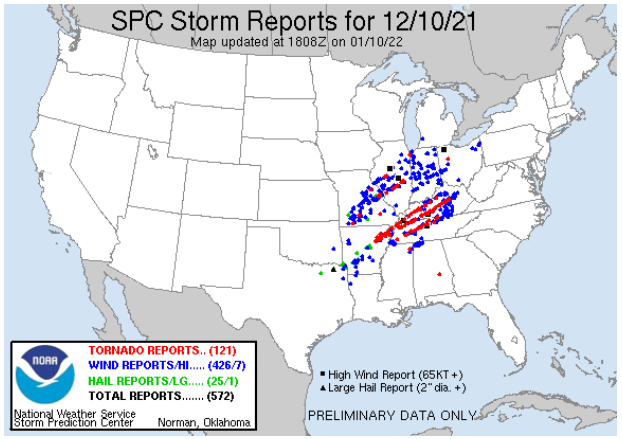
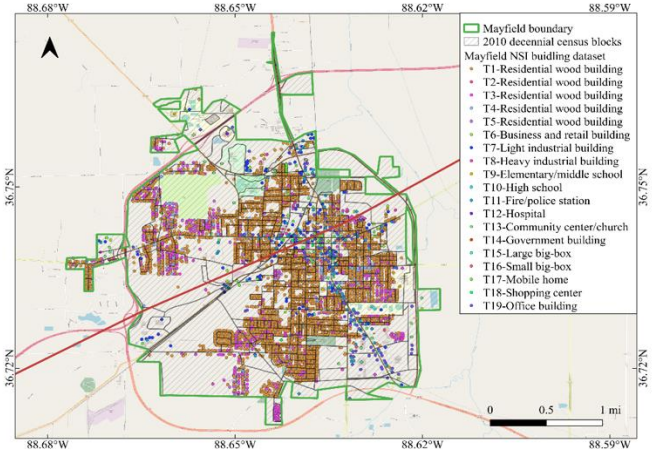
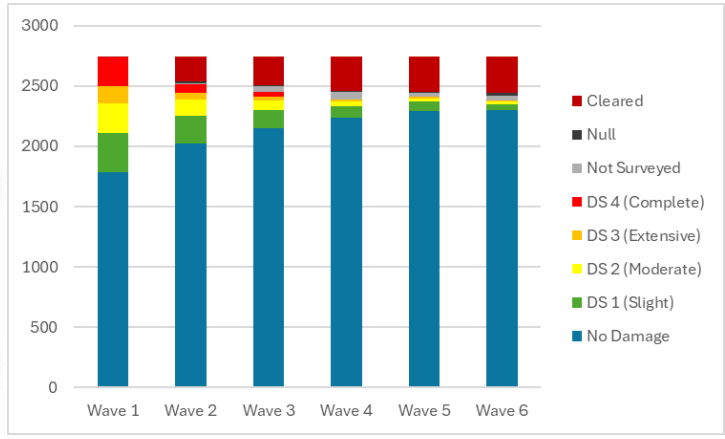







# Midwest Tornado Field Reconnaissance Study

Presenter: Lisa Wang

The Field Team Members: John W. van de Lindt, Shane Crawford, Lisa Wang, Blythe Johnston, Grace Yan, Jarrod Loerzel, Thang Dao, Trung Do, Mojtaba Harati, Tu Nguyen, Chibuke Robinson, Katie Skakel, Silvana Croope, Andre Barbosa

Session C: The Art & Science of Field Studies: Past, Present, and Future
2024 Fall Semi-Annual Meeting
November 7, 2024

IN-CORE

NIST CENTER FOR RISK-BASED COMMUNITY RESILIENCE PLANNING

Resilience

# 1

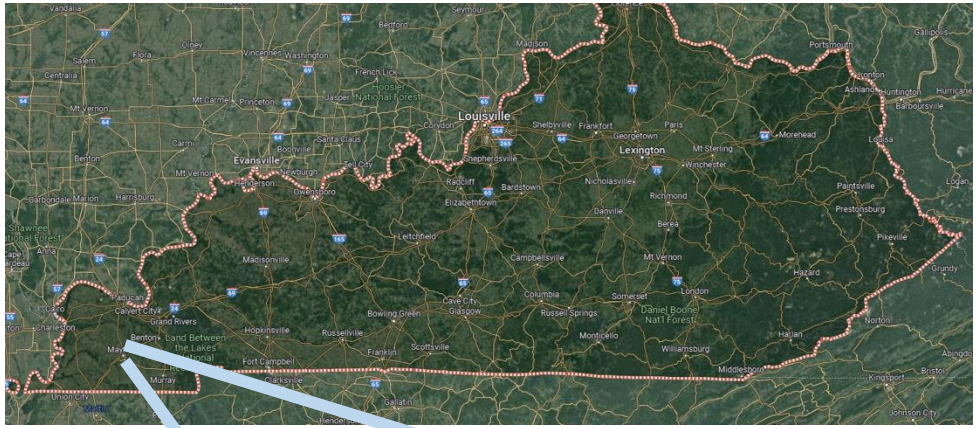
# Data Collection

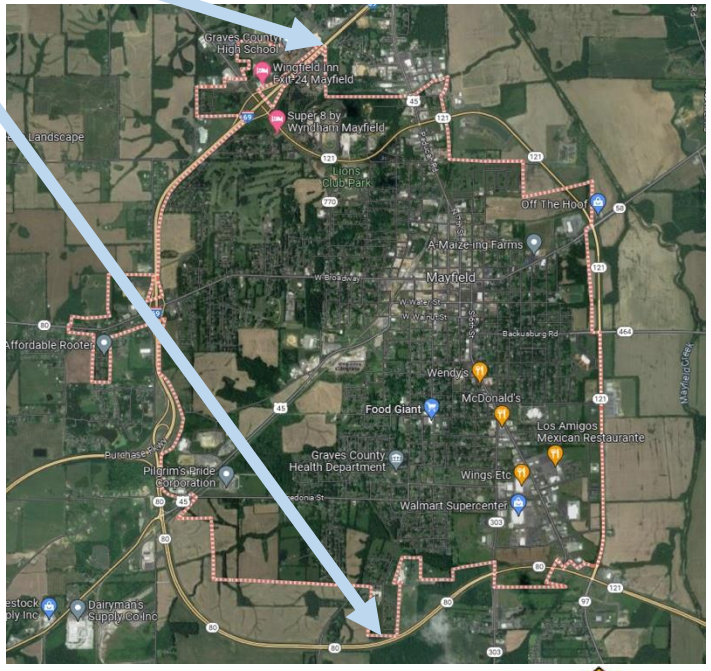
# Background: 2021 U.S. Midwest Tornado Outbreak

van de Lindt, J.W., Wang, W., Johnston, B., Crawford, P.S., Yan, G., Dao, T., Do, T., Skakel, K., Harati, M., Nguyen, T., Robinson, C., and Croope, S. "Social Susceptibility Driven Longitudinal Tornado Reconnaissance Methodology: 2021 Midwest Quad-State Tornado Outbreak." *Earth's Future (under review)*.

