Measuring Tree Growth: Trunk Diameter

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Introduction

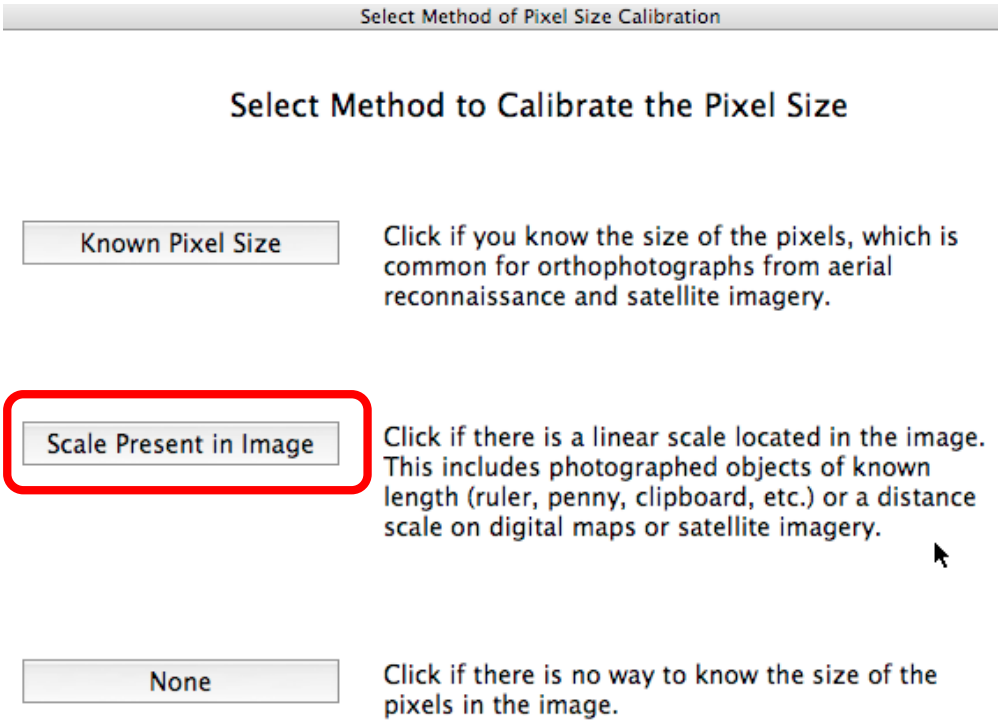
Whenever a tree is cut down, take a look at its tree rings and you will see that the tree adds wood to the trunk during the growing season (photo of tree rings). In addition to what foresters have been using to measure the girth of tree trunks, tape measures and large calipers, we can measure the daily growth of the tree's trunk using digital photos taken from a PicturePost (http://picturepost.unh.edu/) and the free software AnalyzingDigitalImages (the ADI software is part of the Digital Earth Watch (DEW) software bundle at http://www.lawrencehallofscience.org/gss/rev/ip/).

The official term for what foresters measure is the *diameter at breast height* (*DBH*), where breast height is 4.6 ft (1.4 m) above the forest floor on the uphill side of the tree (a number of other countries define breast height as 1.3 m (4.27ft). This is a very common measurement made by foresters, and it is usually used to estimate the amount of timber available in the tree and/or a stand of trees.

Why use pictures taken from PicturePosts? Often the people taking the photos are not foresters, and don't have the proper equipment to measure DBH, but it is valuable data that may be collected by those interested in this information, and as you will see, it is fascinating to study how and when a tree grows throughout the growing season.

