Geospatial Modeling Approach to Determine Potential Sinkholes Risk Probability

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Abstract

- Sinkholes are common and naturally occurring in certain areas such as Florida and Southern Georgia. The region's aquifer is often covered by limestone or dolomite carbonate rock, which are made up of minerals that can dissolve in water under the right conditions. Anthropogenic changes are leading to an increased risk of sinkholes in susceptible areas. The formation of these geologic features is hastened by the improper management of ground water, the increase in watershed pollution and runoff, and the mismanagement of underground fresh and wastewater pipes and structures. The goal of this study is to develop an automated geospatial model to determine areas within the study having a potential high risk for sinkholes.
- Eleven types of geospatial data were collected, processed, and analyzed in ArcGIS Pro Model Builder to calculate sinkhole vulnerability layers in the study area. The eleven data types were geology, soil, land use, aquifer, ground water measurements, road, fault line, elevation precipitation, and evapotranspiration. From this data, ten sinkhole vulnerability layers were produced: 1) subsidence or surface change, 2) average aquifer well depth, 3) ground water vulnerability (DRASTIC), 4) road density, 5) groundwater travel time, 6) aquifer-media (Suwannee Limestone) , 7) geology type, 8) slope, 9) land use, and 10) distance from fault lines. Each layer was reclassified and reassigned a value from 1 to 10 according to its sinkhole vulnerability. The weighted layers were analyzed interpretively using ArcGIS Pro's weighted sum tool producing a Sinkhole Risk Probability Raster. The sampling tool was used for accuracy assessment by comparing the obtained result with historical sinkhole data. This method showed 77% accuracy between known sinkholes and those shown on the sinkholes probability raster. This study is useful to environmental planners/managers and other stakeholders for decision support.

Materials & Methods

Data
- Geology
- Soil (gSSURGO)
- Land Cover (NLCD 2011)
- Aquifer (top of Floridian Aquifer)
- USGS Groundwater Well
- Digital Elevation Map (3DEP)
- Historical Topographic Maps
- TIGER Primary Roads

