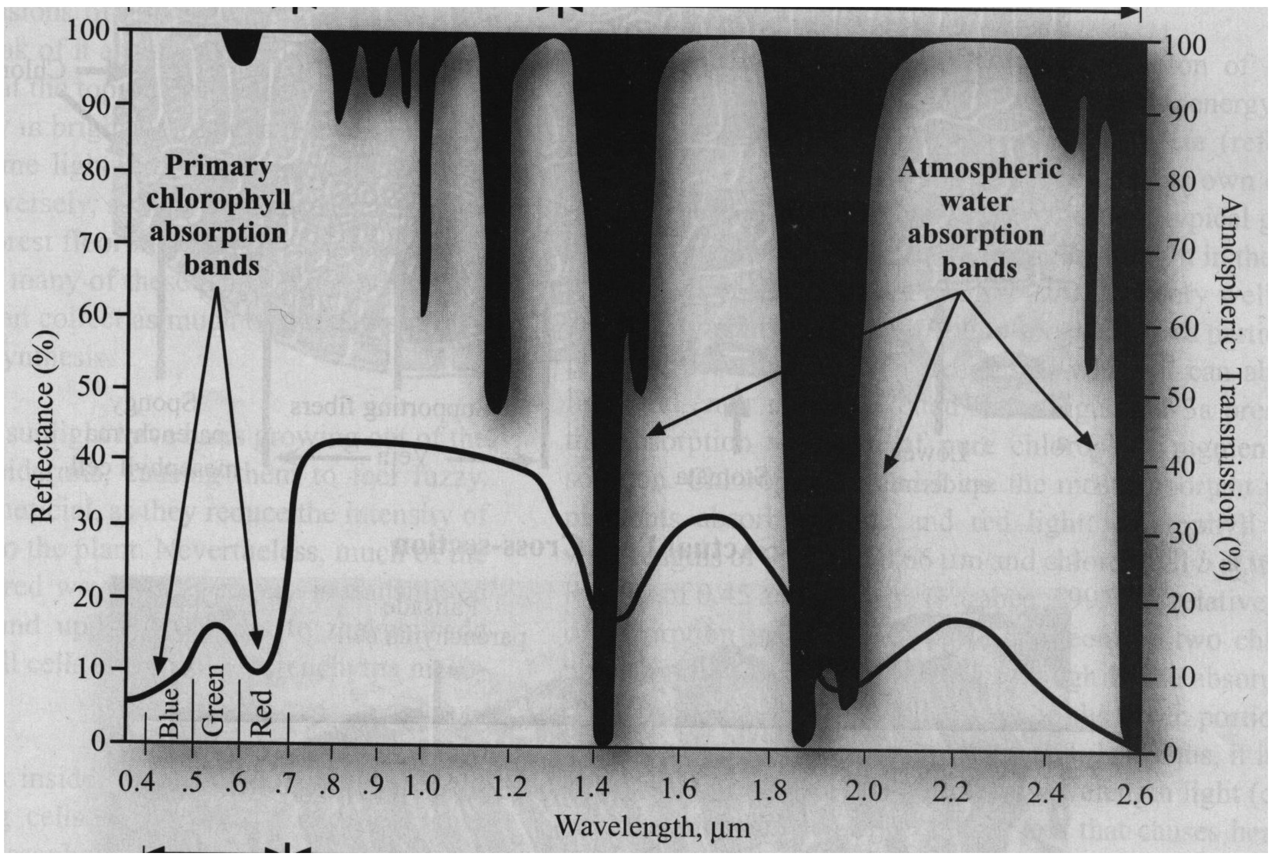
- Sabins: Chapter 12
- Jenkins, "Remote Sensing of the Environment" 2nd ed. 2007
  (text for Botany 4111)
  Chapter 11 (several of following figures from there)

Typical Leaf Spectra

- pigments
- changes with season
- effects of internal leaf structure
- reflection and transmission
- changes with water content
- differences between types of vegetation

• Vegetation Indices (covered last Monday)
  - SR: Near-IR vs. Red, with scatter plots
  - Tasseled Cap

Typical Spectrum of Vegetation

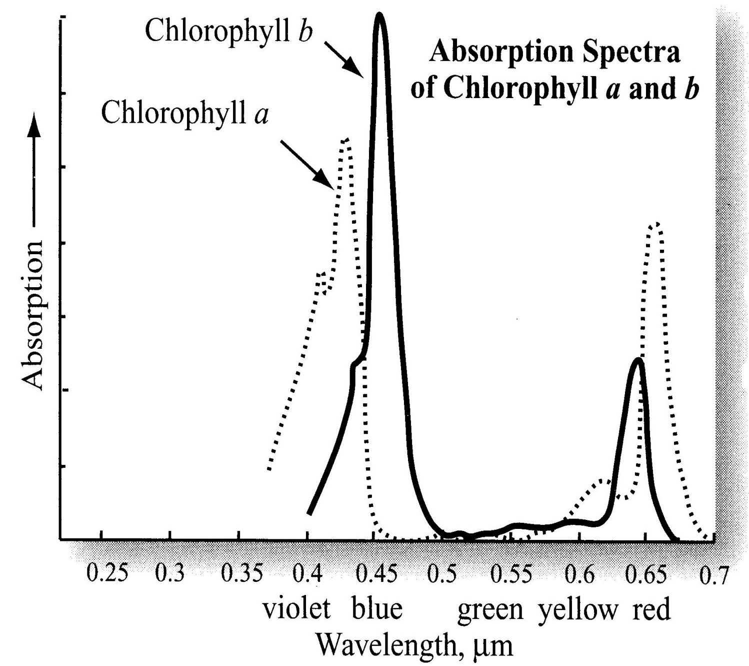


General characteristics

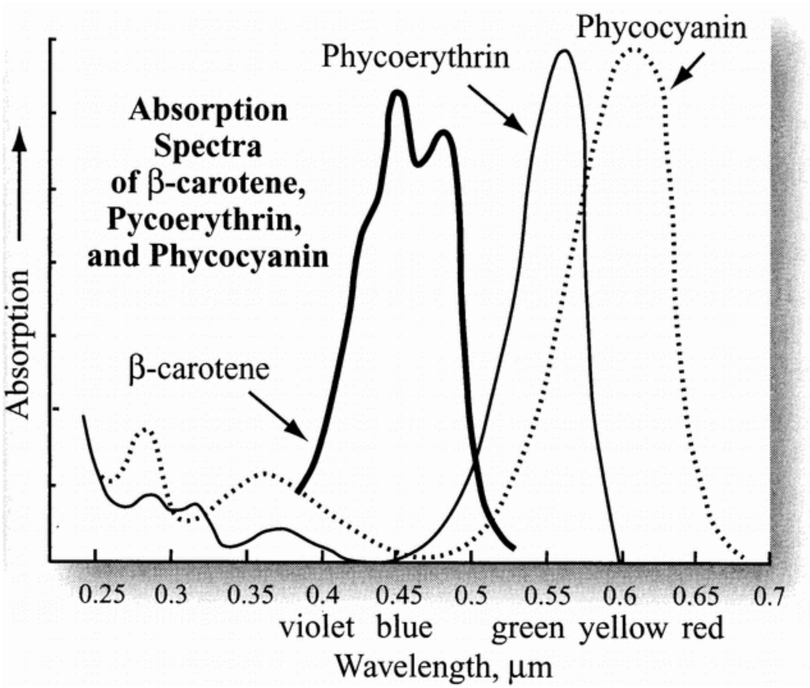
Red to Near-IR increase in reflectance
Green vs. Blue and Red reflectance
H_2O absorptions in Short-wavelength IR (SWIR)
Slow decline in reflectance from NIR to 3 µm

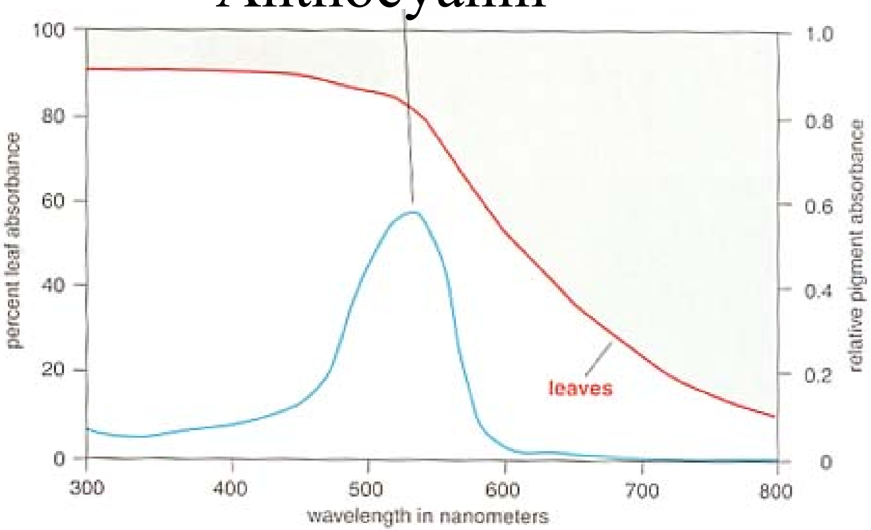
Photosynthesis

- $6\ CO_2 + 6\ H_2O +$ light energy $\rightarrow C_6H_{12}O_6 + 6\ O_2$
- Carried out in "chloroplasts", small bodies in leaf cells which contain chlorophyll
- Two main types of chlorophyll
  - Chlorophyll a
  - Chlorophyll b
  - Other less common types
    - c: some algae
    - d: some cyanobacteria)
  - Principal absorptions are at
    - 0.45 – 0.52 µm
    - 0.63 – 0.69 µm
    - "Photosynthectically active radiation"
    - Most sensitive region to detect Stress
      → less chlorophyll
      → less absorption: "chlorotic"



