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Characterizing Social Vulnerability: a NFIE Integration

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Introduction

Social vulnerability is often referred to as, "the resilience of communities when confronted by external stresses on human health, stresses such as natural or human-caused disasters, or disease outbreaks" (ATSDR). Social vulnerability can be viewed on a variety of different levels, from lacking a vehicle to evacuate a property during a hazardous event, to a disabled individual needing additional resources and assistance after a flood event. Socially vulnerable factors like these can reduce a community's ability to decrease human suffering or financial loss in the event of a disaster. Social vulnerability can also be described within the context of risk:

$$\text{Risk} = \text{Hazard}*(\text{Vulnerability} - \text{Resources})$$

Where risk is the expectation of loss, hazard is an incident posing harm, vulnerability is the extent a person is likely to be affected and resources are assets that reduce said hazards (Flanagan et al. 2011).

One of the main objectives of the National Flood Interoperability Experiment's Response portion (NFIE Response) as defined by Harry Evans is to, "prioritize… population groups that are at a high risk" (2015). In the context of a flood event there are different ways to characterize vulnerability. If your property is within the FEMA 100-year floodplain you could having a geographic vulnerability. If a household has limited financial resources to recover after a flooding event, it would be considered a social vulnerability. These two vulnerabilities are not mutually exclusive and can allow further classification of overall vulnerability.

This report will highlight methods for integrating the Social Vulnerability Index (SVI) into the scope of the NFIE Response, providing resources for its use within the Emergency Response Community. Additionally, this report will introduce a tool to estimate pet populations spatially, which could be used by the Emergency Response Community.

Social Vulnerability Index

Developed by Susan Cutter from the University of South Carolina, the Social Vulnerability Index (SVI) is a "tool to help emergency response planners and public health officials identify and map the communities that will most likely need support before, during, and after a hazardous event" (ATSDR). This mapping tool service is provided through the Center for Disease Control, by the Agency for Toxic Substances and Disease Registry (ATSDR). A link to the main SVI page can be found here http://svi.cdc.gov.

The SVI mapping tool is based on the 2010 or 2000 U.S. Census data, on the scale of the *census tract*. The *census tracks* are small divisions of a county that are demographically homogenous and contain anywhere from 1,200 to 6,000 people, with the ideal size of 4,000 people. *Census track* boundaries normally follow visible and identifiable features and are meant to have consistent boundaries over long time periods to allow long-term statistical comparisons between *census tracts* (U.S. Census Bureau). Figure 1 outlines the geographic hierarchy of the US Census.

Figure 1: U.S. Census Geographic Hierarchy (Source: United States Census Bureau)

The SVI mapping tool contains 4 themes and 1 overall ranking of vulnerability. Fourteen census variables are compiled between the 4 themes. Those 4 themes are then averaged into the overall ranking of vulnerability. Each theme and a description are listed as follows:

- **Socioeconomic Status**: income, poverty, employment and education variables. Economically disadvantaged populations, with less assets, are often less capable to prepare or recover from a disaster and can be disproportionately affected by them.
- **Household Composition/Disability**: age, single parenting, and disability variables. The elderly, dependent children or disabled individuals may be more likely to need further support for transportation, medical care or normal activities during a disaster.
- **Minority Status/Language:** race, ethnicity, and English language proficiency variables. African Americans, Native Americans, and populations of Asian, Pacific Islander, or Hispanic origin have been correlated with higher vulnerability rates (Cutter et al. 2003; Elliot and Pais 2006).
- **Housing/Transportation:** housing structure, crowding, and vehicle access variables. Housing quality and density are of particular concern during evacuations and combined with low automobile ownership increases vulnerability in a disaster zone. Dormitories and prisons are also of concern due to specific precautions potentially needed for evacuations.

(Flanagan et al. 2011)

Each of the variables was ranked from highest to lowest (except for the income variable, which was ranked from lowest to highest) for each *census track.* A percentile ranking was then generated for all the *census tracks* within a particular region (US or a specific State):

$$Percentile\ Rank = (Rank - 1)/(N-1)$$

Averaging the percentile rank of each theme for a particular *census track* developed the overall percentile rank. If a *census track* is in the 90^{th} percentile (0.90 ranking) for the socioeconomic theme, then 90 percent of the *census tracks* were either below or equal to that particular *census track* in regards to socioeconomic vulnerability.

Social Vulnerability Index & NFIE

There are a variety of ways to represent the SVI within the NFIE Geo or NFIE Response. SVI map layers that can be viewed and manipulated in ArcGIS or other mapping services. Map layers can be found through the Center for Disease Control (CDC) located here http://svi.cdc.gov/SVIDataToolsDownload.html. Figure 2 is a map of the Socioeconomic Theme for Travis County, Texas. The Travis County boundary is outlined in brown.