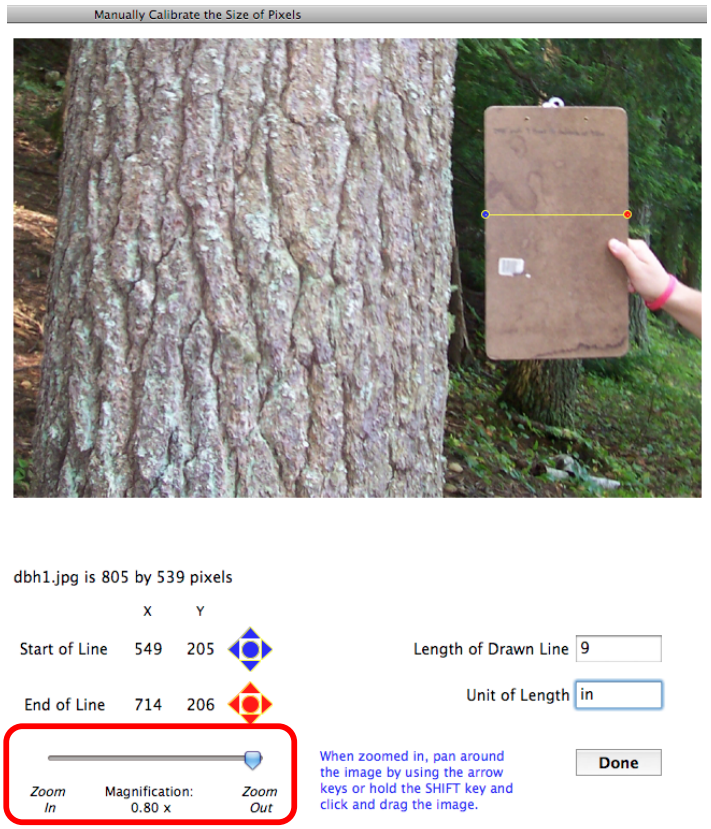
Absolute Measurements of Trunk Diameter

After selecting "Open a Picture", if an object of known size is in the image and in the same plane as the tree trunk you want to measure, the ADI software allows you to scale the measuring tools to the known length. When you open the picture, select the "*Scale Present in Image*" button. Note: if you don't click this button, you may use the "*Calibrate Pixel Size*" option in the File Menu to open this window of calibration options again.



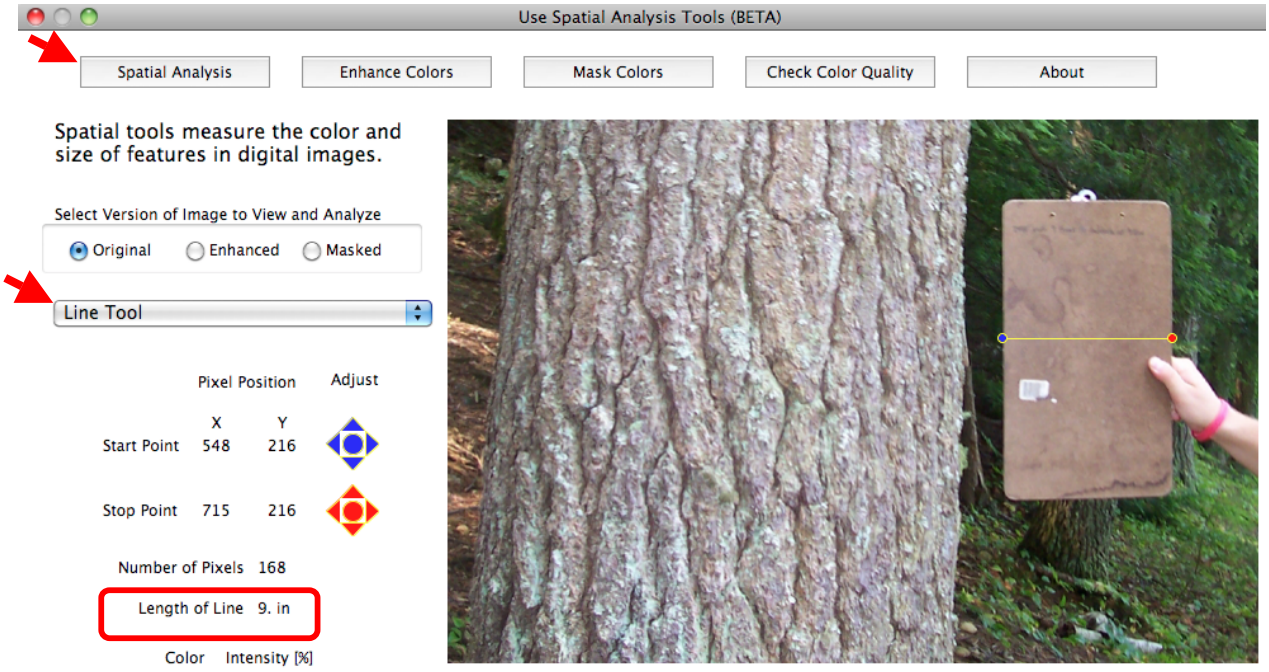
A window will pop up containing the digital picture and tools to draw a line along the known length. Click and drag a line from the beginning of the scale until the furthest known length. This spreads out any error in the position of the line along a greater length, thereby improving the accuracy of the scaling factor. You may zoom into the image to see check the accuracy of your line. To move around the image once zoomed in (called *panning*), hold down the *shift* key and then click and drag the image in the direction you would like to move it. To reposition the line, you may click and drag either end of the it, or you may use the small blue and red arrows to move the corresponding colored end of the line one position in the direction of the arrow on the image. After you feel the line is positioned most accurately, type the length and units of the scale in the two text boxes in the lower left of the window.

