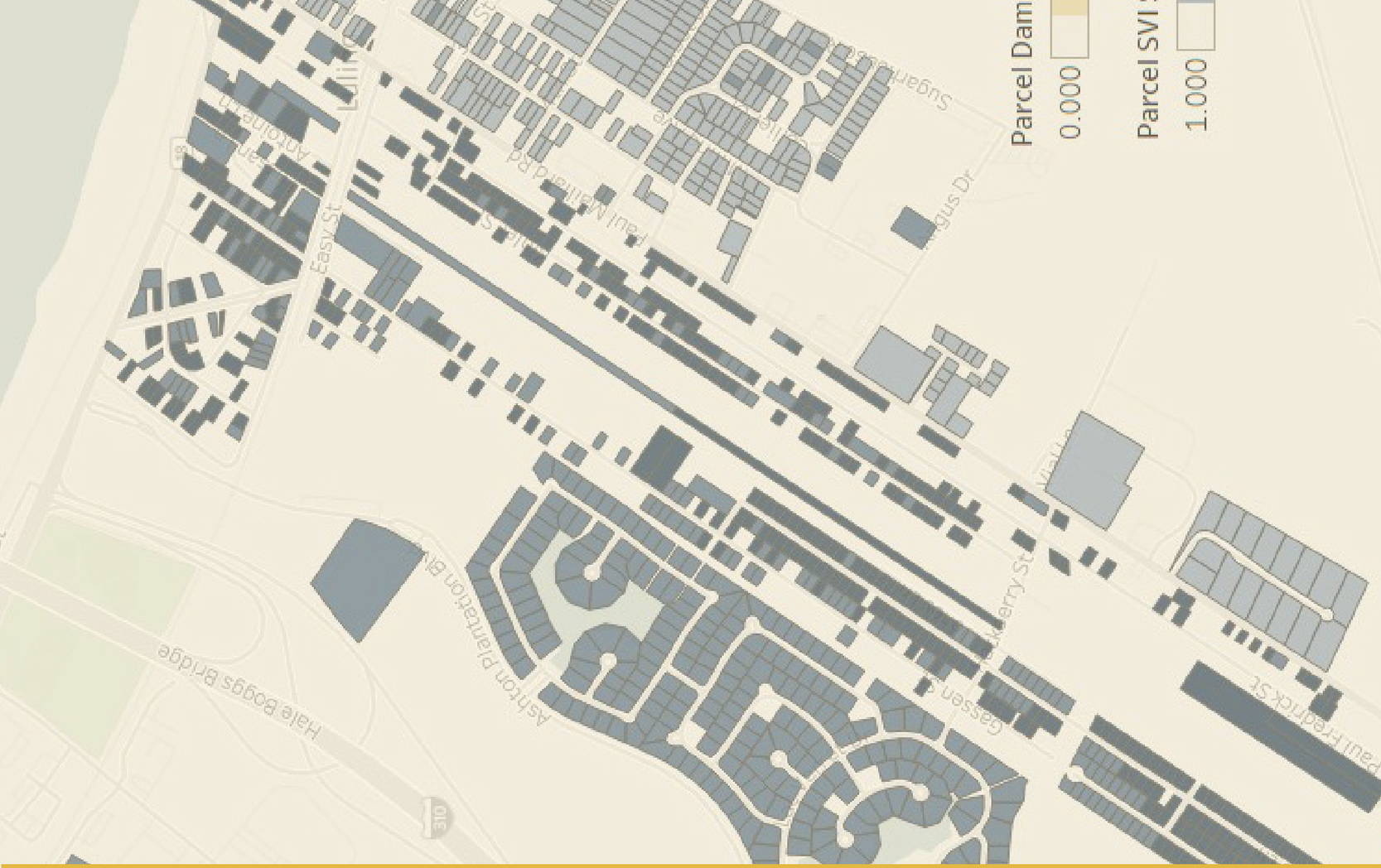


working paper series: rSVI

rSVI

recovery social vulneriability index

5.1 Introduction

Social vulnerability indices (SVIs) are tools used to indicate how vulnerable a community is based on selected social characteristics. SVIs adhere to the understanding that marginalized social groups in the US bear the burden of disasters inequitably and are disproportionately negatively impacted by disasters. Integrating SVIs into disaster management planning processes provides a first step towards identifying communities that demonstrate the greatest need proportional to the resources and capacities available to them.

