Climate Justice and integrated flooding risk assessment and management: A framework and case studies in USA and Taiwan

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Abstract: Climate justice reveals inequitable coping capacity to climate change impacts among socially vulnerable groups. As extreme events have become more frequent and intense under climate change, increased flooding risks have threatened communities around the world, and the hardest hits are the socially vulnerable populations. How can planners assess climate justice and manage integrated risks? What is the role of planners for addressing climate justice and enhancing resilience of vulnerable communities? Climate justice and risk assessment are aligned to integrate exposure to climate change associated hazards (ecological vulnerability), sensitivity (social vulnerability) and adaptability (technological vulnerability) assessment. The framework was applied to case studies in Michigan, USA, and Tainan, Taiwan. Employing Geographical Information Systems, climate justice hotspot in three cities were identified in the Huron River watershed, Michigan, USA. Interviews with planners gauging their institutional capacity towards climate change adaptation revealed that Ypsilanti is the most climate unjust because of a lack of resources to act on climate change. In the case for Rende District, Tainan, Taiwan, the community is identified as one of the most flood-prone districts in in addition to a growing aging population of 65 years old and older, which is considered a climate justice hotspot. A series of technical interventions were conducted with district leaders and residents and demonstrated a range of adaptive capacity among the seniors with various arrangement of dwelling unit. Additionally, the leadership to mobilize community-based risk management integrating smart technology and residents' participation in risk management has enhanced their coping capacity to climate change-induced flooding. The two case studies implied that planners can bridge the gaps between calculated and perceived risks by applying both quantitative and qualitative assessment in order to identify and address climate justice in local communities. Finally, the community-engaged climate change adaptation with the strength of local leadership and stewardship can ensure the long term sustainability and resilience of the community.

Keywords: climate justice; social vulnerability; integrated flooding assessment and management; aging population; Taiwan; USA

Introduction

Urban planning investing infrastructures for flood mitigation, risk management, and resilience building in the communities is urged to integrate climate change planning and prioritize investment to address climate justice (Cheng 2019). Socially vulnerable groups (e.g., female, children, the elderly, low socio-economic status,

migrant and minority groups, people with special needs) who are likely possessing less coping capacity for climate change-induced natural hazards, thus constructing *climate justice* describing inequitable burdens for socially vulnerable people who suffer more under the condition of higher ecological vulnerability as a result of climate change impacts (Cheng 2016). Integrated risk assessment incorporating social-ecological-technological systems (SETs) vulnerability assessment framework provides a critical tool for assessing complex and wicked urban challenges in the built environment under climate change impacts (McPhearson et al. 2016; Cheng 2016). Climate change-induced flooding refers to the increased intensity and frequency of rainfall events and associated flooding as a result of changing precipitation and temperature patterns under global warming impacts (IPCC 2014), which affects hydrological cycles and flooding hazards in the watersheds for local communities (Cheng et al. 2017a). This paper applies an integrated climate justice and risk assessment and management framework and discusses two case studies in Michigan, USA, and Tainan, Taiwan, to investigate vulnerability of place and opportunities and challenges in implementing risk management strategies and addressing climate justice in communities.

Michigan's Case

Study Area and Context

The Huron River watershed drains more than 2,300 km^2 covering seven counties in southeast Michigan, USA, due west of Detroit. The watershed area has a population about 500,000 across 65 municipalities. Based on the previous study, a climate justice index was created based on social-ecological vulnerability assessment (Cheng 2016). Social vulnerability index was constructed based on Cutter's method (Cutter et al. 2003) using 33 socio-economic indicators in 220 census tracts. Ecological vulnerability index was derived from climate change-induced flooding hazard built upon a hydrological model, toxic and waste facility sites, and water quality impaired stream data. The intersection of the high social vulnerability and high ecological vulnerability analysis units constructs climate justice hotspots. Three cities were identified as climate justice cities: Ann Arbor, Ypsilanti, Wixom. A follow up study was conducted to survey the use of climate justice map information in gauging the changing risk perceptions of vulnerability to climate change (Cheng et al. 2017b). Wixom is a middle-class and family oriented suburban city; Ann Arbor is where the University of Michigan is located and has the highest median household income; Ypsilanti has the lowest income level among the three cities in 2015 census. The watershed is predominately white (83.5%) while the climate justice cities are more diverse with African Americans (29.2% in Ypsilanti and 11.1% in Wixom), Asians (14.4% in Ann Arbor), and Hispanics (4.3% in Wixom). This case study focuses on additional interviews with managers in the climate justice cities.

