Measuring Exposure for a Better Tomorrow: An Analysis of Hazard Mapping and Survey Data as Methods to Measure Risk

Sydney Eiss
University of Colorado Boulder
Department of Civil, Environmental, and Architectural Engineering

Abstract

There are many approaches to measure exposure to natural hazards, however, many are not very accessible or easy to approach for resource limited local governments and communities. Hazard maps and community surveying are two approaches that can be used to measure exposure with few resources and relatively easily, however both are not flawless methods. In my research, I look to *compare and contrast* hazard mapping and community surveying and *combine* both methods through overlaying survey data onto hazard maps to discover how each can be best used to assess exposure to natural hazards at post-disaster relocation sites. I discovered that mapping is useful for relocation site planning and visual assessment and surveying is useful for measuring the effects of hazards and community perception of exposure. My recommendation is to combine both when assessing the exposure to natural hazards at a site as the combination can be used to strengthen each method and reveal where further research or data collection is needed before making a risk reduction plan.

1.0 Introduction

Picture your house. The neighborhood park you walk through after a long day at work. Your favorite coffee shop. Now imagine one day—following a storm you never expected would be so destructive—it's all been reduced to rubble. As horrifying as it sounds, this is a reality for people around the world who have faced natural disasters. In

2016 alone, there were 24.4 million displaced peoples by disasters, with South and East Asia the most affected regions (IDMC, 2017). Natural disasters such as earthquakes, forest fires, floods, and typhoons, can destroy decades of infrastructure, bruise social structures, and lead to devastating casualties in their wake. Furthermore, with global climate change increasing the severity of weather related natural disasters (Kevin J.E. Walsh et al., 2016), associated damages may also increase. Unplanned urbanization characterizes many of the cities affected by worsening natural hazards. When disaster strikes the people in these cities may be left with little but the clothes on their backs (Sanderson, 2000). Though natural disasters cannot be prevented, the negative effects can be mitigated if the risks of disasters are well understood and accounted for.

One solution to deal with the decimation of urban settlements after a natural disaster is relocation. Governments will change the location of their citizens through either evacuation or relocation to reduce future losses from natural disasters. Relocation aligns with established “choose change, reduce losses, and accept losses” hazard risk reduction framework (Klein et al., 2003). It is often seen in a negative light by the international community, as relocation can be involuntary and include risks and reduced opportunities for affected populations (Bier, 2017). Though it is not ideal, relocation can provide the opportunity for planned site development, and thus careful decisions and actions designed to reduce risk.

Natural hazard risks can be assessed in a multitude of ways. In the context of this research, I define natural hazard risk as the *exposure* of infrastructure to a natural hazard (Smith, 2004). Risk can also be defined by the relative magnitude of a disaster or the relative response to the disaster, and measured based on the losses already incurred. As a society, we can reduce risk by decreasing physical exposure or social vulnerability to hazards, or increasing social and institutional capacity. In order to reduce risk by targeting *exposure* in a given community, we need to first measure and understand the existing state of community exposure. Although there is a plethora of computational techniques for measuring and modeling exposure and risk, advanced methods are often beyond the means of resource-limited local governments and communities. In contrast, hazard mapping (Costas Amernakis and N. Nirupama, 2012) and community surveying (Anuradha Mukherji et al., 2014) techniques have been shown to be accessible and practiced methods for assessing risk relatively easily. In this research, I look to compare community surveying and mapping techniques by answering the question: *what are the strengths and weaknesses of each method and how can they be combined to successfully analyze exposure to relocation communities?*

1.1 Hazard Mapping

Mapping is a vital tool of analysis for geographical studies when looking at the interaction between humans and the natural environment. When looking at natural hazards, exposure to hazard prone areas have very important implications in risk. Mapping techniques can be used to assess where and with what magnitude of severity certain natural hazards occur (Guzzetti et al., 1999). Spatial analysis is simply the quantitative study of “phenomena that manifest themselves in space” (Luc Anselin, 1988). In the context of natural hazards, spatial analysis is useful to analyze what areas are more prone to hazards and other phenomena in connection to those areas, such as population or infrastructure. In one study looking at the risk of flooding to municipalities in Sweden, municipalities studied the consequences flooding would have on the built environment, such as effects to drinking water, inundated buildings, and even damage to objects of cultural heritage (Norén et al., 2016). They found using geographical spatial analysis to be very important as “flood risk assessment has such a pronounced geographical character” (Norén et al., 2016, pg. 1).

