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Hydrologic Impact Index for the Pinhoti Hiking Trail

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Hydrologic Impact Index for the Pinhoti Hiking Trail

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By

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Abstract

This study aimed to identify flood-prone areas along the Pinhoti Trail and Chinnabee Silent Trail in the Talladega National Forest. Using the Hydrology Flood Index layer that was created using several essential data layers, the research aimed to provide campers, hikers, nature enthusiasts, and trail maintenance teams with information about areas at a higher risk of flash flooding. The Hydrology Flood Index layer rates the risk of flooding on a scale of 1 to 4, with level 1 indicating a low risk of flooding and level 4 indicating an extremely high risk. The data layers for analyzing flood hazards for the Hydrology Flood Index Map include the Soil Survey Geographic Database (SSURGO), National Land Cover Dataset (NLCD), Slope, and Flow Accumulation. The study area includes three Pinhoti campsites and the entire length of the Chinnabee Silent Trail, where high-resolution images were taken after a flood occurred in 2014.

Acknowledgments

I want to thank the people who have supported me on this journey of my life, completing this thesis. First, I want to acknowledge Dr. Ross Martin, my thesis advisor. He was there when I had questions and needed guidance on surviving graduate school without overdoing it. He has kept me on a narrow path on my thesis when I almost went in different directions. I would also like to thank Dr. Sean Chenoweth, who is on my thesis committee. He has introduced me to new skills in technology and a passion for drones. Thanks to him, I can now see the world through a new lens. I also want to thank Dr. Vicki Tinnon-Brock, a professor in the Geography Department at Jacksonville State University. She met me when I lost my passion and helped me find myself again as an undergraduate in 2021. After class, all those small talks about geography planted a seed in my life.

I would also like to thank my family, including my husband. He saw all that I went through with work and school and supported me as I found myself and my niche again.

Lastly, I would like to acknowledge everyone in the Geography Department at Jacksonville State University. You have all been a building block in my life, giving me the knowledge, I can take on my journey. Knowledge is a tool, but how to use it is the key to success in life, “Blessed is the one who finds wisdom and the one who gets understanding” (Proverbs 3:13 ESV).

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Abbreviations

1. FEMA - The Federal Emergency Management Agency
2. ADECA - Alabama Department of Economic and Community Affairs
3. NLCD – National Land Cover Dataset
4. DEM - Digital Elevation Model
5. GIS – Geographic Information Systems
6. AOI – Area of Interest
7. SSURGO – Soil Survey Geographic Database
8. AHP - Analytical Hierarchy Process

INTRODUCTION

Outdoor activities have grown over the years, and so have the safety concerns for visitors (Lee, S. Y et al. 2020) Flash floods, localized flooding that occurs suddenly, usually caused by heavy rainfall in areas with low elevation, are common and a leading cause of weather-related deaths worldwide. It is also difficult to forecast and supply warnings for flash floods, especially for those who are outdoors during the event (Lee, B.-J., & Kim, S., 2019), Flash floods typically occur in mountainous regions where steep slopes and small catchment areas lead to short rainfall-runoff response times, triggering events such as landslides in the Southern Appalachians (Tao & Barros, 2013).

This research aims to find areas prone to high-risk floods around Talladega National Forest and Cheaha State Park that can be hazardous to people doing outdoor activities such as hiking, camping, or visiting. Cheaha State Park is a well-visited area in Alabama because it is the tallest mountain in the Talladega National Forest, at 2,413 feet (about 735.48 m) above sea level (Fukano, R., 2023). It is also popular due to its vast network of trails and inspiring views, which attract people from across the United States (Pruitt et al., 2019). The Pinhoti and the Chinnabee Silent Hiking Trails within the Talladega National Forest are popular trails. Along the trails, there are many water crossings, some of which could be considered unsafe if flooding occurs in areas of erosion, due to the areas prone to flooding (Bratton, S. P. et al., 1979).

LITERATURE REVIEW

Northeast Alabama Trails

The Pinhoti Trail in Alabama starts at Flagg Mountain, located in Sylacauga, Alabama, and ends in Cherokee County, Alabama. From there, it progresses into Georgia. The Chinnabee

Silent Trail is also located in the Talladega National Forest. It is shorter than the Pinhoti but has breathtaking sites. It starts at Cheaha Creek and goes for six miles with the last portion of the trail ending at Caney Head atop Talladega Mountain (*Forest Service- Chinnabee Silent Hiking Trail., 2001).*

Alabama's Terrestrial Ecosystem

Alabama's diversity comprises 64 types of environmental features, including 25 forests and woodlands, 11 wetlands, and seven glades and prairies. It is one of the most biologically diverse states in the United States (*Joe Wheeler*, 2022). The most widespread native ecosystem is the longleaf pine woodland, which extends along the Gulf and Atlantic Coastal Plains from Virginia, south into central Florida, and north into the Piedmont and mountains of northern Alabama and Georgia (Stokes et al., 2010).

The national forests in Alabama, especially Cheaha State Park, are known as national treasures, bringing in tourists all year round (*Cheaha State Park*. Alapark, 2019). The forests of Alabama are home to 900 species of birds, mammals, reptiles, amphibians, and fishes, including endangered and threatened species such as the gopher tortoise, eastern indigo snake, and the red-cockaded woodpecker (*National Forests of Alabama*. Encyclopedia of Alabama).

Alabama's Waterways

Alabama's waterways are known for their exceptional biological diversity, due to having the largest variety of fish species in any river in the United States (Warren, M. L., & Burr, B. M.,1994). This is also why Alabama is known as America's Amazon. (Robertson, David J., 2023). Alabama has 17 major river systems encompassing 132,000 miles of channels (*Rivers of*

Alabama Gallery., 2023). One of the waterways we are looking into that crosses the Pinhoti River is the Hilliabee Creek.

Heavy rainfall in Alabama can cause significant flooding in the state's rivers and streams (April, G. C., & Raney, D. C., 1980). This flooding can lead to a high risk of erosion, landslides, and downed trees due to waterlogging and seasonal rainfall patterns (Jurgen Kreuzwieser, Heinz Rennenberg., 2014). The months with the most rain in Alabama are January through April, with the highest monthly frequency occurring in March (Lecce, S. A., 2000). Even though storms are unpredictable, it is always important to be aware of the risk of flooding in an area, especially during these months. It is worth noting that storms can also occur in June and July, which are the hottest months in the state. Fall and spring are popular for hiking and outdoor activities (Teton, 2016).

Floods are hard to predict due to their rapid formation (Acosta-Coll, M et al., 2018). There are no early warning systems in place for flash flooding. It is hard to predict where flooding will occur and how much rainwater would occur for this to happen. The Federal Emergency Management Agency (FEMA) has created maps that are based on historical hydrologic data, community input, topographic surveys, hydrologic analysis, and hydraulic analysis (ADECA, 2021). FEMA maps may not be reliable for hazards on trails since they are made for flood hazards in residential areas.

Flash Flooding Hazards

Flooding can be a concern for hikers, campers, or any outdoor enthusiasts. When planning, before going outdoors, it is best to see the weather forecast and know where you will be taking a trip (Camotrek Staff., 2022). This is why a Hydrology Impact Index model of the area may prove valuable. A Hydrology Impact Index model is one approach to modeling the potential flooding areas by rating them on a scale of 1 to 4, with 1 representing extremely low flood risk and 4 representing high risk. (Nashwan, M. et al., 2018). The Hydrology Flood Index was created using the Arc Hydrology toolset with four layers: Soil, National Land Cover Dataset (NLCD), Flow Accumulation, and Slope. These layers are individually weighted based on their significance in causing flooding or hydrology issues compared to other layers. Additionally, the data is compared to past flooding reports by FEMA and hikers to determine which areas have been flooded in the past. Since FEMA's flood maps are based on historical data for residential areas the Arc Hydrology toolset will be heavily relied on and could help indicate areas with higher potential to flood. With this, over time, you can see changes in the landscape and indications of elevated risk according to the flow accumulation tool from Esri (Jacinto, R. et al., 2015).

Usually, flash floods can occur if there is enough rainfall, while flooding usually happens after several days of rain. It is important to never underestimate the danger of flash floods (Camotrek Staff., 2022). Sometimes, unexpected rain occurs when it is not forecasted or detected by Doppler radar. This can happen due to a short-lived storm called a microburst, which occurs between radar scans (Wilson, J. W. et al., 1984). Wet microbursts are known for their high wind shear, which can be strong enough to cause airplane accidents (Maaz, M. A., 2022). They are also likely to bring intense hail and substantial rainfall. Light rain that is too small to show up on radar can also contribute to unexpected rain events (Tuttle, J. D. et al., 1989). An example of flash flooding from a microburst was in July 2019 in Saks, Anniston, Alabama (Nunnally, B., The Anniston Star., 2019). A neighborhood of Lenlock Lane and Wildoak experienced a wet microburst which caused 4 feet of standing water. FEMA did not identify this neighborhood as a flood zone risk, even after the 2018 flooding. Another example was found on County Road 24 in Heflin, Alabama, near Lake Hillabee and Morgan Lake. On March 22, 2022, this location also had flash flooding, connected to Choccolocco Creek, which flooded neighborhoods and the Choccolocco Creek Park (Kortright, A., The Anniston Star. 2019, February 22).

Flood Indices

Flooding can be measured by a flood index, which is a tool that helps explain the frequency or intensity of a flood in a particular area. Several other flood indexes can be used, including the Flood Vulnerability Index, Flood Hazard Index, and Social Flood Risk Index. These indexes show either how often an area is to have a severe flood or the potential of the likelihood it would ever flood in a location and the severity of it (Tascón-González, L. Y. et al., 2020).

In the Jackpine watershed in Canada, DEM (Digital Elevation Model), network stream data, and Arc GIS (Geographic Information Systems) Hydrology toolset were used to create a Hydro Index model for flood predictions and hydrology predictions (Li, Z., 2014). Rainwater tends to follow the naturally formed paths created by fluvial networks on higher slopes. These streams have formed over time due to the erosive action of water. As rainwater flows down the slopes, it follows the path of least resistance, which is often along the existing fluvial network. This process helps to guide the water along a predictable path, which can be beneficial for managing water resources and mitigating the risk of flooding (Bloemen, P., 2017). In the Walnut Gulch Experimental Watershed and Las Trampas Creek Watershed, Arc Hydro was used to investigate the properties of hillslope curvature and the impact of curvature on peak flows

(Lapides, D. et al., 2022). Flood indices have been used for a lot of reasons including analyzing and predicting rainfall patterns, assisting emergency services, local authorities, and individuals in devising effective strategies for planning and responding to flood events, and identifying the potential risks and hazards associated with floods.

Flooding events provide valuable data that highlights the areas that are prone to flooding along with the frequency of events and level of risk associated with each area. This information can be instrumental in identifying and mitigating the potential dangers. For predicting flood risk, we would obtain a Digital Elevation Model (DEM) and apply it to the Flow Accumulation of the Arc Hydro tool set. (Strapazan, C., & Pettut, M., 2017). This would highlight areas of erosion due to potential flooding. The Arc Hydrology toolset uses DEM to see if an area is prone to flooding (Bajabaa, S. et al., 2013). DEM is used to define the slopes, the hydrographic network, the delimitation of the basin's slopes, and the extraction of the physical characteristics and water streaming from an inlet (Sami, K et al., 2013).

The Guadalupe River Basin in Texas has been utilized as an example for data modeling in Arc Hydro GIS (Goodall, J. 2003). The Arc Hydro GIS model is specifically designed for analyzing river overflooding caused by excessive rainfall. This data example can also be useful in evaluating floods on trails by identifying rivers and streams that intersect and may potentially overflow.

Study Site

The Pinhoti Study Area starting location is in Flagg Mountain, located at Sylacauga, Alabama with coordinates 32.97814, -86.354578, and ends at Indian Mountain in Cherokee County, Alabama with coordinates 34.0225995, -85.4560683 **Fig 2**. The Chinnabee Silent Trail is located in the Talladega National Forest, in Cheaha Mountain, which is the Study area **Fig 1**. It starts at Cheaha Creek and goes for six miles with the last portion of the trail ending at Caney Head atop Talladega Mountain (Forest Service. (2001).

Figure 1. The Pinhoti Trail and The Chinnabee Silent Trail of Alabama

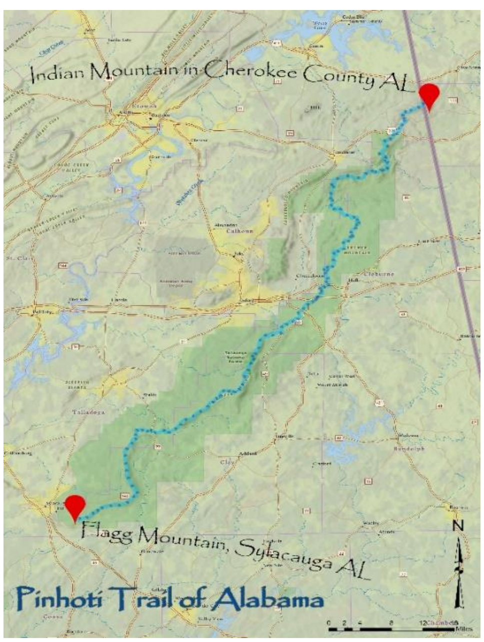

Figure 2. Pinhoti Trail of Alabama

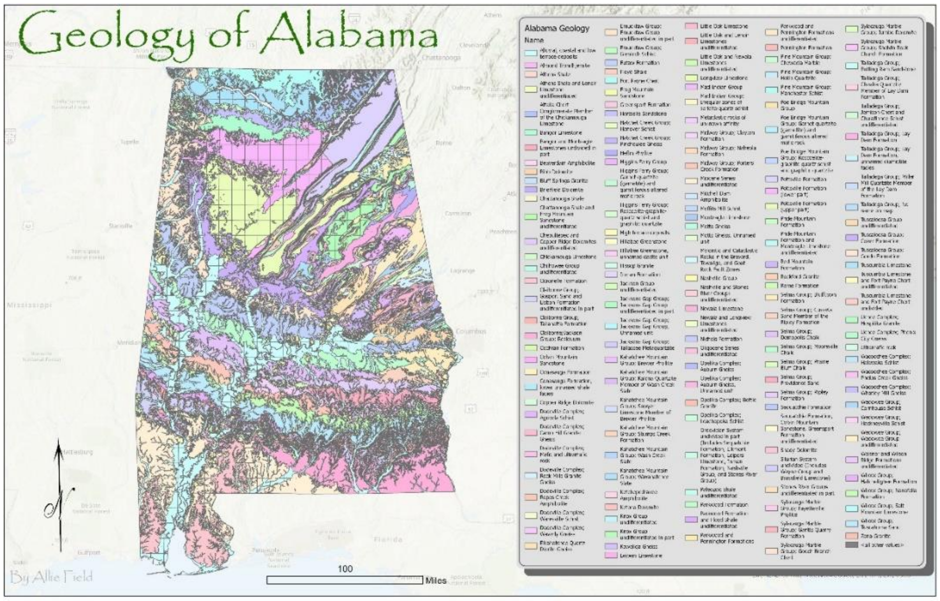

Figure 3. Alabama Geology

The study area is within the Choccolocco Creek Watershed, which is an area known for flood hazards (William Wesson, 2022). The study areas of the Pinhoti and Chinnabee Silent Trails are part of Cleburne County and are by the Calhoun County borderline by Oxford, AL, and Anniston, AL. The terrain varies from steep mountains to gentle valleys with elevations ranging from 1,500 ft to 2,500 ft on the trail and is 15 miles long. The bedrock is composed of Clastic metamorphic sedimentary rock (Keith, A., 2008). There are a few bodies of water that surround this portion of the Pinhoti such as Jackson Creek, Turner Creek, Gold Mine Lakes, Creghton Lake, Abel Lake, Morgan Lake, and Hillabee Lake. The focus is on Hillabee Lake since the river cuts through the Pinhoti Trail several times and the main body of water is next to the trail by County Road 24.

METHODOLOGY

Field Survey

In this paper, we analyzed both the Pinhoti and the Chinnabee Silent Trails located in Cheaha State Park **Fig 2** and the geo-hydrological risks, such as landslides and downed trees, that surround the trail. A field survey on the Pinhoti Trail was conducted gathering data from downed trees, erosion, streams, and hazards blocking the trail, invasive plant species, signage, campsites, and debris along the trail. This data was collected using Field Maps Designer in ArcGIS Online. The point layer was used as the feature layer and the map was set to offline mode for data collection on site. The data that was collected were: Erosion, Invasive Species, Natural Hazards, Human Hazards, Trail Features, and Photos. This was collected using Field Maps on a Trimble or my Samsung S21 when I was out on the trail. The app Field Maps was used on these devices.

Data that Impacts Flooding

Many factors can impact or even cause an area to flood. Factors were chosen for consideration based on findings from a project on flooding in Calhoun County, and include Elevation, Distance from the Stream, Land Use, Flow Accumulation, Slope, and Soil. (Khadka, P. et al., 2022).

The data that was used at the end of this research were: Soil, Flow Accumulation, National Land Cover Dataset (NLCD) also known as Land Use, and Slope. It was easier to do it based on counites than watersheds since you can see easily what counites the Pinhoti Trail runs through.

Slope Data

The Slope Data is based on areas of lower elevation that were assigned as a higher risk for potential flooding. When creating the data, we used a DEM **Fig 4**, which can be downloaded from nationalmap.gov (Kelmelis, J. A. 2003).

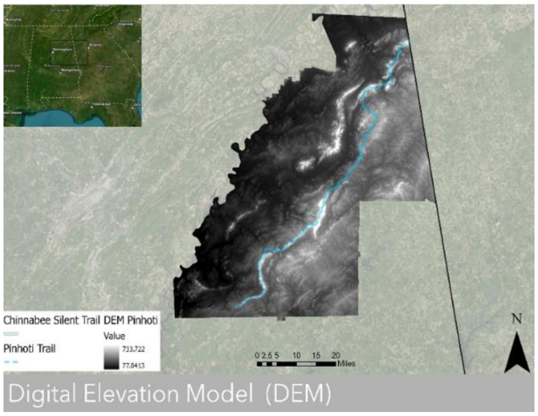

Figure 4. Map of DEM merged and were clipped based on AOI.

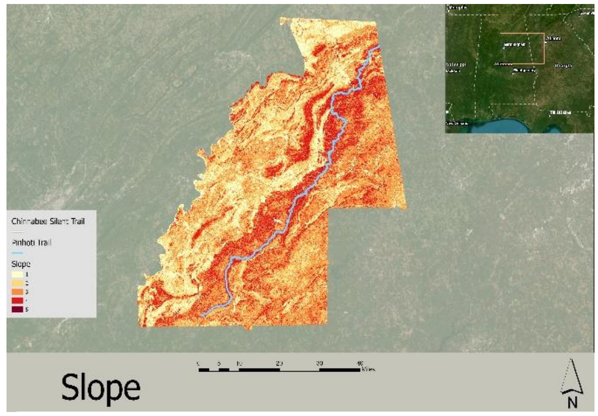

Figure 5. Map of Slope for the trials Pinhoti and Chinnabee Silent Trail

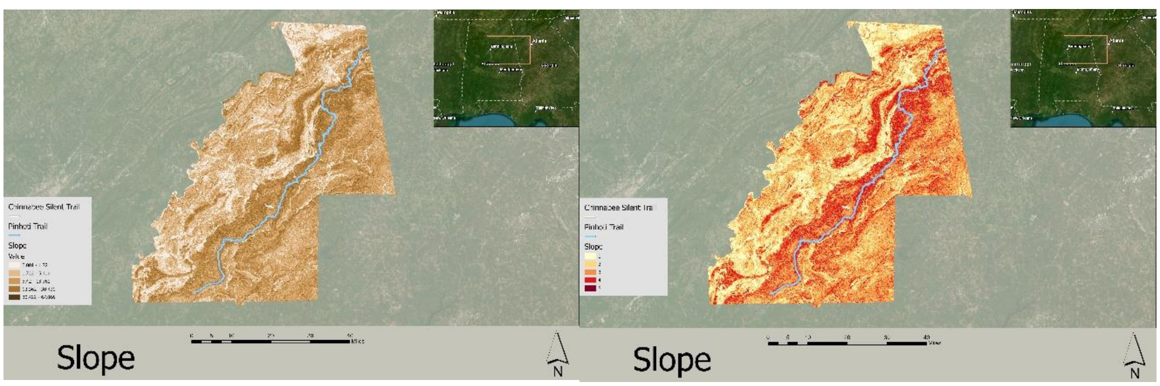

Figure 6. Map of Slope before and after reclassification

These DEMS were then merged and clipped based on the Alabama counties layer Area of Interest (AOI) where the Pinhoti Trail goes through. The Counties layer came from ArcGIS online (*Alabama Counties*, 2018*)*. Elevation can be used to find the area of lower and higher terrain. However, for this research, slope was used because it takes into account the area of high elevation to lower terrain, not just high points. We had to reclass the Slope Data **Fig 5** based on the reclassed version of the Flow Accumulation Data. The Reclassification for the Slope data was based on Elevation.

