Assessing Tornado Impacts in the State of Kentucky with a Focus on Demographics and Roadways using a GIS-based Approach

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Introduction

o Tornadoes are increasing in frequency and strength due to climate change, leading to significant disruptions for communities and infrastructure.

o **This study explores two critical aspects of tornado impacts in Kentucky:**

1. The relationship between tornado exposure and demographic, socioeconomic, and transportation factors using kernel density estimation (KDE) and multiscale geographically weighted regression (MGWR).

2. The quantification of tornado impacts on roadways through scoring methods that combine tornado density and roadway network characteristics.

o The results highlight areas of high tornado exposure and roadway vulnerability, supporting disaster preparedness and sustainability-focused planning.

Methods

Part 1: Tornado Exposure Analysis

o Data Collection:
➢ Tornado incidents (1950–2022) sourced from the Storm Prediction Center (SPC).
➢ Demographic and socioeconomic data from American Community Survey (ACS), Smart Location Database (SLD) and Housing and Transportation Index.
o Tornado Exposure Calculation:
➢ Kernel Density Estimation (KDE) was used to compute tornado density as a proxy for tornado risk at Census Block Group (CBG) level.
➢ Zonal statistics applied to aggregate values at CBG boundaries.
o Spatial Analysis:
➢ Multiscale Geographically Weighted Regression (MGWR) was used to analyze relationships between tornado exposure and independent variables like housing + transportation costs, intersection density, and residential density.
➢ The model chosen considers spatial heterogeneities and distinct spatial scales for variables.

Part 2: Roadway Impact Assessment

o Tornado density and roadway network density was used to simulate occurrence and exposure, respectively. Two scoring method was used.
o In the first scoring method, cumulative, normalized tornado density and roadway network values were summed up. This method highlights regions with significant tornado and roadway vulnerabilities.
o In the scoring method, normalized tornado density and roadway network values were multiplied to identify CBGs with simultaneous high tornado occurrence and roadway network density.
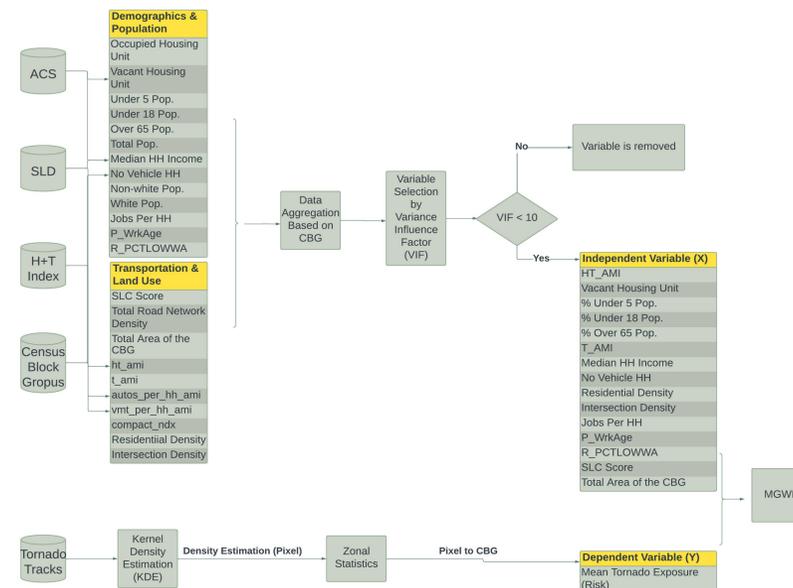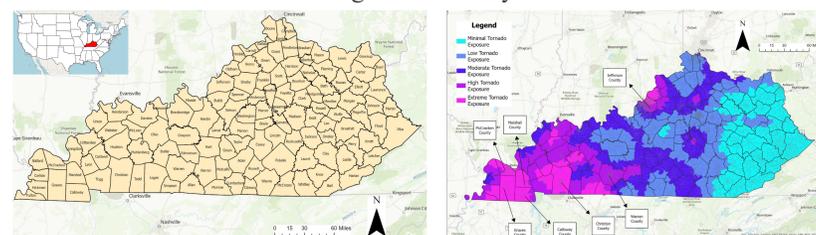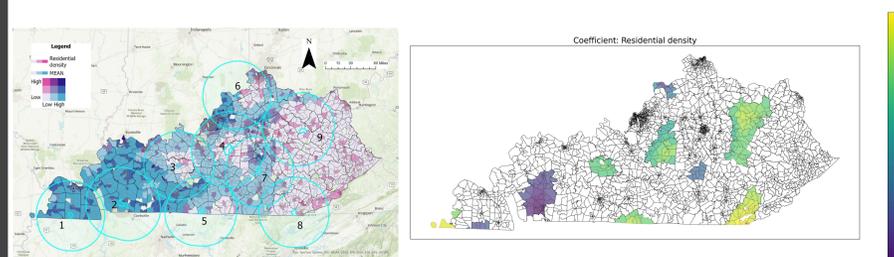

