Spectral Reflectance Curves

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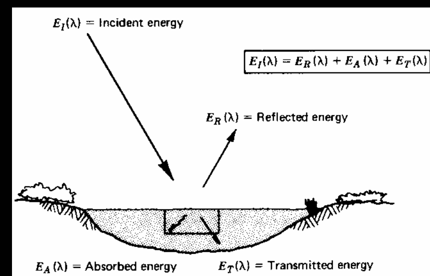
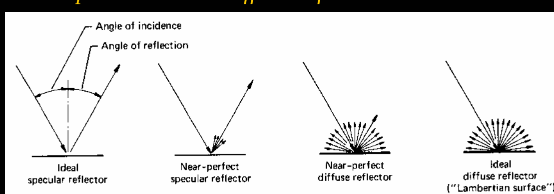
Energy Interactions with Earth Surface Features



$E_R(\lambda) = E_I(\lambda) – [E_A(\lambda) + E_T(\lambda)]$

- Proportions of energy reflected, absorbed and transmitted will vary for different earth features
- Even within a given feature type these proportions will vary at different wavelengths

Specular Versus Diffuse Reflectance



- Diffuse reflections contain spectral information on the "color" of the reflecting surface, whereas specular reflections do not

Hence, in remote sensing, we are most often interested in measuring the diffuse reflectance properties of terrain features.

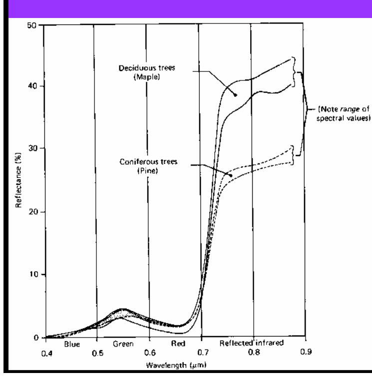
Spectral Reflectance - Albedo

$$R_\lambda = \frac{E_R(\lambda)}{E_I(\lambda)} = \frac{\text{Energy of wavelength } \lambda \text{ reflected from the object}}{\text{Energy of wavelength } \lambda \text{ incident upon the object}}$$

Albedo of various surface features

Surface Type	Albedo (%)
Grass	25
Concrete	20
Water	5–70
Fresh snow	80
Forest	5–10
Thick cloud	75
Dark soil	5–10

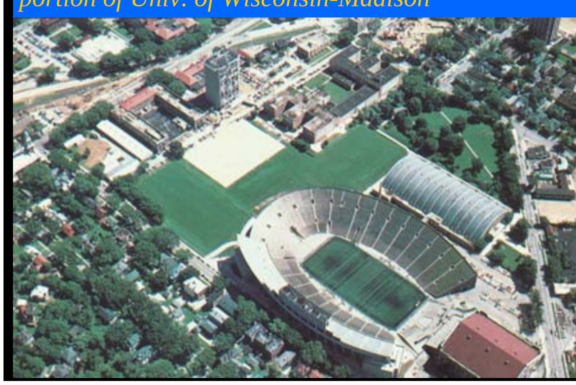
Generalised Spectral Reflectance Envelopes for Deciduous (Broad-leaved) and Coniferous (Needle-bearing leaves) Trees



Spectral reflectance curve for each type overlap in most of the visible portion

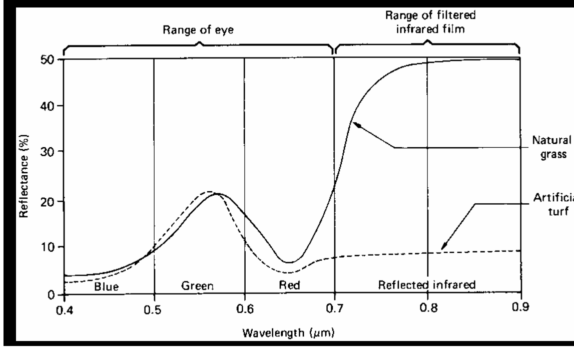
However, in NIR they are quite different and distinguishable

Oblique normal color aerial photograph showing portion of Univ. of Wisconsin-Madison



Oblique color infrared aerial photograph showing portion of Univ. of Wisconsin-Madison

Spectral Reflectance Curves for Natural Grass and Artificial Turf



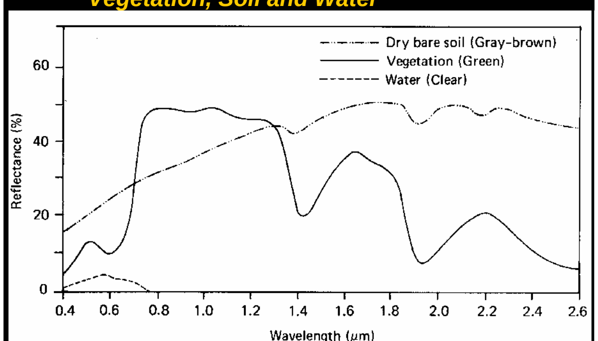
Visible versus Infrared Photos

Visible Portion (Panchromatic)