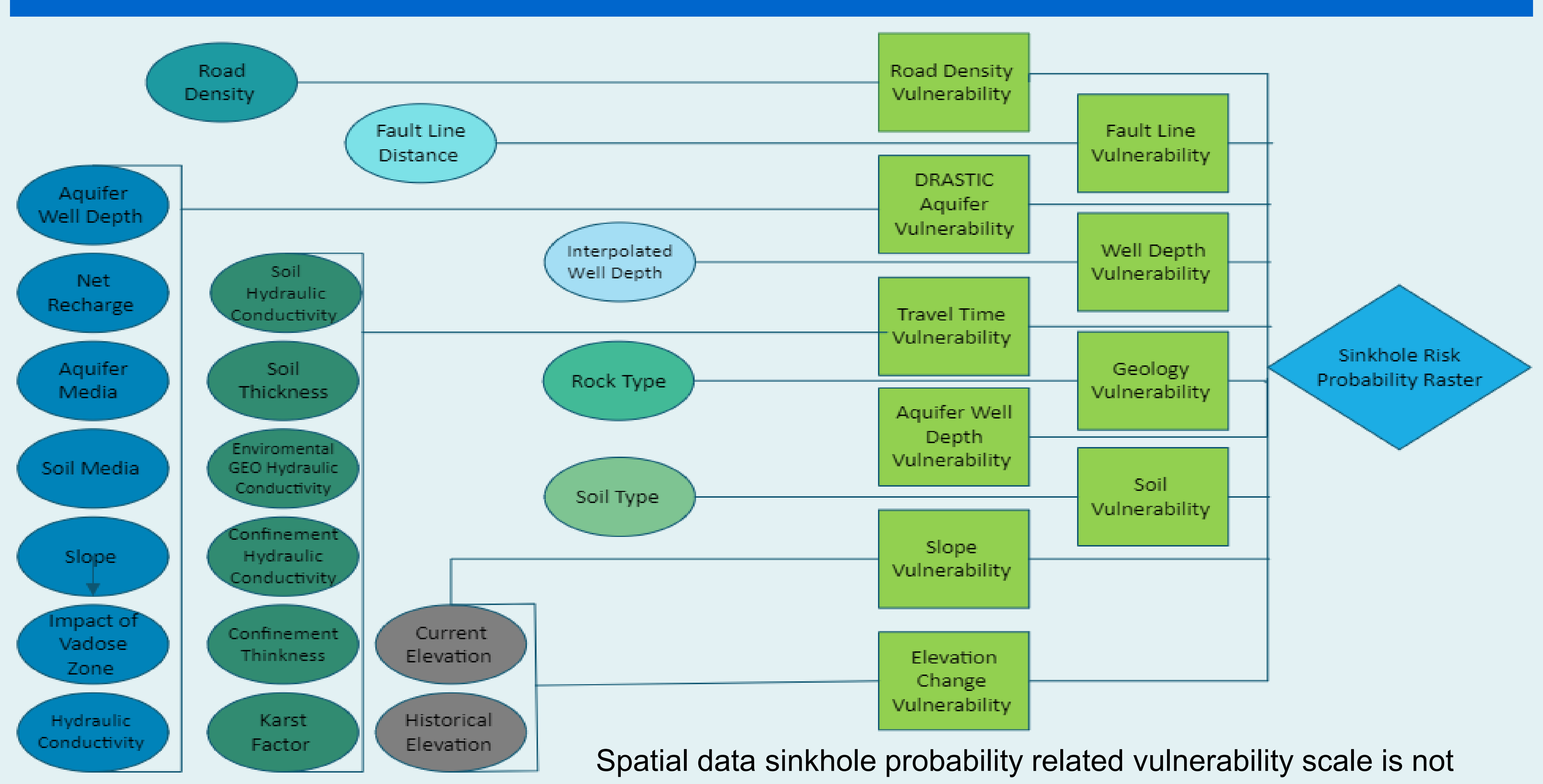
Data sources
- USGS,
- Florida Department of Environmental Protection
- USDA NRCS Geospatial Data Gateway

Software
- ArcGIS Pro 2.6 (ESRI™)

Formulas
- DRASTIC index (vulnerability rating) = (5Dr+ 4Rr + 3Ar + 2Sr + TrTw + 5Ir + 3Cr)
- Travel Time = (Ts/Ks + Teg/Kg + Tcu/Kcu) * Kf

