

# Manual for AnalyzingDigitalImages

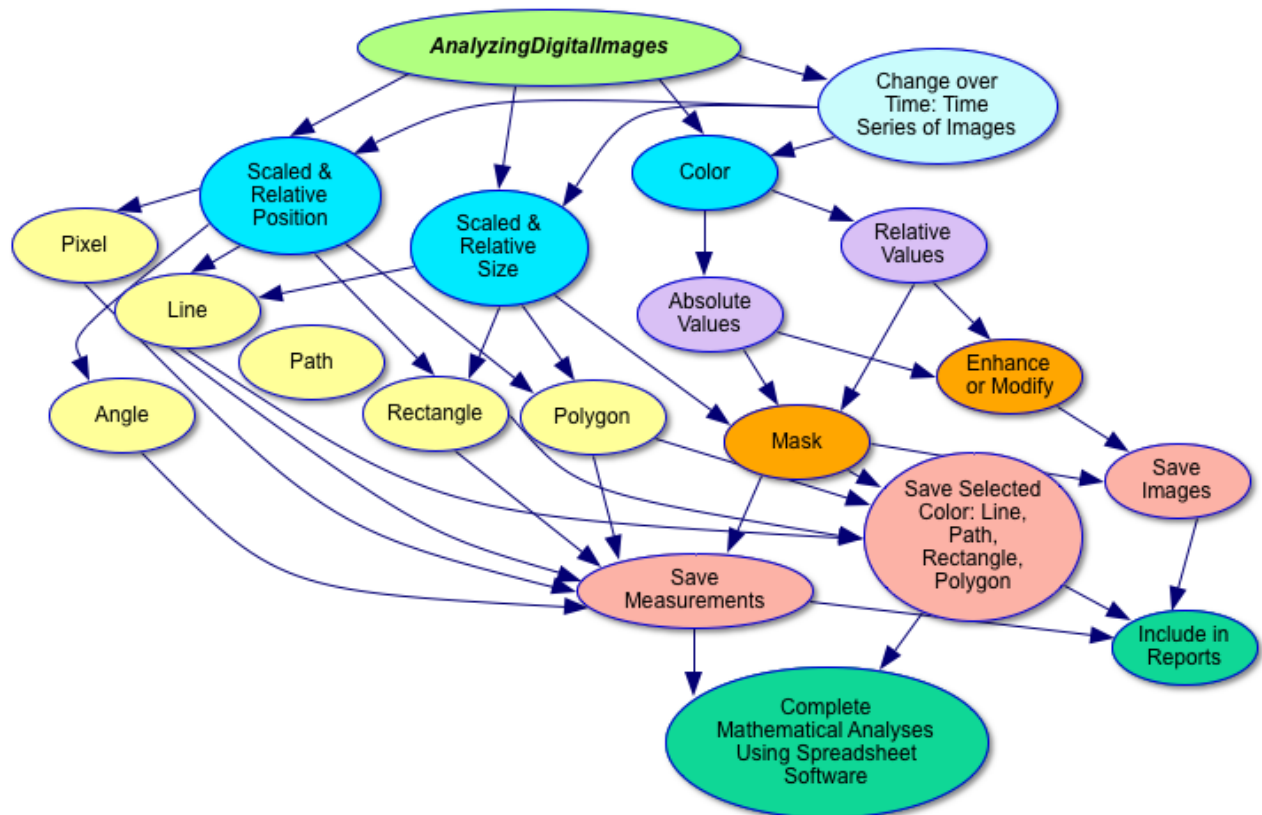
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## Overview of AnalyzingDigitalImages

AnalyzingDigitalImages is a free image analysis program designed for educational use on either PCs or Macs. The latest version of the software may be downloaded at <http://www.lawrencehallofscience.org/gss/rev/ip/index.html>. The software provides integrated tools to analyze the position, size, and color of objects in a digital picture (Figure 1).



## **Overview of Main Windows**

Four main windows provide access to a variety of image analysis tools in this program: Spatial Analysis, Enhance Colors, Mask Color, and Time Series.

The opening window provides access to these four windows, in addition to an example of time series analysis, Old Growth Forests (which is used in the GSS book, *A New World View*, <http://www.lawrencehallofscience.org/gss/sb/newworld.html>), and a general overview of how the software works.

The **Spatial Analysis** window provides tools to measure the position, length, area, and angle of objects of interest. In addition to measuring the spatial information, the colors at, along, or within a drawn tool are measured. Analyze the colors of the original image, a color-enhanced image, or a masked image.

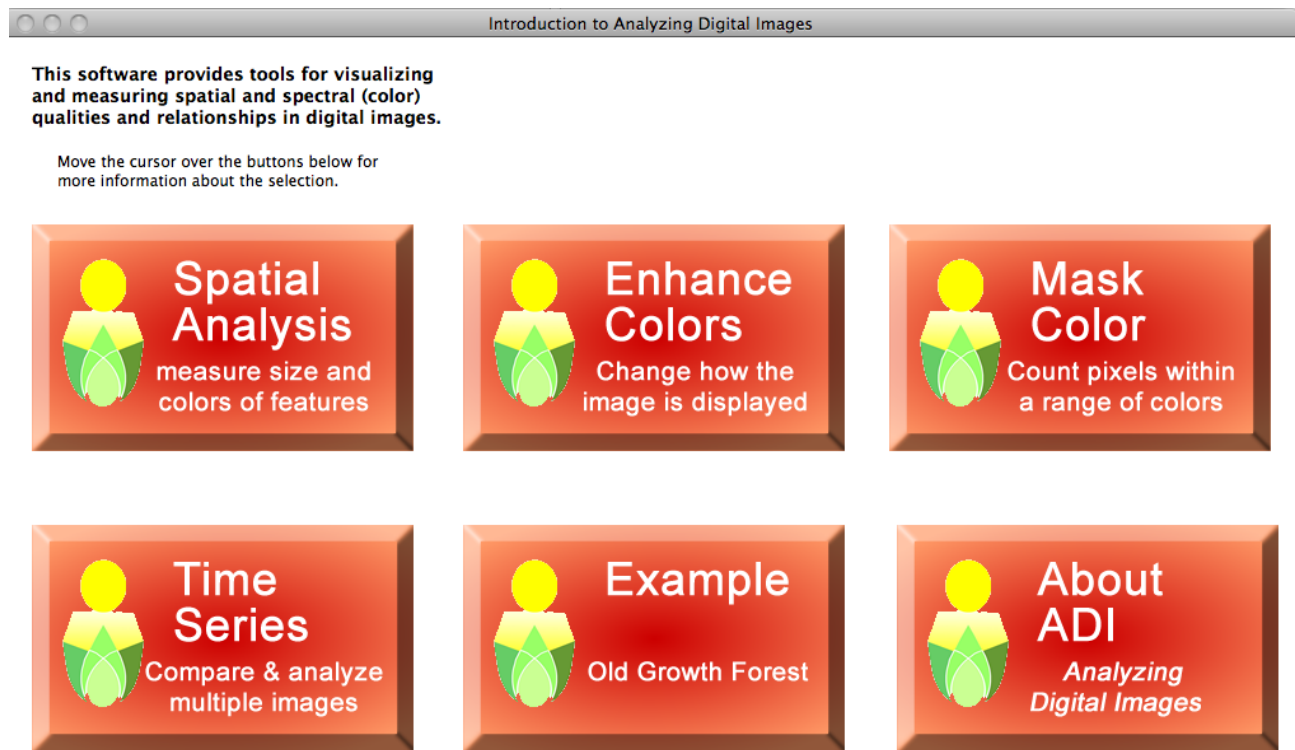
The **Enhance Colors** window allows manipulation of the color layers of the image to create new ways to view the color relationships in the digital image.

The **Mask Color** window provides tools to select pixels within selected color ranges or having specific relationships between red, green, and/or blue intensities.

And the **Time Series** window provides spatial and color enhancement tools to analyze up to 3 images in a time series in order to measure changes over time.

## Details of Main Windows

### Opening Window



Additional options are available in the menu bar. Those that work with single-image analysis (Spatial Analysis, Enhance Colors, and Mask Colors) are marked with an icon of a single image. Those that work with the time series of images are marked with an icon of multiple images. Some options work with both single and multitime images and so are indicated by having both icons.

If you select a menu option that doesn't work for your type of analysis, nothing will happen.

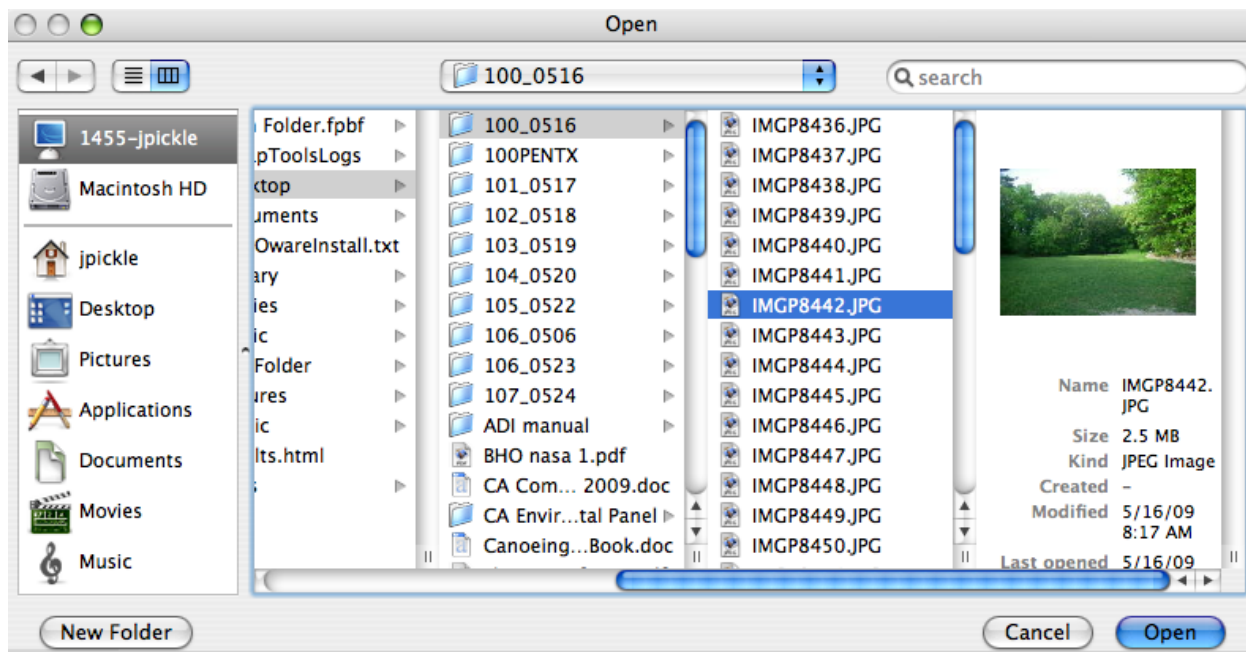
By clicking on the Spatial Analysis, Enhance Colors, Mask Color, or Time Series icons, you will be asked to select a picture(s) to be used in that window. You may also use the options in the Navigation menu. Follow the steps in *Open a Picture* or *Open Time Series Images* that are described in the following sections.

### ***Open a Picture (also available in the File Menu, "Open Picture", or typing ctrl-O)***

To open a picture from the opening window, click any of the top-row icons (*Spatial Analysis*, *Enhance Colors*, or *Mask Color*), and the process of opening a picture stored on the computer, memory card, CD, or DVD begins automatically.

You may also click "Open Picture" in the File menu to open a digital image any time. **Image types that may be opened include *jpg* (or *jpeg*), *tiff*, *gif*, *png*, *pict*, *pdf*, or *bmp*.**

The following window appears to open a digital image.



### ***Open Time Series Images (also available in the File Menu, "Open Time Series Images", or typing ctrl-+)***

To open a picture from the opening window, click on the icon *Time Series* and the process of opening the sequence of images stored on the computer, memory card, CD, or DVD begins automatically.

You may also click "Open Time Series Images" in the File menu to open a series of digital images any time. **Image types that may be opened include *jpg* (or *jpeg*), *tiff*, *gif*, *png*, *pict*, *pdf*, or *bmp*.**

**NOTE:** If you are opening images downloaded from the USGS Earthshots website (<http://earthshots.usgs.gov/>), they must be saved as 450 x 324 jpgs. Also, the last four alphanumeric characters of the filename must be the year of the image. For the example image that follows, the name is *Rondonia\_1986.jpg* (Brazilian rain forest).



**TIP:** Due to time to process up to three images as once, images are limited to 1024 x 768 pixels. If your images are larger than this, use the *Trim Image* tool in the *Utilities* menu to create smaller versions.

Options for opening time series images:

Select the number and type of time series images to open

Open 2 or 3 images from a time series that are the same size (width and height in pixels). The maximum width is 1024 pixels and the maximum height is 768 pixels.

Tip: Use the Trim Function in the Utility Menu above if your images are too large. Trim option 1 or 2 will work best.

Open 2 Photos/Maps

Open 3 Photos/Maps

Open 2 or 3 images from a time series (free images are available at sources such as Landsat Clic 'N Pic: <http://mvh.sr.unh.edu/Landsat/>).

Use composite images called NRGs or Near Infrared-Red-Green.

The maximum width is 1024 pixels and the maximum height is 768 pixels.

Tip: Use the Trim Function in the Utility Menu if your images are too large. Trim option 2 will work best.

Open 2 NIR-Red-Green Satellite Images

Open 3 NIR-Red-Green Satellite Images

Use images from the USGS Earthshots website: <http://earthshots.usgs.gov/>. The accompanying articles provide an overview of the events that created the changes in the landscape.

Tip: save the images with the year as the last 4 alphanumeric of the filename. Example: MtStHelens\_1977.jpg.

Open 2 USGS Earthshots Satellite Images

Open 3 USGS Earthshots Satellite Images

Cancel

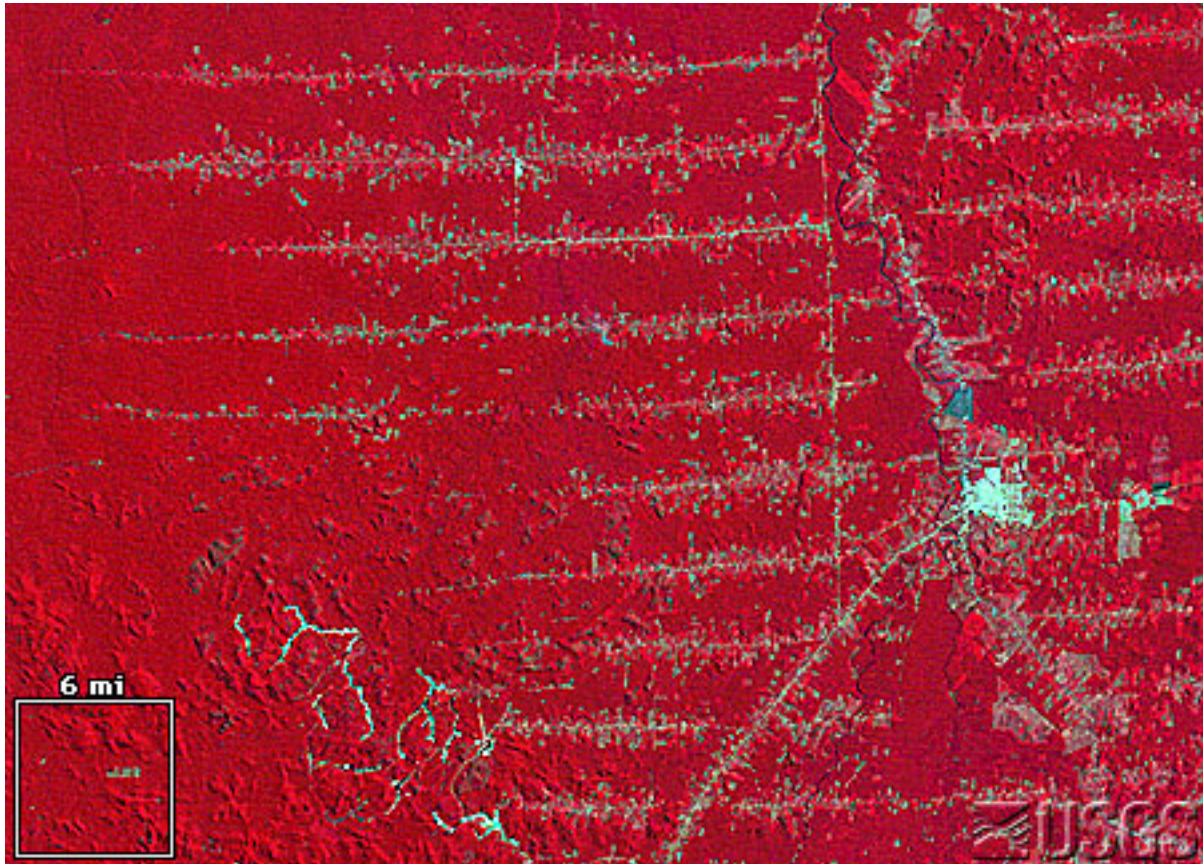
## NIR-Red-Green Satellite Images

A common image created from satellite data designed to monitor the Earth's land surface is a false color image that maps the near infrared measurements as the image's red layer, the red intensities as the image's green layer, and the green intensities as the image's blue layer (if not familiar with this, see the *False Colors* activities in the *DigitalImageBasics* software available in the DEW bundle at <http://www.lawrencehallofscience.org/gss/rev/ip/index.html>).

In these images, vegetation appears red, where the redder the color, the healthier the plant life (see example of the 1986 Brazilian rain forest from the USGS Earthshots

website that follows). Buildings and roads appear gray to light cyan, and water bodies appear black.

This ADI upgrade now includes the software, VegetationAnalysis, which was used in activities in the GSS book, *A New World View*, <http://www.lawrencehallofscience.org/gss/sb/newworld.html>); however, now these tools may be used on a greater variety of digital images.



A false color Landsat image of the Brazilian rainforest in 1986 downloaded from the USGS Earthshots website (<http://earthshots.usgs.gov/>). When saving the jpg from the website, include the year at the last four alphanumeric characters of the filename. This image was named *Rondonia\_1986.jpg*.

### ***Calibrating Pixel Size (Single Image and Time Series)***

After opening an image or a time series of images, you will have the option to *calibrate* the size of the pixel to a known length scale. There are three options: 1) the size of the pixel is given from the source of the image, 2) when an object of known size is visible in the image, 3) if you are using a time series of Landsat satellite images from the USGS Earthshots website (<http://earthshots.usgs.gov/>).