Other Pigments



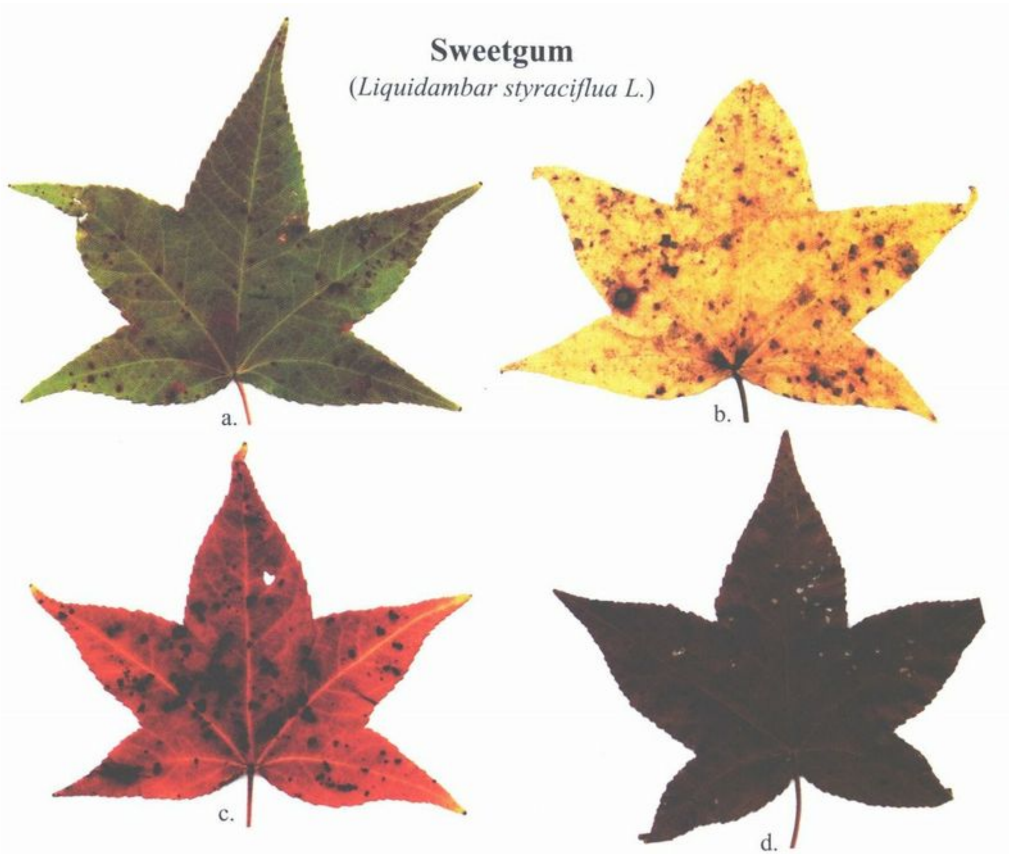


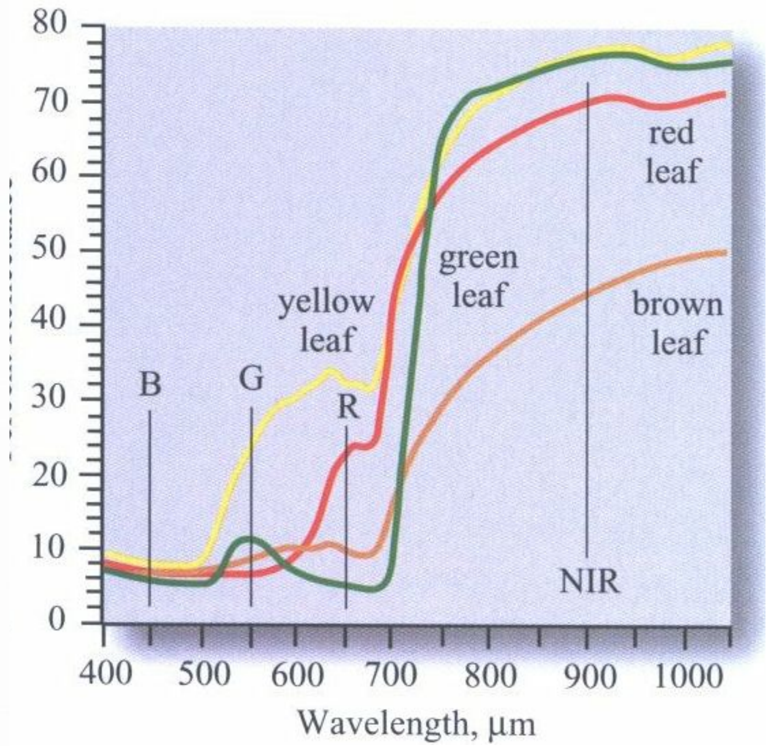
Senescence:

As chlorophyll production declines (eg. in fall) other pigments dominate

Anthocyanin and β Carotin produce red leaves

Leaf Color Changes





Increase in Green + Red reflectance – i.e. leaf becomes more yellow

Red "edge" shifts to shorter wavelengths

Near-IR reflectance drops

Leaf Structure (optional info for 4113 class)

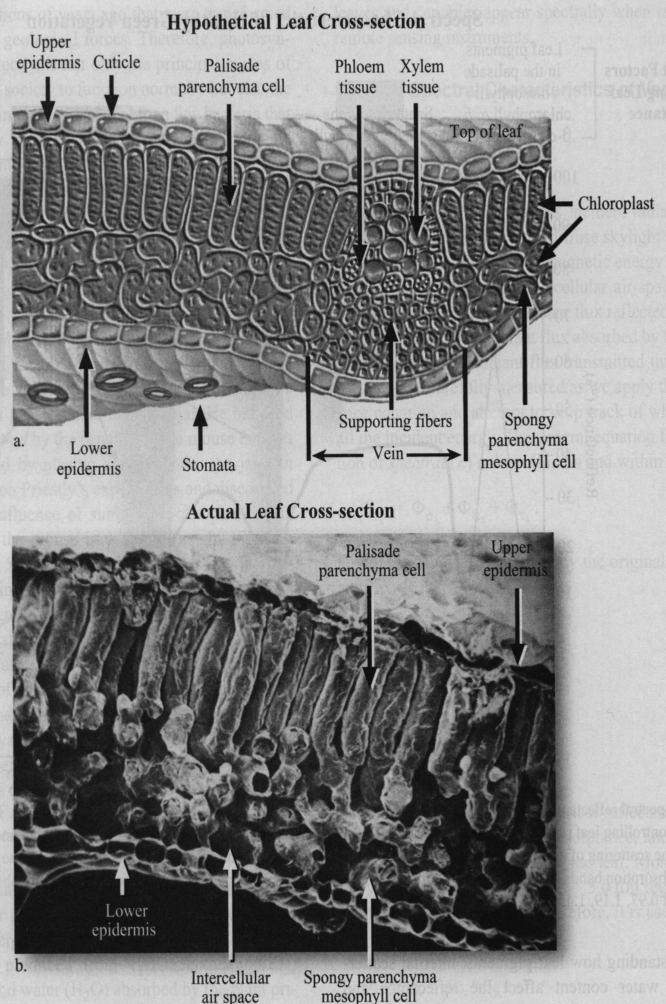


Figure 11-2 a) Hypothetical cross-section of a typical healthy green leaf, showing both the top and underside of the leaf. The chlorophyll pigments in the palisade parenchyma cells have a significant impact on the absorption and reflectance of visible light (blue, green, and red), while the spongy parenchyma mesophyll cells have a significant impact on the absorption and reflectance of near-infrared incident energy. b) Electron microscope image of a green leaf.

Main Leaf Components:

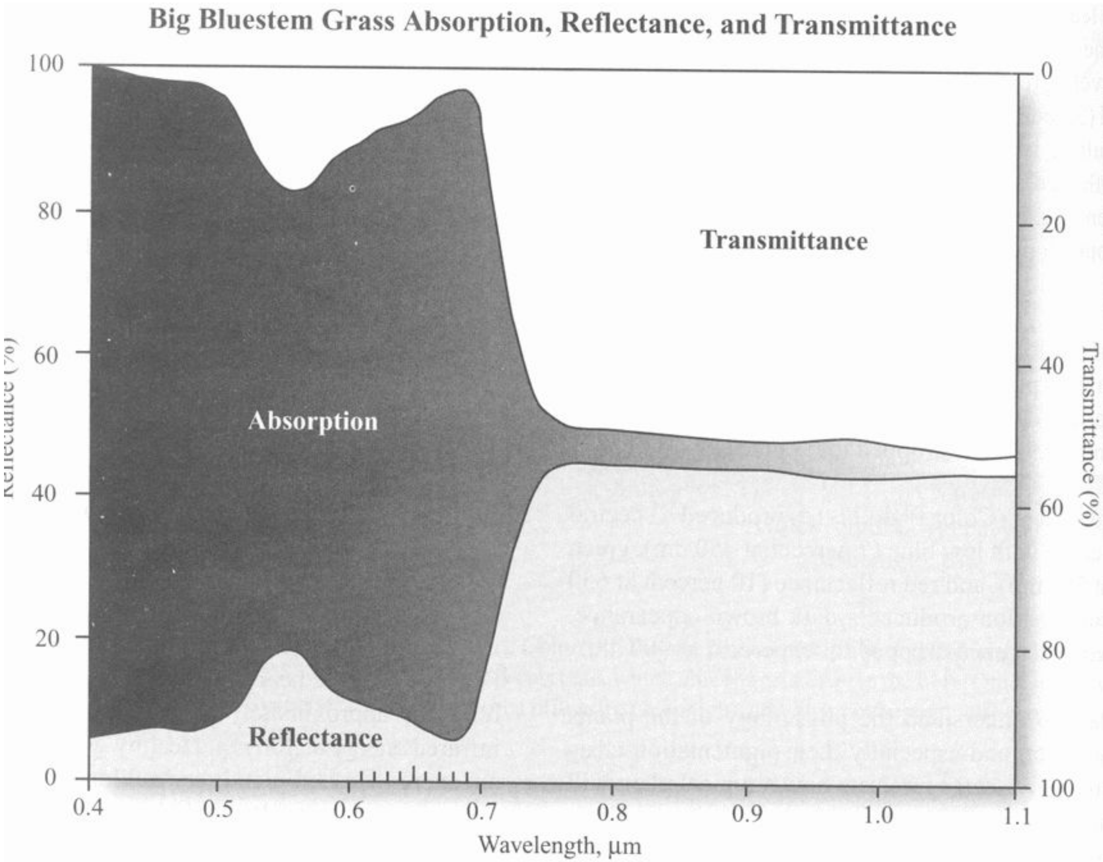
- Upper epidermis
  - Cuticular surface
  - transmits but diffuses light
- Mesophyll cells
  - Palisade parenchyma cells
  - Spongy parenchyma cells
- Lower epidermis

Chlorophyll contained in structures called Chloroplasts in parenchyma cells

Veins composed of
- inner Xylem tissue
- outer Phloem tissue

Most of near-IR characteristics controlled by state of Spongy Mesophyll
(in particular amount of water there)

Reflectance, Transmission Spectrum



IR not useful for photosynthesis

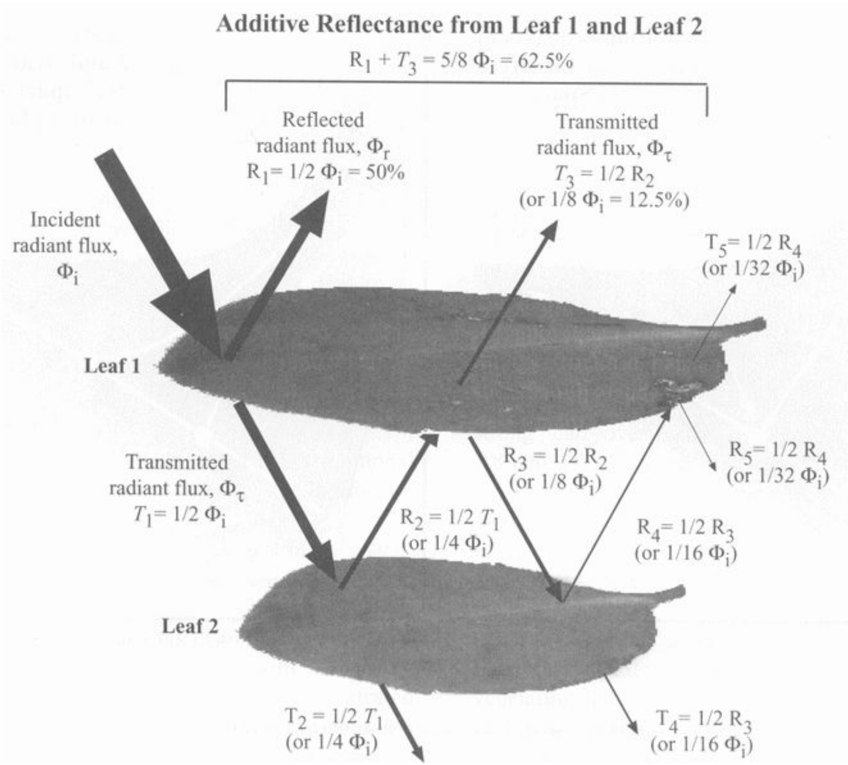
Absorption would just add to heat load in plants

Transmission spectrum is similar to reflection spectrum:

Typical plants reflect ~45% of NIR, transmit ~45% of NIR, absorb only 10%

In NIR where leaves are semitransparent – <u>LEAF ADDITIVE REFLECTANCE IMPORTANT</u>