Tornado hazard (December 10-11, 2021)

- Quad-State Tornado
- $3.9 billion (2022 USD) in damages
- More than 90 fatalities, and at least 667 people injuries
- 2 EF4, 6 EF3, 15 EF2, 30 EF1, and 17 EF0 tornadoes
- The high-end EF4 tornado had a path length of 266.67 km (165.7 miles), a maximum width of 1.82 km (1.13 miles), and a peak wind speed of 84.94 m/s (190 mph)




Mayfield, Kentucky

- Buildings: ***4,749*** (NSI 2020)
- Population: ***9,723*** (US Census Bureau 2010)
- Housing units: ***4,192*** (US Census Bureau 2010)
- One of the communities that were the most heavily damaged during the tornado outbreak

# Field Study Areas, Trips Logistics: Wave 1


Wave 1 (December 2021):

*1. Mayfield, KY*
*3. Dawson Springs, KY*
*4. Bremen, KY*
*5. Centertown, KY*
*6. Hartford, KY*
*8. Monette, AR*
*9. Leachville, AR*
*11. Samburg, TN*
*12. Edwardsville, IL*

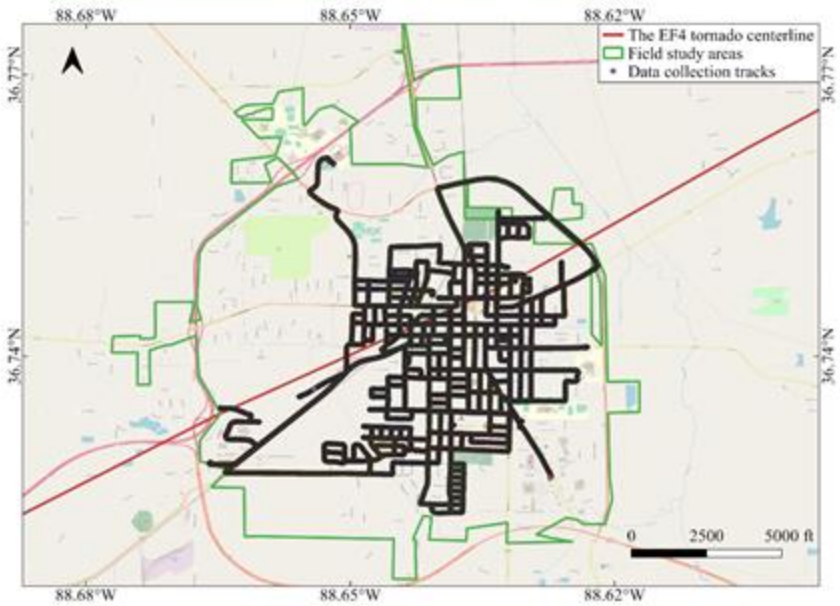
Wave 2, 3, 4, 5 (March 2022, June 2022, December 2022, June 2023):

1. *Mayfield, KY*
2. *Dawson Springs, KY*
3. *Bremen, KY*
4. *Monette, AR*
5. *Leachville, AR*
6. *Samburg, TN*

# Data Collection Methodology and Study Timeline

van de Lindt, J.W., Wang, W., Johnston, B., Crawford, P.S., Yan, G., Dao, T., Do, T., Skakel, K., Harati, M., Nguyen, T., Robinson, C., and Croope, S. "Social Susceptibility Driven Longitudinal Tornado Reconnaissance Methodology: 2021 Midwest Quad-State Tornado Outbreak." *Earth's Future (under review)*.


Data collection setup




GoPro GPS tracks for Mayfield, KY

Select damage photo in downtown Mayfield

Data Collection Waves

W1 W2 W3 W4 W5 W6 W7

Dec. 10 2021 | Dec. 22-23 2021 | Mar. 15-16 2022 | Jun. 14-15 2022 | Dec. 19 2022 | Jun. 13 2023 | Jul. 19 2023 | Dec. 2023 | Dec. 2024

# Data Collection

van de Lindt, J.W., Wang, W., Johnston, B., Crawford, P.S., Yan, G., Dao, T., Do, T., Skakel, K., Harati, M., Nguyen, T., Robinson, C., and Croope, S. "Social Susceptibility Driven Longitudinal Tornado Reconnaissance Methodology: 2021 Midwest Quad-State Tornado Outbreak." *Earth's Future (under review)*.

The 360-degree video created by the GoPro camera – with screenshots grabbed to the left, front, right, and back of the vehicle

# 2

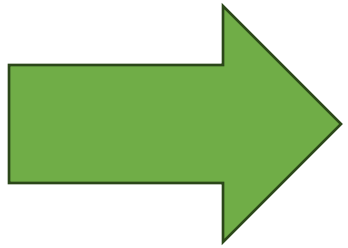
# Community Selection

# Designing the Social Susceptibility Metric to Predict Specific Outcomes

Johnston, B. and van de Lindt, J., 2024. Weighing structural damage and social susceptibility: A decision-making tool to perform longitudinal studies of geographically large hazard events. *Risk analysis*.

**Factors considered for inclusion in the predictive metric**

1 - Educational Attainment
2 - Median Income
3 - Race
4 - Ethnicity
5 - Rental Tenure
6 - Occupancy Rate
7 - Median Age
8 - Population Density
9 - Rurality
10 - Event Cost
11 – Scaled Value for Event Cost
12 - Community Self-Perception
13 - Racial Affinity Groups
14 - Family Ties
15 - %Less than HS
16 - % Population 65+
17 - % Limited English Households
18 - % Population Below Poverty Line
19 - % Unemployed in Labor Force
20 - % Female Unemployed
21 - % Single Parent Households
22 - Mobile Homes as % of HUs
23 - % owner occupied
24 - % Households w/o vehicle
25 - GINI Index
26 - Number of Healthcare professionals per 1,000 residents



