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Article

Risk Communication and Climate Justice Planning: A Case of Michigan's Huron River Watershed

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Abstract
Communicating climate risks is crucial when engaging the public to support climate action planning and addressing climate justice. How does evidence-based communication influence local residents' risk perception and potential behavior change in support of climate planning? Built upon our previous study of Climate Justice maps illustrating high scores of both social and ecological vulnerability in Michigan's Huron River watershed, USA, a quasi-experiment was conducted to examine the effects of Climate Justice mapping intervention on residents' perceptions and preparedness for climate change associated hazards in Michigan. Two groups were compared: residents in Climate Justice areas with high social and ecological vulnerability scores in the watershed (n = 76) and residents in comparison areas in Michigan (n = 69). Measurements for risk perception include perceived exposure, sensitivity, and adaptability to hazards. Results indicate that risk information has a significant effect on perceived sensitivity and level of preparedness for future climate extremes among participants living in Climate Justice areas. Findings highlight the value of integrating scientific risk assessment information in risk communication to align calculated and perceived risks. This study suggests effective risk communication can influence local support of climate action plans and implementation of strategies that address climate justice and achieve social sustainability in local communities.

Keywords
climate change planning; climate justice; risk communication; risk perception; social sustainability; vulnerability

Issue
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1. Introduction

As of August 2017, 372 U.S. Mayors representing 67.5 million people in American cities are committed to upholding the Paris Climate Agreement—an agreement within the United Nations Framework Convention on Climate Change to curtail greenhouse gas emission mitigation and to strengthen adaptation and finance—in response to the derailing of the White House's policy on climate change (climatemayors.org). Climate change associated extreme events (e.g., extreme heat and cold, storms, and droughts) have become more frequent, intense, and uncertain across geographical locations around the globe (Intergovernmental Panel on Climate Change [IPCC], 2014); subsequently, more communities are likely to be exposed to climate change associated hazards and the hardest hit are socially vulnerable groups (e.g., minority populations, the elderly, children, women, people living in poverty or those with low education attainment) (Cutter, Boruff, & Shirley, 2003).

Social ecology studies human-environment relations that reflect psychological, cultural, and institutional context to environmental change and vice versa (Lejano & Stokols, 2013). It provides a holistic frame for examining the dynamic relationship between equity, planning, climate change, and sustainability. Besides environmental and economic sustainability, social sustainability has been overlooked in many U.S. cities. Schrock, Bassett and Green (2015) found that over a hundred cities' sustainability plans failed to include equity as a measurable outcome comparing to extensive measures developed for achieving environmental and economic goals of sustainability. In addition, there is a lack of climate justice outcomes in climate action plans. The deficiency of equity outcomes in public policies implies the need for public support. As climate change adaptation becomes an integral part of urban planning for coping with climate change threats (e.g., municipal climate action plans), identifying strategies for communicating climate change risks and adaptation strategies plays a critical role in engaging the public to support climate planning goals (Hagen, 2016a; Hagen, 2016b; Maibach, Roser-Renouf, & Leiserowitz, 2008; Moser, 2014). One of the goals should address climate justice—the inequitable distribution of burdens and impacts from climate change (Cheng, 2016; Page, 2008)—and equity in local climate planning.

Climate justice was originated from global debates on climate change policies that concern unjust distributions of the causes and burdens of climate change impacts among greenhouse gas emissions contributing countries and countries with lower carbon emissions (e.g., island nations) and suffering the most from environmental changes (e.g., sea level rise) (Page, 2008). Considering unjust social, environmental, and health impacts locally in the U.S., the theory of environmental justice helps to put climate justice in a local planning context. Decades of environmental justice research suggest that racial segregation and discrimination in the U.S. has contributed to placing socially vulnerable groups at disproportionate risk due to toxic and hazardous wastes facilities (Bullard, Mohai, Saha, & Wright, 2007; Mohai, Pellow, & Roberts, 2009; United Church of Christ, 1987), air pollution (Grineski, Bolin, & Boone, 2007), as well as a lack of access to clean water in U.S. cities (Bolin, Seetharam, & Pompeii, 2010). Recent studies have extended environmental justice concepts to climate justice at local scale to include the exposure to climate change associated hazards such as climate change-induced flooding (Cheng, 2013) and extreme heats (Harlan, Brazel, Prashad, Stefanov, & Larsen, 2006) in socially vulnerable communities.

Risk communication connects to sustainability science through the understanding of societal systems via feedbacks from individual-level beliefs and perceptions, as well as identifying communication strategies for improving public engagement with climate change. In turn, societal capacity for anticipating uncertainty can be increased for future planning (Lindenfeld, Smith, Norton, & Grecu, 2014; van der Linden, Maibach, & Leiserowitz, 2015). Communicating risks associated with future climate extremes and adaptation motivates the public to change behavior and support climate planning goals (Moser, 2014; Wolf & Moser, 2011). Moreover, visual representation of scientific evidence is easily comprehended by lay people (Severtson & Henriques, 2009) and offers opportunities for bridging calculated and perceived climate change risks and subsequent behaviors change in support for local planning. This study focuses on the impact of a scientific information intervention on individuals' risk perception of climate change associated extreme events in local communities from planning perspective. To address the linkage between risk communication literature and climate justice planning, we investigated how communicating the notion of climate justice facilitates community's capacity to cope with climate change impacts. Specifically, we examined the effects of an evidence-based visualization (e.g., mapping) intervention on residents' risk perception and potential behavior change in support of climate planning from a case built upon our previous study in Michigan, U.S.

1.1. Risk Assessment, Communication, and Perception

Risk assessment that addresses complex coupled human and natural systems in coping with environmental and social changes can be depicted based on assessment of both ecological vulnerability of a place (e.g., biophysical characteristics susceptible to natural hazards) and social vulnerability (e.g., Birkmann, 2006; Blaikie, 1994; Cutter et al., 2003; Cutter & Morath, 2013). This study built upon previous research on investigating the spatial pattern of climate justice using a *Climate Justice Index* in a social-ecological vulnerability assessment framework (Cheng, 2016) modified from the Hazards-of-Place (HOP) model (Cutter et al., 2003). The HOP model integrates ecological vulnerability (i.e., natural hazards) and social vulnerability (i.e., exposure, sensitivity, and adaptability to hazards) at specific geographic locations and has been widely applied for measuring vulnerability to environmental hazards (e.g., Borden, Schmidtlein, Emrich, Piegorsch, & Cutter, 2007) and assessing climate change associated risks (e.g., climate change-induced flooding risks in Cheng, 2013). Study units (e.g., census tracts) that have high vulnerability scores in both social and ecological vulnerability are defined as "Climate Justice areas" in this study.

The concept of vulnerability involves three interrelated dimensions: 1) exposure to specific social or environmental stresses (e.g., climate change associated hazards), 2) sensitivity to those stresses (e.g., socio-economic characteristics), and 3) adaptive capacity to cope with impacts from those stresses at multiple institutional scales from an individual to collective adaptive capacity (Adger, 2006; Birkmann, 2006; Polsky, Neff, & Yarnal, 2007). Figure 1 illustrates a theoretical framework of relationships and dimensions of risk assessment, risk perceptions, and risk communication. Risk assessment is measured from social and ecological vulnerability, which includes elements of exposure, sensitivity, and adaptability to climate change associated hazards. The risk information derived from risk assessment can be used in risk communication tools as an intervention to affect risk perceptions, which in turn could affect adaptation behavior change. In the meantime, the feedback loop occurs when local knowledge becomes information that is communicated through scientific analysis and becomes new knowledge for risk assessment.