Color	Value	Label
	≤ 1.72142	0.001 - 1.721
	≤ 5.419005	1.722 - 5.419
	≤ 13.361362	5.42 - 13.361
	≤ 30.421425	13.362 - 30.421
	≤ 67.066185	30.422 - 67.066

Color	Value	Label
	1	1
	2	2
	3	3
	4	4
	5	5

Table 1. Reclassification for Slope Data

NLCD

The National Land Cover Dataset (NLCD) provides descriptive data characteristics of the land surface such as urban, agricultural, forest, and grassland (Earth Resources Observation and Science, 2018). The land cover can be a major part of why an area may flood. For example, Forests have deep-rooted trees that aid in drainage, while pavement in residential areas has poor drainage and can cause flooding.

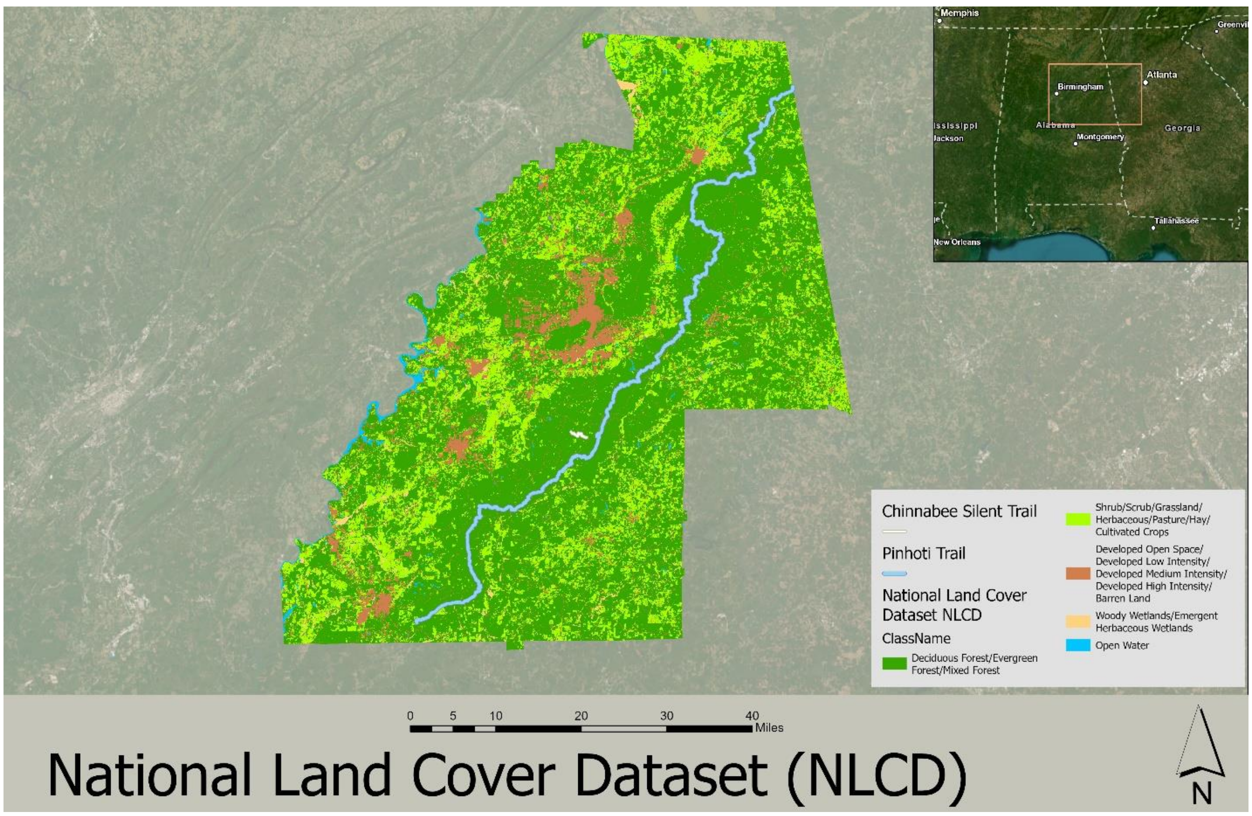

Figure 7. National Land Cover Dataset (NLCD) for the trials Pinhoti and Chinnabee Silent

Most of the area of interest is covered with forests, while some parts have grasslands. The type of trees, vegetation, and soil are the main factors that aid in erosion caused by hydrology issues. The NLCD data came from the USA NLCD Land Cover (*USA NLCD Land Cover*. Arcgis.com) and clipped to the Counties AOI. The NLCD data was reclassified based on the number of classes from the reclassed version of the Flow Accumulation Data.

When choosing which groups to merge for the NLCD data, we had to group those with similarities. For example, those with the category "forest" were grouped and all categories of "residential" were grouped into one group. The reason these categories are grouped, based on class, is that they have the same effect on areas prone to flooding. If you grouped a pasture and residential area, it would be inaccurate since fields can drain water better than pavement.

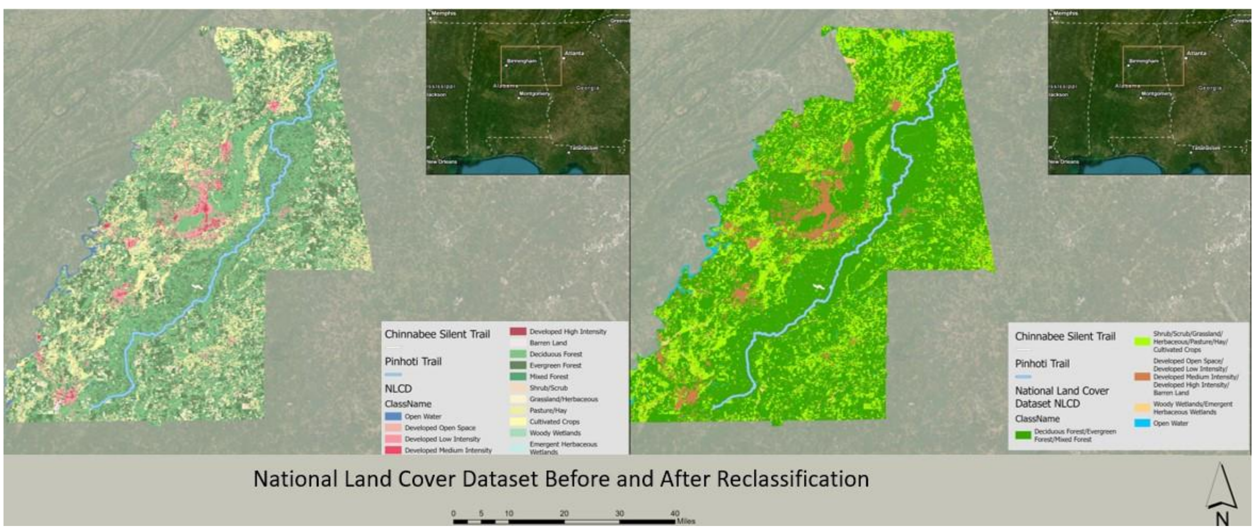

Figure 8. National Land Cover Dataset (NLCD) Before and After Reclassifying

OBJECTID *	Value	Count	Land Cover
1	11	1103167	Open Water
3	21	5766178	Developed Open Space
4	22	1911540	Developed Low Intensity
5	23	623200	Developed Medium Intensity
6	24	237298	Developed High Intensity
7	31	202470	Barren Land
8	41	39028739	Deciduous Forest
9	42	22537266	Evergreen Forest
10	43	6862849	Mixed Forest
12	52	2886768	Shrub/Scrub
13	71	4739967	Grassland/Herbaceous
17	81	13948119	Pasture/Hay
18	82	2148167	Cultivated Crops
19	90	1353254	Woody Wetlands
20	95	84180	Emergent Herbaceous Wetlands

OBJECTID *	Value	Count	Land Cover
1	1	68428854	Deciduous Forest/Everg...
2	2	23723021	Shrub/Scrub/Grassland/...
3	3	8740686	Developed Open Space...
4	4	1437434	Woody Wetlands/Emer...
5	5	1103167	Open Water

Table 2. Reclassification for NCLD Data

Flow Accumulation

The Flow Accumulation data was built based on the tool Flow Direction that comes from the Arc Hydro Toolset, which is the direction the stream flows in each neighboring terrain cell with a low elevation difference or Slope (*Flow Direction*. Hydrology Analyst). DEM is also a representation of the bare ground (bare earth) topographic surface of the Earth excluding trees, buildings, and any other surface objects (USGS, 2022). After building the dataset for Flow Direction, we can use it to build the Flow Accumulation Data. This data can be combined with other hydrology features for a weighted sum in the project. (Zhang, H. et. al., 2017).

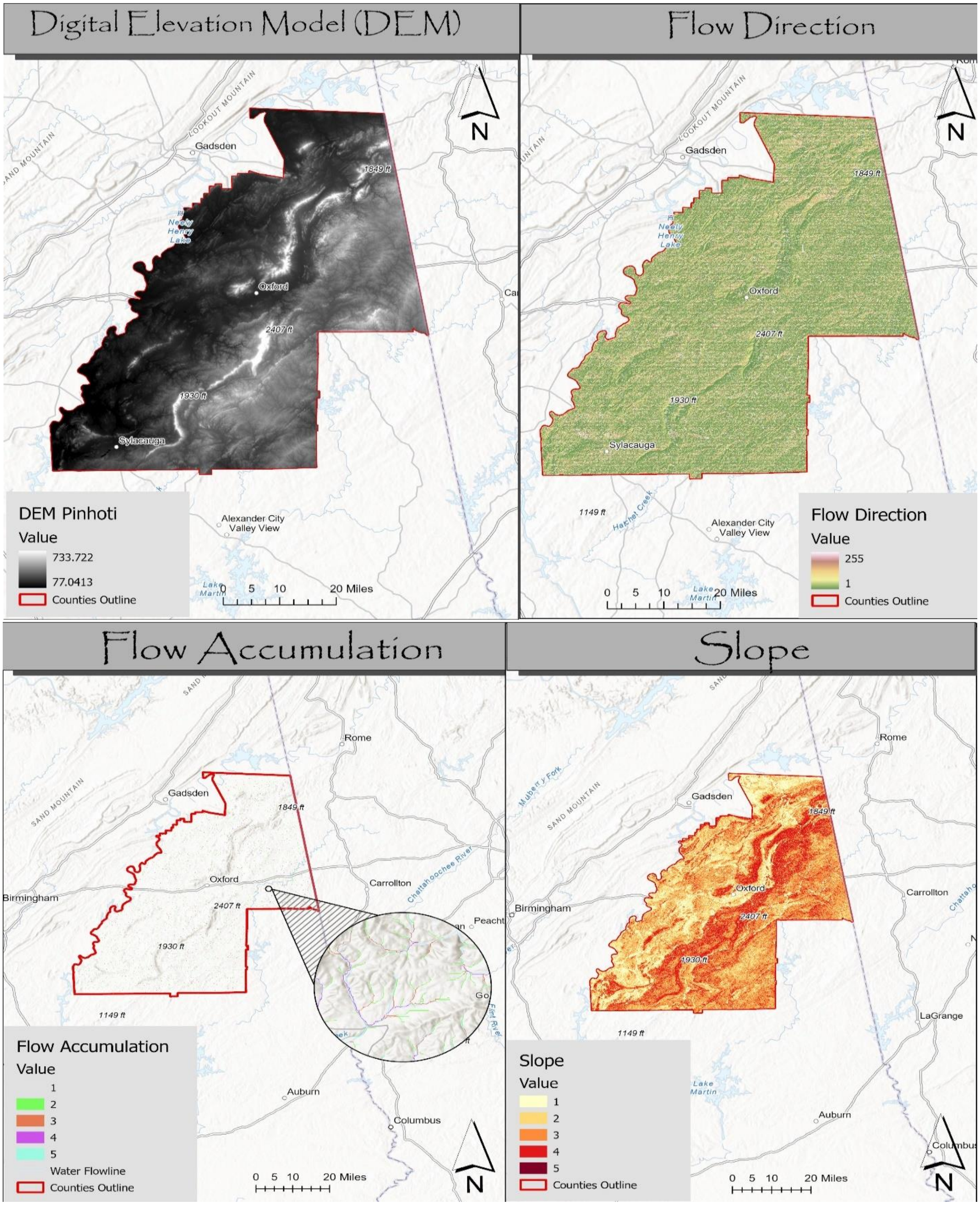

Figure 9. Steps using Arc Hydro Toolset to get to Flow Accumulation Data

Flow Accumulation data is used as the basis for reclassifying all other data layers in this project, as the classes in the Flow Accumulation cannot be recreated. Any changes made to the number of classes in the Flow Accumulation Layer will not be based on the values assigned by Esri the data accumulation tool.

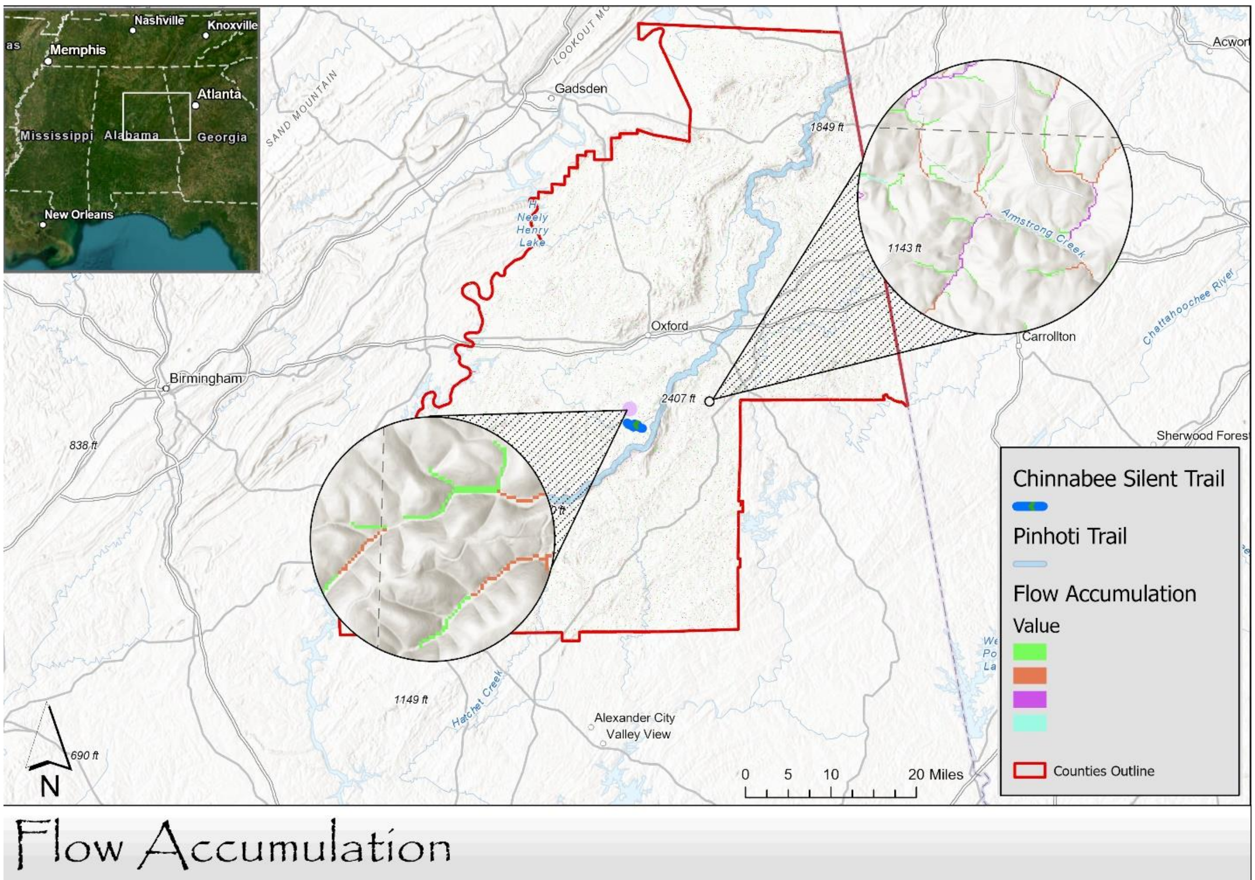

Figure 10. Flow Accumulation Data Value example on the Pinhoti and Chinnabee Silent

Soil

The Soil data is used to determine if the soil in the region has good drainage (Bell, J. C. et al, 1994). Soil samples across the region were collected, but I noticed areas where the data was inaccurate. Due to the impact the soil layer made on the index, I reached out to USDA and

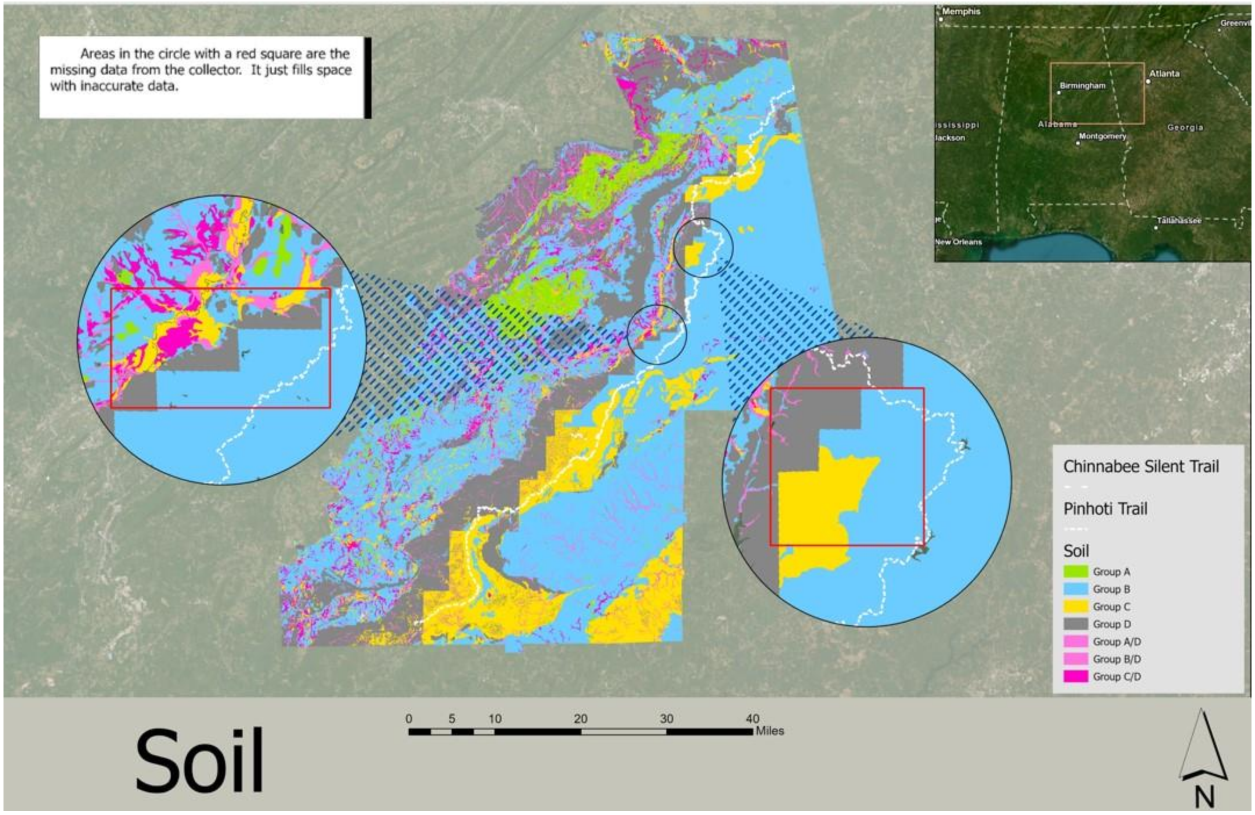

Figure 11. Soil Data on the Pinhoti and Chinnabee Silent Trail

found that the data collected was determined by the ones hired by each county to collect. Also, if the data was not collected, then old data from the years 1899-2005 was put in its place. In **Fig 11** you can see how the data becomes more edged and box-like. These are the areas where the data is incorrect or missing by the county line.

It was revised from the other layer USA SSURGO - Soil Hydrologic Group (USA SSURGO - Soil Hydrologic Group). In **Fig 12** and **Fig 13**, the layers were compared because this particular layer is crucial in determining the flood index across multiple counties. The layer must be seamless and based on accurate data, as the information provided in **Fig 11** may not be sufficient in this regard.