**Monitoring factors which the linear fit model was being trained to predict**

Median Household Income

Population

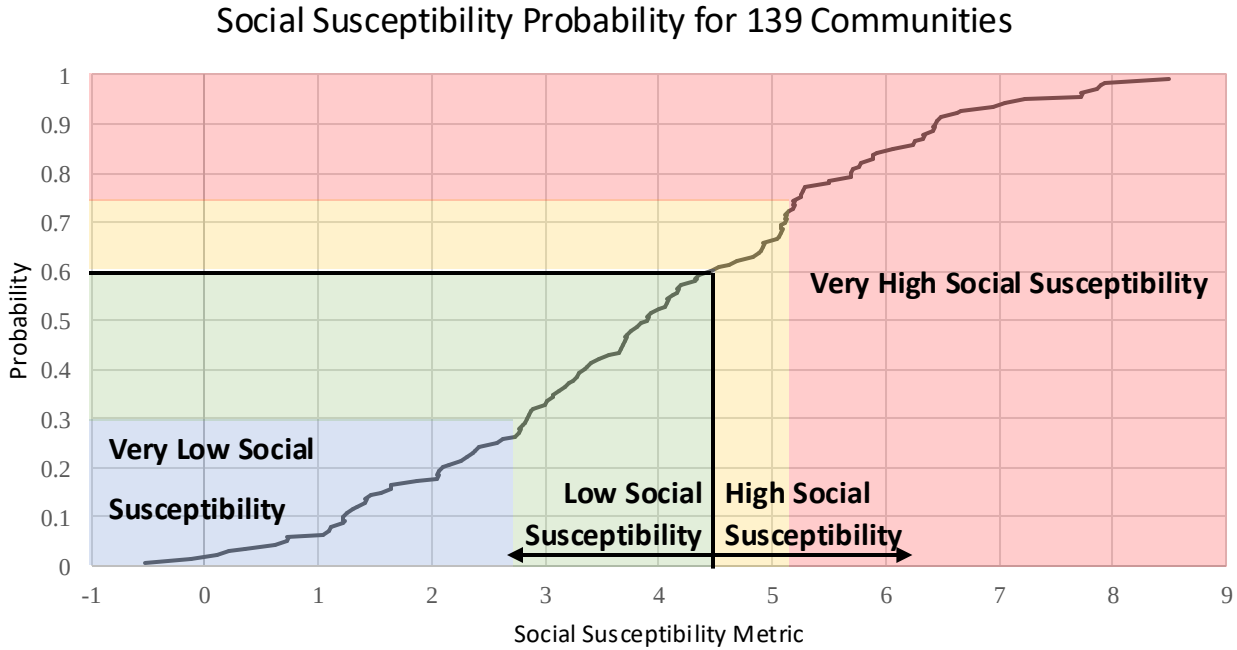
Educational Attainment

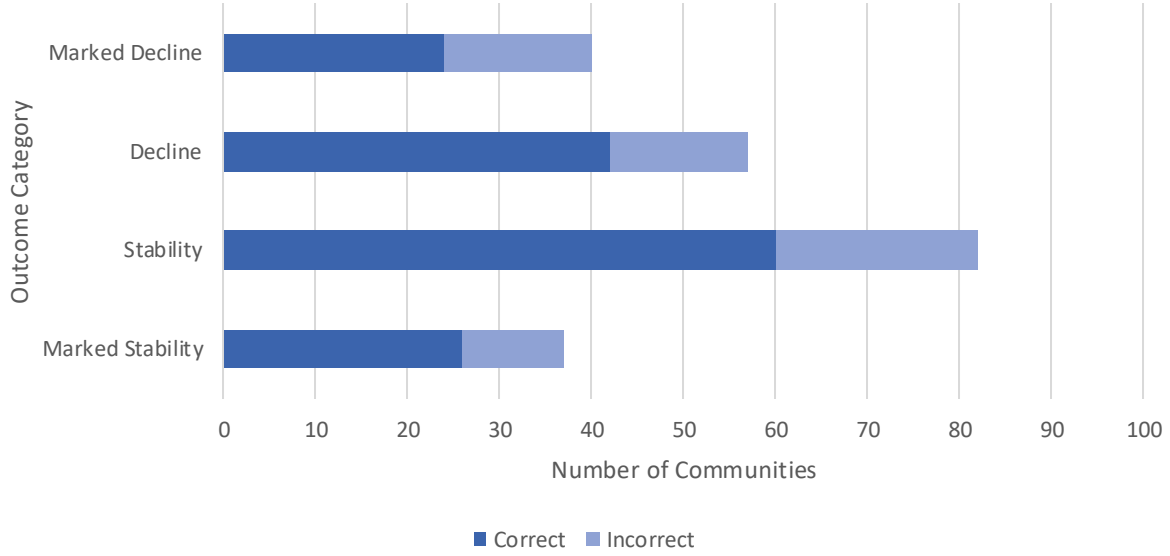
Number of Households

Number of Housing Units

# Binning: Creating Outcome Tiers

Johnston, B. and van de Lindt, J., 2024. Weighing structural damage and social susceptibility: A decision-making tool to perform longitudinal studies of geographically large hazard events. *Risk analysis*.




73% of communities predicted to see stability in monitoring factors did.
74% of communities predicted to see declines also did.

# Implementation of the Metric to Select Communities

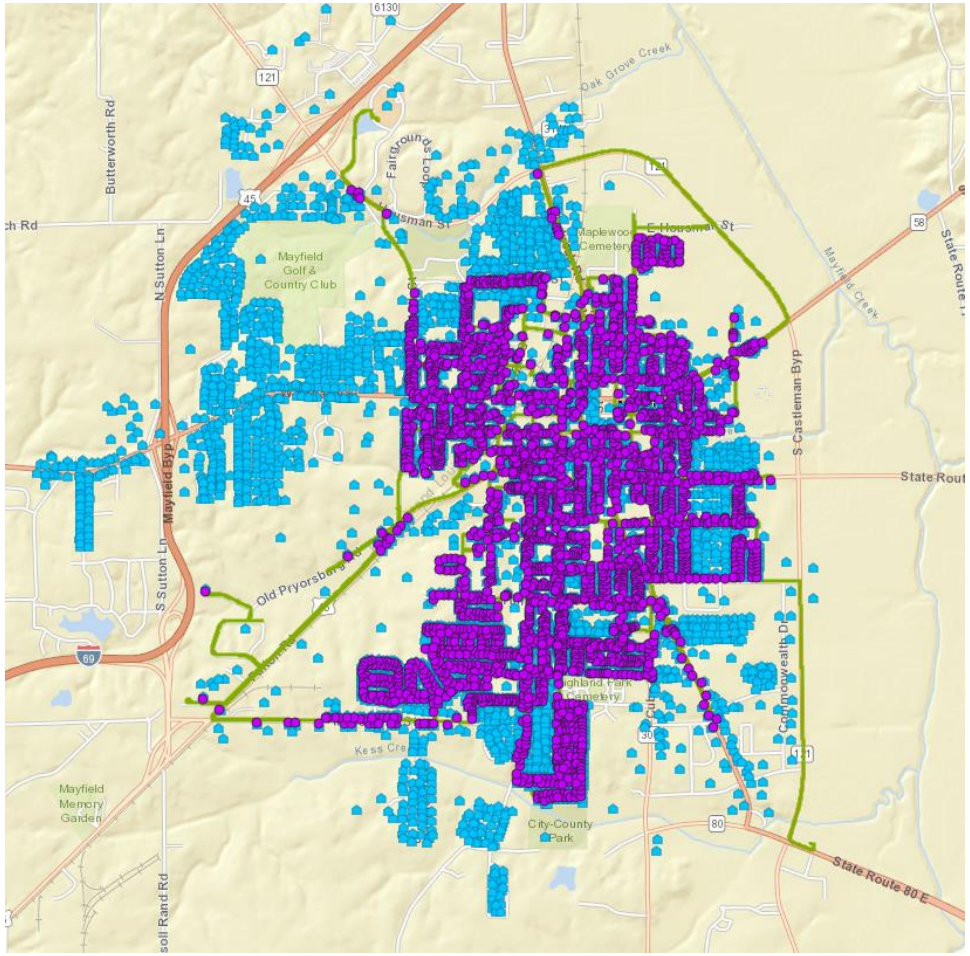
Johnston, B. and van de Lindt, J., 2024. Weighing structural damage and social susceptibility: A decision-making tool to perform longitudinal studies of geographically large hazard events. *Risk analysis*.