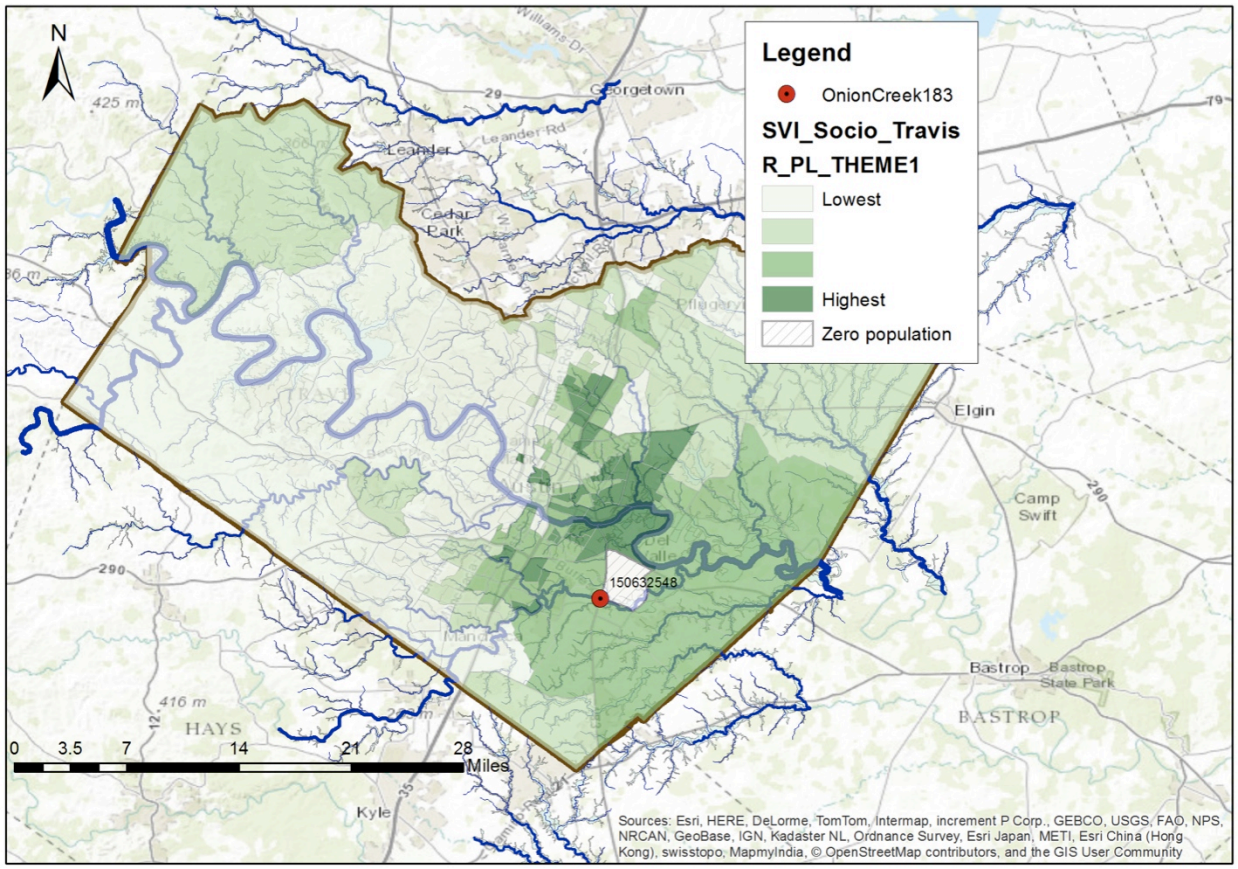


Figure 2: Socioeconomic Theme, Travis County, Texas

The darker shades of green indicate more socioeconomic vulnerability (higher percentile ranking) where the lighter shades indicate less socioeconomic vulnerability (lower percentile ranking). The empty box (near the red dot) is the Austin-Bergstrom International Airport, where there is zero population. The red dot is the Onion Creek at Highway 183 stream gage location. Additional layers such as critical infrastructure (hospitals, schools, water treatment plants, etc.) can be added depending on intended purpose.

Another way to view the SVI is to associate it with address points that are within the FEMA 100-year floodplain. Figure 3 shows nearly 10,000 address points in Travis County that are all within the FEMA 100-year floodplain. Address points are represented based on the overall vulnerability ranking or could be customized for a specific SVI theme.