Select Method of Pixel Size Calibration

#### **Select Method to Calibrate the Pixel Size**

Known Pixel Size

Click if you know the size of the pixels, which is common for orthophotographs from aerial reconnaissance and satellite imagery.

Scale Present in Image

Click if there is a linear scale located in the image. This includes photographed objects of known length (ruler, penny, clipboard, etc.) or a distance scale on digital maps or satellite imagery.

None

Click if there is no way to know the size of the pixels in the image.



## Calibrate Option 1: Known Pixel Size

For a special type of aerial photograph, called an orthophotograph, and some types of satellite images, most commonly Landsat, Modis, DMSP, and IKONOS, the size of a pixel represents a known size of land on the ground. An example of an orthophoto with a pixel size of 2 m of the Charles River, which separates Cambridge and Boston, MA, follows.



To analyze spatial relationships in this image, click "*Known Pixel Size*" and enter "2" in text box adjacent to "*Length of pixel in image*" and "m" in text box adjacent to "*Unit of Length (2 letters)*". Click the "*Done*" button to begin analyzing the image.

### The Size of Pixels is Known

In the uppermost white box, type the length a pixel represents in the image. Type only the number.

In the lower white box, type the two letter abbreviation of the unit of the scale. For example, type "mi" for miles, "cm" for centimeters.

Click 'Done' to go back to the main window.

If you make a mistake, run the calibration procedure again by selecting "Calibrate Length" in the File menu.

Length of pixel in image

Unit of Length (2 letters)

**Done**

Example: if using Landsat imagery, the pixel size is 28.5 m.

Tip: Since digital images contain many pixels, consider converting to a larger unit, such as convert 28.5 m to 0.0285 km.

## Calibrate Option 2) Scale Present in Image

Often the size of an object visible in a digital image is available to help calibrate the pixel size. For example, many digital maps include a scale and field scientists often include a ruler, lens cap, coin, or a person of known height in the image. An example of a leaf with a ruler adjacent to it follows.



With these types of images, click the "Scale Present in Image" button in the window that appears after you selected the image. The following window will appear to complete the calibration.

### Manually Calibrate The Pixel Size

1) Click on the beginning of an object of known length visible in the image.

2) Drag to the end of the scale. Release the mouse.

TIP: Draw along as much of the scale as possible. The longer the line, the more precise the measurement.

A colored line is drawn on the image. If the line does not match the scale, either redraw the line or fine tune the start and stop positions of the line with the small arrows next to the x and y positions of the line end points, which are located below the image.

3) When satisfied with the fit of the line to the scale, enter the length of the scale used in the labeled white box below.

4) Enter two letters that represent the unit of the scale being used in the labeled white box below. For example, type "in" for inches and "cm" for centimeters.

5) Click 'Done' when finished. To re-run the calibration method click 'Calibrate Length' in the File menu.



Leaf with Ruler is 640 by 480 pixels

	X	Y
Start of Line	22	424
End of Line	529	465

Click on a blue or red arrow to move the corresponding end of the line one pixel per click.

Length of Drawn Line

Unit of Length

Zoom In Zoom Factor: # Zoom Out

When zoomed in, pan around the image by using the arrow keys or hold the SHIFT key and click and drag the image.

Done

Click and drag to create a yellow line along the ruler. After drawing the line, you may grab either end to a new position. You may also use the red and blue arrows to reposition the ends of the line. Note: the red arrows move the red end, and the blue arrows move the blue end of the line. TIP: If you have a ruler, draw a line as long as possible, which minimizes small errors that might occur.

If you want a completely new line, you need to go to a different location on the image to draw a new line.

When you are satisfied with the accuracy of your line, enter the length of the line in the two text boxes in the lower left. In this case, the line is 6 inches long. NOTE: Units of length may be only two letters long.

**TIP:** You may change units from those of the ruler. To enter centimeters, use 15.24 cm, which equals 6 in x 2.54 cm/in. You do not need to enter whole numbers for the length of the drawn line.

Length of Drawn Line

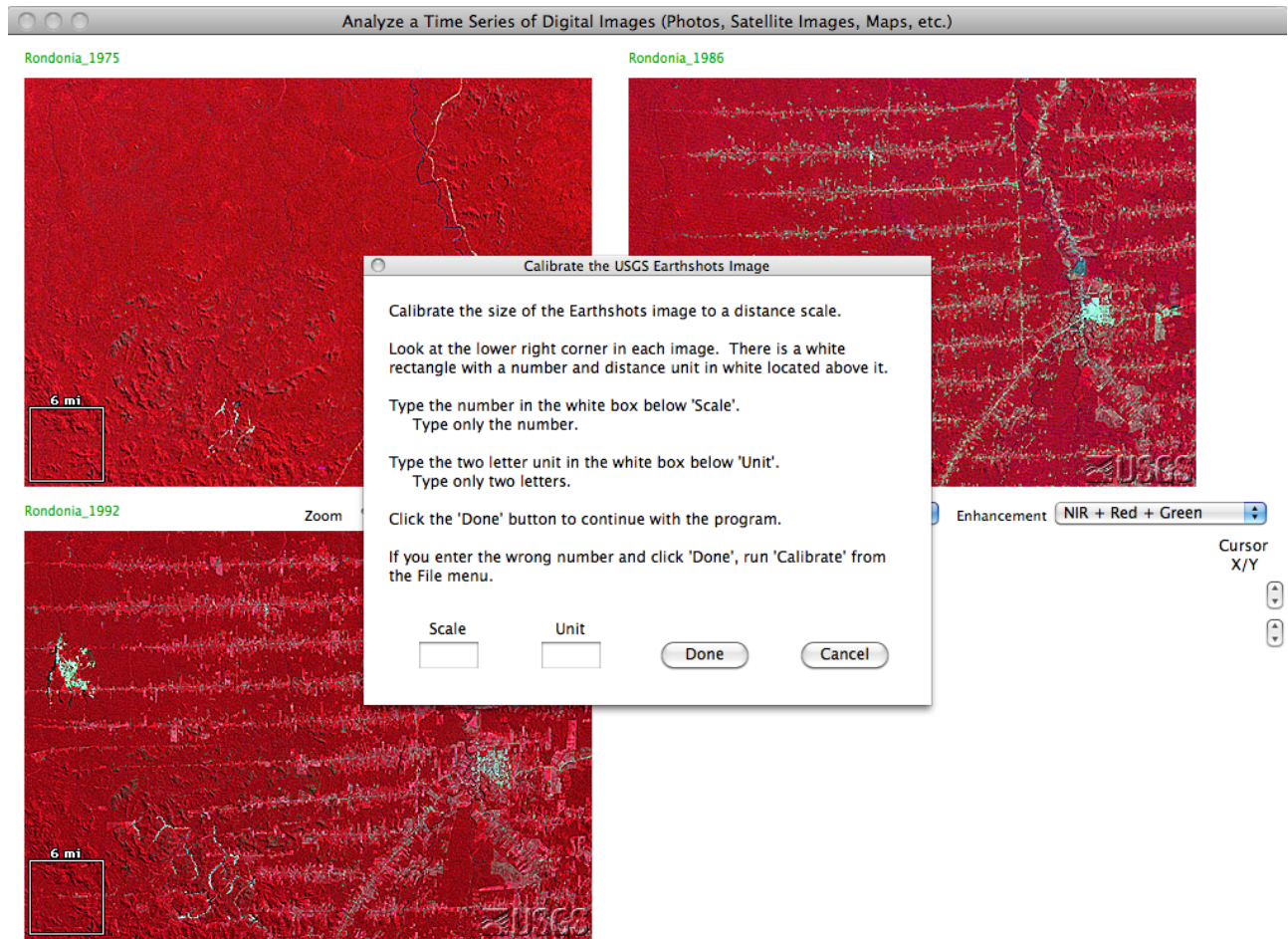
Unit of Length

**TIP:** Use the line tool available in the Spatial Analysis tab panel to measure a line drawn on the scale in the image. If the calibration process was correct, your measurements should correspond to those of the scale.



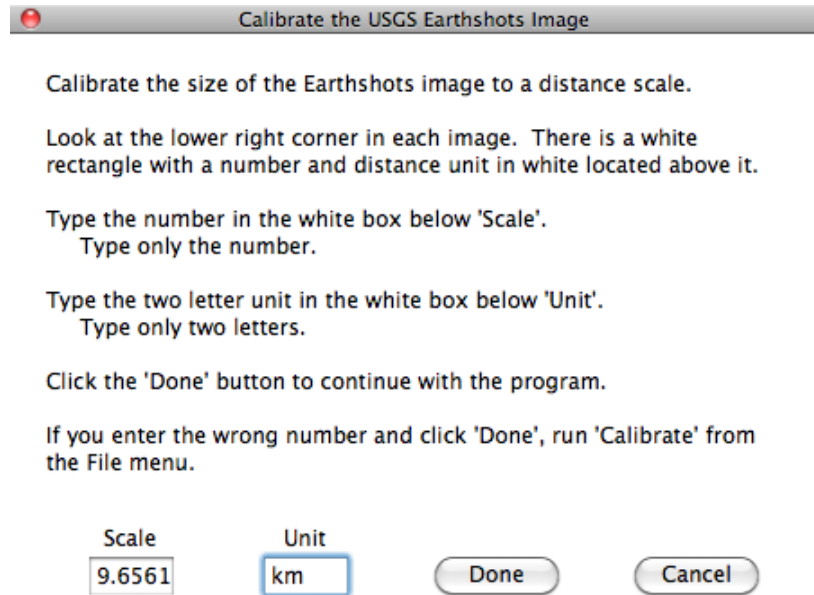
### Calibrate Option 3: USGS Earthshots Images

All USGS Earthshot images have a white square in the lower left that is used to calibrate the pixel size. The software finds the white squares and counts the number of pixels along each edge automatically. All you need to do is tell the software how long an edge of the square is by typing the number and units in the text boxes located in the calibration window that pops up.





**TIP:** You don't need to use the units provided by the Earthshots image. To convert the above example of 6 miles to kilometers, enter 9.6561 km into the text boxes (1 mi = 1.6093 km).



Calibrate the USGS Earthshots Image

Calibrate the size of the Earthshots image to a distance scale.

Look at the lower right corner in each image. There is a white rectangle with a number and distance unit in white located above it.

Type the number in the white box below 'Scale'.  
Type only the number.

Type the two letter unit in the white box below 'Unit'.  
Type only two letters.

Click the 'Done' button to continue with the program.

If you enter the wrong number and click 'Done', run 'Calibrate' from the File menu.

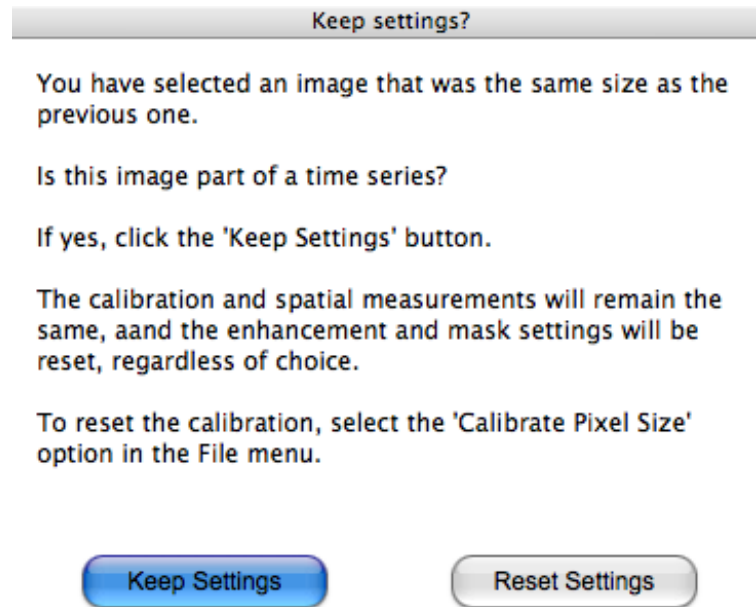
Scale	Unit		
<input type="text" value="9.6561"/>	<input type="text" value="km"/>	<input type="button" value="Done"/>	<input type="button" value="Cancel"/>

### ***Making a Mistake During Calibration***

If a mistake is made during the calibration process, such as forgetting that the image could be calibrated when opening, the calibration process can be run again using the File Menu's "Calibrate Pixel Size" option (or typing apple-C for Macs or ctrl-C for PCs).

## Opening Another Image

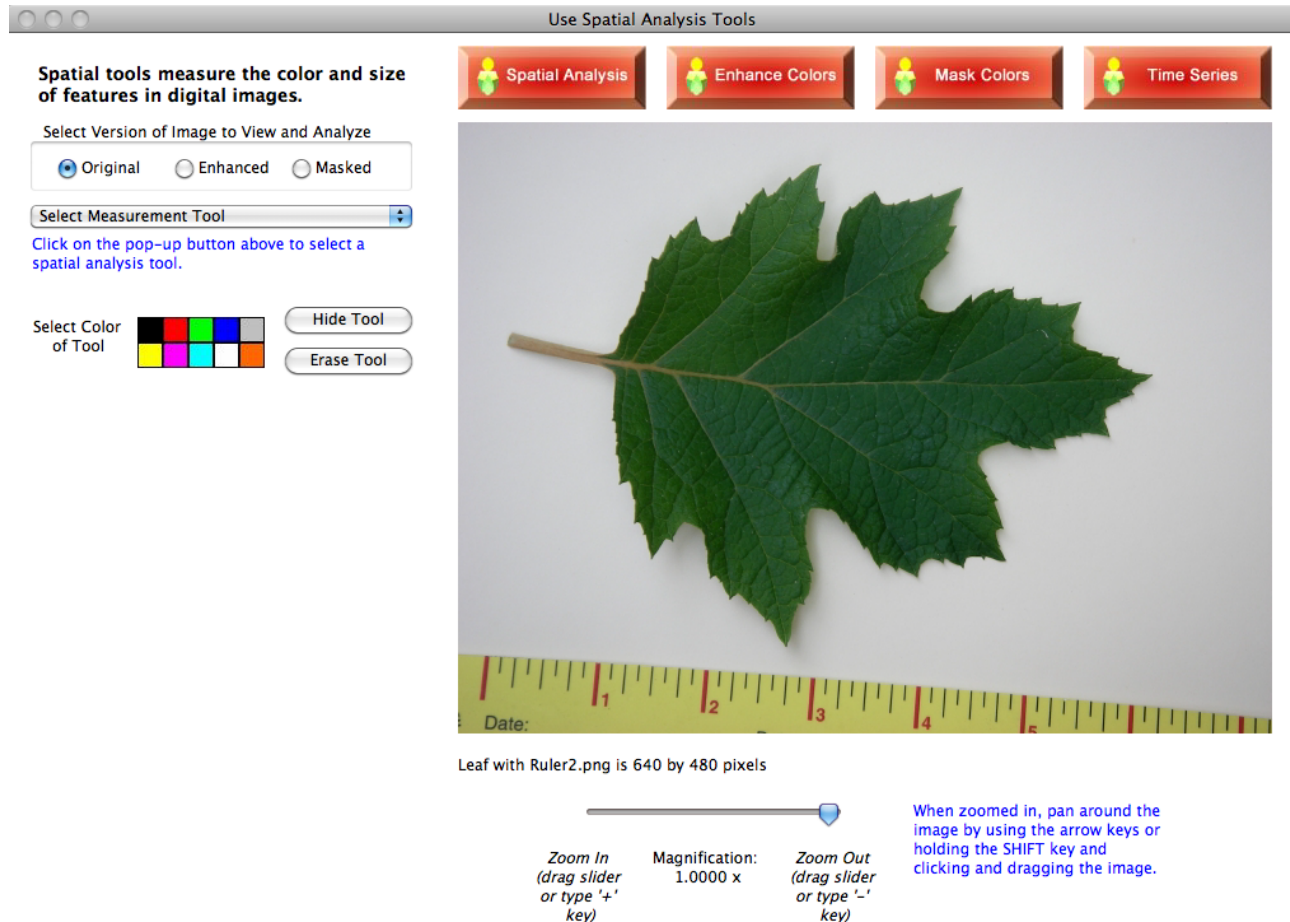
When opening a new image that is a different size from the current one, all parameters and image storage holders are reset, and you will be asked if the image can be calibrated upon opening. However, when opening an image that is the same size as the one that is being replaced, you will first be asked if you would like to keep the same settings that you have been working with on the current image. These include the same calibration factor, and any settings for color enhancement, mask, and spatial tools. This allows you to efficiently collect measurements from a time series of images, including digital maps or time lapse photos.



Clicking "*Keep Settings*" opens the image in the current tab panel, if you are in the Spatial Analysis, Color Enhancement, or Mask Colors tab panels. If you are in a different tab panel, the image will open in the Spatial Analysis tab panel. Clicking "*Reset Settings*" opens the Calibration window.

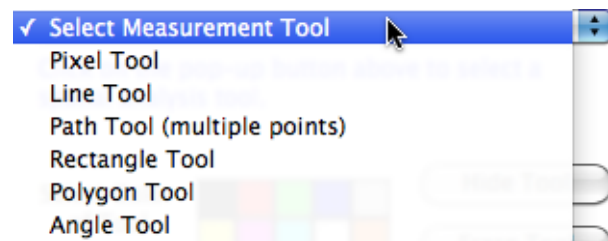
## Spatial Analysis Window

The Spatial Analysis window allows you to measure the location and/or size of objects in the digital image. Tools may be selected by clicking on the drop down menu labeled "Select Spatial Tool".



## Spatial Analysis Tools (Single Image and Time Series)

There are six spatial tools: pixel, line, path, rectangle, and polygon, and angle. The Time Series window provides the pixel, line, path, rectangle, and polygon tools, with the rectangle and polygon tools having an additional option, NDVI masking.



The **pixel** tool shows the location of the pixel and the color at that location in the image. Click anywhere in the image, and a cross hair appears at that location.

Along the left column of the window, the position of the cursor is given.

NOTE: The upper left corner of the image has coordinates X = 0 and Y = 0.

Use the blue arrows in the left column to move the cursor one pixel per click.

The color of the pixel at the crosshairs is provided in the left column of the window. NOTE: the color is based on 0 to 100% intensity. A pixel typically has intensities ranging from 0 to 255, but percentages of intensity are easier to conceptualize.

Use Spatial Analysis Tools

**Spatial tools measure the color and size of features in digital images.**

Select Version of Image to View and Analyze

☒ Original ☐ Enhanced ☐ Masked

Pixel Tool

Click on the image to view the pixel's position and color. Click on the blue arrows below to move the cross hair one pixel at a time.

