Remote Sensing (fjärranalys)

(Ur The Precision Farming Primer av Joseph K. Berry, Topic 7, http://www.innovativegis.com/basis/pfprimer/Default.html)

The GIS/GPS technologies position both *spatial data* and *spatial relationships* on the landscape. But how to effectively identify, measure and monitor farm conditions is a continuing challenge. A GIS and its closely related field of *remote sensing* form an alliance that greatly enhances the technical toolkit for mapping. Remote sensing is actually GIS's older brother, having its modern roots in World War II. Camouflage detection film was used to distinguish between healthy vegetation and cut branches piled on top of military equipment. To the human eye and normal film the healthy and cut branches were both green (at least for a few days), but on the new film they showed up as two different colors.

Remote sensing uses relative variations in *electromagnetic radiation* (EMR) to identify landscape characteristics and conditions. In fact, so do your eyes. Sunlight (the "visible" form of EMR) starts off with fairly equal parts of blue, green and red light. When sunlight interacts with an object, the object's composition causes it to absorb varying amounts of the different wavelengths of EMR "light." What light isn't absorbed is reflected to your eyes. Your brain interprets the subtle differences in the amount of blue, green and red in the reflected light to recognize the thousands of colors we relate to our surroundings.

Vegetation is particularly "photogenic" because of its structure, pigments and water content. Since sunlight is a plant's source of energy, it goes out of its way to present its leaves in the best possible light. When thousands of plants in a field align themselves, their structure forms an excellent receptor and reflector of sunlight.

The physiology of a leaf determines the relative absorption and reflection of light. The equal portions of blue, green and red light from the sun are basically unaffected by the surface of the leaf, but when it encounters the *chloroplasts* containing *chlorophyll A* and *B* it is radically altered (see fig. 7.8). These pigments absorb most of the blue and red light for the energy needed in photosynthesis used in plant growth and maintenance. Other pigments in the leaf (i.e., *carotines*) absorb lesser amounts of the other wavelengths of light.

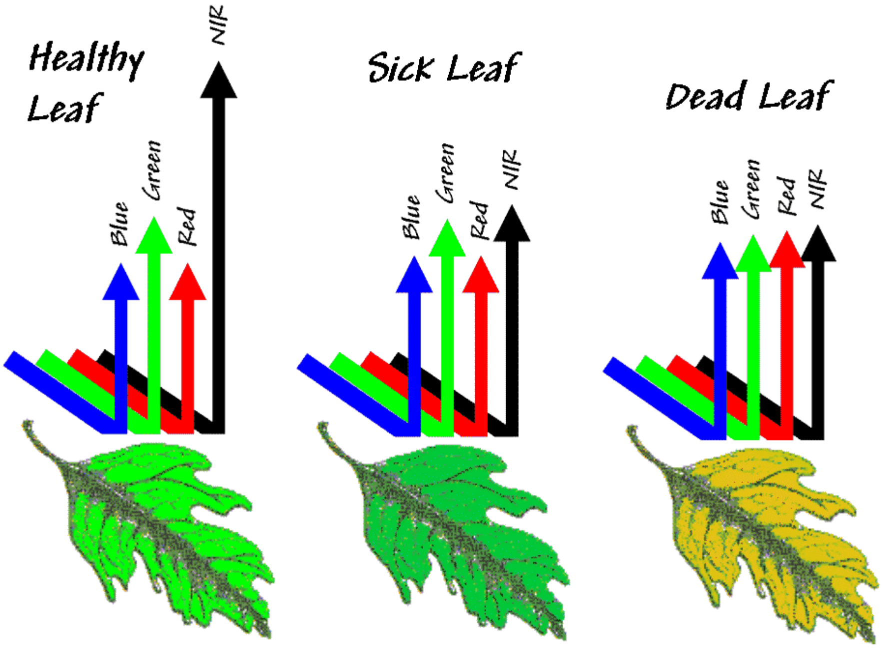

Figure 7.8. Plant physiology determines the quality (color) of reflected light from a leaf.

As the pigment-altered light continues deeper into the leaf, it interacts with the spongy mesophyll. This bubble-like structure acts like a mirror and reflects the light back toward the sky. Since the blue and red wavelengths have been diminished, we see a predominance of green in the reflected light—a healthy "green" leaf (because blue and red are usurped by the plant).

An unhealthy leaf, however, looks a lot different, particularly in remote sensing imagery. When water pressure changes (i.e., cutting a branch from its stem), the spongy messophyll in the leaves collapse within hours and this area's efficiency of reflecting light is greatly reduced. The chloroplasts, on the other hand, keep on working away at photosynthesis for several days. The result is that we "see" a slight change in reflectance (predominantly green) at first, then a slow progression to brown as the chloroplasts eventually quit preferentially absorbing blue and red light.

