

Finding Areas Affected by Drought in Lake Lanier using Aerial Imagery

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Abstract

This paper explains the process of detecting drought areas through the use of full-color RGB NAIP imagery from USGS Earth Explorer. The study area will be Lake Sidney Lanier, specifically the area at the end of Flat Creek Road in Oakwood, Georgia. The severe drought that began in 2007 resulted in the lowest water levels that Lake Lanier had ever seen. This resulted in tensions and lawsuits between Georgia, Florida, and Tennessee due to the fact that all three states share the water. I will be using this specific area and event purely as an example, this process should be able to be used on all similar images for many purposes such as damage, erosion, crop, and migration detection. Put simply, I will be using color segmentation to cut out and sort the drought area that I am interested in from both before and after images in order to compare the surface area of the water, therefore revealing the drought area. This data could then be used for real estate planning, dock permitting, and possibly depth analysis. This paper will outline my methods, data, problems, results, and references. My final product is a very easy to understand raster symbolized to show all of the areas of shoreline that were dry during the drought and then covered by the lake after.

Keywords: Drought, Lake Lanier, Aerial Imagery, GIS

1. Introduction

As we saw during the drought, tensions can quickly run high when a resource as valuable as water is threatened. During the drought, restrictions were placed on usage that seriously affected individuals in the area. For example, lawn watering and swimming pool filling were almost outlawed, resulting in expensive landscapes dying and some pools caved in from lack of water. Recreation on the lake also became extremely dangerous because hazards that had been deep under water might only have a few feet of water covering them during the drought posing a risk to boaters and swimmers, not to mention the hundreds of docks that were destroyed by being forced to sit on dry, uneven land.

The availability of imagery from multiple satellites in many different formats has become one of the most crucial assets in analysis of drought due to the ease of access and increasingly high resolutions that are available. It is crucial that images with not only high spatial resolution are used, but also high temporal resolution is needed in order to capture the drought at its maximum extent which will be the most useful data in many cases. Finding good, usable imagery is often the most difficult part of an analysis like this because droughts happen over a period of months to years and changing conditions mean that the images will be very different and may not even be available in the same format due to satellite changes. Atmospheric water like clouds and haze also ruin a large portion of the imagery that is collected. However, if you are lucky enough, you can use Synthetic Aperture Radar with its “exclusive cloud, rain, and haze penetration capacity”(Rahman & Thakur, 2017).

2. Data and Methods

As previously mentioned, SAR would have been the best tool for this analysis. However, due to access restrictions and temporal resolution requirements, I settled on NAIP imagery from

during and after the drought for comparison. The cloud cover is very little in both images but would still prove to be a problem later. Besides clouds, water clarity also skewed data. The reason I mention this is that water levels were actually much higher in the “after” image but due to clearer water, we still see sand and to the sensor that usually looks like dry land. My study area has very shallow water relative to its surroundings so lake levels have a profound impact on the shore that it covers. This area was actually one of the most dangerous for boating due to dead trees and stumps hidden underwater.