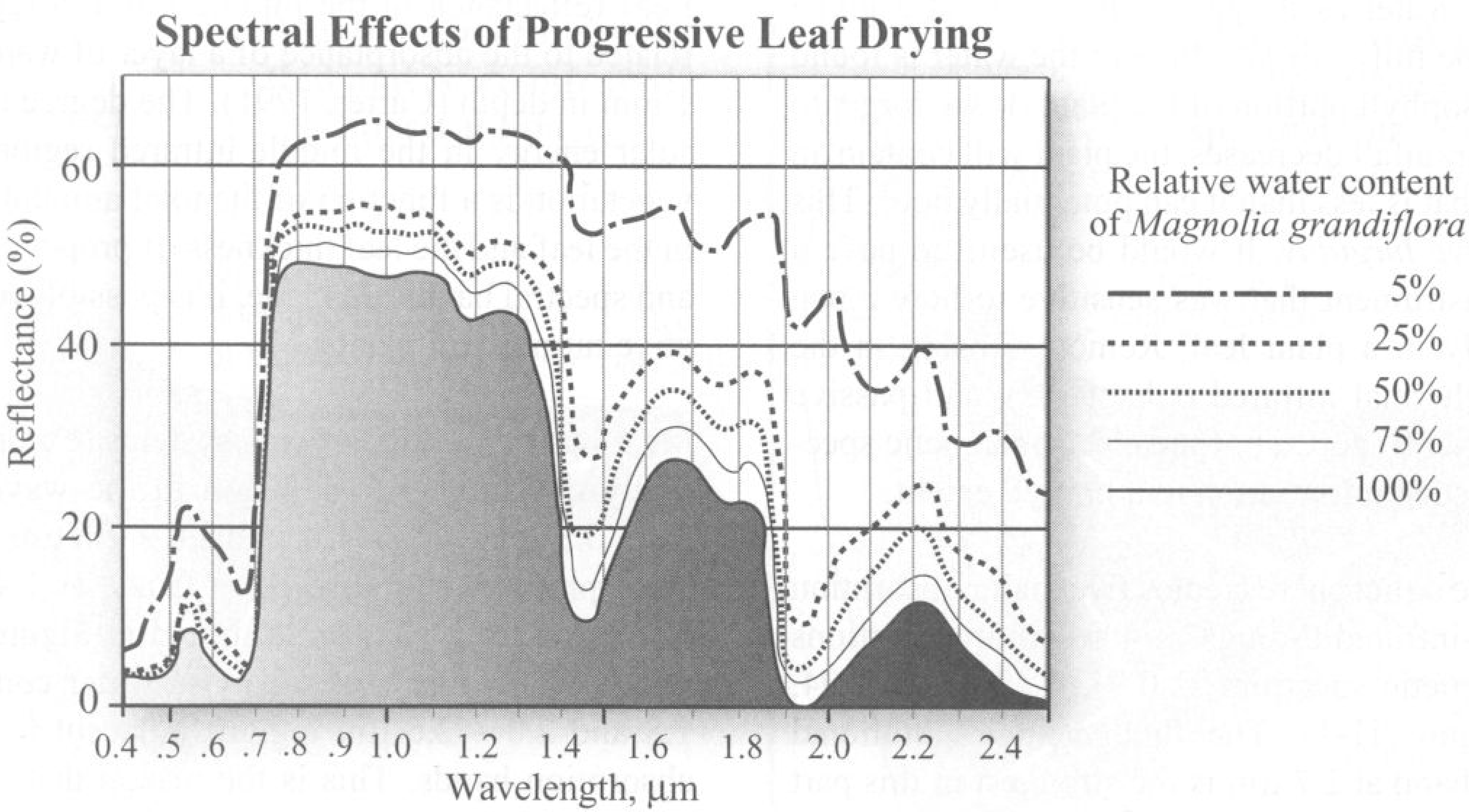
Leaf Additive Reflectance



In Near-IR where leaves are ~45% transparent, you get multiple chances to reflect back, if you have multiple layers of leaves in the canopy.

Does not apply (much) in the visible where leaves are almost opaque.

Near-IR Moisture Effects

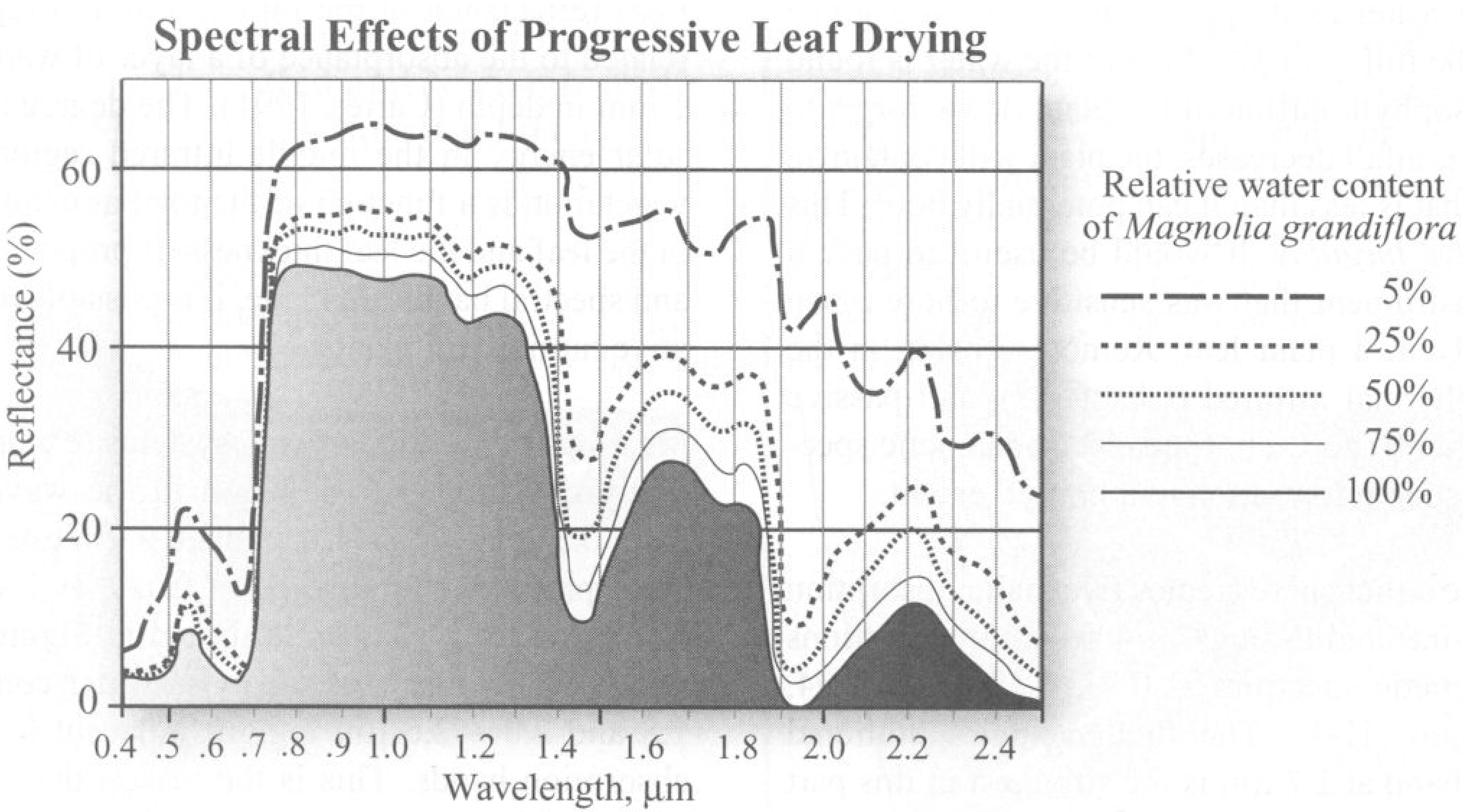


Near-IR scattered by the cell structures (and air spaces) in spongy mesophyll

More water means less air and so less scattering

More water means more IR absorption – especially in water bands

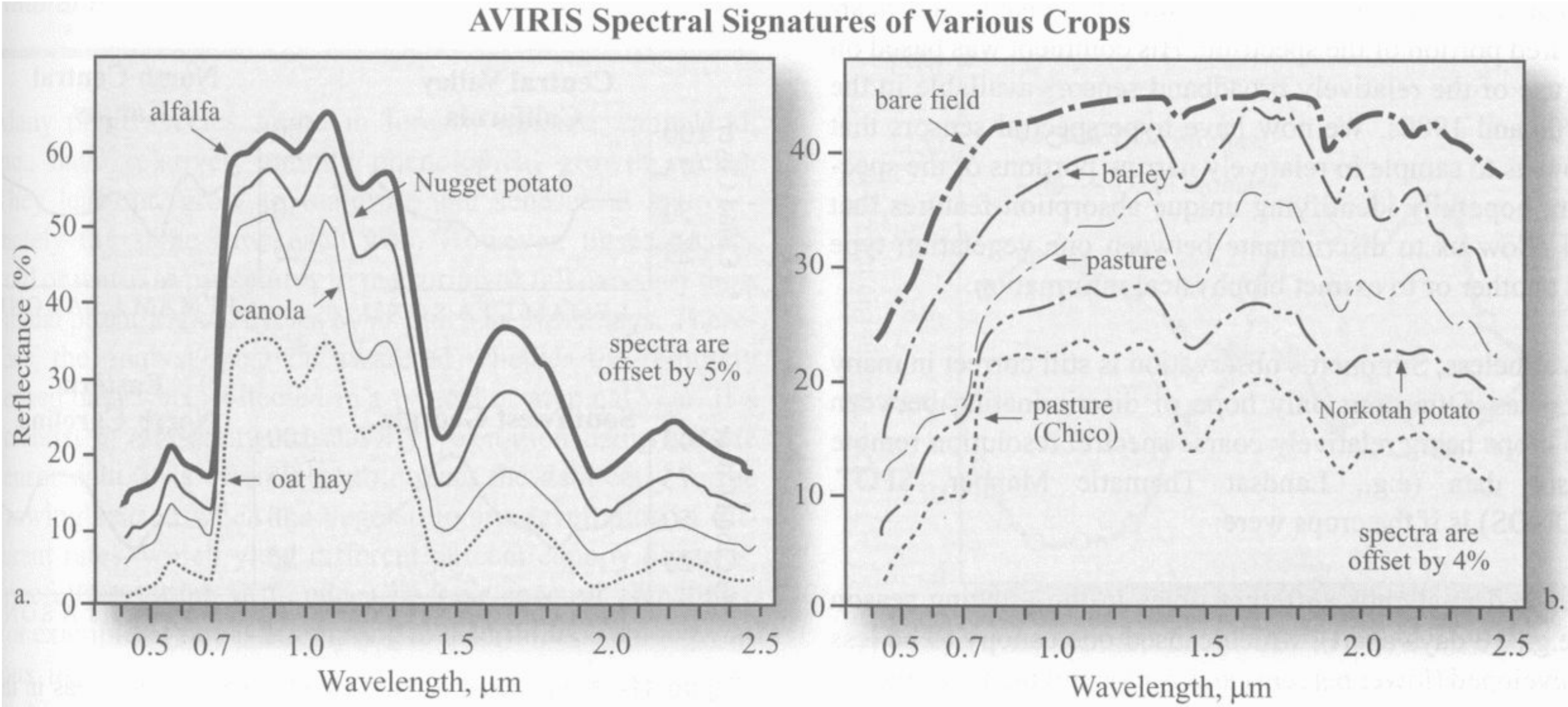
NDMI: Normalized Difference Moisture Index



- NDVI: (NIR-Red)/(NIR+Red) For Landsat TM: (Band_4 - Band_3) / (Band_4 + Band_3)
  - Measures amount of vegetation by sensing characteristic difference between the very reflective NIR band the chlorophyll absorbed Red band

- NDMI: (NIR-SWIR)/(NIR+SWIR) For Landsat: (Band_4 - Band_5) / (Band_4 + Band_5)
  - Measures amount of moisture by sensing characteristic difference between the very reflective NIR band and a water absorbed Short-Wavelength-IR band – usually band 5 at 1.6 µm (although you might also be able to use Band 7 at 2.22 µm if Band 5 was not available.)