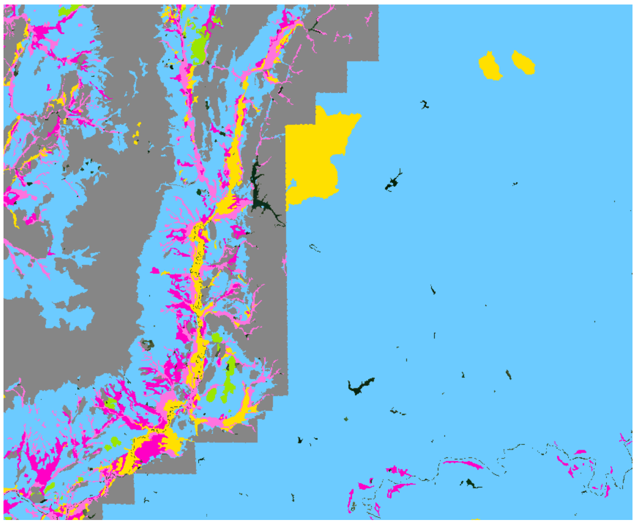

Figure 12. Soil Data

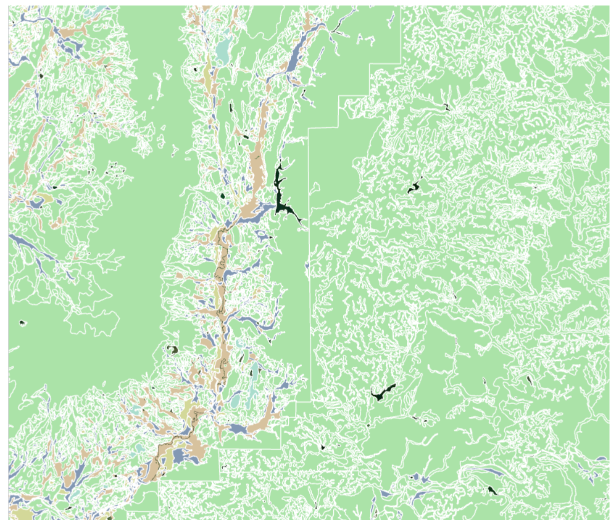

Figure 13. Soil Data Revised

This data from SSURGO (*SSURGO Soil layer*. Arcgis.com) was downloaded for each Section the Pinhoti Layer ran through: Middle Tallapoosa, Lower Coosa, Upper Coosa, Upper Tallapoosa, Middle Coosa. We merged the layers from the downloaded section and clipped them to the Counties AOI layer. However, since the layer was a feature class, we needed to convert it into a raster to use it for the weighted sum. The weighted sum function only works with raster layers. We will convert the layer based on the soil drainage classification. To maintain the accuracy of each cell in the raster, we will choose an output cell size of 1. If a different number is selected, the cells may merge incorrectly based on their values. For example, an area with poor drainage value may be combined with a nearby area with good drainage value, resulting in an inaccurate representation of the actual drainage patterns.

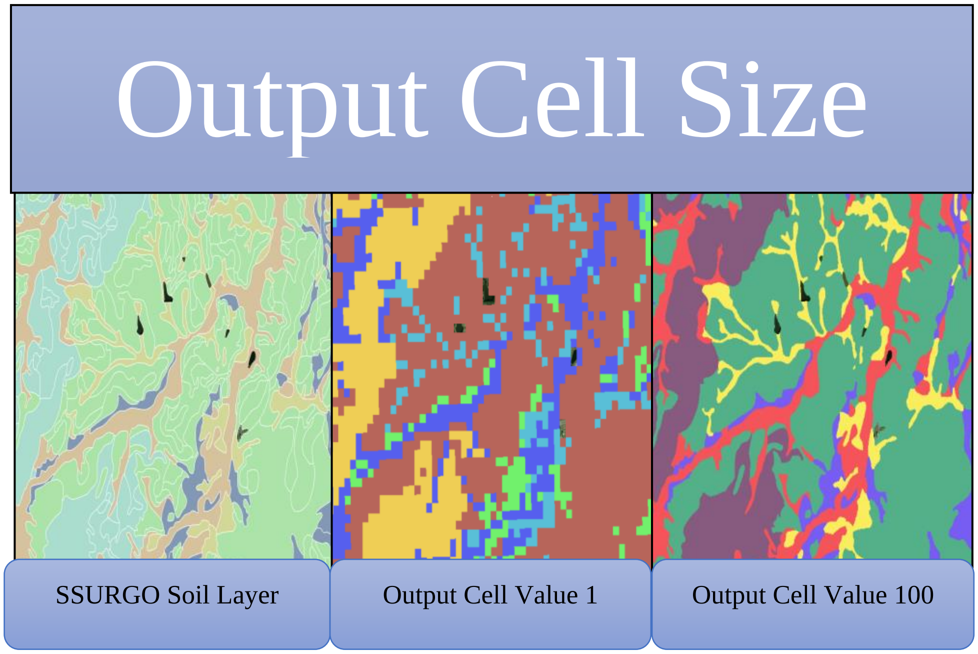

Figure 14. Output cell Values Size

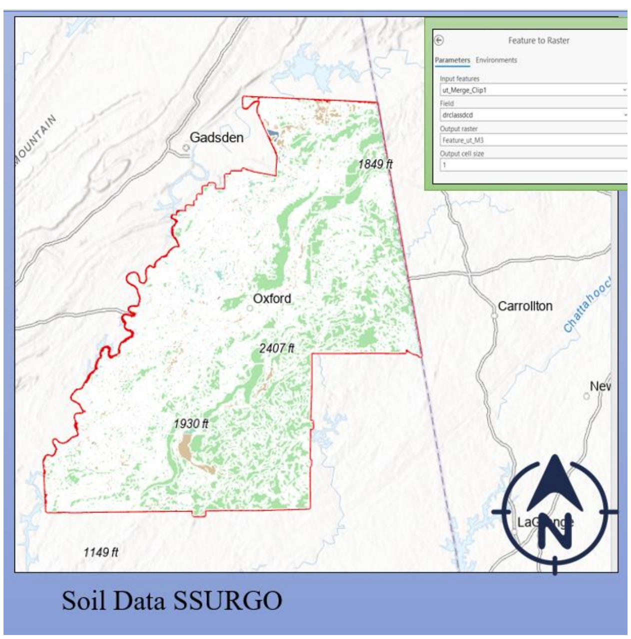

Figure 15. Soil Data SSURGO Feature to Raster based on Soil Drainage Class

the number of classes in the reclassification derives from the Flow Accumulation layer. When it comes to grouping, the focus is on the poor drainage classes because each has distinct qualities that may lead to inadequate water drainage. In **Fig 11** of the other SSURGO data, we combined all the poor drainage classes into a single group. However, this approach posed a challenge when comparing it to the FEMA Flood Data layer, which was provided by Esri (esri_landscape2., 2023). This is because, in the black circle, the blue area (Group D) represents the county line. As previously mentioned, the layers in this SSURGO dataset were collected by workers for each county or using older data that may be inaccurate. This caused the area to be a poor flooding zone even though that is not true at all.

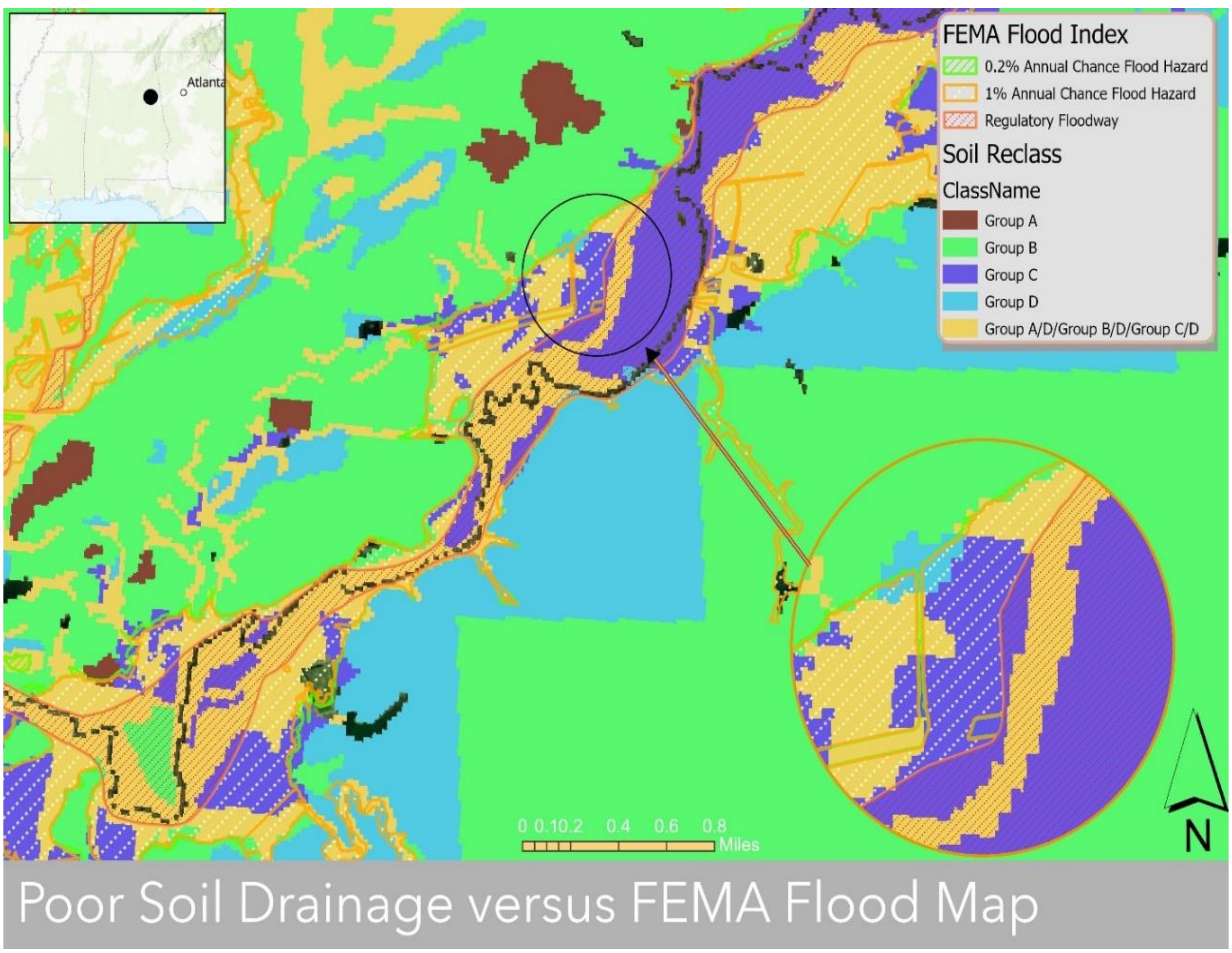

Figure 16. Soil Data SSURGO Feature to Raster based on Soil Drainage Class

In the new SSURGO dataset, when we focus on the poor drainage classification, we can see that the area bordering the county line in **Fig 16** is now seamless, giving it more accurate soil data.

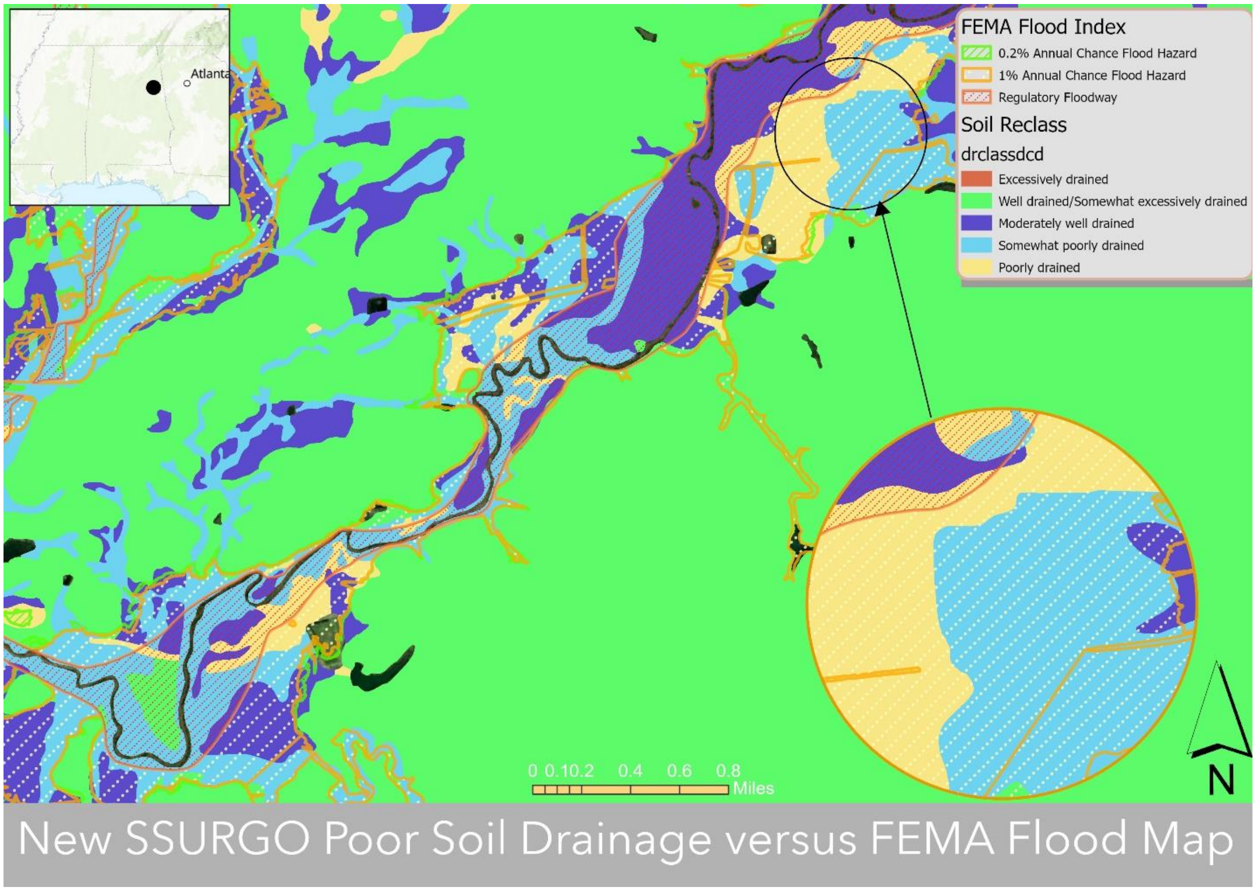

Figure 17. New Soil Data SSURGO Feature to Raster based on Soil Drainage Class

In **Fig 17** we grouped the well-drained classes and left the poor drainage on their own to see if there is a change in the poor versus somewhat poor drainage classes since this is what we are focusing on for the soil data.

Flood Index

After we identified the datasets that have an impact on flooding or hydrology issues, we collected the relevant data and created a Flood Index to help us determine which areas were at risk of flooding or other hydrology issues. To verify these areas, we consulted published articles, reports from other hikers and campers, and ground truthing.

The datasets shown in **Fig 18** were ranked based on their impact on flooding and other hydrology issues. They were then weighted together to determine their contribution to flooding and other hydrology issues in each area. The weights are initially calculated using the Analytical Hierarchy Process (AHP) calculator, which is a mathematical method that assists decision-makers in determining the priority weights for criteria. (Goepel, K. D, 2022).

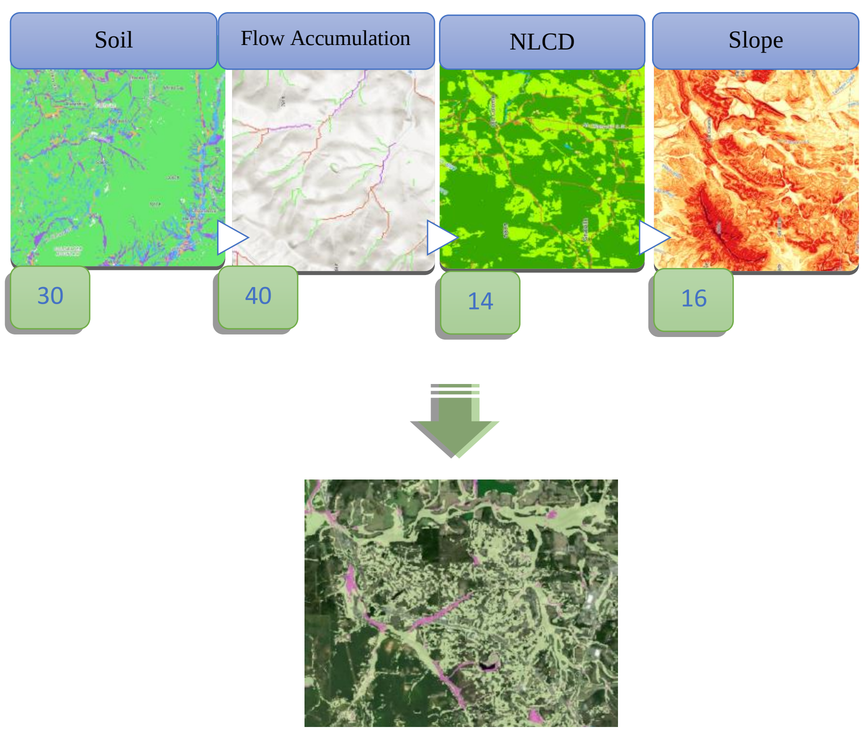

Figure 18. Weighted Sum layers and the result

By utilizing the weighted sum feature of ArcGIS Pro, we can generate a flood index by considering the previous layers that have been created. Any errors or issues with these layers may lead to inaccurate or misleading results in the final weighted sum. Therefore, it's crucial to ensure that all the previous layers are created properly and contain accurate data **Fig 19**.

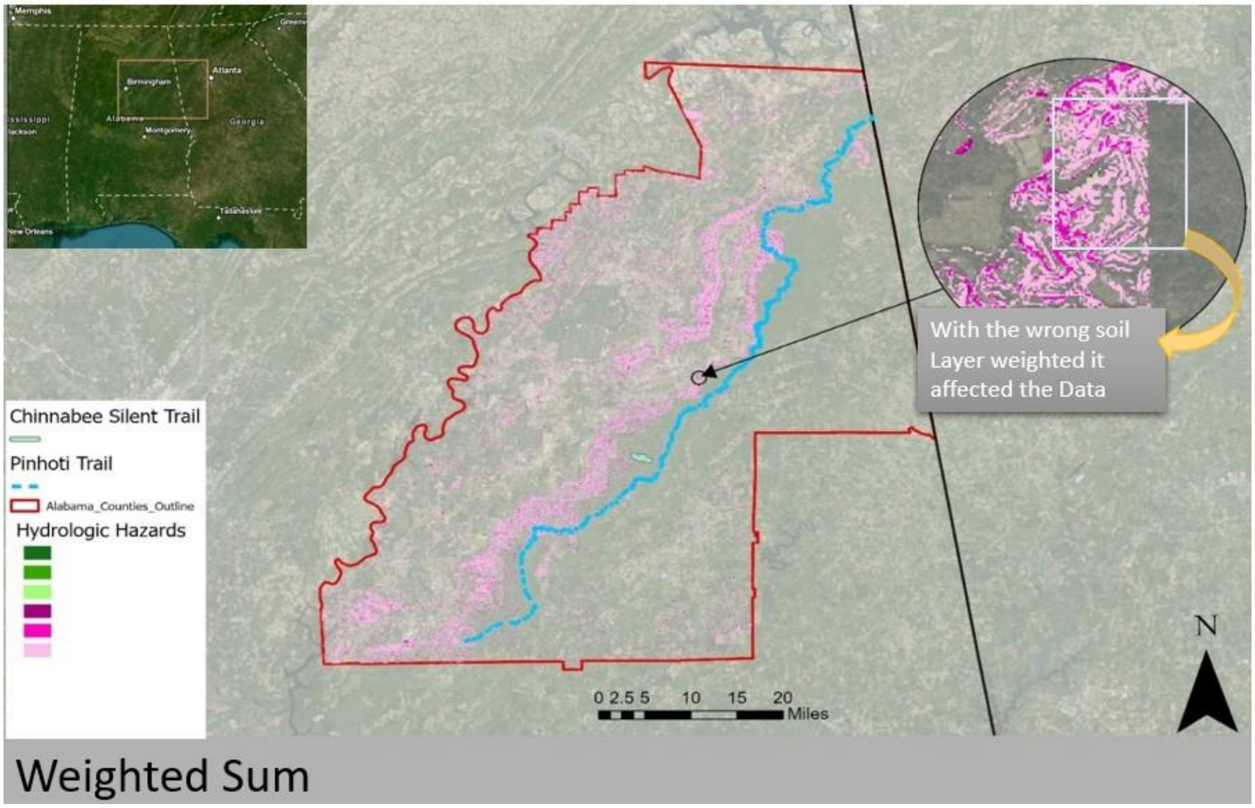

Figure 19. Incorrect Weighted Sum Map due to Soil layer

In **Fig 20** the weighted sum tool was used on these layers to create the final Hydrology Impact Index Map that will be used to determine areas with possible flooding compared to the FEMA flood data map (esri_landscape2., 2023).