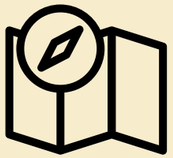
Currently, the National Disaster and Preparedness Center (NDPTC) uses the CDC SVI in their vulnerability assessment. This assessment predicts the vulnerability to damage of an area based on the SVI, the FEMA Hazus dataset, and other NOAA storm predictors. While this methodology is adequate for ascertaining a general sense of vulnerability, it lacks granularity of data due to the nature of large national datasets which often aggregate data at the census tract level. Additionally, the current CDC vulnerability framework is not specifically catered with disaster recovery in mind. Therefore, some variables pertinent to recovery are not included in the CDC social vulnerability index.

Our team has developed a new SVI that updates the CDC SVI values, includes new variables, and incorporates parcel level data. This method of social vulnerability indexing allows for future integration with the YOLOv5 computer vision damage assessments. By including parcel level data, we are able to match damage assessments from geo-located images to vulnerability assessments. This creates a more complete picture of the extent of damage and the capacity for that area to recover from disaster. In addition, this method is able to account for the challenges of using census tract level data, particularly in rural areas where data aggregation eliminates geographic nuances of variables.

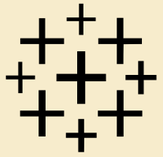
This new recovery SVI (rSVI) is just one piece of the recovery model presented in RIDA+. Considered in tandem with machine learning damage assessments and organizational capacity assessments, this disaster recovery decision making framework will provide a more holistic understanding of the social characteristics influencing individual capacity to recover and the support network of organizations that can enable faster recovery.

Our project focused on Hurricane Ida and St. Charles Parish, Louisiana as a case study for the piloting of this new rSVI methodology. The following pages of the document provides step-by-step details of our methodology as well as rationale for the changes made to the SVI currently used by the NDPTC. In addition, this paper will discuss the results of our findings and potential next steps for further improvements on the rSVI.

TECHNICAL NEEDS



ArcGIS Pro



Tableau

Microsoft Excel

Database Manager

5.2 Methods

The following table shows the various datasets and variables that were compiled to calculate the rSVI. Data was collected at either the census tract or parcel level to simplify data aggregation and calculations. For the census tract SVI, a total of 18 separate social variables were included. For the parcel level social vulnerability index, an additional three parcel specific variables were added to the index. Data for the SVI was only collected for St. Charles Parish. However, we chose data sources that would aid in replicability of the index.

All of the variables used to compile the rSVI are publicly accessible either through government data portals or through obtaining data via a Freedom of Information Act (FOIA) request. Using low cost and publicly available data lowers the cost of performing this analysis and also reduces the risk of using personal homeowner information.

DATA SOURCE	SCALE	DESCRIPTION	TABLE
US Census Bureau 2019 American Community Survey	Census Tract	Population below poverty	B17001
		Unemployed population	DP03
		Median income*	
		Householders over 65 living alone	DP02
		Population with a disability	
		Single parents	
		Speaks English less than well	
		Population under 5 years old	S0101
		Non-white population	B01001H
		Less than high school education	S1501
		Mobile homes	DP04
		Renter occupied	
		Crowded Households	
		Multi-unit apartment homes	
		Households without a car	
		Less than 4 years in current home	
		Group quarters	B26001
		No internet connection	S2801
St. Charles Parish Assessors Office Planning Department	Parcel	Home Assessed Value	
		Zoning District	
		Home Assessed Value	
		Post-Ida Damage Score**	

** Inverse rank*
*** Used for validation only*

VARIABLE RATIONALE

Poverty
Households living in poverty have less disposable income for investing in preparedness measures such as storm shutters and other structure fortifications. In addition, impoverished communities may struggle to finance evacuation and sheltering costs.

Median Income
Median income provides an additional measure of income with the capability to capture income disparities between high and low income communities. Like poverty measures, income provides an indication of the capacity of a community or household to access resources and services that can improve recovery outcomes.

Unemployment
Unemployment can indicate how much disposable income is available to an individual to assist in recovery efforts. In addition, it may also indicate social connectedness. Employed individuals have access to a social network of coworkers and employers who can provide recovery assistance or information about resources. Unemployed individuals do not have the same degree of access to this kind of network.