Select Color of Tool

Hide Tool

Erase Tool

Pixel Position

	X	Y
Start Point	189	172

Adjust

Color	Intensity [%]
Red	15.29
Green	32.55
Blue	11.76
Average Color	19.87

Intensities of colors range from 0%, meaning none of the color is present, to 100%, when maximum color is present.

Zoom In (drag slider or type '+' key)

Magnification 1.0000

Leaf with Ruler2.png is 640 by 480 pixels

The **line** tool shows the location of the end of the line (one marked blue, the other red). To create, click and drag to create the two ends of the line.

**Spatial tools measure the color and size of features in digital images.**

Select Version of Image to View and Analyze

☒ Original ☐ Enhanced ☐ Masked

Line Tool

Click and drag to create a line. Use the blue and red arrows below to move the corresponding end one pixel, or click and drag either end.

Select Color of Tool

Hide Tool

Erase Tool

Pixel Position		Adjust	
	X	Y	
Start Point	118	187	
Stop Point	541	200	
Number of Pixels	424		
Length of Line	4.97 in		
Color	Intensity [%]		
Average Red	13.22		
Average Green	27.96		
Average Blue	12.70		
Average Color	17.96		

Intensities of colors range from 0%, meaning none of the color is present, to 100%, when maximum color is present.

Leaf with Ruler2.png is 640 by 480 pixels

Magnification: 1.0000 x

Zoom In (drag slider or type '+' key)

Zoom Out (drag slider or type '-' key)

When zoomed in, pan around the image by using the arrow keys or holding the SHIFT key and clicking and dragging the image.

Along the left column of the window, the positions of the ends of the line are given. NOTE: The upper left corner of the image has coordinates X = 0 and Y = 0.

The length of the line, in pixels, is provided. If the image has been calibrated to a scale, the length of the line relative to the scale is given.

Use the blue and red arrows in the left column to move the corresponding end of the line one pixel per click. You may also click and drag an end of the line to a new location.

The average color of the pixels intersecting the line is provided in the left column of the window. NOTE: the color is based on 0 to 100% intensity. Color intensities typically range from 0 to 255, but percentages of intensity are easier to conceptualize.



The **path** tool shows the location line segments (the starting point is marked blue, the others are in red). To create a path, click on the image to create straight-line segments. To finish the path, double-click to create the last point. Corners and ends may be dragged.

**Spatial tools measure the color and size of features in digital images.**

Select Version of Image to View and Analyze

☒ Original ☐ Enhanced ☐ Masked

Path Tool (multiple points)

Click on the image to create linear segments of the path. Double click to create the last point. Corners and ends may be dragged.

Select Color of Tool

Color	Intensity [%]
Average Red	30.37
Average Green	41.16
Average Blue	26.16
Average Color	32.56

Intensities of colors range from 0%, meaning none of the color is present, to 100%, when maximum color is present.

Number of Pixels 1,609

Length of Path 18.87 in

Leaf with Ruler2.png is 640 by 480 pixels

Magnification: 1.0000 x

Zoom In (drag slider or type '+' key)

Zoom Out (drag slider or type '-' key)

When zoomed in, pan around the image by using the arrow keys or holding the SHIFT key and clicking and dragging the image.

The length of the path, in pixels, is provided. If the image has been calibrated to a scale, the length of the path relative to the scale is given. **TIP:** use the path tool to calculate circumference of objects or path distances on maps.

To change the shape of the path, click and drag any highlighted corner or end of the path to a new location.

The average color of the pixels intersecting the line segments of the path is provided in the left column of the window. NOTE: the color is based on 0 to 100% intensity. Color intensities typically range from 0 to 255, but percentages of intensity are easier to conceptualize.

The **rectangle** tool shows the location of opposing corners of the rectangle (one marked blue, the other red). To create, click and drag a rectangle.

**Spatial tools measure the color and size of features in digital images.**

Select Version of Image to View and Analyze

☒ Original ☐ Enhanced ☐ Masked

Rectangle Tool

Click and drag to create a rectangle. Use the blue and red arrows below to move corresponding corner one pixel, or click and drag a marked

Select Color of Tool

Hide Tool

Erase Tool

Pixel Position		Adjust	
	X	Y	
Start Point	172	155	
Stop Point	336	270	
Number of Pixels	19,140		
Area of Rectangle	2.63 in*in		
Color	Intensity [%]		
Average Red	12.64		
Average Green	28.33		
Average Blue	14.16		
Average Color	18.38		

Intensities of colors range from 0%, meaning none of the color is present, to 100%, when maximum color is present.

Leaf with Ruler2.png is 640 by 480 pixels

Zoom In (drag slider or type '+' key) Magnification: 1.0000 x Zoom Out (drag slider or type '-' key)

When zoomed in, pan around the image by using the arrow keys or holding the SHIFT key and clicking and dragging the image.

Along the left column of the window, the positions of the corners are given. NOTE: The upper left corner of the image has coordinates X = 0 and Y = 0.

The area of the rectangle, in pixels, is provided. If the image has been calibrated to a scale, the area relative to the scale is given.

Use the blue and red arrows in the left column to move the corresponding corners one pixel per click. You may also click and drag a highlighted corner to a new location.

The average color of the pixels within the rectangle is provided in the left column of the window. NOTE: the color is based on 0 to 100% intensity. Color intensities typically range from 0 to 255, but percentages of intensity are easier to conceptualize.



The ***polygon*** tool allows you to draw irregular shapes on the image. Click the location of each vertex. The last vertex must lie close to the starting vertex for the polygon to be completed, so click the final point at the beginning of the polygon (which is highlighted in blue). NOTE: the polygon has a limit of 25 vertices.

**Spatial tools measure the color and size of features in digital images.**

Select Version of Image to View and Analyze

☒ Original ☐ Enhanced ☐ Masked

Polygon Tool

Click on the image to create corners of a polygon. To finish, click close to the first point. Corners may be dragged.

Select Color of Tool

Hide Tool

Erase Tool

Color	Intensity [%]
Average Red	13.26
Average Green	28.70
Average Blue	13.44
Average Color	18.47

Intensities of colors range from 0%, meaning none of the color is present, to 100%, when maximum color is present.

Number of Pixels 77,468

Area of Polygon 10.65 in\*in

Leaf with Ruler2.png is 640 by 480 pixels

Magnification: 1.0000 x

Zoom In (drag slider or type '+' key)

Zoom Out (drag slider or type '-' key)

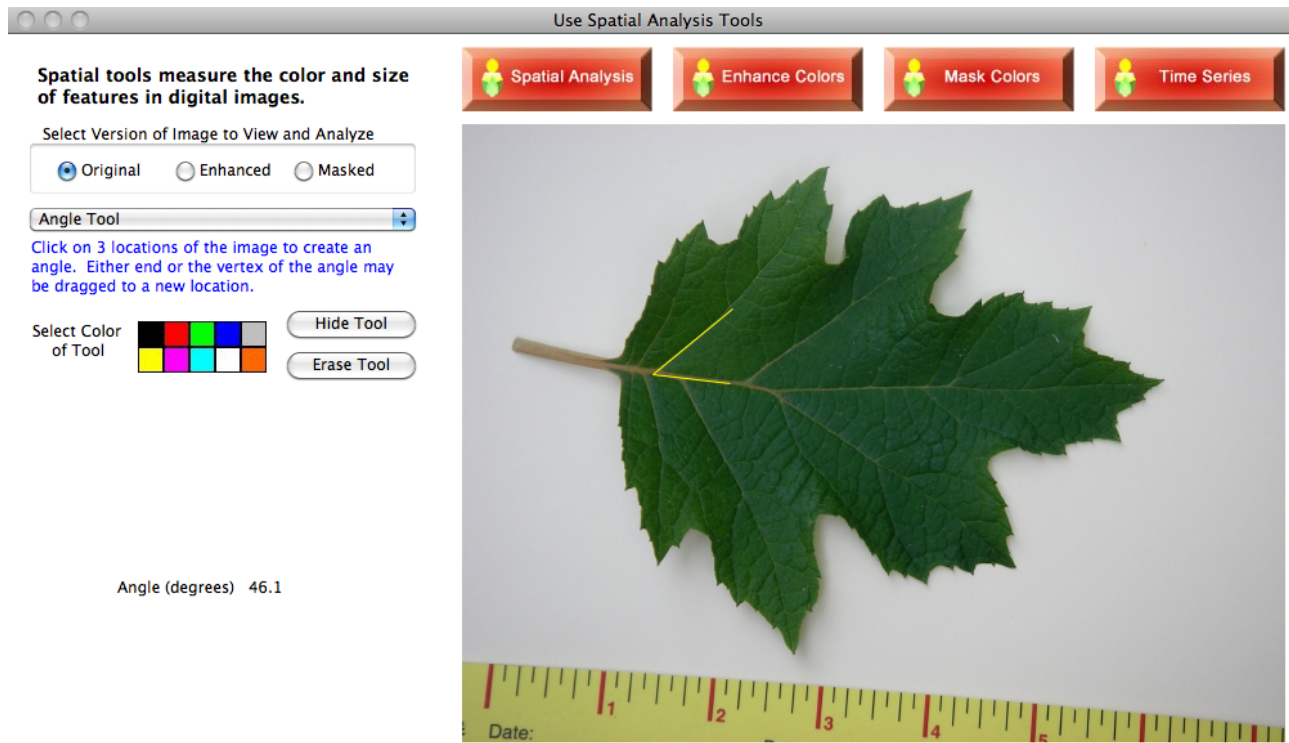
When zoomed in, pan around the image by using the arrow keys or holding the SHIFT key and clicking and dragging the image.

The area of the polygon, in pixels, is provided, and, if the image has been calibrated to a scale, the area relative to the scale is given.

You may change the shape of the polygon by clicking and dragging a vertex to a new location.

The average color of the pixels within the polygon is provided in the left column of the window. NOTE: the color is based on 0 to 100% intensity. Color intensities typically range from 0 to 255, but percentages of intensity are easier to conceptualize.

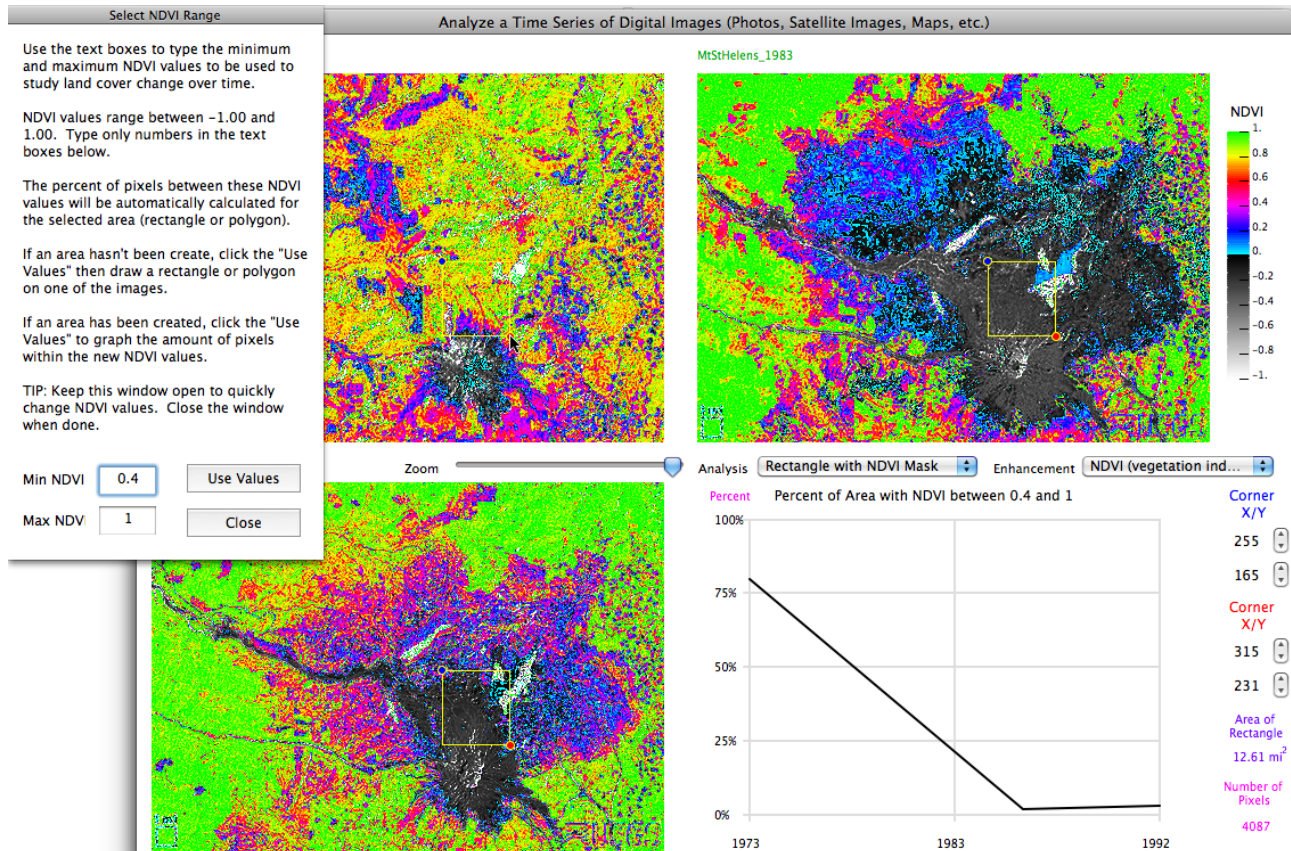
The **angle** tool allows you to measure the angle of objects in the digital image. Click the location of the three points that define the angle.



The angle in degrees is provided.

You may change the angle by clicking and dragging one of the vertices to a new location.

The Time Series window doesn't provide the masking of pixel color, but for false color satellite images, there is one option to count pixels using the **rectangle** and **polygon** tools within a specific range of values of Normalized Difference Vegetation Index (NDVI). These tools are only available for false color images where the measured near infrared (NIR) intensity is mapped as the image's red color, the measured red intensity displayed as the image's green color, and the measured green intensity displayed as the image's blue color (free sites for downloading these types of images are USGS Earthshots <http://earthshots.usgs.gov/> and UNH's Landsat Clic 'N Pic <http://mvh.sr.unh.edu/Landsat/>).



This example shows how the amount of plant cover changed on the north slope of Mt St Helens volcano before, just after, and a nearly a decade after its dramatic eruption. Images are from the USGS Earthshots website <http://earthshots.usgs.gov/>.

## Basics of NDVI

A Vegetation Index is a measure of the amount of vegetation covering the Earth's surface. Healthy vegetation absorbs visible light, especially red and blue light, and reflects much of the infrared. A simple Vegetation Index is based on the difference between these intensities. Another index, NDVI, provides more consistent identification of vegetation.

"Normalized Difference Vegetation Index" means that the difference between the intensities of the reflected infrared and visible red light are divided by the sum of the intensities of the two light measurements:

$$(\text{NIR intensity} - \text{Red intensity}) / (\text{NIR intensity} + \text{Red intensity})$$

This mathematical manipulation tends to compensate for areas experiencing hazy sunshine compared to those in clear skies, or uneven lighting conditions due to hills and valleys.

This formula produces values between -1 and +1. Negative values are produced when the red intensity is greater than the NIR's, and positive values are generated when the NIR intensity is greater than the red intensity.

Dense, healthy vegetation produces NDVI values near +1.0.

Bare soil and rock reflect similar levels of infrared and red light, so these surfaces produce NDVI values near 0.

Clouds, water, and snow reflect more visible light than infrared, which is the opposite of vegetation, and so produce NDVI values near -1.0.

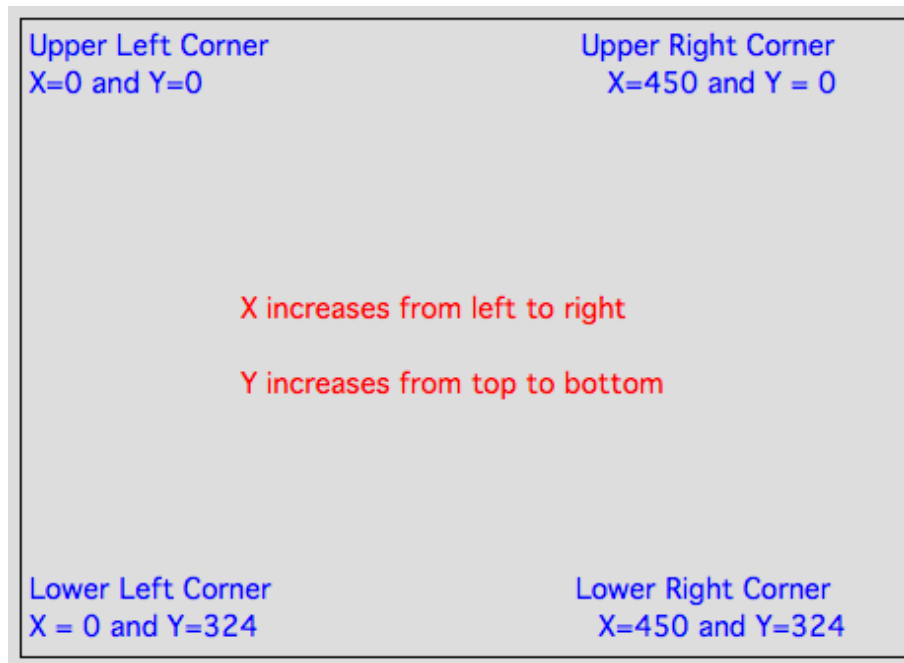
## X and Y Locations (Single Image and Time Series)

Moving the cursor, line, or rectangle with the control buttons can be confusing unless you understand the mapping of X and Y on the image.

Say the size of an image is 451 pixels wide and 325 pixels high. The upper left corner is (0,0).

X controls the horizontal location of the cursor, and the maximum value on the screen is 450 (0 indicates the left edge and 450 the right edge, so 451 pixels make up each row of the image).

Y controls the vertical location of the cursor, and the value of the upper edge is where  $Y=0$ . The lower edge has  $Y=324$ .





### ***Zooming and Panning the Image (Single Image and Time Series)***

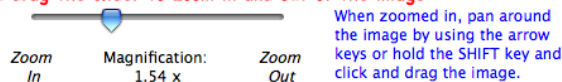
The maximum size of the image that can be displayed is 640 pixels wide by 480 pixels high for single images, 450 x 324 for time series images. This produces an image considerably less than one megapixel, yet most digital cameras, even those on cell phones, have many more pixels than this. In order to access the greater resolution, zoom into the image and pan to objects of interest within the image.

To change the magnification, or zoom, click and drag the slider, click on an end of the slider line, or type "+" to zoom in or "-" to zoom out.



