Flooded Fields

Title: A Real-time Modeling System of Croplands Affected by Extreme Flooding
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Project Repository: https://github.com/SAliHossaini/FloodedFields

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Abstract

a. Thesis statement:
Under changing climatic conditions, extreme rainfall leads to extreme flooding, and many acres of cropland are entirely prevented from planting due to accumulating water. As climate change makes weather events more extreme, GIS can be used very effectively in agricultural land use / land cover analysis as well as damage assessment because of floods and other extreme weather events. This project builds a real-time modeling system that can estimate the number of acres flooded out on a per crop basis each year across the Midwest, particularly croplands affected by extreme flooding in 2019. We follow a Python-based approach for creating a landscape classification, identifying croplands and wetlands using supervised and unsupervised methods, retrieving real-time statistics about the impacts of flooding on agriculture on a per crop basis, and exporting all of this data into shapefiles which can be used for future processing in a GIS software like ArcGIS. This report concludes with a discussion about comparison of our pixel-based classification results with USDA data, economic impacts of weather-damaged cropland, depressional wetlands, and opportunities for future work with the material presented in this project for precision agriculture.

b. Keywords: #cropland #flood_impact #GIS #classification #precision_agriculture

Introduction

For much of the United States, 2019 was a record year for spring precipitation. According to National Oceanic and Atmospheric Administration (2019), a bomb cyclone over Colorado and unusually high precipitation led to nearly the entire country having above average precipitation, and it was the wettest year recorded for the country as a whole. With extreme precipitation came extreme floods. 42 locations across the Midwest, especially around the Missouri River, set record river levels (shown below) and many other areas experienced severe flooding (Erdman, 2019).

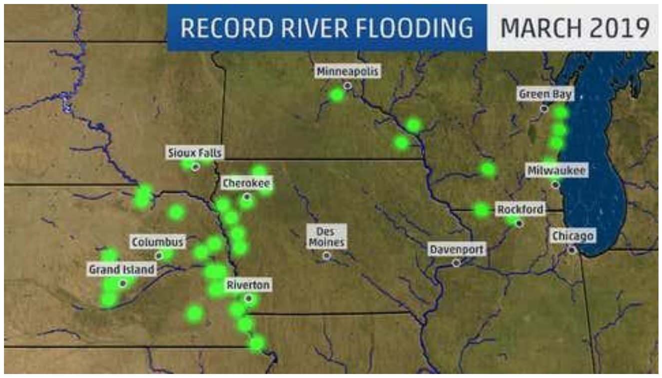
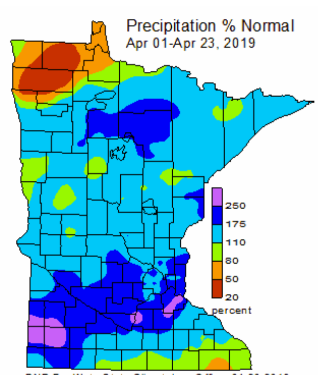


Figure 1. Locations with record river levels

Flooding impacted states throughout the Midwest: 11 states had to seek federal disaster funds used in more than 400 counties, and 14 million people were affected in total (Almukhtar et al., 2019). It led to striking images of extreme flooding, and a lot of news coverage for places like Nebraska and Iowa. While not the most impacted state, Minnesota also experienced extreme precipitation. Southwestern Minnesota was especially impacted: by mid-April, much of the southwestern counties had experienced precipitation almost twice has high as normal (Minnesota Department of Natural Resources). As these are rural counties with considerable agriculture, extreme precipitation during the timespan when corn and soy are planted (University of Minnesota Extension) led to huge impacts on Minnesota's crops.



Minnesota's percentage of precipitation above normal in 2019

The recently glaciated landscape of southwest Minnesota gives it a particular hydrology, called "prairie potholes." In this very flat landscape, water has no clear path of drainage through which to leave the landscape. Instead, water accumulates in low-lying depressions, forming wetlands called "potholes". These "pothole" wetlands were eventually drained with tile drainage systems to make use of the region's valuable agricultural soils (Environmental Protection Agency, 2020). As such, there are few wetlands extant in the region and these depressional areas are used as cropland. However, the low areas where water would collect remain, and can still be inundated if water accumulating outpaces the water drained away. This fact was illustrated clearly in 2019, in which the Midwest saw the wettest 12-month period in history (NOAA News and Features, 2019). Extreme rainfall led to extreme flooding, and many acres of cropland were entirely prevented from planting due to accumulating water (Newton, 2019).