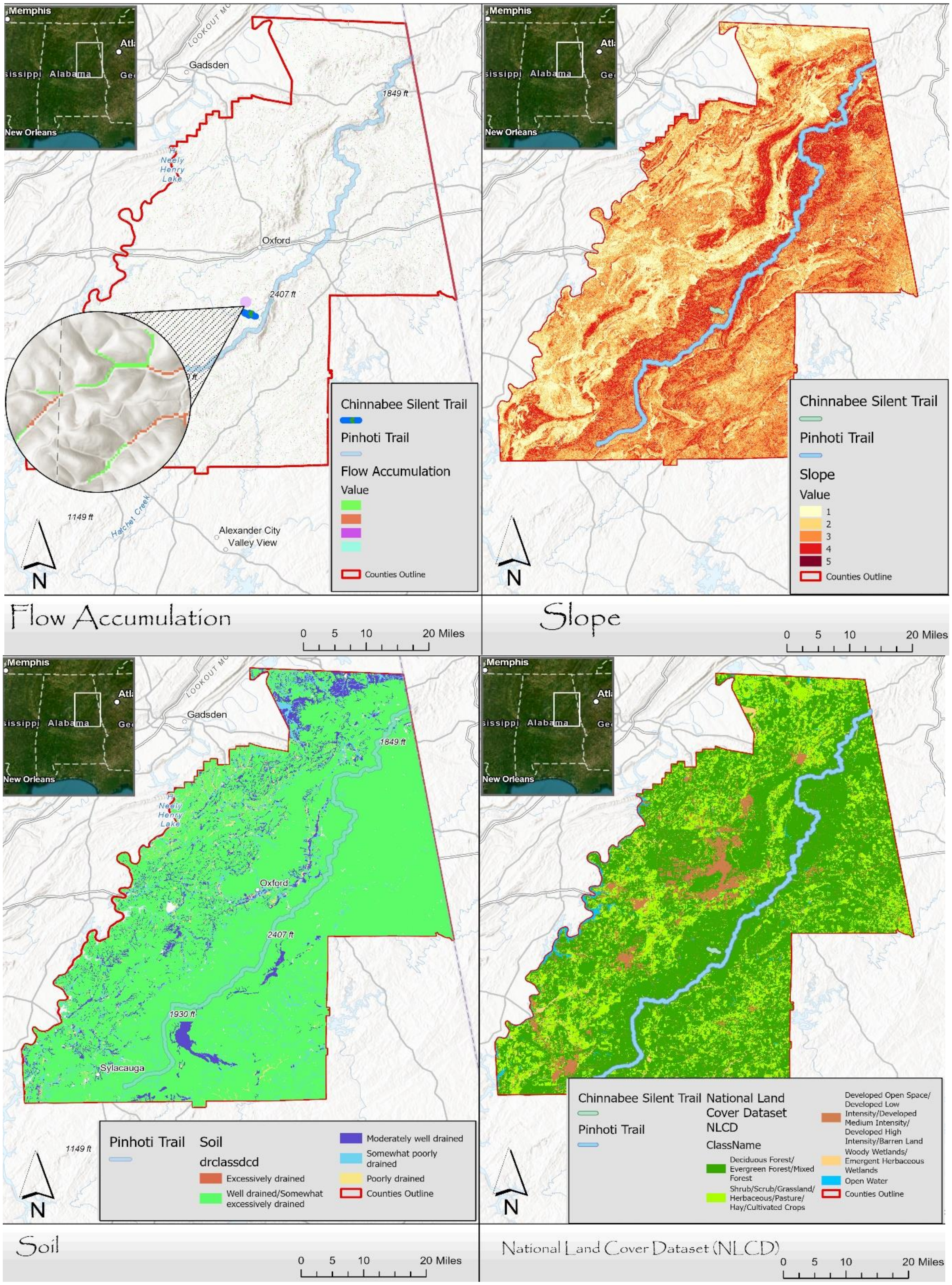

Figure 20. Final Layers used for Weighted Sum

When we ran the layers from **Fig 20** with the values based in **Fig 18**, we came up with a Hydrology Impact Index Data Map, which is a valuable tool utilized to pinpoint regions that are at an elevated risk of experiencing flood-related issues.

We will refer to this map to identify areas with potential flooding hazards and to compare it with the ground truth data. To ensure that our findings are consistent and accurate, we will be comparing both the map and ground truth data with the FEMA Flood Zone Layer Map. By doing so, we can gain a better understanding of the flood-prone areas (esri_landscape2., 2023).

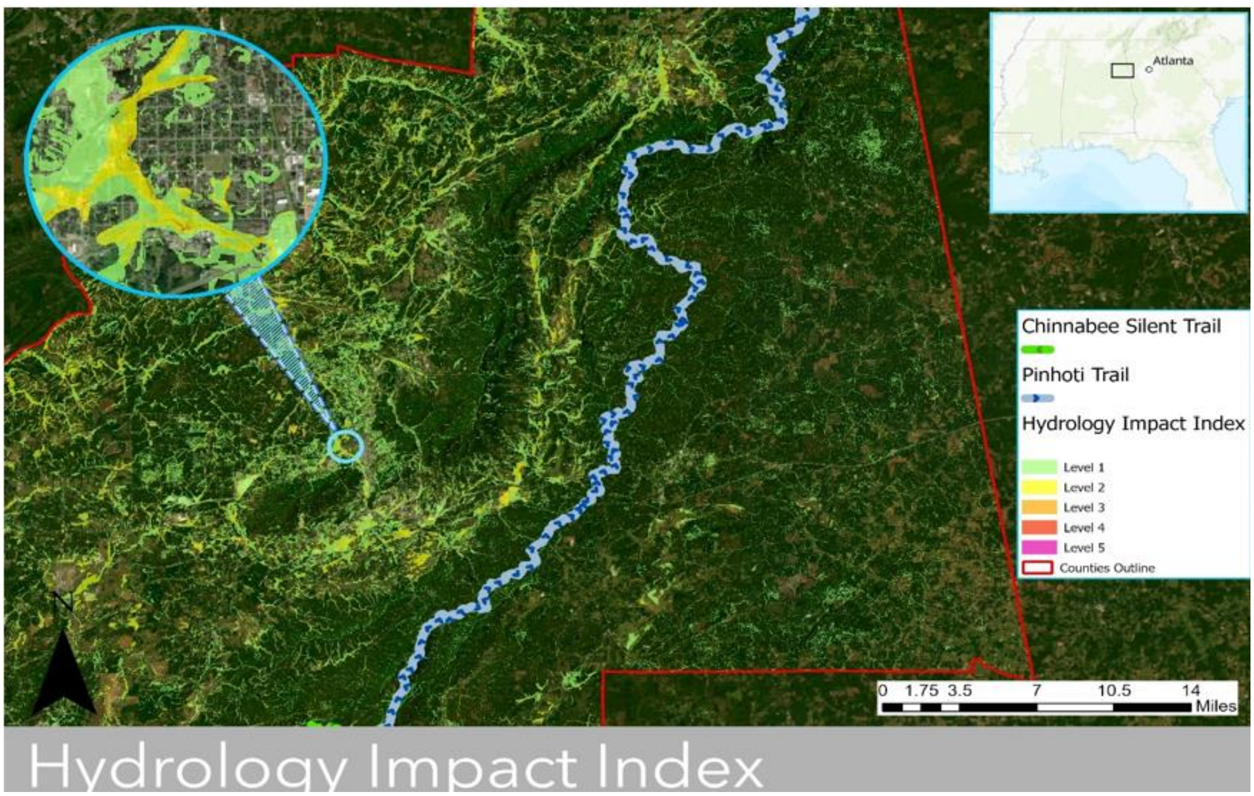

Figure 21. Weighted Sum creates the Hydrology Impact Index

Hydrology Impact Index Results

The Hydrology Impact Index was used to identify areas on the trails prone to flooding or other hydrological issues. We selected four locations as our focus areas. Looking at the campsites in low-lying terrain and near streams it was noted that even if the Flood Hazard Index was low it was still a potential flood hazard zone based on ground observations.

Area 1

Located on the Pinhoti Trail, coordinates Latitude 33.543523 Longitude -85.753007, is surrounded by two crossings of Hillibee Creek, where one must cross to continue the Pinhoti Trail. This information from the map is based on ground truthing and from areas near streams and on identifying with older data of special flood zones known as the 100-year floodplain (Zheng, X et. al 2018). This data alone is based on historical evidence and ground truth.

Fig 22. Area 1 Campsite (Photo Credit: Allie Field, Jacksonville State University Trails Science Institute)

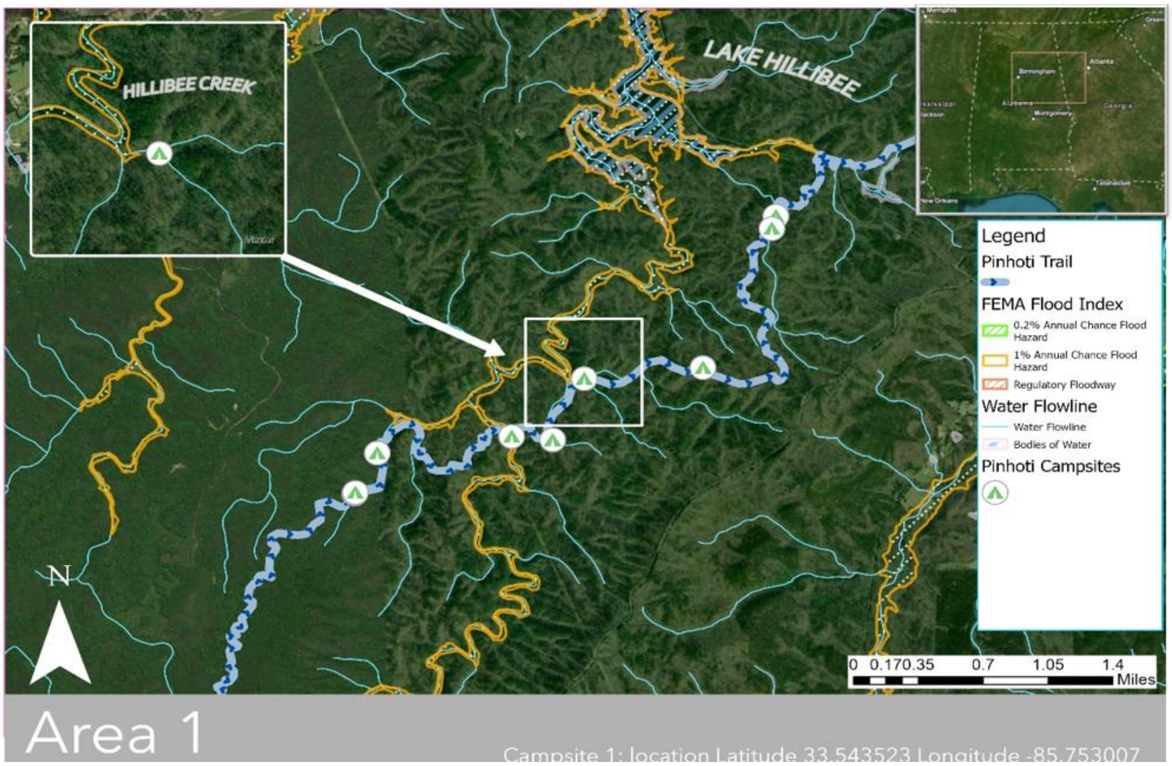

Figure 23. Area 1 Campsite FEMA Map

In **Fig 23** you can see that the campsite does not come close to the flood hazard according to the FEMA Data. We will next look at the Hydrology Impact Index Data Map that was created for this research project and compare it to the FEMA Data. In **Fig 24** we can see that this data is very different from the FEMA data. We can see that in the area where you must cross the stream to continue the Pinhoti Trail, you are crossing an area of a potential Level 1-3 flooding hazard, depending on the total rainfall in the area for a flash flood to occur. In the area, there is documentation of this location to flood and ground truth evidence from March 22, 2022.

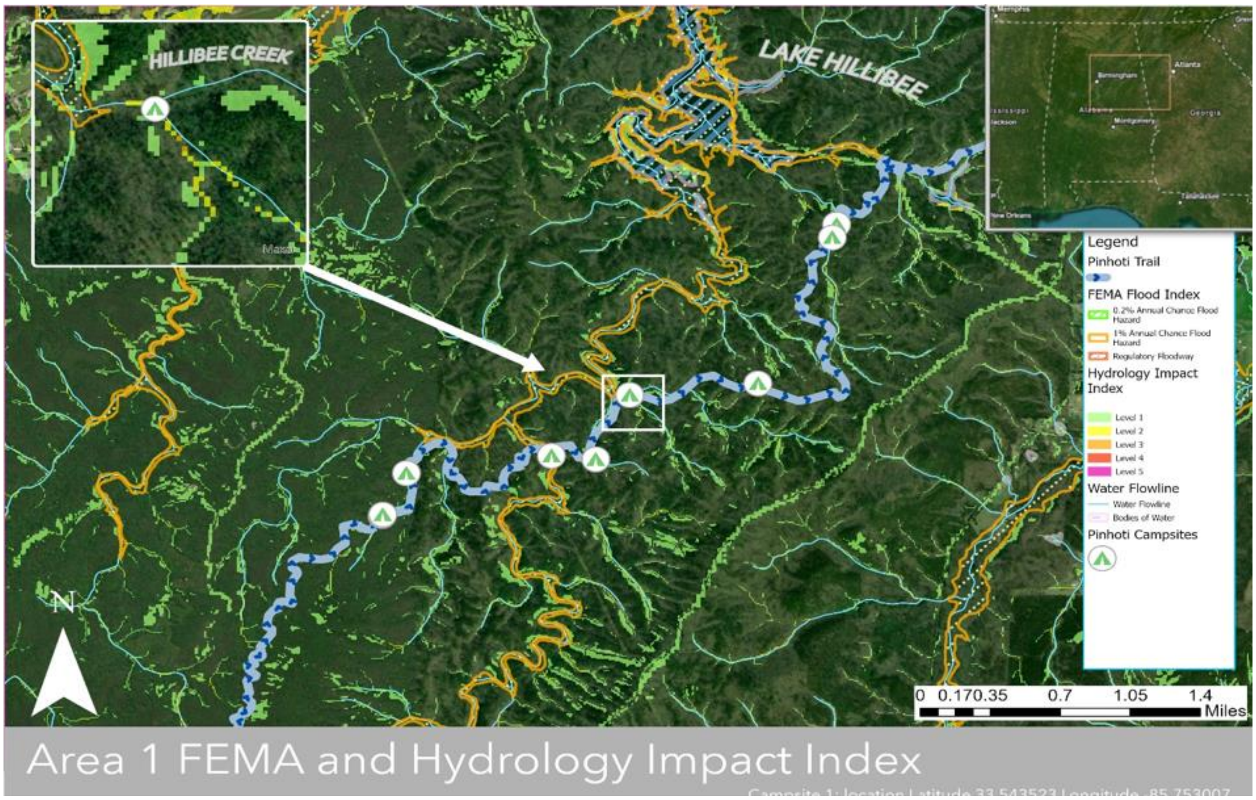

Figure 24. Area 1 Campsite FEMA Map and Hydrology Impact Index

As previously mentioned, in areas affected by hydrology issues, you are likely to see more fallen trees due to their roots becoming waterlogged and weakened, making them susceptible to wind. Additionally, there may be higher levels of erosion on the trails as water carries sediment away from its original location. (Bertol, I. et.al., 2003).

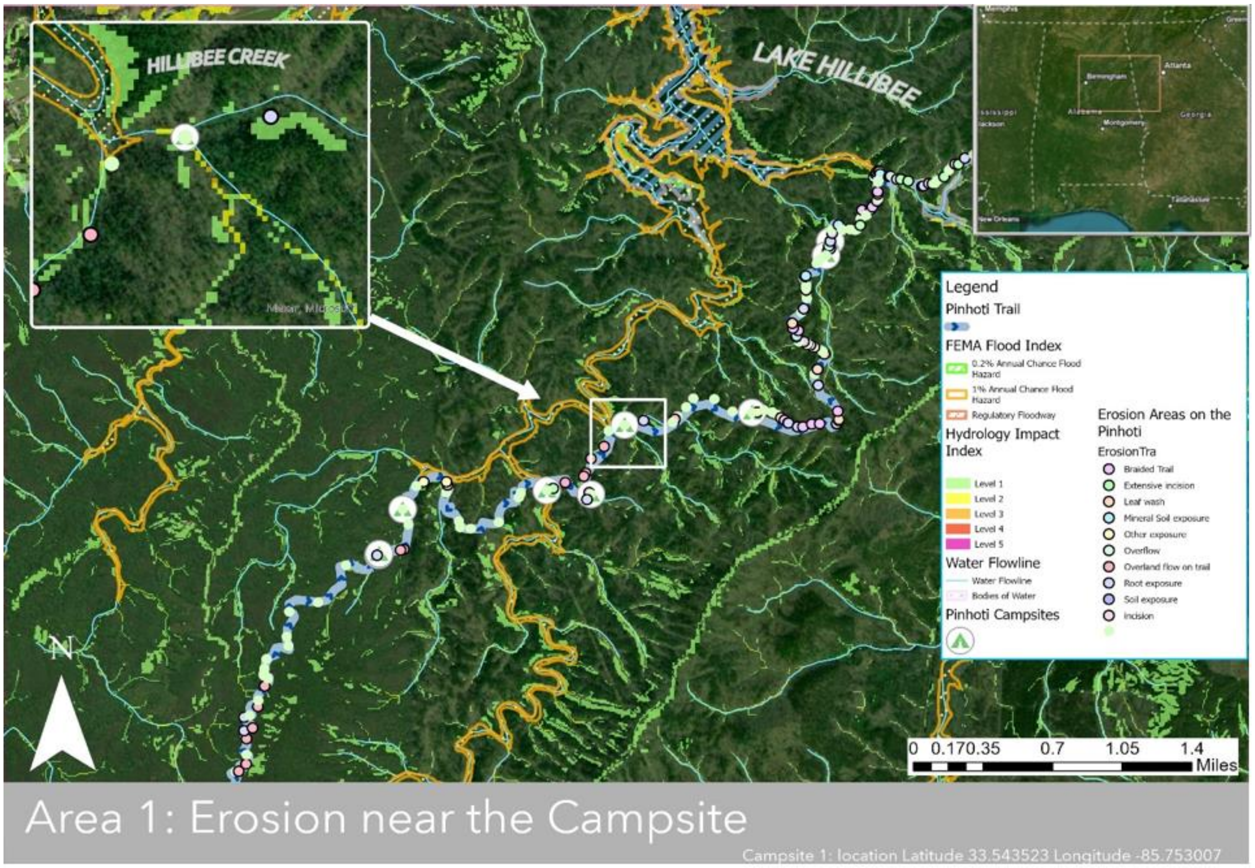

Figure 25. Area 1 Campsite Erosion on the trail

In **Fig 25** areas in the Hydrology Impact Index had some sort of erosion as evidence that hydrology has some type of impact on the erosion in the area. Here in **Fig 26,** you can see that the area is in a Level 1 zone according to the Hydrology Impact Index Data. In the image you can see that the area has minor root exposure over time due to water, after rain, washing the soil down the slope.

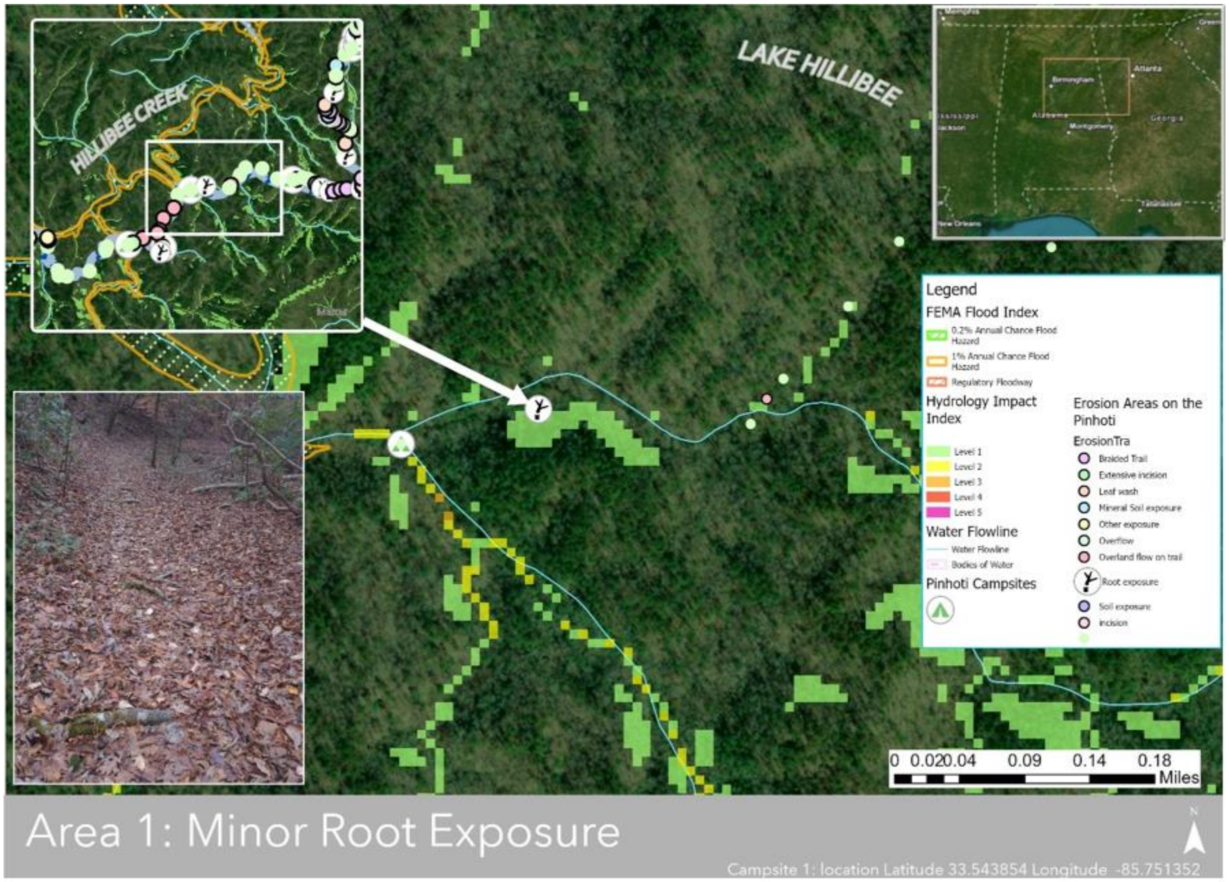

Figure 26. Area 1 Minor root exposure in a Level 1 on the Hydrology Impact Index (Photo Credit: Allie Field, Jacksonville State University Trails Science Institute)

The area has minor root exposure. Surrounding this location is Hillibee Creek, which runs down the slope into Lake Hillibee and from there to the Choccolocco.