First draw a line along length of known length. To improve your accuracy, zoom in to the image and check how well the line's ends match the edge.

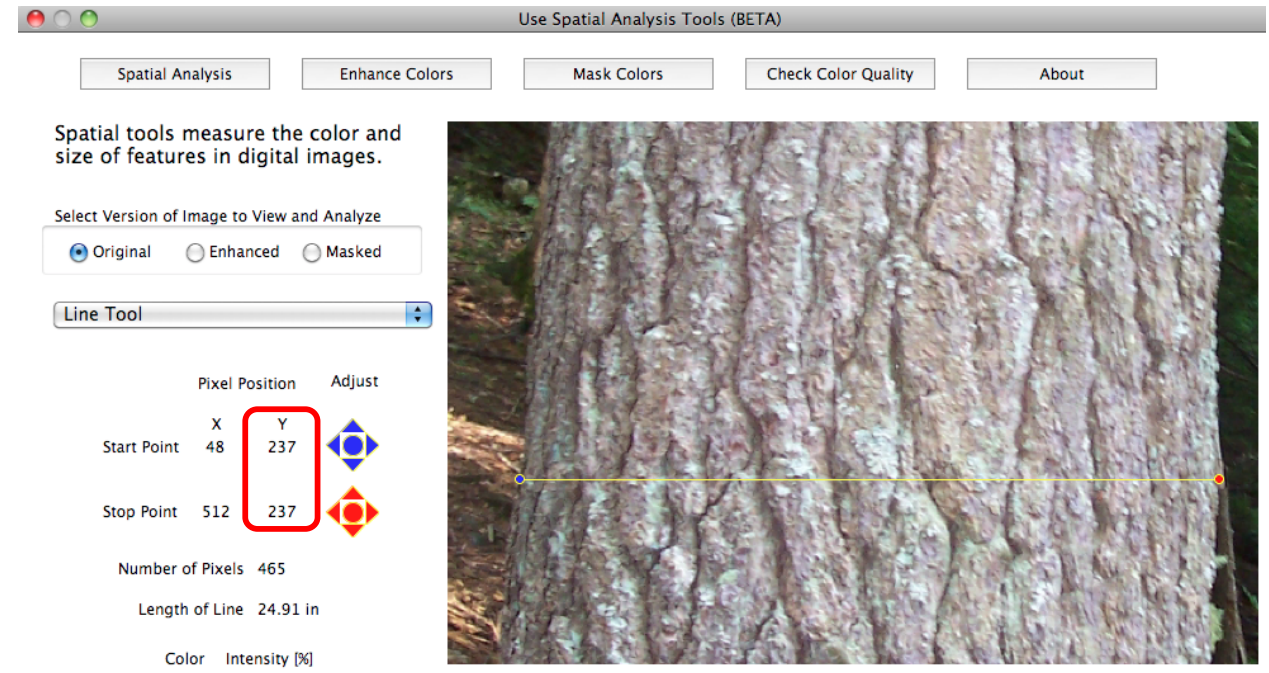


When satisfied that the line aligns well with the scale, type the length and units in the text boxes in the lower left. Then click "*Done*".

In the "*Spatial Analysis*" window, select the "*Line Tool*" and check how well the scale was measured by drawing a line along the scale. In this case, the line drawn along the 9-inch scale turned out to also be 9 inches. Now we are set to measure the width of the tree trunk.



Since the PicturePost is horizontal, the camera should also be horizontal, and if the tree appears to be vertical, the line should also be horizontal (notice that the "Y" position for both ends of the line in the image below are the same).