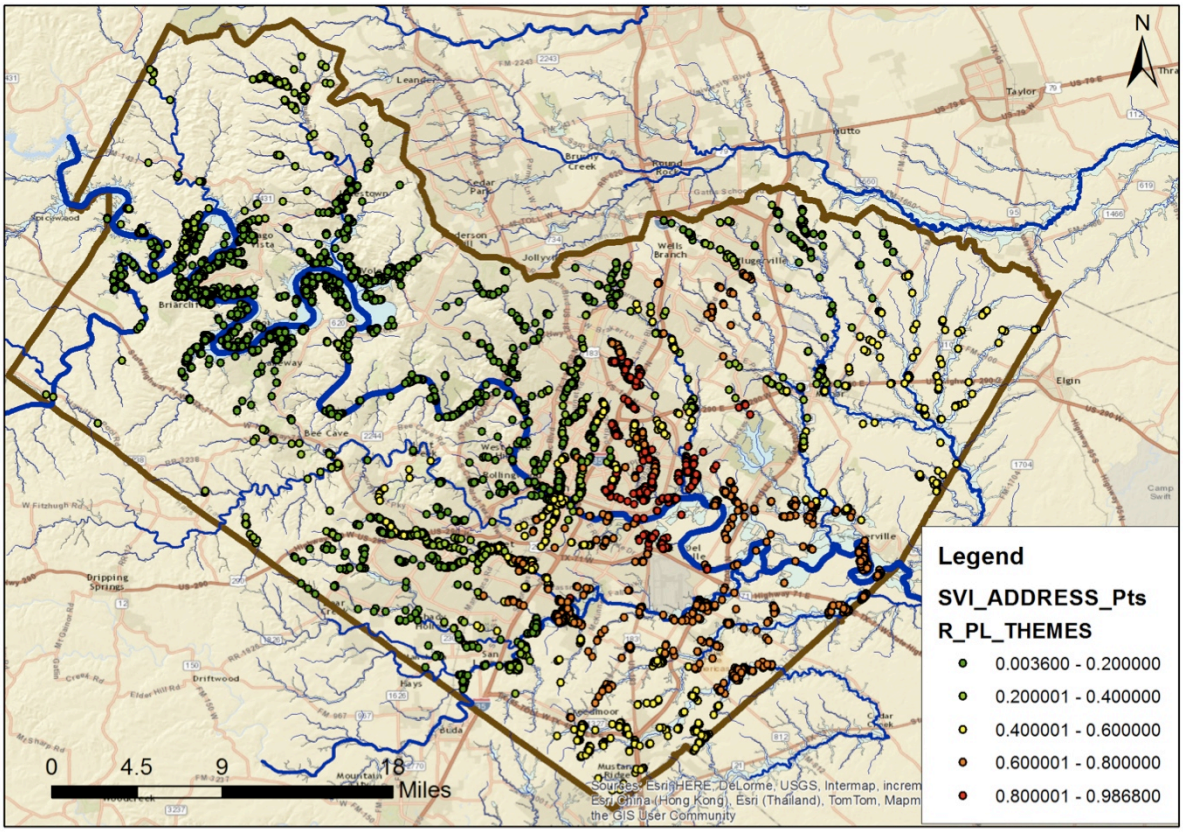


Figure 3: SVI Address Points within FEMA 100-year Floodplain

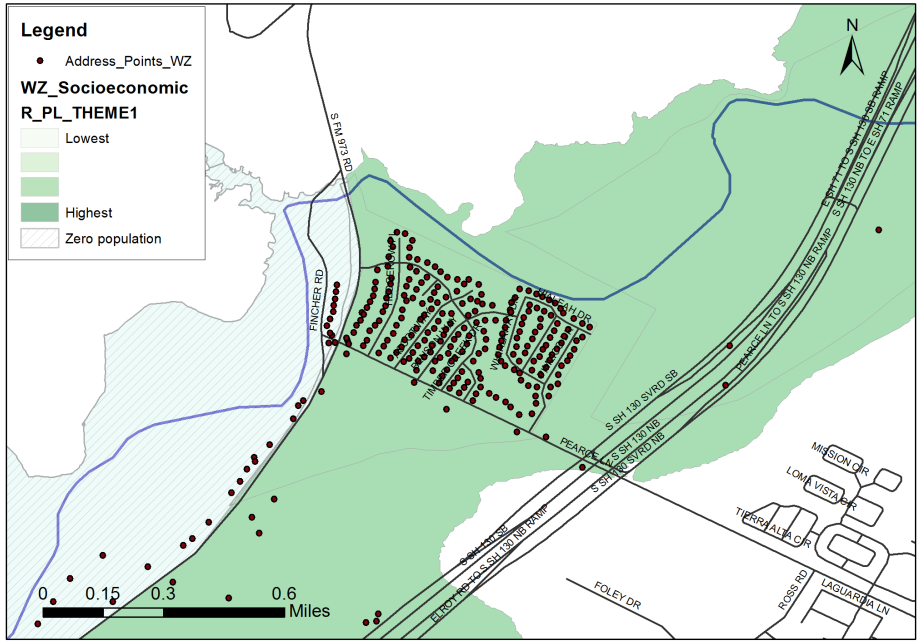
This map provides a new metric to analyze a composite of social and geographic vulnerability. Now one can narrow down 10,000 address points to 700 that are in the 90th percentile for social vulnerability.

The Onion Creek Halloween Flood & SVI

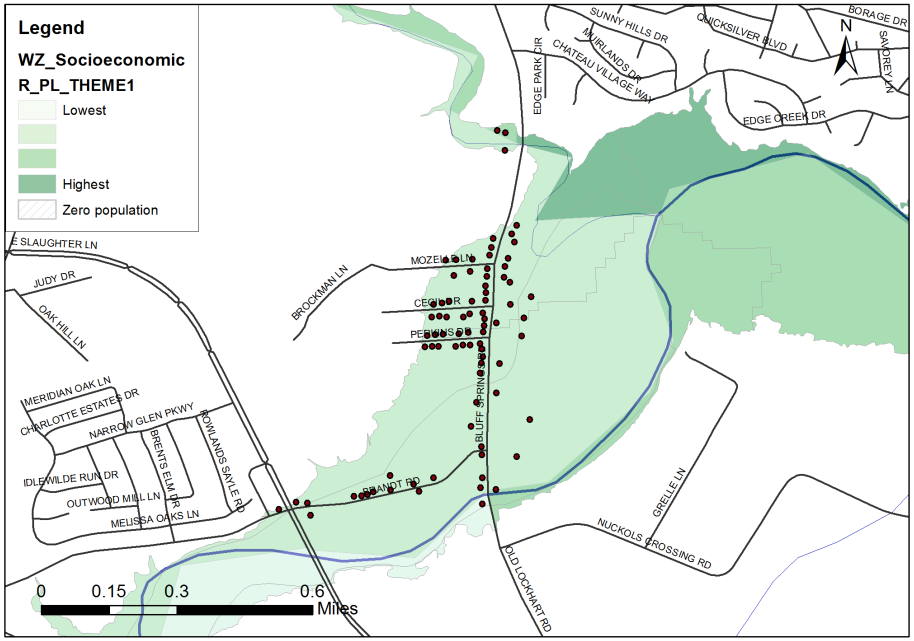
An analysis was conducted using the SVI with the 2013 Halloween flood in Travis County, Texas. The 4 SVI themes and overall ranking was collection for each of the 4 Incident Command Centers (ICC) areas within Travis County where flooding and evacuations occurred. ICC areas and flood statistics were collected from the Austin Fire Department's After-Action Report (2013). Travis County address points and roads were added to the map for spatial context and accessed through the City of Austin website, located at ftp://ftp.ci.austin.tx.us/GIS-Data/Regional/coa_gis.html. Figure 4 shows the 4 ICC areas and the Socioeconomic Theme, which was intersected by the FEMA 100-year floodplain (or Warning Zone in NFIE Geo).

