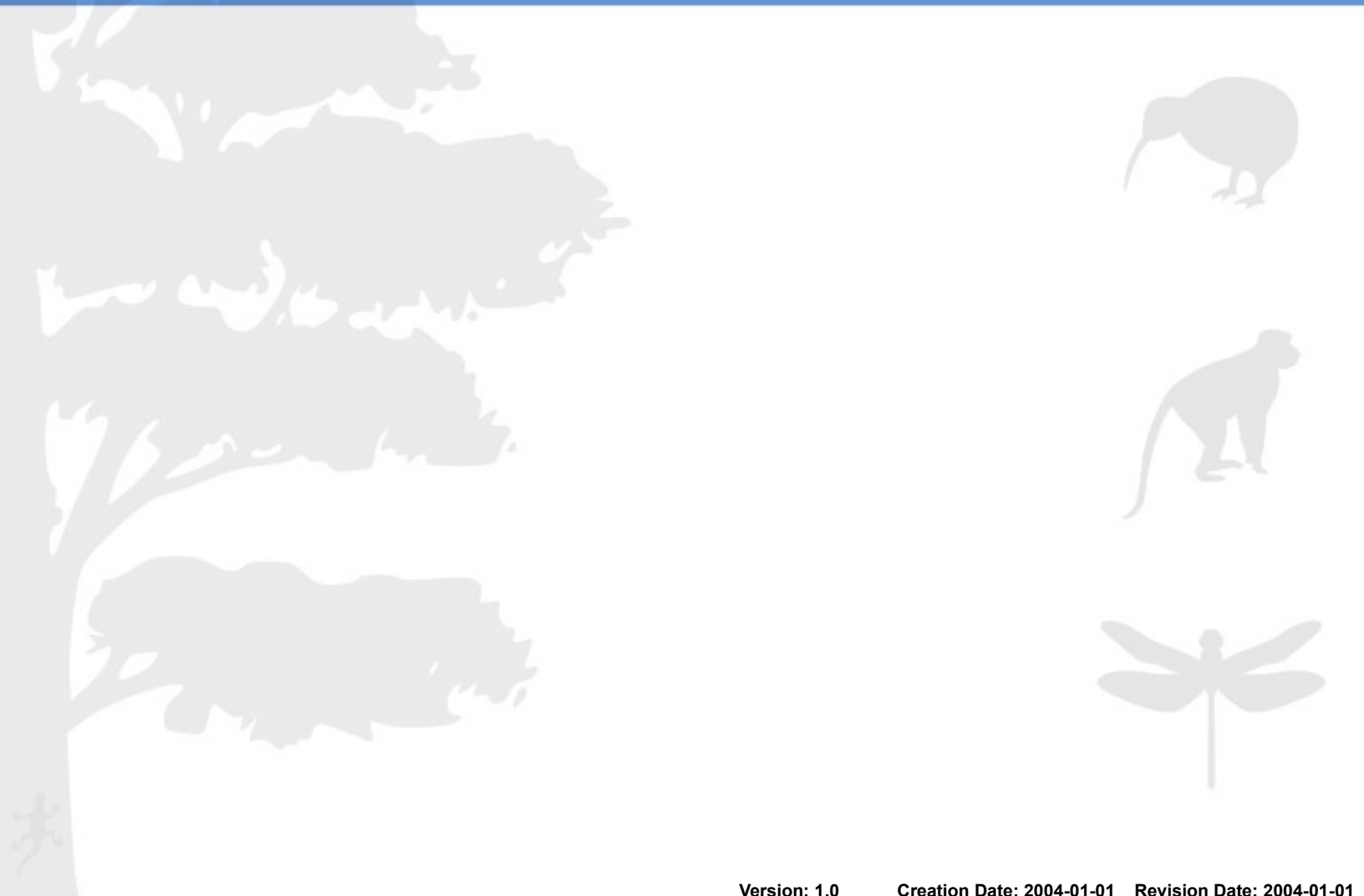# AMERICAN MUSEUM OF NATURAL HISTORY

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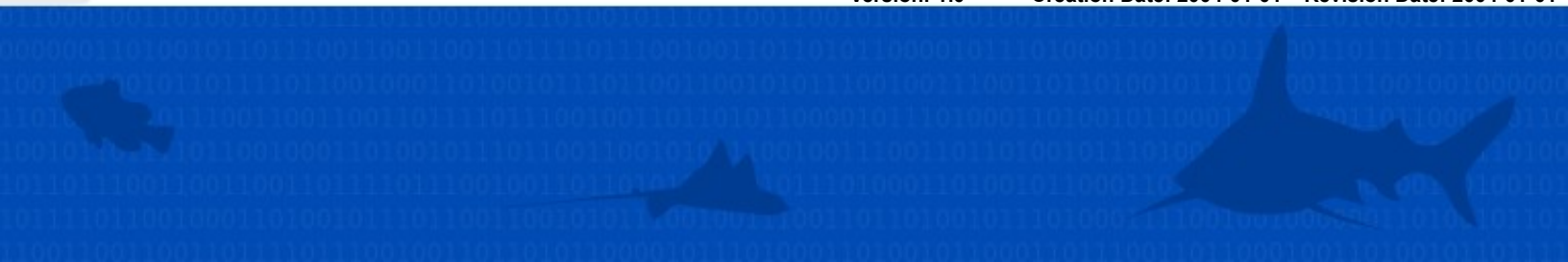
Ned Horning

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Selecting the appropriate band combination for an RGB image using Landsat imagery

This guide explains the concept of multiband or multispectral imagery and illustrates how individual bands can be used to identify different features on the ground and how these bands can be combined to create color pictures. Using this information we can select specific bands from a multispectral satellite image to create color pictures that are specifically tailored to facilitate the identification of the features of interest.

When we see a picture of a satellite image it often looks something like the image in Figure 1. Our initial thought may be that the satellite took this picture using an instrument similar to a digital camera. This analogy is a bit too simplistic but it is a good place for us to begin to understand how a satellite-based imaging sensor works. With a digital camera the detector inside the camera is recording three different wavelengths (or colors) of light - the red, green, and blue wavelengths and this information is combined to produce a picture that looks just like the feature we photographed.

Figure 1: Landsat TM (WRS-2) Path = 125 Row = 49 April 21, 2003 Bands 5, 4, 3 represented with red, blue and green The city of Hue in Vietnam In this image the town of Hue, Vietnam is colored purple. The dark green color in the lower left portion of the image is forest and the green patches throughout the image represent grass, shrubs, and rice. The blue and black linear features are rivers, streams, and a moat around the old city of Hue.

With a multispectral sensor, such as those aboard the Landsat satellites, information from

different wavelengths of light is collected as in a digital camera but there are two major differences. The first is that instead of limiting itself to the visible wavelengths (what we can see with the human eye - red, green, and blue) a much broader range of wavelengths are detected. In addition to the visible wavelengths, information is collected in the infrared and sometimes even the thermal wavelengths.

The second major difference is that instead of automatically combining the information from the different wavelengths to form a picture, the information for each specific wavelength range is stored as a separate image. This image is commonly called a band. When viewed, this single band image is similar to a black and white digital photograph. It is up to us, the image analysts, to combine the images from the different wavelengths to create a color image. Figure 2 illustrates the individual bands that were used to create Figure 1 and the other bands available on the Enhanced Thematic Mapper (ETM) sensor on board the Landsat satellite.