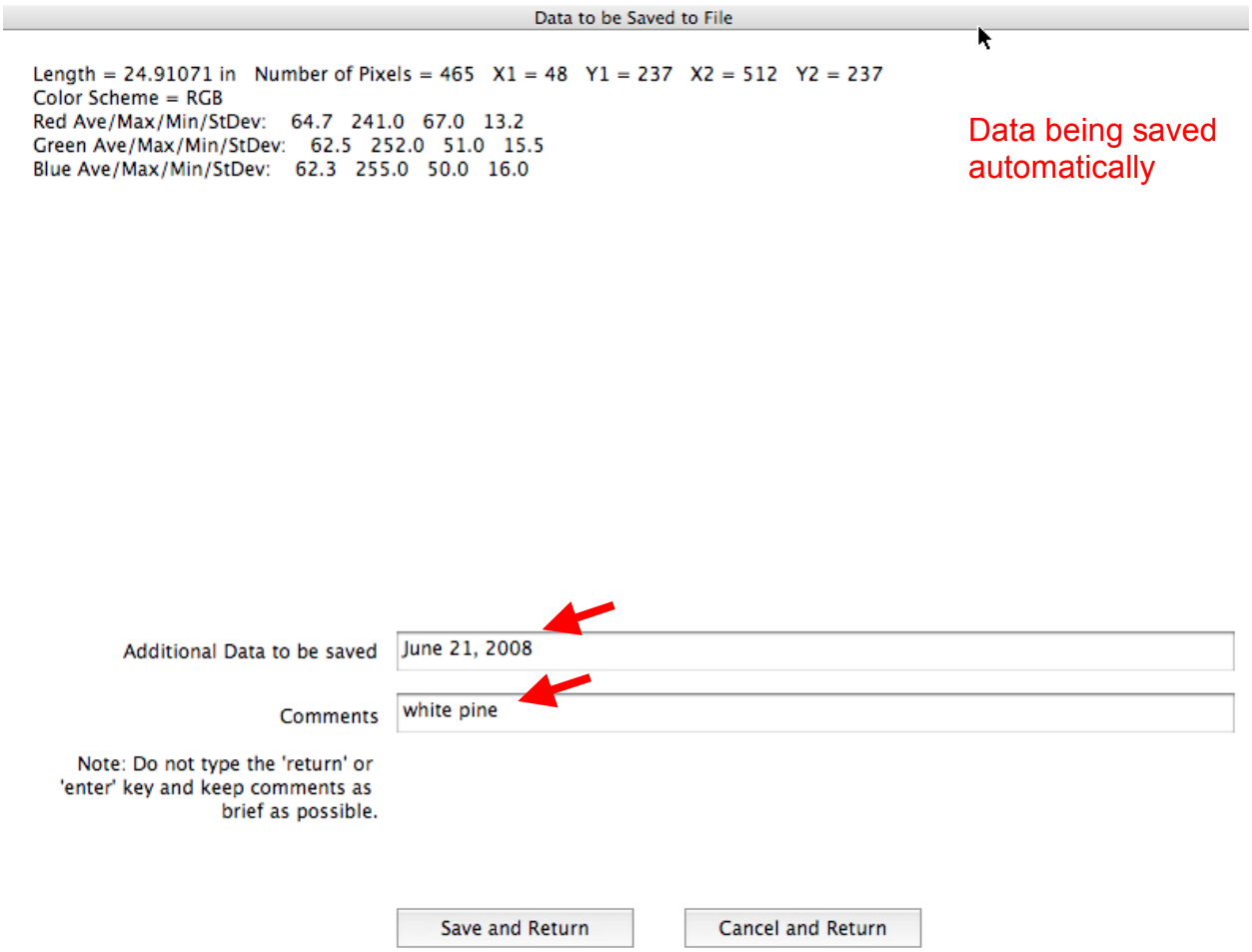


It is important to measure the diameter at the same height on the trunk each time. Although it may not be 1.4 m above the ground, find a scar, mark, or lichen that is near this height so you may return to this location for the next measurement. TIP: take a screen shot of the line on the first image measured as a reference. Below is an example: use the lichen near the center of the trunk to find the same location to measure.