Near Infrared

Football field has Artificial Turf

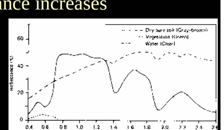
Typical Spectral Reflectance curves for Vegetation, Soil and Water



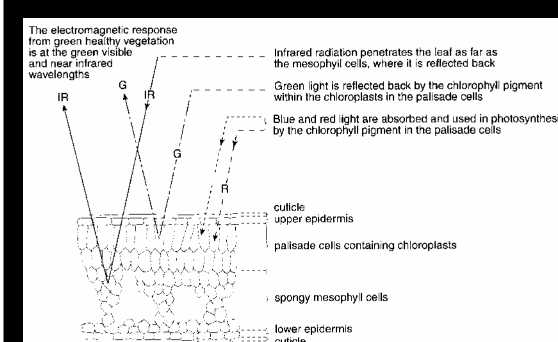
Lines in the figure represent ***average*** reflectance curves

VEGETATION *(Healthy Green Vegetation)*

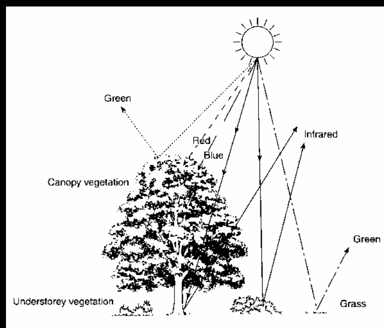
- 'Peak and Valley' configuration
- VISIBLE RANGE
  - Valleys in the visible portion are dictated by the pigments in plant leaves
  - Chlorophyll strongly absorbs energy in 0.45-0.65 μm (Chlorophyll Absorption band)
  - If Vegetation is subjected to stress, chlorophyll content reduces and red reflectance increases
- NIR RANGE (0.7 to 1.3 μm)
  - Very high reflectance (50%)
  - Remaining energy transmitted (very little absorption)
  - Depends on Plant leaf structure
  - Useful for identification of different species
  - Useful for vegetation condition monitoring



Leaf Structure and Reflectance

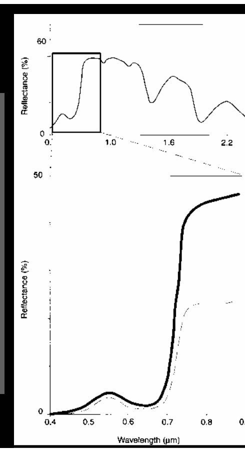


Reflectance from Forest canopy and Layered vegetation

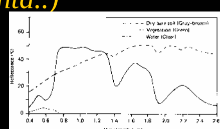


Healthy Vs Stressed Vegetation

- If Vegetation is subjected to stress, chlorophyll content reduces and red reflectance increases
- NIR Range is useful for identification of different species
- Useful for vegetation condition monitoring



VEGETATION (Contd..)

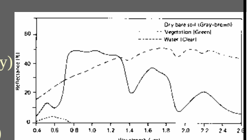


- BEYOND 1.3 μm
  - Essentially reflects or absorbs with little transmittance
  - At 1.4, 1.9, and 2.7 μm water in leaf absorbs strongly

    (Water Absorption Bands)
  - Leaf reflectance is approximately inversely related to the total water present in a leaf

SOIL (Dry Bare Soil – Grey-brown Loam)

- Factors affecting soil reflectance
  - Moisture content
  - Soil texture (proportion of sand, silt, and clay)
  - Surface roughness (reduces reflectance)
  - Iron oxide (reduces reflectance)
  - Organic matter content (reduces reflectance)

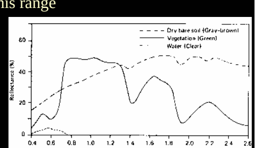


- Inter-related
  - Coarse textured dry soils will have more reflectance than fine textured soils (reverses if water is present)
- Rocks
  - Aggregates of minerals
  - Reflectance depends on mineral composition
  - Weathered surface

WATER (clear deep water body)

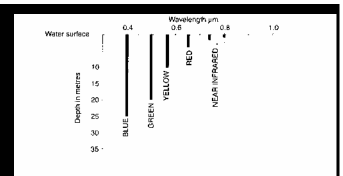
Most of the energy is either absorbed or transmitted