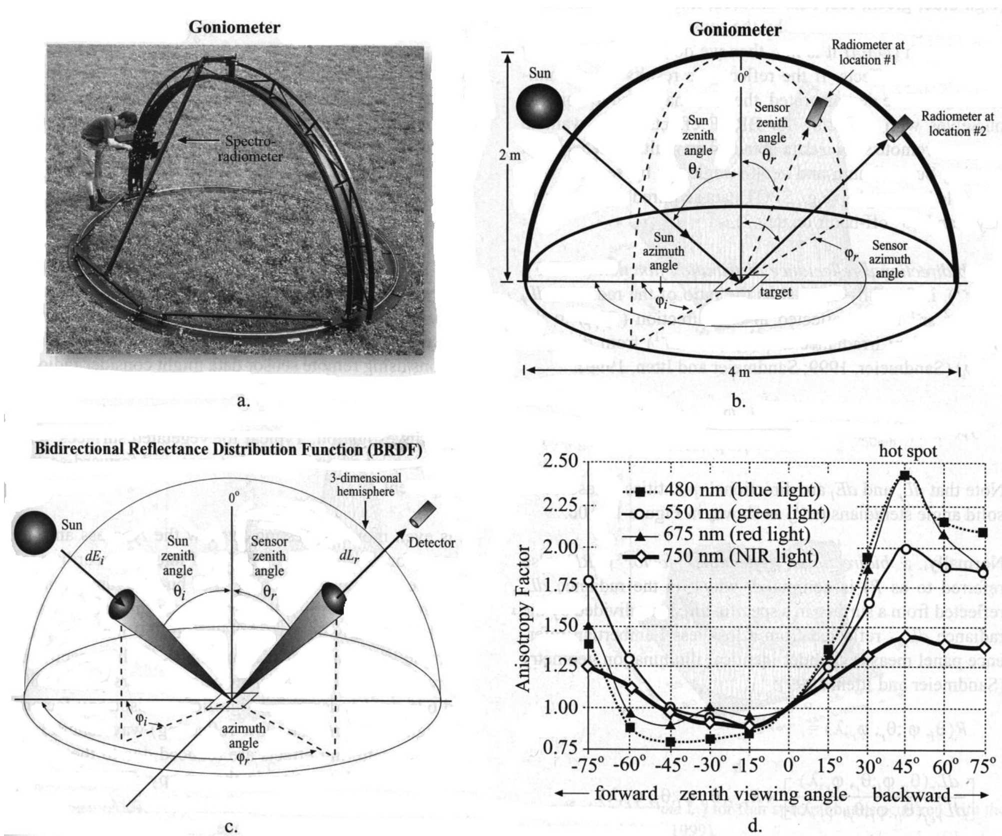
Spectra of different (Fig 11-12)



Spectra of most vegetation is very similar – differences subtle
<u>In above plot spectra offset for clarity</u> – i.e. average reflectance similar

Subtle differences may allow you to distinguish different types of vegetation

Angular Effects – Both for vegetation and geology



Field Goniometer

Solar zenith angle = 35°

Jenson Figure 11-10

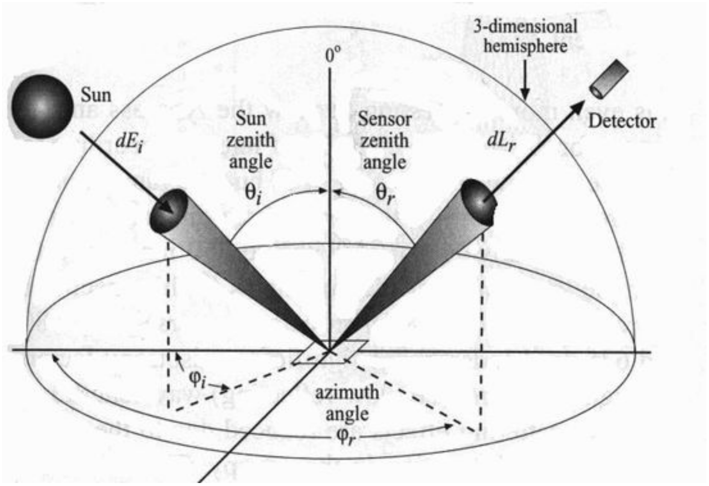
- Reflectance can change with angle of incoming and outgoing light
- Bidirectional Reflectance Distribution Function (BRDF)
- Tends to have peaks for backscatter and specular reflection

3 Essential Angles Involved:

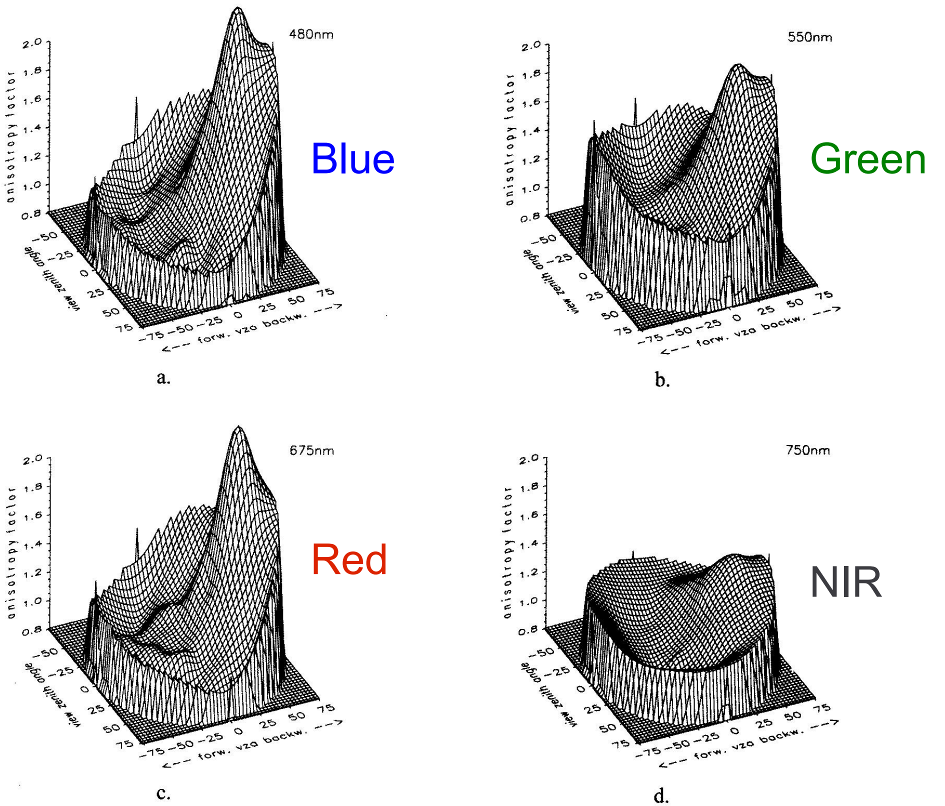
- Incidence angle θ_i below
- Emission angle θ_r below
- Phase angle α Angle measured directly between incoming and outgoing beam

$\alpha = 0$ Backscatter: Sun is "behind" viewer

$\alpha = 180$ Forward scatter: Sun is almost in your eyes



Angular Effects – Wavelength dependent



Measured BRDF
Ryegrass
Solar zenith angle = 35°

Jenson Figure 11-11

Figure 11-11 Anisotropy factors (nadir-normalized BRDF data) of ryegrass (*Lolium perenne L.*) for four spectral bands acquired with the FIGOS instrument with a Sun zenith angle of 35° (after Sandmeier and Itten, 1999).

- At wavelengths where leaves are dark:
  - mostly get reflectance from first surface – highly directional
- At wavelengths where leaves are reflective and transmitting
  - get multiple scattering and almost uniform ("Lambertian") reflectance
- <u>Spectrum will be different for different viewing geometries</u>

Evergreen vs. Deciduous Spectra

- Although broadband sensors often can't distinguish between different plants, coniferous trees have significantly lower IR reflectance

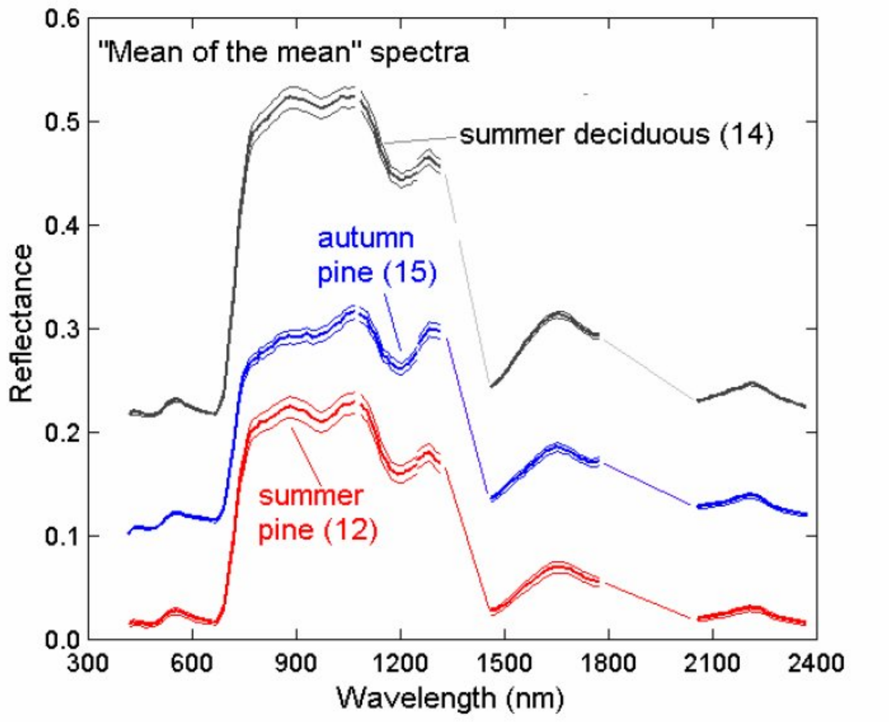


Figure 3. Mean of mean spectra (heavy lines) for several land cover types, offset by 0.1. Standard deviations are the light lines.

