Investigations into Social Vulnerability, Scale, and Hazardous Weather

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Research Context

The Oklahoma Established Program to Stimulate Competitive Research's (EPSCoR) Climate Variability Research program (OIA-1301789) examines whether "socio-ecological systems can adapt sustainably to climate variability"[1] . This research has three objectives:

Establish a Socio-Ecological Observatory
Create an integrated Socio-Ecological Modeling and Prediction System
Design Decision-Support System

The first objective was fulfilled by the creation of an ecologically-focused survey network, the the Meso-Scale Integrated Socio-Geographic Network (M-SISNet). These geo-located households participated in ongoing quarterly surveys in regards to perceived risk and preparation for hazardous weather events, reception of weather warnings during hazards weather, and opinions on climatic variability and its impact on their household[2]. This survey data is crucial to understanding the way Oklahomans react to climate fluctuation and hazardous weather events alike, but does not quantify how vulnerable they would be in the event of a tornado or flood.

Quantification of vulnerability is part of the second objective, the creation of an integrated Socio-Ecological Modeling and Prediction System. This relies on Social Vulnerability Analysis (SVA), a branch of research that examines the relationship between demographics of a region and that regions susceptibility to discrete hazardous events such as a chemical spill or natural disaster[3]. Several different tools have been developed to quantify vulnerability, but the Social Vulnerability Index (SoVI) has become the standard method of SVA. The National Oceanic and Atmospheric Administration (NOAA), the U.S. Army Corps of Engineers, and various state Emergency Management Agencies all use SoVI to measure local vulnerability to hazards.

The SoVI combined twenty-nine demographic variables, mostly collected from the U.S. Census Bureau's American Community Survey[5], which research has identified as impacting an individual's ability to prepare for and respond to a hazardous event. Nationally, the factors found to increase social vulnerability include wealth, race, age, ethnicity, special needs, service sector employment, race, and gender. Initial SoVI research provided an aggregate, nation-wide measure of social vulnerability, regional differences in the measure and how they interact with different types of hazards remains largely unexplored.

Therefore, this research focused on the State of Oklahoma as a more specific region and the use of a hazardous weather events database to compare Oklahoma-specific SoVI results against to investigate whether there is a relationship between particular weather hazards and vulnerable populations. Additionally, this will serve as the foundation onto which the M-SISNet survey data will be projected upon and compared against, examining the difference between Oklahomans' quantified vulnerability and their own perceived vulnerability. This research poster highlights preliminary findings in development of an Oklahoma-specific SoVI and comparison of the SoVI to actual hazardous weather events.

Methodology

The are two datasets required to calculate SoVI for Oklahoma and compare with hazardous weather events. The SoVI data input is produced by the U.S. Census Bureau and made available at the tract and county level, both were analyzed. The weather event data is delivered in a tabular format with some geographic information which required preparation to match the county and tract geographies from Census data. All data presented here is from the 2010 - 2014 American Communities Survey (ACS) data, which overlaps the M-SISNet survey period and is identical to the original, national SoVI[6] time period allowing direct comparison between the two SoVI scales.

SoVI

The preparation of SoVI data mostly consists of acquiring the various ACS data tables specified in The SoVI Recipe[7]. There are a few variables which require simple arithmetic calculations using ACS data. Collation of the various CSV files into a single output, dropping extraneous fields, and calculations were all performed using custom Python scripts. There is a single variable omitted from this research, QHOSPTPC or Percent Hospitals Per Capita, included in the national SoVI due to its residence behind a paywall.

Collected variable data was subjected to a factor analysis. At this step was an opportunity to improve the fit of SoVI analysis to Oklahoma. The final SoVI value is calculated by simply summing factor values, but first the cardinality, or direction of influence on social vulnerability must be decided. For example, the Wealth Factor is negative because increased wealth reduces, or has a negative effect, on vulnerability. Once all relevant factors were assessed for influence, any deemed negative were inverted, and all factors summed to that region's SoVI value.