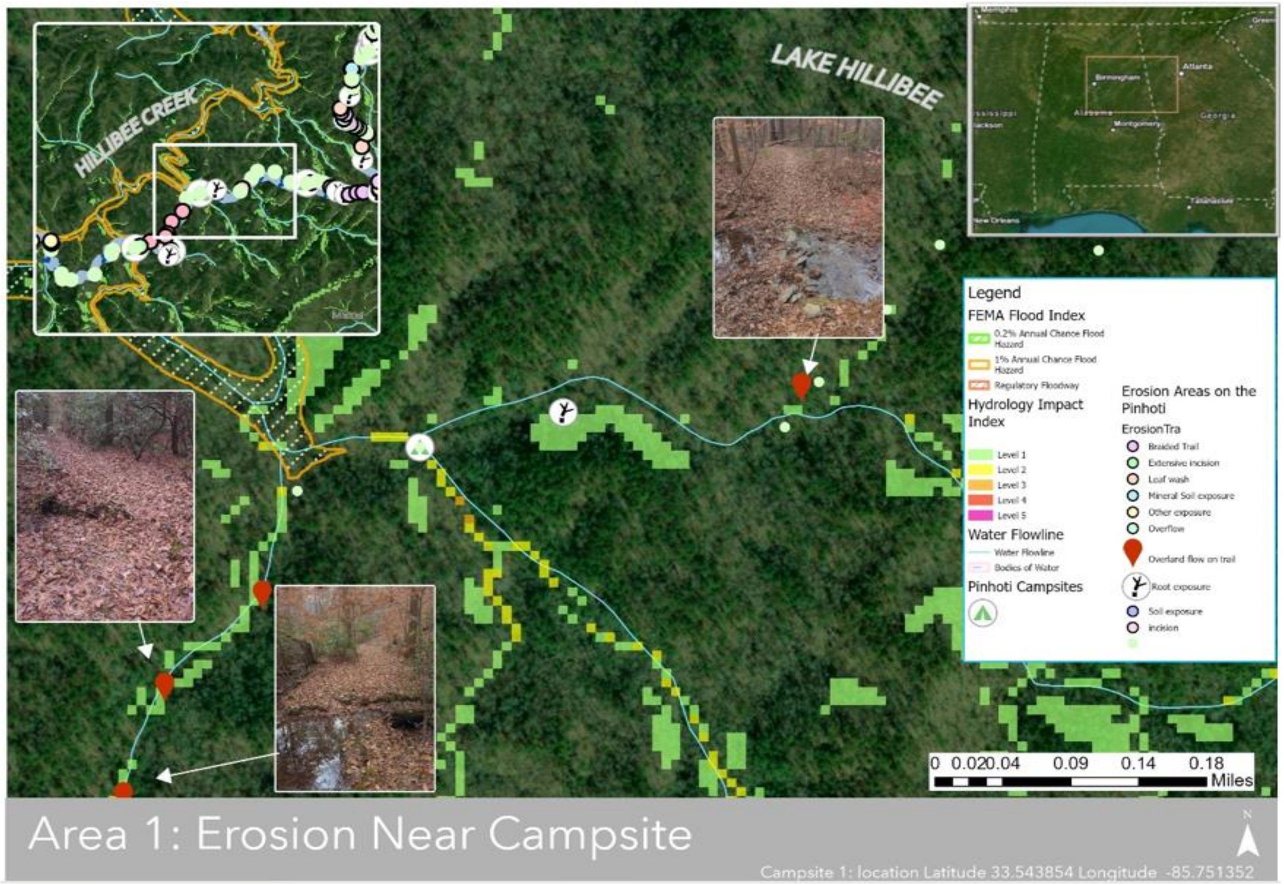

Figure 27. Area 1 Minor erosion areas near the Campsite (Photos Credit: Allie Field, Jacksonville State University Trails Science Institute)

In these maps, you can see the areas of erosion were minor, but they are in a Level 1 zone according to the Hydrology Impact Index, where the crossing of the stream and the campsite is on a Level 2-3. This area on March 22, 2022, was flooded and the water was higher than the regular water level that day. The data I collected was meant to be used as a ground truth to compare with the Hydrological Index that was created. However, due to unfavorable weather conditions, the Trimble device kept losing its connection, causing the recorded GPS location to be incorrect. As a result, the location was manually noted down, and the data was collected again on a day with better weather conditions to ensure its accuracy.

Area 2

Located on the Pinhoti Trail, coordinates Latitude 33.748761 and Longitude -85.579964, is a campsite that is downhill from a stream that flows into Shoal There are several fallen trees surrounding the area, which could indicate a potential risk of water runoff into the creek. This water could saturate the soil around the trees and cause the root systems to weaken over time, resulting in waterlogged or root rot trees.

Figure 28. Area 2 Campsite by Shoal Creek (Photo Credit: John Graffeo)

Additionally, wind may cause them to fall during this process. It is important to note that the trees' support system can be weakened by the soil being washed away, which may lead to windthrow. It is also noticed in **Fig 29** that there are areas surrounding the Campsite of incisions and root exposure where the stream runs through to go to Shoal Creek.

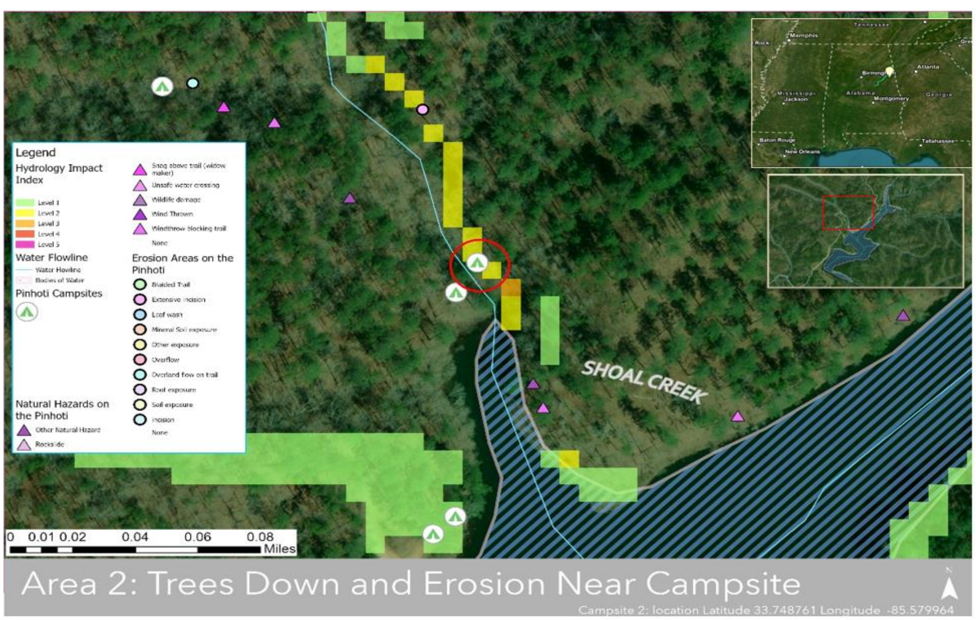

Figure 29 Area 2 Camp Site near Shoal Creek

Area 2, **Fig 30**, is also located, according to the Hydrology Impact Index, in Levels 2 and 3. This is a stronger indication of potential hydrology issues or flooding hazards in that location. According to the FEMA Flood Zone map the campsite is also located in a “1% Annual Chance Flood Hazard”. Meaning that there is a 1 percent chance within that year of a flood to occur in that location (*The 100-year flood completed*. The 100-Year). This is also called the 100-year flood plain (*Flood zones*. FEMA.gov). With Flooding, there will be a higher indication of erosion such as in **Fig 31**.

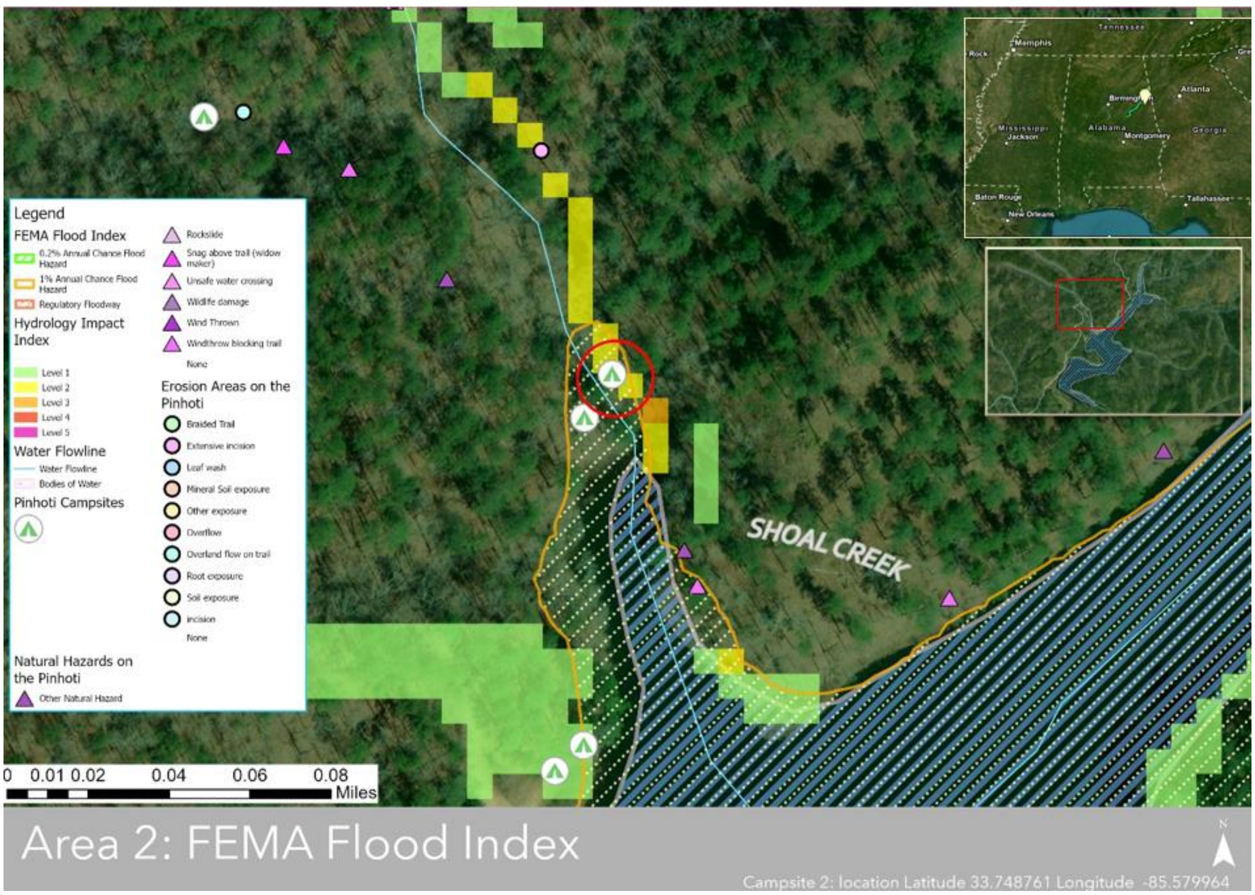

Figure 30. Area 2 Camp Site FEMA Flood Index and Hydrology Impact Index

In **Fig 30**, we can see that this location has flooded before according to FEMA since this means that the data was collected as a historic value (*Flash flood emergency for parts of Jefferson, shelby co.).*

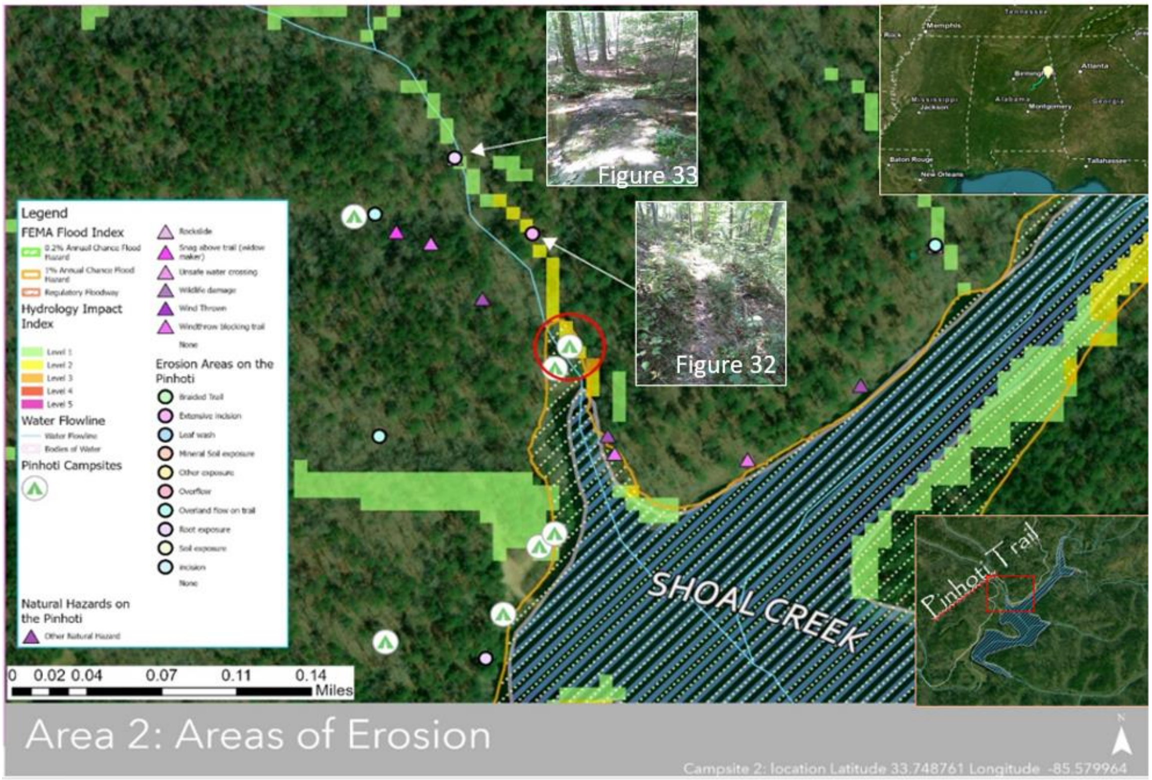

Figure 31. Area 2 Campsite Areas of Erosion and Creek Crossing (Photos Credit: John Graffeo, Jacksonville State University Trails Science Institute)

In **Fig 32** the image of the trail is eroding in the area above is the stream that goes down the trail and to Shoal Creek **Fig 33**.

Figure 32. Trail Eroding (Photo Credit: John Graffeo, Jacksonville State University Trails Science Institute)

Figure 33. Water Crossing on Trail (Photo Credit: John Graffeo, Jacksonville State University Trails Science Institute)

Figure 34. Windthrown Tree on Trial (Photo Credit: (Photo Credit: John Graffeo, Jacksonville State University Trails Science Institute)

Figure 35. Windthrown tree on Trail (Photo Credit: (Photo Credit: John Graffeo, Jacksonville State University Trails Science Institute)

Also, near the Campsite some trees were windthrown **Fig 34, Fig 35, Fig 36**. In both **Fig 34** and **Fig 35,** they are both next to the creek where water can rise and take soil away. In **Fig 34,** it is also below where the stream meets Shoal Creek, so that can also cause the area to erode quicker since it is also noted that portions of the trail were eroding **Fig 32** by the water crossing in **Fig 33.**

Figure 36. Windthrown trees near the campsite and Shoal Creek (Photo Credit: John Graffeo, Jacksonville State University Trails Science Institute)

In **Fig 36** you can see that the FEMA Map does cover some of the areas that the Hydrology Impact Index Data does cover, but not all of it. In the area that is not touched by the FEMA map, we can see issues with water going downhill.

Area 3

Located on the Pinhoti Trail, coordinates Latitude 33.878118 Longitude -85.551654, is located by Terrapin Creek **Fig 37**. This area is in the FEMA Flood map and the Hydrology Impact Index Data layer. This area has a history of flash flooding. However, prior to collecting data on hydrology damage or reports of flooding, there were no concerns about the flooding. This was because there wasn't much residential development in the area, and dams had been built to help mitigate the flooding. The area was primarily used for agricultural and livestock purposes. However, it was reported in previous years that the creek was known as "untamed" due to the flooding, which caused water runoff and erosion, changing the landscape that surrounds the creek. It was also reported that the flooding even covered the roads to where wagons could not pass, which was the reason for the dams being built (Rome News Tribute. (2009*)*. In 2017 it was reported that the creek flooded due to a higher amount of rainfall, which is the same reason that Hillabee and Choccolocco Creek also flooded in 2022 (Cooper, A., 2017).

Figure 37. Area 3 by Terrapin Creek (Photo Credit: Allie Field, Jacksonville State University Trails Science Institute)

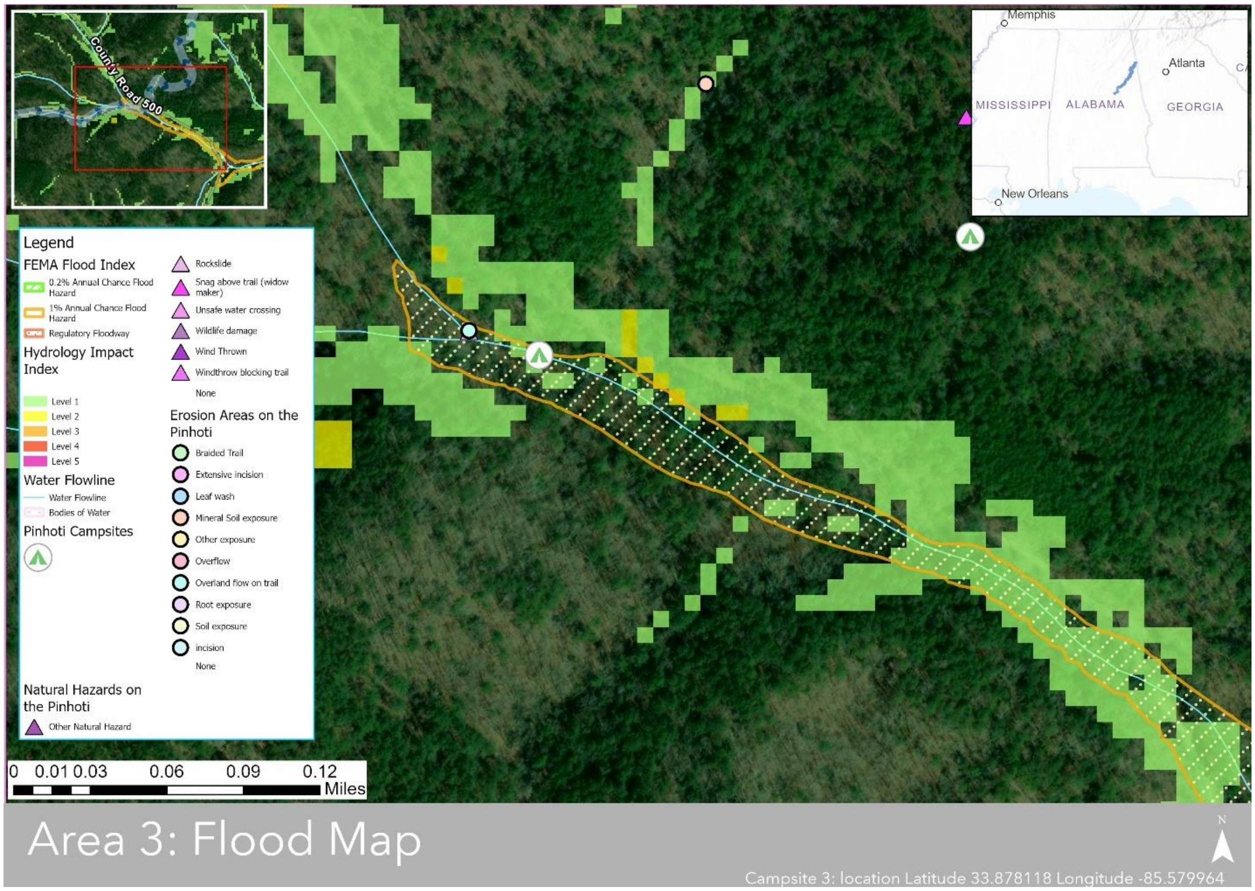

Figure 38. Area 3 FEMA and Hydrology Impact Index Flood Data

In **Fig 38** we can see that the campsite is right next to the creek, which could cause the outdoor enthusiast to be at risk of flooding, especially during the rainfall peak seasons since flash flooding comes without warning (Knocke, E. T., & Kolivras, K. N., 2007). In **Fig 38** we can also see a form of erosion, by which the surface of the soil and other plant materials are worn away or removed by the force of water, typically caused by heavy rain or strong water currents, which in our case is heavy rainfall. In this area, we also have

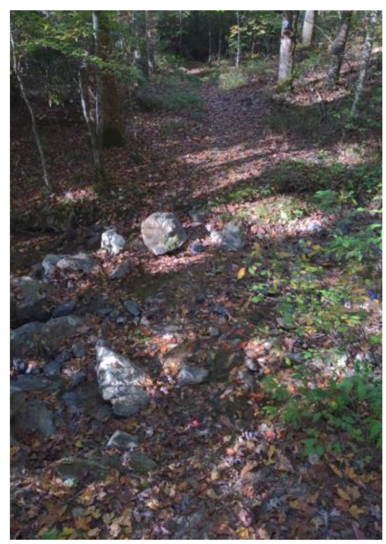

Figure 39. Overflow erosion near area 3 (Photo Credit: Allie Field, Jacksonville State University Trails Science Institute)

an overflow on the trail from the creek. This is due to water that overflows from a river or stream and carries away excess soil and sediments. This occurs with heavy rainfall. In **Fig 39** we can see the small portion of damage erosion causes, but over time it puts the landscape at risk for loss of soil fertility since the top layer of soil is washed away, and essential nutrients and minerals are also carried away, overflow erosion can also lead to landslides, especially in higher terrain areas. As the soil becomes loose and unstable due to erosion, it is more susceptible to mass movement. This can be dangerous for communities living in these areas and can result in loss of property and even lives (Takayama, S., & Imaizumi, F.. 2022).