However, what makes remote sensing's view different is its ability to look at reflected light beyond visible blue, green and red light. "Invisible" *near-infrared light* (*NIR*) is at wavelengths just beyond the red light your eyes can detect. These wavelengths are unaffected by the plant's pigments and are highly reflected by the spongy mesophyll. When the "bubbles" in this portion of a leaf collapse, there is an immediate and dramatic change in the reflectance of near-infrared light. That's the principle behind camouflage detection film—we see a branch as green for days; remote sensing imagery detects a dramatic difference in near-infrared light in a matter of hours.

What makes remote sensing data so useful is that it encapsulates biological and physical characteristics into an image. The encrypted variations in reflected light emanating from a field provides information about changing conditions and crop status—important stuff you should keep your eye on.

Figure 7.9 extends the discussion of the basic concepts of plant physiology and its interactions with light from a plant to a whole field. From a simplified view, as more biomass is added the reflectance curve for bare soil (similar to a dead leaf) is transformed into a *spectral signature* that typifies one big green leaf. As the crop matures, the reflectance pattern changes again. How spectral signatures change provide valuable insight into field conditions.

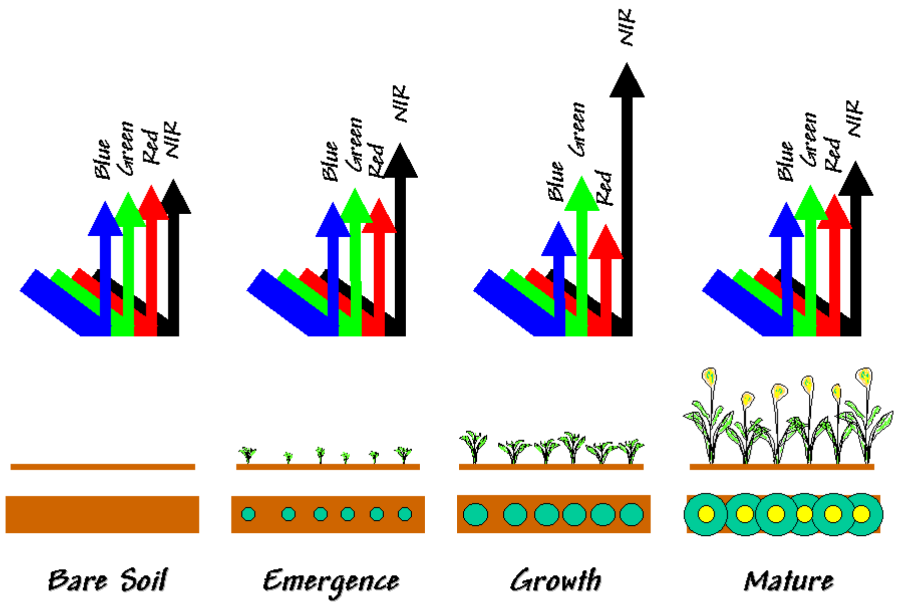

Figure 7.9. Reflectance from various field conditions.

You now have a basic understanding of what happens to light in a plant canopy, let's take a loftier view and see how it is translated into a computer image. An aerial camera operates like your eye, except photographic paper replaces the optical nerves in the retina. The image is focused through the lens, with variation in light recorded by a photochemical process on the film.

The scanner in a satellite operates a bit differently—more like your laser printer that "sees" the world through thousands of dots. Its sensor focuses for an instant at a spot on the ground (a few meters in diameter) as shown in figure 7.10. Like your eyes, it records the relative amounts of the different types of light it "sees"—a lot of green for a dense healthy crop; much less green and more blue and red for bare ground. In addition to normal light (termed the *visible spectrum*), it can record other types that we can't see, such as *near infrared*, *thermal* and *radar* energy. The sensor sweeps from side to side and the satellite moves forward, recording the relative amounts of light reflected from millions of spots on the ground.