Spatial analysis helps researchers, humanitarian practitioners, local governments and communities explore geographic exposure to hazards. However, the hazard maps are often not used correctly or paint an incomplete picture. After the Indian Ocean Tsunami, the selection of inland relocation sites was often driven by post-disaster coastal buffer zone laws, instead of using hazard maps to assess and compare sites for non-tsunami exposure (Ahmed, I. and McEvoy, D., 2014; Palliyaguru, R. et al., 2012). Furthermore, following a disaster, local governments may receive technical assistance to develop or update localized hazard maps. Updated maps help local decision makers to decrease risk when making land use and infrastructure changes, yet they are infrequently amended again to reflect such (sometimes dramatic) development changes. During post-recovery development, it is possible that there are discrepancies between hazard maps and actual community exposure.

1.2 Surveys

When evaluating the risk of natural hazards to a community, there are both physical and sociological factors to consider. To analyze the sociological impact of natural disasters, community member surveys illuminate people’s experiences during hazard events and how they respond to natural disasters (Anuradha Mukherji et al., 2014). After all, it is ultimately people that will be affected by natural hazards, and their knowledge and experience can reveal the true extent of exposure and hazard risk.

Survey responses are extremely useful in quantifying people's experience with risks. By asking questions about exposure, such as how a past earthquake has affected someone or how high along a wall flood waters rose, the actual effect of a hazard can be measured. However, perception of risk and actual risk can be very different, as people's views of a risk are subject to biases and dependent on their own interpretation of how hazardous a certain risk poses (Sullivan-Wiley and Short Gianotti, 2017). If local governments were to rely solely on survey data for determining exposure, their estimations would be liable to both personal and community-level biases, misjudgments, and errors.

1.3 Mixed Methods

Considering the weaknesses inherent in both methods, I will employ mixed methods techniques to combine and compare mapping and survey data. Use of mixed methods allows for analysis of multiple perspectives of the same phenomenon, namely natural disaster risk. Researchers can be more confident in their results, and produce a more robust analysis through mixed methods as well (Jick, 1979). Through including survey responses in the hazard maps, I can visually assess where gaps in survey methodology and mapping methodology can be filled by each other, and which method is more effective for different analysis.

1.4 Context: Tacloban City Relocation

Tacloban City, Leyte, the Philippines, is a highly urbanized city with a population of 246,115 ("City Profile | City of Tacloban," 2016). On November 8, 2013 Super Typhoon Haiyan, locally known as Yolanda, tore through the city. One of the largest storms on record, the typhoon had sustained winds of 195 mph and gusts as strong as

235 mph (Jethro Mullen, 2013). Estimates put fatalities at 6,300 people, 550,928 totally damaged houses, and 95.48 billion Pesos as the total cost of damage (Micheal Bueza, 2016). Faced with the significant devastation, the Government of Tacloban City looked to permanent, dramatic solutions for recovery and to reduce risk, electing to relocate affected coastal populations to Tacloban North.

Tacloban North is a previously undeveloped region north of the city center. The City's goal for the Tacloban North relocation is to create prosperous communities with access to education, health care, sanitation, and government services (Tacloban City, 2016). Relocation in Tacloban North provides a perfect case study into how exposure risk to natural hazards can be measured. The Philippines is known as a climate hotspot as 70 percent of the area of Tacloban City, including Tacloban North, is susceptible to more than one hydro-meteorological risk (Tumamao-Guittap et al., 2015). Considering how prone the city is to natural hazards, and the fact that relocation is designed to reduce risk to natural hazards, it is critical to examine hazard risk at the relocation sites.