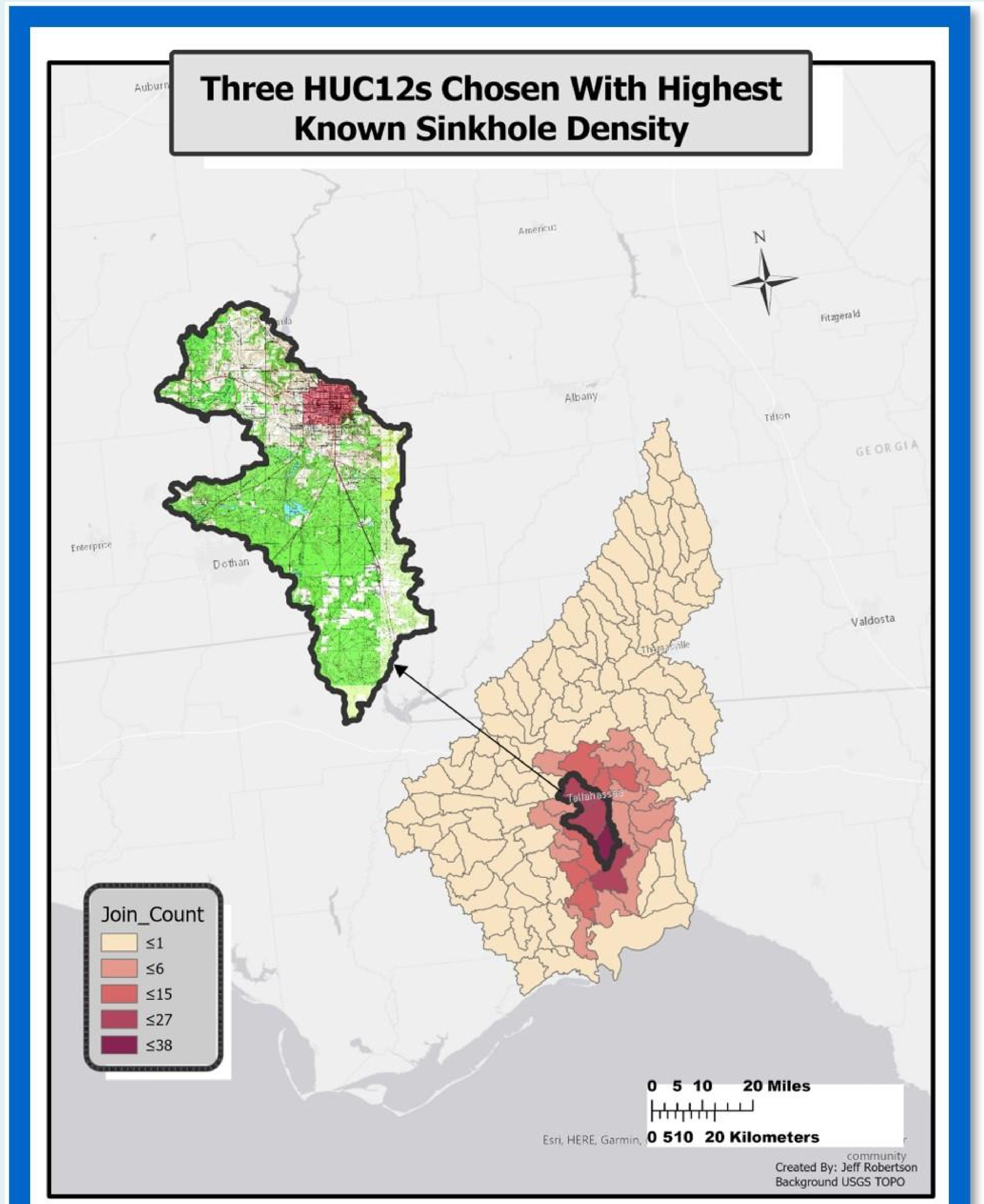
Tools
- Extract by Mask
- Polygon to Raster
- Kriging
- Reclassify
- IDW
- Weighted Sum
- Raster Calculator
- Others