Benefitting from National Agriculture Imagery Program (NAIP) imagery taken before and immediately after the flooding, we can create a striking map of cropland that was flooded in 2019. From that map we can quantify the areas impacted: from calculating the total amount of land kept out of agriculture, down to showing individual depressions within fields that farmers could not plant. While this map is interesting in itself to understand the catastrophic severity of this flood event, it can also help illustrate interesting general ideas about agriculture in the region. Events like this one, which impact the harvest for farmers, are very expensive: farmers are reimbursed the value of their lost earnings (Newton, 2019). Given these costs, it can be argued that the farming of marginal lands (like those that are susceptible to flooding) should be disincentivized, as the land is not worth farming in the long-term. As Minnesota is expected to become wetter with climate change and extreme events like the flooding in 2019 could become more common (Minnesota Pollution Control Agency, 2019), this map can help explore whether all current farmland in the region is truly viable as cropland.

To understand just how much agriculture in Minnesota was impacted by flooding during 2019, we compared classified imagery from 2019 to classified imagery in 2017 and identified areas that could not be planted due to flooding through a real-time modeling system.

Datasets

We used the 2017 and 2019 NAIP imagery for the state of Minnesota for our classification. It has high spatial resolution suitable for identifying regions within fields, a temporal resolution with images from before and immediately after the flooding at the same point in the growing season, and spectral bands useful for differentiating between vegetation and bare earth or water (visible and near-infrared). Supplementary data to our classification include USDA crop data like acreage planted compared to previous years and crop prices (to calculate costs related to flood impacts).

First, we identified the areas of Minnesota with the most extreme precipitation in 2019 to choose our area of interest. We concluded floods mostly impacted the southwest region of Minnesota and chose to focus on Jackson County for its size (for ease of processing) and extent of agriculture (no major towns).

Then, we downloaded the NAIP imagery from Google Earth Engine for 2017 and 2019. We used the near-infrared, false-color images for classification because of its ability to clearly distinguish bare earth, water, and vegetation. Then, we used NDVI and NDWI indices to extract vegetation and water bodies of the region.

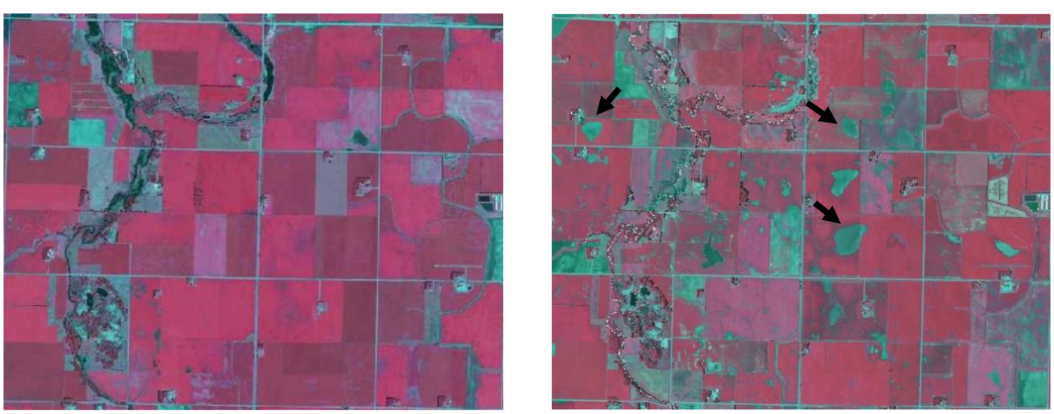


Figure 1. An example of what we identify with NAIP. The images show a section of Renville County, Minnesota in false-color composite. The 2017 image (left) shows the area without significant flooding, and the 2019 image shows the area (right) with significant bare earth scars due to flooding (highlighted).

Methods

Project Preparation

We created a real-time modeling system for land-cover classification map of both 2017 and 2019, with the classes agriculture (broken into individual crops), bare earth, water, and other. We distinguish these classes (most importantly agriculture from bare earth and surface water) by using vegetation indices like NDVI, NDWI, or visible color. This is done with a pixel-based given the high-resolution of NAIP imagery. Noise within fields (like pixels with slightly lower NDVI) is classified as flood-impact using pixel-based methods. However, object-based methods can better discriminate using clear differences in shape and size for agriculture and flood impacts: farm fields have large, square shapes compared to the smaller, irregularly circular depressions that were flooded. Since we use pixel-based interpretation due to time constraints, the small scale at which depressional areas are visible make the creation of training data very time consuming. However, we tested using both supervised and unsupervised methods.