| Town of Interest | Social Susceptibility Metric | Social Susceptibility Tier | Predicted Outcome for Monitoring Factors Based on Social Susceptibility | Qualitative Extent of Damage | Notes on Damage |
|---|---|---|---|---|---|
| **Leachville, AR** | **0.895** | **Very Low Social Susceptibility** | **Marked Stability** | **Low** | **Only severe damage is the cotton factory in town and BBQ restaurant near the tornado track. Very low in residential area.** |
| **Edwardsville, IL** | 1.587 | Very Low Social Susceptibility | Marked Stability | Very Low | Amazon warehouse damage. Minimal roof damage to adjacent neighborhood. |
| **Samburg, TN** | **3.470** | **Low Social Susceptibility** | **Stability** | **High** | **Very small community with extensive damage to residential.** |
| **Mayfield, KY (Graves County)** | **5.101** | **High Social Susceptibility** | **Decline** | * | * |
| **Bremen, KY** | **5.395** | **Very High Social Susceptibility** | **Marked Decline** | **Moderate** | **A small community with extensive damage to residential along the road leading into downtown.** |
| **Mayfield, KY** | **5.847** | **Very High Social Susceptibility** | **Marked Decline** | **Very High** | **Extensive damage to businesses, residential, and social institutions throughout downtown and surrounding neighborhoods.** |
| **Monette, AR** | **6.081** | **Very High Social Susceptibility** | **Marked Decline** | **Very Low** | **Very low in residential area, almost no damage in downtown.** |
| **Centertown, KY** | 6.957 | Very High Social Susceptibility | Marked Decline | Very Low | Damage isolated to a single peripheral neighborhood. |
| **Hartford, KY** | 8.265 | Very High Social Susceptibility | Marked Decline | Low | Damage largely isolated to a single road leading out of town. |
| **Dawson Springs, KY** | **8.453** | **Very High Social Susceptibility** | **Marked Decline** | **High** | **Extensive damage to many residential buildings and several commercial buildings.** |


# Data Processing

# IN-CORE Damage State Tagging: CAPS Interface

van de Lindt, J.W., Wang, W., Johnston, B., Crawford, P.S., Yan, G., Dao, T., Do, T., Skakel, K., Harati, M., Nguyen, T., Robinson, C., and Croope, S. "Social Susceptibility Driven Longitudinal Tornado Reconnaissance Methodology: 2021 Midwest Quad-State Tornado Outbreak." *Earth's Future (under review)*.




Video data processing with the assistance of CAPS partnership

**Elements to Check:**
- Roof Covering
- Window/Door
- Roof Sheathing
- Roof-to-wall connection failure

**DS Selection Steps:**
1. In each row, select the box that best describes the structure's damage.
2. Note the rightmost column in which you selected a box.
3. Select the damage state corresponding to that noted column.
4. Check: The damage state selected should reflect the highest damage state that any single element category reached.

**Wood Frame Building**

| DS1 - Slight | DS2 - Moderate | DS3 - Extensive | DS4 - Complete |
|---|---|---|---|
| *2 - 15% of Roof Covering Damaged* | *15-50% of Roof Covering Damage* | *More than 50% of Roof Covering Damaged* | *More than 50% of Roof Covering Damaged (typically)* |
| AND/OR | AND/OR | AND/OR | AND/OR |
| *1 window or door failure* | *2 or 3 windows/doors failed* | *More than 3 windows/doors failed* | *More than 3 windows/doors failed (typically)* |
| AND/OR | AND/OR | AND/OR | AND/OR |
| *No Roof Sheathing Failure* | *1-3 sections of roof sheathing failed* | *More than 3 sections **AND** less than 35% of roof sheathing failed* | *More than 35% of roof sheathing failed* |
| AND/OR | AND/OR | AND/OR | AND/OR |
| *No Roof-to-Wall Connection Failure* | *No Roof-to-Wall Connection Failure* | *No Roof-to-Wall Connection Failure* | *Roof-to-Wall Connection Failure* |

Incore damage states for residential buildings

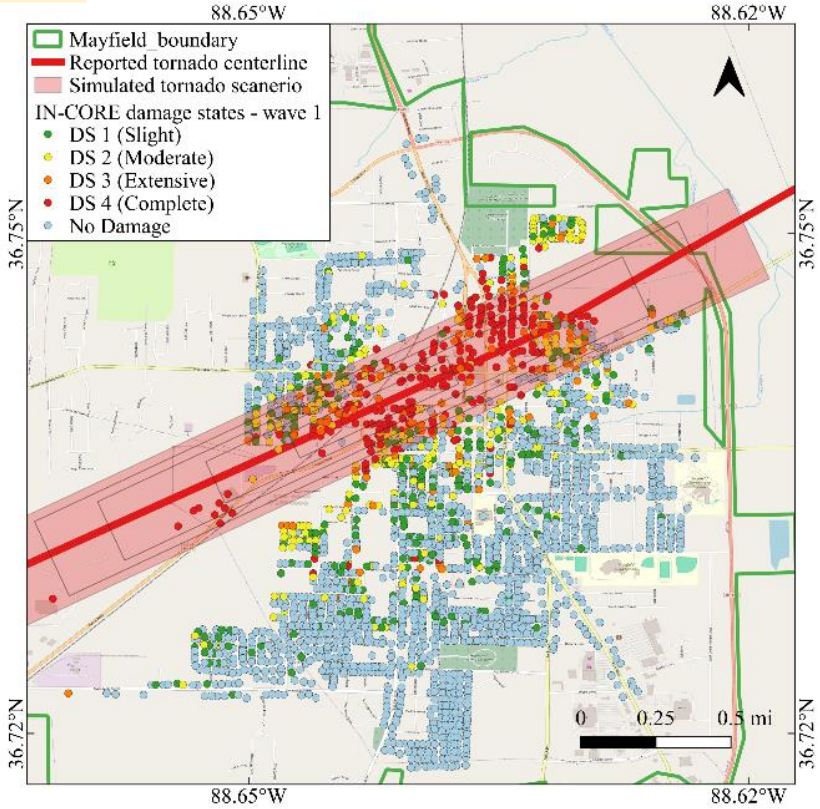
# Data Processing Progress

van de Lindt, J.W., Wang, W., Johnston, B., Crawford, P.S., Yan, G., Dao, T., Do, T., Skakel, K., Harati, M., Nguyen, T., Robinson, C., and Croope, S. "Social Susceptibility Driven Longitudinal Tornado Reconnaissance Methodology: 2021 Midwest Quad-State Tornado Outbreak." *Earth's Future (under review)*.

