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Assessing Changes in Tornado Vulnerability in North Alabama

by

McKenna Danielle Brahler

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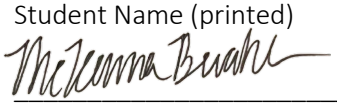

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Assessing Changes in Tornado Vulnerability Across North Alabama

McKenna Brahler

Partnered with Jessica Chace and Laurel McCoy of the National Weather Service in Huntsville, AL

Abstract

High-profile tornado events are not uncommon to North Alabama. Many factors may influence an area's vulnerability to tornadoes including population and housing variables. This project partners with the National Weather Service Weather Forecast Office in Huntsville, Alabama to understand the evolution of tornado vulnerability across North Alabama in the past 50 years. Using ArcGIS Pro, population data, and tornado track data, vulnerability was calculated using a curated formula involving specific variables that NWS was interested in investigating. Additionally, this project investigates the land use / land cover change in the 23 counties included in the study. Land use change along the tornado paths was analyzed and the area of land within the paths that changed to "Developed Land" was calculated. The results of this project will aid NWS - Huntsville in providing improved outreach, education, and communication to the public before, during, and after these severe weather events.

Introduction

Alabama sits in the middle of a tornado hot-spot area known as "Dixie Alley". The frequency of tornado occurrence is much larger in this area than the surrounding regions. Due to the relatively high frequency of tornadoes, National Weather Service Weather Forecasting Offices in this region deal with forecasting, analyzing, and investigating these events before, during, and after they occur. The National Weather Service Weather Forecast Office in Huntsville, AL (NWS - Huntsville) experiences tornado events every year. With this, they strive to understand the profile of the population that exists within their County Warning Area (CWA). The 23 Alabama counties included in the study are Blount, Calhoun, Cherokee, Cleburne, Colbert, Cullman, Dekalb, Etowah, Fayette, Franklin, Jackson, Jefferson, Lamar, Lauderdale, Lawrence, Limestone, Madison, Marion, Marshall, Morgan, St. Clair, Walker, and Winston.

Population density is one of the most important variables to consider when trying to understand the population profile. Alabama has recently experienced a population "boom", and with this, it is important to focus on largely populated areas that may be expanding (Ashley et al., 2014). The "expanding bullseye" creates a larger area that is densely populated. When it comes to tornado vulnerability, an expanding bullseye indicates that if a tornado were to pass through an area near but outside the center of a large population, there is a larger amount of people that will be affected by that tornado.

Another variable used in this study was land cover change. Land cover change is important because it provides information on how the land cover has changed in terms of use. This study focused on identifying areas that had any Developed Land added. New developed land indicates that man-made structures have been added to that parcel of land. Man-made structures signify that people are located here, whether this is through home developments, office buildings, etc. that have been built since the last land use / land cover map was created. As new developed land is added, there is

a higher chance for tornado paths to intersect structures, not only causing monetary effects but also possible life effects (injuries and death).

The last two variables that were utilized in this study were the percentage of mobile homes and percentage of the population that speaks another language besides English. These two variables are a huge contributor to the overall socioeconomic standing of a population. Mobile home percentage and other language percentage were investigated at the census-tract level in this study. Studies have shown that lower socioeconomic status reflects a higher tornado vulnerability (Fricker & Friesenhahn, 2022 & Lim 2016). NWS - Huntsville wanted these two variables included in the study to help them understand how the socioeconomic status of North Alabama was changing and how those changes affected tornado vulnerability.

Methodology

Data was collected from the U.S. Census Bureau, the National Weather Service Storm Prediction Center (SPC), the United States Geological Survey (USGS), and the American Community Survey (ACS). Population data and United States county boundaries were collected from the Census for 2000, 2010, and 2020. From the SPC, a shapefile containing all tornado paths from 1950 to 2020 was utilized. The USGS's Land Use / Land Cover (LULC) maps from 2001, 2006, 2011, and 2019 were collected. A mobile home percentage dataset and a percentage of population that speaks another language dataset were collected at the census-tract level from the American Community Survey 5-year estimate for 2016-2020 due to 2020 Census statistics for these two variables not having been released at the time of this study. All analysis was performed using ArcGIS Pro.

