• 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
    • We’ve actually covered most of this in labs Sabins Ch. 10 (Oil exploration in Sudan and central Saudi Arabia)
Vegetation Overview

- References:
  - Sabins: Chapter 12
  - Jenkins, “Remote Sensing of the Environment” 2\textsuperscript{nd} 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
- $\text{H}_2\text{O}$ absorptions in Short-wavelength IR (SWIR)
- Slow decline in reflectance from NIR to 3 $\mu$m
Photosynthesis

- $6 \text{CO}_2 + 6 \text{H}_2\text{O} + \text{light energy} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6 \text{O}_2$
- 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
    - “Photosynthetically active radiation”
- Most sensitive region to detect Stress
  - less chlorophyll
  - less absorption: “chlorotic”
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)

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)
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 – LEAF ADDITIVE REFLECTANCE IMPORTANT
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
NDVI: \((\text{NIR}-\text{Red})/(\text{NIR}+\text{Red})\) For Landsat TM: \((\text{Band}_4 - \text{Band}_3)/(\text{Band}_4 + \text{Band}_3)\)

- Measures amount of vegetation by sensing characteristic difference between the very reflective NIR band and the chlorophyll absorbed Red band

NDMI: \((\text{NIR}-\text{SWIR})/(\text{NIR}+\text{SWIR})\) For Landsat: \((\text{Band}_4 - \text{Band}_5)/(\text{Band}_4 + \text{Band}_5)\)

- 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 \(\mu\text{m}\) (although you might also be able to use Band 7 at 2.22 \(\mu\text{m}\) if Band 5 was not available.)
Spectra of different (Fig 11-12)

Spectra of most vegetation is very similar – differences subtle

In above plot spectra offset for clarity – i.e. average reflectance similar

Subtle differences may allow you to distinguish different types of vegetation
Angular Effects – Both for vegetation and geology

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

Field Goniometer
Solar zenith angle $= 35^\circ$

Jenson Figure 11-10
3 Essential Angles Involved:

- Incidence angle $\theta_i$ below
- Emission angle $\theta_r$ below
- Phase angle $\alpha$ 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

- 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
- Spectrum will be different for different viewing geometries

Jenson 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).
• 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.
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

Simple Ratio

$$SR = \frac{R_{NIR}}{R_{Red}}$$

Normalized Difference Vegetation Index

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

Normalized Difference Moisture Index

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

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

Tasseled Cap Transformation

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

Jenson Figure 11-21a
GLOBAL MODIS NDVI
available at <http://neo.sci.gsfc.nasa.gov/>
Kauth-Thomas Tasseled Cap Transformation

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
\[
SR = \frac{R_{\text{NIR}}}{R_{\text{red}}}
\]

Normalized Difference Vegetation Index
\[
\text{NDVI} = \frac{(R_{\text{NIR}}-R_{\text{Red}})}{(R_{\text{NIR}}+R_{\text{Red}})} = \frac{(SR-1)}{(SR+1)}
\]

Tasseled Cap
Complex “rotation” to B, W, Third axes

Normalized Difference Moisture Index
\[
\text{NDMI} = \frac{(R_{TM4}-R_{TM5})}{(R_{TM4}+R_{TM5})} \quad (TM4 = 0.83\mu m \ TM5 = 1.65\mu m)
\]

Relative Water Content (in situ measurement)
\[
\text{RWB} = 100 \times \frac{(\text{field weight} - \text{oven dry weight})}{(\text{turgid weight} - \text{oven dry weight})}
\]
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

- 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

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).
Multiple Crops per Season

Phenological Cycles of San Joaquin and Imperial Valley, California, Crops and Landsat Multispectral Scanner Images of One Field During a Growing Season
Crops in Colorado, May 2

Key: A - Alfalfa
     B - Beets
     C - Corn
     R - Range
     S - Small Grain
Crops in Colorado, June 15

Key: A - Alfalfa
B - Beets
C - Corn
R - Range
S - Small Grain
Crops in Colorado, July 3

Key: A - Alfalfa
    B - Beets
    C - Corn
    R - Range
    S - Small Grain
Crops in Colorado, August 26
Crops in Colorado, October 1

Key: A - Alfalfa
    B - Beets
    C - Corn
    R - Range
    S - Small Grain
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