In **Fig 40** we can see also areas that have root exposure where the trees are exposed and potentially damaged due to erosion of the surrounding soil which happens during heavy rainfall and wash away the topsoil, leaving the roots of plants and trees vulnerable to damage and disease. This leads the trees to rot and fall eventually over time, which is another hazard for those on the trails (Reeksting, B. J., Taylor, N. J., & van den Berg, N., 2014).

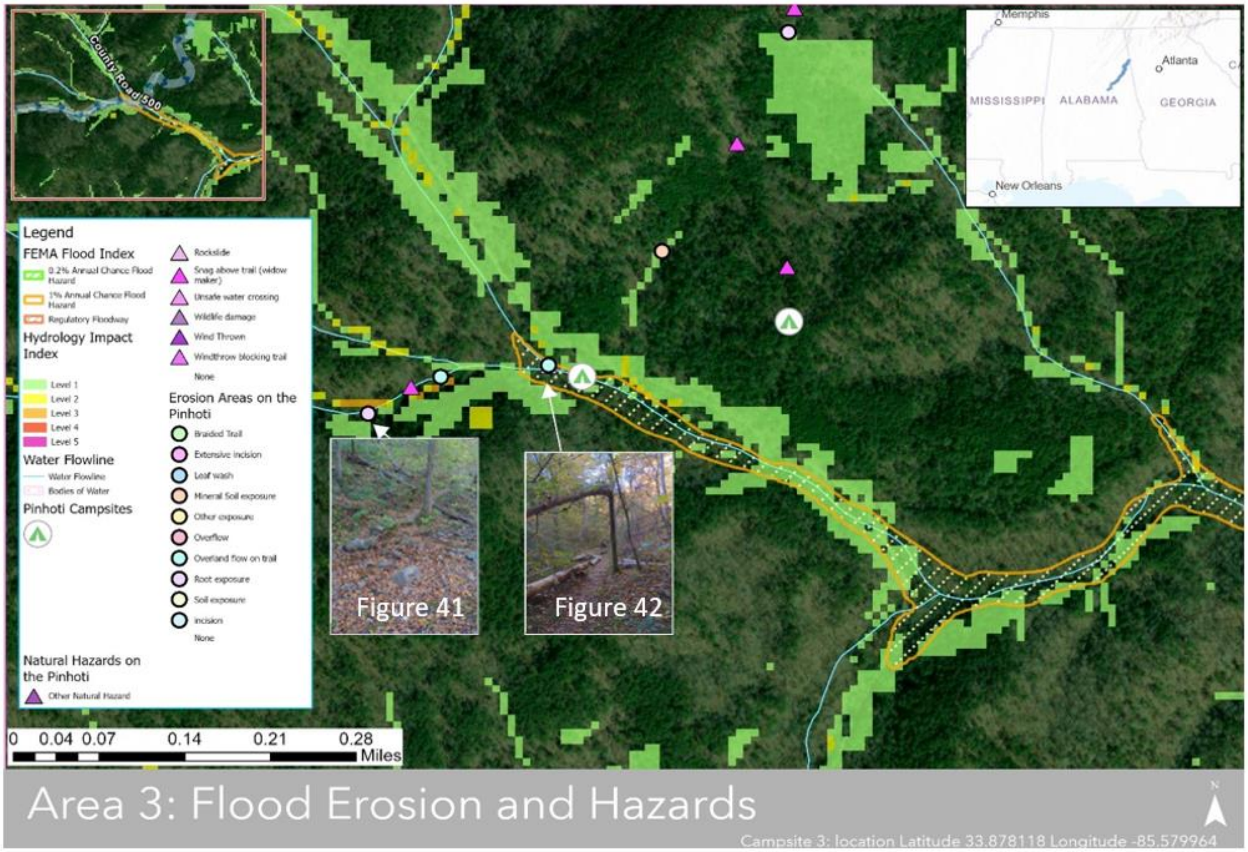

Figure 40. Area 3 Hazards of Erosion Caused by Hydrology (Photos Credit: John Graffeo, Jacksonville State University Trails Science Institute)

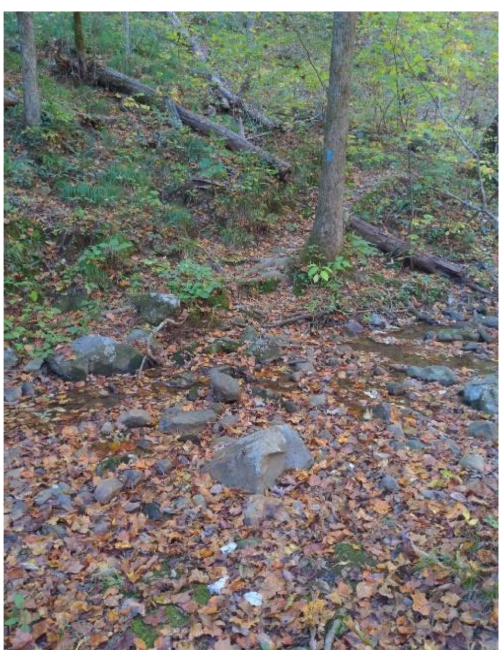

Fig 41. Area 3 Minor Root Exposure (Photo Credit: Jacksonville State University Trails Science Institute)

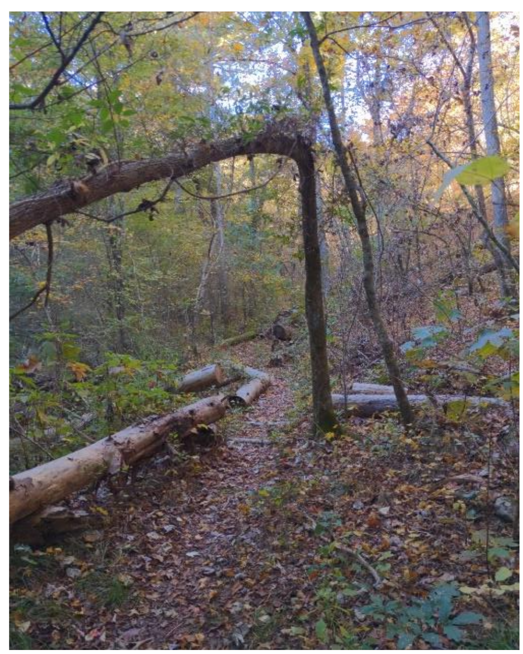

Fig 42. Area 3 Fallen Trees over Time(Photo Credit: John Graffeo, Jacksonville State University Trails Science Institute)

Area 4

The Chinnabee Silent Trail is also located in the Talladega National Forest. It starts at Cheaha Creek and goes for six miles till the last portion of the trail ends at Caney Head atop Talladega Mountain at Lake Chinnabee (*National forests in Alabama - Chinnabee Silent Hiking Trail).* In **Fig 43** we can see the portion where Lake Chinnabee is in a FEMA flood zone and Level 1- 3 on the Hydrology Impact Index Data. This area is located in a flood-prone zone. The campground had to be closed down in 2013 due to flooding, as there was a concern for the safety of the visitors. The flash flooding occurred at night, which caused anxiety for the outdoor enthusiasts. (Nielsen, G., 2013).

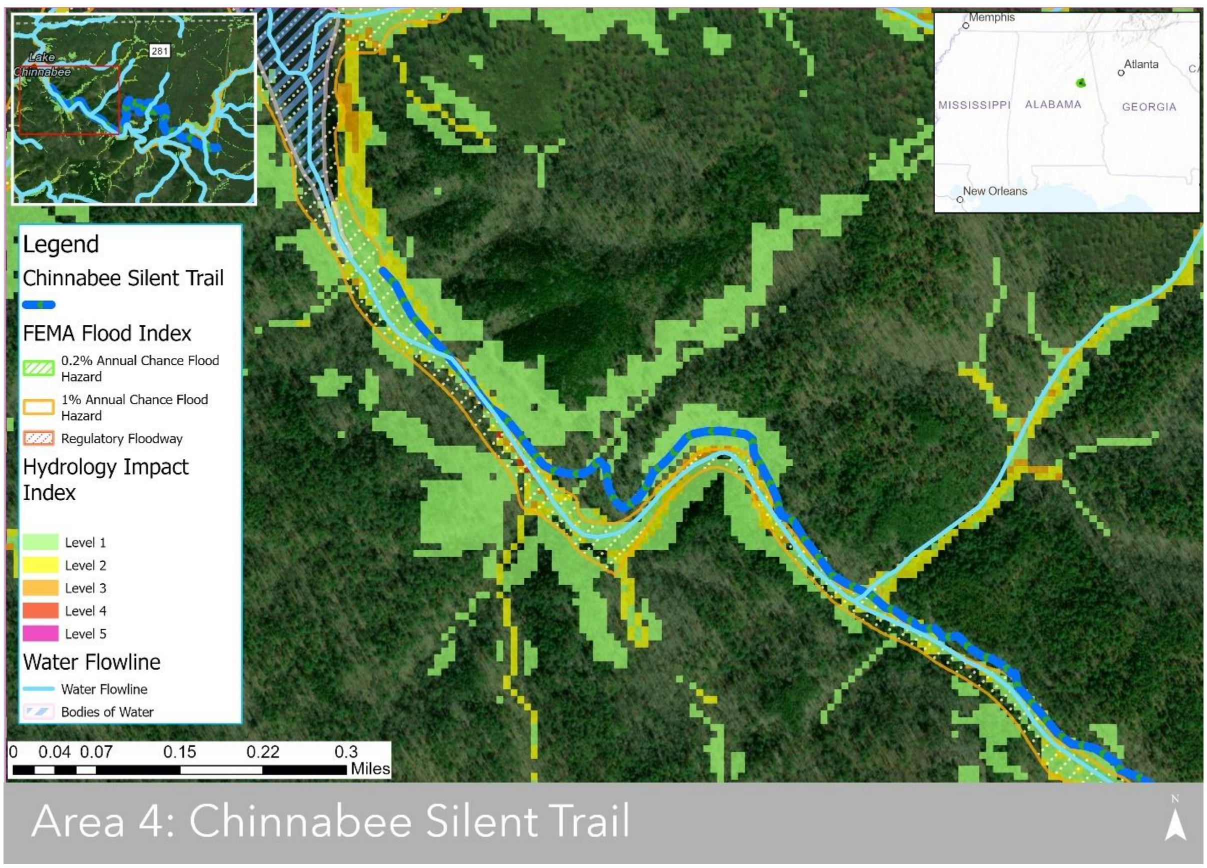

Figure 43. Area 4 Chinnabee Silent Trail and Hydrology Issues

On the Lake Chinnabee Recreation flood damage was done due to the flash flooding that closed this location's campgrounds (Nielsen, G. 2013, May 22). I found the images on Whiteblaze, by OwenM, who went hiking on New Year's Day of 2013 at Chinnabee Silent Trail. He claims, "Would have been a rude awakening for anyone camped along the creek… These are from New Year's Day. I day hiked the Chinnabee from Turnipseed, plus the Lakeshore Trail. From the debris, and state of the trees, the creek looked like it would have had to have gone from the familiar stream to being 50-60ft wide and 10ft deep." (M, Owen., 2014, March 5), where users were talking about the location being reopened for camping, but concerns are still out there about the risk of flooding.

In **Fig 44** we can see that the impact just does not affect the trail, but also Skyway Drive. Roads are not designed to properly channel rainwater, so water can accumulate and cause flooding. In **Fig 44**, the 3D image shows an area on Skyway Drive, AL-281, where water flows out onto a flatter surface, creating an ideal place for flooding due to the tributary stream. This

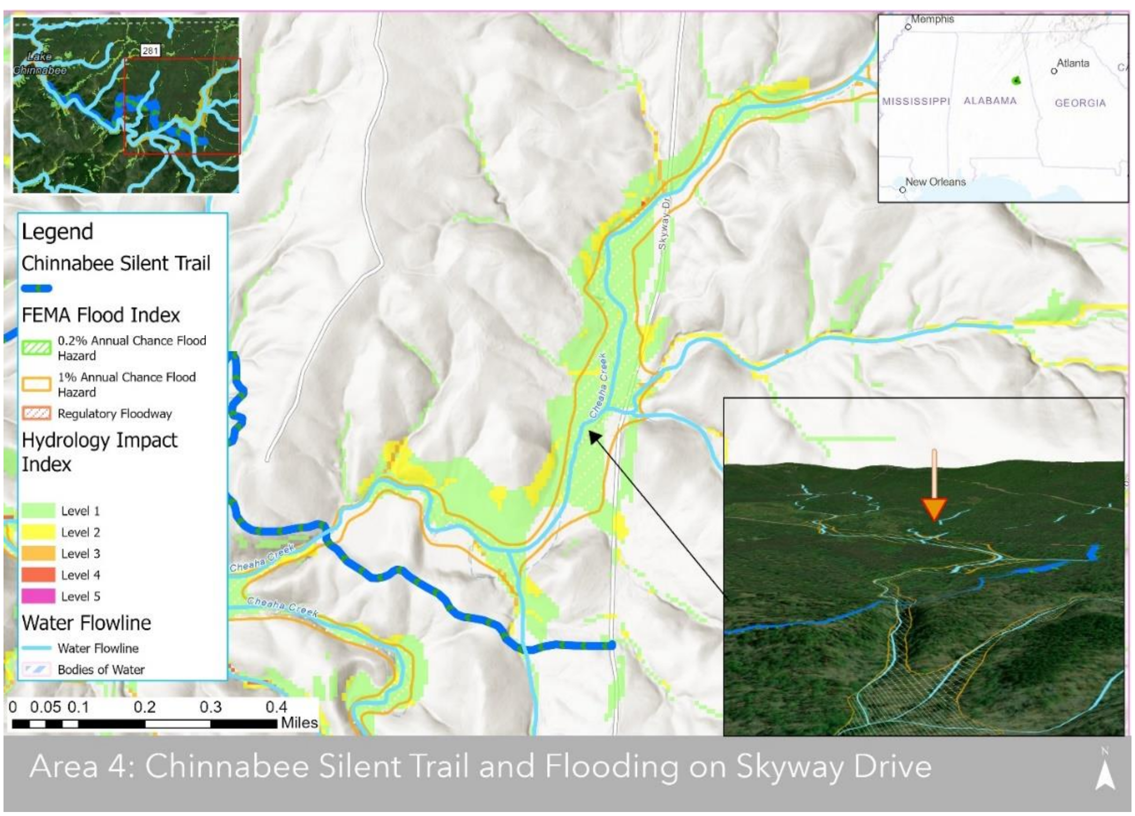

Figure 44. Chinnabee Silent Trail and Flooding on Skyway Drive

area has gravel roads that will deteriorate quickly. It is a part of the Tallapoosa River Basin Watershed. A tributary stream is a small stream that flows into a larger river or body of water.

In **Fig 45,** we can see the location on the Chinnabee by Cheaha Creek and Chinnabee Lake is an area known for flooding. In **Fig 45,** we can see the arrows pointing down the slope of the terrain called an incision, which is a groove made by water flow over the years. This is also the same location as the campsite closing on the trail from flooding.

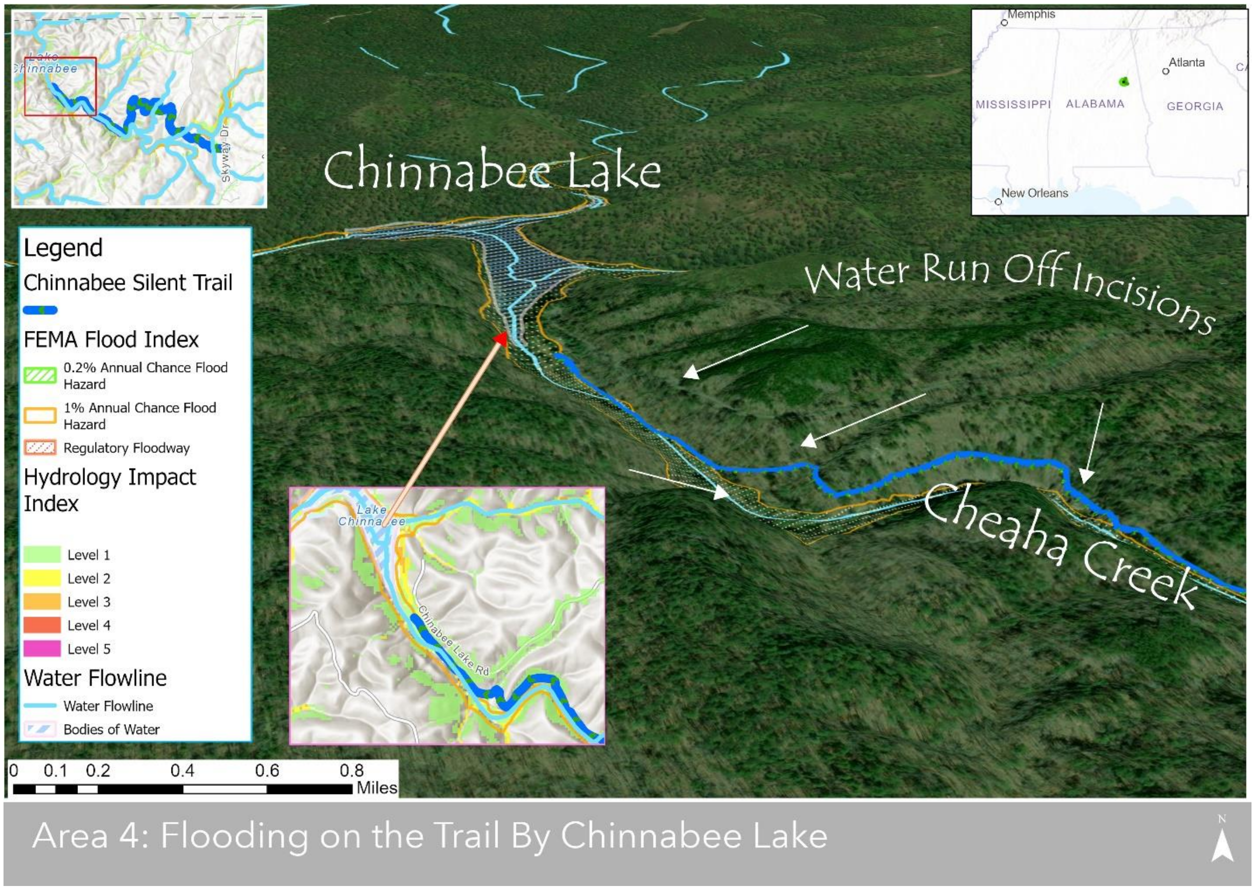

Figure 45. Chinnabee Silent Trail and Flooding that overflowed the Trail.

Addition to Hydrology Impact Index Data

Due to a lack of data about floods in the Talladega National Forest, around the campsites and trails, I expanded my analysis beyond the Talladega National Forest to include other locations as additional confirmation of the index at more intense index values.