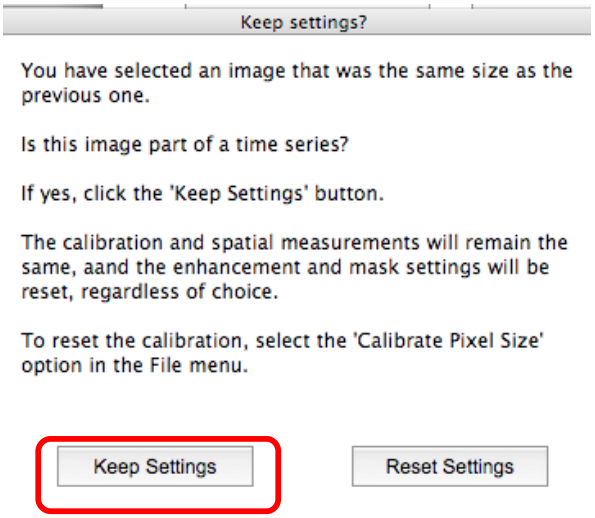
You may save your data to a file of your choosing. If you are working on a series of photos that have already been taken, after you create the file, each additional measurement is added to the bottom of the file (last data record), so it is best to start with the first chronological image and finish with the photo taken most recently.

To save a measurement, click the "*Save Measurement*" option in the *Measurements Menu*, and if a file hasn't been created yet, you may create one at this time.

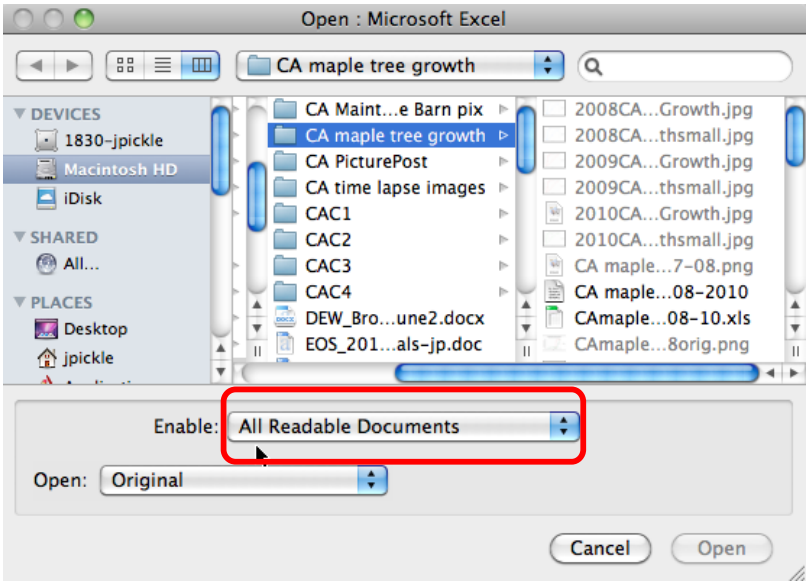
Quite a bit of data is saved automatically with your measurement (what is actually saved depends on the spatial analysis tool that is selected). In addition to what is shown in the Measurement window (see example that follows), the name of the picture being used, the scaling factor that relates the size of a pixel to the size of the physical scale in the picture, and the type of spatial analysis tool being used are also saved. You have two text boxes you may add important data to be saved. In this example, the date of the photo and the species of tree being measured are saved so the data may be used in the final analysis.



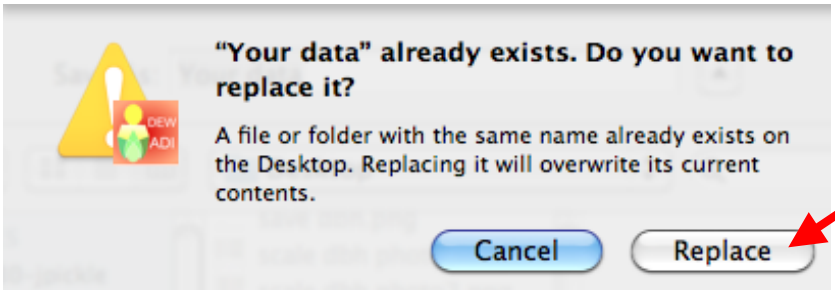
If you are working with a series of photos all at once, and the photos are the same dimensions each time, the option to "*Keep Settings*" will pop up when opening the next photo. Selecting this option will speed up your analysis because the spatial analysis tool remains selected (and the previous settings are kept - so in this case, the line from the earlier image will appear on the new image), and the same zoom factor, panning of the image, and the same scaling factor is kept (you don't need to recalibrate the image since it should be identical to the previous image).



When you are done making measurements, the file may be opened in Microsoft's Excel (make sure you change the *Enable* option to "*All Readable Documents*" (see example below). Sadly, Apple's *Numbers* software will not import text files.