Cipar et al.
Note 0.1 offset between spectra

Vegetation Indices

Lab today involves sensing of vegetation properties using Landsat TM
(no lab – just makeup lecture, last week of classes)

Reading: Sabins pg. 404-407
Supplemental information from Jenkins "Remote Sensing of the Environment" 2nd Edition 2007

Simple Ratio

$SR = R_{NIR}/R_{Red}$

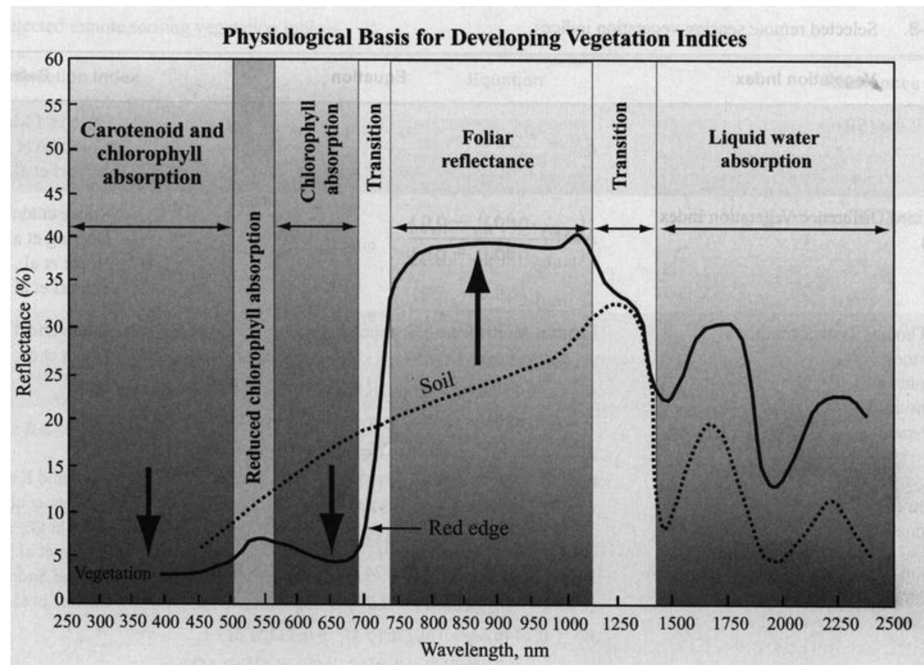
Normalized Difference Vegetation Index

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

Normalized Difference Moisture Index

$NDMI = (R_{NIR}-R_{SWRI})/(R_{NIR}+R_{SWRI})$

(note-- metioned Monday you could use TM7 but more commonly use TM5 = 1.65μm for SWIR)

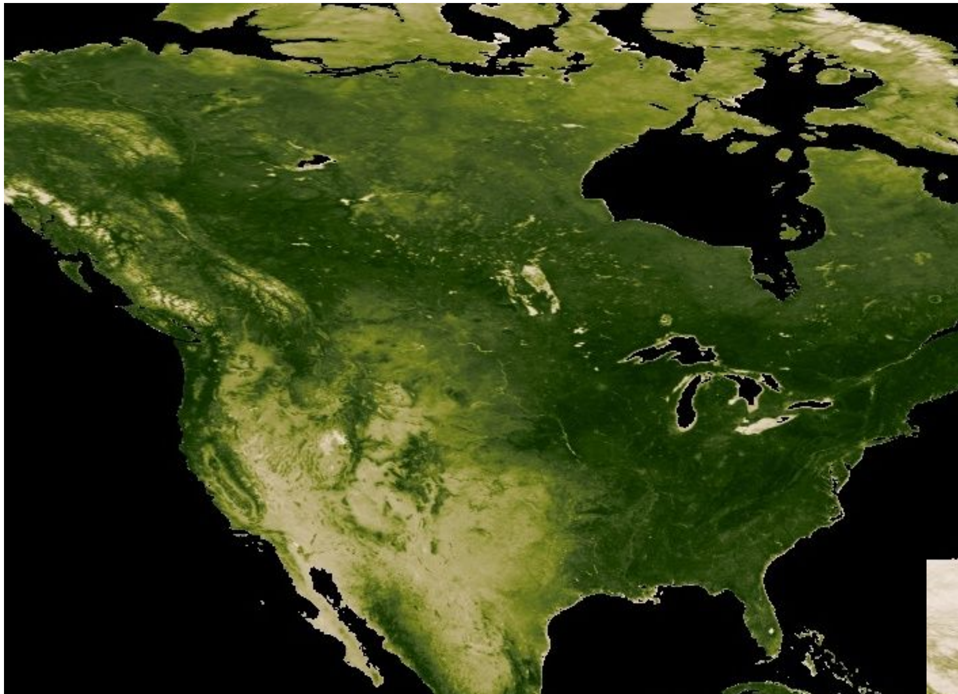


Jenson Figure 11-21a

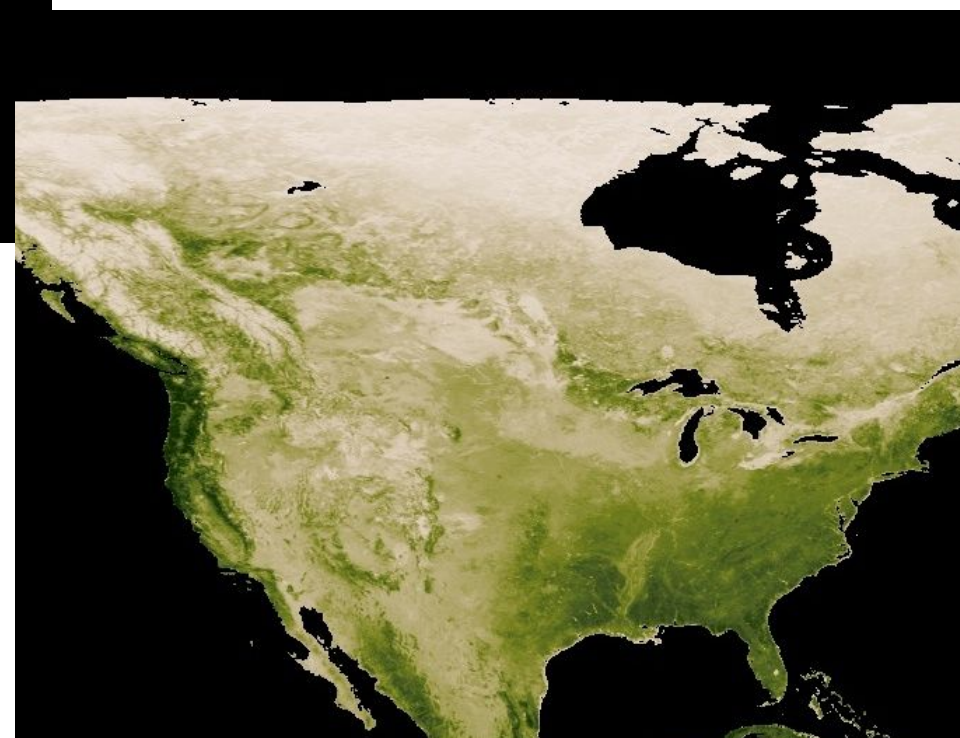
Tasseled Cap Transformation

Also involves R_{NIR} R_{Red} but with more complicated processing

GLOBAL MODISl NDVI
available at <http://neo.sci.gsfc.nasa.gov/>

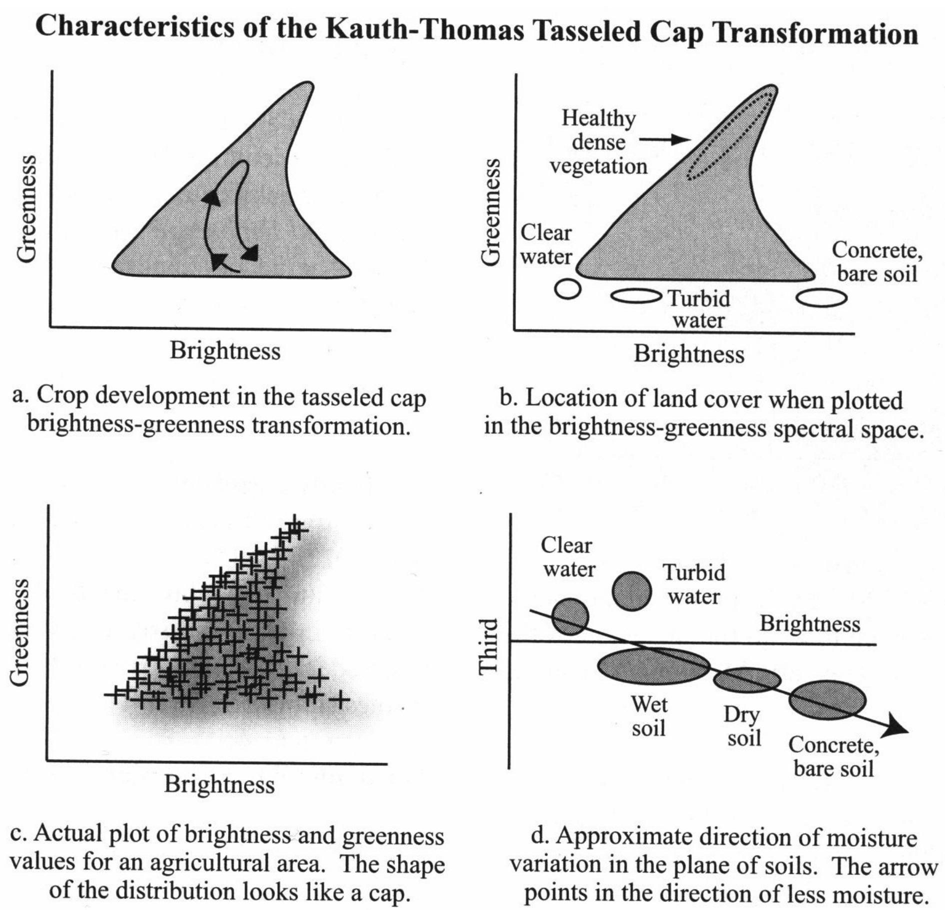


Jan. 2012



July 2011

Kauth-Thomas Tasseled Cap Transformation



a. Crop development in the tasseled cap brightness-greenness transformation.

b. Location of land cover when plotted in the brightness-greenness spectral space.

c. Actual plot of brightness and greenness values for an agricultural area. The shape of the distribution looks like a cap.

d. Approximate direction of moisture variation in the plane of soils. The arrow points in the direction of less moisture.

Similar to NIR-Red version, but includes data from all bands

Math rotates axes to align base of “cap” on X=Brightness axes

Using 6 TM bands, besides B,G,W, can obtain 3 additional components.

“Third” component associated with soil information

Kauth-Thomas Tasseled Cap Transformation

NDVI Image of Charleston, SC,
Derived from Landsat Thematic Mapper Data

a. Brightness.

b. Greenness.

c. Wetness.

Kauth-Thomas (Tasseled Cap)
Brightness, Greenness, and Wetness
Transformation of Landsat Thematic
Data for Charleston, SC

Figure 11-24 Brightness, greenness, and wetness images derived by applying Kauth-Thomas tasseled cap transformation coefficients to the Charleston, SC, Thematic Mapper data (6 bands).

From Jenkins 2nd ed. (2007)

Index Summary

Simple Ratio

$SR = R_{NIR} / R_{red}$

Normalized Difference Vegetation Index

$NDVI = (R_{NIR}-R_{Red})/(R_{NIR}+R_{Red}) = (SR-1)/(SR+1)$

Tasseled Cap

Complex "rotation" to B, W, Third axes

Normalized Difference Moisture Index

$NDMI = (R_{TM4}-R_{TM5})/(R_{TM4}+R_{TM5})$ (TM4 = 0.83μm TM5 = 1.65μm)

Relative Water Content (in situ measurement)

RWB = 100 X (field weight – oven dry weight) / (turgid weight – oven dry weight)

Phenological (growth) Cycles

- Broadband sensors often can't distinguish between different plants
- Watching seasonal growth cycles can distinguish them
  - Evergreens vs. deciduous plants
  - Trees that "leaf out" at different times
    - Cottonwoods, Aspens, growth early in season
    - Russian Olives Trees – very late in season
  - Crops with different planting times and growth rates
  - Crops with multiple harvests per season (alfalfa)

