Assessing social vulnerability to the risk of flooding in Dane county, WI

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Executive Summary

The risk of flooding in Dane county presents a constant threat to the economic, social, and environmental stability of the communities. Utilizing my hazard planning knowledge, statistical analysis skill, and GIS mapping technique, I assessed social vulnerability to the risk of flooding in Dane county, WI. I modified an existing Social Vulnerability Index to incorporate 100-year floodplain map and formed a new model called Social Vulnerability to Flood Index (SoV2FI). The SoV2FI can potentially assist the government and the communities of Dane county in Wisconsin to identify areas that require extra attention in hazard planning and mitigation.

"I shall never be content until the beneficent influence of the University reaches every family of the state." -UW President Charles Van Hise in 1905 (Wisc.edu 2017).

Introduction

Project motivation

My motives of choosing this project are threefold: my love for this community, my influence by the Wisconsin Idea, and my career aspiration as a planner. Firstly, as an international student who has spent five years of my academic life at the University of Wisconsin-Madison, I consider myself as part of the communities in Madison and I would love to see the people and the place thrive and prosper in every possible way. Secondly, as a Badger, I take the Wisconsin Idea introduced by Charles Van Hise dearly to my heart. Upon completing my master degree, this professional project is an opportunity for me to contribute the knowledge I have received throughout my academic career to Dane county, Wisconsin where my beloved communities are located. Thirdly, it aligns with my lifelong career mission as a planner. I seek to foster my communities towards prosperity, equity, and sustainability by assisting them to make a better-informed decision for their environment. The risk of flooding in Dane county presents a constant threat to the economic, social, and environmental stability of the communities. Utilizing my spatial analytical skills and disaster planning knowledge, I want to help the government and the communities of Dane county in Wisconsin to better understand about the challenge and make informed decision to cope with the potential damage from the natural hazard.

Objective

In this project, I seek to enhance community resiliency towards flooding by assessing the geographic distribution and the state of social vulnerabilities to the risk of flooding in Dane county, WI.

Flood

Flood is an inundation of normally dry area caused by heavy precipitation, snow melting, tidal waves, or dam failure (NOAA National Severe Storms Laboratory 2017.). In the U.S., the fatality rates caused by flood is higher than the fatality rates caused by twister, cyclone or lighting. Among the many types of flooding, a flash flood is the deadliest type of flooding which can occur within several minutes to less than six hours of heavy rainfalls. Some possible reasons of flash floods include high population density, low coverage of pervious surface, close proximity to a river, occurrence of dam failures, steep slopes, recent burn scars from wildfire, snowmelts, and ice jams.

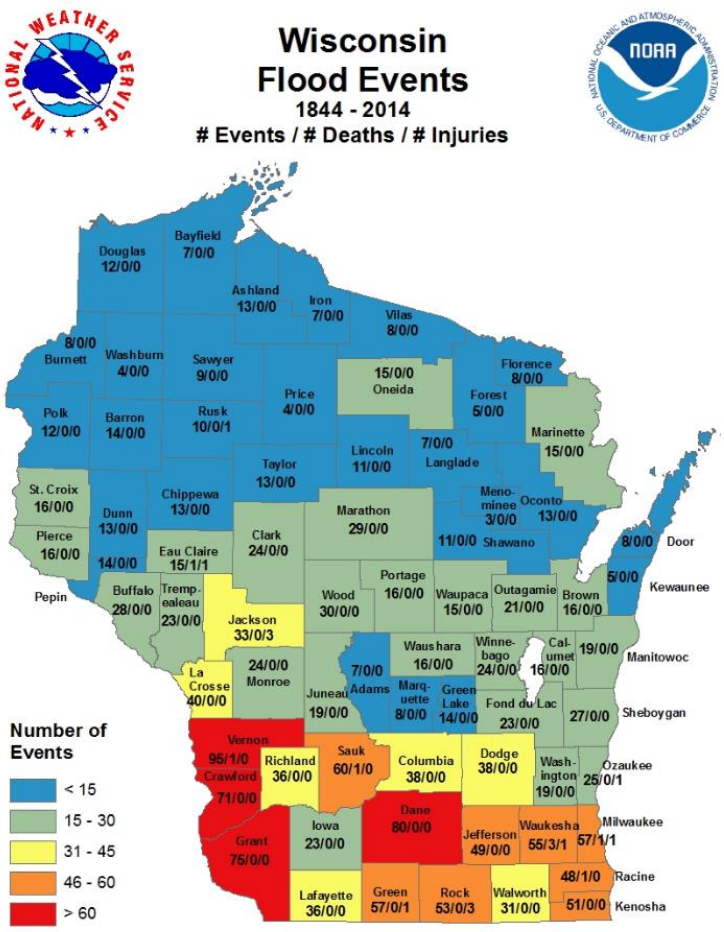

Figure 1 Wisconsin flood events (1844–2014) (Weather.gov 2017)

Flood in Dane County, Wisconsin

Dane county in Wisconsin has a long history of flood events with costly damages. According to the Dane County Natural Hazard Mitigation Plan (2009), seven out of 23 times of federally declared flooding in Wisconsin happened in Dane county since 1978. It cost over $65 million of estimated private, public, and agricultural damages. The latest major flooding, which happened in 2008, was assessed to cost over $13.55 million. In the past century, Dane county ranked second in Wisconsin in terms of frequency of flood events with a total of 80 incidents from 1844 to 2014 (see Figure 1) (NOAA & NWS 2014).

Development of social vulnerability to environmental hazards studies

The ideology of vulnerabilities to natural hazards varies across different focuses of the studies and evolves over time (Cutter et al. 2003; Birkman et al. 2013; Hung et al. 2016).