Leaf with Ruler is 640 by 480 pixels

Click and drag the slider to zoom in and out of the image

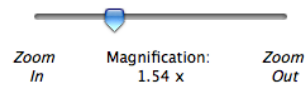


When zoomed in, you must pan across the image to see different parts of the image. To do this, hold down the SHIFT key while clicking on the image and dragging in order to expose undisplayed parts of the image or use the arrow keys on the keyboard.

Once you reach the edge of the image, you cannot pan in that direction any longer. Compare the image above to the image below - both have same magnifications, but different parts of the image are visible.



Leaf with Ruler is 640 by 480 pixels



When zoomed in, pan around the image by using the arrow keys or hold the SHIFT key and click and drag the image.



## Color Analysis with Spatial Analysis Tools

Five of the six spatial analysis tools provide color information of the pixels in contact or within the drawn spatial feature (the *angle* tool does not measure color).

There are three versions of the image that may be displayed: the original, an enhanced color version, and a masked image.

The color information measured with the spatial analysis tools depends on which image is being displayed. When an original or enhanced image is displayed, the colors based on those images are used in the calculations.

When a masked image is selected, the spatial tools count only the masked pixels within the rectangle or polygon tools or touching the selected line or path. Average color is based on the masked pixels. Pixels that haven't been masked have been ignored.

**NOTE:** a pixel is masked when its color falls within the selected color thresholds or meets a specified color relationship (say, the red intensity at a pixel is at least twice as great as the blue intensity). For the image below, the area is based on the counted pixels. The number of pixels within the polygon is 182,984, but the number of masked pixels within the rectangle is 86,243, which translates to a leaf area of 11.86 in<sup>2</sup>.

**Spatial tools measure the color and size of features in digital images.**

Select Version of Image to View and Analyze

☐ Original ☐ Enhanced ☒ Masked

Polygon Tool

Click on the image to create corners of a polygon. To finish, click close to the first point. Corners may be dragged.

Select Color of Tool

Hide Tool

Erase Tool

Number Masked Pixels 86,243

Area of Masked Pixels 11.86 in\*in

Color	Intensity [%]
Ave Red of Mask	13.74
Ave Green of Mask	28.96
Ave Blue of Mask	13.43
Average Color	18.71

Intensities of colors range from 0%, meaning none of the color is present, to 100%, when maximum color is present.

Leaf with Ruler2.png is 640 by 480 pixels

Magnification: 1.0000 x

Zoom In (drag slider or type '+' key)

Zoom Out (drag slider or type '-' key)

When zoomed in, pan around the image by using the arrow keys or holding the SHIFT key and clicking and dragging the image.

Use Spatial Analysis Tools

**Spatial Analysis** **Enhance Colors** **Mask Colors** **Time Series**

**Spatial tools measure the color and size of features in digital images.**

Select Version of Image to View and Analyze

☒ Original ☐ Enhanced ☐ Masked

Polygon Tool

Click on the image to create corners of a polygon. To finish, click close to the first point. Corners may be dragged.

Select Color of Tool

Hide Tool

Erase Tool

Number of Pixels 182,984

Area of Polygon 25.16 in\*in

Color	Intensity [%]
Average Red	48.06
Average Green	55.41
Average Blue	47.95
Average Color	50.47

Intensities of colors range from 0%, meaning none of the color is present, to 100%, when maximum color is present.

Leaf with Ruler2.png is 640 by 480 pixels

Zoom In (drag slider or type '+' key) Magnification: 1.0000 x Zoom Out (drag slider or type '-' key)

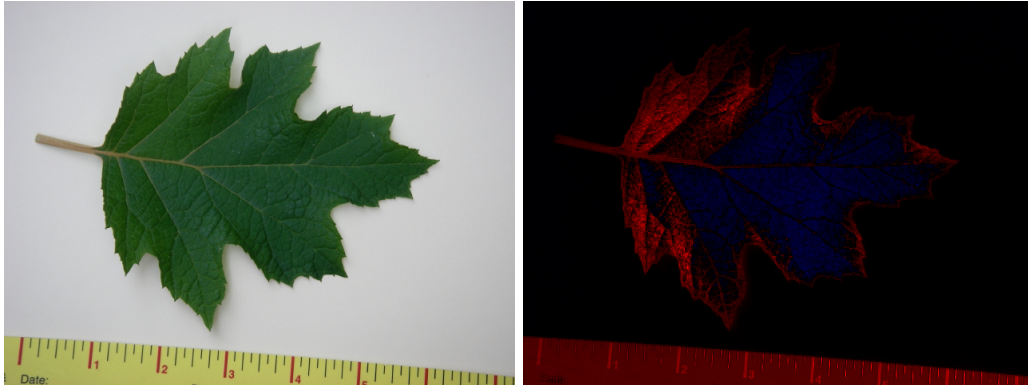
When zoomed in, pan around the image by using the arrow keys or holding the SHIFT key and clicking and dragging the image.

After a spatial analysis tool has been selected and the spatial feature drawn, changing the version of the image being displayed changes the calculated color, and, in the case of the masked image, the measured length or area, since these are based on only the masked pixels.

## Enhance Colors Tab Window

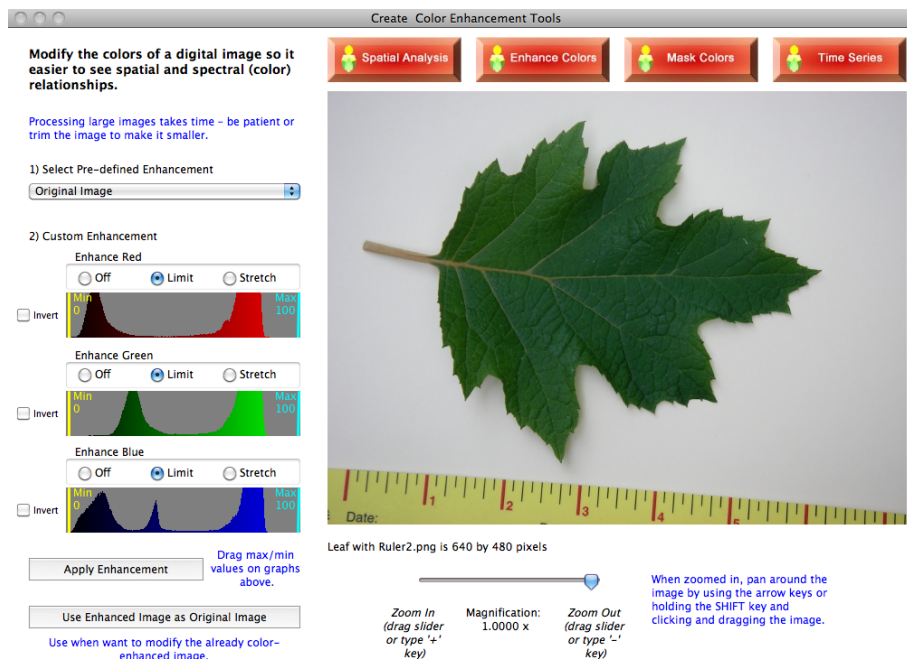
Digital images are made up of three layers of colors intensities that range from 0 to 255. By changing how the layers are displayed, you might see new patterns that have scientific meaning about an object's chemical or physical properties.

For example, scientists at the University of New Hampshire are studying the color enhancement of leaf images to see whether the amount of chlorophyll in leaves produces a specific range of colors observed in the red vs. blue, normalized image (as shown below).



For more information about the basics of digital images using the free software, *DigitalImageBasics*, see <http://www.lawrencehallofscience.org/gss/rev/ip/index.html>.

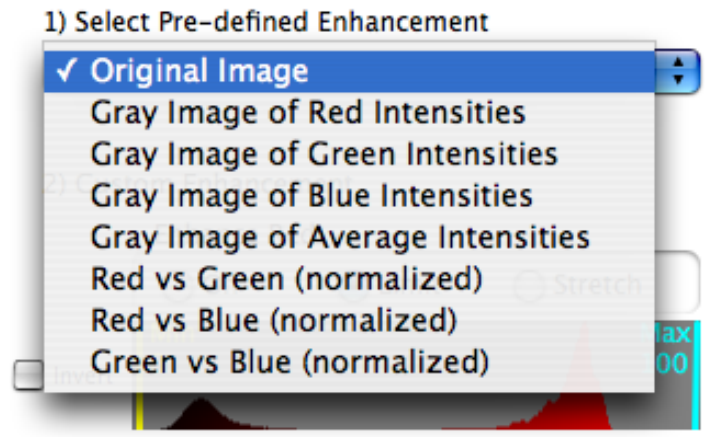
There are two ways to enhance the colors of a digital image: 1) use the predefined manipulations or 2) select color ranges to be modified. To make it easier to deal with the math of colors, the values have been converted from values ranging between 0 to 255 to 0% to 100%.



## Predefined Color Enhancements (Single Image and Time Series)

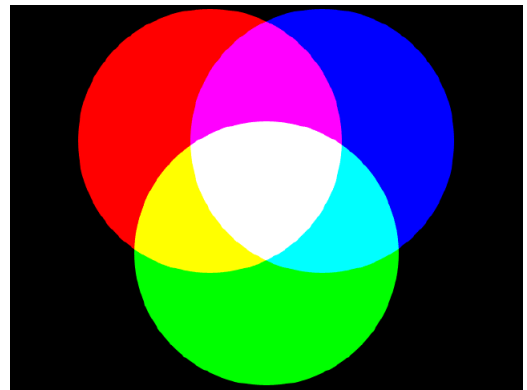
There are 8 predefined enhancements to view the digital image. To select one, click on the menu button, as illustrated on right, and select the enhancement.

**NOTE:** Once an enhancement has been calculated and displayed the first time, the image is stored so it may be redisplayed quickly when reselected.

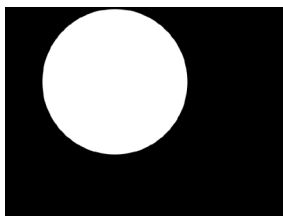


1) *Original Image* is a Red-Green-Blue (RGB) enhancement. This is the standard color arrangement of digital images. To right is an RGB image of three beams of light: red, green, and blue.

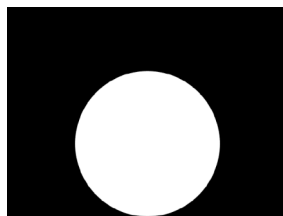
**TIP:** click on this enhancement to see the original image.



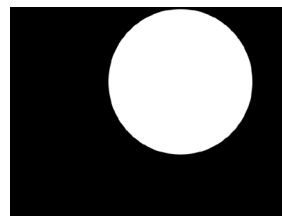
2-5) *Red, Green, Blue, or an Average of the Three Color Intensities as shades of gray*  
This enhancement displays a gray shade image of only one of the images primary colors. Gray shade images allow you to examine the intensities of values without biasing your sensitivity to red, green, or blue. Most of us have variable sensitivities to color - for example, most of us perceive green most acutely. Using shades of gray eliminates this bias in perception so we can gauge the intensities of the separate color fields more uniformly. If red is displayed as gray, high intensities appear white, low intensities appear black. Below are the four enhancements of the above RGB image.



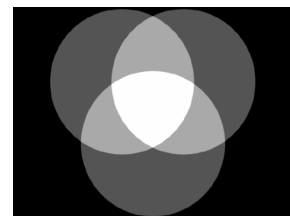
Red as Gray



Green as Gray



Blue as Gray



Average Color as Gray

#### 6-8) Red vs Green, Red vs Blue, or Green vs Blue (normalized)

These enhancements provide a visual comparison between two color layers, which may be useful for highlighting objects of a unique color or for searching for subtle color differences within the image.

The difference between the color intensities is divided by the sum of the color intensities. The color that is displayed is the color with the greater intensity. This enhancement is a common technique used in examining satellite imagery because it minimizes the effects of shadows and indirect lighting within the image. It turns out to be quite useful in observing our everyday world with digital images.

*An example of two calculations:* Suppose Red vs Green (normalized) is selected. If a pixel has red, green, and blue (RGB) values of 40%, 80%, and 60%, respectively, the difference between red and green is 40%, with the green being the more intense color of the two. The sum of the red and green intensities is 120%, so the normalized difference will be  $40\% / 120\%$  or 0.33, which is converted back to percent values of 33% for display purposes. The displayed color for that pixel will be a dark shade of green (RGB values of 0%, 33%, 0%).

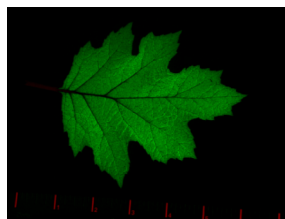
Compare this value to another pixel with a difference between red and green of 40%, but in this case the pixel has RGB values of 0%, 40%, 20%. The normalized difference is  $40\% / (0\% + 40\%)$ , which equals 1. This value is converted back to a percentage of 100%. The pixel will be displayed as a very bright green (RGB value of 0%, 100%, 0%).

**TIP:** The greater the intensity of the color displayed, the greater the relative difference between the two colors being displayed. If the two intensities are equal, the displayed color is black (RGB value of 0%, 0%, 0%).

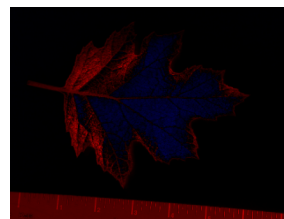
Below are two examples of the normalized difference enhancements. One is of a leaf, and the second is of the red, green, and blue light beams used in the earlier examples of the predefined enhancements.



RGB



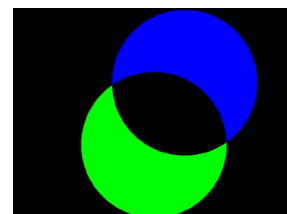
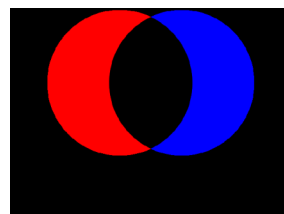
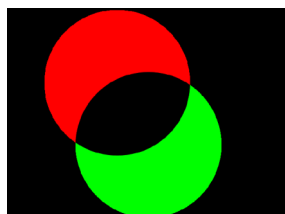
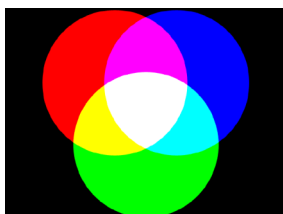
Red vs. Green



Red vs. Blue



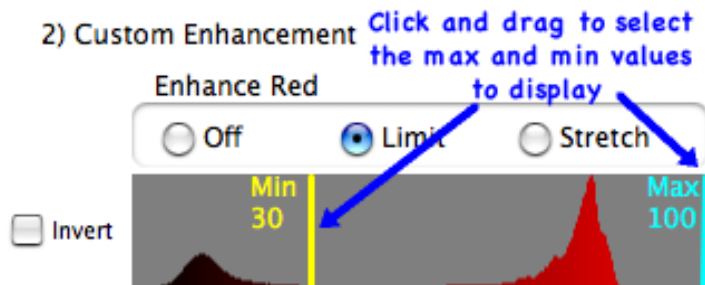
Green vs. Blue





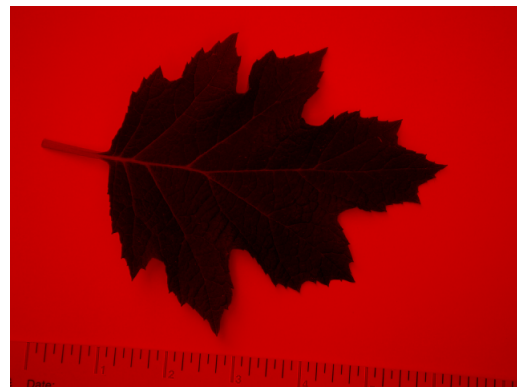
## Custom Enhancement of a Digital Image's Colors

This tool allows you to manipulate and display pixels that meet color thresholds you select. Each color layer may be manipulated separately but with the same features, so we will examine the effects of just manipulating the red color layer.

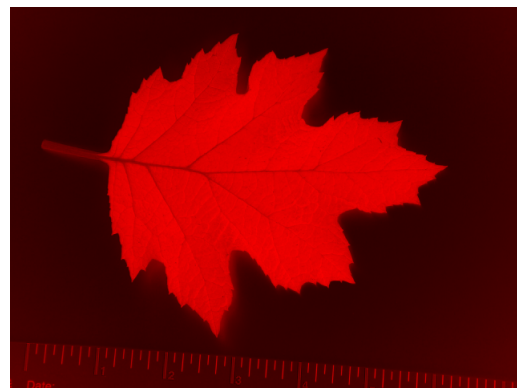


A histogram of the color intensity of the original image is plotted. A color histogram is a graph of the frequencies of the color intensities, ranging from 0 to 255, in the digital image. Colors are plotted in increasing intensity to the right, and the length of the vertical line represents the relative frequency of occurrence. Notice that each line is drawn with that color intensity—the line at the far left will be black (no red intensity), and the line at the far right will be the brightest red. Use the color histograms to identify separate groupings of color, since these often relate to different objects in the image. In this case, the red histogram is for the leaf image, and the darker red grouping is found in the leaf, and the brighter population of red is found in the white background of the image.

To turn off a color layer (or not display it), click the "Off" radio button. If both the green and blue layers are clicked off, and the full range of red colors is displayed, the image is a red-intensity version of the predefined enhancement, "Gray image of Red Intensities".



Checking the *Invert* checkbox *inverts* the selected range of a color layer, which changes those intensities by subtracting the value from 100%. So no intensity, or 0%, becomes 100% ( $100-0=100\%$ ), and the brightest intensity, 100%, becomes 0% ( $100-100=0\%$ ). The red intensity image displayed above has been inverted is displayed on the right.

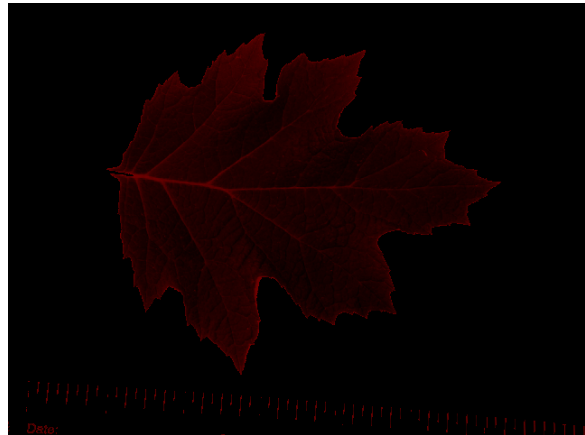
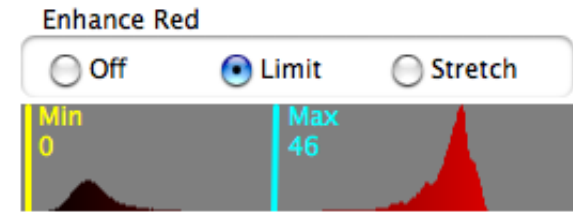


### ***Limiting a Color Range to be Displayed***

By clicking and dragging the maximum and/or minimum values on the color histogram, you can select a range of color to display. When the "Limit" radio button is clicked, only the colors within the selected range will be displayed. In this case, red intensities outside this range will be displayed with red intensity of 0%.

