Satellite sensor types

We stated in class that electromagnetic energy interacts most strongly with objects about the size of the wavelength. Thus if we break the spectrum down by wavelength we can identify what physical processes each region is sensitive to. The following table lists the parts of the spectum used in remote sensing, with the main ones of interest highlighted by a *.

TABLE 1.3 Electromagnetic spectral regions

Region	Wavelength	Remarks
Gamma ray	< 0.03 nm	Incoming radiation is completely absorbed by the upper atmosphere and is not available for remote sensing.
X-ray	0.03 to 3.0 nm	Completely absorbed by atmosphere. Not employed in remote sensing.
Ultraviolet	0.03 to 0.4 μm	Incoming wavelengths less than 0.3 μm are completely absorbed by ozone in the upper atmosphere.
Photographic UV band	0.3 to 0.4 μm	Transmitted through atmosphere. Detectable with film and photodetectors, but atmospheric scattering is severe.
Visible *	0.4 to 0.7 μm	Imaged with film and photodetectors. Includes reflected energy peak of earth at 0.5 μm.
Infrared *	0.7 to 100 μm	Interaction with matter varies with wavelength. Atmospheric transmission windows are separated by absorption bands.
Reflected IR band *	0.7 to 3.0 μm	Reflected solar radiation that contains no information about thermal properties of materials. The band from 0.7 to 0.9 μm is detectable with film and is called the *photographic IR band*.
Thermal IR band *	3 to 5 μm, 8 to 14 μm	Principal atmospheric windows in the thermal region. Images at these wavelengths are acquired by optical-mechanical scanners and special vidicon systems but not by film.
Microwave *	0.1 to 30 cm (same)	Longer wavelengths can penetrate clouds, fog, and rain. Images may be acquired in the active or passive mode.
Radar *	0.1 to 30 cm (same)	Active form of microwave remote sensing. Radar images are acquired at various wavelength bands.
Radio	> 30 cm	Longest wavelength portion of electromagnetic spectrum. Some classified radars with very long wavelength operate in this region.

TABLE 2-2. Wave–Matter Interaction Mechanisms across the Electromagnetic Spectrum

Spectral Region	Main Interaction Mechanisms	Examples of Remote Sensing Applications
Gamma-rays, x-rays	Atomic processes	Mapping of radioactive materials
Ultraviolet	Electronic processes	Presence of H and He in atmospheres
Visible and near infrared	Electronic and vibration molecular processes	Surface chemical composition, vegetation cover, and biological properties
Mid-infrared	Vibrational, vibrational-rotational molecular processes	Surface chemical composition, atmospheric chemical composition
Thermal infrared	Thermal emission, vibrational and rotational processes	Surface heat capacity, surface temperature, atmospheric temperature, atmospheric and surface constituents
Microwave	Rotational processes, thermal emission, scattering, conduction	Atmospheric constituents, surface temperature, surface physical properties, atmospheric precipitation
Radio frequency	Scattering, conduction, ionospheric effect	Surface physical properties, subsurface sounding, ionospheric sounding

Exactly which bands we use will of course depend on what we are trying to study. Recall that when energy is incident on Earth, some is reflected directly and some absorbed and re-emitted later. Since the solar spectrum is concentrated in the visible and near IR, in those regions we are looking at reflected energy, while at longer wavelengths (lower energy) we are viewing radiation emitted by the Earth.

In the microwave region we will see that we'll be most sensitive to macroscopic physical characteristics such as surface roughness and topography.

We'll look at a few examples of different image types.

Identifying Surface Materials

Let's consider the reflected energy spectrum first. This will be most applicable to the visible and near IR region.