Education less than high school
An individual's educational attainment is an important indicator of economic earning potential. In addition, educational attainment may also play a role in the likelihood of an individual to prepare for a disaster. Both of these factors can impact the success and speed of recovery following a disaster

Speaks English less than well
This variable indicates how accessible information materials including disaster preparedness publications, and emergency messages are to people in an area. Understanding this social characteristic can help to direct resources and information in a language other than English to a particular area or region.

Households without a car
The availability of a vehicle can determine whether or not a household is able to evacuate in the event of a major disaster. Additionally, having a vehicle available may also influence whether or not a household is able to return to their home following a disaster.

Internet Access
Having a secure and reliable internet connection can improve the accessibility of disaster related information such as preparedness tips and emergency warnings. In addition, there is a growing trend amongst organizations to communicate with residents and members via social media and/or email. Therefore, households without internet may struggle to receive the most up-to-date information regarding a disaster.

Over 65 living alone
Elderly populations, especially those living alone, are particularly vulnerable to poor recovery outcomes due to limited mobility and reliance on a fixed income. In addition, we heard from community partners in the New Orleans region that elderly populations often view themselves as a burden to their families and communities and frequently suffer from social isolation.

Children under 5
Young children and infants often have different needs than adults particularly in regards to nutritional and sheltering requirements. Households with young children may have a more difficult time finding resources and facilities able to accommodate their varied needs following a disaster. Therefore, households with young children may experience slower recovery.

Single Parents
Single parent homes are uniquely vulnerable to disaster situations due to the need to provide for disaster preparedness and recovery for not only themselves but also for children without the support of second parent.

Mobile Homes
Mobile homes are more susceptible to physical damage during natural disaster events and are a greater risk of being completely destroyed. The market value of mobile homes can be relatively low, which may limit the amount of recovery funds available to households living in mobile homes. Our team of researchers heard from community partners in the New Orleans region that this often traps households in the disaster recovery cycle and inhibits their abilities to either relocat to a safer area, or purchase a sturdier home.

Renter occupied units
Many disaster recovery programs and damage assessments focus on owner occupied structures. Therefore, current disaster recovery models leave out renters and underprovide assistance to these residents.

Fewer than four years spent in home
Research suggests that the longer amount of time a household is in their home, the faster that household is likely to recover. This is because that household is able to form more connections with neighbors and local service providers to help them through the recovery process.

Crowded
Households with greater than two people are more likely to have slower recovery times due to the need to provide for several people. In addition, crowded homes (defined as having more than 1.5 people per room) may indicate non-traditional housing arrangements, and lower income households.

Group Quarters
Individuals living in group quarter arrangements, such as nursing homes and incarceration facilities, may lack strong social ties within their living arrangements and may not have the same level of access to information as residents living outside of group quarters. This makes this subsection of the population more vulnerable to disasters.

Disabled Population
Impaired mobility and additional medical needs limit the number of facilities and resources accessible to disabled individuals which slows down the time of recovery. Disabled populations may also prioritize medical expenses and needs over sheltering expenses.

Non-white population
Racial minorities and marginalized communities face additional barriers to receiving aid and resources following a disaster. Some of this is due to a lack of institutional knowledge created as a result of historic disinvestment. These systemic barriers slow down the time of recovery and makes these populations more vulnerable to displacement. This can have the further effect of damaging the existing social ties within the community leading to further vulnerability in future disasters.

Multi-Unit Apartments
Households living in apartment buildings (defined as any residential building with more than 10 units) are often not included in traditional damage assessments and may have fewer resources available to them for recovery aid. In addition, resident turnover in apartment units is higher than in single-family neighborhoods making it more difficult to form strong social ties that can provide resources after a disaster.

PARCEL SPECIFIC VARIABLES

The following variables were included in the parcel level recovery vulnerability index. Data for each variable was obtained from the St. Charles Parish government.

Market value of home
Higher home value indicates less vulnerability. Rationale is two-fold: higher home value indicates wealth, and some recovery programs are based on value of the structure damaged meaning that residents are more likely to get a larger sum of recovery assistance dollars.