- VISIBLE RANGE
  - Little energy is reflected only in this range
  - Water quality studies
  - Shallow Vs Deep water
  - Clear Vs Turbid water
  - Rough Vs Smooth

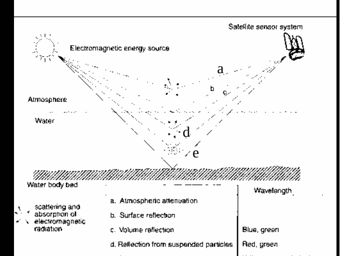


- NIR RANGE (0.7 to 1.3 μm)
  - Completely absorbs
  - Useful for delineating water bodies
  - Algal bloom and/ or Phytoplankton results in reflection

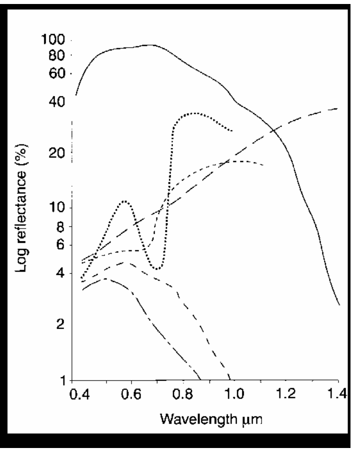
Depth of Penetration of Radiation into clear calm Water Body



Complex Spectral Response from a Water Body



Spectral reflectance curves (Spectral Signatures) for different natural surfaces in Visible & NIR wavelengths



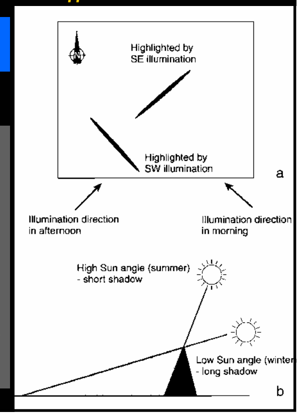
Spatial and Temporal Effects

- Change of reflectance in space
- Change of reflectance in time

Effects of solar elevation and direction on the detection of features on remotely sensed images

(a) Features trending parallel to the illumination direction tend to be subdued whereas features at right angles are highlighted

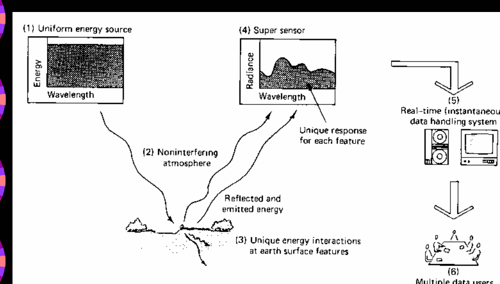
(b) Low-angle illumination highlights topographic features whereas a higher Sun angle allows a better discrimination of tonal variations



Ideal Remote Sensing System

- Uniform Energy Source
  - Source would provide energy over all wavelengths, at a constant, known, high level of output, irrespective of time and place
- Non interfering atmosphere
  - Atmosphere would not modify the energy from the source in any manner
- Unique Energy/ Matter Interactions at the Earth's Surface
  - Reflectance is invariant and unique to each and every earth surface feature
- Super Sensor
  - Highly sensitive to all wavelengths
  - Simple, reliable, require virtually no power or space, be accurate, and economical to operate
- Real-Time Data Handling System
  - Derived data would provide insight into the physical-chemical-biological state of each feature of interest
- Multiple Data Users
  - Knowledge in subject domain & RS image interpretation
  - Same set of data would become various forms of information

Components of an Ideal Remote Sensing System



Real Remote Sensing System

- Energy Source
  - Solar energy
  - Microwave for Active remote sensing
  - RS at specific local time
- Atmosphere
  - Atmospheric windows
- Energy/Matter Interactions
  - Spectral signature and Spectral similarity
- Sensor
  - All sensors have fixed range of spectral sensitivity
  - Limitation on spatial resolution
- Real-Time Data Handling System
  - Capability of current remote sensors to generate data far exceeds the current capacity to handle these data
- Multiple Data Users
  - No single combination of data acquisition and analysis procedures will satisfy the needs of all data users

Advantages of Remote Sensing

- Ability to view large parts of the globe at different scales (Synoptic View)
- Capability to monitor regions which may be very remote or where access is denied
- Ability to analyse different surfaces at wavelengths not detectable to the human visual system
- Ability to obtain imagery of an area at regular intervals over many years in order that changes in the landscape can be evaluated
- Capability to see human-induced effects on our planet

- Disadvantages
  - Certain skill level is required to interpret the imagery
  - Interpretation based solely on remotely sensed data should be treated with caution unless supported by ground verification data.