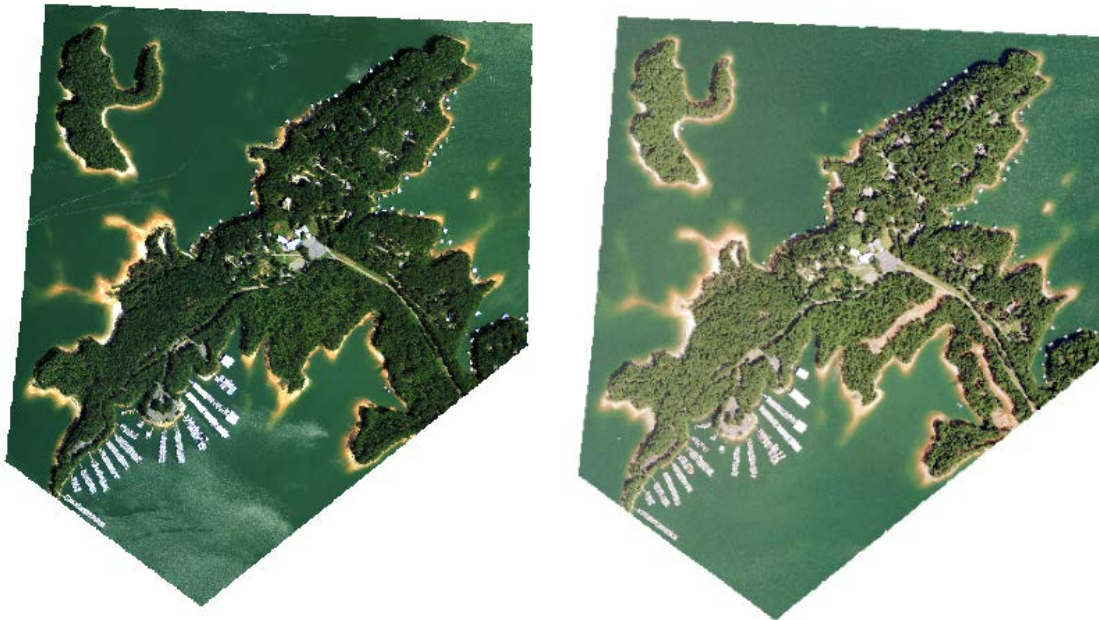


Figure 1. (a), (b) Similar to the imagery I have collected above, the article by Anusha and Bharathi suggest that “Two sets of remotely sensed data are required for detecting the flood and flood mapping: one set consists of the image acquired before the event and the other set comprising the image acquired during the occurrence of the flood event”. Even though I am applying this to a drought, the same principle applies because dry land was “flooded”. The image on the left is during the drought, and the image on the right is after the recovery of the reservoir.

With the data downloaded and added into an ArcGIS Pro project, the first step is to ensure that the images are correctly formatted for use. In this case, both of my images contain four bands, the fourth being the alpha band which is not necessary for this project. The needed bands are the red, green, and blue. The extents and cell sizes of both images must be identical for this tool to work due to the nature of the code.

After getting the data, sample points must be taken. These sample points must be of the type of pixel that you want to analyze. In my case, I used water pixels. As you can see in Table 1, I took 10 sample points for each raster. Statistics will need to be calculated, so it makes sense to go ahead and calculate the average and standard deviation now while the excel spreadsheet is open.

	Before1	Before2	Before3	Before4	Before5	Before6	Before7	Before8	Before9	Before10		Bef Average	Bef StDev
r	47	47	49	61	51	48	41	44	46	46		48	5.31245915
g	60	61	63	69	61	61	48	57	59	58		59.7	5.27151675
b	112	110	110	145	107	106	103	112	111	110		112.6	11.739771
	After1	After2	After3	After4	After5	After6	After7	After8	After9	After10		Aft Average	Aft StDev
r	116	76	49	78	51	39	58	105	123	107		80.2	30.7057722
g	113	67	53	71	48	36	50	97	113	104		75.2	29.1578082
b	147	95	86	89	82	44	66	131	153	140		103.3	37.1604629

Table 1. These are my sample points for each image. Since this tool is creating a color sphere, the average and standard deviation are the important parts.

At this point it is time to go ahead and open ArcGIS Pro. I created a new python toolbox in the folder where my data was and then began editing the blank template. The first items to change are the toolbox name and the name of the tool. Next I imported the necessary modules which are ArcPy, NumPy, and Math. Then give descriptions of each for the user to read. Parameters are the next logical step. For my purpose, I need seventeen parameters. This includes one for each raster, one for the average of each band in the before and after, and two more for the output path and prefix. All of the statistical inputs have a data type of GPLONG, the input rasters are GPRASTERLAYER and the outputs are GPSTRING.

Now we move to the Execute section, where I first set all of the parameters equal to variables for use in the next bits of code. I added the function next, which takes arguments of a raster array, average, standard deviation, and K-value in order to create a color sphere. This color sphere will contain all of the desired colors which are water in my case. Now that I have a working color sphere, we can move back up to the execute section to put this sphere to work.

I made NumPy arrays out of the rasters using ArcPy and used the arrays as inputs for the color segmentation function along with the statistics that went with each. The statistics reference the input parameters, so I actually only input the names of the parameter variables in an array form that the function can handle. I then used NumPyArrayToRaster to convert the products to distance and return rasters. These distance rasters then have to be use to create binary rasters, based on whether or not the distance is greater than or equal to zero. According to Unnikrishnan et. Al, this is the “most sensitive stage” because it decides which pixels will be included. In this case, land and water were assigned values of zero and one. I then used a NumPy logical_and statement to select pixels that had a value of one in the “after” raster and zero in the drought raster and set this to a variable named “affected”. This was in an array form so I used NumPyArrayToRaster again and saved it to another variable.