Table 1 lists the development of the concept of social vulnerabilities to environmental hazards since the mid-20th century.

Table 1: The development of studies in social vulnerabilities to environmental hazard

Timeline	Concept	Source
1940s -1970s	Exposure model: Study phenomenon that causes humans and their settlements exposed to the danger of environmental events.	(White 1945; Burton, Kates, and White 1978)
1980s	Focus on how technology and expert knowledge can intervene the relationship between human and environmental hazards.	(Hewitt 1983)
1990s	Recognize that social situation affects the magnitude of vulnerability towards natural hazards and focus on how and why social factors influence vulnerabilities towards environmental hazards.	(Blaikie 1994; Hewitt 1997; Wisner et al. 2004)
	Hazards of place Model of Vulnerability: Acknowledge both physical and social characteristics can shape vulnerabilities to environmental hazards.	(Cutter 1994)
	Combine the ideas of potential hazards event and social resistance to the study on a specific geographic area.	(Kasperson, Kasperson, and Turner 1995)
2000s- 2010s	Social Vulnerability Index (SoVI): Incorporate GIS mapping technology and statistical analysis to quantify characteristics of social vulnerabilities to environmental hazards at a given place.	(Cutter et al. 2003)
	Recognize fluidity of social vulnerability to environmental hazards across time and space.	(Cutter et al. 2008; Khan 2010)
	Argue that the underlying weights among the factors are unequal. The accuracy of SoVI can be improved by incorporating local expertise information and verification methods to adjust the weights.	(Hebb and Mortsch 2007; Barnett, Lambert, and Fry 2008; Fekete 2012; Tate 2012)

Hazards-of-place Model of Vulnerability

In this project, I incorporated the idea of social vulnerabilities to environmental hazards from the "Hazards-of-place Model of Vulnerability" by Cutter (1996). Cutter argues that the level of danger to an environmental event is a product of the chance of occurrence and the presence of approaches to minimize its consequences. The magnitude of hazard at a location fluctuates according to its physical setting and its social characteristics. They ultimately affect the vulnerability of that location. Some examples of the physical setting are closeness to a hazard event and elevation (Cutter et al. 2003). Whereas, social vulnerability to hazards describes the ability an individual or a community to forecast, handle, response, and recuperate from the consequences of natural hazards can fluctuate according to their location and unique physical, social, and economics conditions (Cutter et al 2003; Wisner et al 2011; Vale 2014). Cutter et al. have developed Social Vulnerability Index (SoVI), a tool to measure and map the social vulnerabilities to hazards at the county level through statistical modeling and Geographic Information System (GIS) mapping (Oulahen 2013).

Social Vulnerability Index (SoVI)

This project adopts the methodology from the SoVI®, a tool widely utilized by national and international researchers and authorities to examine area that are socially vulnerable to natural hazards. According to the Wiley Online Library, over 900 articles, books, and conference papers cited that article since its publication in 2003.

The variables selected for SoVI® calculation require empirical studies on factors that can affect social vulnerabilities. In amidst of turbulence, individuals or communities with certain characteristics could endure larger risk and they could take longer duration to recover compared to the average people (Cutter et al. 2003; Duggan, Deeny, Spelman, and Vitale 2010; Khan 2012; Tate 2013). In general, researchers agree that some of the reasons that can contribute to the social vulnerability to natural hazards are age, gender, ethnicity, race, wealth, socioeconomic status, disability, literacy, literacy level and command of English language (Cutter et al. 2003; Oulahen et al. 2015; Tate 2012). *Table 2* shows a list of literature review on some aspects of the social vulnerability factors and possible indicators for measurement.

Table 2 Social vulnerability indicators and selected variables.

Concept	Description	Metrics Examples
Socioeconomic status (income, politcal power)	The capability to prepare for emergency, recover from losses, and strengthen resilience towards natural hazards are negatively related to income level(Cutter, Boruff, & Shirley 2003, 246;Frankenberg, Laurito, and Thomas 2014, 11;Zottarelli 2008; Andrulis, Siddiqui, and Purtle 2011;(UNISDR) and Centre for Research on the Epidemiology of Disasters (CRED) 2016).	Percent Poverty
		Percent of Households Earning Greater Than $200,000 Annually
		Per Capita Income
Gender	Women have greater household care duty and are less likely to be reemployed compared to men after a disaster (Zottarelli 2008;Frankenberg, Laurito, and Thomas 2014, 8; Khan 2012; Oulahen, Mortsch, Tang, and Harford 2015; Bjarnadottir, Li, and Stewart 2011).	Percent Female
		Percent Female Participation in Labor Force
Minority status and language barrier	Cultural difference and limited English proficiency are mentioned as major challenges for communities to prepare for disaster training (Andrulis, Siddiqui, and Purtle 2011; Nepal, Banerjee, Mark Perry, and Scott 2012;Oulahen, Mortsch, Tang, and Harford 2015;Tate 2013).	Percent Asian
		Percent Black
		Percent Hispanic
		Percent Native American
		Percent Speaking English as a Second Language with Limited English Profiency
Age	Children and elderly face higher mortality rate during disasters (UNISDR and CRED 2016;Frankenberg, Laurito, and Thomas 2014, 8;Bjarnadottir, Li, and Stewart 2011)	Percent of Population Under 5 Years Old or 65 Years Old and Over
		Median Age
Employment loss	People who are jobless have limited financial resources to sustain throughout the disaster recovery (Oulahen, Mortsch, Tang, and Harford 2015; Bjarnadottir, Li, and Stewart 2011; Khan 2012)	Percent Civilian Unemployment
Rural/urban	In an urban setting, people tend to live in a multiunit housing such as apartments and student resident which impose a risk of overcrowding when escaping from a limited emergency exit (Cutter, Mitchell, and Scott 2000;Odeh 2002; Jones and Andrey 2007; Khan 2012)	Population density