Figure 1: Comparision of SoVI Factors

National SoVI Components					Oklahoma SoVI Components			
Component	*Cardinality*	*Name*	*% Variance Explained*	*Dominant Variables*	*Cardinality*	*Name*	*% Variance Explained*	*Dominant Variables*
1	-	Wealth	18.8	MHSEVAL QRICH200K MDGRENT	-	Wealth	28.0	QNOHLTH PERCAP QNATAM
2	+	Race & Social Status	15.7	QBLACK QFH QPOVTY	+	Age (Elderly)	18.5	MEDAGE QSSBEN QUNOCCHU
3	+	Age (Elderly)	12.5	MEDAGE QSSBEN QAGEDEP	+	Non English Speaking Minority	9.37	QHISP QESL QASIAN
4	+	Ethnicity & Lack of Health Ins	10.1	QHISP QESL QNOHEALTH	-	Urban Density	7.24	QNRES PPUNIT MHSEVAL
5	+	Special Needs Populations	7.77	QNRRES QHOSPTC PPUNIT	-	Extractive Employment	4.79	QFEMALE QCVLUN QEXTRCT
6	+	Service Sector Employment	5.72	QSERV QFEMLBR QEXTRACT	+	Commuters	3.87	QBLACK QFHH QNOAUTO
7	+	Race (Native American)	5.55	QNATAM	+	Adults No Kids	3.71	QMOHO
8	+	(Female)	4.96	QFEMALE				
		Total Variance Explained	*78.1*				*75.5*	

WEATHER

Weather event data came from the NOAA Storm Events Database. This database contains a partial representation of weather events focused specifically on hazardous events that include "storms and other significant weather phenomena having sufficient intensity to cause loss of life, injuries, significant property damage, and/or disruption to commerce"[7]. It includes twelve discrete hazardous weather events collected by the Mesonet, Emergency Managers, Local Officials, Social Media, Utility Companies, Park Managers, Broadcast Stations, Police, Fire and Rescue Responders, Forest Service Personnel, National Weather Service Observations, Amateur Radio, Trained Spotters, and Storm Chasers. These report locations have been coded as area, line, or point geometry and either coordinates or a FIPS code identifier. For the county level analysis, only the line geometry required division to conform to county shapefiles from the Census. Damages, injuries, and deaths for line events types were then assigned to the line fragments based on their proportion of total line length. At the tract level the division of lines by Census tract shapefile and proportional allocation was also completed.

SoVI maps at the county and tract level were mapped along with the most common weather hazards as part of exploratory data analysis. Selected counties presenting interesting case studies are presented here.

Comparison Between National and Oklahoma SoVI

Fig. 2a: Oklahoma's National SoVI by County

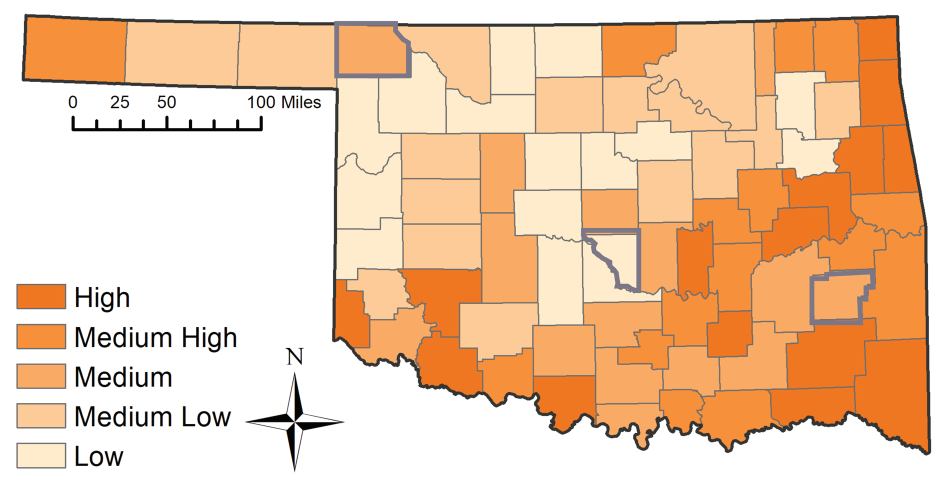
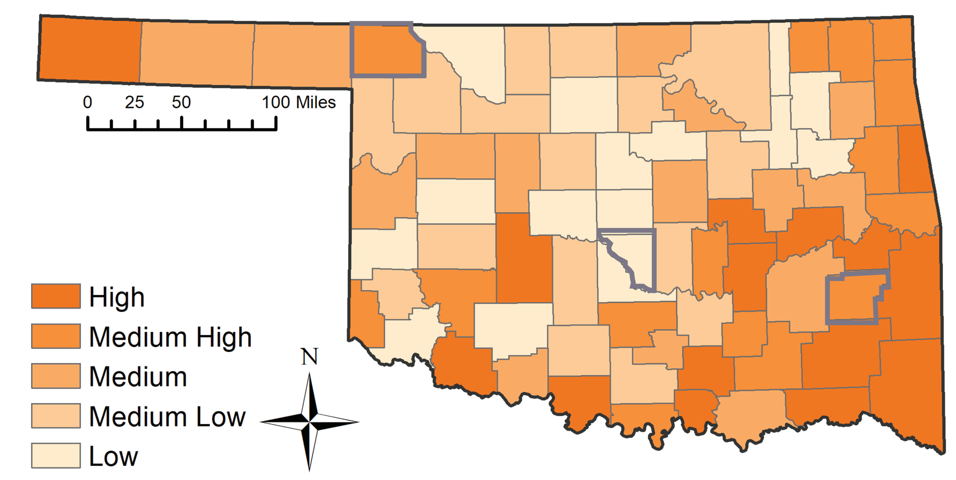