Social vulnerability reflects the dynamic socio-economic and cultural structure and fabric of a society which varies from place to place. The complex political and economic systems that result from urbanization often create socially vulnerable groups within society who are more susceptible to various hazards (Blaikie, 1994; Colten, 2006; Cutter et al., 2003). When communities have insufficient coping capacity for shocks and disturbances, they are likely to become more vulnerable to the adverse effects of uncertainty and extreme variation imposed by climate change associated hazards (IPCC, 2014). Measures of adaptability include wealth, education level, migrant status and associated language barriers, and access to social resources (Cutter et al., 2003; Polsky et al., 2007) that can affect preparedness for coping with disasters. Sensitivity can be a factor of demographic background (e.g., age, gender, race, disability), household structure, social resources dependency, economic status (e.g., poverty status, income level, unemployment, agricultural and service dependent occupations), in addition to the built environment context (e.g., housing density, housing structure, infrastructure age) (Polsky et al., 2007).

Ecological vulnerability can be measured through calculated risks (e.g., integration of climate and hydrological models for climate change-induced flooding hazards in Cheng, Yang, Ryan, Yu, & Brabec, 2017). Exposure to hazards, aside from calculated spatial analyses, could be measured through perceived risks (e.g., past experiences of extreme events). The tension between objective and perceived risks affects behaviors and capacity for coping environmental change (Adger, 2006). Studies have shown that demographic background and individual traits can factor into one's perceived risks. Women (Ho, Shaw, Lin, & Chiu, 2008; Whyte, 1986; Zhang, 2010)

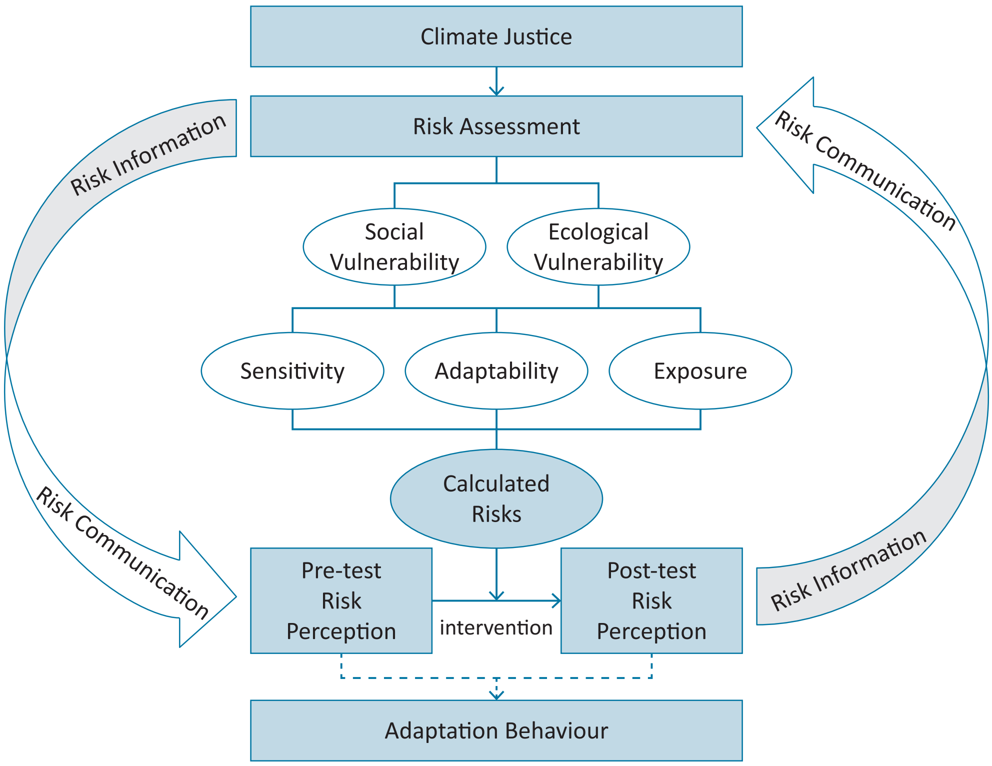


Figure 1. Research framework of relationships between climate justice and dimensions of risk assessment, risk communication, risk perceptions and adaptation behavior. Risk communication using scientifically determined risks (i.e., calculated risks) serves as an intervention in this study to gauge residents' subjective assessment of risk perceptions that affect adaptation behaviors (dashed line indicates using perceived preparedness as a proxy for adaptation behavior).

and the elderly (Alexander, 1998; Whyte, 1986) tend to have increased perceived risks. In general, people who have more experience with hazards tend to think they are more likely to be future victims and have more awareness about the risks (Ho et al., 2008; Weinstein, 1989). On the contrary, people who recently experience disasters tend to have a lower risk perception to future hazards (Ryan & Hamin, 2008; Vinh Hung, Shaw, & Kobayashi, 2007).

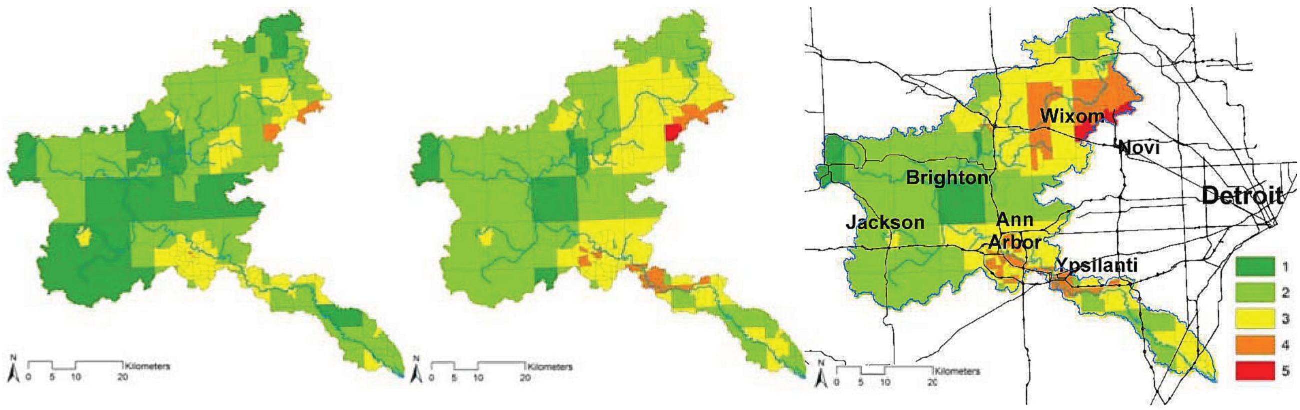
Risk perception is a key determinant of people's behavioral responses to combat climate change (e.g., Maibach et al., 2008). The factors that affect risk perception are also strongly related to hazard mitigation, preparedness, and adaptation behaviors. For example, education and past experiences to disasters are both positively correlated with risk perceptions and flood preparedness (Mishra & Suar, 2007). Those sociodemographic indicators that affect risk perception also are included in the indicators of social vulnerability (e.g., SoVI by Cutter et al., 2003; Cutter & Morath, 2013). Therefore, risk perception serves as a mediator between the explanatory factors of risk assessment and adaptation behavior.

