Finding Areas Affected by the Flooding Following Hurricane Florence Using Satellite Imagery

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GISC 4360k Digital Image Processing

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Abstract

   This paper explains the process of detecting floods through the use of full-color RGB NAIP imagery from NOAA's storm site. The study area will be the affected areas around Wilmington, North Carolina after Hurricane Florence. Hurricane Florence caused significant flooding in the area which rendered many roads unusable, flooded homes, and resulted in a large loss of life. 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 flooded 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 flooding. This data could then be used for disaster prevention, flood insurance requirements and evacuation planning when the next hurricane comes through. 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 flooded areas, and is laid over my "before" map for reference.

Keywords: Hurricane Florence, Aerial Imagery, GIS

1. Introduction

   Flooding is one of the most destructive events that happen due to not only the destructive power of water, but also the damage that happens after the flood like mold and other water damage. It is also extremely frequent in many areas, especially close to the coast like my study area. Monitoring these flood conditions is becoming increasingly important as climate change leads to higher sea levels and more inclement weather. The availability of imagery from multiple satellites in many different formats has become one of the most crucial assets in analysis of flooding 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 flood 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 storms are usually involved. These storms typically mean the atmosphere will contain cloud cover, rain, and haze after a flood event. If you are lucky enough, you can use Synthetic Aperture Radar with its "exclusive cloud, rain, and haze penetration capacity"(Rahman & Thakur, 2017).

   I will be focusing on flooding after Hurricane Florence, which made landfall September 14th, 2018 as a category 1 hurricane. The primary impact area was Wrightsville Beach, North Carolina. The storm moved slowly and dropped almost 40 inches of rain in some of the worst areas. About $24 billion in damage was recorded. Although I will be focusing on a hurricane that pushed water inland, other causes of flooding such as high rainfall and runoff can also be monitored with similar analysis. This has a lot to do with the area you are dealing with, as "Soil type and texture are very important factors in determining the water holding and infiltration characteristics of an area and consequently affect flood susceptibility (Elkhrachy, 2015).

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 drone-captured imagery from NOAA for the flood and NAIP imagery from before the flood for comparison. The imagery from NOAA is from low-flying drones so clouds are a non-issue. My study area is just to the east of Burgaw, North Carolina. This area saw some of the worst inland flooding after the storm due to the rivers and canals in the area and the large amount of flat farmland.
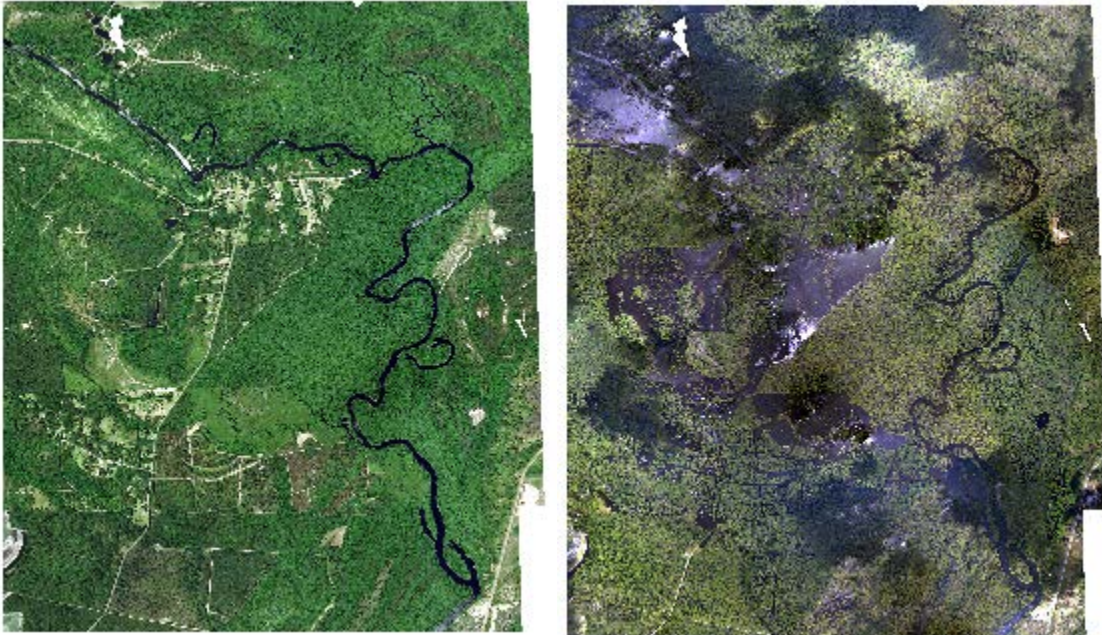

Figure 1. (a), (b) Similar to the imagery I have collected above, the article by Anusha and Bharathi suggest that "Two sets of remotely sensed data are required for detecting the flood and flood mapping: one set consists of the image acquired before the event and the other set comprising the image acquired during the occurrence of the flood event". The image on the left is before the flood, and the image on the right is during the flood.