2.0 Methodology

My analysis draws heavily from data collection by members of Dr. Amy Javernick-Will's research lab as a part of two projects, *Achieving Holistic Risk Reduction: Decision Processes for Resettlement, Reconstruction, and Recovery* and *Resilient and Sustainable Infrastructure Systems: Post-Disaster Reconstruction Processes and Stakeholder Networks*. Data collection expanded throughout seven months in 2016 and 2017 and included observing both community and government events, reviewing plans, legal opinions, and other documents, and conducting dozens of semi-structured interviews. We selected 10 Tacloban City relocation sites to analyze and met with community members and leaders at each.

Sites were selected for their presumed diversity across a range of constructs theorized to be important in post-disaster community risk reduction, such as varying government or NGO funding, owner-driven versus community-led construction, proximity to the city center, and whether most residents were originally from the same community. We selected seven National Housing Authority (NHA) sites, with populations ranging from 300 to 900 households. NHA socialized housing construction is the dominant model for funding and managing government-mandated relocation projects, therefore it was important to include several sites in order to thoroughly investigate outcomes at NHA sites. Additionally, we selected three non-government relocation sites. Two are funded by corporate social responsibility arms of major Philippine companies, GMA Kapuso and SM Cares, while the third was developed by an international NGO, Habitat for Humanity. Non-governmental sites tend to have fewer households; in our case study the population at NGO sites averaged 446 households compared to 653 households at NHA sites. The location of each site is depicted in Figures 4 and 5 in Results.

2.1 Mapping

The majority of my geospatial data was provided by the Tacloban City Planning Office. After Typhoon Haiyan, the City Planning Office undertook a considerable rewrite of their Comprehensive Land Use Plan (CPO, 2016) and cleaned and updated their geospatial data in the process. As one of many international agencies to contributed technical and financial assistance to the new land use plan, the Japan International

Cooperation Agency (JICA) used their scientific expertise to develop new hazard maps. JICA created a base map based on a LIDAR survey (a remote sensing method), integrated storm surge inundation marks from Typhoon Haiyan, and determined worst case scenario hazard maps through advanced mathematical analysis (JICA, 2015). While JICA built maps for numerous hazards, I limit my analysis to flood and ground shaking hazard maps, as both an earthquake and major rain events occurred between household transfer to relocation sites and data collection.

For ground shaking, the Philippine Institute of Volcanology and Seismology Earthquake Intensity Scale (PEIS) was used. This scale, from I to X, is a measure of how an earthquake is felt. As a result, this method is not as sound for direct analysis of the magnitude of potential earthquakes at the sites but is still effective in analysis of exposure to earthquakes. Tacloban North is exposed to PEIS VI (Very Strong) and VII (Destructive) respectively (Official Gazette of the Republic of the Philippines, 2016).

In addition to JICA-developed hazard maps, the City Planning Office also shared geospatial data they created in-house, such as maps for municipal and barangay boundaries, road networks, and waterways. I created one data layer myself, the map of Tacloban North relocation sites, by drawing the outline of the sites overtop satellite imagery. I procured the base satellite imagery from the European Space Agency's Sentinels Scientific Data Hub (European Space Agency, 2016). The Sentinel-2 data has a 10-meter resolution, which allowed me to clearly identify the outlines of the relocation sites.

In my analysis, I performed intersections between the sites and different hazard maps to look at to what degree sites are exposed to different hazards. This percentage is based off the area of intersection and total site area for each site.

2.2 Survey

The survey is designed to elicit experiences in past hazard events and perspectives on how respondents' houses and sites will perform in future hazard events. Question types included dichotomous yes-no, multiple choice, and Likert-type questions (with no middle point) with some short answer questions for clarification.