Phenological Cycles in South Carolina

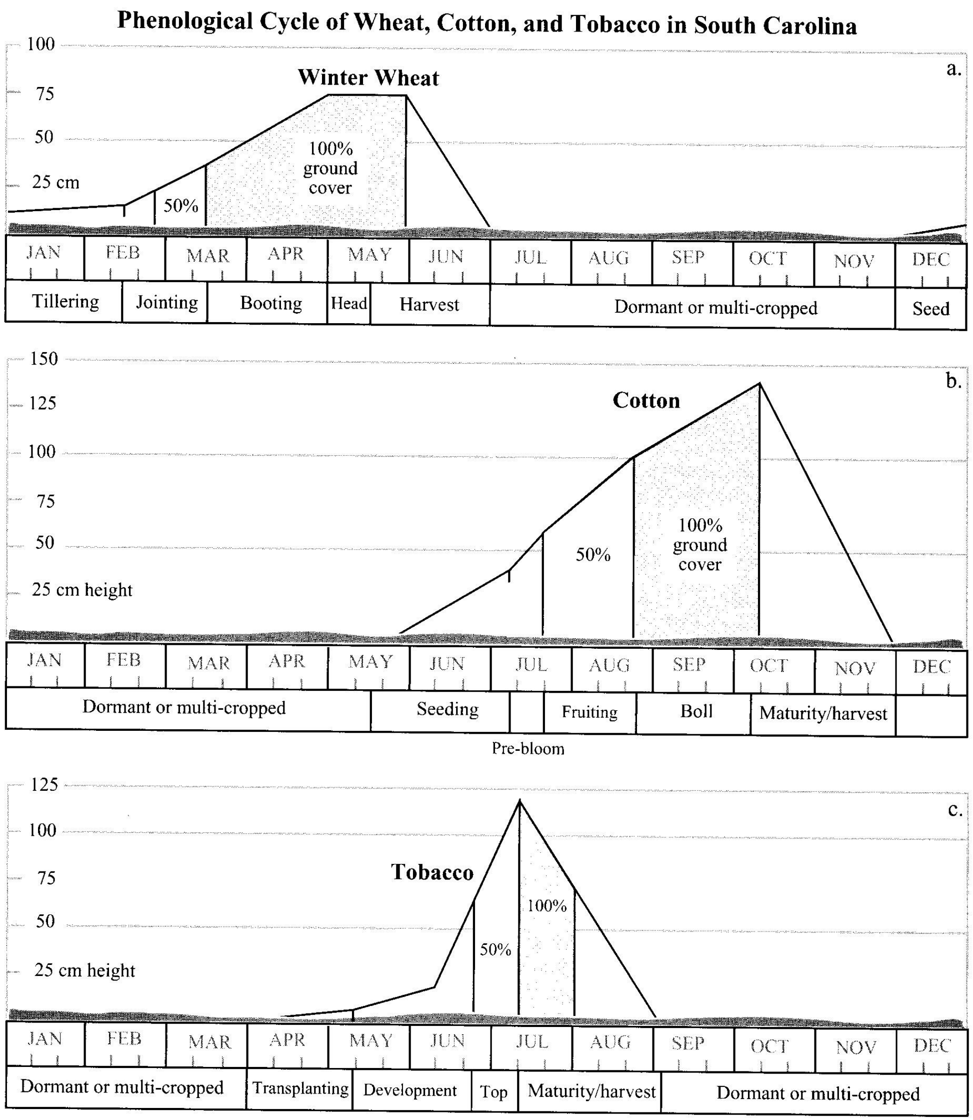
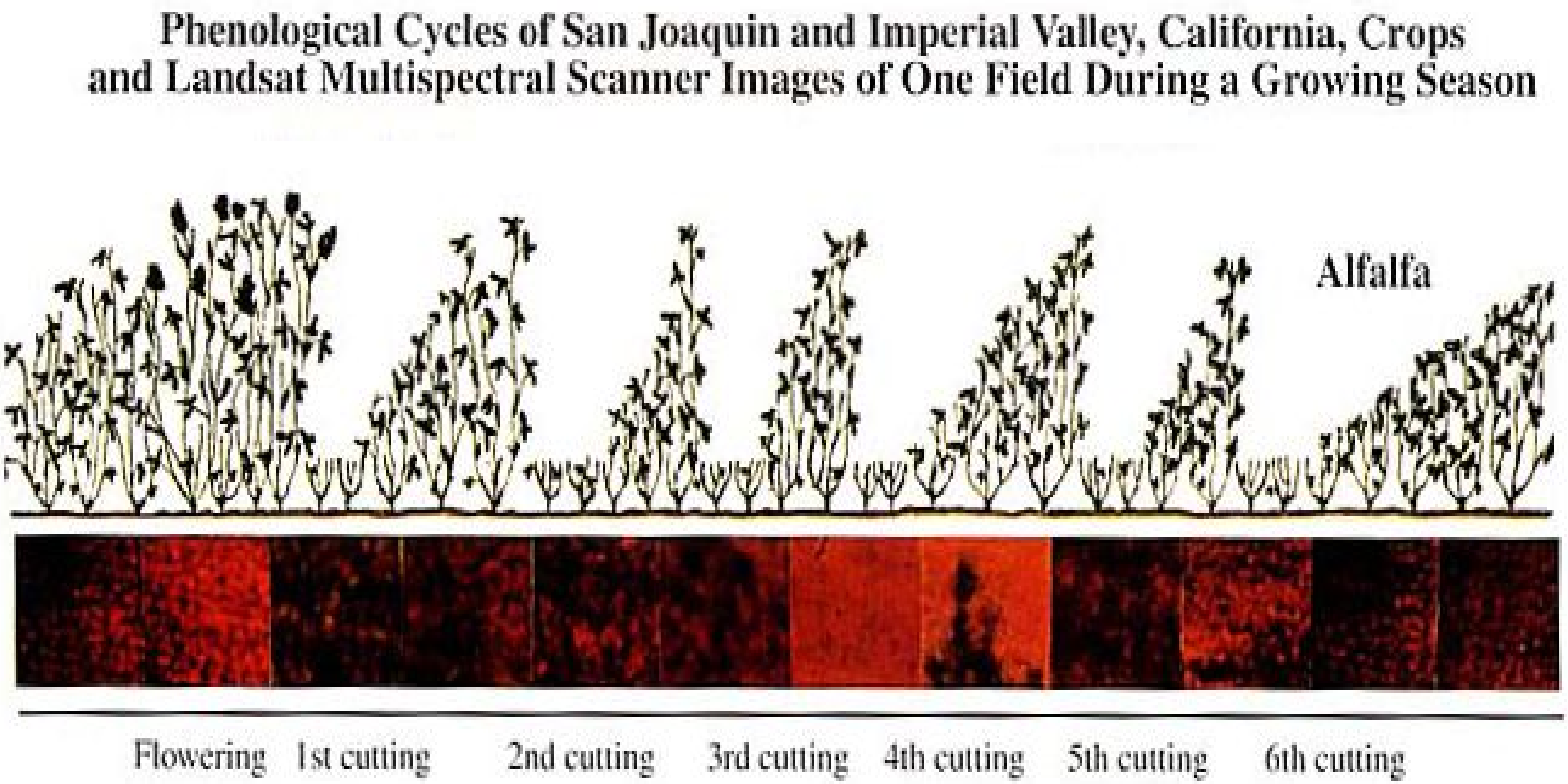


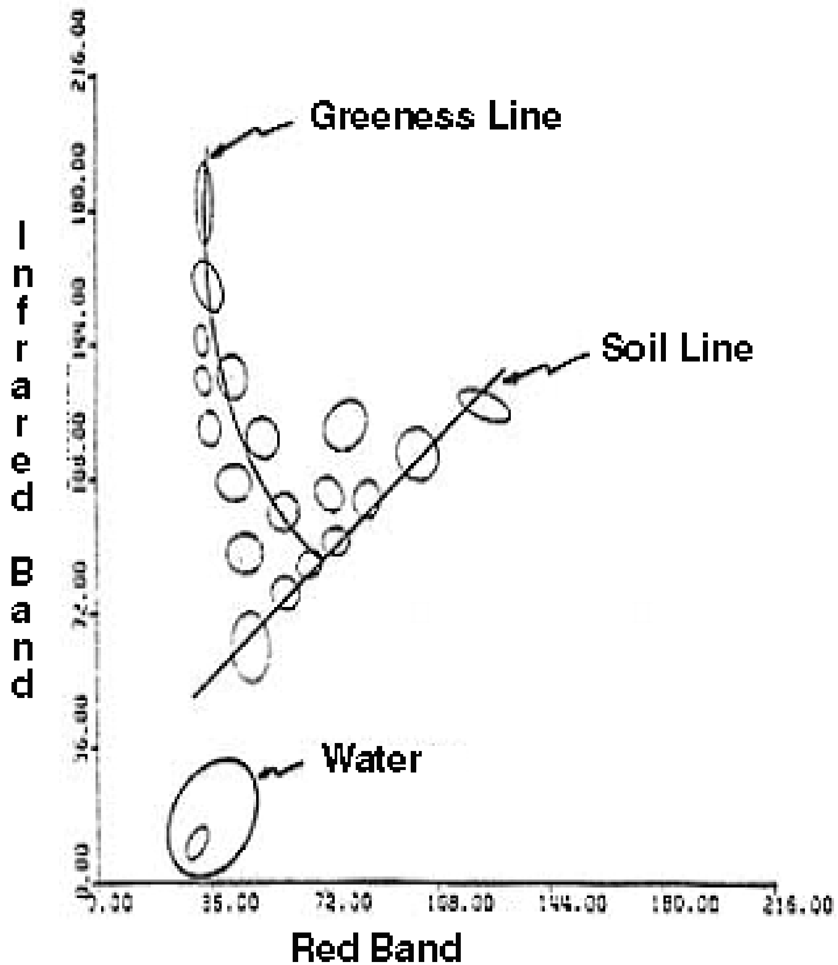
Figure 11-19 Phenological cycles of winter wheat (a), cotton (b), and tobacco (c) in South Carolina. The information was obtained from county agricultural extension agents, Clemson land-grant university extension personnel, and field work (Savitsky, 1986).

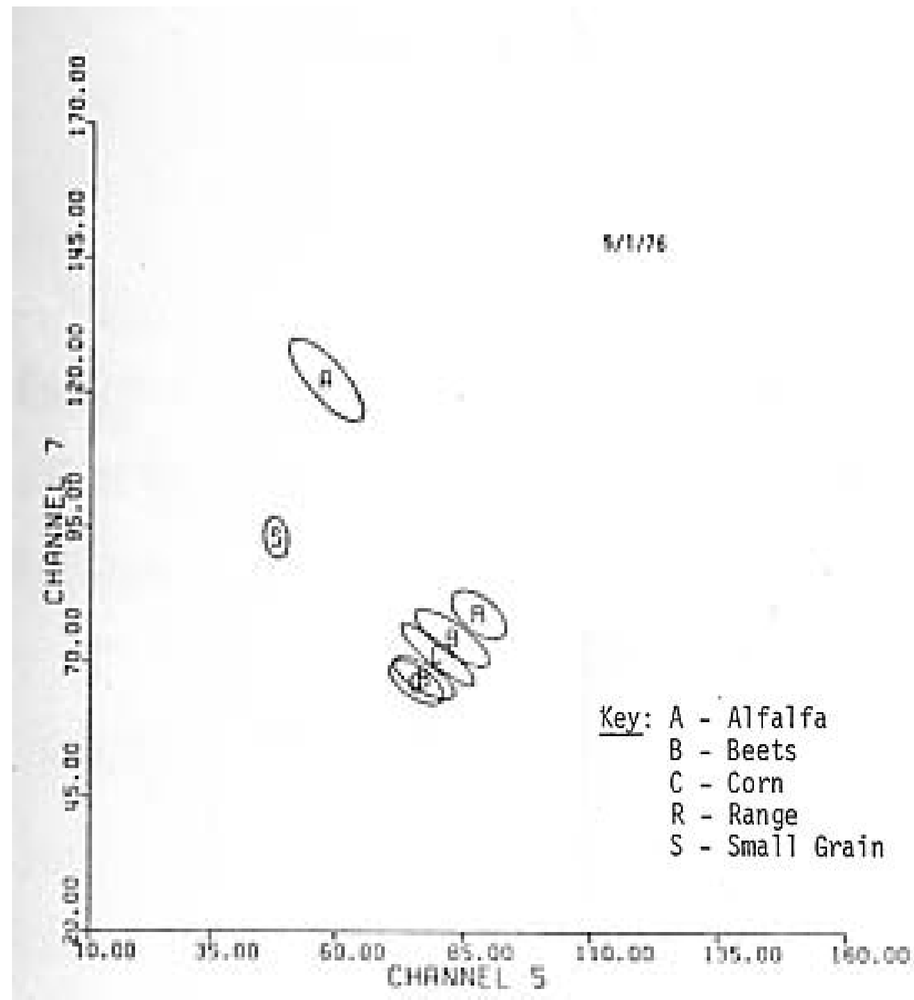
- Time, duration, and detailed shape of coverage curve vary with plant type
- Also varies with climate – so different here in Wyoming even if same plants could grow