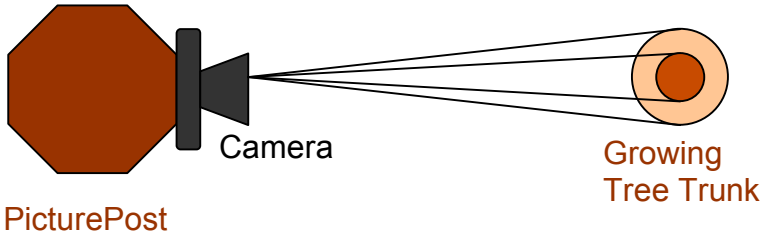


If you are not done making measurements, you may close the software. The next time you have a photo, open the software and select either "*New Measurement File*" or "*Save Measurement*" from the *Measurements Menu*, and you will be asked to either create a measurement file or select an existing file. If you select an existing file, you will be asked to replace it - although this sounds like you will lose your existing data, you won't in this case, so select the "*Replace*" option. The data you save will be added from the last line of the existing data, just as if you had been working with time series of data.



Relative Measurements of Trunk Diameter

If you don't have an object of known length, you may still make some useful measurements of the growth of tree trunks. Since the distance between the camera and the tree remain constant, the percent the tree width relative to the width of the photos is directly proportional to the width of the actual tree. To guarantee that the width of the photo remains the same, you need to use photos taken with the same make and model of the camera, have the same setting of resolution (number of pixels recorded), and with the same focal length of the lens (important to check if the lens can be zoomed), then you may use the first measurement of the tree trunk as the starting diameter in pixels to compare measurements to.



At the end of the growing season, the final picture compared to the starting picture provide the entire growth in pixels, which may be used to recalculate the growth in pixels as the percent growth observed during the growing season.

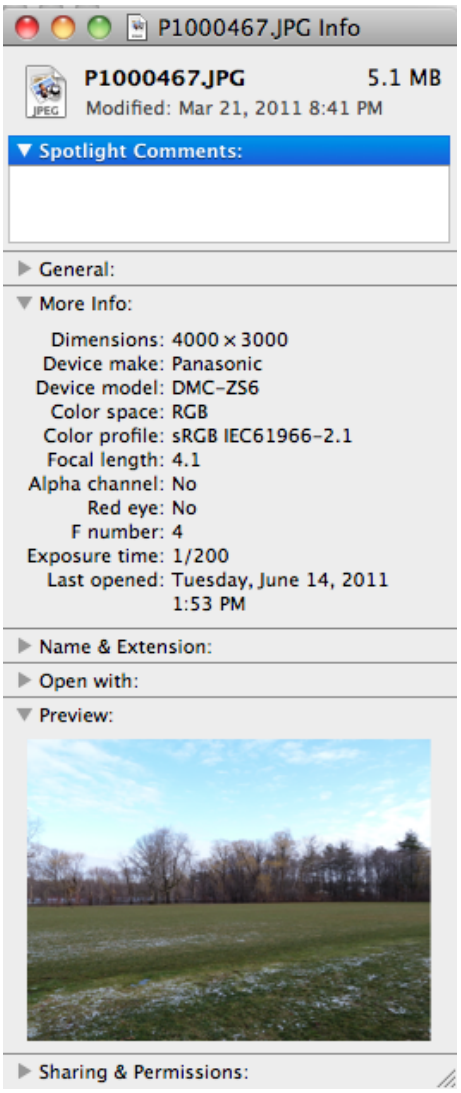
$$\text{Percent Growth}_{\text{Day X}} = (\text{Dia}_{\text{Day X}} - \text{Dia}_{\text{Day 1}}) / (\text{Dia}_{\text{Day Final Growth}} - \text{Dia}_{\text{Day 1}}) * 100$$

Note: Dia = Diameter at Breast Height for a given day and measured in pixels.