Zoning
R1A-M, R1-M zones allow mobile homes on the structure, households living in mobile homes are more likely to sustain greater amounts of damage, and more likely to be displaced from the community. R13, multi-family housing, households living in apartment buildings are more likely to be disconnected from community and less likely to be targeted by recovery programs which often focus on homeowners. Zoning was incorporated as a binary variable in the rSVI.

Flood Zones
Special Flood Hazard Areas (SFHA) are those within the 1-percent flood area. Zones included in the SFHA are Zones A, AO, AH, A1-A30, AE, A99, AR, AR/AE, AR/AO, AR/A1-A30, AR/A, V, VE, V1-V30. Areas of moderate flood hazard are listed as Zone B or Zone X. Zone C has minimal flood risk. A binary variable is used for the vulnerability assessment with SFHA zones receiving a value of one, and all other zones receiving a value of zero.

Our parcel rSVI compares the vulnerability of 13,924 individual parcels in St. Charles Parish. This sample represents approximately 31% of the total 45,059 parcels in the parish. The sample does not include parcels that did not have a Hurricane Ida Damage Assessment report or parcels for which property market values could not be matched to existing records. Duplicate parcel identification codes were also excluded from this sample.

DATA CALCULATIONS

Tract rSVI

Similar to the CDC's SVI, our rSVI relies on ranking census tracts on each variable to create a composite vulnerability score. For our process, the census tracts in St. Charles were compared to only the census tracts in that parish. This differs from the CDC process which compares each census tract to all census tracts in the nation. By comparing the census tracts to tracts within their county or parish, a more specific and localized comparison can be made which better enables the NDPTC and local emergency managers to draw conclusions about vulnerability in areas expected to experience natural disasters.

For each variable, percent of population (or households) is calculated by dividing the estimated value by the population or number of households. For simplicities sake, margin of errors are not accounted for in these measurements. After percentages are calculated for each variable, percentile rankings are calculated by using the percentile.inc function in Microsoft Excel. Once each census tract has been ranked across all variables, rankings are summed for each tract to provide an overall ranking of vulnerability. These summed rankings are categorized based on the 25th, 50th, 75th, and 100th percentiles of summed totals and given a recovery vulnerability score of 1-4 with 1 being least vulnerable and 4 being the most vulnerable. By ranking census tracts on the vulnerability variables, we are able to get a sense of how vulnerable a census tract is relative to all other census tracts in the study area. This makes comparisons—and by extension, prioritization— between census tracts easier.

Due to the large number of variables and the nature of indices, regression analyses were not run to determine the significance of each variable in determining the vulnerability score of each tract. However, simple scatterplots were created to get an indication of any possible relationship in the data. To eliminate any possible error or bias that could be introduced through variable significance analyses, variables were left unweighted. While this method may not be statistically rigorous, it does allow for greater interpretation of values. This can provide opportunities for community members to participate and weigh in on which variables they feel are most impactful to the community.

After calculations are complete, the rSVI data is visualized as a map in Esri ArcGIS. Visualizing data as a map allows planners and emergency managers to better understand the spatial distribution of vulnerability in the study area. Image 1 on the following page shows the tract level vulnerability index visualized for St. Charles Parish.

Parcel rSVI

To calculate the parcel level rSVI, a similar process was adopted. First, a spatial join between parcel and tract boundaries was performed in ArcGIS pro to determine which census tract each parcel belonged to. The information from this new feature layer was exported as a database file so that additional data calculation could be performed in excel. Each parcel is associated with a property identification number (PID) and all parcel related data including zoning information, market value of properties, and flood zone designation includes PID numbers. These values are then matched (using xlookup) to their associated parcels using PIDs and rankings are calculated for each parcel. These parcel rankings are added to the tract rSVI summed rankings of the tract associated with each parcel. Like with the tract rSVI, the summed rankings for each parcel are categorized based on the 25th, 50th, 75th, and 100th percentiles and parcels are assigned a rSVI score of 1-4 with 4 being the most vulnerable.

By calculating a parcel rSVI as well as the tract rSVI, greater nuances of vulnerability can be captured. While the tract level index captures a macro view of vulnerability and provides average values for certain social characteristics, the parcel level index is able to pinpoint specific households in a neighborhood that may be uniquely vulnerable to disasters due to aging or poor structural integrity of their home. In addition, parcel level zoning data is able to give a clearer indication of which households may be renter occupied and therefore more likely to be disconnected from community resources and assets.