Multiple Crops per Season

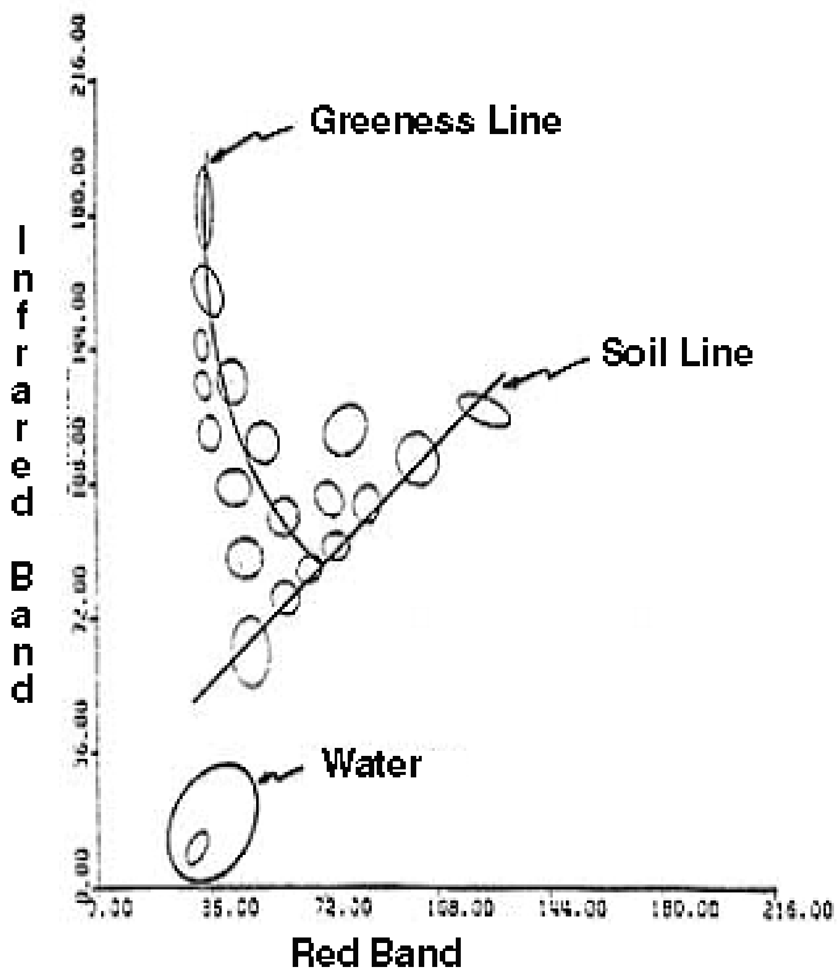


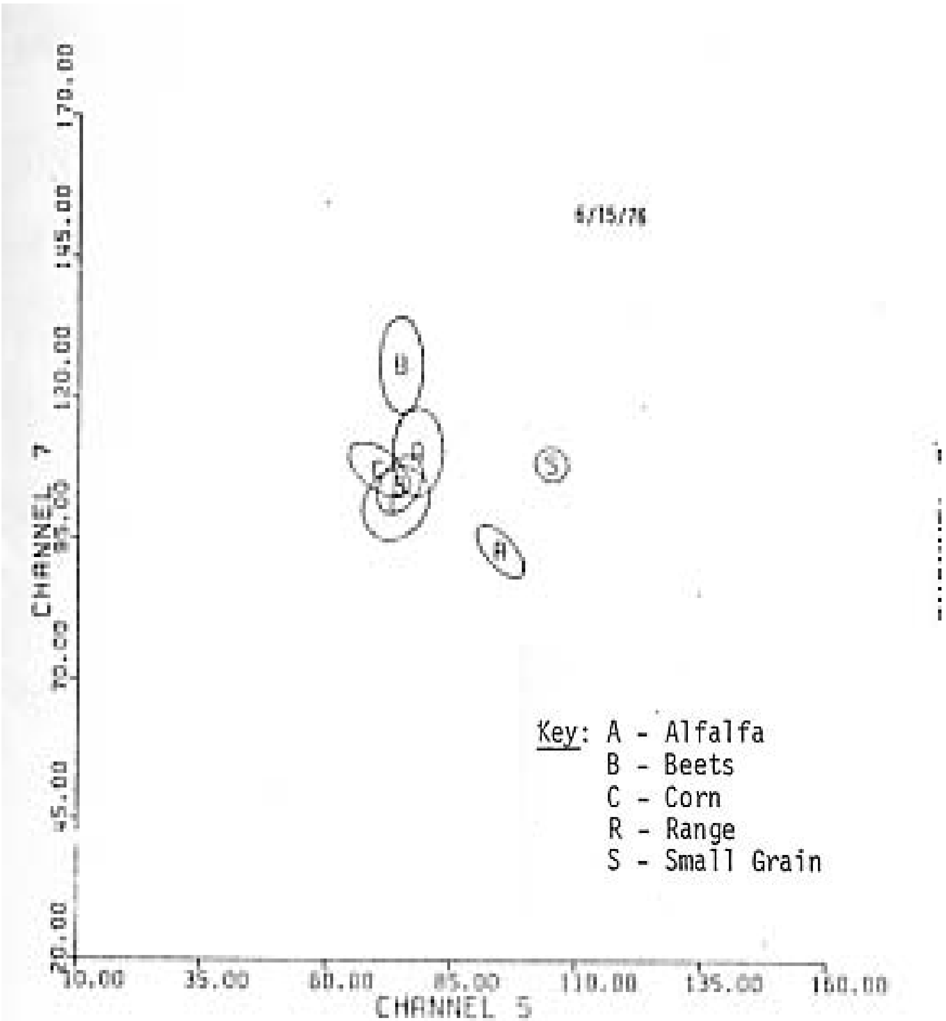
Crops in Colorado, May 2



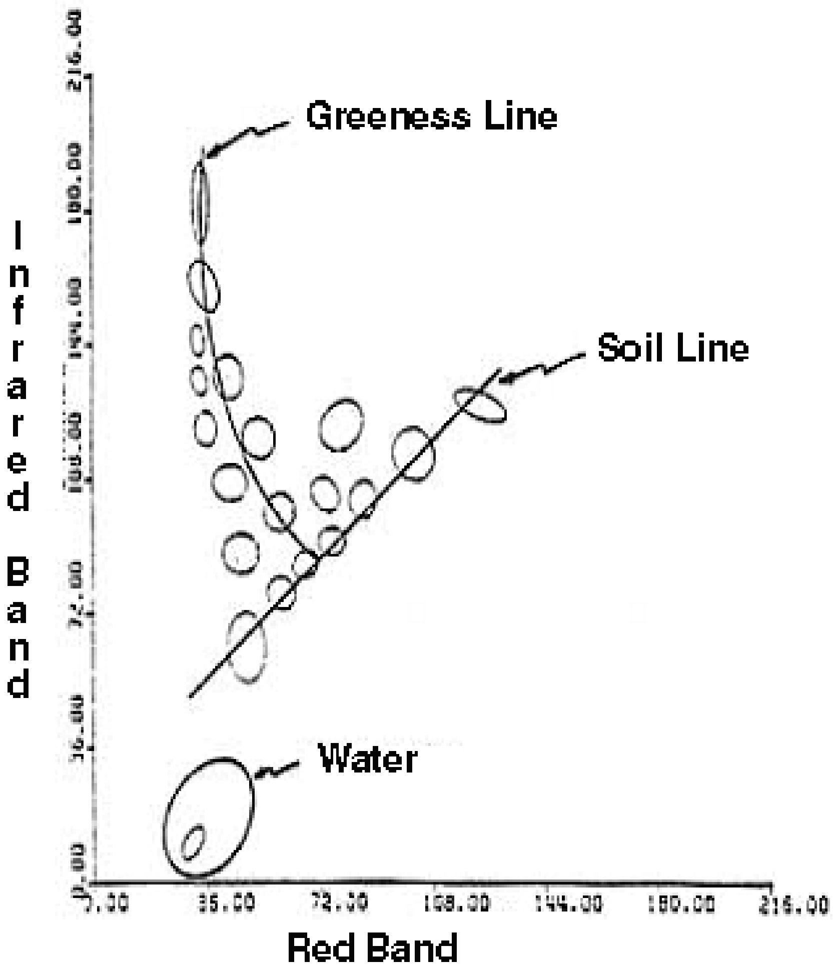


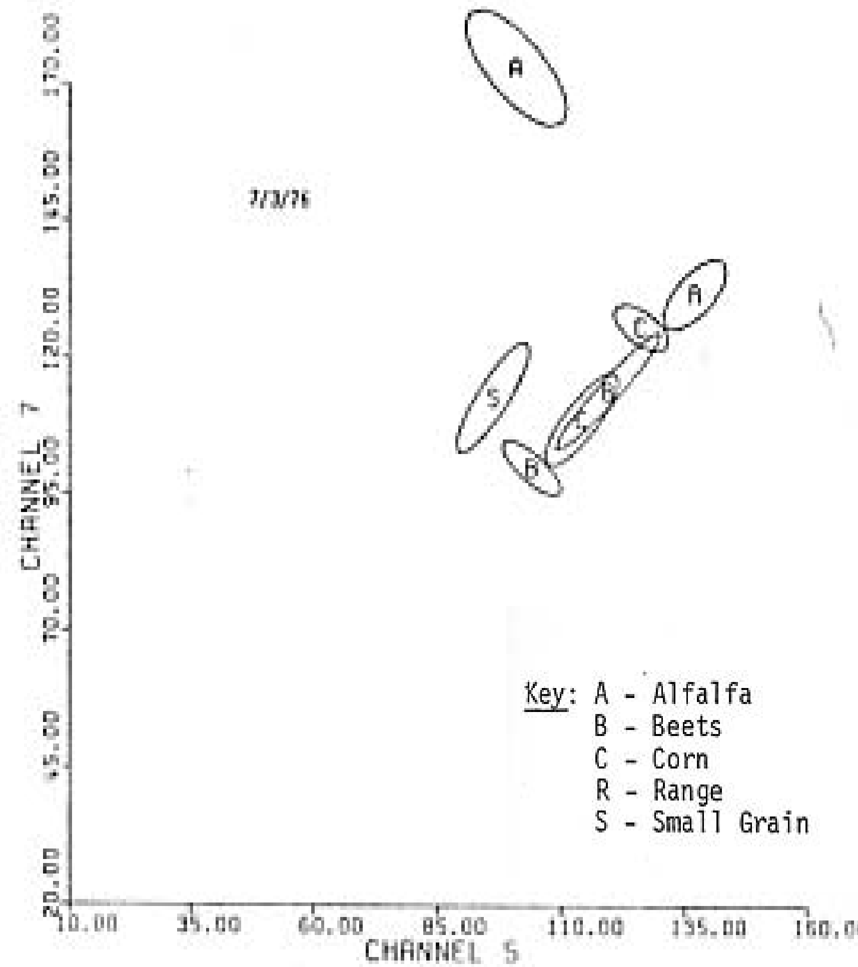
Crops in Colorado, June 15



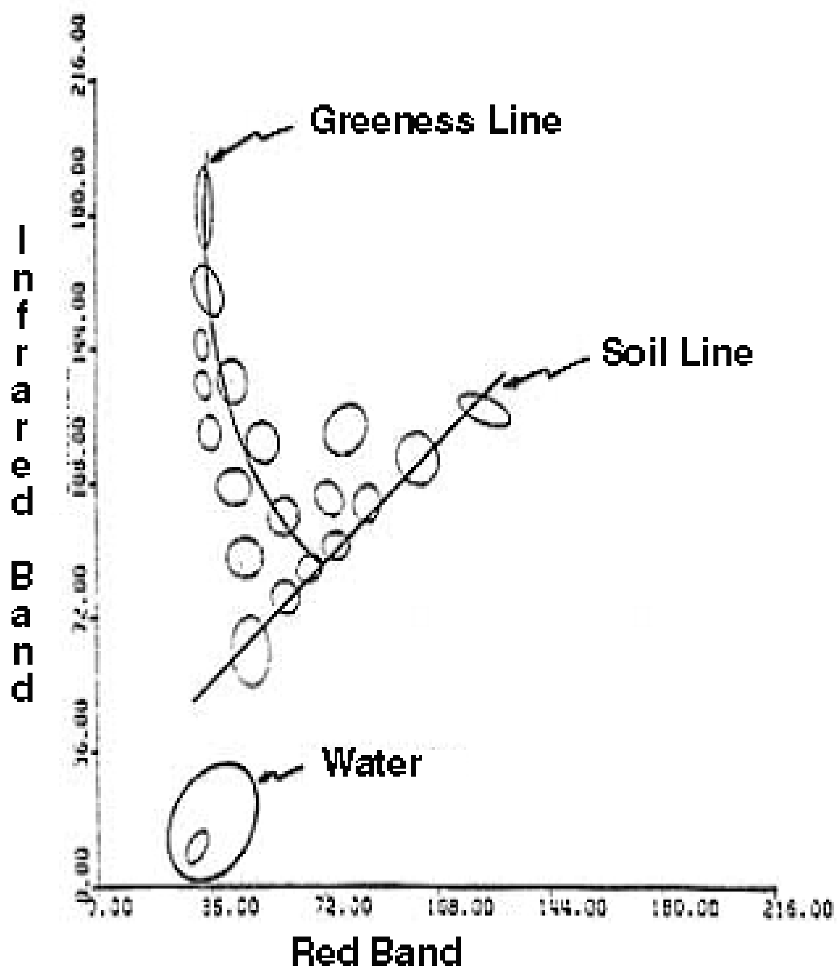


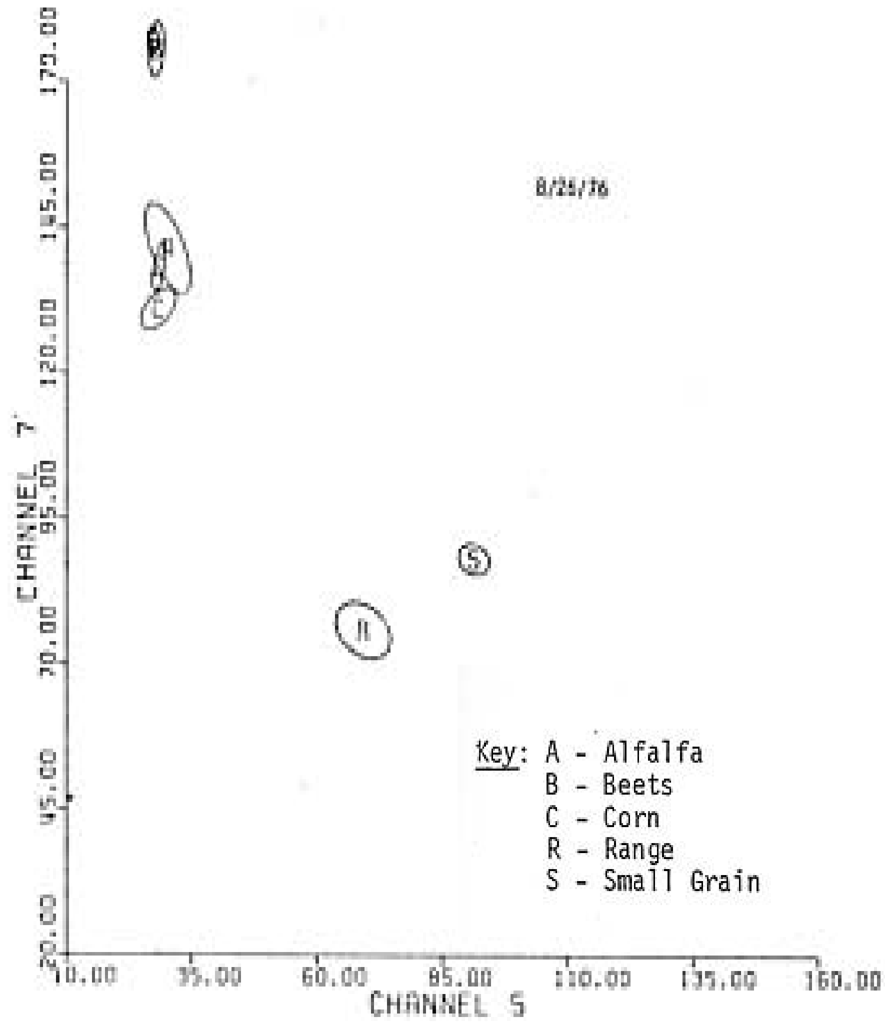
Crops in Colorado, July 3



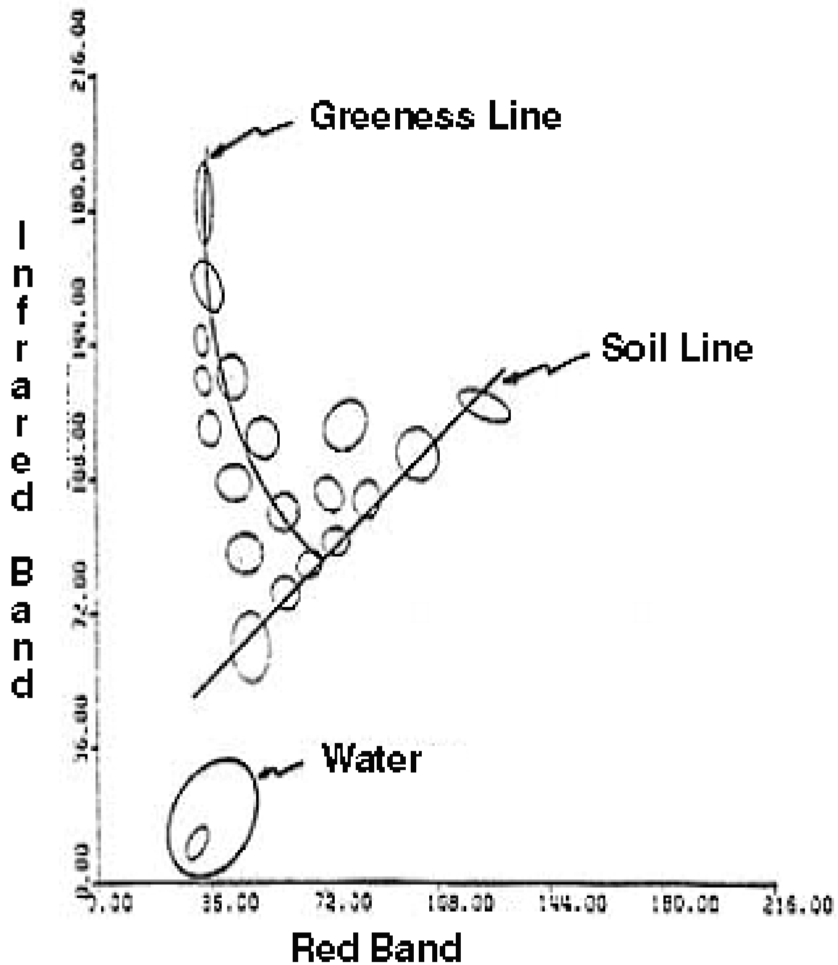


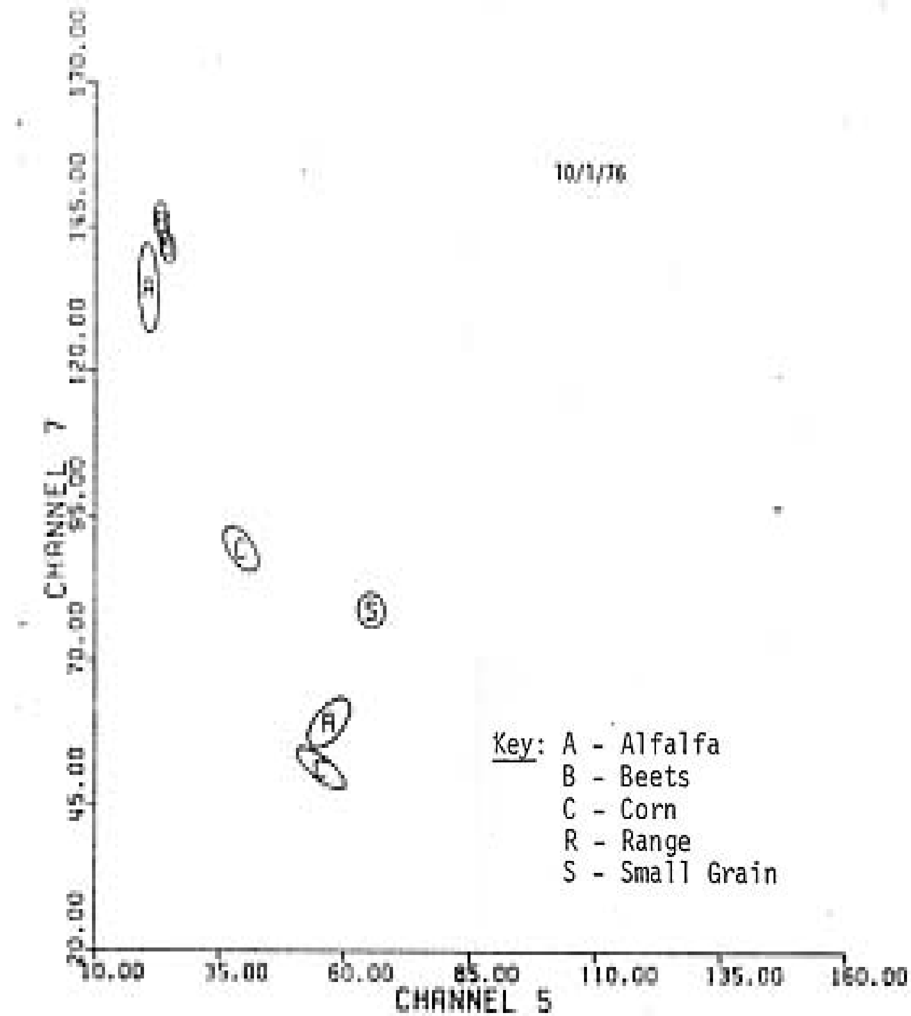
Crops in Colorado, August 26





Crops in Colorado, October 1





Landscape Ecology Metrics

- Vegetation indices measure effects in individual pixels
- General "health" of land may depend on pixel to pixel differences (e.g. diversity of vegetation types)

- Patch unit: Pixels with the same signal
- Pattern unit: Collection of patch units which are "minimum unit descriptor" of larger spatial area
- Landscape units: (e.g. Watersheds, Landscape pattern types)

- Example of 3 metrics
  - Dominance (0 – 1) Measure of diversity of land cover
  - Contagion (0 – 1) How "clumped" are different covers?
  - Fractal Dimension: Human landscapes geometrically "simple" while natural landscapes are complex