Fig. 2b: Oklahoma SoVI by County



Figures 2a and 2b show that the national SoVI ranking for Oklahoma counties varied from the SoVI ranking based only on Oklahoma. The state SoVI showed increased vulnerability in the western part of the state and less in urban areas, but overall each region was similar between the two methods. The national SoVI showing increased vulnerability in the south and east part of the state and the Oklahoma SoVI indicating the northeast as less than High vulnerable. Harper, Pushmataha, and Choctaw counties were categorized as the same level of vulnerability in both methods. The average difference between national and Oklahoma SoVI values was only 0.4%, with a maximum difference of 10%.

Comparision of Tract-level SoVI to County

Figures 3a, 3b, and 3c show three counties across the state broken down by SoVI at the tract level. The rural character of Oklahoma can be clearly seen in Harper and Pushmataha's low tract count and their large size. The tract map of Cleveland County's SoVI includes more, smaller tracts, and shows the difficulty in aggregations of vulnerability to the county scale. There are regions of high and low social vulnerability contained within Cleveland County, even though it is ranked Low when taken as a whole. This is in contrast to Pushmataha County's homogeneity, with all three tracts in the same quintile. At the tract scale, additional granularity can be seen in SoVI results.

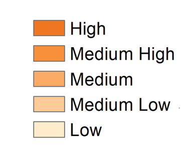


Figure 3a: Harper County SoVI by Tract

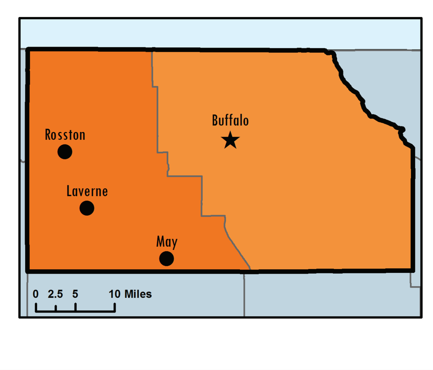


Figure 3b: Cleveland County SoVI by Tract

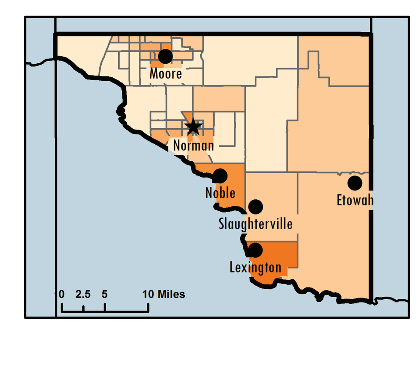
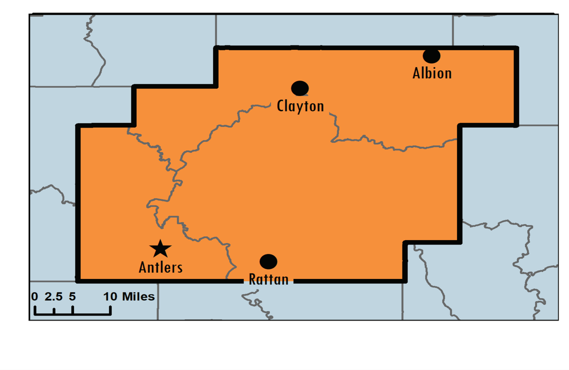


Figure 3c: Pushmataha County SoVI by Tract



Weather Events: Spatial and Temporal Scales

Mapping selected hazardous weather events reports along with selected city points in Figure Series 4 clearly shows there is bias towards populated areas for reports, as expected. This map series highlights two features per map, the most prevalent point event as the background, and tracts of a selected line event on top. The most frequently reported point hazardous weather event was Hail. A raster image map representing the density of Hail event reports across the state forms the background image. Over this, selected line events are represented, depending on which event was reported most often in the county.