Concept	Description	Variables Examples
Residential property	Weak structure of mobiles home presents high risk towards hazards (Cutter, Boruff, & Shirley 2003;Kusenbach, Simms, and Tobin 2009).	Percent Mobiles Homes
Renters	Renters are often not allowed to modify the structure of their house which undermined the resilience of their house towards natural hazards (Andrulis, Siddiqui, and Purtle 2011;Oulahen, Mortsch, Tang, and Harford 2015, 479, Khan 2012; Bjarnadottir, Li, and Stewart 2011; Tate 2013).	Percent Renters
Occupation	Migrants who often fill the low-skilled service position suffer longer job recovery due to an overall decline of dispensable income caused by a disaster (Cutter 2003).	Percent Employment in Service Industry
	Workers in the extractive sectors such as fisheries and agriculture are exposed to the risk of production loss due to a storm, floods, and other weather hazards (Cutter 2003; Food and Agriculture Organization of United Nation 2013)	Percent Employment in Extractive Industries
Household structure	A household with married couple and children are more likely to have a family plan for disaster preparedness (Basolo, Burby, Cruz, and Huang 2008).	Percent of Children Living in Married Couple Families
	Single-parent families linked to financial constraint for childcare services, leading to overburdened by work and childcare responsibilities (Cutter, Boruff, and Shirley 2003)	Percent Female Headed Households
	The absence of personal vehicle reduces mobility to escape from disaster (Khan 2012; Oulahen, Mortsch, Tang, and Harford 2015).	Percent of Housing Units with No Car
Education	the emergency warning (Cutter, Morath, and Dunning. 2013; Brown, Lisa M., Jolie N. Haun, and Lindsay Peterson 2014)	Percent with Less Than 12th Grade Education
Social dependence	The social security receivers are usually people who have disabilities or 65 years old or older and they already face financial and social constraint on a daily basis (Cutter 2003; Andrey and Jones 2008; Khan 2012)	Percent of Households Receiving Social Security
	Population without insurance coverage face greater risk during the disaster compared to those with better health care network (Davis et a. 2010; Runkle et al. 2012)	Percent of Population Without Health Insurance (County Level Only)
	People with disabilities has mobility constraint which makes a response to a hazard event harder than people without disabilities (Cutter, Morath, and Dunning 2013).	Percent of Population with a Disability

Social Vulnerability to Flood Index (SoV2FI)

The aforementioned studies highlight some traits for the variable selection of SoVI. While SoVI reveals the social aspects of the hazards vulnerability in Dane county, it fails to take the degree of the flood risk into consideration. In order to create a more relevant representation of the hazard, I modified SoVI and created a new model called Social Vulnerability to Flood Index (SoV2FI) by integrating the risk of flooding in Dane county, WI into the model.

Methodology

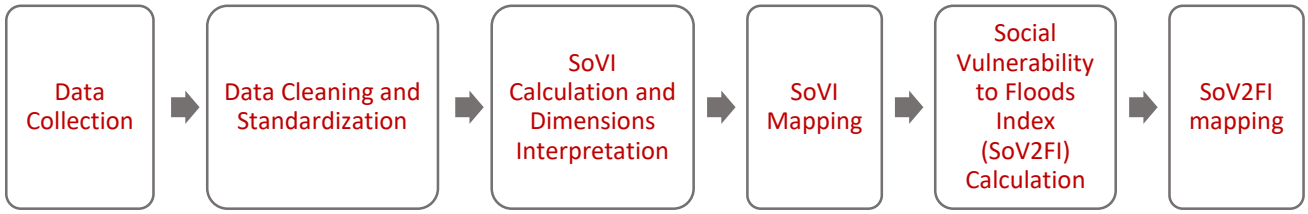

Figure 2 Methodology process

Figure 2 shows the process of SoV2FI calculation including data collection, data processing, SoVI calculation, SoV2FI calculation, and the software application usage throughout the project.

Step 1: Data Collection

1.1 American Community Survey (ACS) 2011- 2015

I sourced data from the U.S. Census Bureau's five-year American Community Survey (ACS) 2011- 2015, a survey collected by U.S. Census Bureau annually about the population in U.S (U.S. Census Bureau 2017). Specifically, I chose the data at the blockgroups-level because it can provide the finest details of SoV2FI in Dane county, WI (see *Table 2*).

1.2 Digital Flood Insurance Rate Map (FIRM) database

In addition, I used a 100-year floodplain map that indicates areas with 1% or a higher annual chance of flooding from the Digital Flood Insurance Rate Map (FIRM) database of Dane county, Wisconsin (FEMA n.d.).

Table 3 Variables selected for the Social Vulnerability Index calculation.