Population data, mobile home data, and language data were clipped at the census-tract level. It is important to note that between the 2000/2010 and 2020 census datasets, some census tracts were divided into two or more tracts. These datasets were clipped to the 23 counties of interest using the "Clip" tool in ArcGIS Pro.

Tornado paths were also clipped to the 23 counties. NWS - Huntsville was interested in strong tornado events since 1970 for this study; therefore, only tornadoes of EF3, EF4, and EF5 that caused injury or death were kept in the dataset. These parameters included a total of 53 tornadoes. Additionally, the tornado paths were adjusted to reflect their maximum width across the entirety of the tornado path. It is important to note that tornadoes do not maintain the same width along their paths, but this procedure was done to represent "worst-case scenarios".

LULC data sets were formatted to reflect the same symbology for all four years collected. The "Extract by Mask" tool was used to extract the LULC raster data that fell into North Alabama. For each tornado path line, the LULC layer that was created closest in terms of date to the tornado date was extracted. This provided visualizations of new developed land along these strong tornado paths.

Vulnerability maps were created using the "Weighted Sum" tool in ArcGIS Pro. Discussions with NWS - Huntsville created the following weights for the four vulnerability variables, with 1 being lowest weight and 4 being the highest weight:

4 - Percent of Mobile Homes
3 - Percent of Population that Speaks Another Language at Home
2 - Added Developed Land
1 - Population Density

Excel was used to calculate the area of added developed land in each LULC year compared to the most current year, 2019. The area of added developed land along each tornado path was also calculated. Areas were calculated in square miles.

Results

The first set of results that were reviewed was the added developed land along the tornado paths. A total of 24.6 square miles of developed land had been added along the paths of the 53 tornadoes. There were 7 tornadoes that had over 1 square mile added along their single paths (Appendix A, Table 1). The tornado with the largest increase in developed land along its path was the Hackleburg - Phil Campbell Tornado from the 2011 Super Outbreak, with 4.556 square miles of added developed land as of 2019 (Appendix A, Figure 1). One of the clearest cases of development along a previous tornado path is an EF3 tornado from April 1st, 1974 (Appendix A, Figure 2).

The second set of results were the completed vulnerability maps. These maps were created for the years 2000 (Appendix A, Figure 3), 2010 (Appendix A, Figure 4), and 2020 (Appendix A, Figure 5). While the percentage of mobile homes variable had the highest weight in the "Weighted Sum" tool, population density had an overwhelming effect on the vulnerability, especially between 2010 and 2020. Areas that had the largest increases in vulnerability were areas surrounding cities. This reflects the definition of the "expanding bullseye", as cities such as Huntsville and Birmingham continue to expand from their centers. Results of the increasing vulnerability were given to NWS - Huntsville for their use in improving outreach, education, and communication to the public.

Conclusions

Population Densities are continuing to increase, even as some Census Tracts are split into new parts for the Census surveys. This continued growth indicates that the "expanding bullseye" is occurring around several large cities in north Alabama including Huntsville, Decatur, and Birmingham. This phenomenon is important to NWS - Huntsville because the expanding bullseye indicates that tornado warnings in the future will include more developed land which implies more people.

Land Cover Change is indicating an increase in Developed Land. This shows that more developed land will be in the paths of future tornadoes, as Developed Land is being added in the entire study area. This increase in Developed Land indicates that more man-made structures will be included in future tornado events, as the chance of a tornado impacting Developed Land increases.

Looking to the future, based on the vulnerability weights that were selected, Percent of Mobile Homes will be the most important to reinvestigate when the 2020 Census Housing Data is released in early 2023. This is an area that should be investigated in the future to continue NWS - Huntsville's understanding of the vulnerability of their County Warning Area and the surrounding region.

Overall, since the year 2000, there has been an increase in tornado vulnerability across North Alabama, with the areas surrounding big cities having the largest increases.