Image 2 illustrates the parcel level rSVI for St. Charles Parish. The scale of the map has been decreased to improve legibility for print format. For an interactive

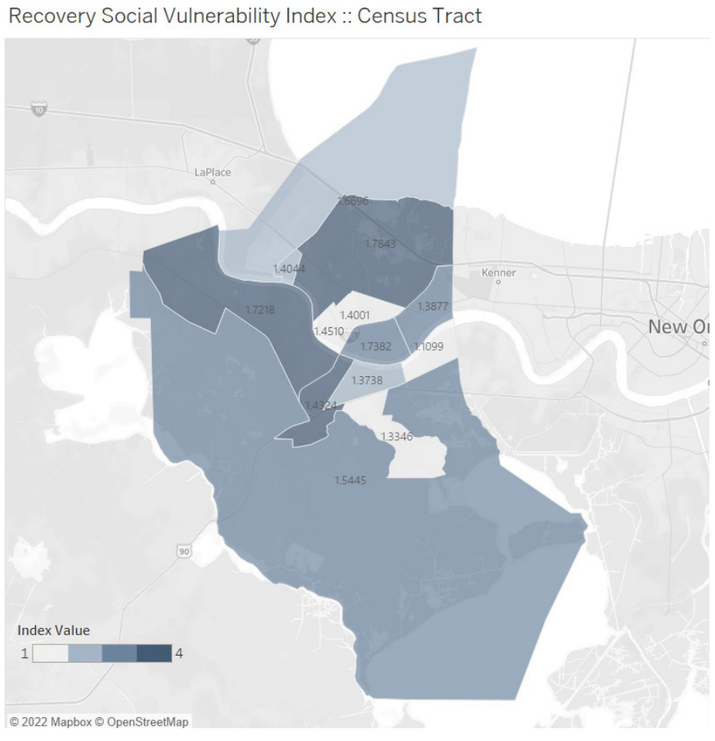


Image 5.1: St. Charles Parish tract level rSVI. Most vulnerabile populations are shown in dark blue, while the least vulnerable are shown in white. Census tract level rSVI provides a macro view of vulnerability in a region. Best used for intitial prioritization. Graphic made with ArcGIS Pro and Tableau

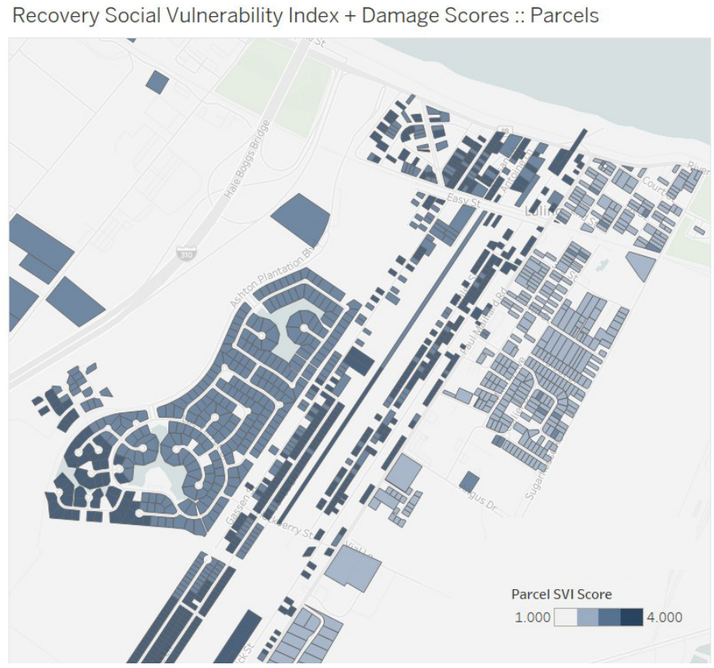


Image 5.2: St. Charles Parish parcel level rSVI. Map is zoomed in to Luling, Louisiana near the Mississippi River. Similar to the tract level rSVI, more vulnerable parcels are shown in dark blue, while lighter blue parcels indicate less vulnerable parcels. Parcel level rSVI provides a greater level of nuance and helps planners and emergency managers better understand vulnerability in a community. Graphic made with ArcGIS Pro and Tableau

version of this map that allows you to zoom and pan across the entirety of the parish, please go to our website.