EXIF Data to Check Camera Make and Model and Camera's Settings

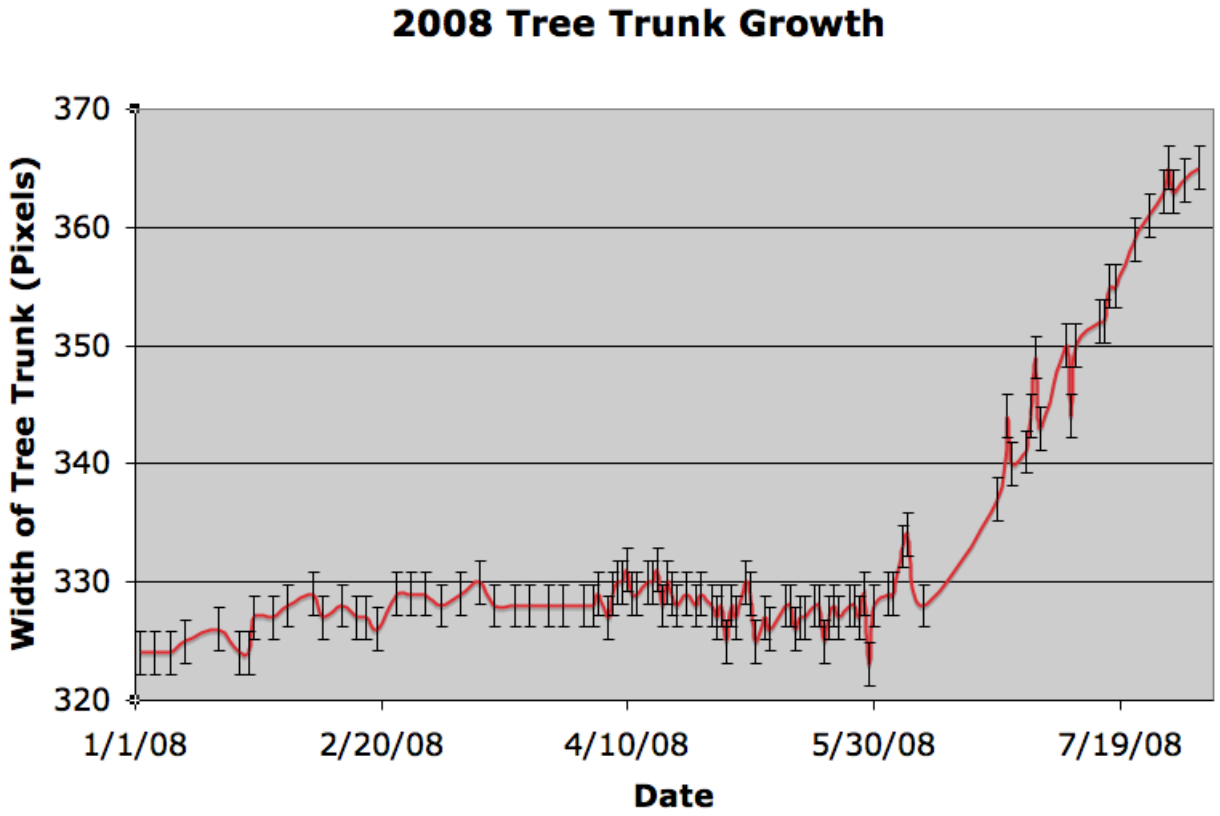
There is data included with every digital photograph, called EXIF data, that states the make and model of the camera as well as all of the camera settings used to take the photo (focal length of the lens, shutter speed, aperture, etc.). If you are making relative size measurements of the tree's DBH, use these data to make sure that you are using photos from the same type of camera with the same focal length setting.

To access this EXIF information on a Mac, click on the photo's icon when viewing using the Finder, and click the control-I (Get Info) keys. (On a PC?)