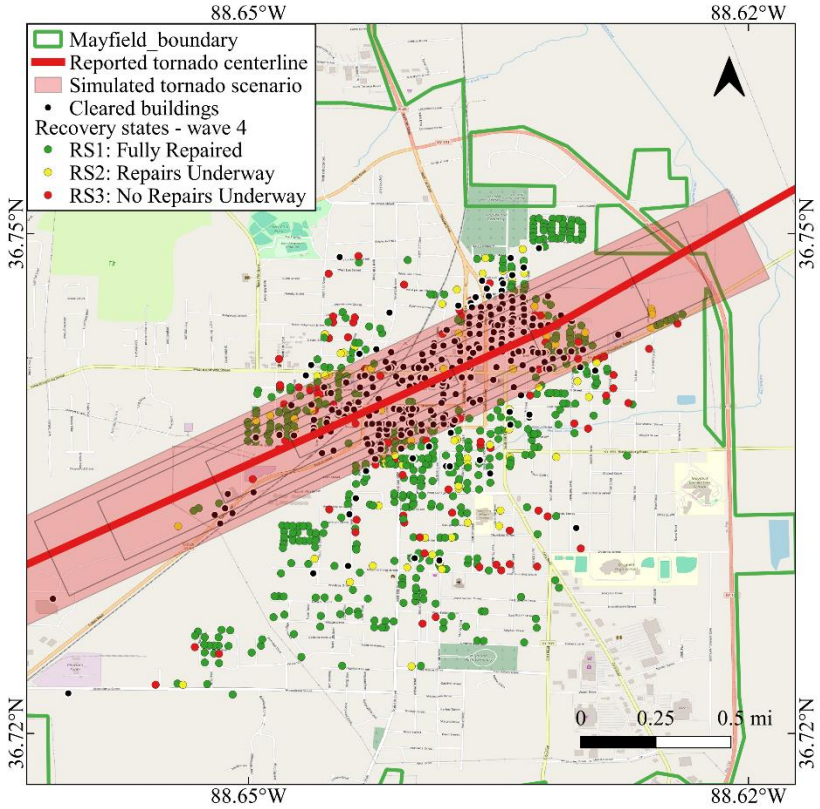
## Other Communities' Progress

Wave 1 Data Processing | Wave 4 Data Processing | Wave 2 Data Processing | Wave 3 Data Processing | Wave 5 Data Processing | Wave 6 Data Processing