5.3 Results

The following section disccuses the results of the rSVI analysis and offers ways to incorportate the rSVI into the RIDA+ model.

COMPARISON TO CDC SVI

In general, the vulnerability index rankings for census tracts in St. Charles Parish, Louisiana increased when using the rSVI as compared to the CDC SVI. In total 5 out of 13 census tracts saw an increase in vulnerability rankings while only two decreased (see Image 4 for greater detail). It is most likely that the shift from comparing tracts nationally to regionally resulted in these changes in vulnerability assessments.

RELATIONSHIP TO DAMAGE ASSESSMENTS

After calculating parcel rSVI scores for each of the 13,924 parcels with damage assessment data available, we can test the relationship between vulnerability and damage using St. Charles Parish Assessor's damage assessment data. This can help provide an understanding of how, if at all, the vulnerability of a household impacts the amount of damage sustained by the structure. If the relationship is strongly correlated in a positive direction (i.e. the greater the vulnerability score, the greater the amount of damage we can expect to see to the structure) our rSVI could be used as a predictive tool.

The damage assessment data that was provided from the St. Charles Parish Assessor's Office is based on a 0-4 scale. A damage assessment score of 0 indicates cosmetic damage only, 1 indicates minor damage (minimal shingle damage, damage to outbuildings), 2 indicates moderate damage (significant shingle loss, no structural damage to main building), 3 indicates major damage (visible structural damage, large portions of roof missing, likely water damage), and finally, 4 indicates complete structural damage (structure is unusable, significant sidewalls or roofing missing or destroyed). Damage assessments were determined based on aerial imagery taken shortly after Hurricane Ida made landfall. For tract level rSVI comparisons to damage scores, parcel damage scores were summed across the tracts and divided by the number of parcels in each tract that had damage scores available. While this is an imprecise way to calculate parcel damage averages, we determined that this was the best way given our data constraints and availability of parcel level damage assessments.

Figure 2 shows a scatterplot mapping the relationship between the tract rSVI and the tract average damage score. This plot shows a positive relationship at the tract level between our newly developed rSVI and average damage assessments. Census tracts with the highest level of vulnerability also have average damage scores at the high end of the scale. Further investigation of individual rSVI variables is necessary to understand which social variables have the strongest relationship to observed damage assessments.

This graphs and the supporting maps provide justification for the development of vulnerability indices as tools for prioritizing deployment of recovery resources since they show that there is a relationship between the two variables. Planners and emergency managers can use the rSVI to predict where damage is likely to be most severe and where community residents have the least amount of resources available to help with recovery efforts. This can help to make recovery more equitable and faster for those who are traditionally slow to receive help from disaster relief and recovery agencies.

5.4 RIDA+ Integration

The rSVI should be deployed in the earliest phases of the RIDA+ process. After determining the likely storm trajectory for a given storm, rSVI calculations should be made for all census tracts and parcels within that storm path. Deployment of aerial imaging tools (drones, planes, etc) should be based on the most vulnerable tracts in the study area. Within the most vulnerable and second most vulnerable tracts, deployment of street level imaging should be based on parcel level rSVI. This will help to prioritize perishable data capture and analysis of the most at risk communities first.
In addition, the rSVI should be revisited at the end of a disaster recovery cycle to assess its efficacy in predicting the amount of damage sustained by homes. Revisiting the rSVI regularly also allows for data to be updated as new data becomes available. Keeping data as up to date as possible (something that the CDC has not done with its SVI—it's currently drawing from 2018 data) will ensure that vulnerable populations are being targeted to the best of NDPTC's ability.

5.5 Next Steps

While our team has made significant innovations to the existing SVI used in the RIDA model by adding more specific disaster specific variables and introducing a parcel level rSVI, there is still additional work to be done to further improve on this new methodology. Most importantly, regression analyses should be performed on individual variables to see which variables included in the rSVI have the greatest level of statistical significance in predicting damage outcomes. In future iterations of the rSVI, variables or groups of variables could be weighted according to their significance to better estimate vulnerability and therefore disaster outcomes. This can help reduce the "noise" in the vulnerability index produced by having a large number of variables.