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Appendix A

Table 1. Details of the 7 tornadoes that have more than 1 square mile of added developed land since tornado occurrence.

Tornado Paths with > 1 mi² of Added Developed Land

Outbreak / Event Name	Date	Magnitude	Injuries	Deaths	Counties Affected	Area of Added Developed Land (mi²)
May 22-31, 1973 Outbreak	5/27/1973	3	44	1	Jefferson, St. Clair, Etowah	1.110
Tornado Outbreak of April 1-2, 1974	4/1/1974	3	6	1	Madison	1.114
Super Outbreak of 1974	4/3/1974	3	7	2	Morgan, Madison, Jackson	1.299
Super Outbreak of 1974	4/3/1974	5	267	28	Lawrence, Morgan, Limestone, Madison	1.743
2011 Super Outbreak	4/27/2011	4	1500	64	Jefferson*	1.871
May 1995 Tornado Outbreak Sequence	5/18/1995	4	55	1	Limestone, Madison, Jackson	3.566
2011 Super Outbreak	4/27/2011	5	145	72	Marion, Franklin, Lawrence, Morgan, Limestone, Madison	4.556

*Note: This tornado was the "Tuscaloosa Tornado" of the 2011 Super Outbreak. Tuscaloosa County was not included in this study. Therefore, some of the deaths and injuries could have occurred outside the area of study. The added developed land for this tornado only includes land within the study boundaries.

Figure 1. This image shows the land change along a portion of the EF5 Hackleburg - Phil Campbell Tornado from April 27th, 2011. Shades of red indicate added developed land since 2006.