With the green and blue layers turned "off" (not displayed), the image of the leaf with displaying only red intensities between 0 and 46% is displayed on the right.

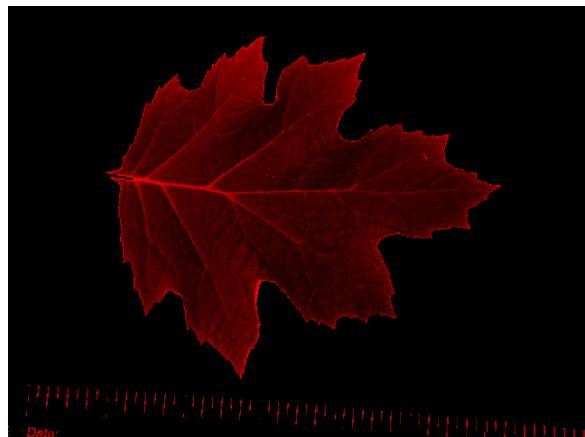
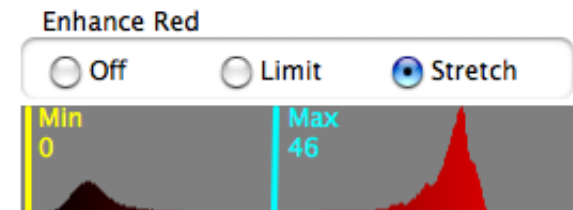
Since the background was near white, which has intensities of red, green, and blue near 100%, it now appears black since the blue and green were turned off and the high intensity red values were ignored.



### ***Stretching a Color Range to be Displayed***

Stretching a range of color is similar to the limiting method described above: only the color within the selected color range will be displayed. The difference is that the color that is displayed is stretched to fill a complete range from 0 to 100%. For the selected range of red intensities from 0-46% will be stretched so that the 0% remains 0%, the halfway intensity,  $46\%/2$  or 23% will be displayed at 50%, and the 46% will be displayed at 100%. All values between 0 and 46% will be linearly "stretched" in a similar way.

Compare the nearly identical settings for the leaf shown above (limited red intensities between 0-46% (shown above) and that when the range from 0-46% are stretched (shown on right).





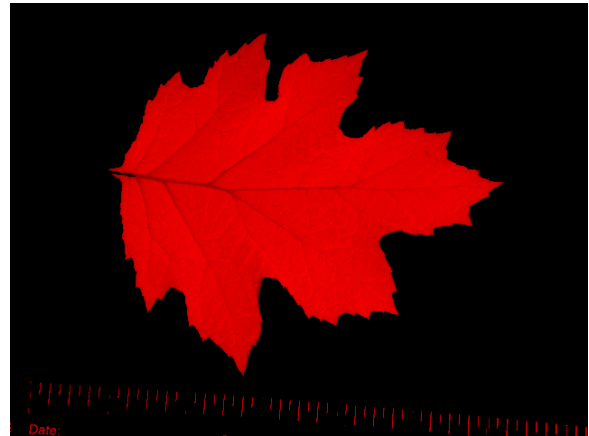
### Combining Enhancement Features

You can combine the *limit* and *stretch* features with the *invert* tool.

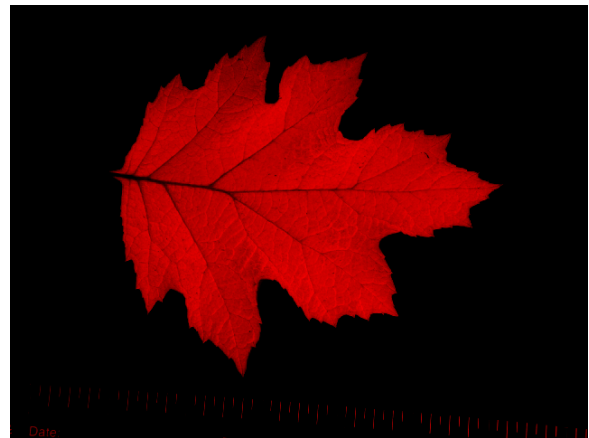
Remember, the invert tool converts the intensity value to 100%-intensity value. For the red intensities limited to 0-46%, that range will now appear at 100-0% or 100% to 100-46% or 54%.

When inverting a stretched range of color, since the stretched values are displayed from 0-100%, the inverted colors will also range from 0-100%. However, what was to be displayed as 0% in the stretched image will not appear as 100-0% or 100%, and a stretched color that would have been displayed as 100% will now be displayed as 100-100% or 0%.

**TIP:** To continue modifying colors of an already color-enhanced image, click the button *Use Enhanced Image as Original Image* in the lower left of window.



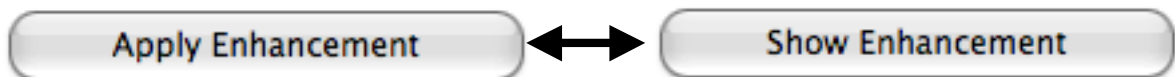
Red intensities *limited* to 0-46% and *inverted*.



Red intensities *stretched* from 0-46% and *inverted*.

### Recalling Pre-Defined and Custom Color Enhancements

Once a pre-defined enhancement has been calculated and displayed the first time, the image is stored so it may be redisplayed quickly when reselected. Similarly, once a custom color enhancement has been created, it is stored until a new custom enhancement is created. This allows you to look at pre-defined and the current custom color enhancements quickly. As a reminder that the custom enhanced image is stored, the text of the button that is used to create the custom enhancement, is changed to "*Show Enhancement*". NOTE: if any custom enhancement tool/option is changed, the stored custom enhancement is no longer available, and the text of the button is reset to "*Apply Enhancement*".



Opening a new image clears all stored images, so pre-defined enhancements will need to be calculated before it can be displayed.

## Mask Colors Tab Panel

Similar to the Enhance Colors tab panel, the Mask Colors tab panel provides tools to display pixels that meet color thresholds you select. However, with these masking tools, pixels meeting the color criteria are displayed as black. White pixels represent those that did not meet the criteria. The masked image may be used in combination with the spatial analysis tools to count the masked pixels. Using the masked image and the spatial analysis tools allows you to measure areas and color characteristics of irregular shaped objects.


Use Masking Tools to Select and Highlight the Colors of Features


Select a range of colors to highlight, or see which pixels meet color relationships between the pixels' red, green, and blue intensities. The masked image will be black and white, in which black pixels passed the color tests, white did not.


Use the masked image with the rectangle and polygon spatial tools to measure areas of features highlighted with the color masking tests.

Select Image to Mask  
☒ Original ☐ Enhanced

TEST 1: Select range of color intensities. Pixels with colors in these ranges are made black.

☒ Red 

☒ Green 

☒ Blue 

Apply Mask-TEST 1

Drag max/min values on graphs above or drag area on digital image.

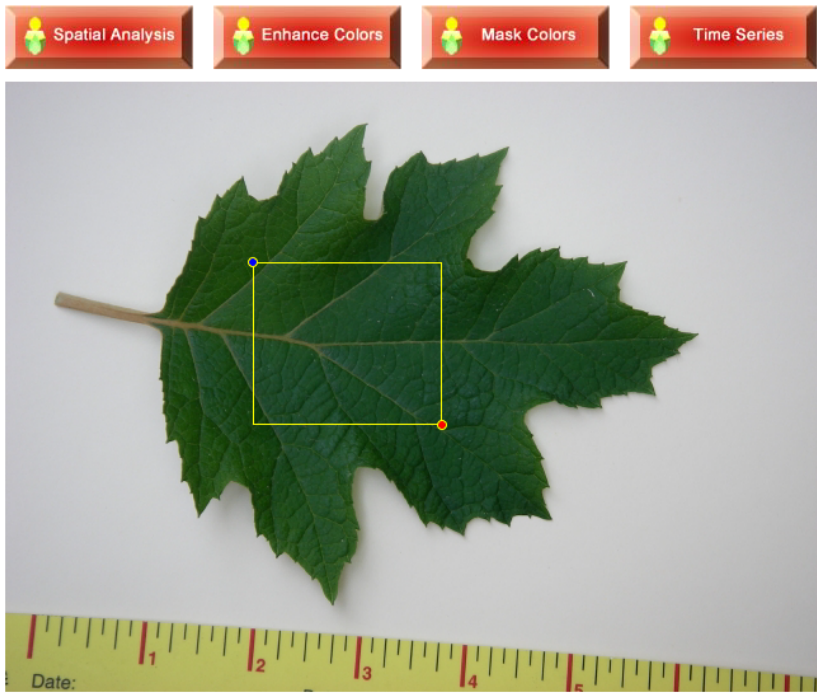
Create TEST 2 Relationship Mask

TEST 2 example: Highlight pixels that have blue intensities at least twice as great as red values.  
**NOTE: this is a very time-consuming process.**

Leaf with Ruler2.png is 640 by 480 pixels

Zoom In (drag slider or type '+' key) Magnification: 1.0000 x Zoom Out (drag slider or type '-' key)

When zoomed in, pan around the image by using the arrow keys or holding the SHIFT key and clicking and dragging the image.



Either the original image or the currently displayed color-enhanced image may be used to create a masked image. Use the radio buttons labeled "Original" and "Enhanced" to select which image will be masked. Remember, two color-enhanced images may be stored: one using the pre-defined enhancement tools and one using the custom enhancement tools. So the color-enhanced image available in the Mask Colors tab panel is the one that is displayed on the Enhanced Colors tab panel.

There are two ways to mask an image: 1) select a range of colors or 2) create a relationship of color intensities to mask.

## Creating a Masked Image by Selecting a Range of Colors

To quickly select a range of colors, click and drag a rectangle within the object of interest in the digital image. This minimizes the need to understand how color is created on a computer using intensities of red, green, and blue. However, learning this color space may help you become more intuitive in both masking and color-enhancing images. See the activities and the free color-training software, *ColorBasics*, at <http://www.lawrencehallofscience.org/gss/rev/ip/index.html>.

Two types of color TESTS generate black and white results: Black pixels passed the color tests, white did not.

The resulting black and white image is called a mask, and may be used with the "area" spatial tools (rectangle and polygon) to measure areas of features that have been isolated from surroundings with the color tests.

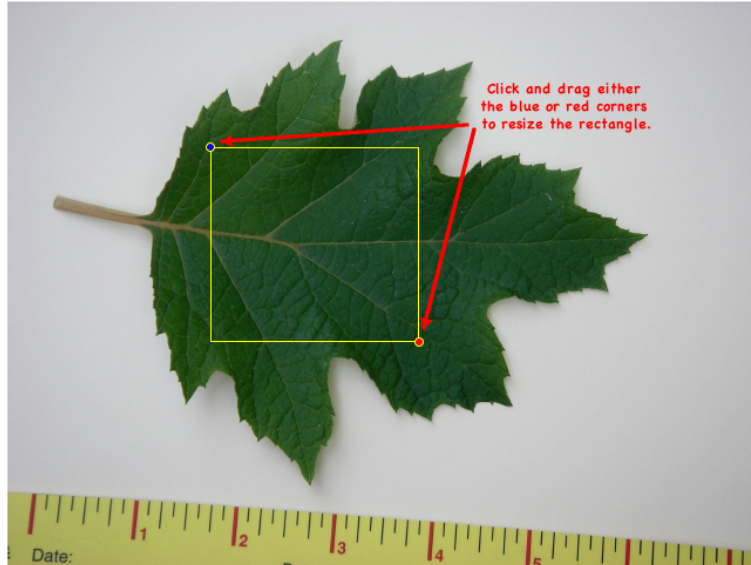
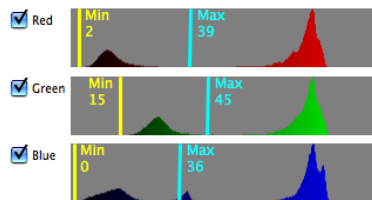
Select Image to Mask

☒ Original ☐ Enhanced

TEST 1 Magnitude of colors.

Select range of color intensities.

Pixels with colors in these ranges are made black.



The maximum and minimum values of the red, green, and blue color layers are displayed on the color histograms shown in the lower left of the tab panel. The color histogram is based on the image being displayed. Displaying the *Enhanced* image will change the color histograms, and the maximum and minimum values within the selected rectangle, which remains unchanged, will be updated on the histograms.

Two types of color TESTS generate black and white results: Black pixels passed the color tests, white did not.

The resulting black and white image is called a mask, and may be used with the "area" spatial tools (rectangle and polygon) to measure areas of features that have been isolated from surroundings with the color tests.

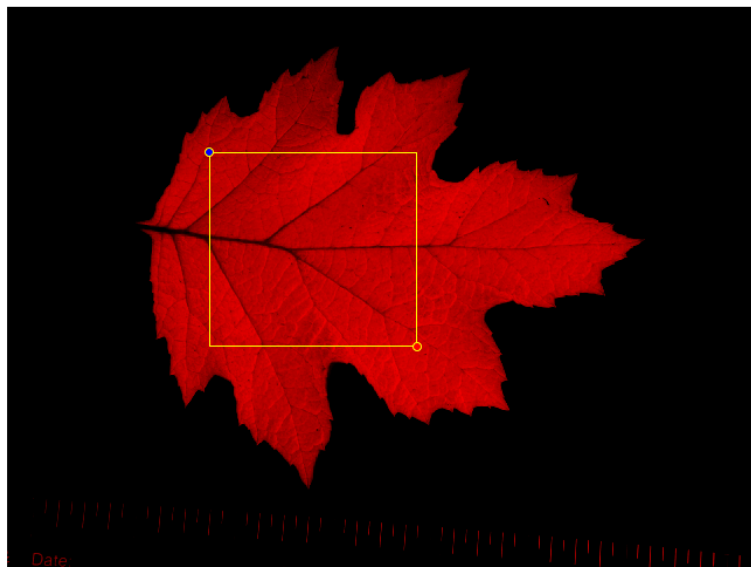
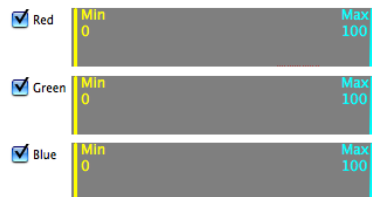
Select Image to Mask

☐ Original ☒ Enhanced

TEST 1 Magnitude of colors.

Select range of color intensities.

Pixels with colors in these ranges are made black.



To create a masked image, click the button labeled "Apply Mask-TEST 1"; however, before clicking, consider ways to speed up the masking process. Using all three criteria of color intensities takes the longest since each of the three ranges of color must be checked. If one or two colors may be tested, the process speeds up considerably. In the example with the leaf, either using the spatial analysis tools or the color histograms, you could have determined that the leaf's red, green, and blue colors were all less than the background's colors. So only the red color thresholds will be used to create the mask of the leaf. To turn off the green and blue tests, click the appropriate checkboxes so the checks disappear.

Two types of color TESTS generate black and white results: Black pixels passed the color tests, white did not.

The resulting black and white image is called a mask, and may be used with the "area" spatial tools (rectangle and polygon) to measure areas of features that have been isolated from surroundings with the color tests.

Select Image to Mask  
☒ Original ☐ Enhanced

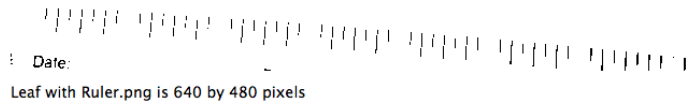
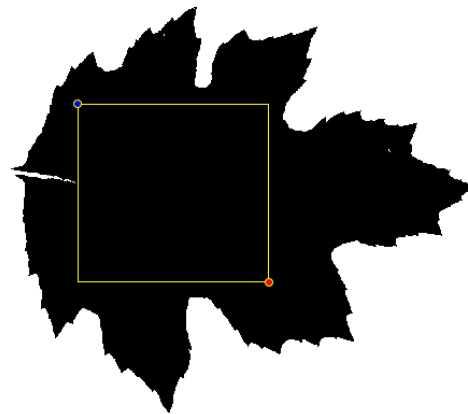
TEST 1 Magnitude of colors.  
 Select range of color intensities.  
 Pixels with colors in these ranges are made black.

☒ Red ☐ Green ☐ Blue

Min 2 Max 39

Show Mask

Drag max/min values on graphs above or drag area on digital image.



In the above mask, a bit of the main stem is not masked, so expand the range of red to be masked. Click and drag the yellow minimum line to 0% and the blue maximum line to 56% (NOTE: the main stem is lighter than the leaf, so it has a higher red intensity). Notice that when the maximum and/or minimum values are changed on the color histograms, the yellow rectangle displayed on the image disappears.

Two types of color TESTS generate black and white results: Black pixels passed the color tests, white did not.

The resulting black and white image is called a mask, and may be used with the "area" spatial tools (rectangle and polygon) to measure areas of features that have been isolated from surroundings with the color tests.

Select Image to Mask  
☒ Original ☐ Enhanced

TEST 1 Magnitude of colors.  
 Select range of color intensities.  
 Pixels with colors in these ranges are made black.

☒ Red ☐ Green ☐ Blue

Min 0 Max 56

Show Mask

Drag max/min values on graphs above or drag area on digital image.





To test if the mask is adequate, click on the "*Original*" radio button to display the original and compare it to the masked image. To see the masked image again, click on the button that has been relabeled "*Show Mask*". If the mask covers the object of interest, in this case, the leaf, you should not see a change in the boundaries of the leaf in both images. Until new mask criteria are created, the masked image is stored so it may be quickly displayed again.

Two types of color TESTS generate black and white results: Black pixels passed the color tests, white did not.

The resulting black and white image is called a mask, and may be used with the "area" spatial tools (rectangle and polygon) to measure areas of features that have been isolated from surroundings with the color tests.

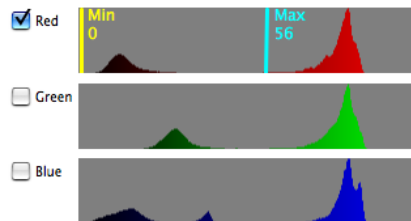
Select Image to Mask

☒ Original ☐ Enhanced

TEST 1 Magnitude of colors.

Select range of color intensities.