Method

A structured interview of ten questions with managers who oversee long-range planning, public works, and sustainability in the three climate justice cities was conducted. The questionnaires include a) responsibility in the institution and in relation to climate change planning, b) access to resources for climate change planning, implementation, and management, c) equity goals in city's plans, d) incentives and obstacles to implement climate change actions, e) trans-boundary coordination, f) green infrastructure as a strategy for climate change planning and its implementation challenges.

Results

In general, the three managers revealed several challenges in coping with climate change: 1) the general obstacle in city's operation with a lack of resources both internally and externally and motivation to go beyond day-to-day tasks, 2) a lack of strong leadership in addressing climate change and equity in long range planning, 3) inability to integrate multi-disciplinary tasks across departments, 4) short-term project driven rather than

achieving sustainability goals, and 5) a lack of community-driven and place-based planning process. For example, one city has a Climate Action Plan

"*but it was prepared by a consultant. They did a lot of public input and they've got a plan that looks great, but it's not something we've been in the habit of incorporating into decision making and all that good stuff. It did feed into our master plan, which we did in 2013, but a lot of the pieces that are in this are things that aren't quite underneath our purview or things that just aren't feasible for a community of our size, to incorporate green building standards into incentive programs. We don't have a whole lot of incentive programs, so this is kind of a meaningless.*"

In terms of moving forward, "*I think that very much relies on strong leadership…and we don't have that right now. We have multiple competing priorities…. It's that sort of thing. Between these two projects, most of our discretionary funds are being used, and even some nondiscretionary funds are being allocated to these things.*"

Taiwan's Case

Study Area and Context

Taiwan is a Pacific island country exposed to multiple ecological vulnerability such as earthquakes, typhoons, floods, and droughts. This study investigates the social-ecological-technological impacts from two extreme and disastrous flooding events in the past decade: Typhoon Morakot on August 8, 2009, and the "823 floods" on August 23, 2018. Typhoon Morakot attacked Taiwan with a record-high daily precipitation resulted in the worst floods in Taiwan since 1959 (MOEA 2009) and the accumulated rainfall reached the world's record of heaviest storm event in the 24- and 42-hour durations (Figure 1). The associated flood damages have resulted in a total loss of 1.6 GDP. The "823 floods" was signified by a short duration but heavy rainfall. The precipitation exceeded design standards of many drainage systems and resulted in heavy flooding.

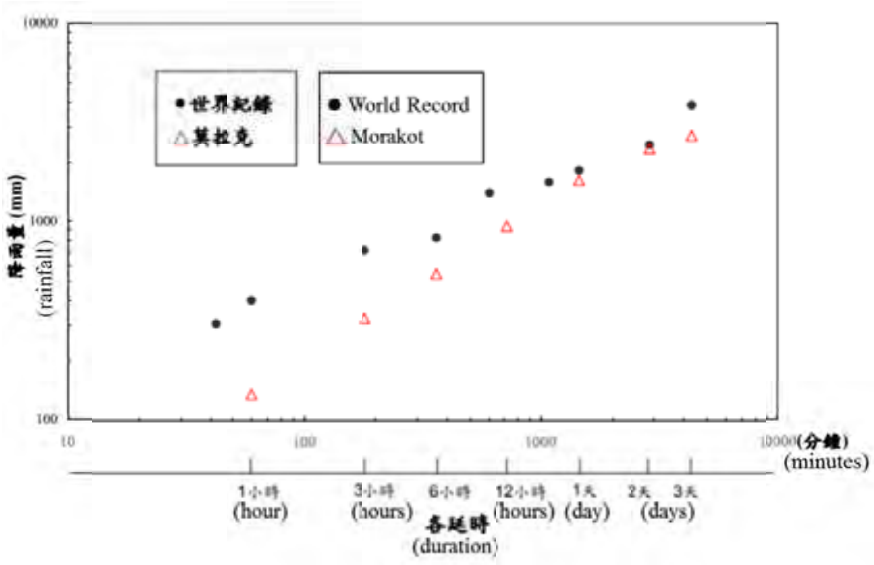

Figure 1. Rainfall duration in the typhoon Morakot compared to the world record

The flood-prone areas in Taiwan are located in western coastal low-lying areas susceptible to land subsidence. Some areas are lower than the sea level, as much as one or more meters below. Under this circumstance, drainage systems applying gravity flow to achieve drainage was very difficult. Therefore, excessive water could only be drained away by intense pumping equipment.