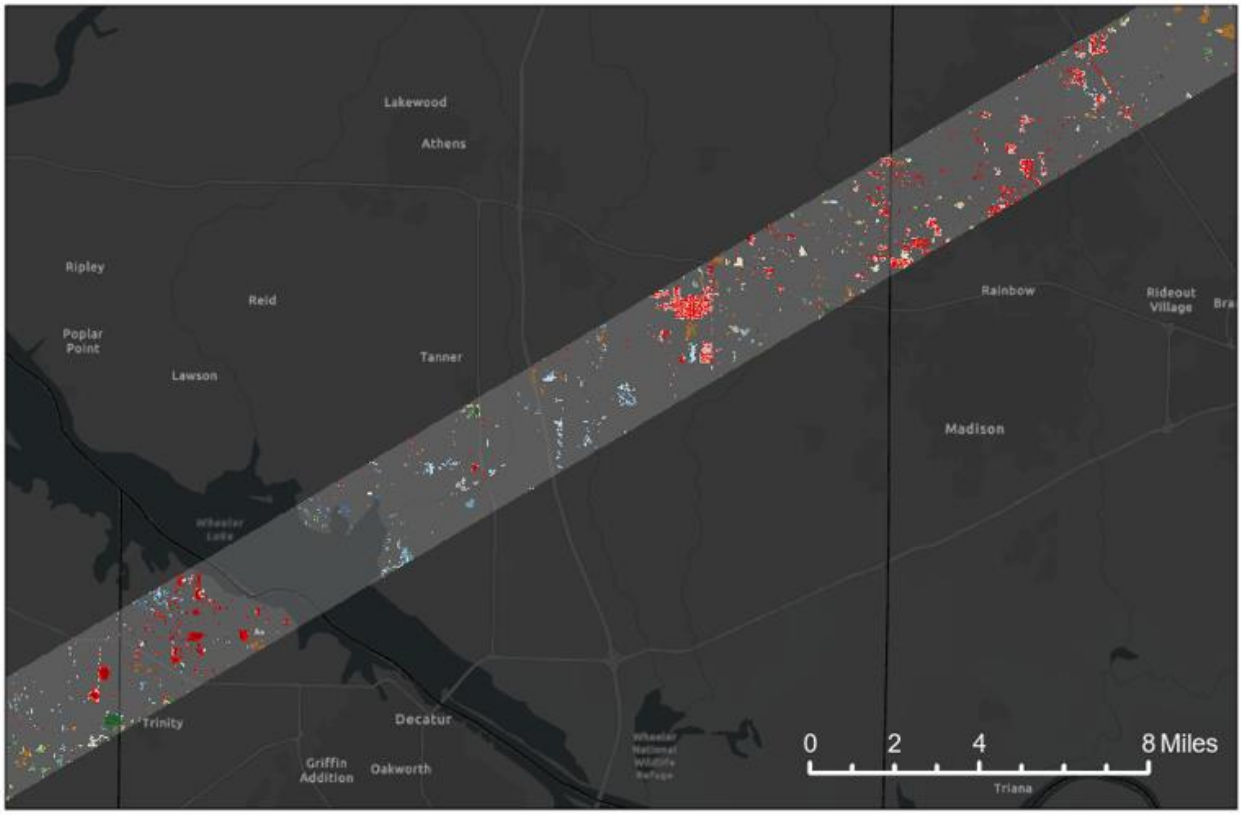

Figure 2. This image shows the land change along the path of an EF3 tornado from April 1st, 1974. Shades of red indicate added developed land since 2001.