Surveys in developing countries are likely to encounter unique barriers. In recognition of challenges in the Tacloban City context, as well as limitations in our own resources, we relied upon a mix of cluster and convenience sampling to select survey participants. Using the relocation site maps obtained from the government or relocation site leadership, we first conducted a visual inspection of occupancy to validate site population numbers. Next, we divided each site into 6-10 geographic clusters and determined the proportional number of surveys necessary per cluster to achieve a minimum confidence level of 95 percent and acceptable sampling error of 5 percent across the site. On-site, the team used convenience sampling within clusters to solicit participants. To administer the survey, we hired local research assistants, trained them according to our research protocol, and taught them how to effectively use our offline data collection software, Qualtrics. Prior to survey administration, our research team met with both the Tacloban City government and community leaders to introduce the research. Assistants administered the survey in Waray-Waray, the local language, and used tablets to record responses digitally. Each survey lasted approximately 30 minutes. Across our ten case study sites, we administered 794 household surveys and surveyed at least 8 percent of the population at each site.

Table 1: Survey Demographics

Site	Number of surveys	Estimated January 2018 population	Percent of population surveyed
GMA Kapuso	64	394	19.8
Guadalupe II (NHA*)	83	737	11.1
Habitat for Humanity	43	450	16.4
New Hope (NHA)	87	914	9.5
North Hill Arbours I (NHA)	79	923	8.7
Ridgeview I (NHA)	76	830	9.2
SM Cares	86	495	17.4
St. Francis I (NHA)	73	300	24.3
Villa Diana (NHA)	78	378	20.6
Villa Sofia (NHA)	80	488	16.4
Total	749	5909	12.7

**Constructed by the National Housing Authority*

For my analysis, I draw from survey questions inquiring about past exposure to hazards, such as the July 2017 Leyte earthquake: "During the earthquake, the houses in my community were affected." Exposure referred to any incidences that respondents already faced during their time at the relocation site. Questions reveal the effects of previous natural hazards on respondents, both by asking about specific events or by asking effects in general such as the question "In general, when it rains our community does not flood."

During the survey period, Tropical Storm Urduja passed over Tacloban City. This provided the unique opportunity to ask questions about relevant examples of hazards due to storms. Questions such as "Did your community experience significant flooding?" reveal actual physical examples of disasters.

2.3 Integration of Both Methods

Integration of hazard maps and survey data was done by overlaying survey responses on the actual hazard maps. Table 2 gives descriptions of the questions and hazard maps I overlaid to analyze flooding and earthquakes. In arcMap, I then created an attribute of the percentage of respondents agreeing with the statement for each site in the site layer I had previously made. The hazard map and the question responses layers were overlaid for a visual representation of the sites, their proximity to hazards, and community member's responses to survey questions about the hazard and visually analyzed.

Table 2: Summary of Integrated Hazard and Survey Data

Hazard	**Hazard Map**	**Survey**
Flooding	Low Flood Zone (Source: JICA/City of Tacloban; Depth: .5 meters or less (CPO, 2016))	Question item: During Tropical Storms Urduja, did your community experience significant flooding? Response type: Y/N
Earthquake	Ground Shaking (Source: JICA/City of Tacloban; VI and VII intensities)	Question item: During the earthquake, the houses in my community were affected. Response type: Likert

Through using hazard mapping, surveying, and combined techniques, I will be able to measure the exposure sites have to both types of hazards. More importantly I can analyze what strengths, weaknesses, and combined attributes these techniques have in measuring exposure risk.

3.0 Results

Each method proved to have its own flavor of measuring exposure. Mapping techniques showed physical exposure risk, surveying revealed severity and discrepancy among sites, and the combination of both highlighted where further analysis would be beneficial in assessment of risk due to exposure.

3.1 Mapping

In the three categories of floods: Low, Medium, and High, only low flooding was present in Tacloban North. Within that, three sites were within the low flooding zone. 16 percent of the GMA Kapuso relocation site, 97 percent of Ridgeview, and all of St. Francis overlapped with the flood zone (Figure 1).