In terms of social vulnerability, Taiwan is becoming an aged society with increasing percentage of population are equal or greater than 65 years old (typical retirement age). Rende district in Tainan, Taiwan, is a community at outskirt of the city and composed of 13.82% of aged population in 2017, increased from 10% in 2012, and continues to grow. The most predominate housing type in this community is multi-story single family house or townhouses without basement. In order to accommodate aged population in the built environment during flooding events, this study explored the interactions between technological (flood-proof building infrastructure) and social vulnerability and resilience (physical and mental state of adaptive capacity).

Method

Targeted interviews and measures of their physical and mental state of the elderly and their realistic needs are conducted. In addition, an integrated management with smart technology and collaboration between home security industry, China steel Security, and community on flooding monitoring and preparation is implemented in two houses that are in flood-prone areas (point 1 and 2 in Figure 2) based on the interviews and entrusting the local community leader to select the appropriate locations.

Figure 2. Locations of smart monitoring devices in point 1 and point 2 within flood-prone areas Rende District, Tainan, Taiwan

According to the United States Federal Emergency Management Agency (FEMA), the disaster prevention architecture flood-proof design is necessary to incooperate the following equipment: a) water level sensor, b) security reporting system, c) CCTV camera, d) security host, and e) the 24-hour control center (Figure 3). The water level sensor is located at the low-lying location to collect water level information during the flood. The CCTV camera is installed in a position where the water level change is clearly observed remotely by the security control center. The video data from the CCTV camera can be combined with the video host to set the video recording time and provide query images of historical data. The water level sensor's signal will be connected to the security host, and then the security host will pass through the ADSL or dedicated lines sending the signal back to the control center. Whenever the water level sensor's signal exceeds the warning value, the signal will be transmitted back to the control center through the security host. The control center will contact the emergency contact person and the lieutenant of the community to visit and investigate the needs of the observed residents.

Figure 3. Smart technology system equipment for flood risk management: a) water level sensor, b) security reporting system, c) CCTV camera, d) security host, and e) the 24-hour control center

Results from Users Experience

The US Federal Emergency Management Agency (FEMA 2017) provides four resilient design suggestions for flood-prone buildings: 1) Relocation, 2) Elevation, 3) Wet-proof, and 4) Dry-proof. The most common dry-proof approach taken in Taiwan is to install the floodgate. However, according to interviewees, there are several obstacles and dilemmas for implementing technological solutions:

1. There is no sufficient monitoring and evaluation for the performance of the floodgate. Many owners lack the knowledge of maintenance and drill procedures.

2. The access route is blocked once the floodgate is installed, causing risk for residents to escape from emergency situations.

3. Residents living in flood-prone areas are constantly facing enormous psychological pressures, especially during the rainy seasons, due to the difficulty in making decisions on an appropriate timing of floodgate installation.

4. A lack of maintenance on existing panels of floodgate could cause malfunction and fail to prevent from flooding in the dwelling unit.

5. A large portion of the elderly or physically disabled individuals who live alone need various help from others to install the floodgate.

6. When flooding occurs, water usually back flow from drain pipe, causing serious public health issues (Figure 4). Therefore, if there is no satisfying solution to these problems, it is suggested to elevate their living unit and life-support equipment to avoid such affliction.