Figure 2a: Band 1 image

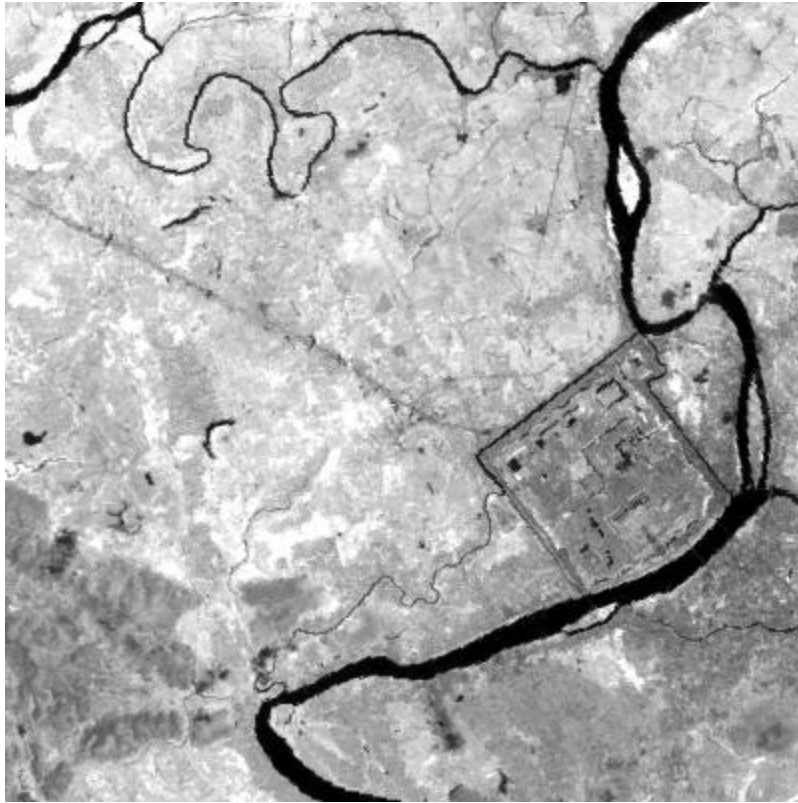*Figure 2b: Band 2 image*

Figure 2c: Band 3 image

Figure 2d: Band 4 image

Figure 2e: Band 5 image

Figure 2f: Band 6 image

Figure 2g: Band 7 image

We can create color images similar to the one in Figure 1 on a computer screen by using red, green, and blue light to illuminate bands 5, 4, and 3 respectively. This is easy to do if you have the appropriate software such as Adobe Photoshop, the Image Processing freeware package OpenEV, or most GIS and remote sensing image processing packages.

All of the colors on a computer screen, television, or any other display device are comprised of a combination of red, green, and blue light. These are called the primary colors because all colors that we can see are made using these wavelengths of light. When we see white, the three primary colors are all present in the same full intensity and black is an absence of all visible light. Shades of grey are created using the same intensity of the three primary colors of light but somewhere between full intensity and no light. The RGB interactive tool illustrates how primary colors can be mixed to create any color.

Now that we understand how a color image is made we need to determine which of the bands should be used to make the color image and which of the primary light colors should be used to illuminate each band. Determining which of the primary colors should be used to represent a particular band is largely a matter of how the image looks although some people are more sensitive to certain colors than others. For example, most people can see more detail in the red wavelengths. In Figure 1 vegetation is green and water is blue. Those are colors that people unfamiliar with remote sensing expect to see, and for those people, representing features with reasonably life-like colors helps them interpret the image. Another way to represent those same bands is to change the primary light colors that are used to illuminate each band. Figure 3 shows the same image used for Figure 1 but bands 4, 5, and 3 (in figure 1 the band order was 5, 4, 3) are represented using red, green, and blue light. This band order makes the vegetation look red instead of green. This is a band combination popular with

remote sensing specialist largely due to historical reasons. Since this looks similar to what you would get if you took a picture using a camera with color infrared film. Since infrared film was very popular for monitoring vegetation before the advent of digital remote sensing devices there is a tendency to continue simulating this effect.

Figure 3: Landsat TM (WRS-2) Path = 125 Row = 49 April 21, 2003 Bands 4, 5, 3 represented with red, blue and green The city of Hue in Vietnam   In this image the town of Hue, Vietnam is colored light blue. The reddish brown color in the lower left portion of the image is forest and the orange patches throughout the image represent grass, shrubs, and rice. The blue and black linear features are rivers, streams, and a moat around the old city of Hue.