1.2. Research Framework and Hypotheses

This study investigated how visual communication such as mapping of climate vulnerability based on scientific evidence can influence risk perception and subsequent adaptation actions among local residents (Adger et al., 2009.; Lu et al., 2016; Safi, Smith, & Liu, 2012). Vulnerability mapping has been identified as an effective tool to support urban planning and to inform the public about local climate change impacts (Preston, Yuen, & Westaway, 2011). We utilized mapping as a visualization tool in risk communication with climate justice information derived from a previous study in the Huron River watershed in southeastern Michigan (Cheng, 2016; Xu et al., 2017) as a risk information intervention (Figure 2). The *Climate Justice Index* was represented in a 5-scale ranking. The orange (scale = 4) and red (scale = 5) colors indicate places where 1) flooding is more likely to occur as the climate changes, 2) there is a greater threat of environmental hazards occurring based on the presence of contaminated sites, waste disposal facilities etc., and 3) a higher portion of the population is vulnerable to disasters (the elderly, children, minorities, etc.). In other words, a higher ranking represents a community having greater social and ecological vulnerability under climate change impacts. In this study, these highlighted areas are referred to as "Climate Justice areas" and we focus on the three cities they contain largely: Ann Arbor, Ypsilanti, and Wixom.

We compared samples from two groups: 1) residents living in the zip codes or cities that contain large "Climate Justice areas" identified in Figure 2, and 2) residents in Michigan zip codes that do not contain Climate Justice areas as "comparison areas."

Our study explored the following questions: 1) how well are residents aware of their climate risks and social and ecological vulnerability to climate change; and 2) to what degree does climate risk information affect residents' perceptions and adaptation behaviors? Taken together, we hypothesized that the communication of visualized risk information would increase individuals' awareness of climate associated hazards and decrease their perceived levels of preparedness to respond to future extreme events, especially in Climate Justice areas.



(a) Baseline (Current Conditions) (b) Lower Climate Change Impact (Better case scenario) (c) Higher Climate Change Impact (Worse case scenario)

Figure 2. The Climate Justice maps as included in the survey illustrate the results from a previous study conducted for the Huron River watershed in Michigan, which found various degrees of climate change impacts of flooding and associated environmental hazards (Cheng, 2016; Xu et al., 2007). The following texts were used in the survey to describe the maps: "The color represents a 5-scale ranking and the orange (scale = 4) and red (scale = 5) colors indicate places where 1) flooding is more likely to occur as the climate changes, 2) more environmental hazards occur (contaminated sites, waste disposal facilities etc.), and 3) a higher portion of the population is vulnerable to disasters (elderly, children, minorities, etc.)."

Hypothesis 1: The effect of risk mapping intervention on perceived exposure will be more pronounced for residents who live in Climate Justice areas than for those in comparison areas. Residents receiving the risk information intervention will report higher ratings of perceived exposure to climate change associated extreme events than their pre-intervention scores, particularly in Climate Justice areas.

Hypothesis 2: The effect of risk mapping intervention on perceived sensitivity will be more pronounced for residents who live in Climate Justice areas than those in comparison areas. That is, residents receiving the risk information intervention will report higher ratings of perceived sensitivity to extreme events than their pre-intervention scores, particularly in Climate Justice areas.

Hypothesis 3: The effect of risk mapping intervention on perceived adaptability will be more pronounced for residents who live in Climate Justice areas than those in comparison areas. That is, residents receiving risk information intervention will report lower ratings of perceived adaptability than their pre-intervention scores, particularly in Climate Justice areas.

2. Study Area and Background

The Huron River watershed is located southwest of the Detroit metropolitan area in Michigan, U.S. The Huron River Watershed Council (HRWC), a not-for-profit organization dedicated to river protection, has served the watershed communities since 1965. HRWC runs several scientific programs, outreach and education, and watershed management projects that engage with the public, local stakeholders, and governments to influence decision-making and strengthen stewardship of the watershed. In recent years, in an effort to build climate-resilient communities, HRWC brought together scientists, policy advisors, and local practitioners to improve stormwater management, public awareness of drinking water safety, and green infrastructure implementation.

In collaboration with HRWC, our research team integrated hydrological modeling (Xu et al., in press), environmental justice, and social vulnerability sciences to develop a Climate Justice Index forecasting the probability and spatial distribution of climate change-induced flooding hazards in the next fifty years in addition to water quality impairment and social vulnerability implications (see detailed methods in Cheng, 2016).

The social-ecological vulnerability assessment included in the *Climate Justice Index* was conducted in the census tract level, rather than specific cities. However, local planning relies on municipal governance and the assistance of regional planning agencies such as the HRWC. To understand the context of social and institutional capacity in coping with climate change (e.g., sensitivity and adaptability measures), Table 1 summarizes commonly used social vulnerability indicators from U.S. Census data across the Huron River watershed (HRW), the three cities that contain large Climate Justice areas in the watershed, the state of Michigan, and the entire U.S.

Overall, the populations of young children, the elderly, and women in the HRW are comparable to the demographics of the state and the nation. Older adult populations are slightly relatively smaller in the three cities (11.9% in HRW compared to 9.3% in Ann Arbor and 7% in Wixom) whereas Wixom has slightly more children (6.8% comparing to 5.4% in HRW and 4.3% in Ann Arbor). The watershed is predominately white (83.5%) while the three cities are more diverse. Ypsilanti and Wixom have a larger African American population (29.2% and 11.1% respectively compared to 8.1% in the HRW) while Ann Arbor has more Asians (14.4% compared to 4.8% in HRW) and Wixom has slightly more Hispanics (4.3% compared to 2.6% in HRW). In general, the HRW has a smaller population without a high school diploma (6.7% compared to 10.4% in Michigan and 13.3% in USA), yet Ypsilanti is higher than the HRW in percentage of its population (9.9%) with lower education attainment. In addition, the three cities also have significantly more renters, which are generally more vulnerable to disasters, than the HRW (69.1% in Ypsilanti, 55.2% in Ann Arbor, 49.3% in Wixom compared to 27.7% in HRW). Michigan's median household income is $49,576 in 2015 dollars with 15.8% of the population in poverty, compared to $46,420 and 15.4% in Wixom, $31,061 and 33.4% in Ypsilanti, and $55,990 and 23.4% in Ann Arbor. Ypsilanti has the lowest median housing values and lowest per capita income among all study areas, Michigan, and the U.S., in addition to its high poverty rate (33.4% compared to 23.4% in Ann Arbor, 15.4% in Wixom, 15.8% in Michigan, 13.5% in the U.S., and the lowest of 11.6% in the HRW).

3. Method

3.1. Study Design and Participant Recruitment

We conducted a *quasi-experiment* with the nonequivalent pretest-posttest design by recruiting adults over 18 years old living in Michigan to assess the impacts of climate risk mapping intervention. The between-subject factor is participants' current area of residency in two groups: 1) Climate Justice areas and 2) comparison areas (defined in Section 1.2). The within-subject factor is *Time*—pre- vs. post-receipt of Climate Justice mapping intervention (shown in Figure 2).