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 first bit of cleanup was using the Extract By Mask tool to trim the images down to my study area so they would be the exact same size. We will refer to these as the before and after "clipped" images. Next, I added the red, green, and blue bands of each clipped image to prepare for my first conditional statement.

This first conditional statement would require the input of minimum and maximum pixel values acquired from sampling areas of visible water. I used ten sample points in order to make

for an accurate assessment.

	Before1	Before2	Before3	Before4	Before5	Before6	Before7	Before8	Before9	Before10		BeforeMin	BeforeMax
r	47	47	49	61	51	48	41	44	46	46		41	61
g	60	61	63	69	61	61	48	57	59	58		48	69
b	112	110	110	145	107	106	103	112	111	110		103	145

	After1	After2	After3	After4	After5	After6	After7	After8	After9	After10		AfterMin	AfterMax
r	116	76	49	78	51	39	58	105	123	107		39	123
g	113	67	53	71	48	36	50	97	113	104		36	113
b	147	95	86	89	82	44	66	131	153	140		44	153

Table 1. These are my sample points for each image.

I then used these in my conditional statements in ArcGIS Pro's Raster Calculator to create a binary raster in which the water was given a value of "1" and everything else a value of "0". The statement is written like this: Con(("R">=Rmin) & ("R"<=Rmax) & ("G">=Gmin) & ("G"<=Gmax) & ("B">=Bmin) & ("B"<=Bmax), 1, 0). This made it easy to separate water from land using the Reclassify tool. Using Reclassify, I set the value of "0" to NODATA so that I would be left with only water in my rasters. If I were seeking only a statistical analysis, an evaluation of the area of these two rasters would have been sufficient. However, my goal is affected area identification so we must go further.

The next step in the process is actually somewhat optional, but can be a good product to display when explaining what we are doing. I elected to use Extract By Mask again to clip the RGB "before" and "after" imagery to the rasters from the previous step so I could see the extent of the flooding in true color and verify that there was only water in the pixels.

Next is another conditional statement, where I set all of the dry land to a value of -9, which is used as a placeholder because it is an impossible color and guaranteed to not appear anywhere else on the raster. This is the statement: Con(IsNull(Reclassified Layer), -9, Reclassified Layer). This can be considered an intermediate step, as the only reason for performing it is to set up rasters for the next step.

Nearing the end of the process, my goal is to extract all pixels from the "before" raster with an assigned value of -9 and all of the pixels from the "after" raster that do not have a value of -9. After these are selected, adding the two rasters together gives me all of the dry land that was later covered in water, or the affected area. The statements used in this step are Con("c1b9" != -9, 0, 1) and Con("c1a9" == -9, 0, 1).
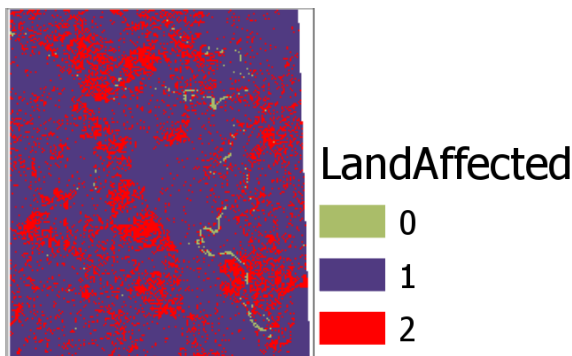

LandAffected
- 0
- 1
- 2

Figure 2. This is product of the final raster calculation. Values of "2" indicate area affected by flooding, values of "1" represent dry land during the flood, and a pixel value of "0" represents water that existed in the "before" raster.

To finish up and create a visually pleasing final product, I used the Reclassify tool again to set the "0" and "1" values to NODATA so that I would be left with only the affected areas. I then toggled on the "before" RGB raster to lay my "2" value raster on top of, thereby making it easy to see which areas were affected. This step is crucial for use by emergency personnel because it will allow them to see which roads may be impassable, which houses may be flooded, and how much the existing water bodies have grown.
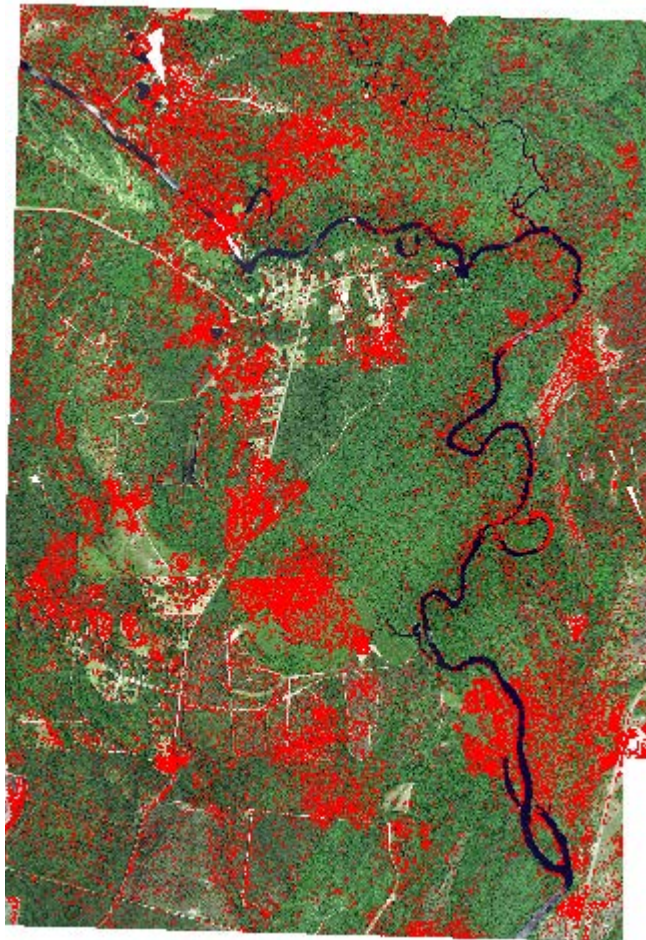