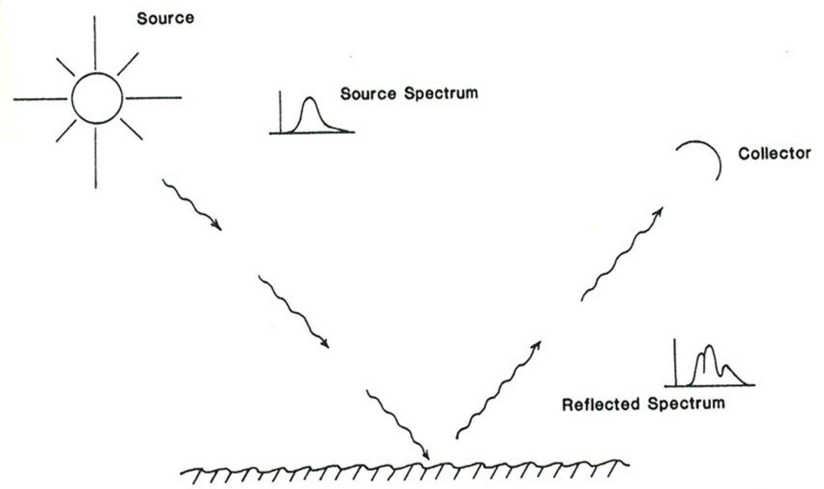


Figure 3-1. The surface spectral imprint is reflected in the spectrum of the reflected wave.

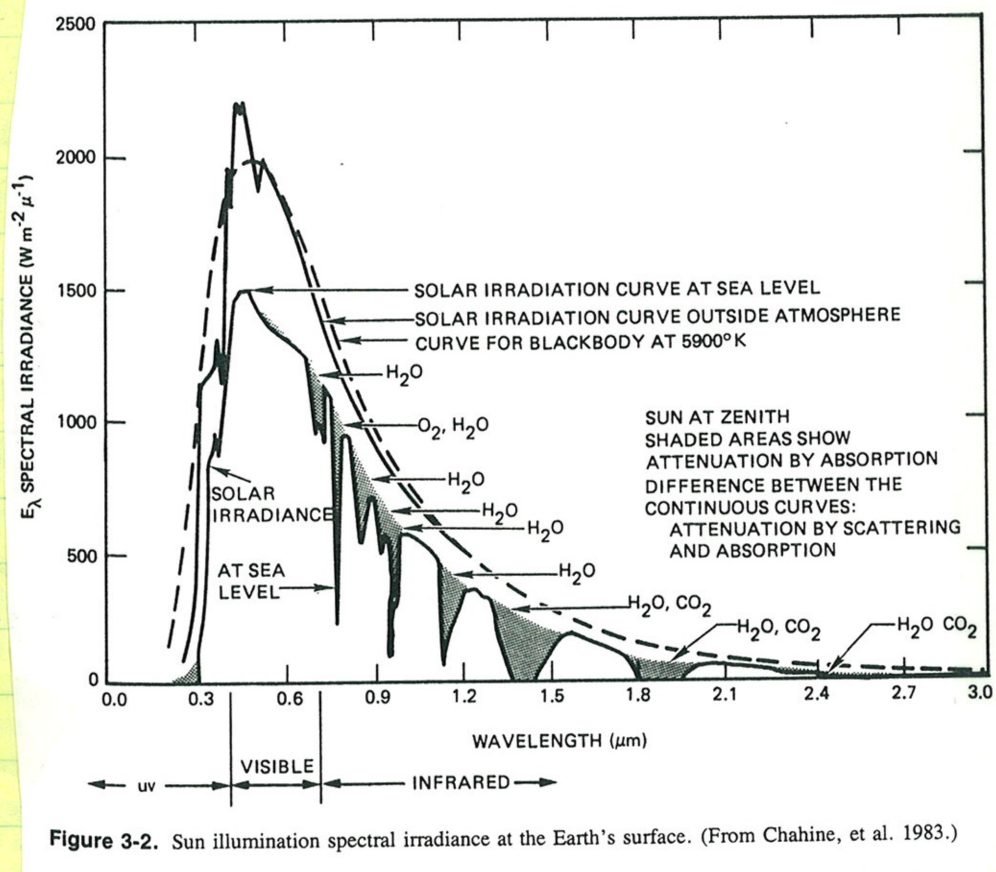


Figure 3-2. Sun illumination spectral irradiance at the Earth's surface. (From Chahine, et al. 1983.)