No	Variable	Description
1	POPDEN	Population Density
2	QASIAN	Percent Asian
3	QBLACK	Percent Black
4	QHISP	Percent Hispanic
5	QNATAM	Percent Native American
6	QAGEDEP	Percent of Population Under 5 Years or 65 and Over
7	QFAM	Percent of Children Living in Married Couple Families
8	MEDAGE	Median Age
9	QSSBEN	Percent of Households Receiving Social Security
10	QPOVTY	Percent Poverty
11	QRICH200K	Percent of Households Earning Greater Than $200,000 Annually
12	PERCAP	Per Capita Income
13	QESL	Percent Speaking English as a Second Language with Limited English Profiency
14	QFEMALE	Percent Female
15	QFHH	Percent Female Headed Households
16	QNOHLTH	Percent of Population Without Health Insurance (County Level Only)
17	QED12LES	Percent with Less Than 12th Grade Education
18	QCVLUN	Percent Civilian Unemployment
20	QRENTER	Percent Renters
21	QMOHO	Percent Mobiles Homes
22	QEXTRCT	Percent Employment in Extractive Industries
23	QSERV	Percent Employment in Service Industry
24	QFEMLBR	Percent Female Participation in Labor Force
25	QNOAUTO	Percent of Housing Units with No Car
26	QUNOCCHU	Percent Unoccupied Housing Units
27	QSPNEEDS	Percent of Population with a Disability

Source: U.S. Census Bureau 2016; Cutter, Boruff, & Shirley 2003

Step 2: Data Cleaning and Standardization

2.1 American Community Survey (ACS) 2011- 2015

I removed observations with missing values in the 27 variables from American Community Survey (ACS). Then I normalized the data using the following formula:

$$z = \frac{x - \mu}{\sigma}$$

The equation transformed the data from different scales of measurement into comparable readings (Cutter, Boruff, & Shirley 2003; Tate 2012; Oulahen 2013).

Step 3: SoVI Calculation

After normalization, I conducted Principal Component Analysis (PCA) to consolidate the 27 variables into a smaller set of statistically optimized components (Oulahen 2013; Minitab, 2017; Penn State Eberly College of Science 2017). Once the number of components with Eigenvalues greater than one is determined, I used that number to calculate factor analysis with Varimax rotation (Cutter 2003; Penn State Eberly College of Science 2017). After factor analysis, the directionality (positive (+) or negative (-)) of the factor loadings are adjusted according to the previous literature findings to ensure accurate correlation between the components and vulnerability scale (Cutter, Boruff, & Shirley 2003). For each factor, I chose variables with an absolute value greater than or equal to 0.5 as my dominant variables (Cutter, Boruff, & Shirley 2003). Then, I gave each factor an appropriate name to summarize the meaning of the dominant variables. Lastly, I calculated the SoVI by summing all of the components at an equal weight to create social vulnerability score for each blockgroup. The scores indicate the relativity of vulnerability among all of the blockgroups in Dane county.

$$SoVI_i = Factor_1 \times Variable_i + Factor_2 \times Variable_i + \ldots + Factor_7 \times Variable_i$$

$$i = Blockgroups\ 1\ to\ Blockgroup\ 108$$

Step 4: SoVI Mapping

After SoVI calculation, I mapped them by quintiles to highlight the top 20 percentile and bottom 20 percentile of SoVI. The SoVI score assigned to each blockgroup on the map shows relativity of social vulnerabilities among the blockgroups in the Dane county.

Step 5: Social Vulnerability to Flood Index (SoV2FI)

I customized the SoVI map to incorporate the 100-year floodplain by using the formula below and named it Social Vulnerability to Flood Index (SoV2FI).

$$SoV2FI = SoVI \times Percentage\ of\ floodplain\ area$$

Step 6: SoV2FI mapping and validation

Again, I mapped the previously calculated scores to show the distribution of SoV2FI in quintile.

Software Applications

I used software such as Microsoft Excel, R, and ArcMap 10.4.1. interchangeably throughout the processes of data collection, data processing, data analysis, and mapping. I have attached a copy of the R scripts at Appendix A for future application and reference.

Results and Interpretation

Social Vulnerability Index (SoVI)

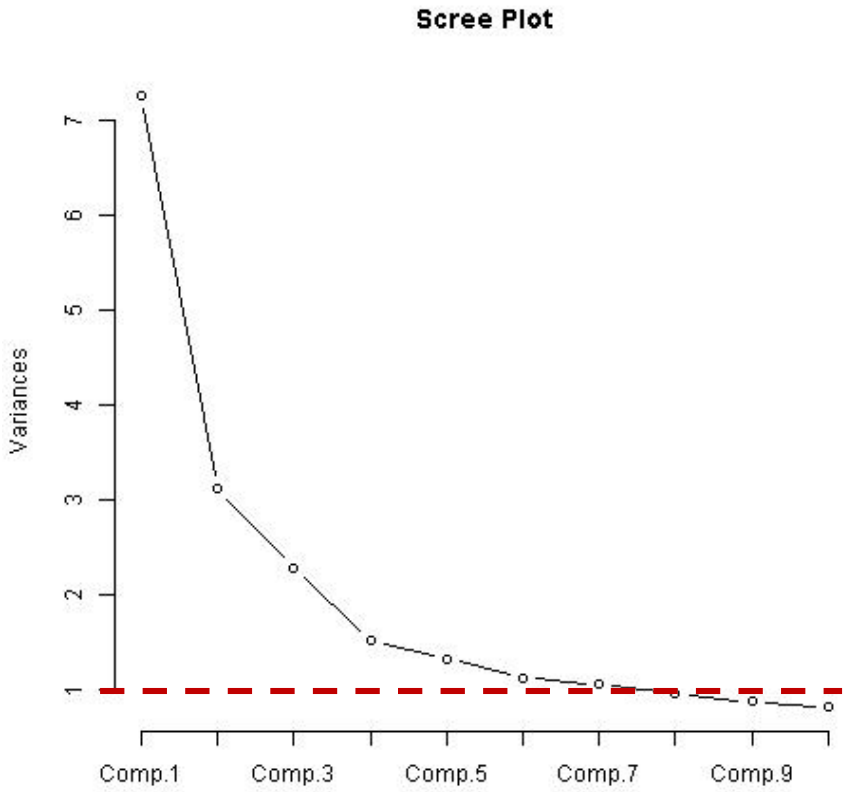

Figure 2 Scree plot of Principal Component Analysis.