The term *quasi-experiment* was firstly coined by Cook and Campbell (1979) to describe an approximation of a true randomized experiment where researchers have absolute control over randomly assigning participants to two or more treatment conditions. The process of randomization ensures internal validity for testing effects of a treatment by isolating between-group variations (Leedy & Ormrod, 2010). As described by Shadish, Cook & Campbell (2002), quasi-experiments share the similar advantage of true experiments: "to test descriptive causal hypotheses about manipulable causes (p. 14)."

Table 1. Summary of commonly used socio-economic indicators of social vulnerability in U.S. census data across the Huron River watershed (HRW), three cities containing large Climate Justice areas in the watershed (Ann Arbor, Ypsilanti, and Wixom), the state of Michigan, and the U.S.

Indicators	HRW	Ann Arbor	Ypsilanti	Wixom	Michigan	USA
Population[a]	812,170*	113,934	19,435	13,498	9,883,640	308,745,538
Age and Sex						
Persons under 5 years old, percent[a]	5.4	4.3	4.9	6.8	6.0	6.5
Persons 65 years old and over, percent[a]	11.9	9.3	8.3	7.0	13.8	13.0
Female persons, percent[a]	50.6	50.7	50.3	50.1	50.9	50.8
Race						
African American, percent[a]	8.1	7.7	29.2	11.1	14.2	12.6
Native American, percent[a]	0.2	0.3	0.6	0.2	0.6	0.9
Asian, percent[a]	4.8	14.4	3.4	4.9	2.4	4.8
Two or More Races, percent[a]	2.7	4.1	3.9	5.1	4.4	16.3
Hispanic or Latino, percent[a]	2.6	3.6	2.1	4.3	2.3	2.9
White, percent[a]	83.5	70.4	59.4	77.0	76.6	63.7
Housing						
Housing density[b]	903	1789	2141	719	80	37
Renter-occupied housing unit rate[c]	27.7	55.2	69.1	49.3	29.0	36.1
Median value of housing units[d]	$190,233	$240,700	$118,000	$191,300	$122,400	$178,600
Median gross rent[d]	$848	$1,063	$746	$644	$783	$928
Education						
Age 25 years+ with no high school diploma, percent[e]	6.7	3.6	9.9	5.8	10.4	13.3
Economy						
Age 16 years+ in civilian labor force, percent of total population[d]	53.6	61.1	69.4	77.1	61.2	63.3
Age 16 years+ female, percent of total civilian labor force[d]	62.4	57.8	67.3	70.8	57.1	58.5
Income and Poverty						
Per capita income in past 12 months[f]	$33,018	$36,334	$22,346	$32,085	$26,607	$28,930
Persons in poverty, percent[d]	11.6	23.4	33.4	15.4	15.8	13.5

* HRW population was estimated based on entire census tracts that are intersected with the watershed without area appropriation adjustment. This estimate is greater than HRWC's estimate of a 600,000 population within the watershed boundary only.
[a] U.S. Census 2010 for U.S., Michigan, Ann Arbor, Ypsilanti, and Wixom; U.S. Census 2009–2013 estimate for HRW census tracts mean (n = 220).
[b] calculated from total population/total square miles from data source (a)
[c] calculated from 100%–%owner occupied housing unit rate of data source (d)
[d] U.S. Census 2011-2015 estimate for U.S., Michigan, Ann Arbor, Ypsilanti, and Wixom; U.S. Census 2009–2013 estimate for HRW census tracts mean (n = 220)
[e] calculated from 100%–%high school graduate or higher of persons age 25 years+ from data source (d)
[f] U.S. Census 2011-2015 estimate in 2015 dollars for U.S., Michigan, Ann Arbor, Ypsilanti, and Wixom; U.S. Census 2009-2013 estimate in 2013 dollars for HRW census tracts mean (n = 220)

However, quasi-experiments do not assign individuals to treatment conditions randomly. In applied social science, random assignment of study participants is often not feasible. Accordingly, this method is the preferred method to evaluate the effects of educational programs in schools, community-based health interventions, and risk communication programs for natural hazards (e.g., Tanaka, 2005; Terpstra, Lindell, & Gutteling, 2009).

In summary, the nonequivalent pre- and post-intervention design in quasi-experimental studies offer several methodological advantages. First, a quasi-experiment is the most sensible way to answer our research questions as random sampling of assigning participants to different areas of residency was not applicable. Second, incorporating a pre-intervention assessment offers the possibility for controlling initial participants' demographic differences due to self-selection (Shadish et al., 2002). Third, the mean differences between treatment (Climate Justice areas) and comparison (comparison areas) groups allows us to estimate the effects of a risk mapping intervention on perceived risk of extreme events (Cook & Campbell, 1979).

We conducted a web-based survey using a convenience sample (i.e., non-random sample) of Michigan residents. Survey responses were collected during October 2016 and January 2017 using the professional software *Qualtrics*. In order to yield sufficient statistical power to detect accurate and reliable inferences, participants were solicited using multiple ways to reach a sample size required in experimental designs. Statistical power is critically important to experimental studies, as it represents the probability of finding an observed difference between two groups when a difference actually exists (Oakes & Feldman, 2001). According to Guo et al. (2013), a sample size of 40 participants per treatment group was our target to yield a statistical power of at least 0.80 for assessing the significance of a *Time by Treatment* interaction in our repeated measures design.

Participants living in the Huron River watershed were recruited through a liaison in HRWC since the project outcomes can advance HRWC's efforts in assisting communities in the watershed for developing their climate action plans and implementing adaptation strategies. In October 2016, the liaison distributed the first wave of invitation emails to members of HRWC who subscribe to HRWC's electronic newsletters. The first solicitation email went to 6,488 recipients, 1,428 opened the newsletter, and 34 clicked on the embedded survey link. The second wave of invitation emails was sent out in November, and 28 more HRWC members clicked on the survey website. In addition, we recruited participants through social media platforms such as public community-based Facebook pages in targeted three cities as well as other local community groups (e.g., *Taiwanese in Michigan*).

The quasi-experiment consisted of the following three procedures. First, participants responded to a range of demographic characteristics associated with social vulnerability to hazards such as age, gender, race, employment status, housing status, educational attainment, length of living in the community, and past experiences. Second, questions were asked to reveal their risk perceptions before receiving the risk mapping intervention and to indicate how well they feel connected with their communities. Third, both groups received the same intervention derived from the previous climate justice study in the watershed. During the intervention, participants were instructed to read the scientific study results carefully and not allowed to click back in previous survey questions. Lastly, participants finished surveys with measures of risk perceptions and behavioral intention to support climate change actions in city policies such as implementing green infrastructure instruments.

3.2. Characteristics of Study Participants

Of the 241 adults that attempted the online survey, a total of 149 completed questionnaires (response rate = 62%) with no missing values. Among completed samples, four cases were excluded because they did not indicate their zip code within Michigan when they took the survey, resulting in 145 valid cases for final analysis. Among valid samples (N = 145), 52% (n = 76) reside in Climate Justice areas (6.6% from Wixom, 30.2% from Ypsilanti, 63.2% from Ann Arbor) and 48% (n = 69) are from comparison areas (26.1% within the Huron River watershed and 73.9% outside the watershed area but within Michigan). The decision to include respondents living outside the watershed in the comparison group was driven by two reasons. First, since the hydrological modeling did not project social-ecological vulnerability outside the watershed, participants from these areas are assumed to not be affected by the Climate Justice mapping intervention, which made them equivalent to a control condition that received no treatment. Second, we included more eligible participants into the comparison group to give us more statistical power to detect smaller effect sizes (Oakes & Feldman, 2001).