Geologic materials

While the exact reflectance spectrum of every mineral is different, much as our finger-prints differ, there are certain features that are easy to recognize and can be used for classification of geologic materials.

Water-bearing minerals - These show the characteristic signature of water at 1.4 μm and 1.9 μm. One problem with these and remote sensing - the atmosphere also contains water, masking the effect.

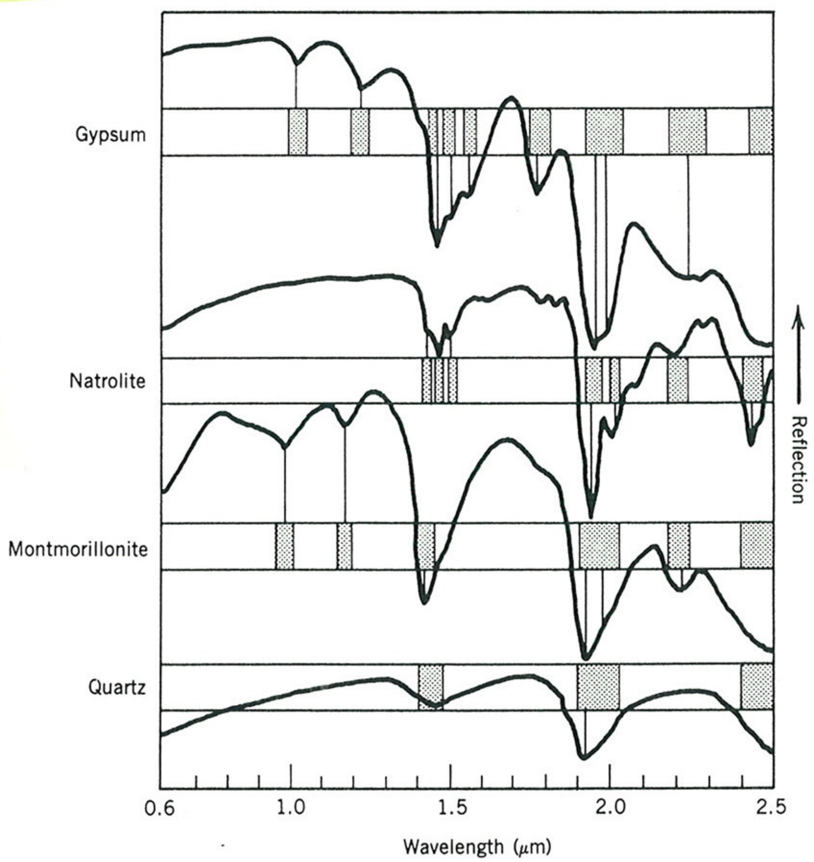


Figure 3-10. Spectra of water-bearing minerals illustrating the variations in the exact location and shape of the spectral lines associated with two of the tones of the water molecule: $2\nu_3$ near 1.4 μm and $\nu_2 + \nu_3$ near 1.9 μm. (From Hunt, 1977.)

Hydroxyl (OH) bearing minerals. These minerals display bands at 1.4 μm and 2.3 μm, and are therefore separable from the water group.