The second improvement that should be made to the rSVI is including information gathered from the asset mapping process recommended as part of the RIDA+ model. (See the working paper on community asset mapping and network analysis for more information on asset mapping.) Following asset mapping processes that indicate the number of resources available to each household, this information can be added to the parcel rSVI to better identify gaps between needs and resources available. The image below shows where clusters of households exist in St. Charles Parish that are both highly vulnerable to disasters and have the fewest number of resources available to them. This visualization shows the potential for combining our proposed rSVI and asset mapping processes to develop an overall measure of vulnerability and resource availability.

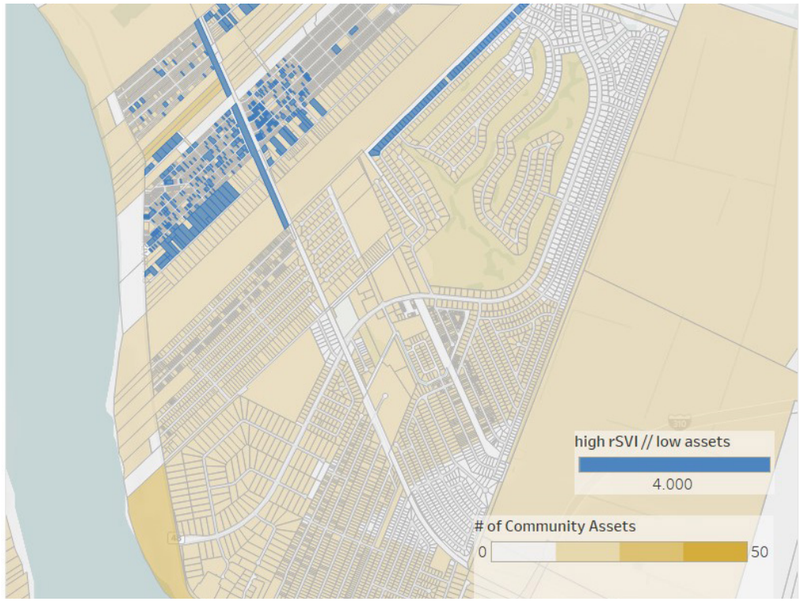


Image 5.3: St. Charles Parish Needs + Resource Gaps. This map shows, in blue, where households exist that have the highest vulnerability ranking and lowest access to resources. After more comprehensive assett mapping processes, analysis like this one could contribute to the rSVI to further refine our identification of vulnerable households. Graphic made with ArcGIS Pro and Tableau

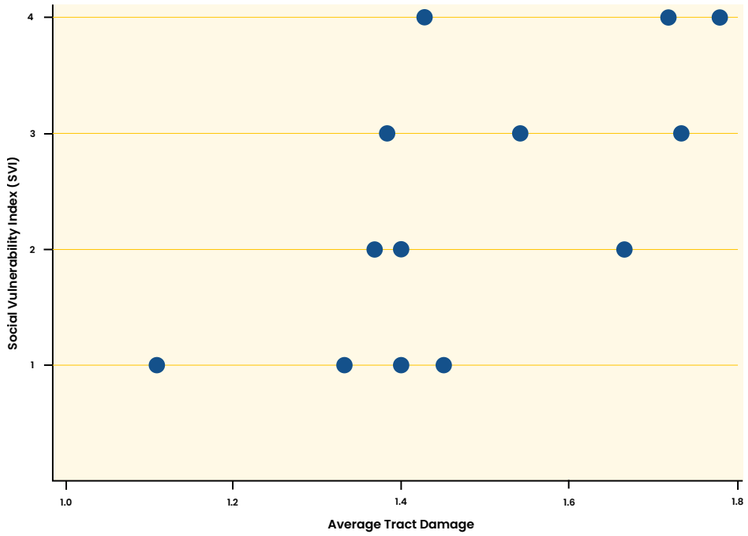


Figure 5.2: Relationship between tract rSVI and average tract damage. This scatter plot shows a generally positive relationship between the rSVI and average damage scores. With a low n value of 13, further study is needed to determine if this relationship is strengthened or weakened by additional observations. Graph made with Stata