S. Pleasant Valley Area

Pearce & I-130 Area



Bluff Springs Area



Pinehurst Area

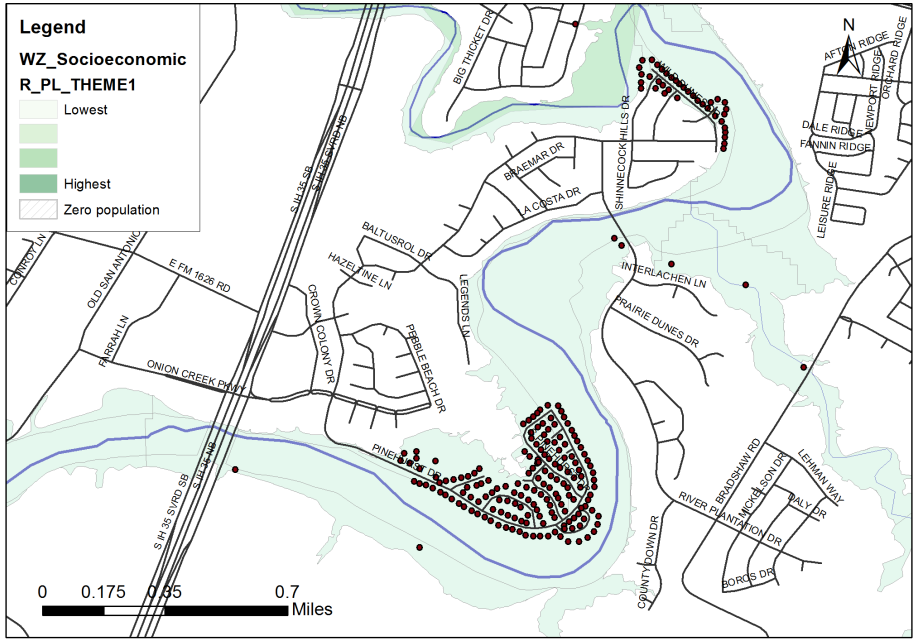


Figure 4: ICC Areas For Halloween Flood of 2013

Figure 5 shows the SVI rankings for the 4 ICC areas. Each theme's rankings are quite unique compared to each other. The overall percentile ranking shows the most social vulnerable area as S. Pleasant Valley, then Pearce & I-130.

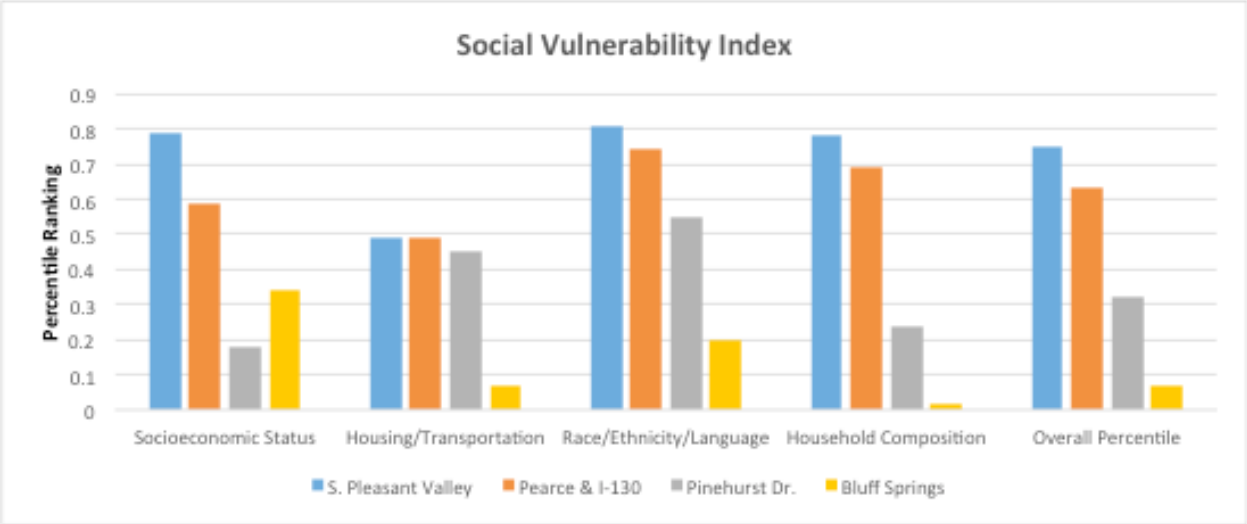


Figure 5: SVI Rankings for the Halloween Flood's ICC Areas

Table 1 explores the potential connection between social vulnerability and percent of the community that needed evacuation. Using rescue statistics from the Austin Fire Department's After Action Report (2013) a comparison was made between high social vulnerability and percentage of people rescued in each community. Since there was not accurate data on flood inundation levels it was assumed that the entire FEMA 100-year floodplain was inundated and all the households were evacuated. Local household sizes for each census tract were used to compare households/address points in the FEMA 100-year floodplain to percent of community rescued.