After conducting the PCA, I identified seven components that have Eigenvalues (variance2) greater than or equal to one as shown in Figure 2. I used seven as the number of output for the Factor analysis for SoVI. Table 4 indicates a summary of the factor analysis with the components and their component loadings that explained 64.76% of the variation in this analysis. A strong correlation between ethnicity, race, limited education, and inadequate insurance coverage explained the largest variation (23.2%), which is the first component of the output. The rest of the dominant variables that shows a strong correlation to the other variables in the factors are the availability of a personal vehicle, age, gender, wealth, English proficiency, and female-headed household.

Table 4 Summary of the Factor analysis and its component loadings.

Factors	Directionality	Variance Explained	Name	Dominant Variables	Description	Component Loadings
1	+	23.20%	Minorities with limited education and health care network	QNOHLTH	Percent of Population Without Health Insurance (County Level Only)	0.7269
				QED12LES	Percent with Less Than 12th Grade Education	0.7205
				QHISP	Percent Hispanic	0.7187
				QBLACK	Percent Black	0.5132
2	+	12.53%	Poverty	QNOAUTO	Percent of Housing Units with No Car	0.8026
				QPOVTY	Percent Poverty	0.6726
				QRENTER	Percent Renters	0.5898
				POPDEN	Population density	0.5892
				QSERV	Percent Employment in Service Industry	0.5782
3	+	8.72%	Social benefit receiver	QSSBEN	Percent of Households Receiving Social Security	0.9182
				QAGEDEP	Percent of Population Under 5 Years or 65 and Over	0.8466
				MEDAGE	Median Age	0.706
				QSPNEEDS	Percent of Population with a Disability	0.5721
4	-	6.53%	Wealth	QRICH200K	Percent of Households Earning Greater Than $200,000 Annually	0.9503
				PERCAP	Per Capita Income	0.6781
5	+	4.71%	Female	QFEMALE	Percent Female	0.8067
				QFEMLBR	Percent Female Participation in Labor Force	0.8388
6	+	4.61%	Limited English proficiency	QESL	Percent Speaking English as a Second Language with Limited English Profiency	0.8581
7	+	4.45%	Female headed household	QFHH	Percent Female Headed Households	0.8444
	Total	**64.76%**				

100-year floodplain in Dane county, Wisconsin

The 100-year floodplain (*Figure 3*) indicates a one-percent or a higher chance of flooding in a year (FEMA 2017). *Table 5* entails a summary of the floodplains compared to the total blockgroups in Dane county, WI. The floodplains area distributed among 41.61% of the blockgroups in Dane county. The floodplain also covers approximately 13% or 156.61 square miles of the total area of Dane county.

Table 5 A summary of floodplain area.

	Floodplain	Blockgroups	Units
Count	129	310	#
Minimum	0.000534	0.02	sq. mi.
Maximum	15.4456	66.70	sq. mi.
Sum	156.61541	1238.41	sq. mi.