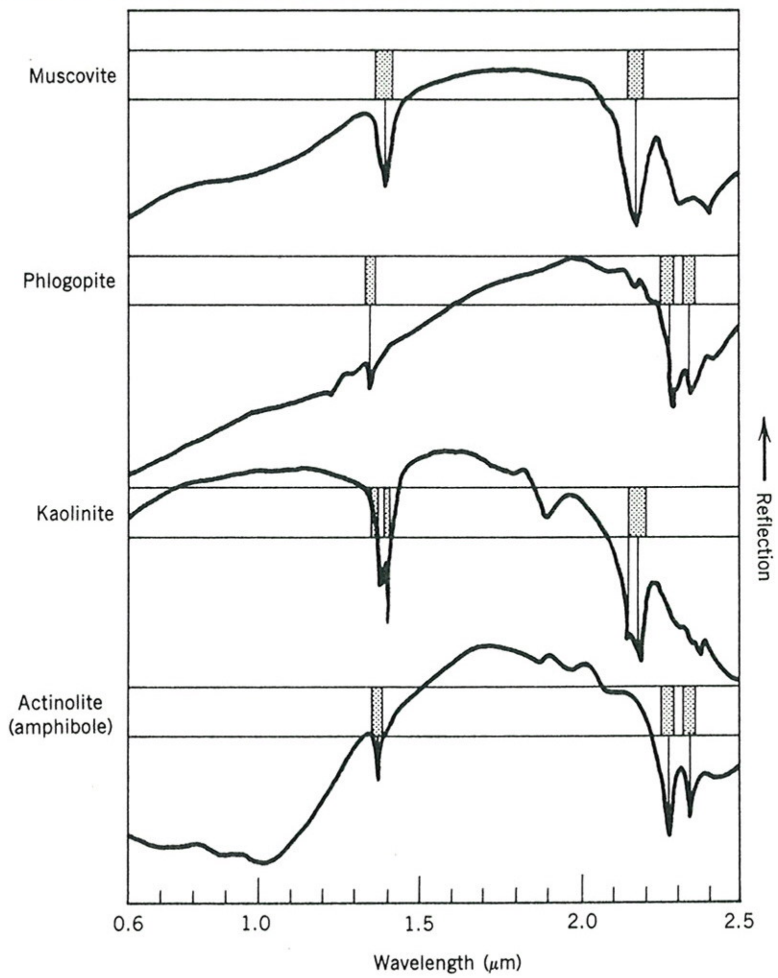
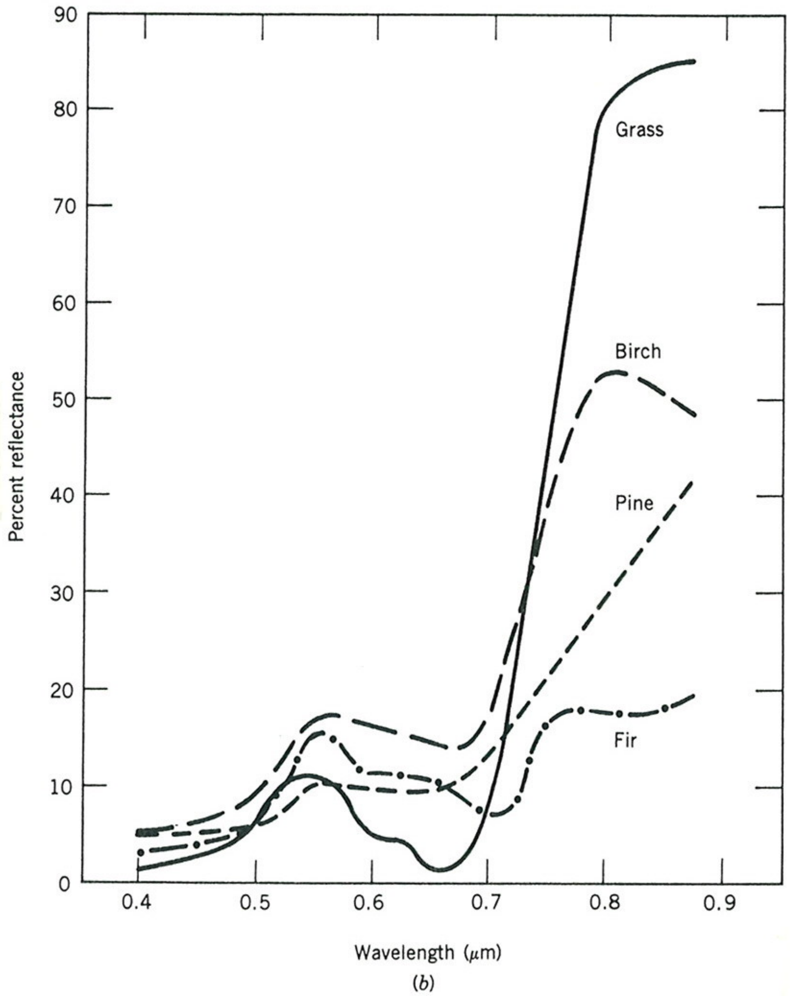


Figure 3-11. Spectra displaying the hydroxyl group tones: overtone near 1.4 μm and combination tones near 2.3 μm. (From Hunt, 1977.)