Flowchart of Part 1

Results

Part 1: Tornado Exposure Analysis Result

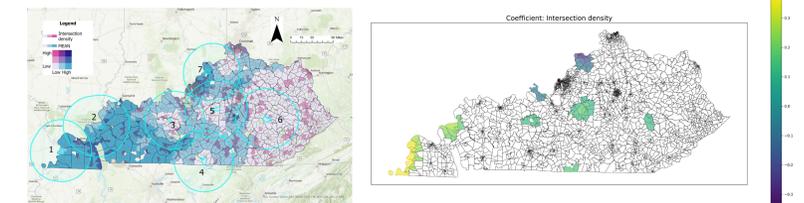o Tornado risk distribution along the Kentucky:
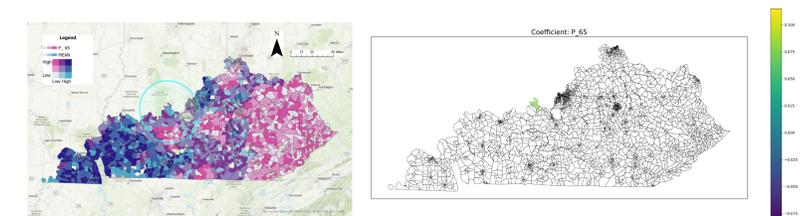

Kentucky counties and tornado risk map

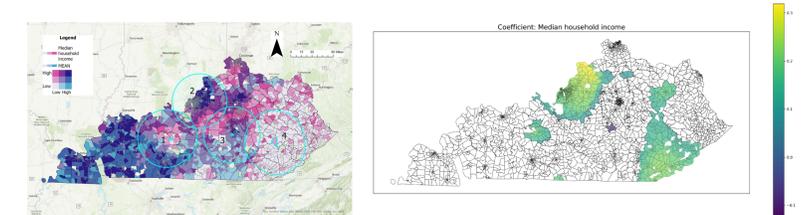o Statistical distributions of significant explanatory variables over the study area:

Spatial distribution of significant residential density coefficient along the study area

Spatial distribution of significant intersection density coefficient along the study area
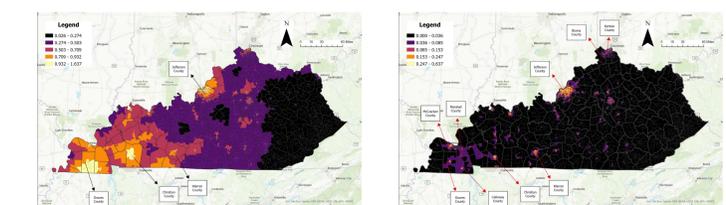

Spatial distribution of significant P_65 coefficient along the study area

Spatial distribution of significant median household income coefficient along the study area

Part 2: Roadway Impact Assessment Results

o Kentucky Tornado roadway exposure map:

First method   Second method

Conclusion

o Tornado exposure and impacts on roadways vary significantly across Kentucky.
o Southwest Kentucky and Jefferson County are the most vulnerable areas.
o MGWR effectively captures spatial variations in relationships between tornado exposure and demographic, socioeconomic, and transportation factors.
o Roadway vulnerability scoring highlights critical areas for emergency response and infrastructure resilience.
o Findings can guide disaster preparedness, emergency response planning, and community resilience efforts.