Table 1: SVI & Rescue Statistics Comparison

Region	Overall SVI Percentile	Households in Floodplain	People Rescued	% People Rescued
S. Pleasant Valley	0.75	886	169	5.4
Pearce & I-130	0.63	236	45	5.6
Pinehurst Dr.	0.32	163	15	4.0
Bluff Springs	0.07	79	117	85.6

No correlation was noticed except for the average percent of community that was rescued at around 5%. Bluff Springs was the anomaly in this table and further investigation into assumptions is needed. If more information on flood inundation levels were available a more accurate estimation of households affected by the flood could be used to revise statistics. Additionally, a person rescued is not the sole metric that could be compared with the SVI, but was the only one available for this flood. Other numbers such as resources or personal dispatched during and after an event could be used to compare with the SVI.

SVI & Emergency Response Community

The SVI and stated figures are a potential resource for the Emergency Response Community (ERC). The ERC could use the SVI to more accurately allocate resources or personal if multiple regions are being inundated from a single flood event. If a city or county uses flood awareness education the SVI can help determine which communities could benefit the most from educational initiatives.

Individual SVI themes can be utilized on a more specific level for allocation of resources or personal during a flood event. Comparing rankings of the Minority/Language Theme may allow an emergency manager to better utilize bi-lingual staff members during or after a flood event. Additionally, the Household Composition Theme may be used to better allocate resources for disabled individuals who may need increased assistance.

Pet Geospatial Data

A pet is often viewed as a member of the family and emergency responders frequently interact with pets during and after disaster events. No resources appear to be available for the emergency response community to plan for and estimate pet populations spatially. The development of this resource is explained in this section.

The American Veterinary Medical Association publishes the U.S. Pet Ownership and Demographic Sourcebook (2011). This sourcebook has a variety of statistics based on type of pet (dog, cat, bird, horse, etc.) and pet populations based on a variety of factors such as household income or house size (Table 2).

Table 2: Texas Pet Demographics

Texas Demographics	Units	Dogs	Cats
Average Number of Pets Per Household - Texas	Number	1.8	2.2
Average Percentage of Pet Owners - Texas	Percentage	44.0	28.3
Households owning pets by annual household income			
Under $20,000	Percent	34.5	34.1
$20,000 to $34,999	Percent	40.0	36.8
$35,000 to $54,999	Percent	42.4	35.6
$55,000 to $84,999	Percent	43.8	34.0
$85,000 and over	Percent	43.9	31.7
Households that own pets by household size			
One member	Percent	26.8	29.8
Two member	Percent	40.1	34.6
Three member	Percent	50.0	38.3
Four member	Percent	53.7	34.9
Five or more member	Percent	54.2	38.1
Community Size			
Less than 100,000	Percent	50.4	41.5
100,000 to 499,999	Percent	44.4	37.0
500,000 to 1,999,999	Percent	42.1	34.0
2,000,000 or more	Percent	37.4	31.6
Source: U.S. Pet Ownership & Demographic Sourcebook, 2011			

This data was used to create a statistical averaged number of dogs or cats per household (Equation 1). A variety of statistics could be integrated and assigned its own unique weight, as long as $\sum_{i=1}^{n} w_i = 1$.

Equation 1: Number of Dogs per Household

$$\begin{aligned} &\#\ Dogs\ per\ HH \\ &= w_1[\%\ of\ HH\ with\ dogs, s.t. HH\ income][Average\ \#Dogs\ per\ HH, Texas\ ] \\ &+ w_2[\%\ of\ HH\ with\ dogs, s.t. HH\ size][Average\ \#Dogs\ Dogs\ per\ HH, Texas\ ] + \cdots \end{aligned}$$

[s.t. = Subject To]

These statistics were joined to the US Census 2013 American Community Survey data at the *block group* level. The *block group* level is a smaller division than the *census track* level and has between 600 to 3,000 people. Once these statistics were joined to the US Census block group level data, map layers could be generated for dogs and cats (Figure 6 & 7).