Again, atmospheric ~~interactions~~ interactions may mask some of the features. But careful choice of observational bands may still allow discrimination.

Biological materials

All chlorophyll-containing materials exhibit a peak in their reflectance spectrum at 0.55 µm, in the green portion of the spectrum. Vegetation is also usually highly reflective in the near IR, which is why it appears bright red in the color IR images.



(*b*)

Figure 3-19. (*Continued*) (*b*) Reflectance of various types of foliage. (From Brooks, 1972.)

Other examples follow:

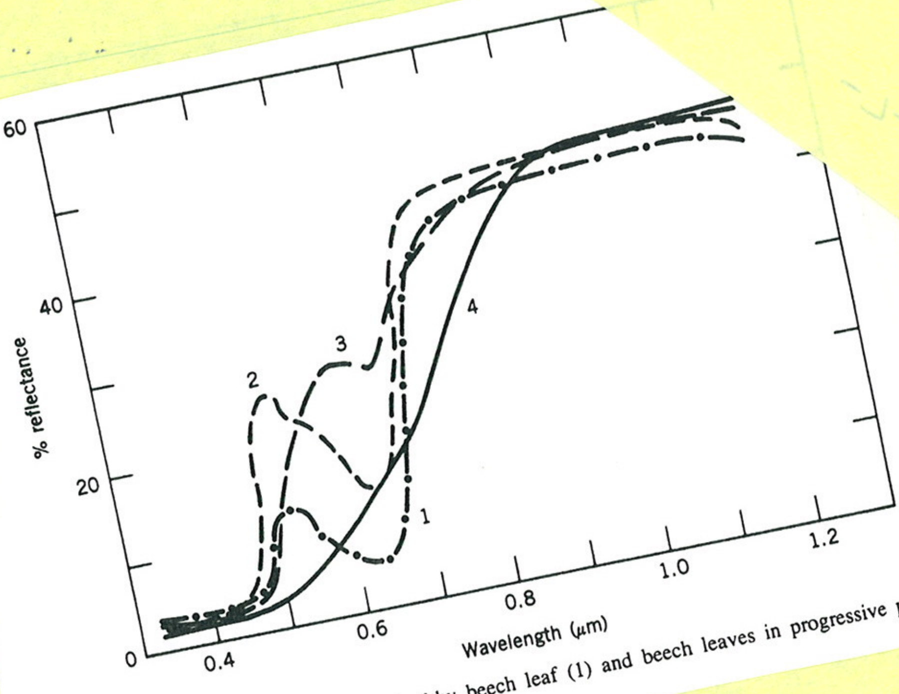


Figure 3-22. Reflectance spectra for a healthy beech leaf (1) and beech leaves in progressive phases of senescence (2–4). (From Knipling, 1969.)