The majority of respondents are female (70.3%) and white (73.1%). The average age is 35–44 years old. In terms of ethnicity, 11.7% are African Americans; 2.8% Hispanics; 7.6% Asians. The relatively larger Asian participants in our sample represent a higher Asian population in Ann Arbor. All participants have a high school diploma and 7.6% have an associate's degree, 29.7% have a bachelor's degree, 46.2% have a master's degree and 11.7% have a doctorate degree. Our samples represent higher education attainment than Michigan's 26.9% of bachelor's degree or higher education population, which is comparable to 39.1% in Ypsilanti, 41.2% in Wixom and reflects the exceptionally high 71.9% in Ann Arbor, a city with a public research university. Approximate 63% live in an owned property. Participants varied in the annual household income (median income = \$60k∼79k), and about 23% report the income level of more than \$100K.

Table 2 summarizes social vulnerability indicators comparing sample characteristics between Climate Justice areas and comparison areas. Participants of two respective groups did not significantly differ (p-value less than 0.05) in their age, gender, educational level, household income, length of residence in the community, and the elder and youth composition in their households. Nevertheless, samples from Climate Justice areas did present a significantly higher percentage of socially vulnerable population of renters (46.1% vs. 27.5%) and part-time employees (25% vs. 7.2%), whereas samples in comparison areas have more African Americans (21.7% vs. 2.6%).

3.3. Survey Measures

The complete survey includes six sections with a total of 41 questions: 1) demographic information; 2) past expe-

Table 2. Summary of demographics associated with social vulnerability comparing among all samples and two groups (Climate Justice areas and comparison areas).

Selected Social Vulnerability Indicators from 33 variables in Cheng, 2016	**All samples** (N = 145)	**Comparison** (n = 69)	**Climate Justice** (n = 76)	**Chi-Square** (*p*-value * < 0.05)
Age and Gender				
Household with more than one person under 14 years old	23.4	27.5	19.7	1.61 (0.806)
Household with more than one person of 65 years and over	19.3	23.1	15.8	1.28 (0.527)
Women	70.3	75.4	65.8	1.20 (0.274)
Race				
African American	11.7	21.7	2.6	12.76*(0.000)
Asian	7.6	7.2	7.9	0.02 (0.883)
Hispanic	2.8	2.9	2.6	0.01 (0.922)
Two or more races	4.8	4.3	5.3	0.06 (0.797)
White	73.1	63.8	81.6	5.84*(0.016)
Housing				
Owners	62.8	72.5	53.9	5.31*(0.021)
Renters	37.2	27.5	46.1	
Homeowner property insurance	61.4	69.6	53.9	3.72 (0.054)
Renters insurance	24.1	20.3	27.6	1.07 (0.302)
Education				
High school	4.8	2.9	6.6	6.53 (0.163)
Associate's degree	7.6	13.0	2.6	
Bachelor's degree	29.7	29.0	30.3	
Master's degree	46.2	44.9	47.4	
Doctorate degree	11.7	10.1	13.2	
Economy: Employment status				
Employed, full-time	60	66.7	53.9	2.44 (0.118)
Employed, part-time	16.6	7.2	25	8.25*(0.004)
Retired	16.6	20.3	13.2	1.33 (0.248)
Others(Including not-employed and disabled)	6.9	5.8	7.9	0.25 (0.619)
Economy: Annual household income level				
Less than $20,000	11.7	11.6	11.8	6.11 (0.296)
$20,000-$39,999	15.9	15.9	15.8	
$40,000-$59,999	18.6	26.1	11.8	
$60,000-$79,999	20.0	14.5	25	
$80,000-$99,999	10.3	10.1	10.5	
More than $100,000	23.4	21.7	25	
Residency in the community/city				
Less than 1 year	6.2	7.2	5.3	6.78 (0.238)
1–5 years	30.3	24.6	35.5	
5–10 years	13.1	17.4	9.2	
10–20 years	18.6	14.5	22.4	
20–30 years, percent	13.8	13	14.5	
More than 30 years, percent	17.9	23.2	13.2	

rience to extreme events and perceptions of future risks; 3) perceived responsible parties for risk management; 4) beliefs and behaviors regarding green infrastructure implementation; 5) Climate Justice maps and risk perception and behaviors; and 6) attitudes and emotions toward climate change. Major measurement of risk perceptions demonstrated satisfactory internal consistencies. All these questions were rated on a 5-point Likert scale ranging from 1 (very unlikely/very vulnerable/not well at all) to 5 (very likely/ very vulnerable/extremely well)

(Kaplan & Kaplan, 1989). To ensure measurement reliability and validity of the survey scales, we conducted a pilot study with a total of 187 college students enrolled in two public Southwestern Universities in early October 2016. After obtaining voluntary consent, student completed the baseline assessments, mapping intervention, and answered posttest questionnaires online to receive extra credits for courses. The pilot study provided feedback on question wording to help improve the survey's organization and clarity.

This study focused on comparing participants' ratings of perceived risk associated with climate change impacts pre- and post-receiving the intervention. Table 3 summarizes a selected set of questions comparing risk perceptions across past experience, pre-intervention, and post-intervention temporal scales and in responding to the three dimensions of vulnerability concepts—exposure, sensitivity, and adaptability.

Perceived exposure was assessed using two identical items in pre- and post-intervention (Terpstra et al., 2009): "How likely do you think you may experience any one of those extreme events in the next 10 years?" Examples of possible extreme events included storms, floods, droughts, extreme heat or cold, tornadoes, and forest fires, in addition to an option of "others" with a write in for other types of extreme events that were not listed. Perceived sensitivity was captured by a single-item measure: "Based on your experience, how vulnerable do you consider your community is to future extreme events?" Finally, participants were asked the extent to which they feel well-prepared for future extreme events as a proxy for measuring perceived adaptation in this study. This study applied selected questionnaires rather than using comprehensive indices for measuring each dimension of perceived vulnerability.

3.4. Statistical Analysis

All Michigan residents who completed the pre-intervention and post-intervention measures were included in the analyses (N = 145). No data points were missing. Descriptive statistics were used to report mean and standard deviation for interval/ratio variables and percentage frequencies for nominal measurement. The assumption of univariate normality was met for dependent variables.

To evaluate the effects of the Climate Justice mapping intervention on participants' perceived exposure, sensitivity, and adaptability scores over time, we performed a series of statistical analyses including repeated measures and mixed model analysis of variance (ANOVA). In each of these mixed models, *Group* (Climate Justice areas or comparison areas) served as the between-subject factor and *Time* (pre- vs. post- intervention) as the within-subject factor. As recommended by O'Brien and Kaiser (1985), using the multivariate approach of the general linear model test to conduct the repeated measures mixed ANOVA is robust for testing the main effects of between-subject and within-subject factors. More importantly, it examines the *Group X Time* interaction to indicate that the Climate Justice areas and comparison group differed in the change over time of their perceptions of risk to climate associated hazards. Effect size was computed using partial eta squared: 0.01, 0.06, and 0.14 indicate

Table 3. Summary of measurement of risk perceptions aligned with dimensions of vulnerability—perceived exposure, sensitivity, and adaptability—across temporal scales of past experience, pre-intervention and post-intervention.