Pixels with colors in these ranges are made black.



Show Mask

Drag max/min values on graphs above or drag area on digital image.



Leaf with Ruler.png is 640 by 480 pixels



### ***Creating a Masked Image by Creating a Relationship of Color Intensities***

As with the predefined color enhancements that compare one color layer to another, for example, the red versus green (normalized), different patterns will appear compared to looking at ranges of color. To create a masked image based on a relationship between color intensities, click the button labeled "*Create TEST 2 Relationship Mask*" located in the lower left corner of the tab panel.

Create TEST 2 Relationship Mask

A window appears in which you may create a mathematical relationship between two or three color layers. NOTE: the color values are now based on 0-255, since you need access to the full range of colors for this tool.

Create a Mask based on Relationships between Colors of a Digital Image

Create color relationships to identify spatial and spectral relationships in digital images.  
  
This is a slow process, and for large digital images, it can be dramatically slow. Consider trimming the size of the digital image to identify the best relationship before applying to the original, full-size image.

Example: Show the pixels with more than twice as much red as blue:  
 $1 \times \text{Red} + 0 \times \text{None} \geq 2 \times \text{Blue}$  OR  $1 \times \text{Red} * 0.5 \times \text{Blue} \geq 1 \times \text{None}$

Example: Show the pixels where the red values are within 5 of green:  
 $1 \times \text{Red} +/- 5 \times \text{None} = 1 \times \text{Green}$

1

 x 

Choose Color

+ ...

0

 x 

Choose Color

 = 

1

 x 

Choose Color

NOTE: To increase the flexibility for this tool, pixel values range from 0-255 rather than the previous 0-100%, respectively.

Apply Relationship Mask

Close Window

***TIP:*** This option takes a long time to complete the calculations for each pixel. To minimize the time, use the "Trim Image" in the Utilities Menu to make an image so it just fills the 640 x 480 image space.

## About Tab Panel

The About tab panel describes how the software was developed by the seven collaborating institutions funded by NASA. Move the cursor over an icon to see the address for the website for each institution.

About the Project

IntroSpatial AnalysisEnhance ColorsMask ColorsCheck Color QualityAbout

The original software components were created by John Pickle and Jacqueline Kirtley, Museum of Science, Boston, MA in support of the Lawrence Hall of Science's Global Systems Science student series in 2002 with NASA funding.


These revisions were created to support the NASA-funded project, Digital Earth Watch, originally named Measuring Vegetation Health - <http://mvh.sr.unh.edu/>. This educational project is a collaboration between seven institutions (logos have rollover urls) to develop learning activities, technologies, and software to measure environmental health by monitoring plants:


- Museum of Science, Boston, MA (lead institution) - [www.mos.org](http://www.mos.org)
- Global Systems Science, Lawrence Hall of Science, Berkeley, CA (co-lead)  
- [www.lawrencehallofscience.org/gss](http://www.lawrencehallofscience.org/gss)
- Forest Watch, University of New Hampshire, Durham, NH (co-lead)  
- [www.forestwatch.sr.unh.edu/](http://www.forestwatch.sr.unh.edu/)
- EOS-Webster, University of New Hampshire, Durham, NH  
- [eos-webster.sr.unh.edu/](http://eos-webster.sr.unh.edu/)
- Remote Sensing and GIS Laboratory, Indiana State University, Terre Haute, IN  
- [baby.indstate.edu/geo/rs/main.htm](http://baby.indstate.edu/geo/rs/main.htm)
- Blue Hill Observatory, Milton, MA - [www.bluehill.org/](http://www.bluehill.org/)
- College of Education and Human Development, University of Southern Maine, Portland, ME - [www.usm.maine.edu/cehd/](http://www.usm.maine.edu/cehd/)


John Pickle programmed these revisions, which reflect invaluable feedback and input from the DEW team and years of working with teachers and informal science educators. Unless otherwise credited, photos by John Pickle.


This software may be freely copied and used for all educational applications.  
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Version 12 created March 20, 2009.

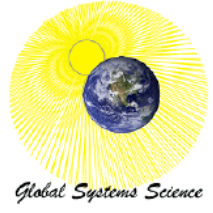
  
Measuring Vegetation Health


  
Museum of Science


  
Forest Watch

  
Indiana State University  
More. From day one.

  
usm

  
Global Systems Science

  
EOS WEBSTER

  
1885

## Overview of Menus

There are five primary menus: *File*, *Utilities*, *Measurements*, *Save Color Masks*, and *Apply Color Masks*. The *File* Menu has the basic operations to load, save, and print images; calibrate pixel size; show or hide the original image; and display color histograms. The *Utilities* Menu allows images to be trimmed for faster analysis and create a new image by combining multiple images. The *Measurements* Menu provides tools to save spatial measurements to text files, which may then be used by spreadsheets to numerically analyze and graph the data. *Save Color Masks* and *Apply Color Masks* provide efficient analysis of color-coded maps, such as those used at the Pollen Viewer website (<http://www.ncdc.noaa.gov/paleo/pollen/viewer/webviewer.html>).

## Details of Menus

### File Menu

The File Menu provides has the tools to load, save, and print images; calibrate pixel size; show or hide the original image; and display color histograms.



### Open Picture

To select a digital image that is stored on the computer, an external memory device (i.e., a flash drive or removable hard drive), or a CD or DVD, select this tool. This function has been described in the Intro tab panel (see page xx).

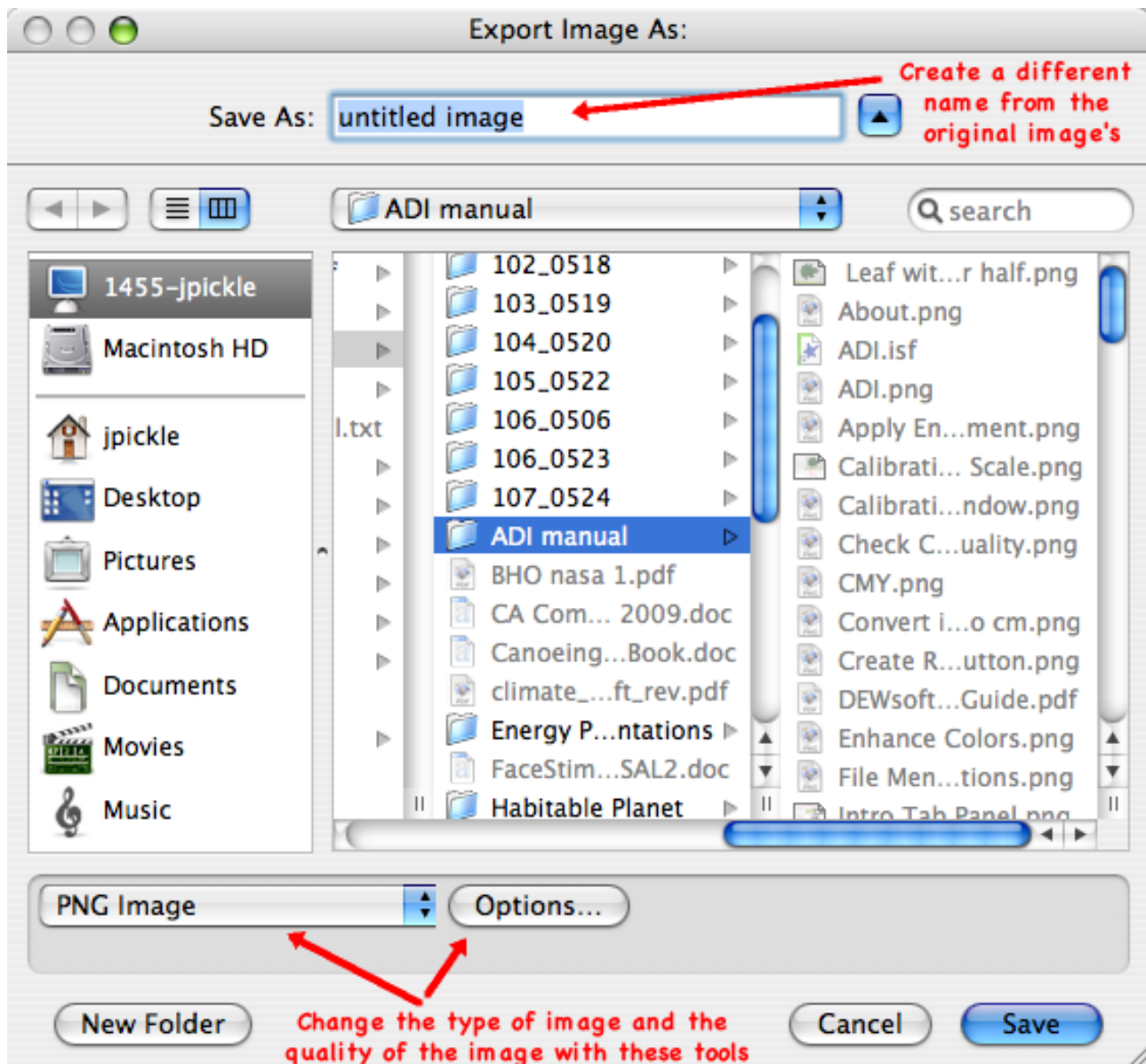
### Calibrate Pixel Size

To select a digital image that is stored on the computer, an external memory device (i.e., a flash drive or removable hard drive), or a CD or DVD, select this tool. This function has been described in the Intro tab panel (see page xx).

## Save Picture

Saving a picture has two main purposes: 1) include the images created/analyzed in reports and presentations, and 2) save a manipulated/enhanced image to be analyzed with the software since some tools aren't able to work on a "temporarily" enhanced image. This second option requires that the save image be opened (see *Open Picture* function).

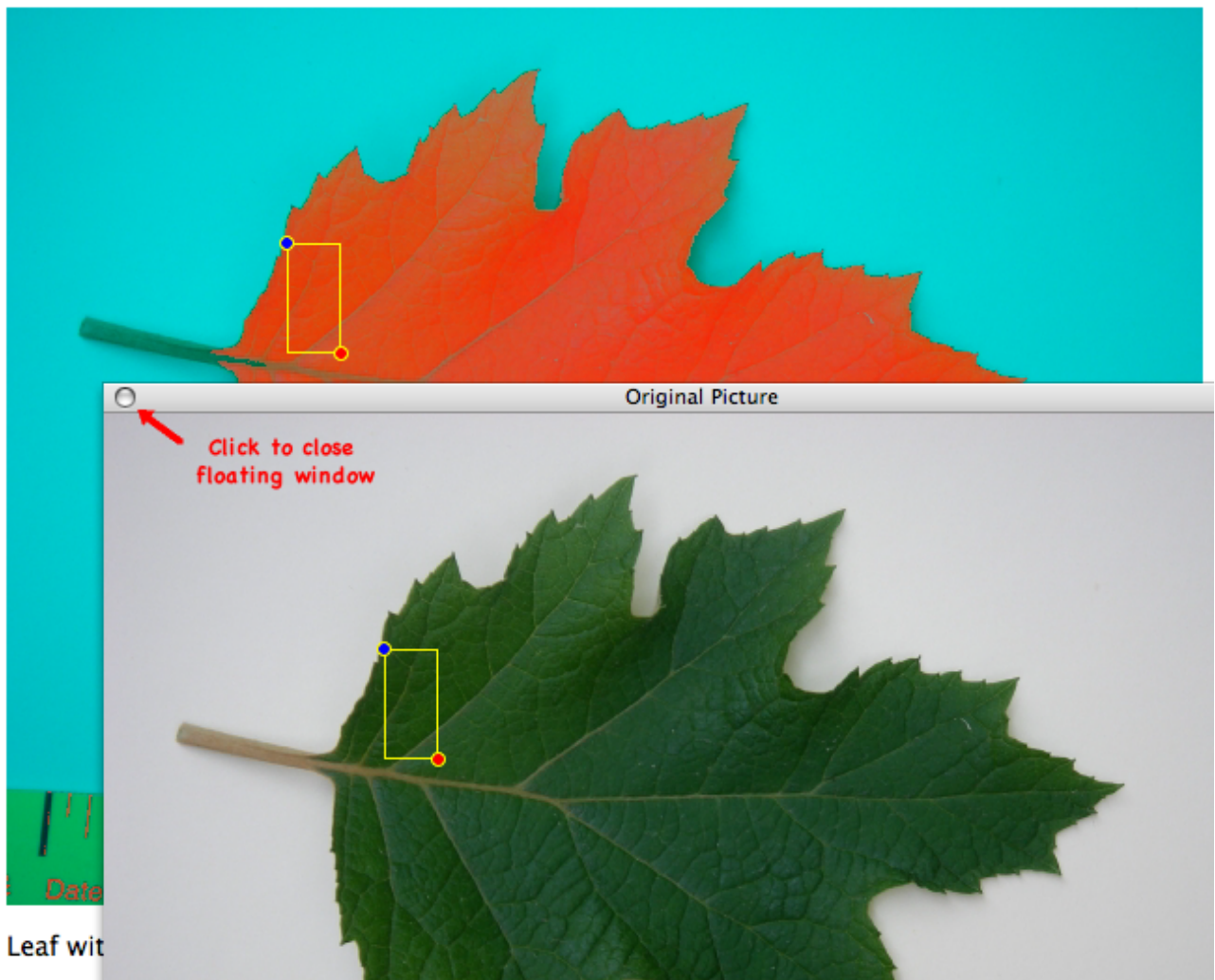
When this tool is selected, you may create a name for the image that is different from the image used to create it (TIP: this is HIGHLY recommended), and you may change the type and quality of the image being saved. TIP: always check the default options for the type of file being saved since computers do not have a standard default setting.



### **Show/Hide Original**

Sometimes it is necessary to view both the color-enhanced or masked image and the original image simultaneously. To create a floating original image (a floating image is one that may be dragged around the window without disturbing other windows), click the *Show/Hide Original* option. If you are using spatial analysis tools, you may draw on either image, and the spatial tool is drawn on both images at the same time. The average color measured with the spatial tools will be based on the enhanced/mask image, and not the floating original image.

Close the window by clicking the small close button or selecting the *Show/Hide Original* option again.

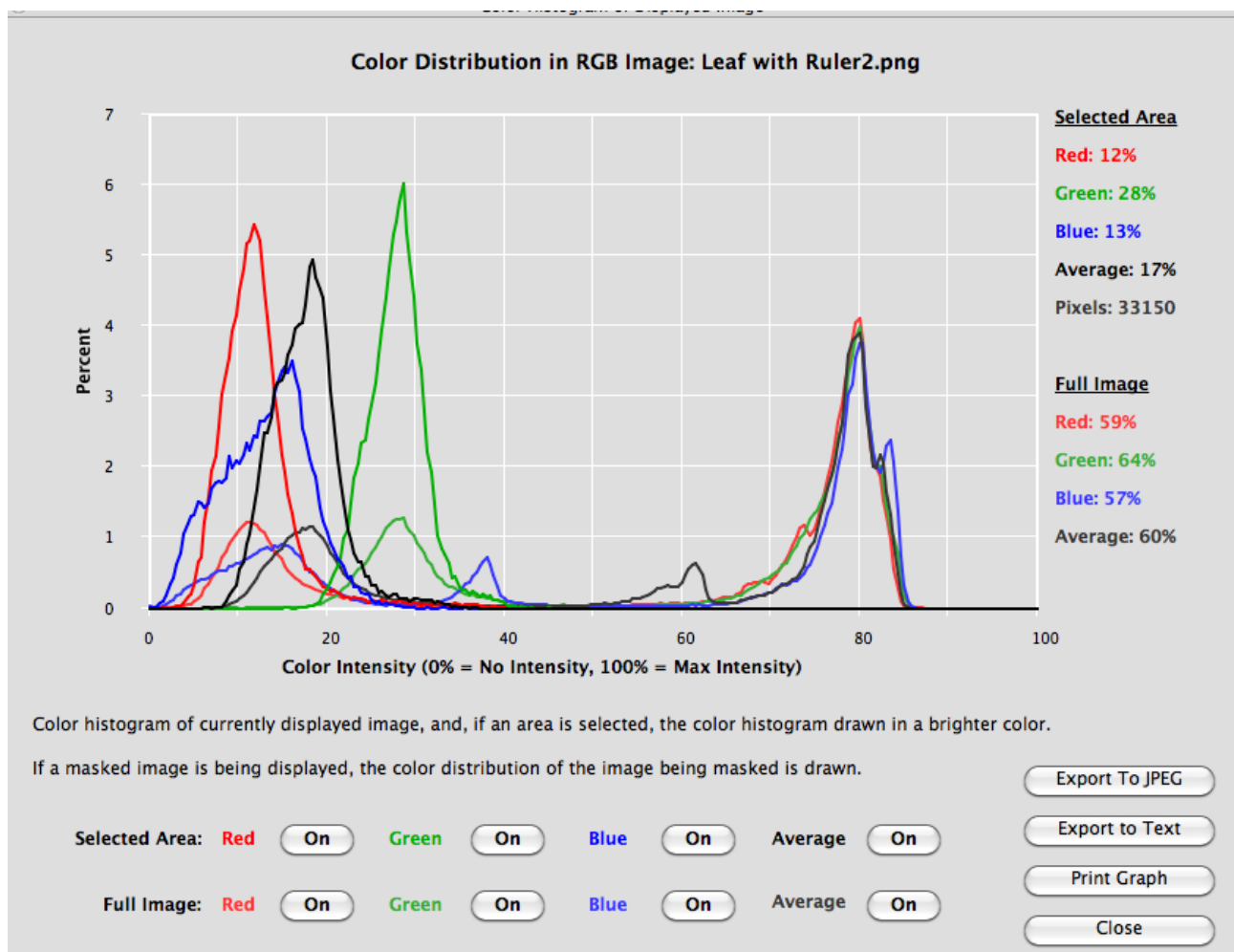




## Draw Color Histogram

When one of the area spatial analysis tools (rectangle or polygon) is used, a histogram of the frequencies of the colors within the boundary of the drawn area and the entire image is available by selecting " *Graph Selected Colors* " in the *File Menu*. The "dulled" colored lines represent the frequency of colors within the complete image, and the "intensely" colored lines represent the frequency of colors within the selected area. Hide or show lines using the "On" buttons (which becomes "Off" when the line becomes hidden).

A color histogram is a graph of the frequencies of the color intensities, ranging from 0 to 255, but the scale of intensities on the x-axis remains 0-100%. Colors are plotted in increasing intensity to the right, and the vertical height of the line at any point represents the relative frequency of occurrence for the given color intensity.



The data used to create the histograms may be saved to a tab-delimited text file that may be imported in any spreadsheet software. The frequencies for the complete image and the selected area are saved for the corresponding color intensities. The graph may be saved as a jpg or printed.