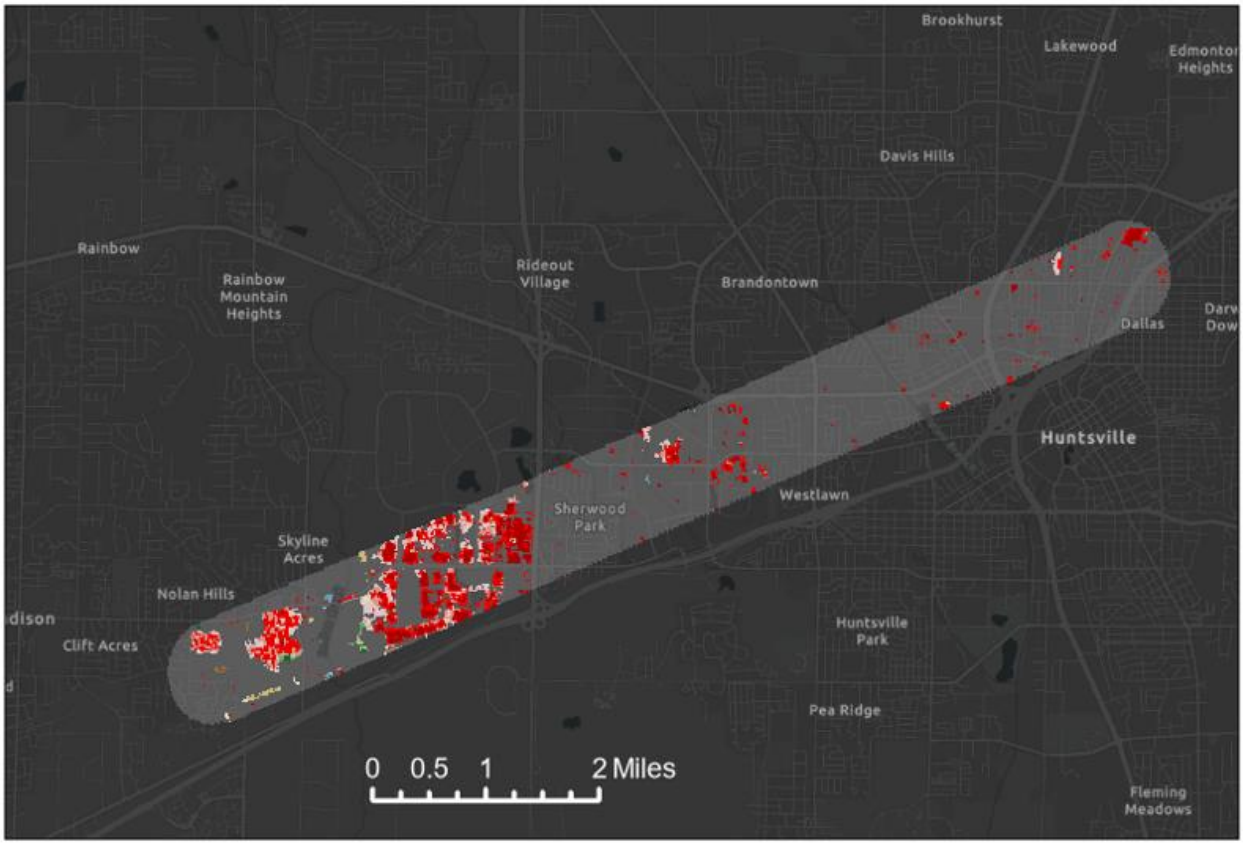

Figure 3. Vulnerability Map for 2000. The darker the red shade, the higher the vulnerability.

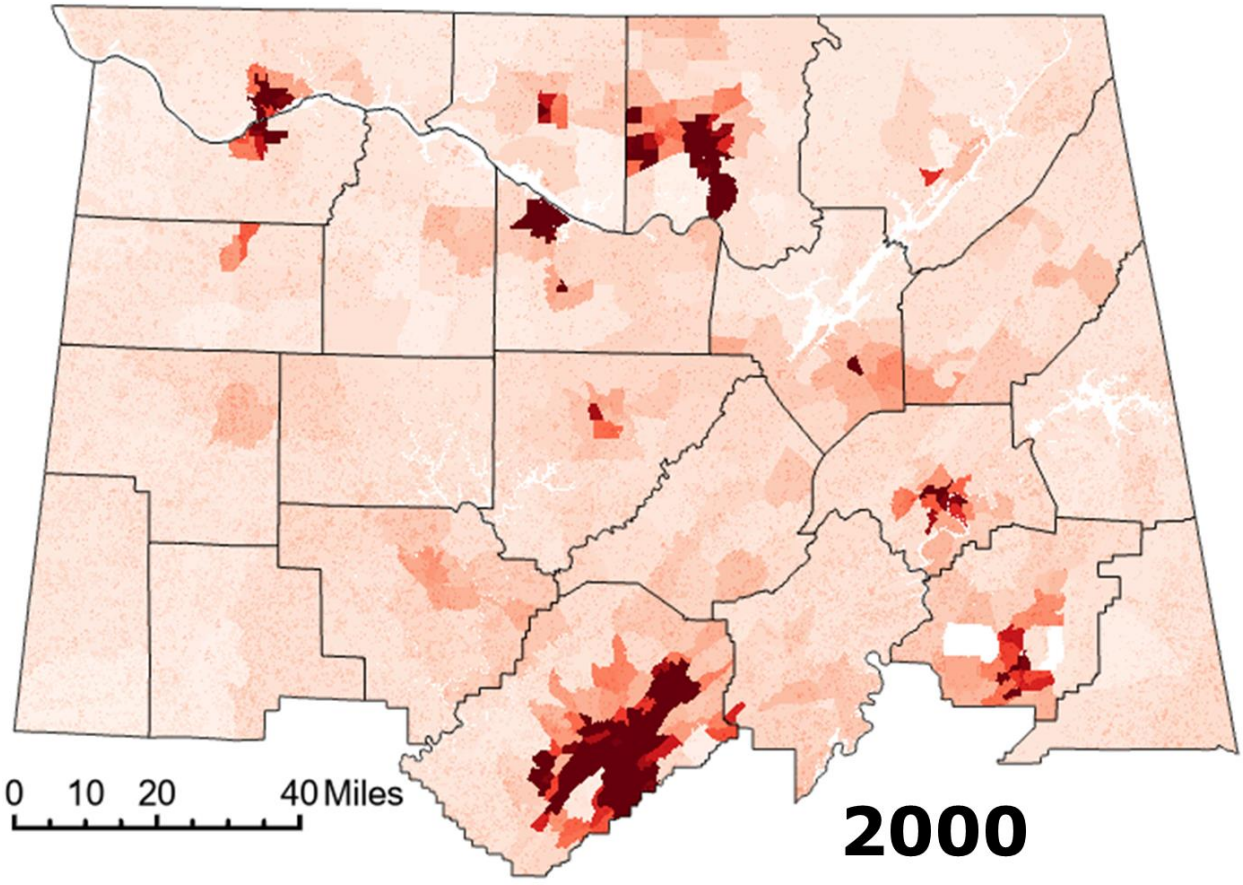

Figure 4. Vulnerability Map for 2010. The darker the red shade, the higher the vulnerability.