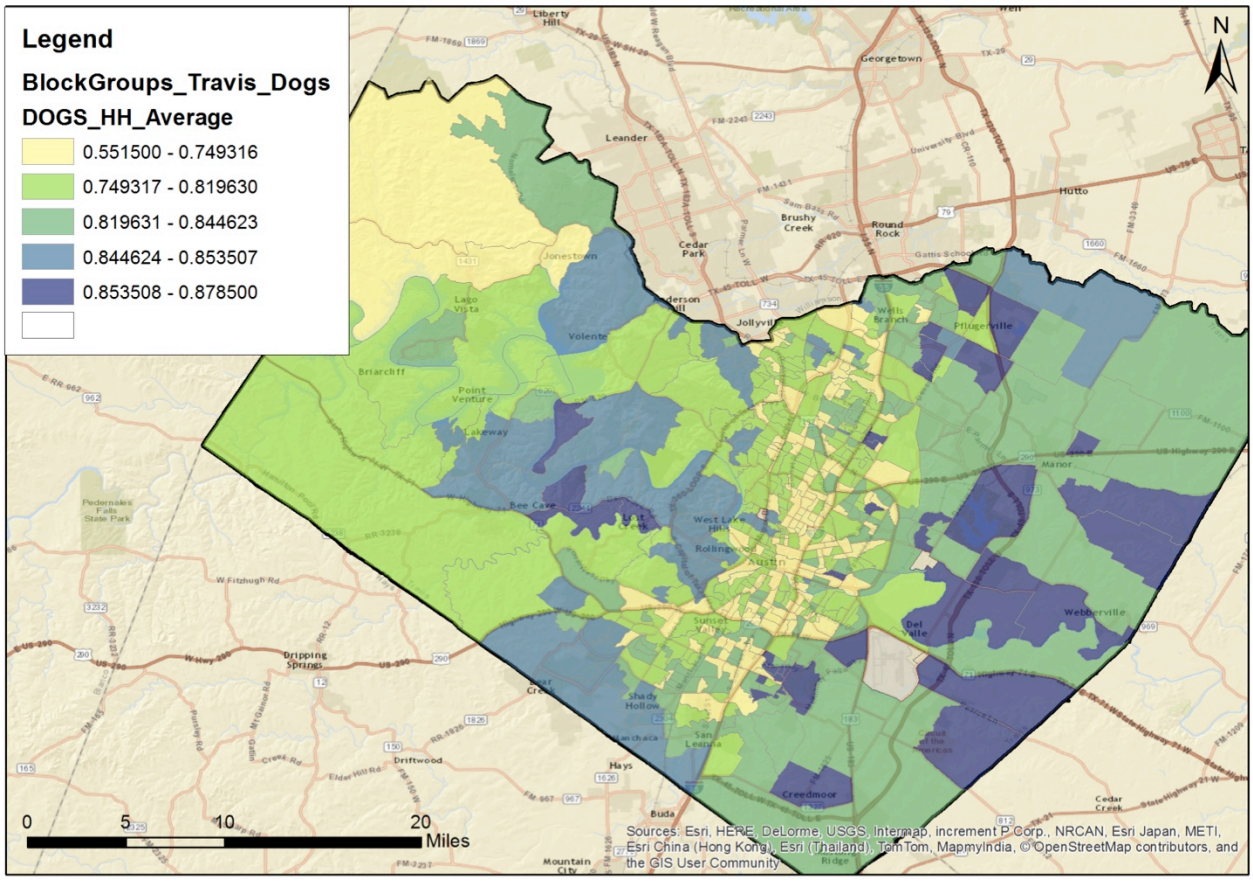


Figure 6: Average Number of Dogs per Household for Travis County

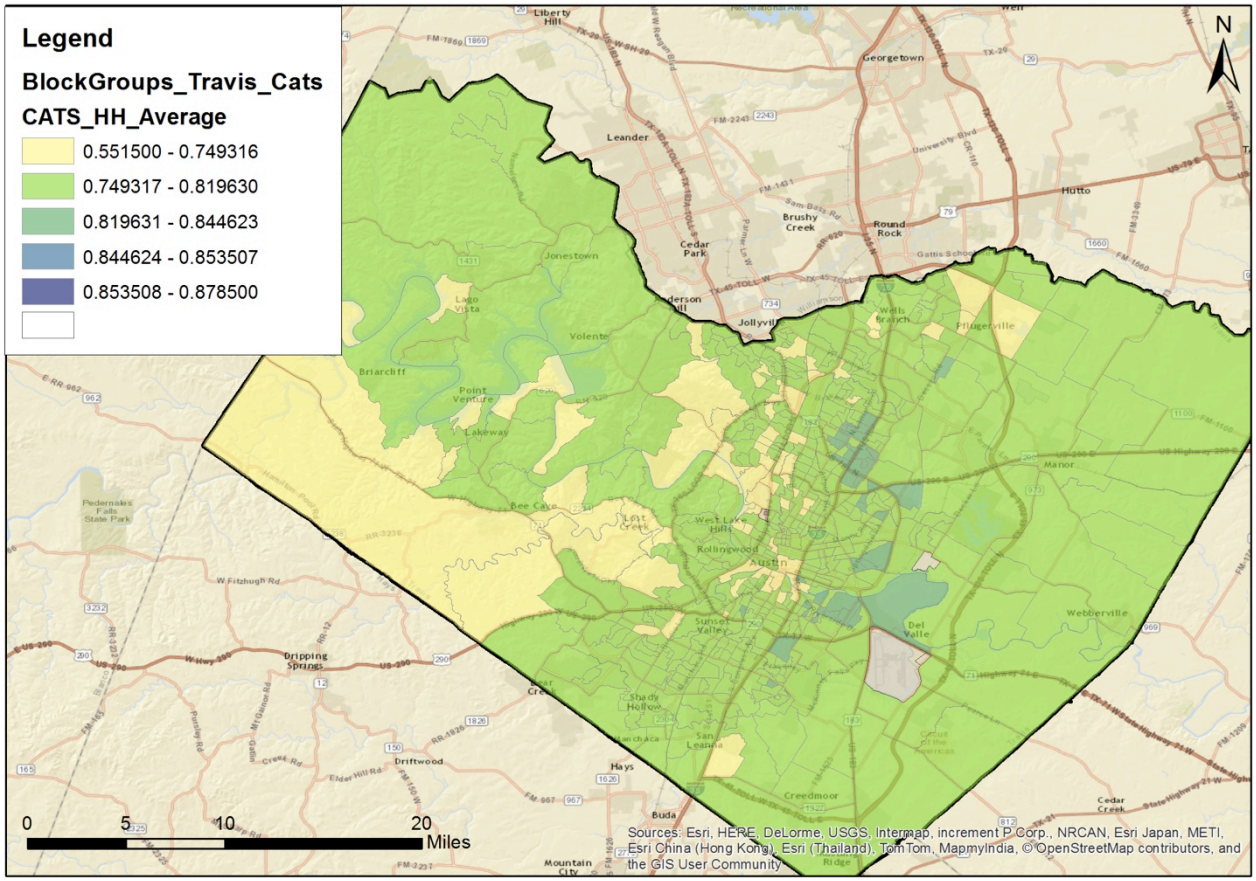


Figure 7: Average Number of Cats per Household for Travis County

Initially, the community size statistic (Table 2) was also incorporated into the overall average but the results decreased variability within dog and cats numbers for each block group. Figure 6 & 7 only use the household income and household size statistics.

Figure 8 & 9 are additional ways to represent dog and cat populations by address points within the FEMA 100-year floodplain. It summarizes the data to local regions where pet population information would be most needed during a flood event.

Similar to the SVI, these resources were compared to the 2013 Onion Creek Halloween Flood's statistics on numbers of animals rescued (Table 3).

Table 3: Dogs/Cats Rescue Statistics during the 2013 Halloween Flood

Region	Dogs per HH	Cats per HH	Pets Rescued	Households in Floodplain	% of Household Pets Rescued
S. Pleasant Valley	0.84	0.8	>10	886	0.7
Pearce & I-130	0.88	0.76	2	236	0.5
Pinehurst Dr.	0.76	0.73	No Data	163	-
Bluff Springs	0.74	0.77	24	79	20.1

Similar to Table 2 there seems to be little correlation which may be attributed to a variety of assumptions that were made due to lack of accurate data from the Halloween Flood's statistics or pet number maps.