	Exposure	**Sensitivity**	**Adaptability**
Past Experience	2-1. Please indicate the most recent extreme events that you have experienced during the period of time you have lived in this community/city.		2-3. In general, how well were you prepared to respond to the latest extreme events?
Pre-Intervention	2-5. How likely do you think you may experience any one of those extreme events in the next 10 years?	2-7. Based on your experience, how vulnerable do you consider your community is to future extreme events?	2-8. Since the last event, how well have you prepared to respond to future extreme events?
Post-Intervention	5-1. After viewing the results of the previous study, how likely do you think you are to experience an extreme event(s) (e.g., floods, droughts, extreme cold and heat) associated with climate change in the next 10 years?	5-3. After viewing the results of the previous study, how vulnerable do you consider your community to future extreme events?	5-4. After viewing the results of the previous study, how well have you prepared to respond to future extreme events?

small, medium, and large effects respectively (Cohen, 1988). All analyses were performed in *SPSS Version 24*. An alpha level of 0.05 was used to determine statistical significance.

4. Results

As reported in Table 4, means and standard deviations for three indicators of vulnerability in the pre- intervention baseline showed that participants reported high levels of perceived exposure (M = 4.41, SD = 0.89), moderate levels of perceived sensitivity (M = 3.70, SD = 1.02), and moderate ratings of perceived adaptability (M = 3.33, SD = 0.99). In addition, respondent from Climate Justice areas had slightly higher levels of perceived exposure (M = 4.57, SD = 0.74) than that of comparison group (M = 4.25, SD = 1.01, t(143) = 2.16, p = 0.032). No significant differences were found between two groups in their pre-intervention scores of sensitivity (t(143) = 1.30, p = 0.195), preparedness for past extreme climate change associated hazard events (t(143) = 0.25, p = 0.806), and adaptability for future extreme events (t(143) = 0.89, p = 0.373).

The first hypothesis stated that risk communication intervention increased respondents' perceived exposure to climate change risk, and the effect was stronger among individuals living in Climate Justice areas. A two (*Group*: Climate Justice areas vs. comparison areas, between-subject factor) by two (*Time*: pre-intervention vs. post-intervention, within-subject factor) mixed ANOVA revealed a significant main effect of *Time* (F(1, 143) = 9.61, p = 0.002, partial η^2 = 0.063). Contrary to our prediction, participants judged the likelihood to experience extreme events in the next 10 years after the intervention (M = 4.13, SD = 1.10) to be significantly lower than they did in the pre-intervention (M = 4.41, SD = 0.89) (Table 4). The main effect of group was significant (F(1, 143) = 8.61, p = 0.004, partial η^2 = 0.057). On average, respondents living in the Climate Justice areas reported significantly higher levels of perceived exposure (M = 4.46, 95% CI: 4.28–4.64) than did those who lived in other comparison areas (M=4.07, 95% CI: 3.87–4.25). Notably, both groups' perceived exposure to extreme events decreased significantly after reading the Climate Justice mapping intervention, indicating an opposite trend of our hypothesis. Last, the interaction effect of group by time interaction on perceived exposure was not significant (Figure 3). Therefore, Hypothesis 1 was not supported.

The second hypothesis predicted that an increase in participants' perceived sensitivity assessment as a result of the intervention differed between two groups. As shown in Table 5, the results support Hypothesis 2 with a significant *Group* × *Time* interaction effect (F(1, 143) = 10.02, p = 0.002, partial η^2 = 0.065) and a significant linear effect of *Time* (F(1, 143) = 10.02, p = 0.002, partial η^2 = 0.065. The results indicate that the Climate Justice mapping intervention significantly increased participants' scores of perceived sensitivity from 3.70 (95% CI: 3.54–3.87) to 3.96 (95% CI: 3.80–4.10). The impact of risk communication intervention on increasing perceived sensitivity was stronger among respondents living in Climate Justice areas than those residing in other comparison areas. Figure 4 indicates that that the mapping intervention has substantially elevated residents' concerns about community's vulnerability to future extreme events in Climate Justice areas, while participants from comparison areas experienced no change on this scale. Thus, we concluded that Hypothesis 2 was supported.

The third hypothesis assumed the residents in Climate Justice areas would have lower scores in perceived adaptability after the intervention than participants from other Michigan cities. As shown in Figure 5, analysis of the changes in adaptability using a mixed ANOVA indicates a significant main effect of *Time* (F(2,286) = 32.86, p = 0.000, η^2 = 0.187) suggesting that 18.7% of multivariate variance of perceived adaptability ratings is associated with the pre-intervention and post-intervention factor. The main effect of *Group* and *Group by Time* interaction effect were not significant. Two groups did not differ significantly in ratings of preparedness at pretest (t(143) = 0.89, p = 0.373) and posttest (t(143) = 1.37, p = 0.174). All participants reported significantly lower levels of preparedness in response to future extreme events after receiving the risk information intervention (M = 2.65, 95% CI: 2.49–2.82) than they did

Table 4. Means and standard deviations for three dimensions of vulnerability for participants in climate justice and comparison areas at pre- and post-intervention.

	Exposure		**Sensitivity**		**Adaptability**		
Intervention	Pre- M (SD)	Post- M (SD)	Pre- M (SD)	Post- M (SD)	Past M (SD)	Pre- M (SD)	Post- M (SD)
Climate Justice areas (n = 76)	4.57 (−0.74)	4.36 (−0.84)	3.59 (−1.01)	4.09 (−0.8)	3.32 (−0.93)	2.78 (−1.02)	2.54 (−1.04)
Comparison areas (n = 69)	4.25 (−1.01)	3.88 (−1.29)	3.81 (−1.02)	3.81 (−1.05)	3.28 (−1.06)	2.93 (−1.02)	2.77 (−0.97)
All sample (N = 145)	4.41 (0.89)	4.13 (−1.1)	3.7 (−1.02)	3.96 (−0.93)	3.3 (−0.99)	2.85 (−1.02)	2.65 (−1.01)

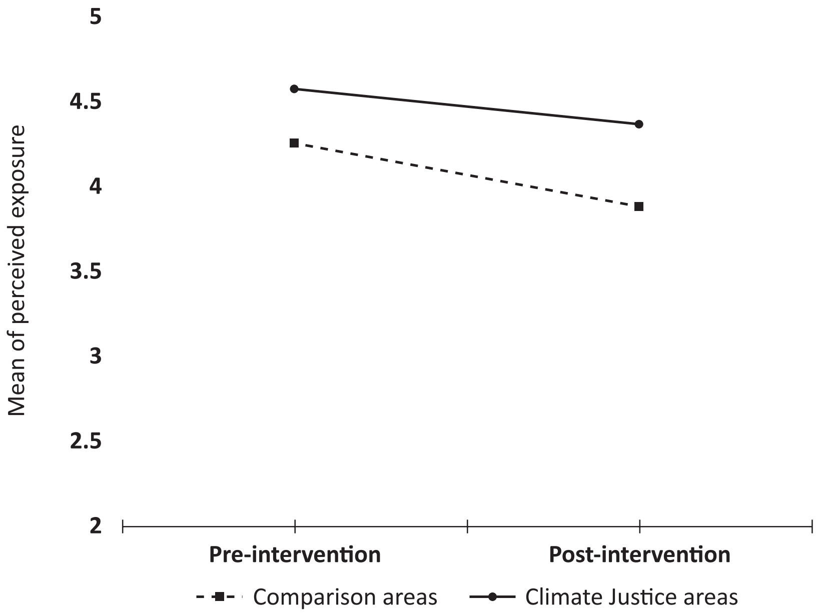


Figure 3. The effects of the Climate Justice mapping intervention and group on participants' ratings of perceived exposure to future extreme events.