Due to variability in the area of counties, Figure Series 5 displays event reports normalized by county area. Even normalized, Hail and Thunderstorm Wind are the most frequently reported hazardous weather events.

The quantity of hazardous weather event reports is not necessarily indicative of the relative danger to populations. Figure Series 6 compares report frequency with either property damages or the aggregate of injuries and deaths. In Harper County, only Thunderstorm Wind led to damage reports even though there were almost as many Hail reports. Cleveland County suffered massive damages due to an EF5 Tornado, but second highest total damage was Hail. Although Hail was second in damages, no deaths or injuries were reported. Pushmataha also shows Hail, Thunderstorm Winds, and Tornados with high reports and high damages. However, the most property damage came from a single Ice Storm.

In addition to spatial variability, there is apparent temporal variability in the types of hazardous storm events that Emergency Managers should be prepared to face. Figure Series 7 has meteorological seasons color coded in the outer band, the most common report type color-coded in the pie, and the percentage this event was reported.

Figure 4a: Harper County SoVI by Tract

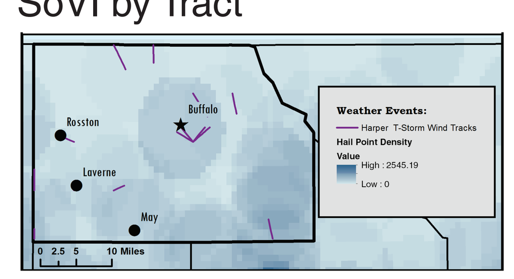


Figure 4b: Cleveland County SoVI by Tract

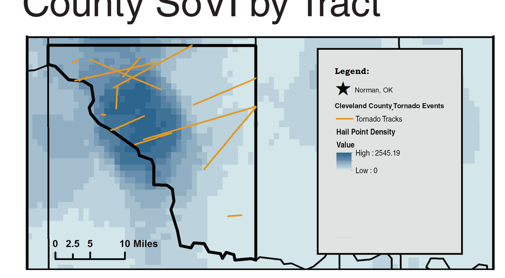


Figure 4c: Pushmataha County SoVI by Tract

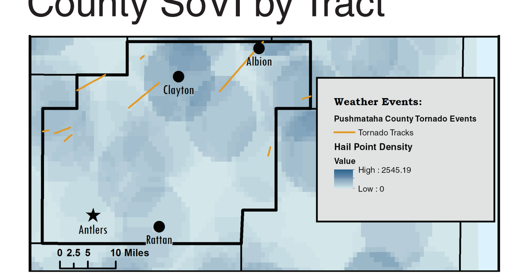


Figure 5a: Harper County Event Reports (#/km²)

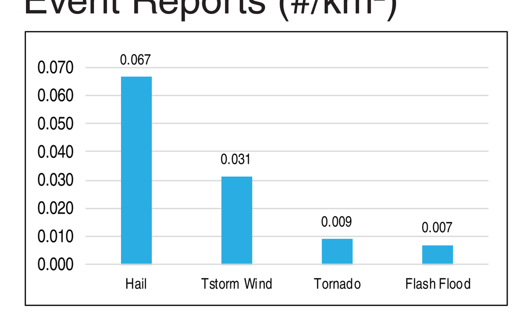


Figure 5b: Cleveland County Event Reports (#/km²)

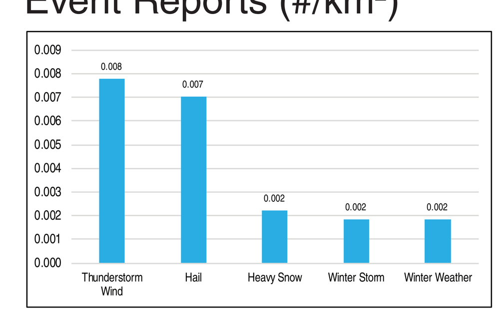


Figure 5c: Pushmataha County Event Reports (#/km²)