## Mayfield Progress



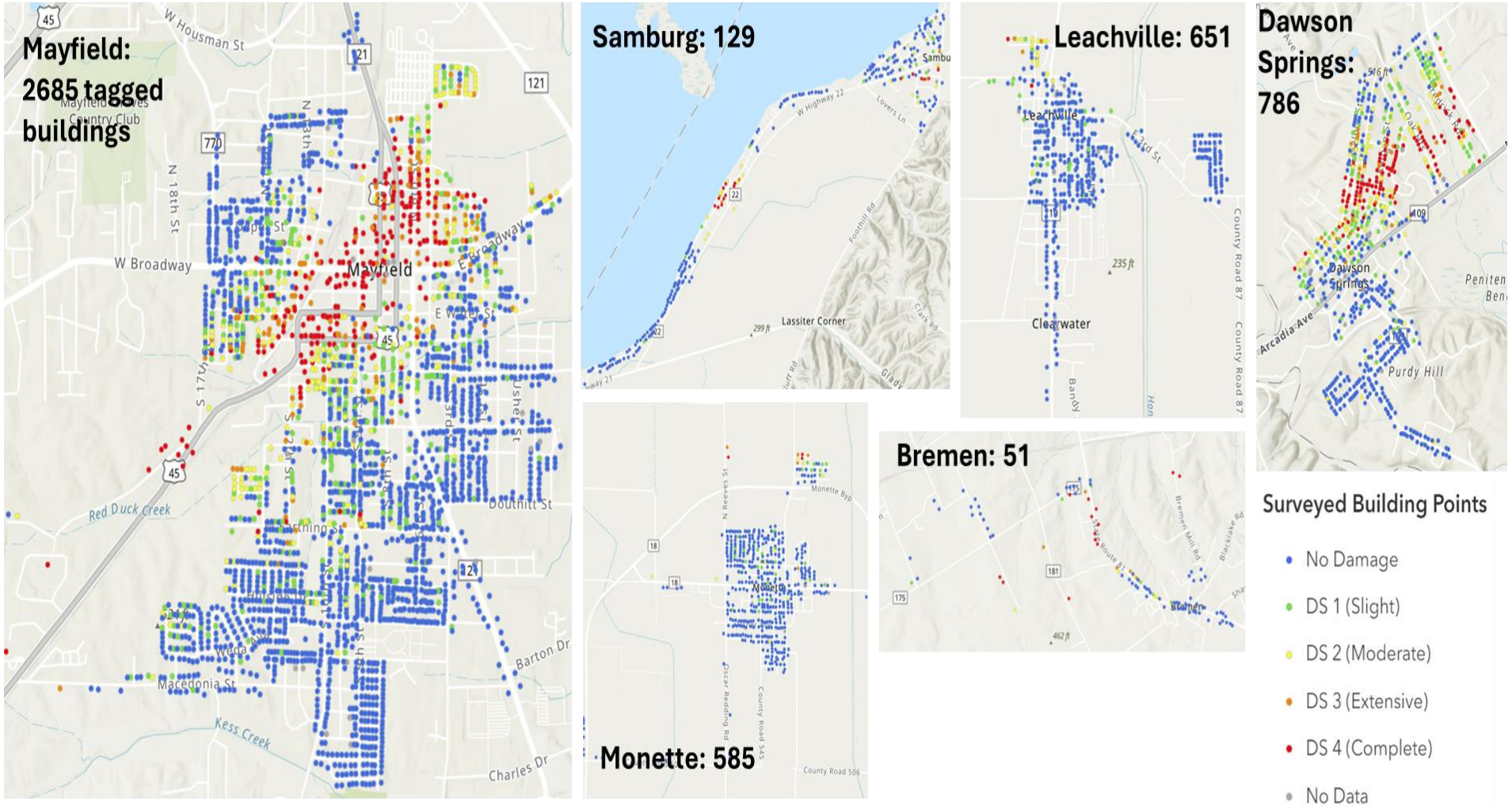

Mayfield building damage states




Mayfield building recovery states after 1 year

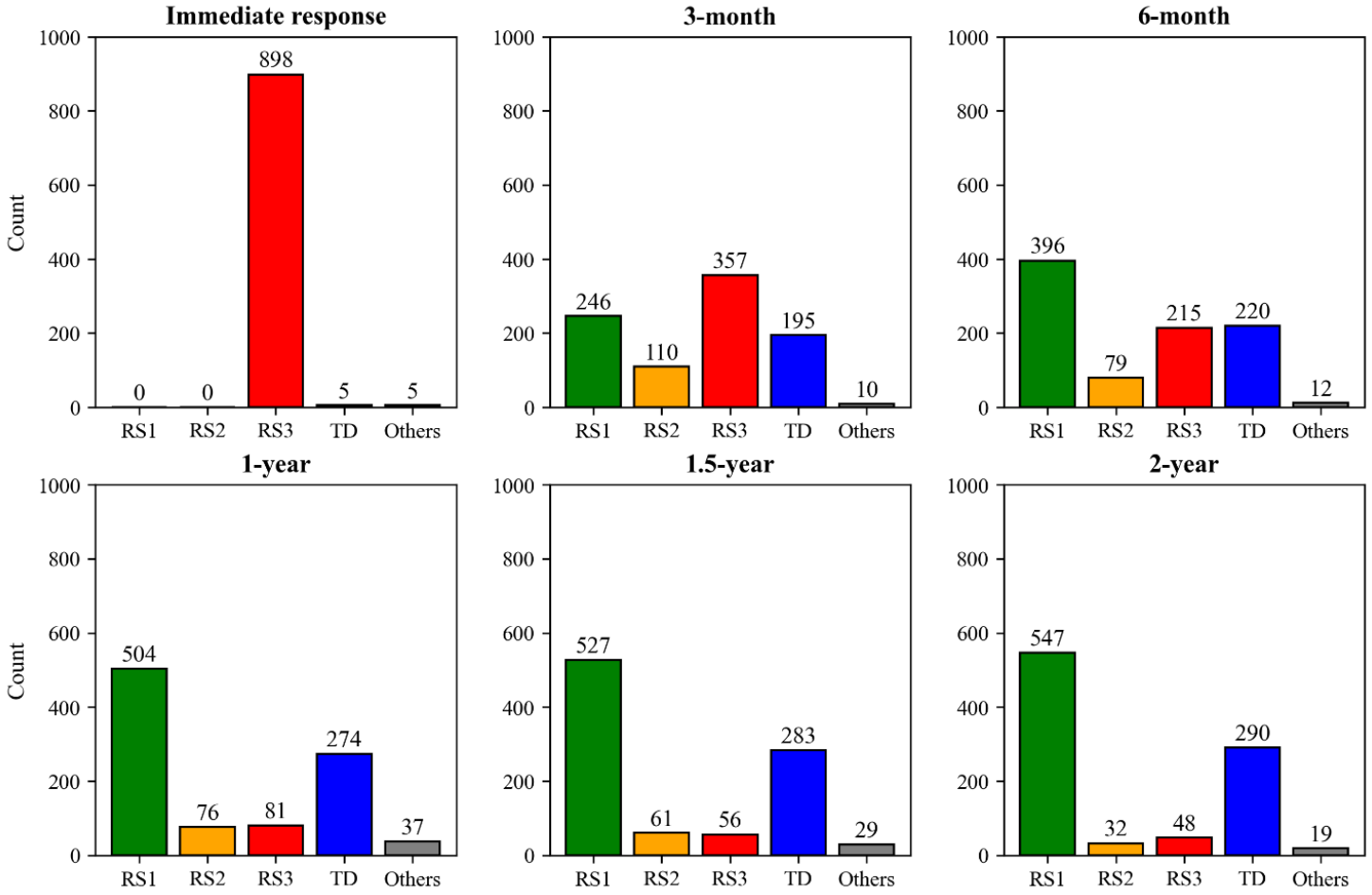
# Data Processing – Damage – All Communities

Johnston, B., Wang, W., van de Lindt, J. W., Crawford, S., Harati, M., Skakel, K., Dao, T., Yan, G., Do T., Umeike, R., Croope, S., Nguyen T., and Barbosa, A., 2024. "Midwest Quad-State Tornado Longitudinal Field Study." *Natural Hazards Research Summit 2024*.