Test Area 1

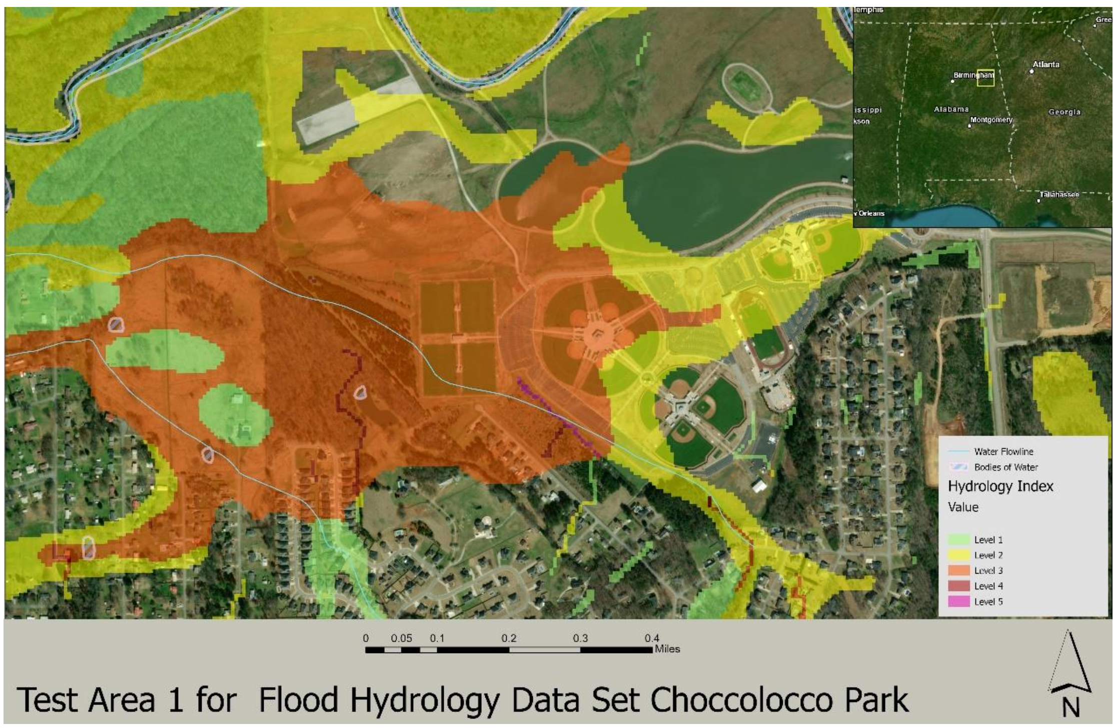

Figure 46. Test Area 1 for Flood Hydrology Data Set Choccolocco Park. With Figure 51

This location is known for its flooding, especially on March 22, 2022, which was the same day I experienced the flooding on the trail. WBRC wrote an article on the Choccolocco Park flooding due to roads nearby being reported impassable (WBRC., 2022, March 23). The

Choccolocco Park is close to Choccolocco Creek, which is the same creek near the Pinhoti and Lake Hillibee and connects to Lake Hillibee.

Test Area 2

Coldwater Creek is known for flooding, including over Highway 202 going towards the old Dollar General over the bridge (Gross, S., The Anniston Star., 2016).

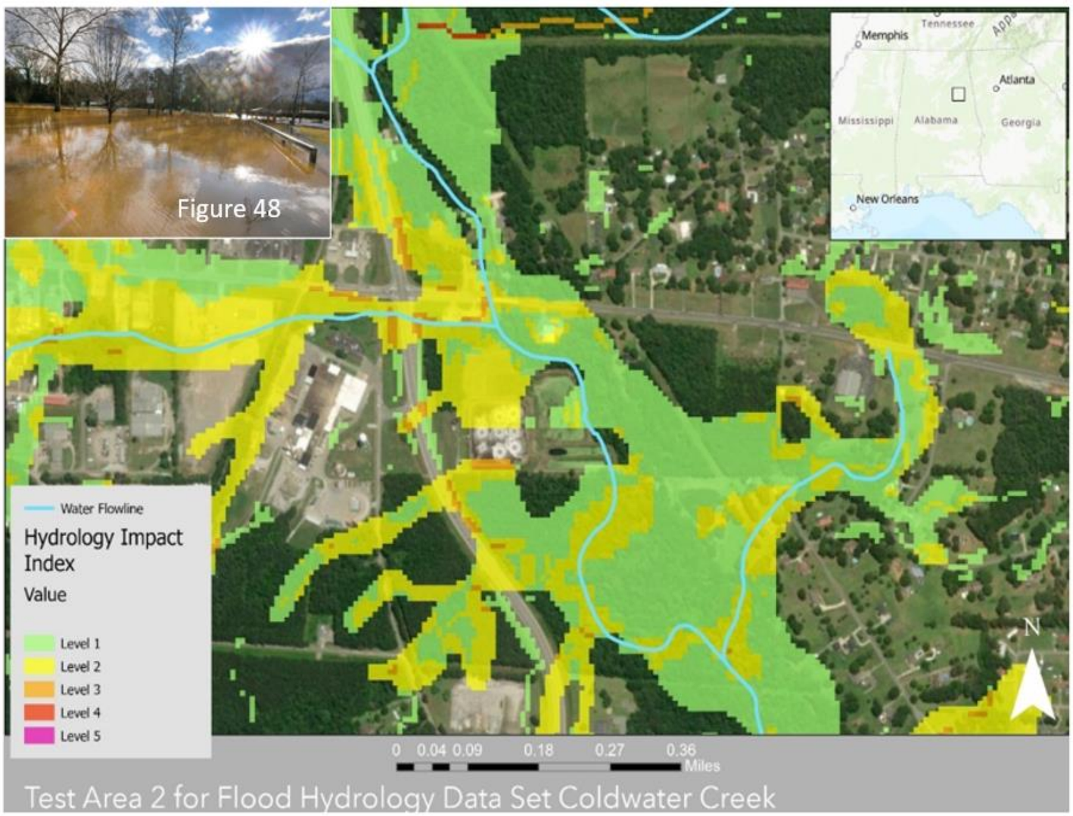

Figure 47. Test Area 2 for Flood Hydrology Data Set Coldwater Creek With Figure 48 (Photo Credit: Stephen Gross, The Anniston Star)

Figure 48. Coldwater Creek Flooding (Photo Credit: Stephen Gross, The Anniston Star)

Test Area 3

This is the location of Lenlock Lane in Anniston, Alabama (The Anniston Star. 2019, July 19), which was chosen because it was not on the FEMA Flood Data Map. This is the location where I grew up and experienced four floodings over eighteen years. This location was the data set to confirm the accuracy of the Hydrology Impact Index data.

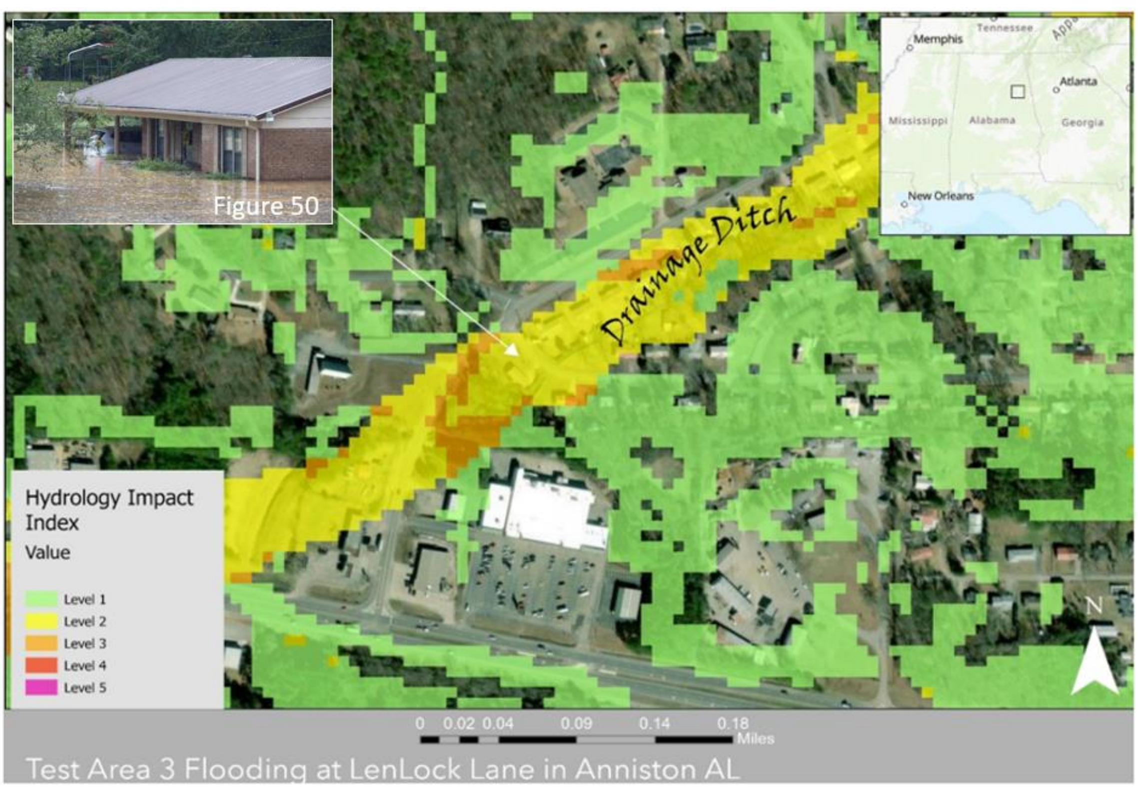

Figure 49. Test Area 3 Lenlock Lane Anniston Alabama Flooding. With Figure 50 (Photo Credit: Trent Penny, The Anniston Star)

Figure 50. Lenlock Lane Flooding Elderly Resident Trapped Inside
(Photo Credit: Trent Penny, The Anniston Star)

DISCUSSION

Floods are one of the most common and destructive natural disasters, causing significant damage to property and loss of lives. However, floods can also pose a high risk to people engaging in outdoor activities such as hiking, camping, or visiting areas prone to flooding. One such area is Cheaha, located in the Talladega National Forest in Alabama.

Area 1 is in level 1 according to Hydrology Impact Index data **Fig 27** is next to Hillibee Creek, which had higher than normal water levels in two areas on March 22, 2022. This led to flooding on Highway 24, dividing the trail on Hillibee Creek. Portions of Area 1 are Level 1 to Level 3. The area is also next to a 1% Annual Chance Flood Hazard, also known as the 100-year flood plain. The Hydrology Impact Index Data measurement is accurate in comparison to the FEMA Flood Risk Map, as witnessed during the flooding event on March 22, 2022.

Area 2 is near Shoal Creek. It's in Level 2 and Level 3 of Hydrology Impact Index Data. FEMA Flood Map shows it's in "1% Annual Chance Flood Hazard". The campsite is by a stream that flows into Shoal Creek. Signs of erosion and fallen trees are visible around the stream, which can contribute to landslides and the down trees in the location **Fig 36**.

Area 3, **Fig 38**, located by Terrapin Creek, is in a flood hazard zone and experienced flooding in 2017 due to higher rainfall. The area is popular for kayaking but the Creek has a history of flooding causing erosion issues. **Fig 41** shows overflow on the land and braided trails due to erosion.

Area 4 on the Chinnabee Silent Trail **Fig 43** is prone to flooding and ranks Level 1-3 on the Hydrology Impact Index Data, leading to the closure of the campground in 2013. Flooding can be dangerous, especially for campers at night.

All these areas have one major thing in common and that is their location by streams and creeks, in an area of water runoff that can rise due to higher-than-average rainfall, and they are in a Level 1- 3 on the Hydrology Impact Index Data in or near a FEMA flood zone. Also, the Hydrology Index Data is effective in analyzing both residential and deciduous forest areas. To validate the accuracy of the site locations, I compared the data with other sources such as hiker or camper discussions online, newspaper articles, online sites on the locations, or ground truthing from when I collected data. If a location is in both a Hydrology Index Data zone and a FEMA Flood Map zone, it has a higher risk of severe flooding than other locations. For example, the Chinnabee Silent Trail had reports of severe flooding that endangered the lives of hikers and campers who would have camped out overnight.

Areas, even at a level 1 risk, had erosion issues and other concerns such as down trees due to the possibility of being waterlogged. In other sites with a level 3 or 4 risk, there were more down trees, erosion issues, and even rockslides at some spots. These issues alone create a hazard for outdoor enthusiasts. This research could continue by comparing the data before and after a flooding event or heavy rainfall in the area. However, road closures and the risk of being stuck or getting in a flash flood situation present limitations, particularly for areas far on the trail.

CONCLUSION

In conclusion to this research, the best way for outdoor enthusiasts to avoid the hazards of a flash flood is to be aware of areas that are at risk for flooding. This can be achieved by researching the area beforehand and checking for any potential flood warnings or advisories. It is also important to pay attention to weather forecasts since flooding can happen at any time. It is also advisable to avoid sleeping in areas that are prone to flooding, particularly during nighttime. This is because floods can be extremely hazardous, especially when you're asleep and unable to move to a safer location.

In this research, some interesting findings were the difference between the Hydrology Impact Index data and the FEMA Data used for flood analysis. Areas where I experienced flooding, were showing on the Hydrology Impact Index, but the FEMA Flood Data Map was either close or barely overlapping, except for Test Area 3, where the FEMA Flood Data Map was not showing the area at all was in a zone for flooding even though it flooded several times in the past. Areas that were in both the FEMA Flood Data Map and the Hydrology Impact Index Data Map, especially Terrapin Creek and the Chinnabee Silent Trails, had a history of severe flooding. It is crucial to consider the quality of data used since every layer included in the weighted sum calculation can be the difference in an area not draining water like it should be expected.

Also, it was observed that campsites located near a body of water or stream were situated in low-lying areas, which makes the campsites vulnerable to flash flooding incidents due to the rapid rise of water levels during heavy rainfall or flooding.

Future research can compare FEMA Flood Data and Hydrology Flood Index in various locations to identify discrepancies. The data analysis could be carried out at different scales, with a focus on trails that have experienced flooding and possess more accurate data. Moreover, the data from different environments could be compared to identify patterns and trends that may be useful in developing effective flood management strategies.

REFERENCES

Abu El-Magd, S. A., Maged, A., & Farhat, H. I. (2022). Hybrid-based Bayesian algorithm and Hydrologic Indices for Flash Flood Vulnerability Assessment in coastal regions: Machine Learning, Risk Prediction, and environmental impact. *Environmental Science and Pollution Research*, *29*(38), 57345–57356. https://doi.org/10.1007/s11356-022-19903-7%20%20

Acosta-Coll, M., Ballester-Merelo, F., Martinez-Peiró, M., & De la Hoz-Franco, E. (2018). Real-time early warning system design for Pluvial Flash Floods—a review. *Sensors*, *18*(7), 2255. https://doi.org/10.3390/s18072255

ADECA. (2021). *Frequently asked questions (Flood zones)*. https://adeca.alabama.gov/floods/frequently-asked-questions/#:~:text=The%20special%20flood%20hazard%20areas,for%20determination%20for%20each%20community.

Alabama Counties. Arcgis.com. (Mar 9, 2018). https://www.arcgis.com/home/item.html?id=61c55b4ccd9f4bf29e5d467dff28e9ab

Aldrees, A., Bakheit Taha, A. T., & Mustafa Mohamed, A. (2022). Prediction of sustainable management of sediment in rivers and reservoirs. *Chemosphere*, *309*, 136369. https://doi.org/10.1016/j.chemosphere.2022.136369

Alipour, A., Jafarzadegan, K., & Moradkhani, H. (2022). Global sensitivity analysis in hydrodynamic modeling and flood inundation mapping. *Environmental Modelling & Software*, *152*, 105398. https://doi.org/10.1016/j.envsoft.2022.105398

Al-Juaidi, A. E. (2023). The interaction of topographic slope with various geo-environmental flood-causing factors on flood prediction and susceptibility mapping. *Environmental Science and Pollution Research*, *30*(21), 59327–59348. https://doi.org/10.1007/s11356-023-26616-y

April, G. C., & Raney, D. C. (1980). Predicting the effects of storm surges and abnormal river flow on flooding and water movement in Mobile Bay, Alabama. *Estuarine and Wetland Processes*, 217–245. https://doi.org/10.1007/978-1-4757-5177-2_8

ArcGIS (2017, November 27). *SSURGO Soil layer*. Arcgis.com. https://www.arcgis.com/home/item.html?id=cdc49bd63ea54dd2977f3f2853e07fff

Bajabaa, S., Masoud, M., & Al-Amri, N. (2013). Flash flood hazard mapping based on quantitative hydrology, geomorphology and GIS techniques (Case study of Wadi Al Lith, Saudi Arabia). *Arabian Journal of Geosciences*, *7*(6), 2469–2481. https://doi.org/10.1007/s12517-013-0941-2

Basri, H., Syakur, S., Azmeri, A., & Fatimah, E. (2022). Floods and their problems: Land Uses and soil types perspectives. *IOP Conference Series: Earth and Environmental Science*, *951*(1), 012111. https://doi.org/10.1088/1755-1315/951/1/012111

Bell, J. C., Cunningham, R. L., & Havens, M. W. (1994). Soil drainage class probability mapping using a soil-landscape model. *Soil Science Society of America Journal*, *58*(2), 464–470. https://doi.org/10.2136/sssaj1994.03615995005800020031x

Bertol, I., Mello, E. L., Guadagnin, J. C., Zaparolli, A. L., & Carrafa, M. R. (2003). Nutrient losses by water erosion. *Scientia Agricola*, *60*(3), 581–586. https://doi.org/10.1590/s0103-90162003000300025

Bloemen, P., Reeder, T., Zevenbergen, C., Rijke, J., & Kingsborough, A. (2017). Lessons learned from applying adaptation pathways in Flood Risk Management and challenges for the further development of this approach. Mitigation and Adaptation Strategies for Global Change, 23(7), 1083–1108. https://doi.org/10.1007/s11027-017-9773-9

Bradley, C. M., Hanson, C. T., & DellaSala, D. A. (2016). Does increased forest protection correspond to higher fire severity in frequent-fire forests of the Western United States? *Ecosphere*, *7*(10). https://doi.org/10.1002/ecs2.1492

Bratton, S. P., Hickler, M. G., & Graves, J. H. (1979). Trail erosion patterns in Great Smoky Mountains National Park. *Environmental Management*, *3*(5), 431–445. https://doi.org/10.1007/bf01866582

Brázdil, R., Kundzewicz, Z. W., & Benito, G. (2006). Historical Hydrology for studying flood risk in Europe. *Hydrological Sciences Journal*, *51*(5), 739–764. https://doi.org/10.1623/hysj.51.5.739

Camotrek Staff. (2022, December 22). *20 hiking hazards you should be aware of: Camotrek backpacking blog*. Camotrek. https://camotrek.com/blogs/news/hiking-hazards/

Cheaha State Park. Alapark. (2019). https://www.alapark.com/parks/cheaha-state-park

Collier, C. G. (2007). Flash flood forecasting: What are the limits of predictability? *Quarterly Journal of the Royal Meteorological Society*, *133*(622), 3–23. https://doi.org/10.1002/qj.29

Cooper, A., The Anniston Star. (2017, July 15). *High rainfall increases flooding frequency, raises safety concerns on Terrapin Creek*. *The Anniston Star*. https://www.annistonstar.com/news/piedmont/high-rainfall-increases-flooding-frequency-raises-safety-concerns-on-terrapin-creek/article_9a8f6e72-69a7-11e7-b54c-173ba4501f9f.html

Dragovich, D., & Bajpai, S. (2022). Managing tourism and environment—trail erosion, thresholds of potential concern and limits of acceptable change. *Sustainability*, *14*(7), 4291. https://doi.org/10.3390/su14074291

Dullo, T. T., Darkwah, G. K., Gangrade, S., Morales-Hernández, M., Sharif, M. B., Kalyanapu, A. J., Kao, S.-C., Ghafoor, S., & Ashfaq, M. (2021). Assessing climate-change-induced flood risk in the Conasauga River watershed: An application of ensemble hydrodynamic inundation modeling. *Natural Hazards and Earth System Sciences*, *21*(6), 1739–1757. https://doi.org/10.5194/nhess-21-1739-2021

Earth Resources Observation and Science (EROS) Center. (2018, September 11). *National Land Cover Database Active*. National Land Cover Database | U.S. Geological Survey. https://www.usgs.gov/centers/eros/science/national-land-cover-database.

Elliot J. W., Page--Dumroese D., and Robichaud R. P., (2003). *The effects of forest management on erosion and soil productivity* William J. Elliot, Deborah Page-Dumroese, and Peter R. Robichaud*. The Effects of Forest Management on Erosion and Soil Productivity - https://forest.moscowfsl.wsu.edu/smp/docs/docs/Elliot_1-57444-100-0.html

Encyclopædia Britannica, inc. (n.d.). *Shale*. Encyclopædia Britannica. https://www.britannica.com/science/shale

Esri (2019, June 5). *USA NLCD Land Cover*. Arcgis.com. https://www.arcgis.com/home/item.html?id=3ccf118ed80748909eb85c6d262b426f

esri_landscape2. (2023, September 20). *USA Flood Hazard Areas*. Arcgis.com. https://www.arcgis.com/home/item.html?id=2b245b7f816044d7a779a61a5844be23%2B

Federal Emergency Management Agency (FEMA). (2020, July 8). *Flood zones*. FEMA.gov. https://www.fema.gov/glossary/flood-zones

Forest Service. *(2001). National forests in Alabama - Chinnabee Silent Hiking Trail. Forest*

Service National Website. https://www.fs.usda.gov/recarea/alabama/recarea/?recid=30129

Forest Service. (2001). *National Forests of Alabama*. Encyclopedia of Alabama. (2023, October 18). https://encyclopediaofalabama.org/article/national-forests-of-alabama/

Fukano, R. (2023, December 19). *Highest Peaks in Every State*. arcgis. https://experence.arcgis.com/experience/528e79391be44babaec1c66e82508890/page/Photos/

Gaines, E. M., Campbell, R. S., & Brasington, J. J. (1954). Forage production on longleaf pine lands of Southern Alabama. *Ecology*, *35*(1), 59–62. https://doi.org/10.2307/1931404

Gangrade, S., Kao, S.-C., & McManamay, R. A. (2020). Multi-model hydroclimate projections for the Alabama-Coosa-Tallapoosa River basin in the Southeastern United States. *Scientific Reports*, *10*(1). https://doi.org/10.1038/s41598-020-59806-6

Geology In. (2024, January 13). *Types of drainage patterns*. https://www.geologyin.com/2014/03/drainage-pattern.html

Geology of Alabama. Encyclopedia of Alabama. (2023, March 27). https://encyclopediaofalabama.org/article/geology-of-alabama/

GISGeography. (2022, May 25). *Alabama lakes and Rivers Map*. GIS Geography. Alabama Lakes and Rivers Map - GIS Geography

Goebel, D. E (2005). *Stratigraphic succession--paleozoic*. KGS. (n.d.). https://www.kgs.ku.edu/Publications/Bulletins/189/04_paleoz.html#:~:text=The%20Lamotte%20is%20a%20basal,are%20the%20dominant%20rock%20types.