Table 5. Repeated measures mixed ANOVA analysis on participants' ratings of perceived sensitivity.

Effect	**MS**	**df**	**F**	**p**	**Partial eta squared**
Time	4.52	1	10.02	0.002	0.065
Group	0.07	1	0.05	0.829	0.000
Time × Group	4.52	1	10.02	0.002	0.065
Error	64.5	143			

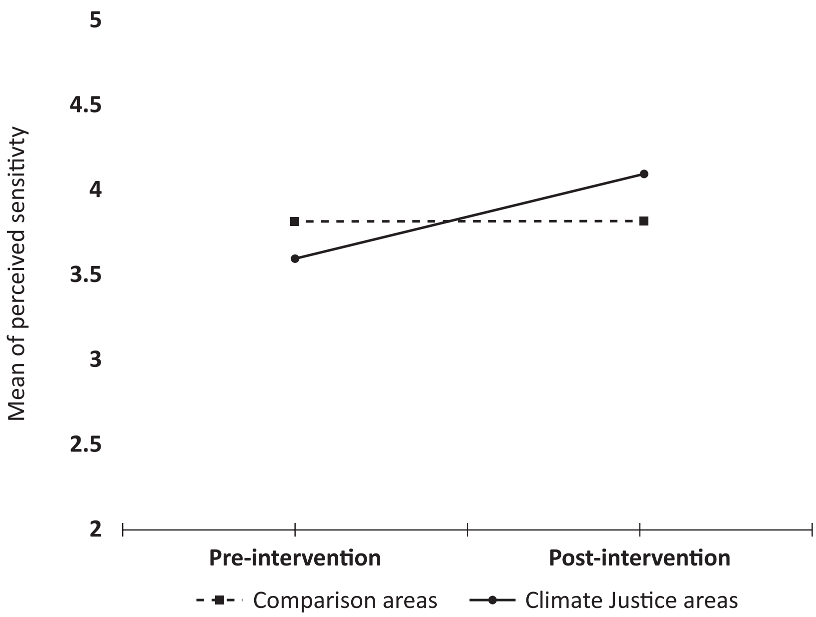


Figure 4. The effects of Climate Justice mapping intervention and group on participants' scores of perceived sensitivity to future extreme events.

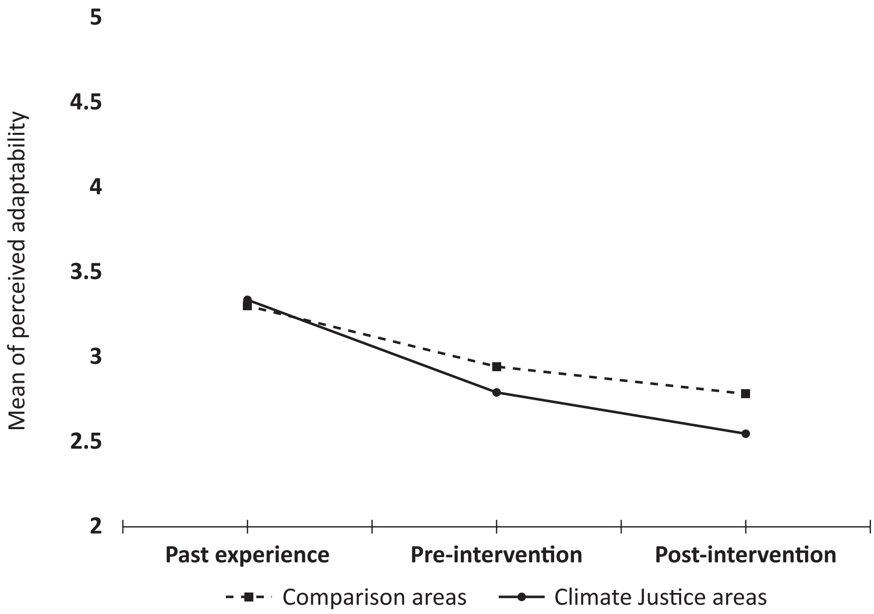


Figure 5. The effects of Climate Justice mapping intervention and group on participants' ratings of perceived preparedness for future extreme events.

before reading the Climate Justice maps (M = 2.85, 95% CI: 2.69–3.02). Hence, Hypothesis 3 was partially supported with a general trend of lower perceived adaptability ratings after receiving the intervention regardless of participants' residency in Climate Justice areas or not.

5. Discussion

5.1. Calculated vs. Perceived Climate Justice

In contrast to our predication, results from Hypothesis 1 indicated that risk mapping intervention significantly decreased participants' perceived likelihood of experiencing extreme events in the next 10 years. One possible explanation could be that recent past experience (e.g., less than 5 years) can lower people's perceived possibilities of encountering extreme events in the near future (e.g., in 10 years) (Ryan & Hamin, 2008; Vinh Hung et al., 2007). Our survey instrument also asked one question about past experience with extreme events: *Please indicate the most recent extreme events that you have experienced during the period of time you have lived in this community/city?* Seven time period options included none, less than a year ago, 1–5, 5–10, 10–20, 20–30, and more than 30 years ago. Specifically comparing flooding hazard that was included in the Climate Justice mapping intervention, over half of the samples (55%) have experienced floods within the past five years. Respondents' recent personal experience with flooding might lead to engaging in temporal and spatial discounting psychologically after the intervention (van der Linden et al., 2015). That is, people tend to view climate change associated risks as a distant future threat. In addition, negative impacts are more likely to be more serious for other people and communities than for themselves.

Notably, residents in Climate Justice areas did perceive higher likelihood of exposure to future climate change associated hazards in addition to being more vulnerable and less prepared in general. Results imply that people who are identified as socially vulnerable to climate change associated hazards may indeed perceive themselves to be more vulnerable. Since most literature using vulnerability mapping focusing on ecological or biophysical vulnerability of a place without including social vulnerability or justice impacts, this research presents a novel approach in combining both social and ecological vulnerability into climate justice mapping for risk perception and behavioral science studies. Our findings could support climate change and equity planning through the alignment of calculated and perceived climate justice at a local scale. The large gap between the calculated and perceived climate justice (e.g., high calculated social-ecological vulnerability areas with population of low perceived climate justice) implies the community is potentially at high risks to climate change associated hazards. Climate justice planning should focus on reducing the gap to lower both social and ecological vulnerability through prioritizing strategies to mitigate hazards and make resources assessable to socially vulnerable groups. Subsequently, socially vulnerable communities that lack support in risk management and adaptability to cope with changes can be addressed in climate justice planning.