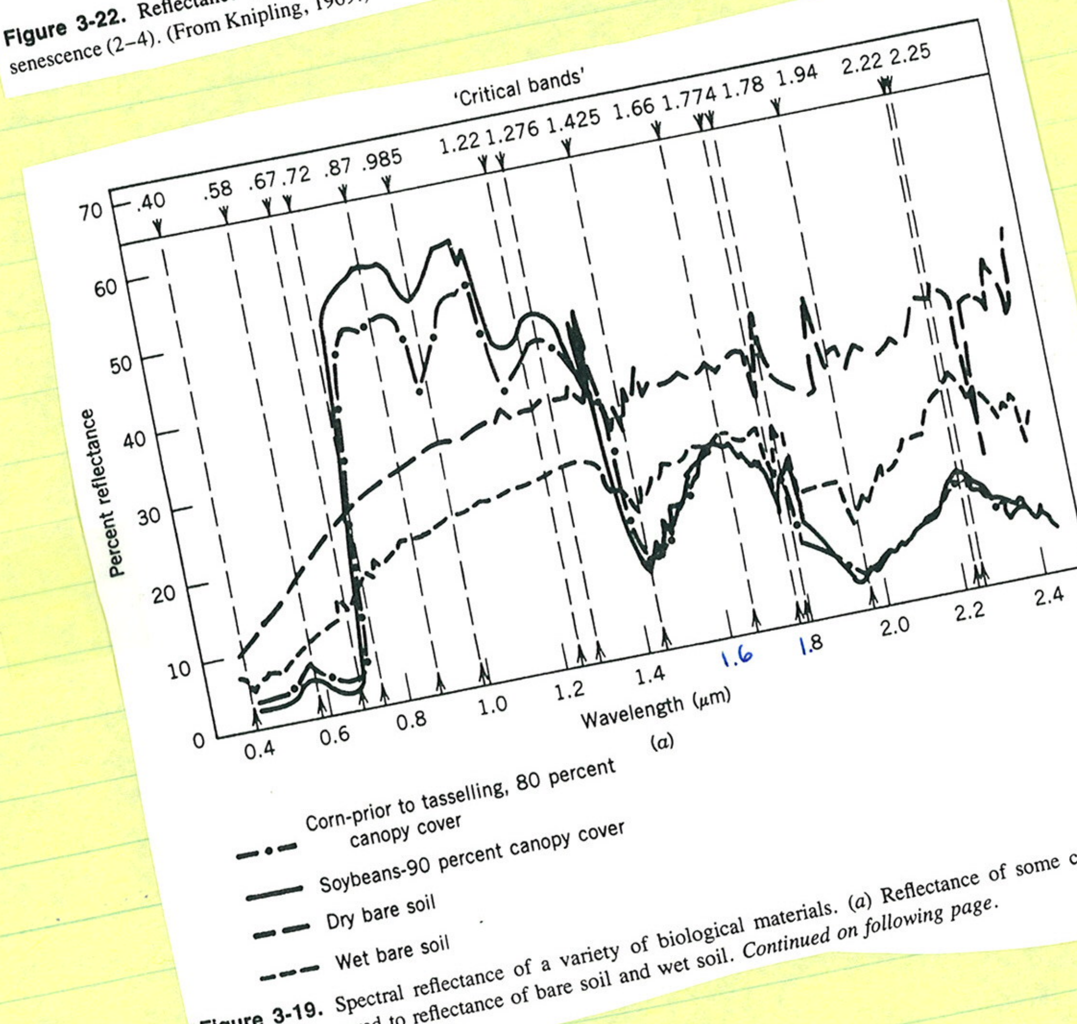


Figure 3-19. Spectral reflectance of a variety of biological materials. (*a*) Reflectance of some cultivated vegetation compared to reflectance of bare soil and wet soil. *Continued on following page.*