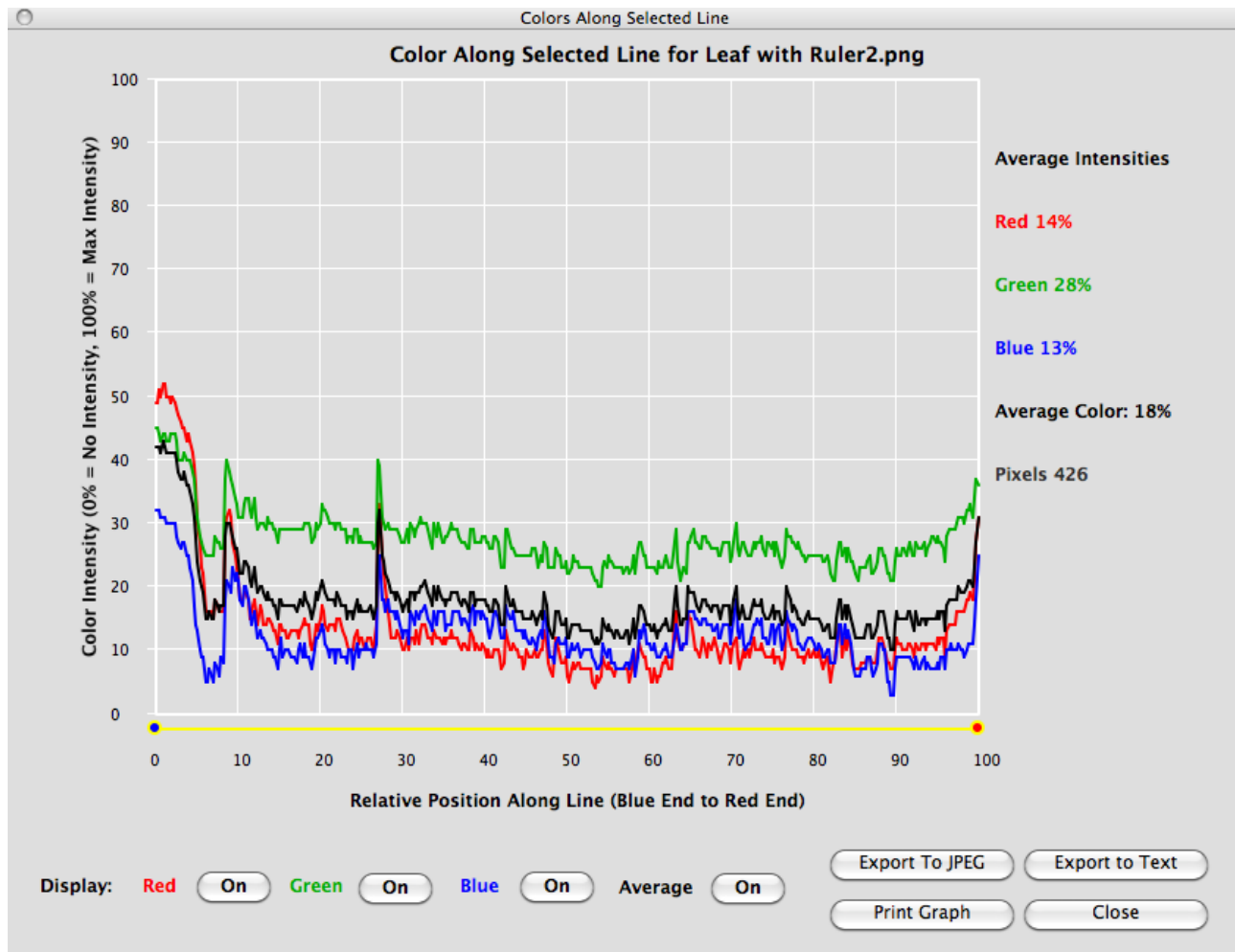
test color histogram.txt							
	A	B	C	D	E	F	G
1	Image	Leaf with Rule	RGB	Scaling Factor	-1 --		
2							
3							
4	Number of Pixels	646					
5							
6							
7	Intensity	Red Rel Freq	Green Rel Freq	Blue Rel Freq	Red Rel Freq	Green Rel Freq	Blue Rel Freq
8	0	0	0	0.03	0	0	0
9	1	0	0	0	0	0	0
10	2	0	0	0.01	0	0	0
11	3	0	0	0.01	0	0	0.15
12	4	0	0	0.03	0	0	0.3
13	5	0	0	0.04	0	0	0.9
14	6	0	0	0.08	0	0	1.2
15	7	0	0	0.11	0	0	3.15
16	8	0	0	0.16	0	0	2.4
17	9	0.01	0	0.2	0	0	3.45
18	10	0.02	0	0.25	0	0	4.05

Example of the tab-delimited text file opened in Excel. Notice the columns are labeled.

### ***Draw Color Along Line and Path***

Using the Spatial Analysis line or path tools, you can explore the colors of the pixels touching the line or path using the "*Graph Selected Colors*" option in the *File Menu*. The graph shows which is the blue and the red end of the line or path.

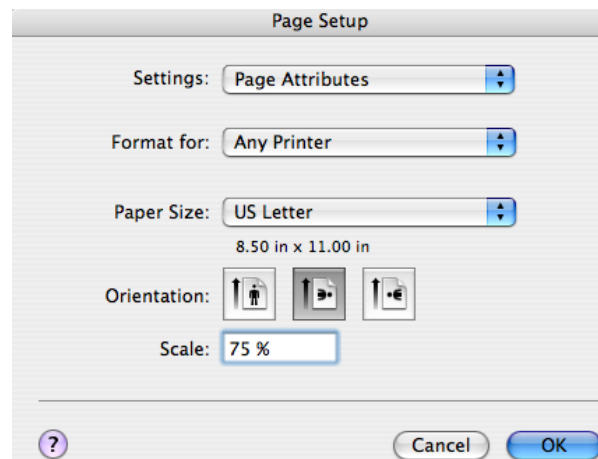




Hide or show lines using the "On" buttons (which becomes "Off" when the line becomes hidden). Export the graph as a jpeg, print the graph, or save the color data to a tab-delimited text file that may be used in many spreadsheet programs such as Microsoft Excel.

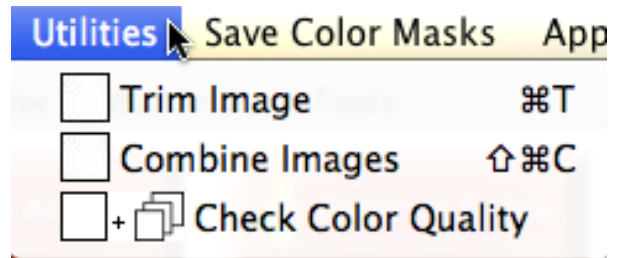
### Page Setup

In order to print a picture, especially large ones, you will need to setup the page values. You may need to explore the proper scale (percentage) to fit the image onto one page.



### ***Utilities Menu***

There are two utilities that allow you to create images that may be used in the software. The trim options allow you to create smaller sized images, which speed up time-intensive analysis operations. The second utility creates a new image by combining images in a variety of ways. A third utility allows you to check the color quality of your computer display.



## Trim Image Utility

An image may be trimmed in three ways:

1) the complete image may be subsampled (systematically skip pixels) to make it a smaller size, 2) the part of the image that is displayed by using the zoom and pan tools is saved at the resolution of the original picture (only a portion of the original image is being saved - useful when working with images with known pixel size, such as satellite image and aerial photographs), and 3) save the part of the image being displayed at a different resolution from the original.

### ✓ Select Trim Option

- 1) Full image at selected resolution
- 2) Displayed image at full resolution
- 3) Displayed image at selected resolution

Trim Your Image (Crop and/or Subsample) to Speed Up Computer Processing Time

Pictures with millions of pixels (megapixels) take much more computer time to analyze than images that are roughly a megapixel. To save time, trim the photo with any of the three options to use only the pixels needed.

1) Scale the full image to a lower resolution (subsample).

Use to rapidly survey the image for interesting results. When important trends are discovered, then use the full-size image to add precision.

2) Cut out (crop) the displayed image at the full resolution of the original image.

Use with images with "known" pixel size (common with satellite images and orthophotographs), and only part of the image is of importance. Use the zoom and pan tools to display the part of the image of interest.

3) Subsample and crop. Use the zoom and pan tools to display the part of the image that is of interest and scale to a lower resolution (the minimum size is 640 x 480 pixels).

Use this option when you don't need the precision and only part of the image is of importance.

Select Trim Option

Selected Width 640 Selected Height 480

Trim and Use Image

Cancel

Leaf with Ruler2.png is 640 by 480 pixels

Resolution of Displayed Image = 640 by 480 pixels

Image Left 0 Image Top 0 Width 640 Height 480

Magnification: 1.0000 x

Click to zoom in or use '+' key

Click to zoom out or use '-' key

When zoomed in, pan around the image by holding the SHIFT key and click and drag the image, clicking the small arrows above, or use the arrows on your keyboard.



Notice that the size and left/top values change when you zoom in and pan the image. Use this information to create the best selection of the image to keep in the trimmed image.

Pictures with millions of pixels (megapixels) take much more computer time to analyze than images that are roughly a megapixel. To save time, trim the photo with any of the three options to use only the pixels needed.

- 1) Scale the full image to a lower resolution (subsample).


Use to rapidly survey the image for interesting results. When important trends are discovered, then use the full-size image to add precision.

- 2) Cut out (crop) the displayed image at the full resolution of the original image.

Use with images with "known" pixel size (common with satellite images and orthophotographs), and only part of the image is of importance. Use the zoom and pan tools to display the part of the image of interest.

- 3) Subsample and crop. Use the zoom and pan tools to display the part of the image that is of interest and scale to a lower resolution (the minimum size is 640 x 480 pixels).

Use this option when you don't need the precision and only part of the image is of importance.



Select Trim Option

Selected Width 640

Selected Height 480

Trim and Use Image

Cancel

Leaf with Ruler2.png is 640 by 480 pixels

Resolution of Displayed Image = 640 by 480 pixels

Image Left 67

Image Top 63

Width 428

Height 321

Magnification: 1.4925 x

Click to zoom in or use '+' key

Click to zoom out or use '-' key

When zoomed in, pan around the image by holding the SHIFT key and click and drag the image, clicking the small arrows above, or use the arrows on your keyboard.

After clicking "*Trim and Use Image*", you will have a chance to calibrate the image at the changed resolution. If you are using an image with known pixel size, you can't use the "*Known Pixel Size*" option because the pixels didn't change size—rather, pixels have been lost.

**NOTE:** The image has not been saved, so if you plan on using it again, save it with a different name from the original.

## Combine Image Utility

You have three options to combine digital images into one:

1) put two or three different images into the color layers of the new image, 2) subtract one image from another, and 3) average a selectable number of images into one. NOTE: in all of this options, you must use images that are the same size.

Since digital images are made up of three layers of color, combining two or three images from a time sequence of images (e.g., a time series of maps, frames from a movie, a time lapse series of images with the camera on a tripod, etc.) quickly shows change of objects in the image. Use option 1) *Use Color Layers from Different Images* to create these types of images. TIP: If the images have been saved as a *Gray Image of Average Intensities* (a pre-defined color enhancement), then the unchanged parts of the image appear black-and-white and the parts that have changed have a color other than gray.

Clicking option 1 opens a window to select the images to be placed in the color layers. In this example, the "before" picture was placed in the red and blue layers, and the "after" picture was placed in the green layer. Images that appear magenta are where a moved object started, and the green shows where it moved.

Combining images helps identify similarities and differences between the images. Use these three options to combine two or more images and use the analysis tools to explore the new image.

1) Put color layers from different images into a new image to compare up to three images at once.

TIP: Use Enhancement tools to create grayscale images of colors first so that identical areas are in black and white and the differences will be colorized.

2) Select two pictures and subtract their color intensities.

3) Average a set of images into one image.

**Note: each image must have the same dimensions.**

1) Use Color Layers from Different Images

2) Subtract images from each other

3) Average a Set of Images into One

Use Image with Analysis Tools

Clear and Start Over

Cancel

Make One Image from Several

Select images to be placed in the color layers of one image.

The color layer of the selected image will be used for the color layer of the final image.

Select Red Image

Select Green Image

Select Blue Image

**Note: each image must have the same dimensions (number of pixels wide by number of pixels high).**

Close



Before



After



Combined

A second option subtracts images from each other, which may be used to study the differences between images. Compare the subtracted before and after images of the office above to the combined image. Once selecting this option, a series of windows allows you to select the two images and what colors should be subtracted and how displayed (shade of color or gray).



Select two images to subtract

Select two images to be subtracted from each other.

After both images are selected, select which color intensities should be subtracted.

Select First Image

Select two images to subtract

Select two images to be subtracted from each other.

After both images are selected, select which color intensities should be subtracted.

Select Second Image

Note: each image must have the same dimensions (number of pixels wide by number of pixels high).

Select two images to subtract

Select two images to be subtracted from each other.

After both images are selected, select which color intensities should be subtracted.

Subtracting one image from another can be quite time consuming for large images.

To speed up your explorations, consider trimming the images using the Trim Utility first, and then resume this process.

When you have the desired image, use the originals to create the best image for printing or detailed analyses.

Subtract Red Only ☒ Gray Shades

Subtract Green Only ☒ Gray Shades

Subtract Blue Only ☒ Gray Shades

Subtract Red, Green, and Blue

Close

This feature also creates artistic images from two images of nearly the same object(s). Consider the image created by subtracting two images of vultures roosting in a tree.



The third option lets you average any number of images into one image. After selecting the number of images, the number of images average so far and the file name of the last picture opened is provided to help you keep track.

Average a Series of Images into One

Select a series of images to average into one image.

After typing in the anticipated number of images, click "Select Pictures to Average".

**Note: each image must have the same dimensions (number of pixels wide by number of pixels high).**

Number of Pictures to Merge

Select Pictures to Average

Number of Pictures Averaged so far: 0

Last Picture Opened:

To cancel this process once started, cancel selecting a picture three times in a row.

Close

Average a Series of Images into One

Select a series of images to average into one image.

After typing in the anticipated number of images, click "Select Pictures to Average".

**Note: each image must have the same dimensions (number of pixels wide by number of pixels high).**

Number of Pictures to Merge

Select Pictures to Average

Number of Pictures Averaged so far: 5

Last Picture Opened:  
Sunrise051001-1min 5.png

To cancel this process once started, cancel selecting a picture three times in a row.

Close

The image on the right is an average of three frames from a timelapse sequence of a sunrise on Cape Cod.





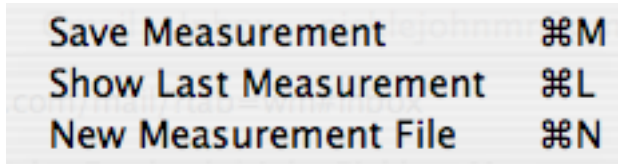
### **Check Color Quality Utility**

Check Display's Color is a visual test to see if the quality of the computer screen/television/projector has adequate range in color reproduction to provide a meaningful exploration of the digital image activities. The panel displays 81 color tiles of shades of gray, red, green, blue, yellow, magenta, cyan, and brown. If all 81 color tiles are visible, the quality of the display is adequate for the seeing subtle color differences in most images.





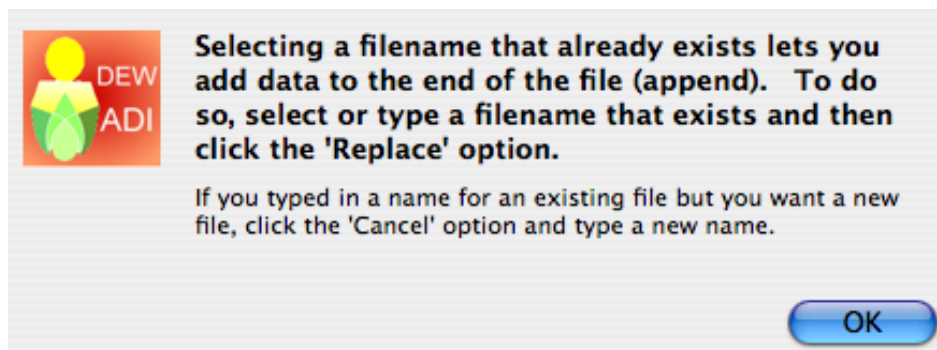
## Measurements Menu

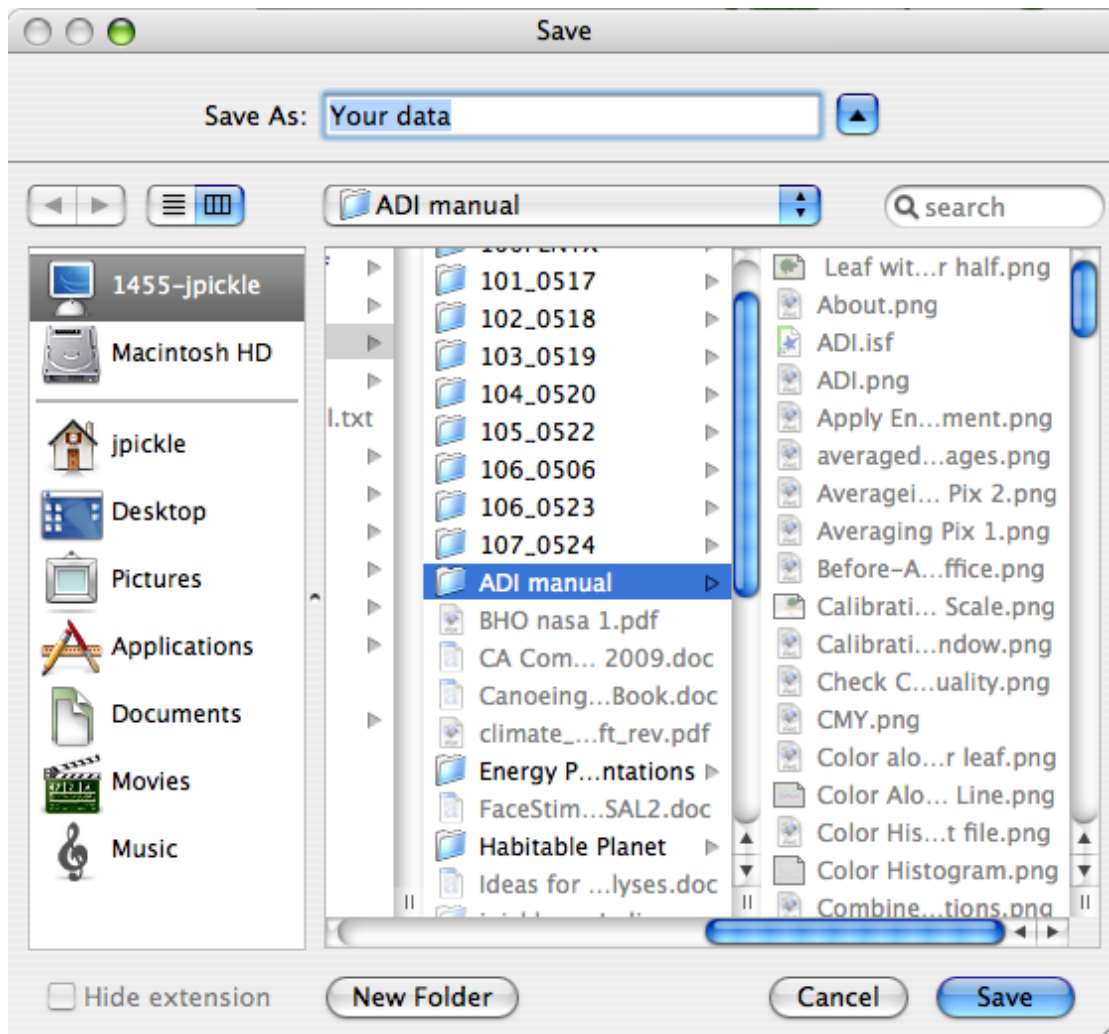


Doing research often requires collecting and then analyzing measurements, and to support the first effort, this software strives to make collecting measurements for analysis as efficient (and painless) as possible. So any measurement you can make with the spatial analysis tools available in this program can be written to a tab-delimited text file, which is a file format that allows any spreadsheet program to import. Once in a spreadsheet, the data may be graphed and analyzed using software that is a standard in middle and high schools (for example, Microsoft Excel or iWork's Numbers).