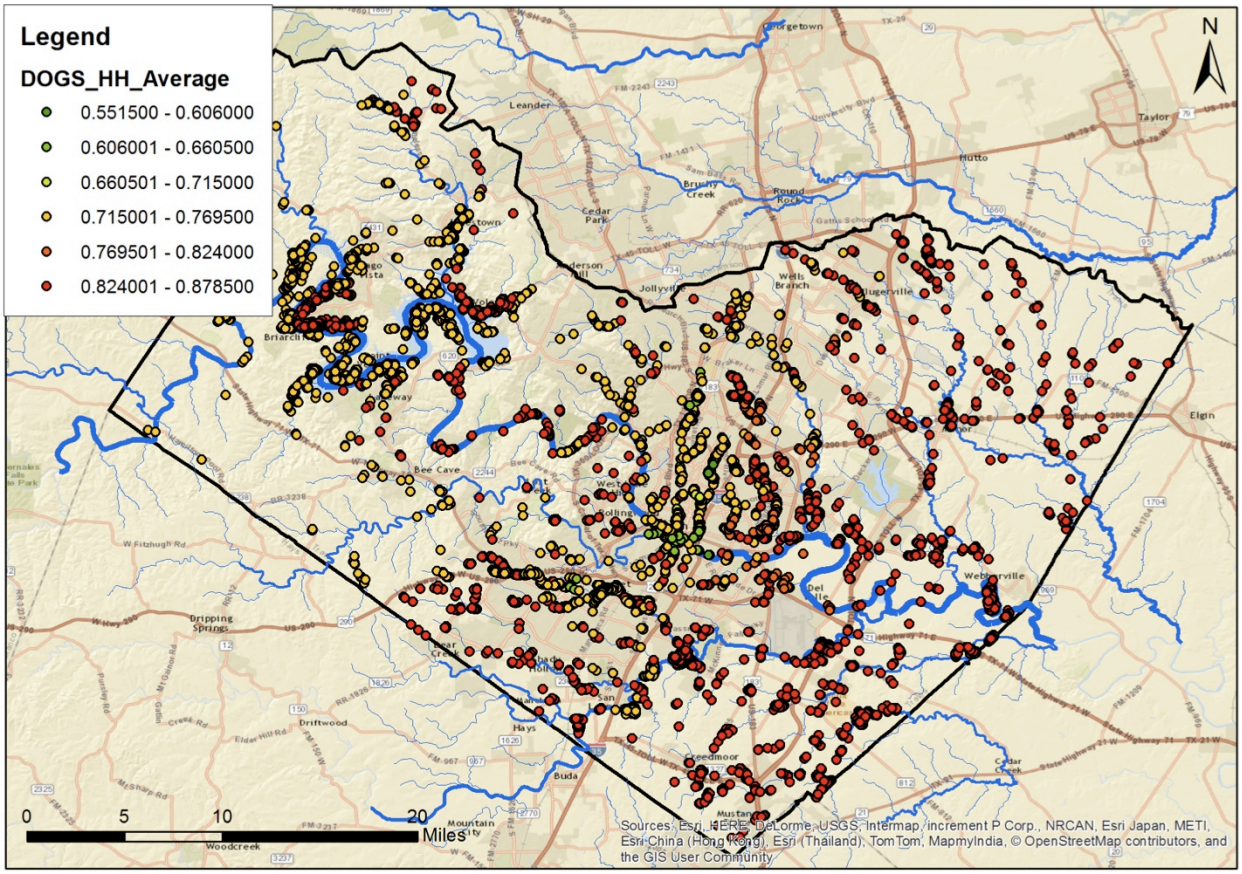


Figure 8: Number of Dogs per Household within 100-year Floodplain

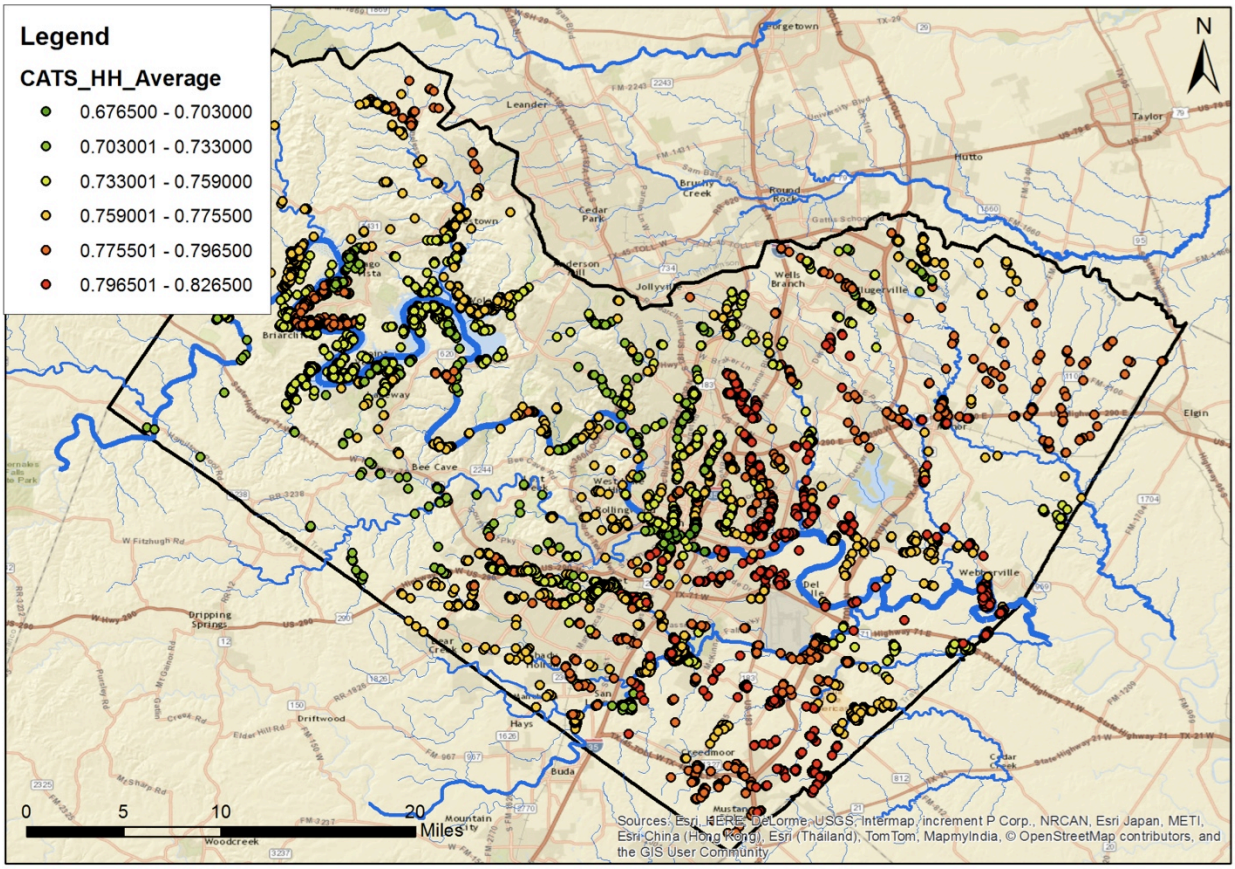


Figure 9: Number of Cats per Household within 100-year Floodplain

Pet Populations & Emergency Response Community

With pet population sizes on the *block group* level, emergency managers could estimate the number of pets that would also need to be evacuated if a household is evacuated. If 100 homes were flooded in Travis County there could be anywhere from 55 to 90 dogs, depending on the area, to evacuate as well. Knowing these general pet population numbers may allow emergency managers to better allocate personal or resources according to pet numbers.

Conclusions

The Social Vulnerability Index (SVI) can be an important tool for flood planning and response, and characterizing risk. The SVI can be easily incorporated into existing maps or combined with address points within the FEMA 100-year floodplain. The emergency response community could use this resource to better allocate resources and personal during or after a flood or disaster event.

An analysis was performed with people rescued from the 2013 Halloween Flood and the SVI. There was no clear correlation between numbers of people rescued and social vulnerability. An average of 5% of the community was evacuated for 3 out of the 4 ICC areas during the flood event.

Emergency responders frequently interact with pets during and after disaster events yet no clear resources appear to be available to estimate pet populations spatially. Maps showing number of dogs or cats per household were developed for Travis County, Texas based on statistics from the U.S. Pet Ownership and Demographic Sourcebook and U.S. Census block group level data. With geospatial data on pet populations the emergency response community could better plan and allocate resources during or after a flood or disaster event.

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