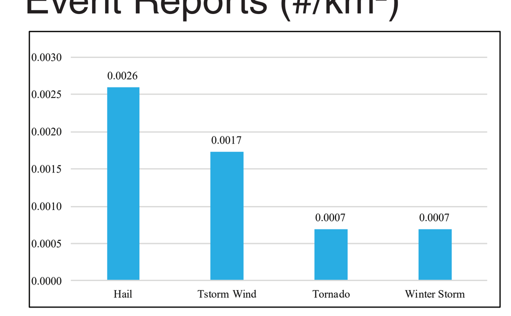


Figure 6a: Harper County Reports vs Damages

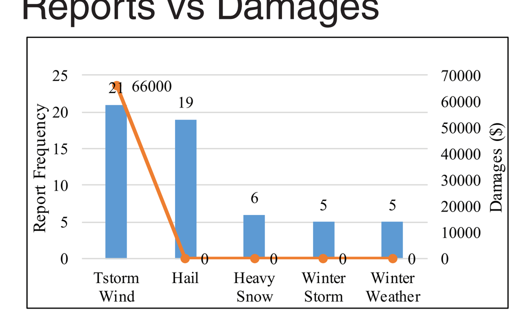


Figure 6b: Cleveland County Damages vs Harm

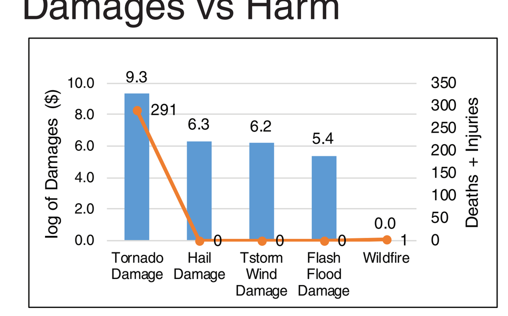


Figure 6c: Pushmataha County Reports vs Damages

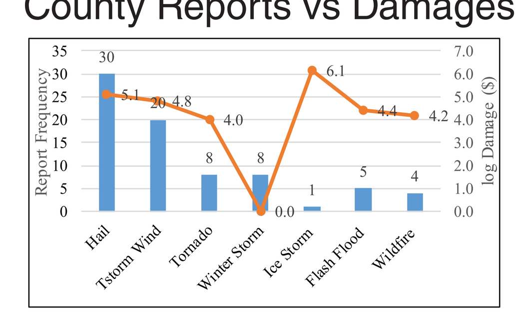


Figure 7a: Harper County Top Event Report By Month

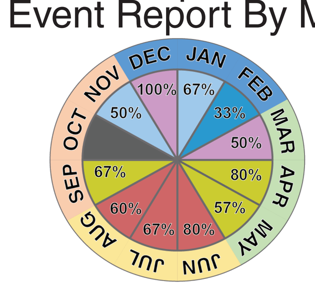


Figure 7b: Cleveland Top Event Report By Month

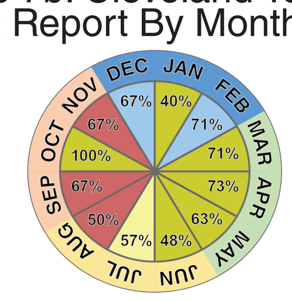
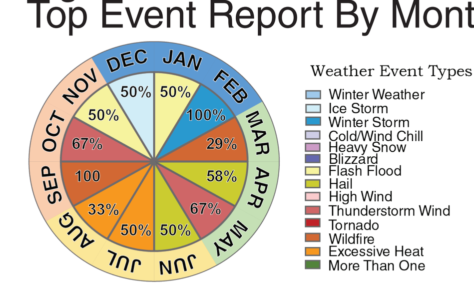