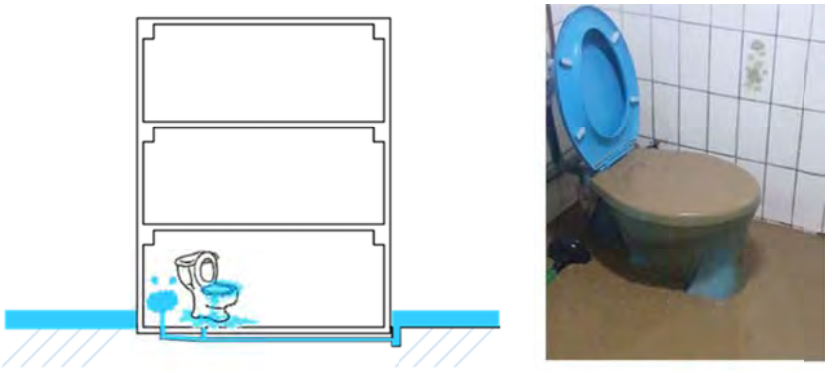

Figure 4. Floodwater back flowed from drain pipe into the building

7. Building with basements and elevators (such as hospital, nursing home) will encounter another problem. Water intrusion in elevator pits is common in the rainy season. Given that the elevator pits are usually on the lowest elevation in a building and therefore water accumulates there and disable the elevator. This will seriously threaten the daily lives of the elderly, especially those with disabilities (crutches, wheelchairs, bed-ridden) who rely on the elevators for transportation (Figure 5).

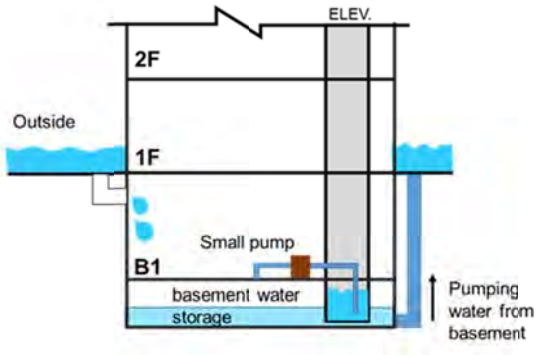

Figure 5. Water intrusion in an elevator pit

Discussion

Bridging the gaps between calculated and perceived risks

Based on Michigan's case in a previous survey with residents, there exist a gap between calculated and perceived risks (Cheng et al. 2017b). People who have recently experienced flooding would consider less susceptible to future events. Similar findings from Taiwan's case that residents tend to think that the devastating floods will not come to their life again. In Taiwan, people have developed different attitudes towards installing floodgate in different regions. Acceptance of floodgate was affected by the individual's experience, opinions of the elders who have lived long in the neighborhood, community associations, and government's attitudes. Most interviewees cannot picture the level of inconvenience and particular accommodation that the elderly will face and need to prepare in advance. In addition, most elders felt that they are incapable of doing any changes to their own buildings or even influence their own resilience to cope with emergency situations. However, regular seasonal flooding has already become a part of their lives and become a source of cyclical psychological pressure for residents.

Place-based integrated risk management

Due to the close relationship between the neighborhoods and local government such as community leaders (elected officials) in Taiwan, the access to local community resources and support is the most immediate and

effective way for risk management and disaster relief before upper level government resources would arrive. As a result, the accumulated local wisdom from the elderly plays an important role for place-based risk management and disaster relief efforts.

Challenges for technology and resource-intensive strategies

Implementing advanced technology systems often rely heavily on external resources, which can lead to vulnerability to the community once the access to the resources is constrained. An integrated central and local government disaster prevention units require sufficient funds, manpower and capacity to coordinate across institutional scales and boundaries. In Taiwan's case, connecting the industry with community and governmental resources to facilitate the dispatch from all parties to carry out disaster relief is the key to the success of the smart technology system. Finally, the intervention of technology should not be limited to the planning of infrastructure and software development. Technology plays an important role in assisting decision-making across institutional scales and various sectors, connecting individual to national security.

Strong leadership in building resilience

It is the leader's ability to communicate the common goals and motivate the public as well as the enterprises to work in collaboration to achievements the common goods. In Taiwan's case, strong local community leaders with well-supported and connected network internally and externally is critical to gain trust and resources needed for building community's resilience. For example, the community leader has effectively mobilized community-based risk management integrating smart technology and residents' participation in risk management, which in turn has enhanced the community's coping capacity to climate change-induced flooding. On the other hand in Michigan's case, a weak leadership leads to a lack of hope and incentives for envisioning futures and implementing strategies that can benefit long term suitability and resilience of the community in lieu of day-to-day tasks and short-term priority projects.

Conclusion

The two case studies implied that planners can bridge the gaps between calculated and perceived risks by applying both quantitative and qualitative assessment in order to identify and address climate justice in local communities. Finally, the community-engaged climate change adaptation with the strength of local leadership and stewardship can ensure the long term sustainability and resilience of the community.

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