Source: U.S. Census Bureau

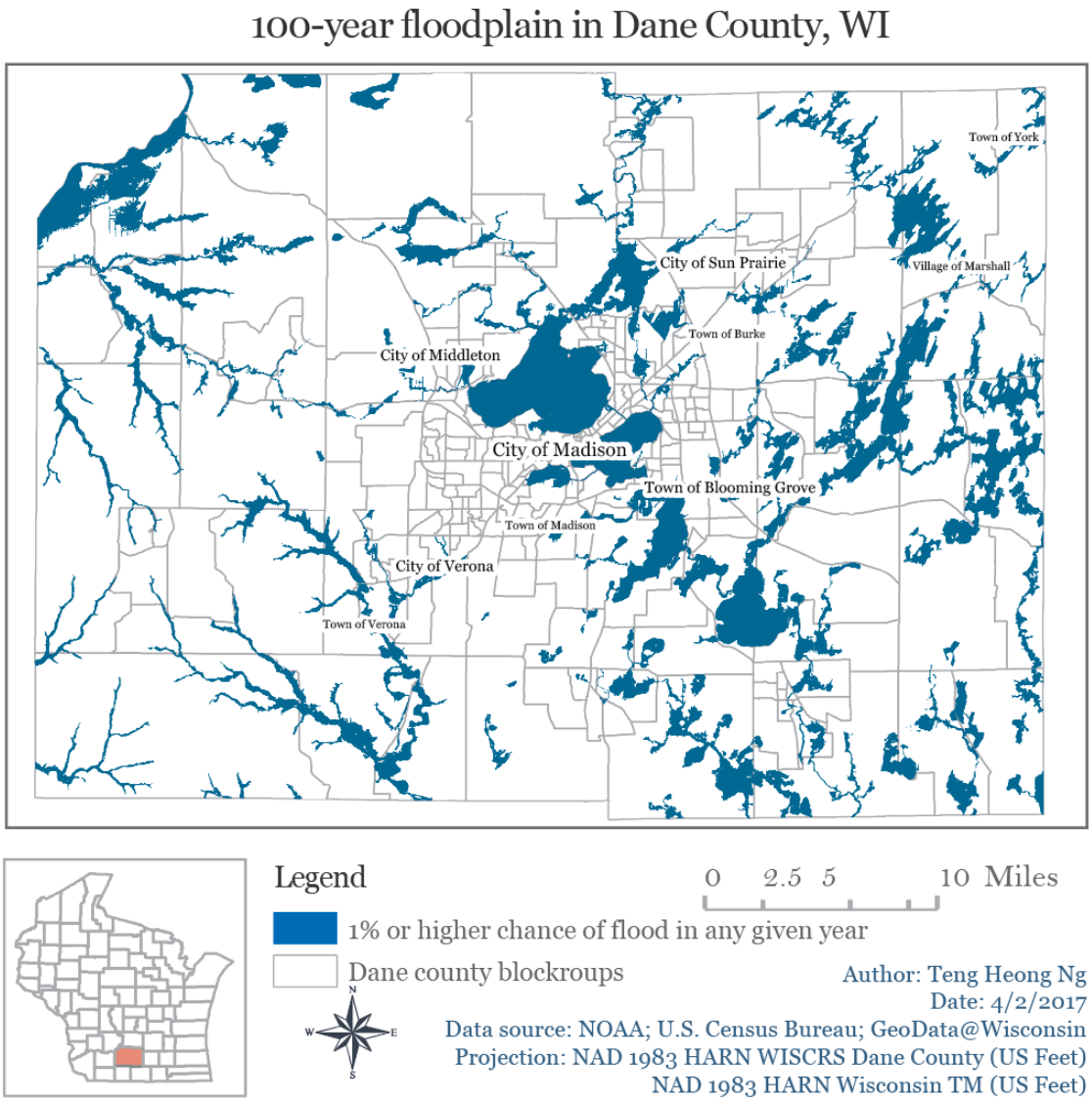

Figure 3 100-year floodplain in Dane County, WI.

SoVI Mapping

Appendix D: SoVI Map shows the distribution of High (SD>= 1.5), Medium (-0.5<= SD <0.5), Low (SD <-0.5) SoVI at the blockgroups-level in Dane county, WI. One of the blockgroups with High SoVI are located at the south of Lake Mendota (Eagle Height Residence Hall) where diverse communities of international graduate students and visiting scholars are living. The average income of a graduate student is around USD 25,000 (Glassdoor 2017). The blockgroups to the west of Eagle Heights are one of the most affluent neighborhoods in Dane county and it is not included as the High SoVI. This demonstrates the validity of the SoVI index, which reflects the actual social economic status of the blockgroups. *Table 6* shows the area, number of blockgroups, and the percentage of floodplains by SoVI level. From the table, only 18% of the High SoVI blockgroups are overlapping with the floodplain. Thus, it does not reflect the objective of identifying areas that are vulnerable to floods.

Table 6 Summary of floodplain by SoVI level.

Level of SoVI	Area (sq. mi.)		No. of Blockgroups	
High (SD>=1.5)	2.59/16.53	18%	6/26	23%
Low (SD< -1.5)	0.57/5.678	10%	3/4	75%