## Save Measurement

The first time this feature is selected after the software has been opened, you will be asked to select a file where the data will be saved. If you select an existing file, data will be saved to the end of the file (this is called *appending* the data to a file). If you create new file, a file will be created on the computer, and measurements will be saved sequentially.





TIP: create a filename that has meaning about the data being collected. For example, "file1" or "MyData" does not provide what data is being stored. After you have collected a number of files of data, you don't want to open up a file to see what it contains. A file containing leaf measurements of poison ivy might be named "PoisonIvyJuly42009".

Each measurement has additional data automatically saved. The data include:

- Filename of image currently opened
- Scaling factor based on calibration (will be set to -1 if image has not been calibrated)
- Scaling unit, if calibrated (for example, cm, km, etc.)
- Spatial analysis tool currently selected
- Spatial measurement
  - Two measurements are saved
    - Calibrated measurement (if not calibrated, will equal "-1")
    - Measurement in pixels

- If the image being analyzed is a mask (pixels within the selected color range have been turned black), then the area or length represented by only the masked pixels is given in the measurement.
- Percent of masked pixels within selected area or along selected line (will equal "-1" if not a masked image)
- If pixel tool selected, all values will equal "-1"
- X and Y coordinates of measurement on the image (based on pixel location with upper left corner having the coordinates 0, 0)
  - Pixel tool: only one X/Y coordinate given, remaining pair equal -1, -1
  - Line tool: X/Y given for both ends of line
  - Rectangle tool: X/Y given for opposing corners of the rectangle (marked with red and blue dots)
  - Polygon tool: there are too many "corners" (vertices), so the two sets of X/Y equal -1, -1
- Color enhancement being used (RGB, Enhanced, or Masked)
- Color measurements associated with selected feature using the Spatial Analysis Tool (average, maximum, minimum, and standard deviation for the red, green, and blue values of the pixel at the cross hair of the pixel tool, pixels touching the line using the line tool, or pixels within the selected rectangle or polygon)

NOTE: each measurement contains the same number of saved items in the same sequence (and each item is labeled), which makes it easier to use in a spreadsheet.

In addition, you may add two additional pieces of information. You decide if they should be numerical (say, date or time of measurement) or information (for example, location of sample, species of leaf, etc.).

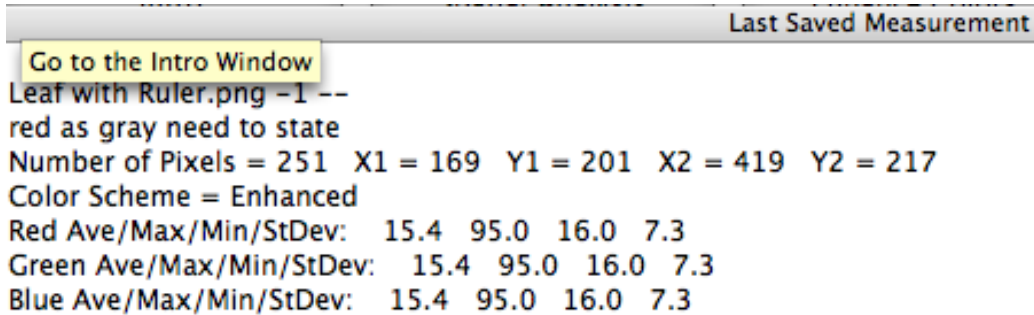
Additional Data to be saved

Comments

Note: Do not type the 'return' or 'enter' key and keep comments as brief as possible.

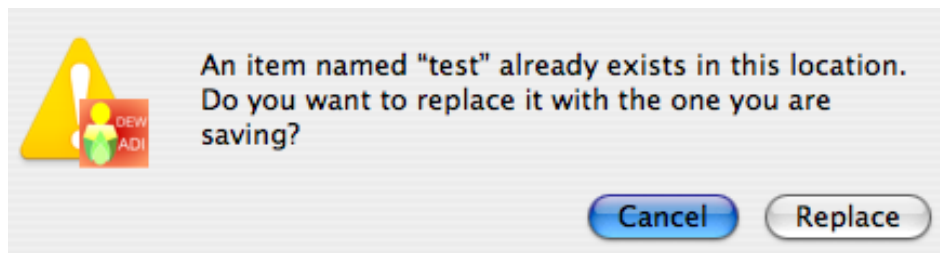
### Show Last Measurement

When you are making many measurements at one sitting, it is sometimes hard to remember what was your last measurement. To help you, you can review what was last saved using this feature.



### New Measurement File

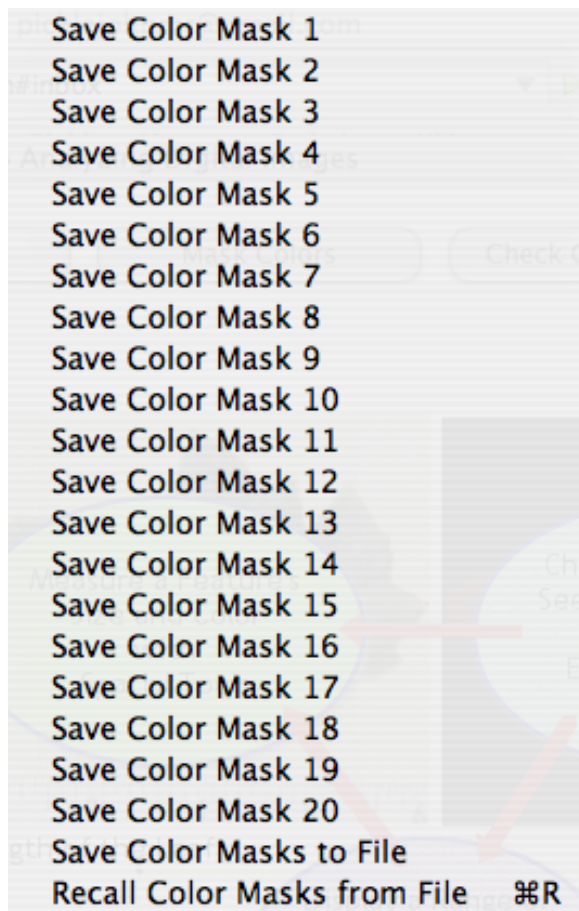
You might want to create different files to keep different measurements organized to make the analysis more efficient. To save to a new measurement file, select this option and either create a new file or select an existing one. If you do select an existing file, you will be asked if it should be replaced. If you want the measurements to be appended (added to the end of the existing measurements), click "*replace*". If you click "*cancel*", you will be asked to create or select another file.



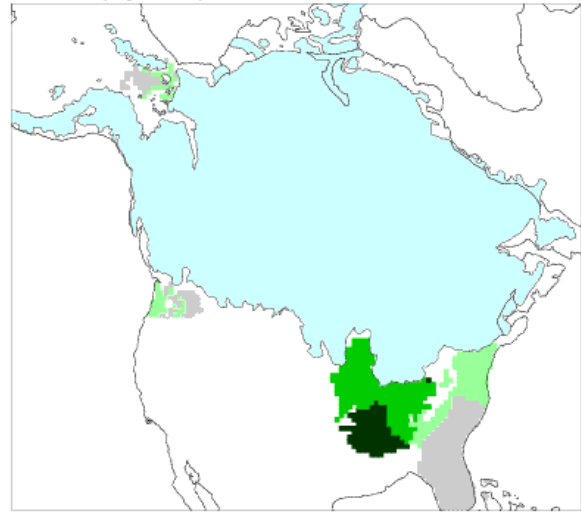
NOTE: The above window can be misleading, but unfortunately, it cannot be changed. Remember, you aren't replacing the existing measurement file, rather the new data will be added to the file.

## Save Color Masks

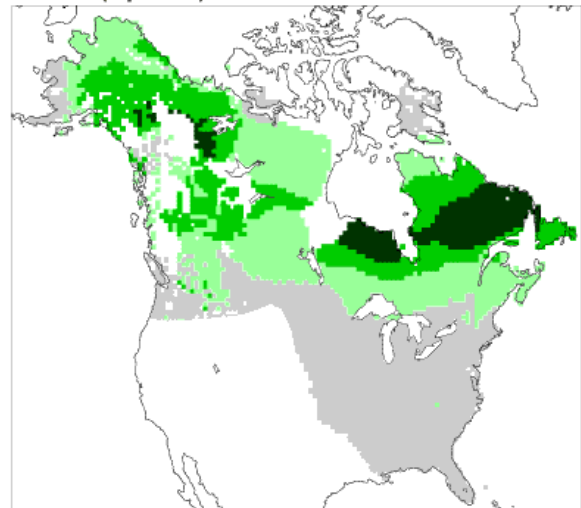
If a time series of digital maps uses the same colors to represent the same numerical values, the software allows you to efficiently analyze the time series of maps by saving the ranges of colors representing the maps numerical values. For example, the maps used to show the extent and concentration of tree species across North America over the past 21,000 years (from the Pollen Viewer website: <http://www.ncdc.noaa.gov/paleo/pollen/viewer/webviewer.html>). Using the mask tool combined with the spatial tools (rectangle or polygon), you can measure the distribution of trees and ice in any selected area of the map as the ice sheets retreated across the continent.



***Picea* (Spruce) Differentiated 21,000**



***Picea* (Spruce) Differentiated Modern**



Legend of Colors  
(Values are percent coverage)



Light blue is ice.



## Save Color Mask #

To select a range of colors to mask, click and drag a rectangle in an area with only that color present. For ice, the color on the map is 80% red, 100% green, and 100% blue.

Two types of color TESTS generate black and white results: Black pixels passed the color tests, white did not.

The resulting black and white image is called a mask, and may be used with the "area" spatial tools (rectangle and polygon) to measure areas of features that have been isolated from surroundings with the color tests.

Select Image to Mask

☒ Original ☐ Enhanced

TEST 1 Magnitude of colors.

Select range of color intensities.

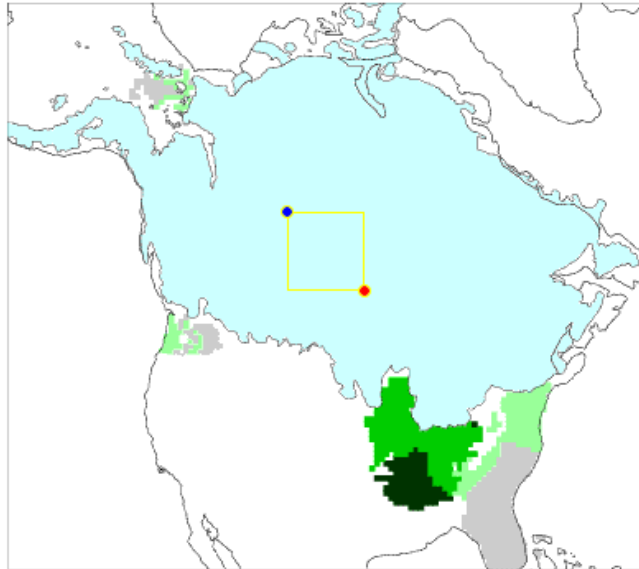
Pixels with colors in these ranges are made black.

☒ Red Min 80 Max 80

☒ Green Min 0 Max 100

☒ Blue Min 0 Max 100

**Picea (Spruce) Differentiated 21,000**



To save this color for ice so it may be used on maps from the remaining time sequence, click "Save Color Mask 1".

A window appears to provide a name for the color mask. Use a name that is easy to remember how to use.

Name of Color Mask

Add or change the name of the saved color mask?

Type a name using up to 12 characters in the text box below.

Ice blue

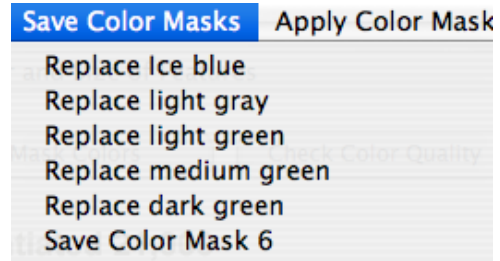
Cancel

Done

Save Color Mask 1  
Save Color Mask 2  
Save Color Mask 3  
Save Color Mask 4  
Save Color Mask 5  
Save Color Mask 6  
Save Color Mask 7  
Save Color Mask 8  
Save Color Mask 9  
Save Color Mask 10  
Save Color Mask 11  
Save Color Mask 12  
Save Color Mask 13  
Save Color Mask 14  
Save Color Mask 15  
Save Color Mask 16  
Save Color Mask 17  
Save Color Mask 18  
Save Color Mask 19  
Save Color Mask 20  
Save Color Masks to File  
Recall Color Masks from File ⌘R

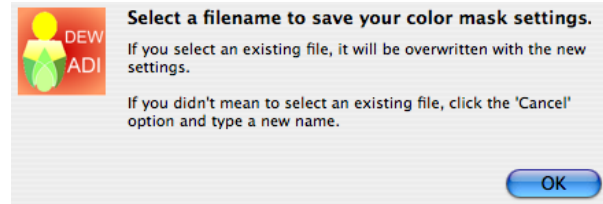
Save masks in an organized way, starting with mask 1.

If you make a mistake on naming the color mask or in setting the range of colors defining the color mask, you may change by "*Replace 'name'*".



### ***Save Color Masks to File and Recall Color Masks from File***

If you can't finish your analysis in one session, you can save the mask settings so they may be used at a later time. Click the "*Save Color Masks to File*", which is the second to last option in the *Save Color Masks menu*. The first window appears that indicates you may create a new file or open an existing file. Opening an existing deletes the original and saves the new file in its place. Use the *Recall Color Masks from File* to select the file to restore the color masks during your next session.



## Apply Color Masks

Once all of the colors used in the map have been saved as color masks, you are ready to analyze the time sequence of maps. Remember, the mask and spatial analysis tools work together to count the mask pixels within a selected area. So, first, select an area of interest in the map using either the rectangle or polygon tools. In the example below, the entire area of the digital map is selected.


Spatial tools measure the color and size of features in digital images.


Select Version of Image to View and Analyze

☒ Original ☐ Enhanced ☐ Masked

Rectangle Tool

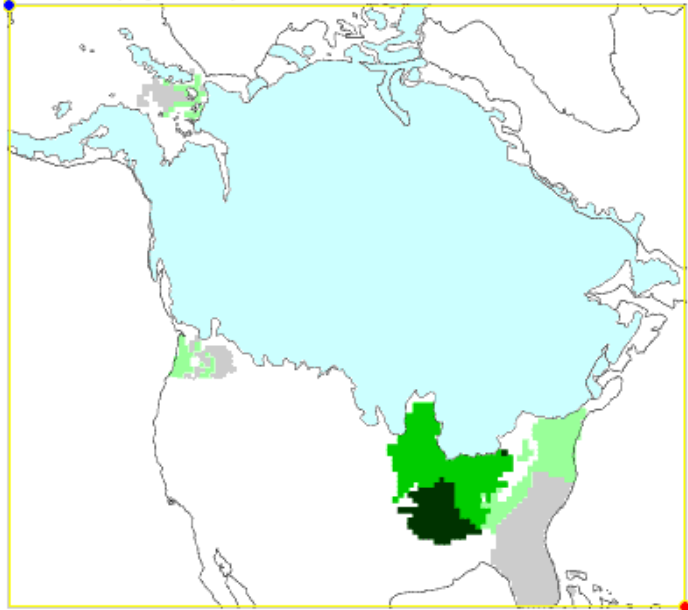
Pixel Position Adjust

Start Point X Y 

Stop Point 389 368 

Number of Pixels 133,128

### Picea (Spruce) Differentiated 21,000



Next, apply a color mask. In this case, the area of the ice sheet across North America will be first masked and displayed in the *Mask Colors* tab panel, then automatically calculated when going to the *Spatial Analysis* tab panel.

Apply Color Masks	Mon 8:4
Apply Ice blue	⌘1
Apply Light Gray	⌘2
Apply Light Green	⌘3
Apply Medium Green	⌘4
Apply Dark Green	⌘5
Apply Color Mask 6	⌘6

Two types of color TESTS generate black and white results: Black pixels passed the color tests, white did not.

The resulting black and white image is called a mask, and may be used with the "area" spatial tools (rectangle and polygon) to measure areas of features that have been isolated from surroundings with the color tests.

Select Image to Mask

☒ Original ☐ Enhanced

TEST 1 Magnitude of colors.

Select range of color intensities.

Pixels with colors in these ranges are made black.

☒ Red Min 80 Max 80

☒ Green Min 100 Max 100

☒ Blue Min 100 Max 100

Show Mask

Drag max/min values on graphs above or drag area on digital image.



SPD21000.GIF is 392 by 371 pixels

Spatial tools measure the color and size of features in digital images.

Select Version of Image to View and Analyze

☐ Original ☐ Enhanced ☒ Masked

Rectangle Tool

	Pixel Position		Adjust
	X	Y	
Start Point	3	25	
Stop Point	389	368	

Number Masked Pixels 43,067