Figure 7c: Pushmataha County Top Event Report By Month



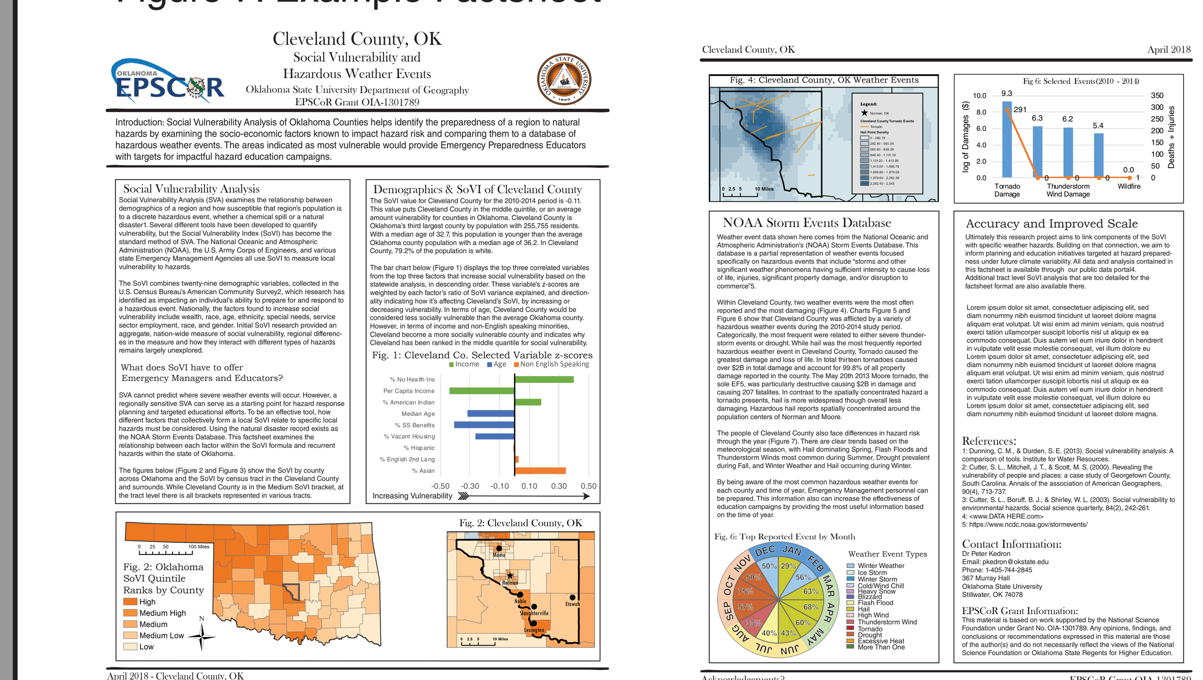
Discussion

The initial mapping of hazardous weather event reports from NOAA's Storm Events Database and Oklahoma-centric SoVI results is nearly complete. The factor analysis and comparison between the national SoVI and Oklahoma SoVI components (see Figure 1) indicate that similar factors influence both SoVI. It is interesting to note that this despite sometimes different dominant variables, and sometimes variables appearing in other factors, the overall top factors were still attributable to Wealth, Old Age, and aspects of being Hispanic and/or a Minority. Overall, only seven factors were chosen as important for Oklahoma SoVI, with 75.5% of variance explained, which is comparable to the national SoVI's eight factors explaining 78.1% of the variance. It also seems more attuned to Oklahoma in terms of the factors driven by Extractive Employment and Suburban Commuters.

Comparisons between the national and Oklahoma SoVI at the county level will require additional statistical analyses. It will be interesting to investigate whether the national SoVI accurately estimate social vulnerability when compared to the hazardous weather event database values for death, injures, and property damage. The value gained from extending SoVI analysis to the tract-level is apparent when compared to the county aggregates (Figures 3). The variability between the resolutions in an urban county is apparent in Cleveland County, and rural counties have been seen as homogenous or varied. Development of this better resolution, more sensitive SoVI can serve as a starting point for hazard response planning and targeted educational efforts.

These products are only part of one output in pursuit of quantification of vulnerability as the basis of an integrated Socio-Ecological Modeling and Prediction System. These figures, charts, and maps exploring each county and major metropolitan area are being collected along with analysis into factsheets targeting Emergency Managers and Educators (Figure 7). These factsheet are to be shared online, along with the Oklahoma SoVI Rankings for each county and tract. The development of additional tools to analyze SoVI with hazardous events displayed are longer-term plans.

Figure 7: Example Factsheet



Expected Output

County Factsheets
Oklahoma SoVI by County
Oklahoma SoVI by Tract
Both SoVI data available online
SoVI and Hazardous Event Viewer

References

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7: https://www.ncdc.noaa.gov/stormevents/

Acknowledgments

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