Once all of the code is set up, the tool can be loaded into the ArcGIS Pro project and the user has to input all of the parameters and run the tool. If the tool is successful, an output will be saved in the location specified by the user. The output raster can then be added to the map as the final product and should look like figure 3 below.



Figure 3. This is the affected areas. The product is best seen along shorelines, as bad data created a lot of noise and inaccurate pixels.

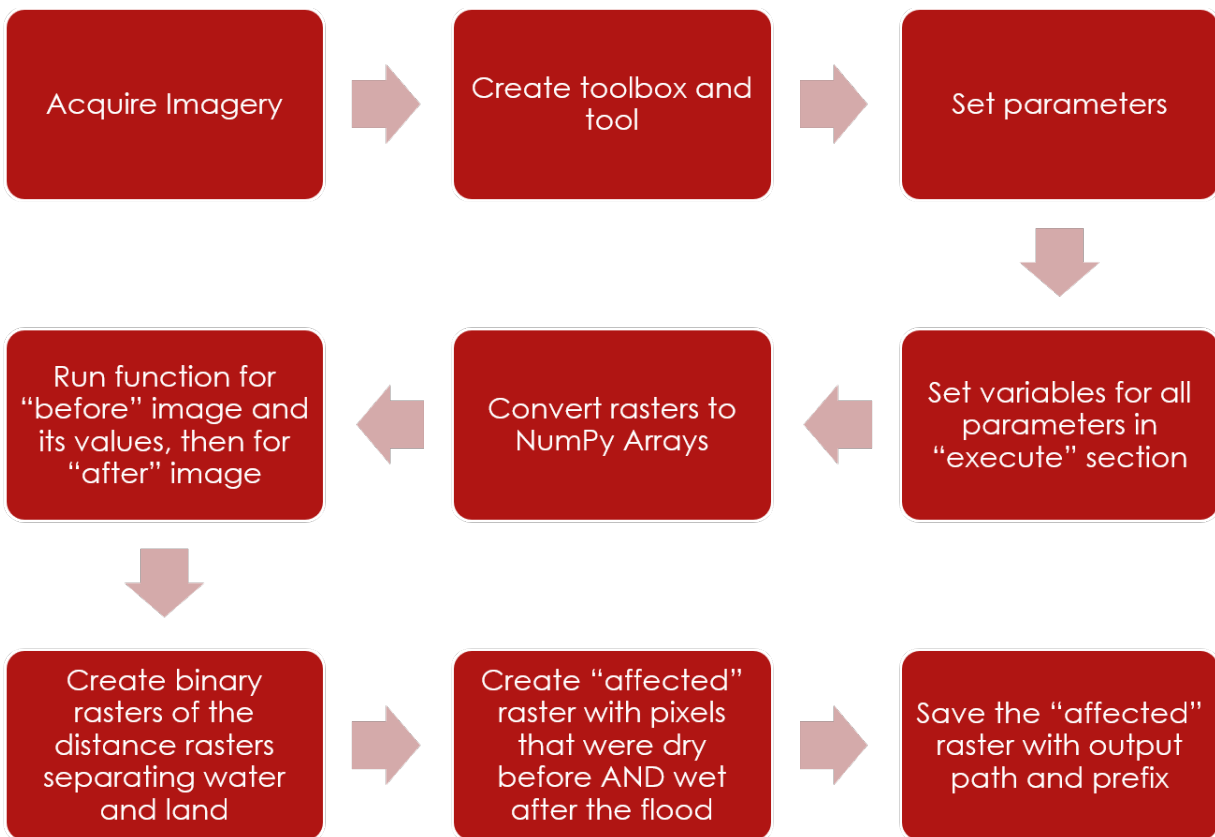


Figure 3. This is the general workflow that I used in creating my tool.