Goepel, K. D. (2022, February 26.). *AHP Priority calculator*. AHP calculator - AHP-OS. https://bpmsg.com/ahp/ahp-calc.php

Goodall, J. (2003). *Time Series in Arc Hydro*. Applying the ArcGIS Hydro Data Model. https://www.caee.utexas.edu/prof/maidment/giswr2003/ex6/extimeseries.htm

Gross, S., The Anniston Star. (2016, March 16). *Coldwater Creek Flooding*. The Anniston Star. https://www.annistonstar.com/coldwater-creek-flooding/image_5cace086-db13-11e5-89fd-571f952a8c37.html

GSA. (2016, October 13). *Limestone: Characteristics, uses and problem*. https://www.gsa.gov/real-estate/historic-preservation/historic-preservation-policy-tools/preservation-tools-resources/technical-procedures/limestone-characteristics-uses-and-problem#:~:text=Limestone%20is%20a%20sedimentary%20rock,fragments%20and%20other%20fossilized%20debris.

Institute, U. W. (2024). *Alabama butterfly atlas*. Geographic Regions - Alabama Butterfly Atlas. https://alabama.butterflyatlas.usf.edu/geographic-regions

Jacinto, R., Grosso, N., Reis, E., Dias, L., Santos, F. D., & Garrett, P. (2015). Continental Portuguese territory flood susceptibility index – contribution to a Vulnerability index. *Natural Hazards and Earth System Sciences*, *15*(8), 1907–1919. https://doi.org/10.5194/nhess-15-1907-2015

Joe Wheeler state park. Alapark. (2022.). https://www.alapark.com/parks/joe-wheeler-state-park/outdoor-alabama-wildlife

Keith, A. (2008, April 7). *Topography and Geology of the Southern Appalachians*. Npshistory.com. http://npshistory.com/publications/usfs/region/8/sen-doc-84/appb1.htm

Kelmelis, J. A. (2003). To the national map and beyond. *Cartography and Geographic Information Science*, *30*(2), 185–197. https://doi.org/10.1559/152304003100011018

Khadka, P., Akhigbe, A., Gaskins, T., & Gharehchahi, S. (2022). *Flood Risk and Vulnerability Analysis Calhoun County Alabama*. "Flood Risk Mapping and Vulnerability Analysis of Anniston-Oxford, Alab" by Tim Gaskins (jsu.edu)

Knocke, E. T., & Kolivras, K. N. (2007). Flash Flood Awareness in southwest virginia. *Risk Analysis*, *27*(1), 155–169. https://doi.org/10.1111/j.1539-6924.2006.00866.x

Kortright, A., The Anniston Star. (2019, February 22). *Oxford Neighborhoods Flood, some residents evacuated*. The Anniston Star. https://www.annistonstar.com/free/oxford-neighborhoods-flood-some-residents-evacuated/article_4a68da5a-36c4-11e9-b0f8-8b062f5338cc.html

Kreuzwieser, J., & Rennenberg, H. (2014). Molecular and physiological responses of trees to waterlogging stress. *Plant, Cell & Environment*. https://doi.org/10.1111/pce.12310

Lapides, D., Sytsma, A., O'Neil, G., Djokic, D., Nichols, M., & Thompson, S. (2022). Arc Hydro Hillslope and critical duration: new tools for hillslope-scale runoff analysis. *Environmental Modelling & Software*, *153*, 105408. https://doi.org/10.1016/j.envsoft.2022.105408

Lecce, S. A. (2000). Spatial variations in the timing of annual floods in the Southeastern United States. *Journal of Hydrology*, *235*(3–4), 151–169. https://doi.org/10.1016/s0022-1694(00)00273-0

Lee, B.-J., & Kim, S. (2019). Gridded Flash Flood Risk Index coupling statistical approaches and toplats land surface model for mountainous areas. *Water*, *11*(3), 504. https://doi.org/10.3390/w11030504

Lee, S. Y., Du, C., Chen, Z., Wu, H., Guan, K., Liu, Y., Cui, Y., Li, W., Fan, Q., & Liao, W.

(2020). Assessing safety and suitability of old trails for hiking using ground and drone surveys. *ISPRS International Journal of Geo-Information*, *9*(4), 221. https://doi.org/10.3390/ijgi9040221

Li, Z. (2014). Watershed modeling using ARC Hydro based on Dems: A case study in Jackpine Watershed. *Environmental Systems Research*, *3*(1), 11. https://doi.org/10.1186/2193-2697-3-11

Lin, Q., & Luo, R. (2021). Projection of changes in flash flood occurrence under climate change at tourist attractions. *Journal of Hydrology*, *595*, 126039. https://doi.org/10.1016/j.jhydrol.2021.126039

M, Owen. (2014, March 5). *Thread: Chinnabee Silent trail update...* WhiteBlaze RSS. https://www.whiteblaze.net/forum/showthread.php/98780-Chinnabee-Silent-Trail-Update?p=1870788&viewfull=1

Maaz, M. A. (2022, July 8). *Microbursts - the most dangerous wind shear a pilot can face*. Simple Flying. https://simpleflying.com/microburst-pilot-wind-shear/

Maidment, D. R. (2010). *Arc Hydro: Gis for Water Resources*. ESRI.

Malins, D. C., McCain, B. B., Brown, D. W., Chan, S. Lam., Myers, M. S., Landahl, J. T., Prohaska, P. G., Friedman, A. J., Rhodes, L. D., & et al. (1984). Chemical pollutants in sediments and diseases of bottom-dwelling fish in Puget sound, Washington. *Environmental Science & Technology*, *18*(9), 705–713. https://doi.org/10.1021/es00127a013

Martin, S. (2021, May 21). *Flash flood emergency for parts of Jefferson, shelby co.. until 8:15 PM*. The Alabama Weather Blog. https://www.alabamawx.com/?p=228152

Mayaud, J. R., Bailey, R. M., & Wiggs, G. F. (2017). A coupled vegetation/sediment transport model for dryland environments. *Journal of Geophysical Research: Earth Surface*, *122*(4), 875–900. https://doi.org/10.1002/2016jf004096

Melville, N., & Morgan, R. P. C. (2006). The influence of grass density on effectiveness of contour grass strips for control of soil erosion on low angle slopes. *Soil Use and Management*, *17*(4), 278–281. https://doi.org/10.1111/j.1475-2743.2001.tb00038.x

Merz, B., Blöschl, G., Vorogushyn, S., Dottori, F., Aerts, J. C., Bates, P., Bertola, M., Kemter, M., Kreibich, H., Lall, U., & Macdonald, E. (2021). Causes, impacts and patterns of disastrous river floods. *Nature Reviews Earth & Environment*, *2*(9), 592–609. https://doi.org/10.1038/s43017-021-00195-3

Nashwan, M., Shahid, S., Chung, E.-S., Ahmed, K., & Song, Y. (2018). Development of climate-based index for Hydrologic Hazard Susceptibility. Sustainability, 10(7), 2182. https://doi.org/10.3390/su10072182

Nielsen, G. (2013, May 22). *National forests in Alabama - News & Events*. Forest Service National. https://www.fs.usda.gov/detail/alabama/news-events/?cid=STELPRDB5421327

Nunnally, B., The Anniston Star. (2019, July 19). *Saks resident escapes flooded home with firefighters' help*. The Anniston Star. https://www.annistonstar.com/news/local/saks-resident-escapes-flooded-home-with-firefighters-help/article_7ec899e2-aa5b-11e9-bbee-b3a009de9f4f.html

Okazawa, Y., Yeh, P. J.-F., Kanae, S., & Oki, T. (2011). Development of a global flood risk index based on natural and socio-economic factors. *Hydrological Sciences Journal*, *56*(5), 789–804. https://doi.org/10.1080/02626667.2011.583249

Palik, B. J., Michener, W. K., Mitchell, R. J., & Edwards, D. (1999). The effects of landform and plant size on mortality and recovery of longleaf pine during a 100-year flood. *Écoscience*, *6*(2), 255–263. https://doi.org/10.1080/11956860.1999.11682526

Penny, T., The Anniston. (2019, July 19). *071919_Flash flood_019 tp.jpg*. The Anniston Star. https://www.annistonstar.com/071919-flash-flood-019-tp-jpg/image_aec65a22-aa50-11e9-9383-ffc26d710a11.html

Pinter, N., Thomas, R., & Wlosinski, J. H. (2001). Assessing flood hazard on Dynamic Rivers. *Eos, Transactions American Geophysical Union*, *82*(31), 333–333. https://doi.org/10.1029/01eo00199

Posted by: Jessica Curl and Laura Bell. (2023, June 29). *Hydrogeologic provinces of Alabama*. Alabama Cooperative Extension System. Hydrogeologic Provinces of Alabama - Alabama Cooperative Extension System (aces.edu)

Prasad, R., & Pani, P. (2017). Geo-hydrological analysis and sub watershed prioritization for flash flood risk using weighted sum model and Snyder's synthetic unit hydrograph. Modeling Earth Systems and Environment, 3(4), 1491-1502.

Pruitt, H., Oot, M. B., & Cuhaj, J. (2019, August 15). *A guide to Alabama's state high points*. RootsRated. https://rootsrated.com/stories/a-guide-to-Alabama-s-state-high-points

Rabb, W. (2022, November 6). *Update: FEMA flood maps are misleading, blocking insurance uptake, report shows*. Insurance Journal. https://www.insurancejournal.com/news/national/2022/11/03/693006.htm

Reeksting, B. J., Taylor, N. J., & van den Berg, N. (2014). Flooding and phytophthora cinnamomi: Effects on photosynthesis and chlorophyll fluorescence in shoots of non-grafted Persea americana (mill.) Rootstocks differing in tolerance to phytophthora root rot. *South African Journal of Botany*, *95*, 40–53. https://doi.org/10.1016/j.sajb.2014.08.004

Rivers of alabama gallery. Encyclopedia of Alabama. (2023b, February 15). https://encyclopediaofalabama.org/gallery/rivers-of-alabama-gallery/

Robertson, D. J. (2023). Saving America's Amazon: The threat to our nation's most biodiverse river system. *Natural Areas Journal* 43(2), 144-145. https://doi.org/10.3375/0885-8608-43.2.144

Roering, J. J., Kirchner, J. W., & Dietrich, W. E. (1999). Evidence for nonlinear, diffusive sediment transport on hillslopes and implications for landscape morphology. *Water Resources Research*, *35*(3), 853–870. https://doi.org/10.1029/1998wr900090

Rome News Tribute. (2009, August 3). *Terrapin Creek watershed has long history of flood protection*. Northwest Georgia News. https://www.northwestgeorgianews.com/archive/terrapin-creek-watershed-has-long-history-of-flood-protection/article_5b55db20-d7e5-5e5f-b162-442dbe215e3a.html

Sami, K., Mohsen, B. A., Afef, K., & Fouad, Z. (2013). Hydrological modeling using GIS for mapping flood zones and degree flood risk in Zeuss-Koutine Basin (south of Tunisia). *Journal of Environmental Protection*, *04*(12), 1409–1422. https://doi.org/10.4236/jep.2013.412161

Sear, D. A., Newson, M. D., & Brookes, A. (1995). Sediment-related river maintenance: The role of fluvial geomorphology. *Earth Surface Processes and Landforms*, *20*(7), 629–647. https://doi.org/10.1002/esp.3290200706

WBRC. (2022, March 23). *Images: Flooding at Choccolocco Creek in Oxford*.

https://www.wbrc.com. https://www.wbrc.com/2022/03/23/images-flooding-choccolocco-creek-oxford/

Stokes, T. A., Samuelson, L. J., Kush, J. S., Farris, M. G., & Gilbert, J. C. (2010). Structure and diversity of longleaf pine (*pinus palustris*mill.) forest communities in the Mountain Longleaf National Wildlife Refuge, northeastern Alabama. *Natural Areas Journal*, *30*(2), 211–225. https://doi.org/10.3375/043.030.0208

Strapazan, C., & Petruţ, M. (2017). Application of arc hydro and Hec-HMS Model Techniques for runoff simulation in the headwater areas of Covasna Watershed (Romania). *Geographia Technica*, *12*(1), 95–107. https://doi.org/10.21163/gt_2017.121.10

Sugergeo. (2023, June 26). Hydrology Analyst > Flow Direction. Hydrology Analyst > Flow Direction (supergeotek.com)

Systems, S. & A., & 22, J. (2019, February 6). *Digital Elevation Models (Dems) explained: Part 2 - how are DEMS created?*. L3Harris® Fast. Forward. https://www.l3harris.com/newsroom/editorial/2019/01/digital-elevation-models-dems-explained-part-2-how-are-dems-created

Syvitski, J. P. M., & Brakenridge, G. R. (2013). Causation and avoidance of catastrophic flooding along the Indus River, Pakistan. *GSA Today*, *23*(1), 4–10. https://doi.org/10.1130/gsatg165a.1

Takayama, S., & Imaizumi, F. (2022). Effects of coarse particles on downstream face erosion processes and outflow discharge during the overtopping of a landslide dam. *Landslides*, *20*(2), 351–366. https://doi.org/10.1007/s10346-022-01973-w

Tao, J., & Barros, A. P. (2013). Prospects for flash flood forecasting in mountainous regions – an investigation of tropical storm fay in the southern appalachians. *Journal of Hydrology*, *506*, 69–89. https://doi.org/10.1016/j.jhydrol.2013.02.052

Tascón-González, L., Ferrer-Julià, M., Ruiz, M., & García-Meléndez, E. (2020). Social Vulnerability Assessment for flood risk analysis. *Water*, *12*(2), 558. https://doi.org/10.3390/w12020558

TETON. (2016). #getoutdoors during the shoulder season. TETON. https://tetonsports.com/blogs/adventure-blog/get-outdoors-shoulder-season

The Alabama Climate Report. (2012). https://www.nsstc.uah.edu/alclimatereport/

The Anniston Star. (2019, July 19). *Homes deluged, cars submerged as rain pounds Calhoun County*. https://www.annistonstar.com/free/homes-deluged-cars-submerged-as-rain-pounds-calhoun-county/article_2d1133a0-aa3a-11e9-96ac-97b8172b0030.html

The Geological Society of London (2013). *Metamorphic rocks*. The Geological Society. https://www.geolsoc.org.uk/ks3/gsl/education/resources/rockcycle/page3459.html#:~:text=Metamorphic%20rocks%20were%20once%20igneous,(foliated%20or%20banded)%20texture.

The National Map | U.S. Geological Survey. (2021)..*The national map*. https://www.usgs.gov/programs/national-geospatial-program/national-map

The University of Kansas. (2020). *Chert*. GeoKansas. https://geokansas.ku.edu/chert#:~:text=Commonly%20called%20flint%2C%20chert%20is,rounded%20nodules%20within%20limestone%20formations.

Tuttle, J. D., Bringi, V. N., Orville, H. D., & Kopp, F. J. (1989). Multiparameter Radar Study of a microburst: Comparison with model results. *Journal of the Atmospheric Sciences*, *46*(5), 601–620. https://doi.org/10.1175/1520-0469(1989)046<0601:mrsoam>2.0.co;2

U.S. Geological Survey. (2018, June 7). *The 100-year flood completed*. https://www.usgs.gov/special-topics/water-science-school/science/100-year-flood

U.S. Geological Survey. (2019). *What are Igneous Rocks?*. What are igneous rocks?. https://www.usgs.gov/faqs/what-are-igneous-rocks#:~:text=Igneous%20rocks%20(from%20the%20Latin,then%20rises%20toward%20the%20surface.

U.S. Geological Survey. (2021). *What are sedimentary rocks?*. What are sedimentary rocks?. https://www.usgs.gov/faqs/what-are-sedimentary-rocks#:~:text=Common%20sedimentary%20rocks%20include%20sandstone,Tuffaceous%20sandstones%20contain%20volcanic%20ash.

USA SSURGO (2017, June 19) - *Soil Hydrologic Group*. Arcgis.com. https://www.arcgis.com/home/item.html?id=be2124509b064754875b8f0d6176cc4c

USGS (2023). *Multi-resolution land characteristics (MRLC) consortium*. ScienceBase. https://www.sciencebase.gov/catalog/item/57d9e8e5e4b090824ffb109e

USGS. (2022, March 25). *What is a digital elevation model (DEM)?*. What is a digital elevation model (DEM)? | U.S. Geological Survey. https://www.usgs.gov/faqs/what-digital-elevation-model-dem#:~:text=A%20Digital%20Elevation%20Model%20(DEM)%20is%20a%20representation%20of%20the,derived%20primarily%20from%20topographic%20maps.

Warren, M. L., & Burr, B. M. (1994). Status of freshwater fishes of the United States: Overview of an imperiled fauna. *Fisheries, 19*(1), 6–18. https://doi.org/10.1577/1548-8446(1994)019<0006:soffot>2.0.co;2

Wesson, W. (2022, March 23). *Flooding at Choccolocco Creek in Oxford Source: William*

Wesson. https://www.wbrc.com. https://www.wbrc.com/video/2022/03/23/flooding-choccolocco-creek-oxford-source-william-wesson/

Wesson, W., (2022, March 23). *Images: Flooding at Choccolocco Creek in Oxford*. IMAGES: Flooding at Choccolocco Creek in Oxford (wbrc.com)

Wilson, J. W., Roberts, R. D., Kessinger, C., & McCarthy, J. (1984). Microburst wind structure and evaluation of Doppler radar for airport wind shear detection. *Journal of Climate and Applied Meteorology*, *23*(6), 898–915. https://doi.org/10.1175/1520-0450(1984)023<0898:mwsaeo>2.0.co;2

World Wildlife Fund. (2012). *What is erosion? effects of soil erosion and land degradation*. WWF. https://www.worldwildlife.org/threats/soil-erosion-and-degradation#:~:text=The%20effects%20of%20soil%20erosion,water%2C%20which%20can%20worsen%20flooding.

Zhang, H., Yao, Z., Yang, Q., Li, S., Baartman, J. E. M., Gai, L., Yao, M., Yang, X., Ritsema, C. J., & Geissen, V. (2017). An integrated algorithm to evaluate flow direction and flow accumulation in flat regions of hydrologically corrected Dems. *CATENA*, *151*, 174–181. https://doi.org/10.1016/j.catena.2016.12.009

Zheng, X., Maidment, D. R., Tarboton, D. G., Liu, Y. Y., & Passalacqua, P. (2018). Geoflood: Large-scale flood inundation mapping based on high-resolution terrain analysis. *Water Resources Research*, *54*(12). https://doi.org/10.1029/2018wr023457

Zhu, Z., & Zhang, Y. (2021). Flood disaster risk assessment based on Random Forest algorithm. *Neural Computing and Applications*, *34*(5), 3443–3455. https://doi.org/10.1007/s00521-021-05757-6

APPENDICES

Appendix A

Permission from Jacksonville State University Trails Science Institute and John Graffeo

JACKSONVILLE STATE UNIVERSITY

Department of Chemistry and Geosciences
700 Pelham Road North
Jacksonville, AL 36265-1602

April 21, 2024

Allie Field has been granted permission to use the data, information, and images from the Trail Science Institute at Jacksonville State University. This data was obtained during the Pinhoti Trail Project for Alabama Trails Foundation. Dr. Ross Martin and John Graffeo participated in data collection and processing. The Trail Science Institute is responsible for data collection and management, and grants permission for the use of such material in this Thesis.

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Appendix B

Permission from WBRC To Use Their Articles and Publications

JW Jenna Wood <jenna.wood@wbrc.com>
To: Allie Field

Hi Allie,

You are more than welcome to reference the article with credit to us.

However, the photo by William Wesson would have to be cleared through him. We were only given permission at the station-level.

Thank you!

JENNA WOOD
Digital Content Manager | WBRC FOX6 News

1720 Valley View Drive, Birmingham, AL 35209
o: 205.327.5846 | **c:** 205.478.0301 | **e:** jenna.wood@wbrc.com

Appendix C

Permission from Anniston Star To Use Their Articles, Publications, and Images Giving To The Photographers

Sue Magouirk <smagouirk@annistonstar.com>
to me

April 17, 2024

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