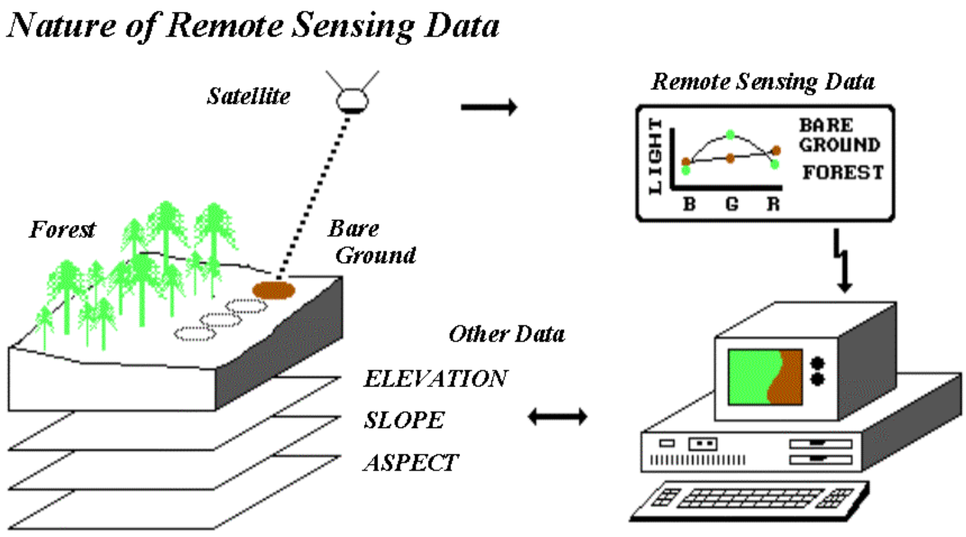

Figure 7.10. Remote sensing data is composed of millions of numbers tracking the reflected energy from spots on the ground.

When these spots (termed *pixels* for "picture elements") are displayed on a computer, they form an image similar to an aerial photograph. In fact, a photograph can be "scanned" to generate a digital image—like pulling the satellite out of the sky and passing it over the photo instead of the actual terrain. The important point is that behind any digital image there are millions of numbers recording the various types of light reflected from each instantaneous spot.

Three factors govern the quality and appropriateness of remote sensing data: 1) spatial, 2) spectral and 3) temporal resolutions.

Spatial resolution identifies the smallest thing (*spatial unit*) contained in the data. In a photograph, it is a glob of developed crystals embedded in the emulsion; in a digital image it's the size of the pixel. Up to a point, smaller is better. If there is too much spatial detail, you "can't see the forest for the trees," nor store the burgeoning file.

Spectral resolution refers to the number and width of the *wavelength bands* (colors) contained in the data. Again, more is better, up to a point. The human eye and normal film "see" just three broad bands of light—blue, green and red. Optical scanners can record many more narrowly defined bands that can be "tuned" for specific wavelengths to enhance features of interest. The ability to extend the bands beyond our vision (particularly to near infrared energy) and analyze just the important ones allows us to gain a lot more information from the data than simply viewing an image.

The rub is that there is a tradeoff between spatial and spectral resolutions—pushing both of them to the maximum results in too little energy for a sensor's detector. Early satellite systems required a lot of energy to activate their detectors; therefore, they only had four broad bands and a footprint of about an acre. Modern detectors can record many more narrow bands and commonly have a footprint of only a few meters. At these resolutions (spectral and spatial), even satellite data becomes appropriate for some aspects of site-specific management.

Temporal resolution refers to the time step between images. A series of images collected each week over a field provides far more information than a single image taken at just one point in the crop's growth. You guessed it; more is better, up to a point. But this time the point isn't driven by optical physics but your wallet. By its very nature, site-specific management implies small areas, while most remote sensing systems (particularly satellites) are designed to service large areas. Pricing and distribution channels for digital data in smaller bites (and bytes) and turn-around times needed by farmers are just now coming on line.

While the full potential of remote sensing might be just around the corner, an *aerial photo backdrop* is an essential element of any precision farming system. There's a growing number of ways you can acquire such an image. If you're lucky you can download a "rectified" image from the Internet or pick up one from a governmental agency in your locale. Some farmers have struck a deal with the local flight instructor to snap a few frames over their fields a couple of times a month. The 35 mm slides are scanned for a few dollars at growing numbers of photo shops. The digital images can be aligned in most desktop mapping systems using the GPS coordinates of a set of control points visible in the image.

Once the photo backdrop is in place, it immediately adds reality to the abstract lines and colors of a map. Important features and patterns can be encoded by tracing them directly on the screen (termed *heads-up digitizing*). This ability is an important component to drawing *management zones* discussed in "topic 2, Zones and Surfaces." Linking a differentially-corrected GPS unit to a portable computer allows you to "walk or drive" on a backdrop-photo (really cool!), encoding a map as you go (termed *feet-down digitizing*). Before you start drawing on maps, you need to realize that the patterns you see are the result of complex biological and physical interactions; you might "see" something, but be sure you know what it is before you canonize it as a map.