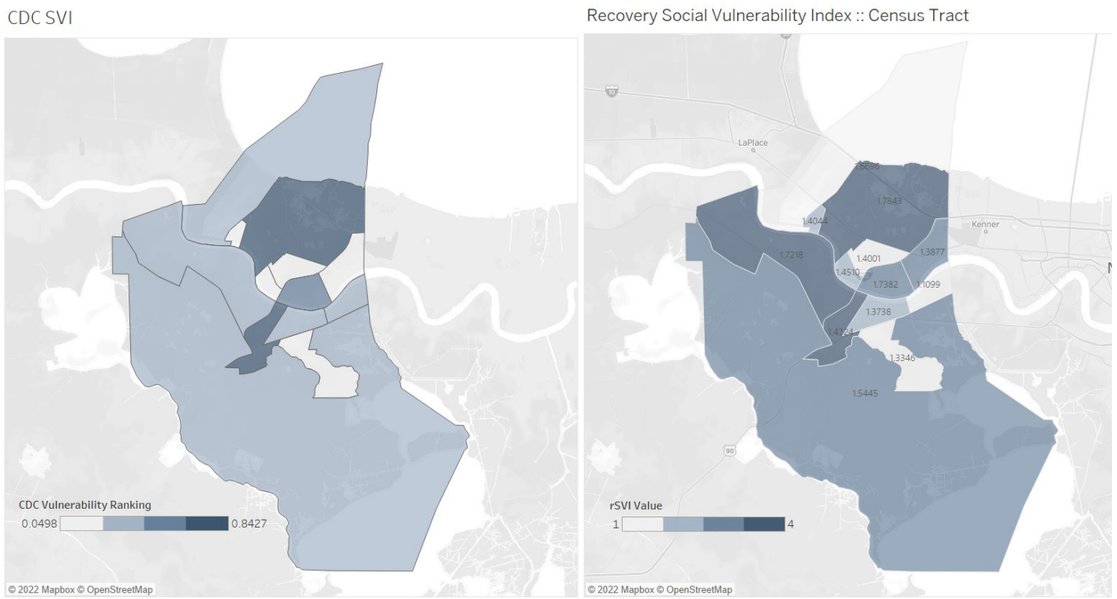


Image 5.4: Map showing comparison between CDC SVI (left) and Deluge rSVI (right). In both maps, more vulnerable census tracts are shown in dark blue. The most significant changes occured in census tracts south of the Mississippi River. Graphic made with ArcGIS Pro and Tableau

5.6 Conclusions

To increase the efficacy of the social vulnerability index (SVI), it is necessary to integrate additional measures that add nuance to our understanding of vulnerability. One way of accomplishing this is by using multiple units of analysis to capture both macro and micro perspectives of vulnerability. On the macro level, it is important to cater social vulnerability indices specifically to disaster contexts to capture the variables that speak directly to a household or individual's capacity to seek out recovery resources. These types of indicators, such as renter occupancy, and access to internet connections are widely available on the census tract level. Aggregating and averaging these types of variables across the census tract provide a sweeping overview of a large population and allow users of RIDA+ to make first level prioritizations for tool and resource deployment. For rural and sparsely populated regions where census tract level measurements are inadequate, parcel level SVIs provide a closer glimpse of vulnerability and enable us to identify clusters of at-risk households. This can further support the prioritization of RIDA+ deployment.

The method proposed in this working paper provides the NDPTC with a first step toward improving on the existing RIDA framework. This team believes that through our suggested improvements, RIDA+ has the potential to become a revolutionary tool for delivering recovery assistance in a timely and equitable manner.

RISING ABOVE THE DELUGE

RECOVERY SOCIAL VULNERABILITY INDEX

about this project

This project is a joint effort by students and faculty within the Master of Urban and Regional Planning program at the University of Michigan and the National Disaster Preparedness Training Center (NDPTC) as a Capstone project for the Winter 2022 semester.

A key focus of the University of Michigan team is to work in a manner that promotes the values of equity, uplifting local voices, transparency and honesty. As a result, the outcomes of this capstone aim to speak to both our collaborators at the NDPTC and the local communities impacted by disasters across the United States. Our responsibilities as researchers will also include the implementation and/or recommendation of innovative solutions to issues surrounding machine learning, damage assessments, prioritization determinations, and social infrastructure networks.

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