5.2. Reframing Climate Justice for Planning

Environmental justice theory, which is largely based on environmental racism presented in the U.S., was initially employed for framing climate justice at the local scale in this study. Unlike typical environmental justice cases in which minority neighborhoods are targeted for hazardous waste disposal and unwanted land uses, natural hazards and climate change associated extreme events such as hurricanes, floods, droughts, heat waves, and extreme cold, do not target any particular population. In addition, the Social Vulnerability Index (SoVI) presented in the previous study (Cheng, 2016) applied 33 indicators, including not only demographic and socio-economic variables but also built environment variables such as urban/rural population, building structure (e.g., mobile home), housing density, and social infrastructure such as per capita number of community hospitals. SoVI was calculated using a series of statistical methods including standardization and principal component analysis. Substantial research has revealed vulnerability of a place reflects socio-economic characteristics and accumulated racial divide and inequitable planning practices throughout the urban development history in the U.S. (e.g., Colten, 2006; Bolin et al., 2010). The unequal adaptive capacity as a result of societal context should serve as the fundamental framing for climate justice, not race or environmental justice theory alone. Therefore, SoVI implies a dynamic and complex nature of societal context that varies from place to place and changes upon different units of comparison. We do not intend to use SoVI for identifying specific variables for representing social vulnerability; on the contrary, SoVI serves as a tool to gauge potential decline of social services and adaptive capacity of a place in coping with environmental and societal stresses. This study revealed the values of using social science research methods such as surveys and interviews to complement or contrast quantitative tool such as SoVI. Having comprehensive understanding of social vulnerability at various institutional levels from individual, neighborhood, municipal to regional governance can assist prioritizing resources in climate change planning and address climate justice.

5.3. Risk Communication, Climate Justice Planning, and Sustainability

Climate justice emphasizes social impacts of inequitable burdens from the impacts of climate change associated hazards. Social sustainability can be accomplished through: a) attainment of social justice and the sustainability of communities (e.g., social capital, social cohesion), b) cultivation of behavior changes to achieve environmental sustainability goals; and c) maintenance of the socio-cultural characteristics of the community in the face of change, and the ways in which people actively embrace or resist those changes (Vallance, Perkins, & Dixon, 2011). Therefore, addressing climate justice works toward achieving social sustainability. To this end, risk communication plays a vital role in urban planning for facilitating the development and influencing public behaviors to reduce greenhouse gas effects—climate change mitigation—while becoming more resilient in coping with change and uncertainty—climate change adaptation (Hagen, 2016b). Based on the findings from this study, we recommend the following for urban planners in pursuit of climate justice planning and social sustainability:

- *Make residents scientifically informed*. This study demonstrated the positive effects of using well-presented empirical and scientific information as interventions in communicating risks and influencing people's risk perceptions and behaviors. Engaging stakeholders and residents in place-based risk assessment and climate justice analysis should be integrated into spatial planning and be made easily accessible and understandable for the general public. Additional efforts should be made to reach out socially vulnerable groups.
- *Reduce the gap between calculated risks and perceived risks*. Planners should be alarmed when the gap between calculated risks and perceived risks among residents, planners, and decision-makers is substantial. Each level of institutional capacity can make significant impacts on the development and implementation of climate action plans. This study revealed mixed results that vulnerable populations would tend to have higher levels of perceived exposure, sensitivity, and lower levels of perceived adaptability to climate change associated hazards. Calculated social vulnerability indicators may initially serve as a planning tool; nevertheless, ground-truthing using risk communication to gauge people's risk perception and adaptive behavior is even more valuable and necessary.
- *Assist residents to be prepared*. Our findings suggest that residents felt significantly less prepared after receiving risk information that they are likely to be exposed to future climate change associated hazards. This implies local Michigan respondents may not be well informed about where and how to access risk information and management resources. In turn, they may perceive themselves to be less prepared for coping with uncertainties of future extreme events. Planners should incorporate education and outreach programs that outline risk information and access to currently available risk management resources in climate action plans. In particular, plans shall outline proposed expansion of community resources in risk management and climate change adaptation for vulnerable populations.
- *Improve risk communication to facilitate decision-making*. This study supports the strong relationship between an evidence-based intervention and local resident's risk perception. By acknowledging scientific information and understanding risks, vulnerable populations can make informed decisions that support planners' efforts in climate action plans and implementation. Our results suggest residents in Climate Justice areas given the cli-

mate justice mapping did perceive lower preparedness to climate change impacts compared to their pre-intervention scores. The same pattern was consistent among residents in comparison areas where have higher percentages of African Americans likely living outside the Huron River watershed boundary (e.g., part of Detroit's 82% black population). We only provided climate justice mapping information within the watershed boundary in this study, the comparison groups were influenced by reviewing limited available risk information they received. Their adaptive capacity can be enhanced with additional risk information provided in their areas. Thus it is particularly critical in local planning to ensure all residents, especially socially vulnerable groups, receive transparent and up-to-date risk information in preparing for climate actions.

5.4. Future Research

Based on a convenience sample of local respondents in Michigan, our final sample size yields a statistical power required for making valid and reliable inferences to the study population who participated in the quasi-experimental design. It should be noted that people who chose to participate in the study might be moderately aware of the risks of climate change impacts and might not represent all characteristics of socially vulnerable groups in the study area. Future research could invest more resources in recruiting representative participants (e.g., cash incentives), particularly in Climate Justice areas, and target socially vulnerable groups in order to better understand the needs for equity planning. Second, further studies could investigate the effectiveness of using message framing and graphic designs associated with delivering risk information as interventions for influencing risk comprehension and perceptions. Finally, future research could include linking the survey results with additional modeling efforts. The survey results describing risk perception and adaptation behavior can be summarized as residents' behavioral rules for future modeling purposes. An agent-based model can be built upon these behavioral rules—defining residents as "agents"—and coupled with a process-based hydrologic model to quantitatively identify the link between individual adaptive behavior and effective adaptation policy to mitigate climate change impacts.

6. Conclusion

Climate change planning to address climate justice and enhance adaptive capacity of the community is crucial to the sustainability of a community. This study moves toward a better understanding of the role of risk communication in minimizing the gap between people's perception and behavior in response to climate change threats, particularly in climate justice communities. Using a novel experimental design to uncover differences between Climate Justice and comparison areas in both their calculated and perceived risks, findings presents common challenges in risk perception and behaviors. In turn, climate justice risk perception could affect the willingness to act upon climate action plans and implementation, particularly for addressing equity planning under climate change impacts. Communities who are socially vulnerable to hazards have common characteristics to those of low social sustainability outcomes drawing from social ecology framework such as a lack of sense of community and low social capital and social cohesion (Vallance et al., 2011). Therefore, tailored communication interventions addressing different levels of social sustainability should be integrated into climate change planning to motivate adaptation actions.

Risk communication plays a critical role in bridging individual and collective actions in governance. In light of the increasing importance of local actions to combat climate change, effective risk communication plays an important role in serving a platform for consensus-building and decision-making at multiple scales. In addition, integrating scientific information in climate justice risk communication can influence risk perception and behavior to better support local climate action plans that integrate equity goals toward achieving social sustainability.

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Conflict of Interests

The authors declare no conflict of interests.

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