3. Results and Discussion

This method seems to work very well for any kind of RGB imagery that is given, as long as the imagery is cloud free and taken during similar conditions. As usual, this is the most difficult part because accessing data with the correct spatial and temporal resolution can be impossible to the average civilian. In my case, I would have been much better off if I had access to Synthetic Aperture Radar which can see through clouds. This is especially useful if the tool is being applied to a storm situation like a flood because of all of the associated atmospheric moisture.

4. Literary review

For my review, I would like to discuss an article titled “Integrating GIS and HEC-RAS to model Assiut plateau runoff”, written by Hesham Ezz. The purpose of this paper is to help officials plan a road through the Assiut region of southwestern Egypt. As the article explains, the area is subject to flash floods, so the road must be planned accordingly. In this paper, a digital elevation model and geographic information system were used to create a hydrologic model that could estimate the water depths throughout the area during heavy flooding (refer to figure 4).

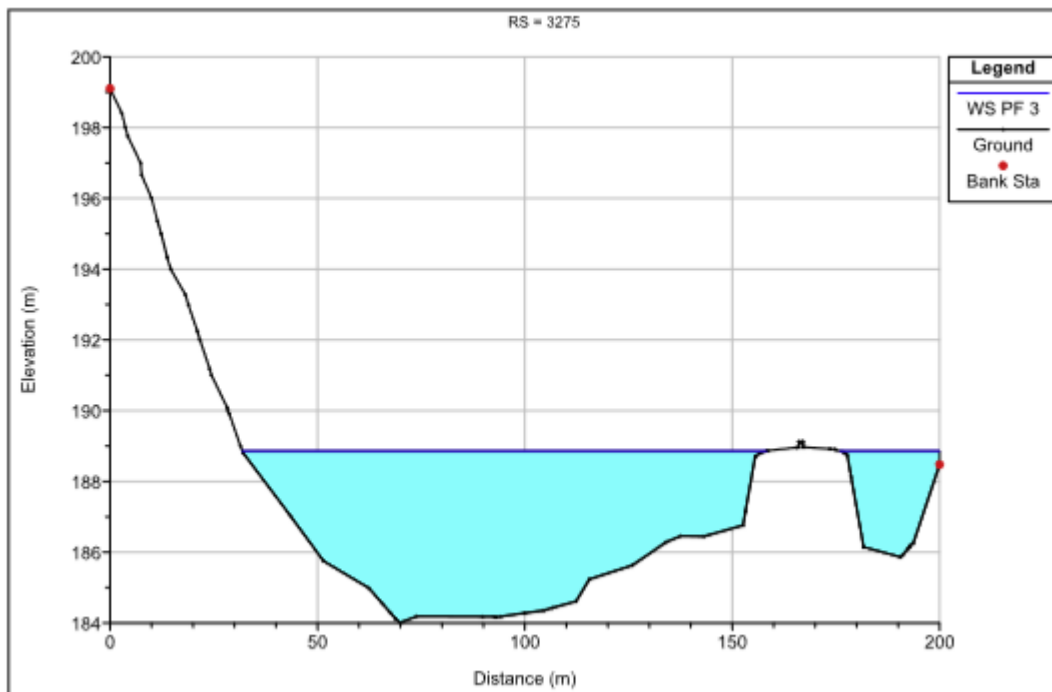


Figure 4. This figure from the article depicts the depths of water modeled by the author using a digital elevation model and precipitation data.

As I mentioned previously, I would like to add elevation data to my project in order to collect statistics on water depth just like what was done in this article. In my case, this data would be useful to estimate water level rise after the drought. Then, an analysis of the size of the water body could tell the user the volume of water that was added to the water body. With the addition of this analysis, risk management would be much easier and the best routes could be identified. The author could also add my analysis to his method to better visualize which areas of the new road would be affected in the event of a flood if imagery is available.

5. Conclusion

This analysis is still early in development, but once completed it could prove to be very useful for mapping drought extent. The uses could also be broadened to any purpose that requires identification of a set of features that are close to the same color. Imagery is still the main determinant of whether my process will work in a given situation. ArcGIS Pro software also makes the whole process very easy for the average user to understand so that this analysis can be faithfully replicated by whoever may desire. Once the ability to choose sample points in ArcGIS Pro is added in, the user will no longer have to set up an excel spreadsheet to manual calculate the averages and standard deviation as I did.

References

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