Figure 3. This is the final product, with the red areas being affected by flooding from the storm. You can see that some areas of the existing river were marked as being flooded. This is likely because the imagery for those areas was not perfect, usually containing cloud reflections or shadows.

3. Results and Discussion

This method seems to work very well for any kind of RGB imagery that is given. It is very useful for identifying areas that may be dangerous to emergency first responders, areas that

may need preventative measures put in place, and for planning of evacuation routes. The biggest problem is obtaining usable imagery

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).
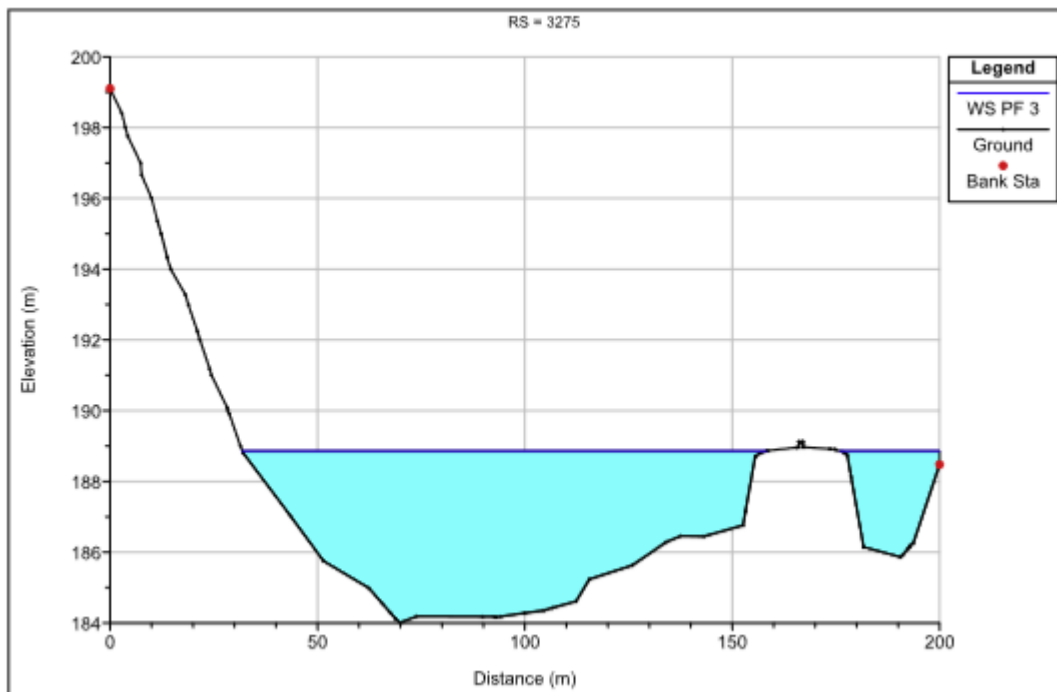

Figure 4. This figure from the article depicts the depths of water modeled by the author using a digital elevation model and precipitation data.

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 invaluable to first responders because if they only have data from my current project, roads with only a small amount of water may be deemed unpassable. 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 in the event of a flood, especially in areas that flood frequently. 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.

References

Ismail Elkhrachy (2015), Flash Flood Hazard Mapping Using Satellite Images and GIS Tools: A case study of Njran City, Kingdom of Saudi Arabia (KSA), The Egyptian Journal of Remote Sensing and Space Sciences

Hesham Ezz (2017), Integrating GIS and HEC-RAS to model Assiut plateau runoff, The Egyptian Journal of Remote Sensing and Space Sciences

N. Anusha and B. Bharathi(2018), Flood detection and flood mapping using multi-temporal synthetic aperture radar and optical data, The Egyptian Journal of Remote Sensing and Space Sciences, https://doi.org/10.1016/j.ejrs.2019.01.001

USGS. (2016). Earth Explorer Home. 20 August 2019, Retrieved from https://earthexplorer.usgs.gov

NOAA. (2018). Hurricane Florence Imagery. 20 August 2019, Retrieved from https://storms.ngs.noaa.gov/storms/florence/index.html#13/34.2993/-77.9144