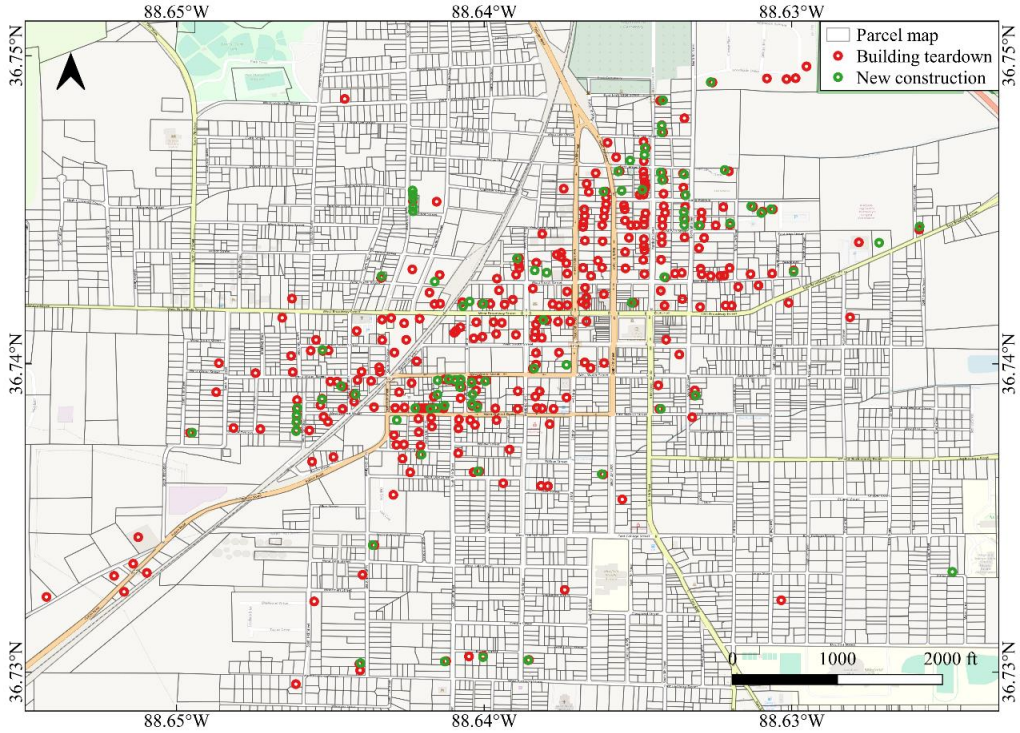



Wave 1 damage state results for the communities surveyed

# Data Processing – Recovery and Reconstruction – Mayfield

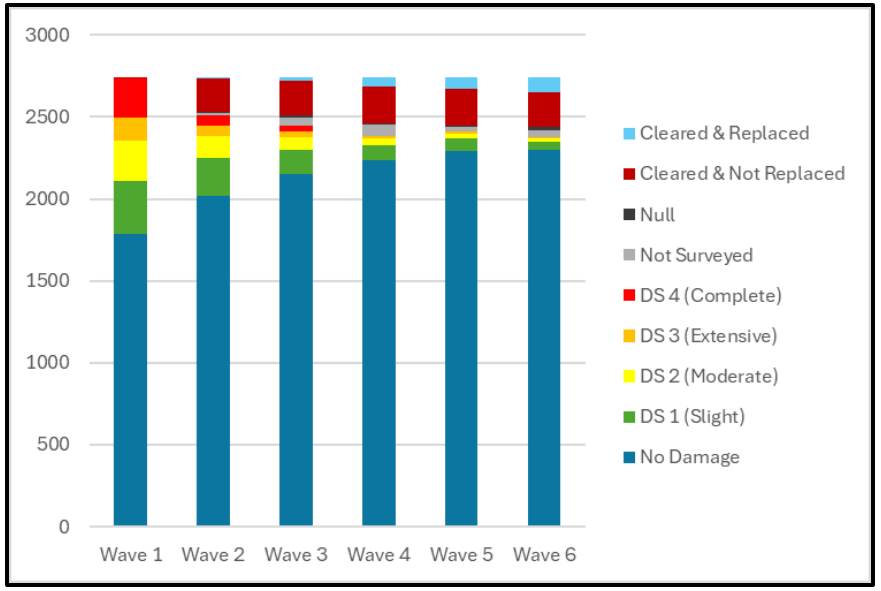



All Mayfield building recovery

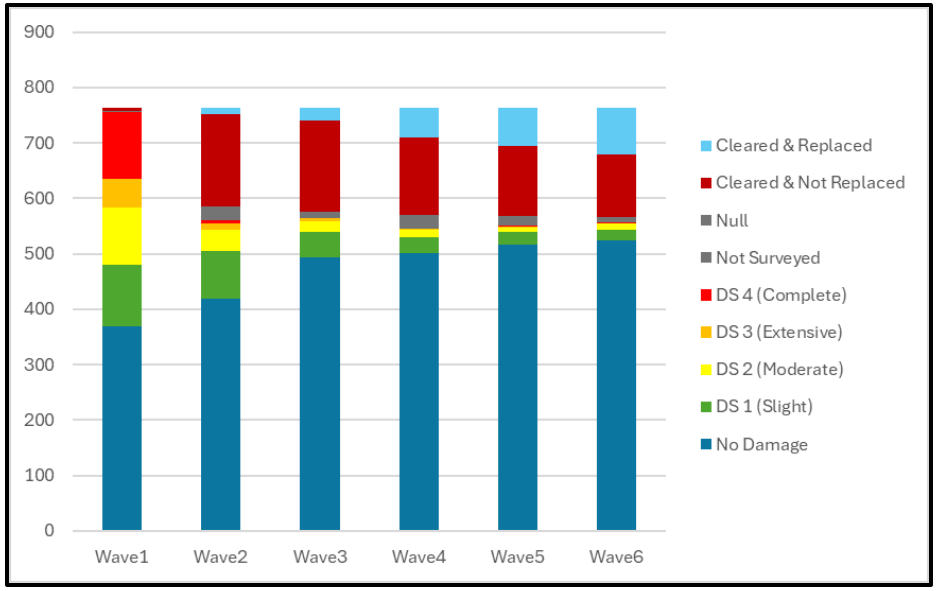



Mayfield building teardown and new construction

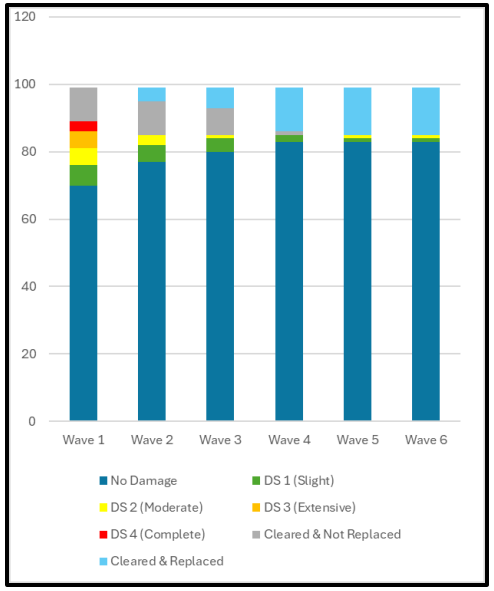
# Data Processing – Recovery and Reconstruction – All Communities