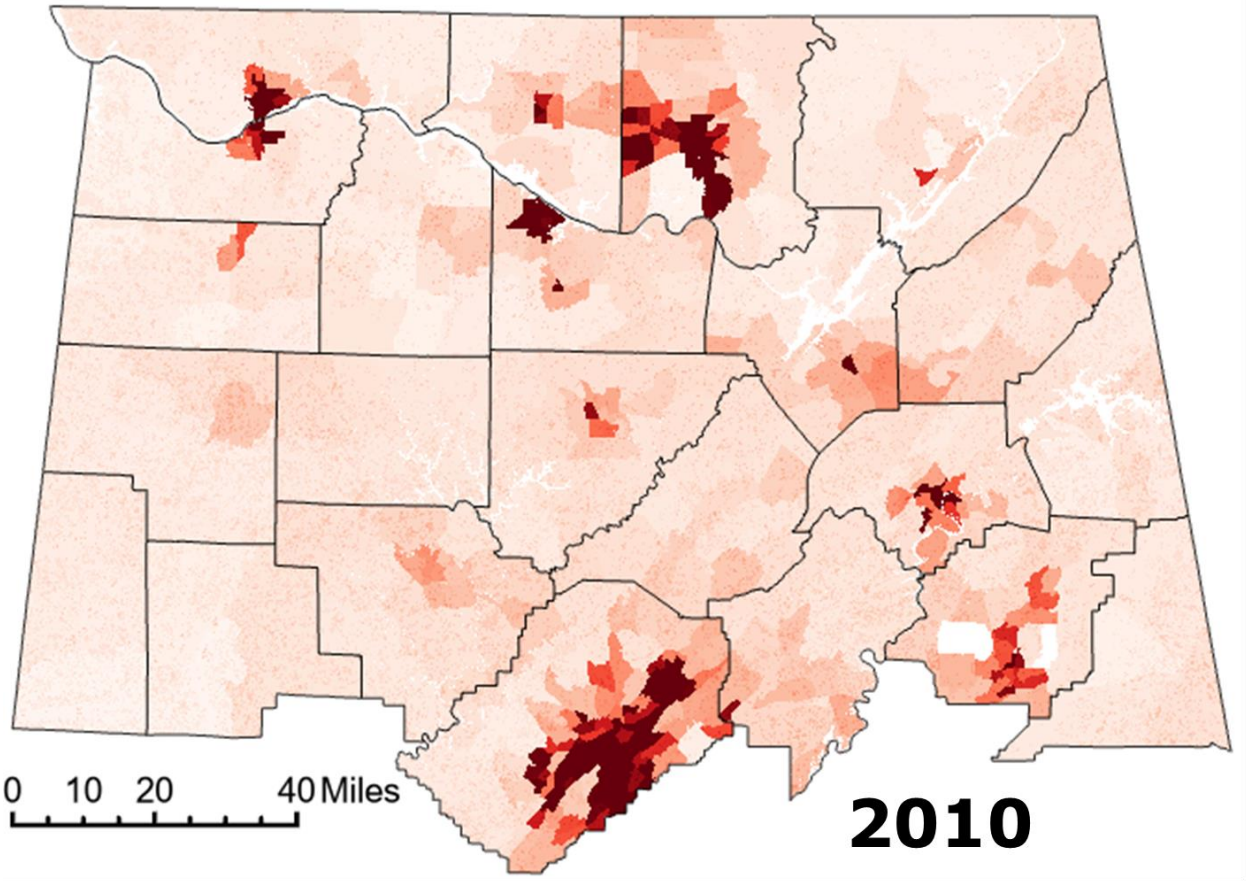

Figure 5. Vulnerability Map for 2020. The darker the red shade, the higher the vulnerability.