Selecting the appropriate bands to use in the color image on the other hand does have a huge impact on which features can be seen in a particular image. The list below explains some of the features of the seven Landsat Thematic Mapper bands and how they are tailored for detecting different features.

Band 1 (0.45-0.52 μm, blue-green): Since this short wavelength of light penetrates better than the other bands it is often the band of choice for aquatic ecosystems. It is used to monitor sediment in water, mapping coral reefs, and water depth. Unfortunately this is the noisiest of the Landsat bands since short wavelength blue light is scattered more than the other bands. For this reason it is rarely used for "pretty picture" type images.

Band 2 (0.52-0.60 μm, green): This has similar qualities to band 1 but not as extreme. The band was selected because it matches the wavelength for the green we see when looking at

vegetation.

Band 3 (0.63-0.69 µm, red): Since vegetation absorbs nearly all red light (it is sometimes called the chlorophyll absorption band) this band can be useful for distinguishing between vegetation and soil and in monitoring vegetation health.

Band 4 (0.76-0.90 µm, near infrared): Since water absorbs nearly all light at this wavelength water bodies appear very dark. This contrasts with bright reflectance for soil and vegetation so it is a good band for defining the water/land interface.

Band 5 (1.55-1.75 µm, mid-infrared): This band is very sensitive to moisture and is therefore used to monitor vegetation and soil moisture. It is also good at differentiating between clouds and snow.

Band 6 (10.40-12.50 µm, thermal infrared): This is a thermal band, which means it can be used to measure surface temperature. This is primarily used for geological applications but it is sometime used to measure plant heat stress. This is also used to differentiate clouds from bright soils since clouds tend to be very cold. One other difference between this band and the other multispectral ETM bands is that the resolution is half of the other bands (60 m instead of 30 m).

Band 7 (2.08-2.35 µm mid-infrared): This band is also used for vegetation moisture although generally band 5 is preferred for that application, as well as for soil and geology mapping.

Now we can experiment with different band combinations. In Figure 4 you will see several commonly used band combinations with a brief explanation on why it is used. We also have an interactive band combination tool that you can use to experiment with different band combinations using Landsat Enhanced Thematic Mapper Plus (ETM+), ASTER, and MODIS imagery. One of the best ways to better understand which features one can see using different band combinations is to experiment to see what works for you.

Figure 4: Landsat TM (WRS-2) Path = 125 Row = 49, April 21, 2003, The city of Hue in Vietnam. Red=3, Green=2, Blue=1

This color composite is as close to true color that we can get with a Landsat ETM image. It is also useful for studying aquatic habitats. The downside of this set of bands is that they tend to produce a hazy image.

Figure 4.2: Landsat TM (WRS-2) Path = 125 Row = 49, April 21, 2003, The city of Hue in Vietnam. Red=4, Green=3, Blue=2

This has similar qualities to the image with bands 3,2,1 however, since this includes the near infrared channel (band 4) land water boundaries are clearer and different types of vegetation are more apparent. This was a popular band combination for Landsat MSS data since that did not have a mid-infrared band.

Figure 4.3: Landsat TM (WRS-2) Path = 125 Row = 49, April 21, 2003, The city of Hue in Vietnam. Red=4, Green=5, Blue=3

This is crisper than the previous two images because the two shortest wavelength bands (bands 1 and 2) are not included. Different vegetation types can be more clearly defined and the land/water interface is very clear. Variations in moisture content are evident with this set of bands. This is probably the most common band combination for Landsat imagery.

Figure 4.4: Landsat TM (WRS-2) Path = 125 Row = 49, April 21, 2003, The city of Hue in Vietnam. Red=7, Green=4, Blue=2

This has similar properties to the 4,5,3 band combination with the biggest difference being that vegetation is green. This is the band combination that was selected for the global Landsat mosaic created for NASA.