Model

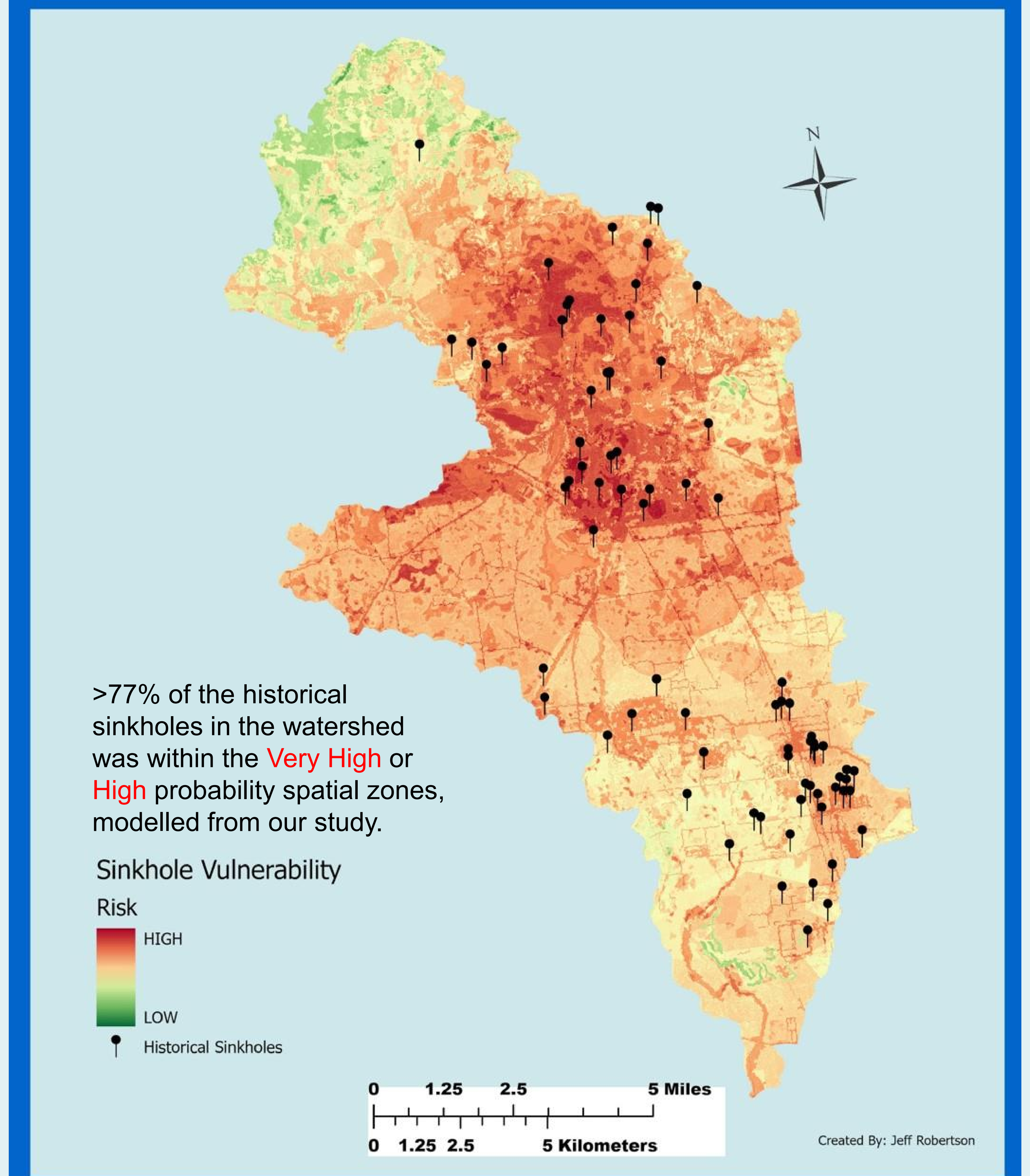


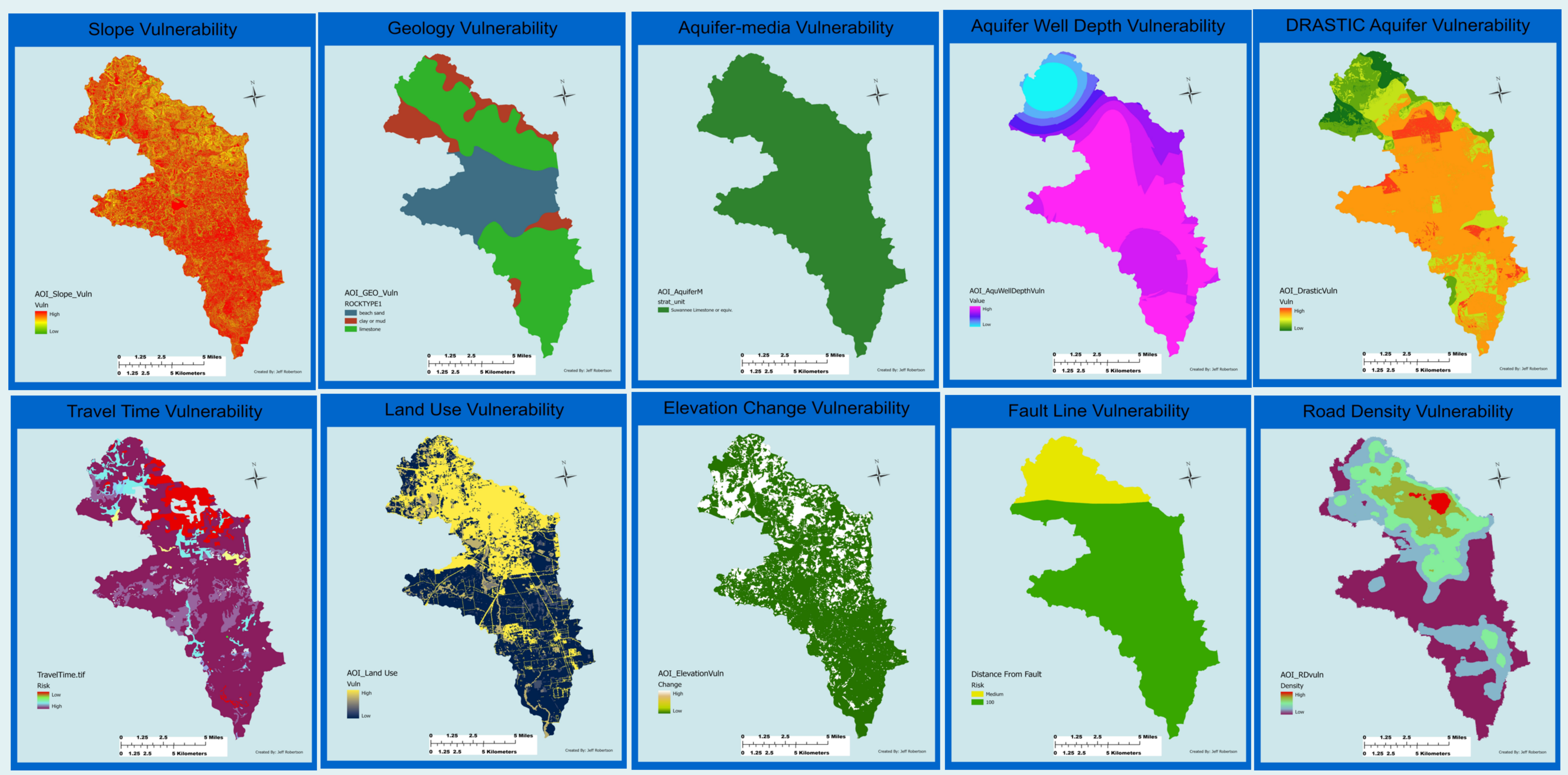
Spatial data sinkhole probability related vulnerability scale is not shown here in the model. They will be available on request.

Study Area



Sinkhole Risk Probability Raster





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Challenges & Lessons

- Initially, area of interest was southern Georgia but was unable to find historical sinkhole data for the state of Ga. This data is available for AL and FL. This data was important for the accuracy assessment.
- The digitizing of historical topographic maps was very time consuming and tedious. There is software available, but it is pricey and was not an option for this project.
- Subsidence can be caused by the depletion of groundwater. Also, in coastal areas saltwater intrusion can also cause aquifer problems. The goal for this study was to learn MODFLOW to do groundwater modeling. Unfortunately, due to the time constraints for this project it was infeasible.

Program of Study & Goals

You are never too old to change your trajectory in life. As a retired Coastie, I am proof of that. In 2017, I went back to college at the University of North Georgia to get Bachelor of Science degree studying environmental spatial science. I will graduate this fall and currently, I am in the process of applying to graduate school. While at graduate school I hope to continue professionally growing via honing my skills in geospatial technology. Geospatial technology is a great way to study the effects of anthropogenic development. While in graduate school, I wish to conduct research on the effects, of urbanization on forest biomass production and forest watershed management. Hopefully, my research and this study will help environmental decision makers get a better understanding of water quality/quantity management related issues. After twenty years at a job, where the primary mission was to protect people, I wanted to continue that further and find ways to protect the environment that subsequently safeguard human sustenance. Graduate school, for me, is not about advancing a career, but carving out a path for a career where I can make a difference in protecting our natural resources.

Collaboration & Contributions

- Dr. Sudhanshu Panda , Professor, UNG
- Dr. Ying Ouyang, Research Hydrologist, USDA
- Dr. Johnny Grace, General Engineer, Forest Service
- Zach Pilgrim , UNG Undergraduate student