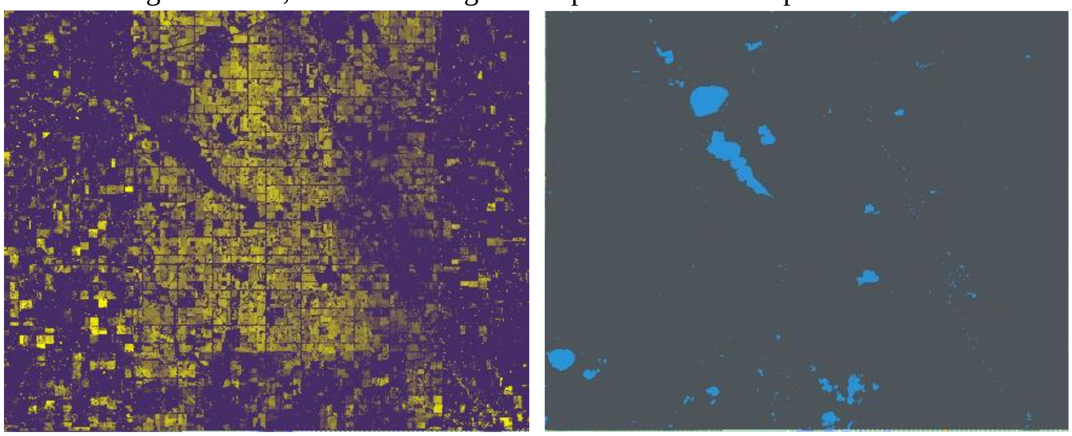


Figure 2. NDVI and NDWI indices.

Geoprocessing

To identify the best classification method, we clipped a test area and classified it with different approaches, then checked them for accuracy against known landcover using the USDA Crop Data Layer (2019). We tested various numbers of classes and compared a pixel-based for supervised and unsupervised classifications. We chose to do a supervised pixel-based classification with at least 1000 random training points per class and 3 classes: vegetated, water, and non-vegetated. We chose this method because it gave satisfying results without significant processing time. While these classes are broad, we care specifically about vegetated cropland that became barren or water. We can get to these specific changes and avoid confusion (forests being included in the vegetated classification, urban areas being included in the barren classification, etc.) by masking our results to only include agricultural land with the USDA Crop Data Layer.

We measured the amount of barren and ponded land within each crop type in 2017 and compared it to the same in 2019. This way, we could see the growth of wet areas as a result of flooding and the decrease in actually vegetated area for each crop type.

The crop data mask we used for 2019, made from the USDA Crop Data Layer Note that the most common crops in southwest Minnesota are corn and soy.

Results

I need to work more on coding of this part to first normalize the classification result and extract some statistics about each class pixels.

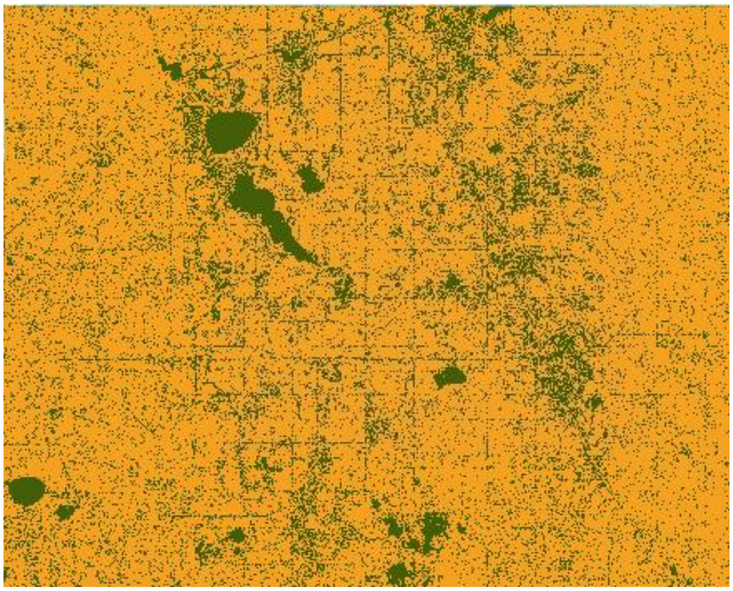


Figure 2. classification for 2019.

Result verification

Total Cropland:
2017

According to the USDA Crop Data Layer mask, there should be 366,938 acres of cropland in 2017. Within these areas identified as cropland, we identified … acres as vegetated, … as barren, and … acres as wet.

Count of pixels classified to each type, each pixel is 900 square meters

Much less land was in production in 2019, and a lower proportion of cropland was identified as vegetated in 2019.

Discussion & Conclusion

Acknowledgements

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