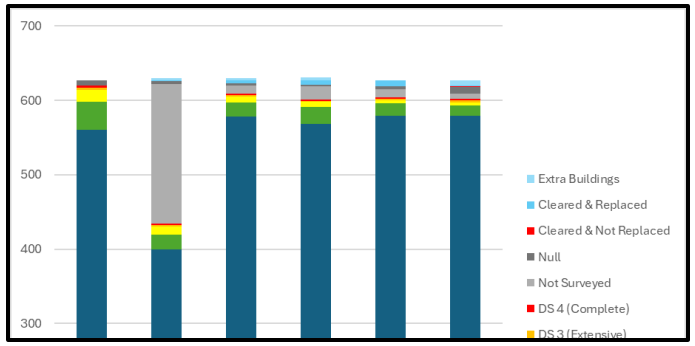

Mayfield



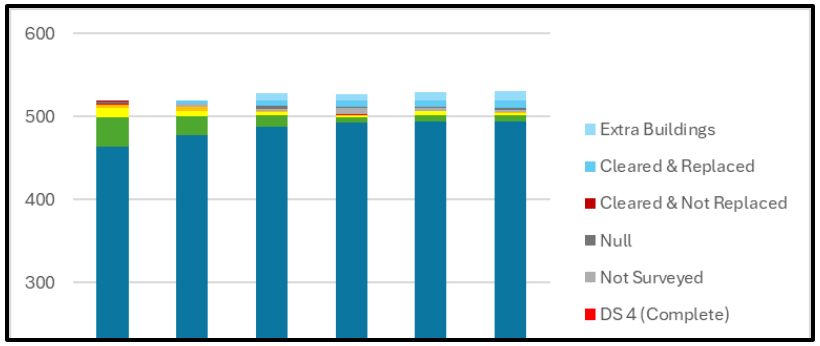

Dawson Springs



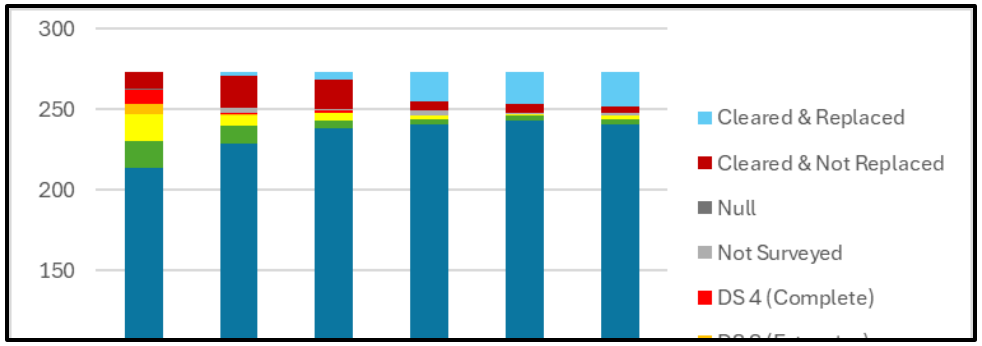

Bremen




Leachville

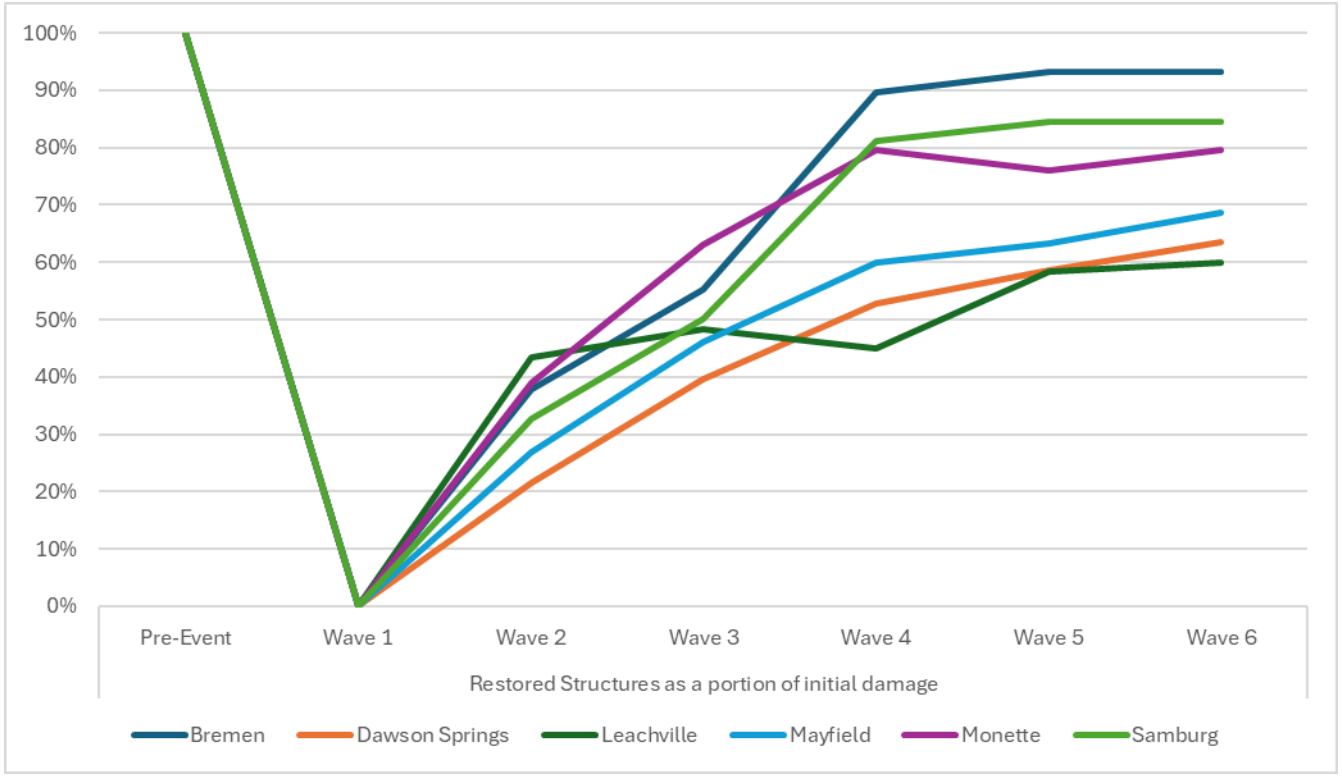



Monette

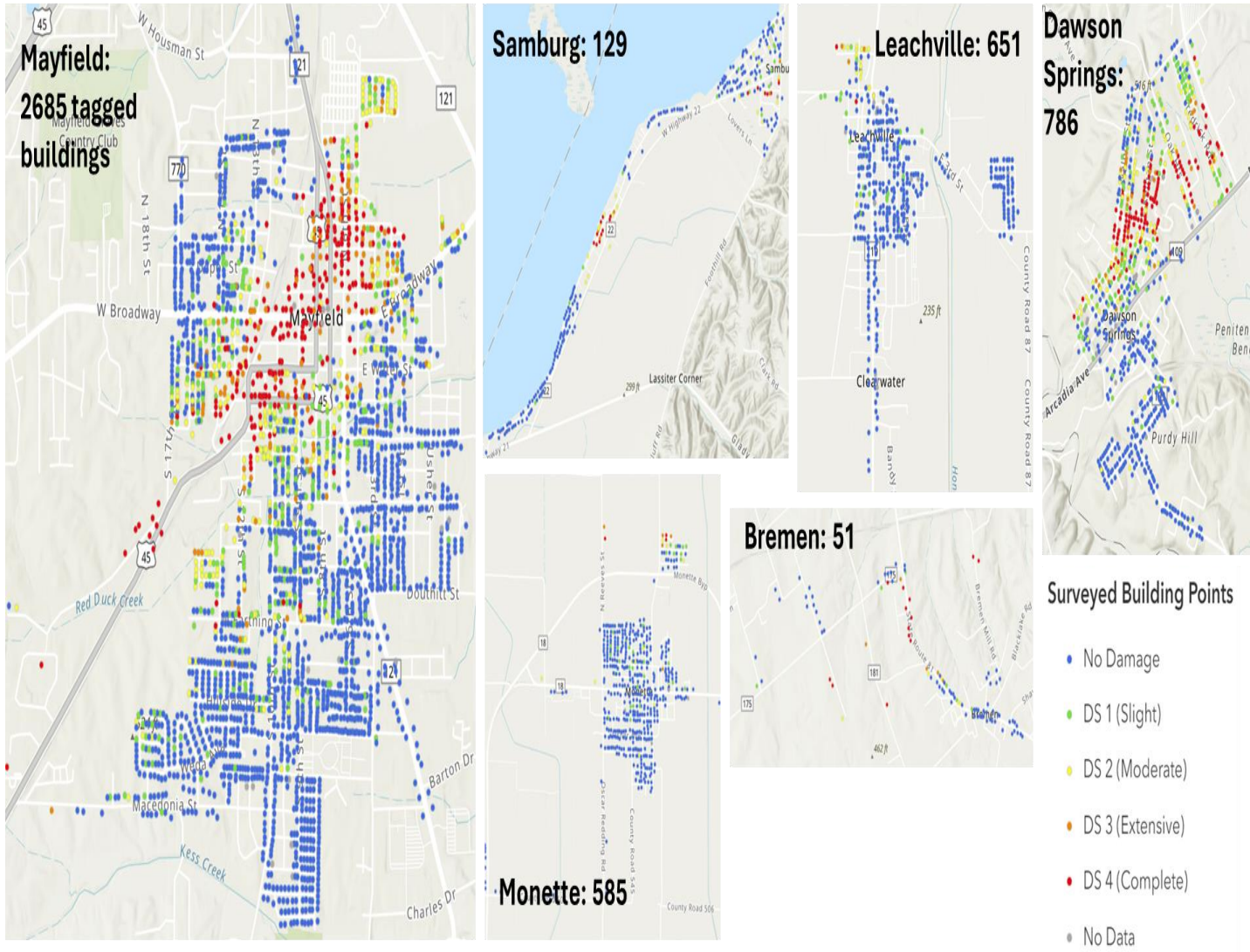



Samburg

# Data Processing – Recovery Trajectory




# Data Implementation



## Paper Plan and Progress

| Paper | Paper Description | Lead | Brief Description of Progress |
|---|---|---|---|
| 1 | Overview of full study | Lisa coordinating progress | Being Revised for Resubmission – Earth's Future |
| 2 | Big Box Buildings | Grace and Trung | Revising and almost ready to submit. |
| 3 | Community Interaction | Grace | Conference Paper from INSPIRE & Journal of Wind Engineering - Still Under Review |
| 4 | Methodology for investigation | Blythe | Accepted at Risk Analysis |
| 5 | Variability in damage and intensity | Thang | Shifted to an image processing paper for damage - now part of paper 8 |
| 6 | Discuss tornado damage indicator | Shane | Blythe will provide data by mid October - provided data 10/7. Augmenting Data by 10/25 |
| 7 | Prediction of recovery | Lisa & Trung | Lisa is speaking at AGU and NHERI Comp Symposium on his topic. Decided to submit to SIE. Due in mid December |
| 8 | AI Damage Assessment (NIST DFS and Tanya) | Robinson - with Grace assisting | Johns Hopkins students working with video AI. Mainly focused on single building right now, but exploring how this could be applied at community-level. Tagging through Natural Language processing. |

## Acknowledgments

We deeply acknowledge the undergraduate student data tagging team for their efforts on the virtual damage and recovery assessment. The team members include Nabila Ahmad, Lourlie Jannah Baniqued, Lindsay Barr, Kate Call, Mallory Glenn, Danielle Lewis, Marianna Medearis, Audrey O'Malley, Anther Oravec, Isadora Savaris, Hannah Shawver, Bridget Wicker, Ethan Young, and Phoenix Ywanciow.