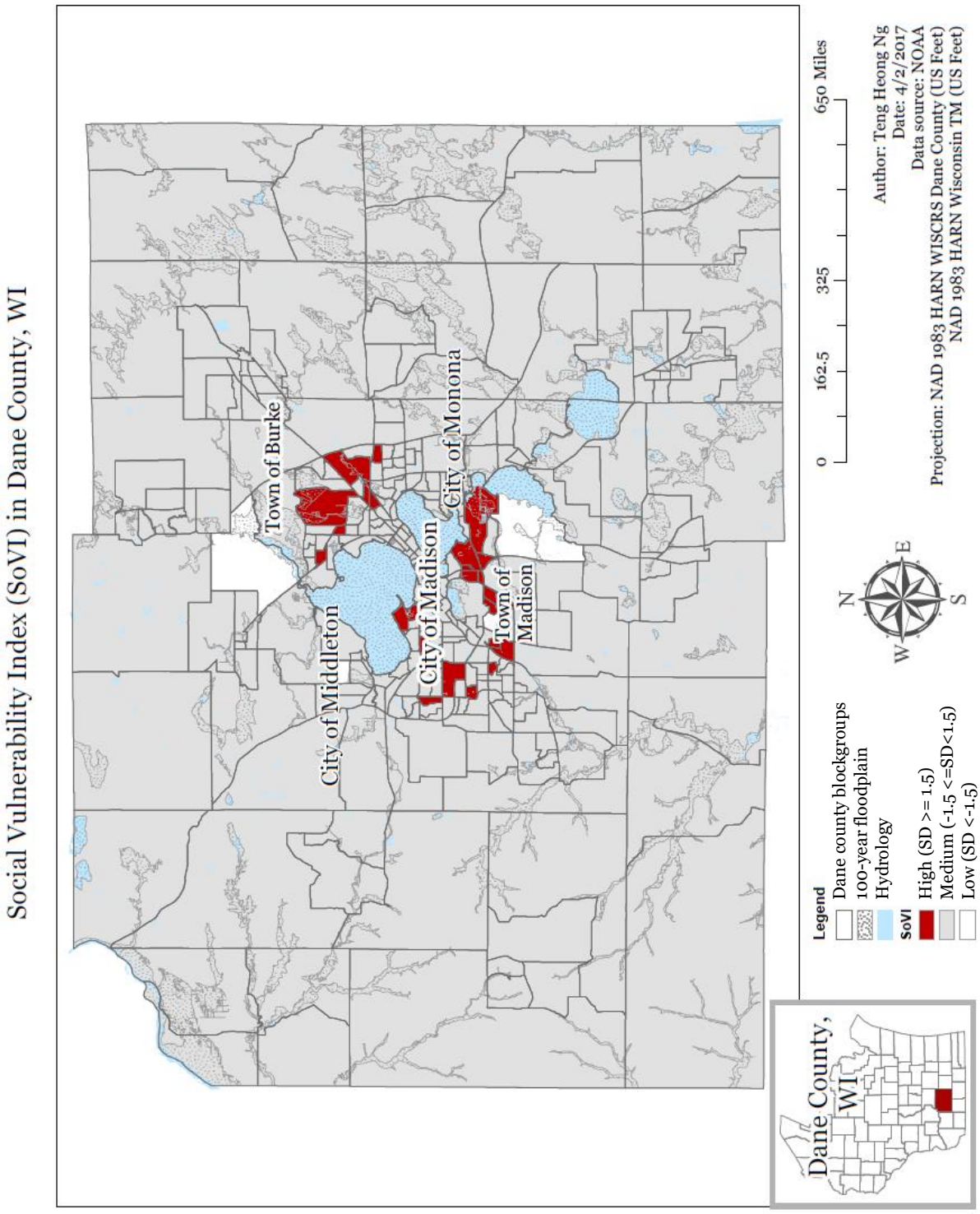

Figure 4 Social Vulnerability Index (SoVI) in Dane County, WI

SoV2FI

Table 7 Descriptive summary of SoV2FI.

SoV2FI	
Count	308
Mean	-1.36
Minimum	-91.12
Maximum	180.4
Standard Deviation	14.72

Table 7 indicates a descriptive summary of the SoV2FI scores. Out of the 308 blockgroups, the minimum and maximum scores are -1.36 and 180.44 respectively.

Again, the SoV2FI scores only illustrate the relativity but not the exact scale of social vulnerability to flooding among the blockgroups in Dane county, WI. After taking the percentage of floodplain into consideration, I successfully eliminated blockgroups that are not intersecting with the floodplain. The percentage of floodplain area in the High SoV2FI is 17% larger compared with the percentage of floodplain area in the High SoVI category (See *Table 8*). This has proven that SoV2FI is a more accurate model to evaluate social vulnerabilities to flood in Dane county, WI.

Table 8 Floodplain area by SoV2FI level.

Level of SoV2FI	Area (sq. mi.)		No. of Blockgroups	
High (SD >= 1.5)	4.65/13.31	35%	7/7	100%
Low (SD< -1.5)	38.55/121.58	32%	10/10	100%

Figure 5 shows the SoV2FI distribution after taking into consideration of the percentage of 100-year-floodplains in each blockgroup. Overall, the seven blockgroups with High SoV2FI are distributed in the northwest, central, and south of the City of Madison and the south of the City of Monona. In addition, the residents around the south side of Lake Monona and the residents at the City of Middleton are classified as high social vulnerable areas. Appendix F provides a detailed list of blockgroups by High SoV2FI.

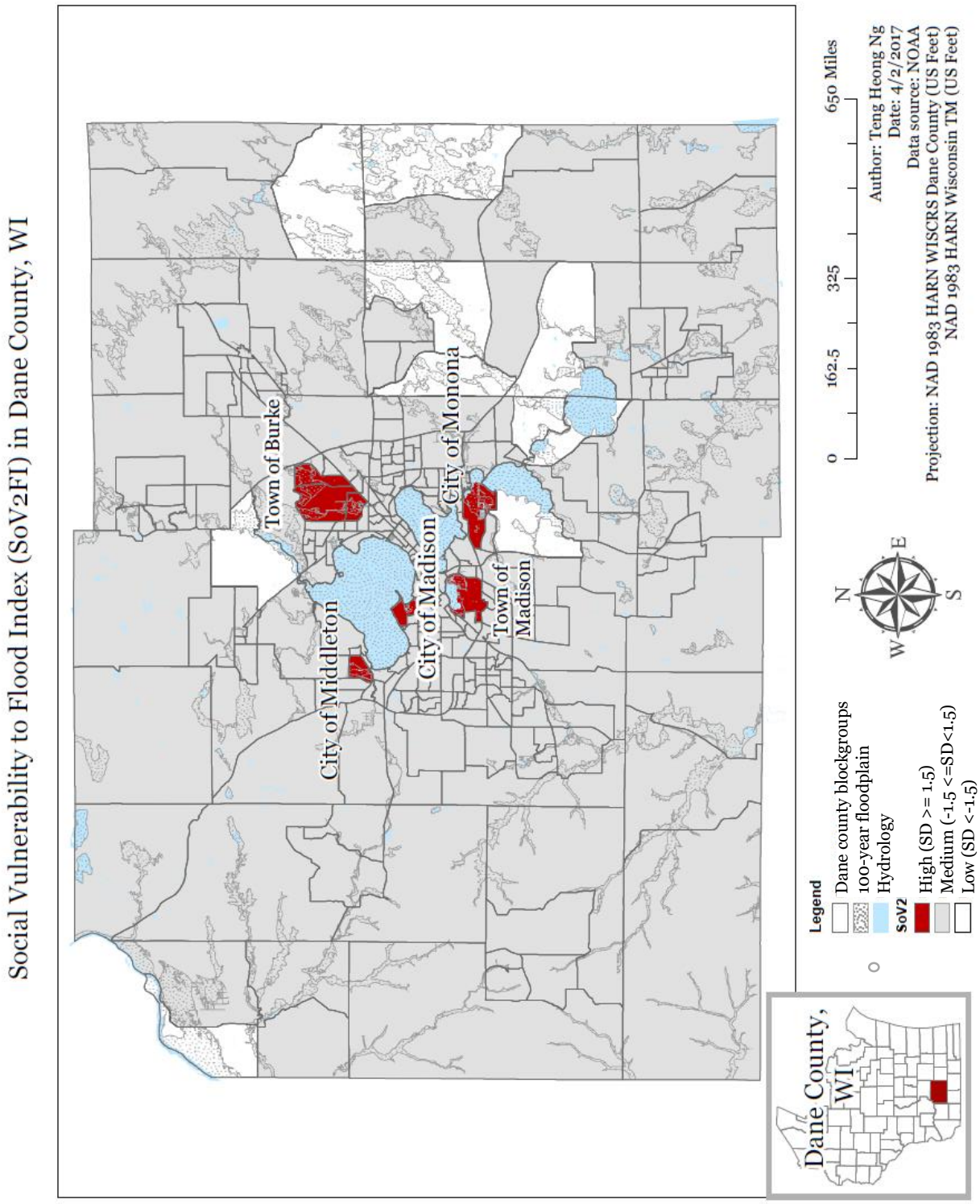

Figure 5 Social Vulnerability to Flood Index (SoV2FI) in Dane County, WI.