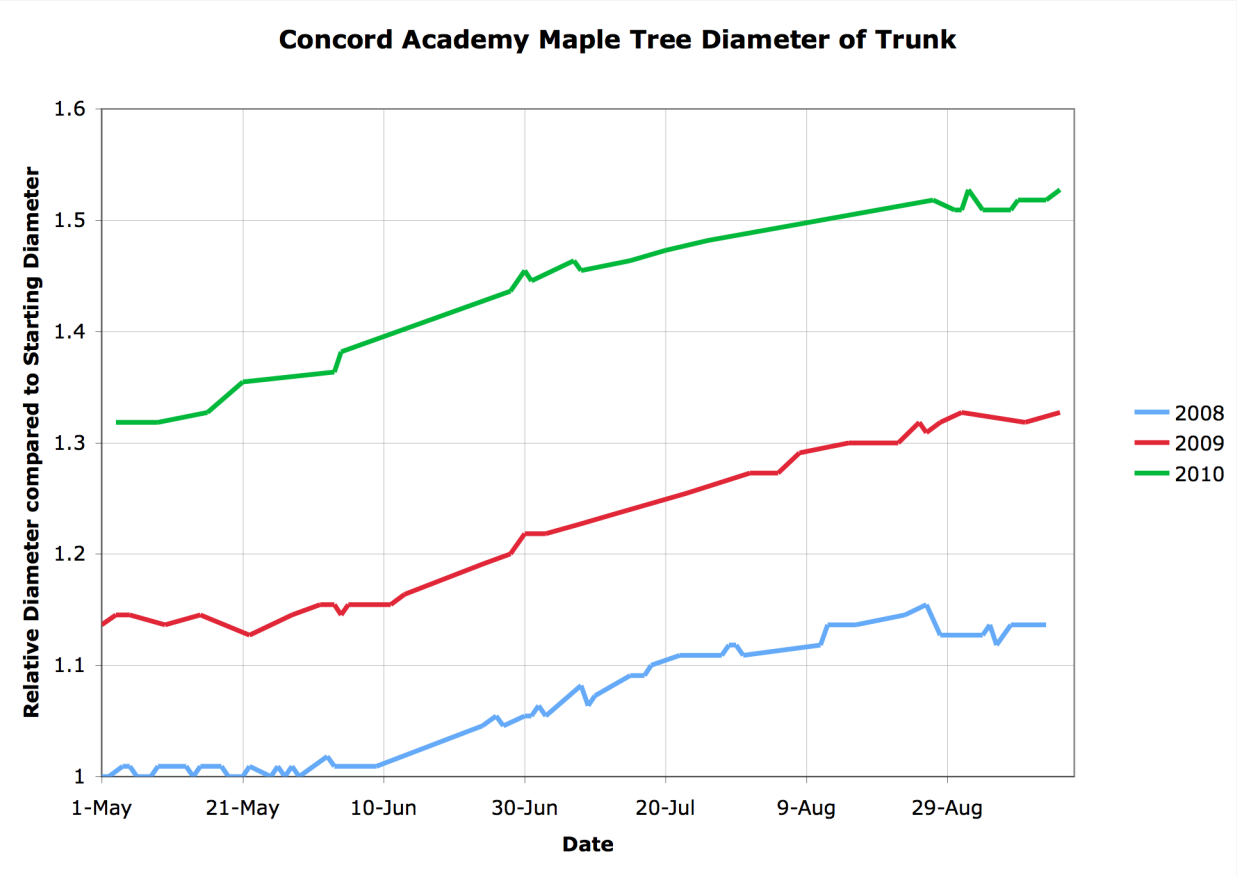
Uncertainty of Measurements

As much as we would like to believe data are perfect, they contain imperfections. You can quickly calculate the uncertainty in the measurements by analyzing either the same photo ten times or analyze a sequence of images where the tree should not have been growing (most likely when it doesn't have leaves). In the example below, measurements from January 1 to May 30, 2008 were averaged, and the standard deviation of the nearly daily measurements indicated that the uncertainty in DBH measurements was 1.8 pixels, which is shown on the graph below.



Examples of Tree Trunk Growth

The PicturePost at Concord Academy was installed during November, 2007, so we have three complete years of the life of a maple tree near the PicturePost. We have used the relative growth method since we have used the same camera to take nearly daily photos from the post. Interestingly, the tree tends to grow with proportional growth rate each of the three years (same slope); however, the tree has been adding new wood each year since we began taking photos. The end of the growing season appears to be the same though - so it appears the tree is adding more wood each year due to the longer growing season.



Extensions:

How Does a Tree Growth During a 24-Hour Period? Set up an experiment using a time lapse camera to take hourly or half hourly photos for a 24 hour period, then you may study whether the growth rate of wood changed throughout the day and nighttime hours.

How Does Weather Affect Growth? Waterproof digital camera with the time lapse feature, such as those in the Pentax waterproof Optio series (I have used the W30 and W90 for many years) would allow one to study if wood is added during rainy days. A second camera photographing the cloud cover would allow the amount of sunlight reaching the leaves during to be measured.

In both experiments, to get the precision needed for this experiment, use the zoom feature on the camera to fill much of the frame with the tree trunk while being as far from the trunk as possible. This minimizes the parallax of the measurements while improving the resolution of the camera to measure the growth of the tree.