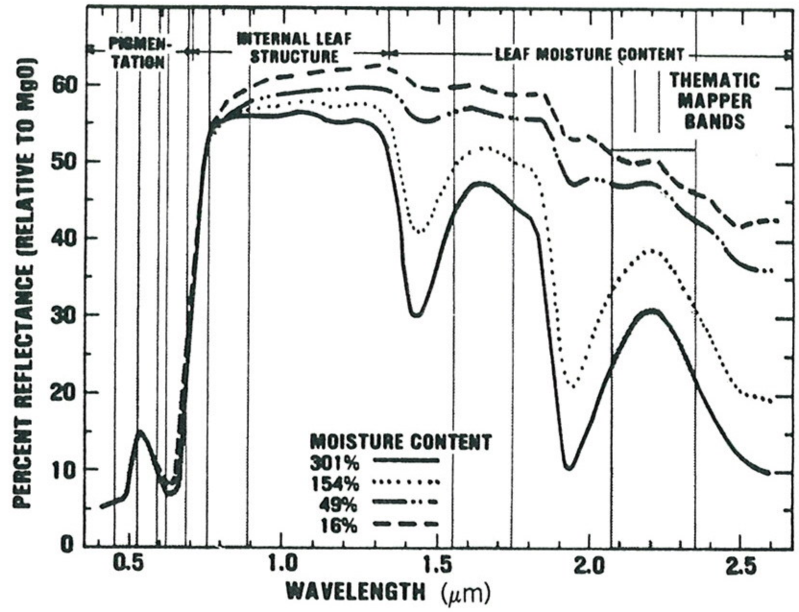


Figure 3-20. Progressive changes in the spectral response of a sycamore leaf with varying moisture content (Short, 1982).

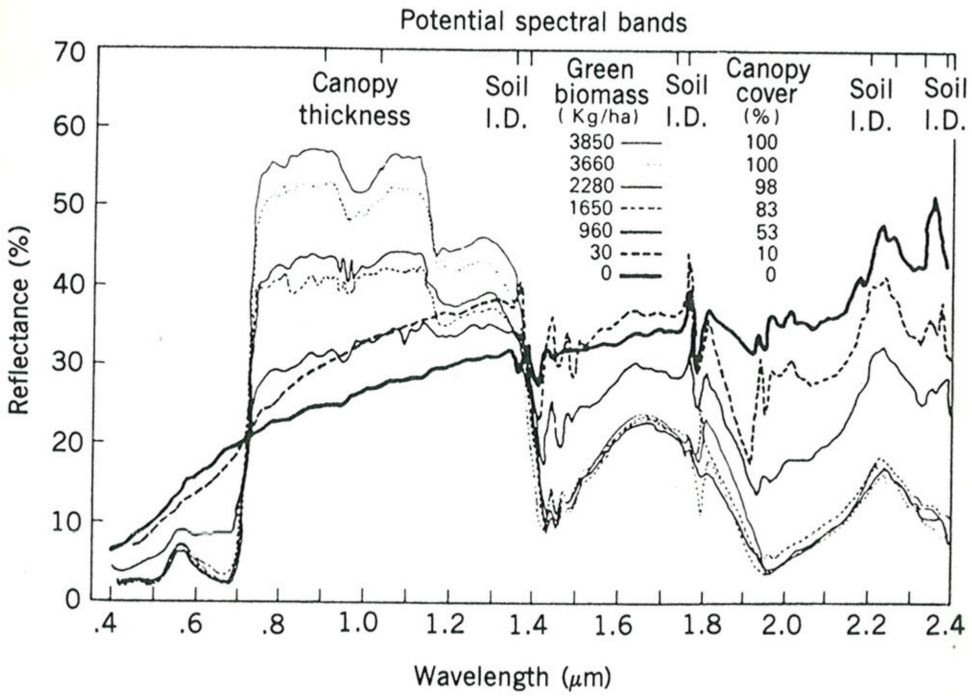


Figure 3-21. Variations in spectral reflectance as functions of amounts of green biomass and percent canopy cover (Short, 1982).

Because of the biological material high reflectivity at the near IR, people often look at the ratio of reflectance at IR and visible as an indicator for vegetation and vegetation stress.

Sometimes the data are displayed with the IR reflectance coded as red and the visible channels in green and blue, as in the USA mosaic. This was acquired by the AVHRR satellite, for Advanced High Resolution Radiometer. This instrument has five channels, two of which are

Channel 1: 0.58 - 0.68 um   Red visible spectrum
Channel 2: 0.72 - 1.1 um   Near infrared

At other times the data reduced to a quantity denoted "Normalized Difference Vegetation Index", or NDVI. If R_V denotes reflectance in the red visible, and R_{IR} reflectance in the IR, using the bands above we define

$$NDVI = \frac{R_{IR} - R_V}{R_{IR} + R_V}$$

This results in a quantity that is a single number and is qualitatively related to vegetation density. Tracking this quantity over time results in a way to monitor vegetation growth, dieback, and regrowth.