Limitations

The residents in high SoV2FI blockgroups might not actually live in the 100-year floodplain. For instance, Eagle Heights is a resident area in high SoV2FI blockgroup but the location of residents are not overlapping with the actual 100-year floodplain. The Eagle Heights residents are less likely to experience flooding. A few further steps are required to verify the validation of the result. For instance, an actual field trip to the high SoV2FI blockgroups can help identify whether the residents are exposed to the risk of flooding.

The accuracy of the result is constrained by the margin of error of the data collected from the American Community Survey.

Conclusion and Recommendations

In conclusion, SoV2FI demonstrates the potential to enhance SoVI by taking the scale of floodplain risks in Dane county, WI into consideration. The information can be useful for local authorities to align disaster management policy and allocate resources to the neglected communities. Dane county government can utilize SoV2FI to work on consistency in mitigation plan, allow input from stakeholders, enhance communication of flood risk through media, and identify opportunities for collaboration.

Firstly, relevant governmental agency and regional planning commission in Dane county, Wisconsin such as Dane County Department of Emergency Management and Capital Area Regional Planning Commission should make a parallel between its recognition of the socially vulnerable groups to natural hazards with the actual hazards mitigation plan. For instance, in the multi-hazards mitigation plan April 2009, Dane County Department of Emergency Management identified limited English speaking skills as one of the causes of vulnerability to natural hazards. However, Dane county sets multilingual education materials as a low priority and at the same time considers public communication is the highest priority of communication (2009). Such inconsistencies in the priority setting has ignored the fact that Dane county has 11.9% of the population speaking a language other than English at home and 6.3% of the population with Hispanic or Latino origins. In addition, the Dane county Emergency Management website only provide English as the only language for communication. Local authorities should address the needs of diverse communities to ensure effective hazard mitigation plan.

Secondly, this project can improve its reliability by receiving feedback from the local authorities as well as the communities to verify the accuracy of the map. After all, the purpose of the report is to aid the locals in creating relevant hazard mitigation policy (Hebb and Mortsch 2007; Oulahen 2013). Disaster Mitigation Act of 2000 requires the involvement of communities in mitigation activities and revision of studies and reports (Dane county 2009).

Thirdly, the evolution of SoVI should not stop at GIS mapping. With the advancement of communication technology, it is also promising to create a user-friendly tool that allows planners or communities to calculate SoV2FI, generate a report, and share the information instantaneously through a website. For instance, using both R and model builder from ArcMap 10.4.1, Dane county government can create a website that hosts the SoV2FI tool and allows a user who has no prior knowledge of mapping to select and customize variables and generate an analysis.

Lastly, Dane county, WI could consider collaboration between local government, community, and or non-government organization to mitigate the risk of flooding. The SoV2FI at the blockgroups-level can reveal very detailed information such as the location of the neighborhood. Dane county can use this information to identify potential partners for public education. For instance, at the High SoV2FI blockgroups in the south of Madison, Dane county can work with the Centro Hispano, a community center located at the heart of a large population of Hispanic who has limited English proficiency. Partnership with the local agencies that have a deep understanding about the local situation can make communication more effective.

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Appendices

Appendix A: R Script for Principal Component Analysis (PCA) and Factor Analysis

```
# Professional Project: Assessing Social Vulnerability to Floods in Dane County, WI
# Teng Heong Ng
# 4/2/2017

# Set working directory
setwd ("C: /Users/Teng Heong/Desktop/pplog")

# Load data
mydata<- read.csv ("C: /Users/Teng Heong/Desktop/pplog/data_stad.csv")
attach (mydata)

# Define variables
X <- cbind(POPDEN, QBLACK,  QASIAN,     QNATAM,   QHISP,      QFEMALE,
           MEDAGE,  QAGEDEP,  QFAM,      QRICH200K,        QSSBEN,
           PERCAP,  QPOVTY,   QFHH,      QUNOCCHU,         QRENTER,
           QMOHO,   QESL, QED12LES,  QCVLUN,   QSPNEEDS,  QNOAUTO,
           QFEMLBR,  QEXTRCT,  QNOHLTH,  QSERV)

# Principal Component Analysis
pca1 <- princomp (X, scores = TRUE, cor = TRUE)

# Summary of PCA
summary (pca1)

# Scree plot of eigenvalues
jpeg ("plot.jpg")
plot (pca1)
graphics.off ()

jpeg ("screeplot.jpg")
screeplot (pca1, type="line", main="Scree Plot")
graphics.off()

# Conduct factor analysis using varimax rotation
sink ("fa2.csv")
fa2 <- factanal(X, factor=7, rotation="varimax")
fa2
sink ()

rm (list = ls ())
```

Appendix B: List of blockgroups with High (SD>= 1.5) SoV2FI in Dane county, WI

Blockgroup ID	Municipalities
550250014021	City of Madison/ Town of Madison
550250032001	City of Madison
550250025001	City of Madison
550250025002	City of Madison
550250026022	City of Madison
550250111024	City of Middleton
550250015022	City of Monona