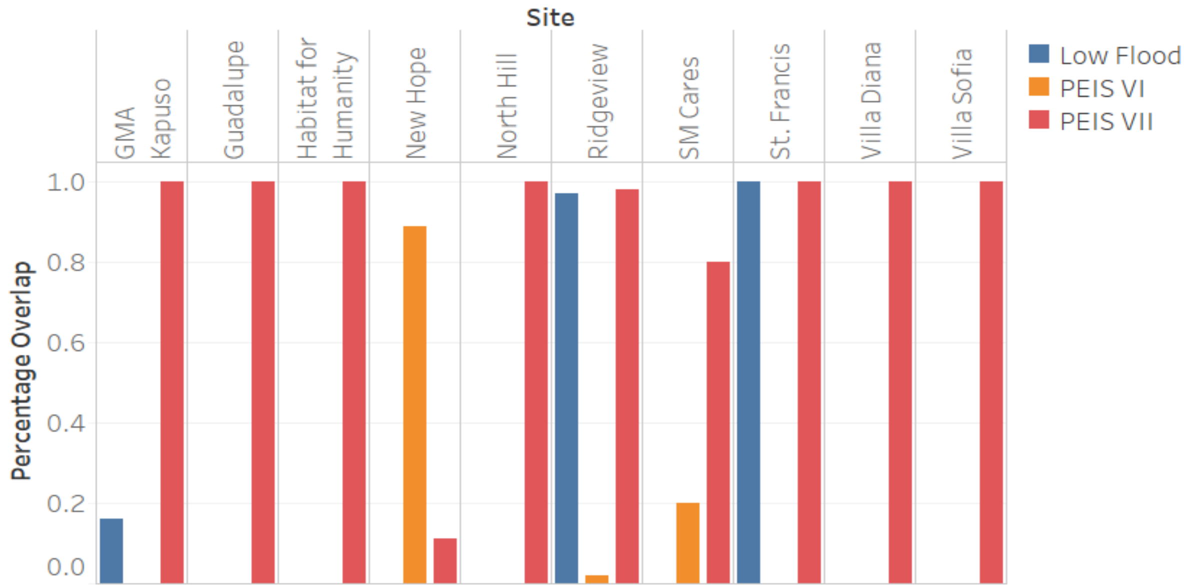

Figure 1: Percentage Overlap of Hazard Map over Each Site

For Ground Shaking due to earthquakes, there was 100 percent overlap for each site, however with differences in the category of shaking. Tacloban City is exposed to a VI and VII on the PEIS scale for ground shaking: "Very Strong" and "Destructive" respectively. All sites overlapped at least in part with the PEIS VII hazard area, yet three—North Hill, Ridgeview, and SM Cares—were partially within both the VI and VII levels of shaking (Figure 1). Based on site overlap with hazard areas on the map, there would be less destructive shaking at North Hill, Ridgeview, and SM Cares.

3.2 Survey

The survey results depict respondent's perceptions and experience with natural disasters. When looking at the specific past exposure to sites during Tropical Storm

Urduja, all sites seem to have experienced flooding to a certain degree, with 100 percent of respondents at New Hope and 91 percent of respondents at Ridgeview stating there was significant flooding in the community. However, only 3 percent of Habitat for Humanity respondents and 7 percent of SM Cares respondents reported flooding.

Interestingly, despite the past exposure to a storm powerful enough to induce flooding, the exposure question asking about general exposure to floods had much lower percentage of respondents saying they had experienced flooding (Figure 2). Villa Diana, Villa Sofia, and Habitat for Humanity reported no flooding despite only Villa Diana reporting no flooding during Tropical Storm Urduja. Discrepancies can be seen in comparison of Guadalupe compared to GMA Kapuso where less than five percent of respondents considered their community to flood.

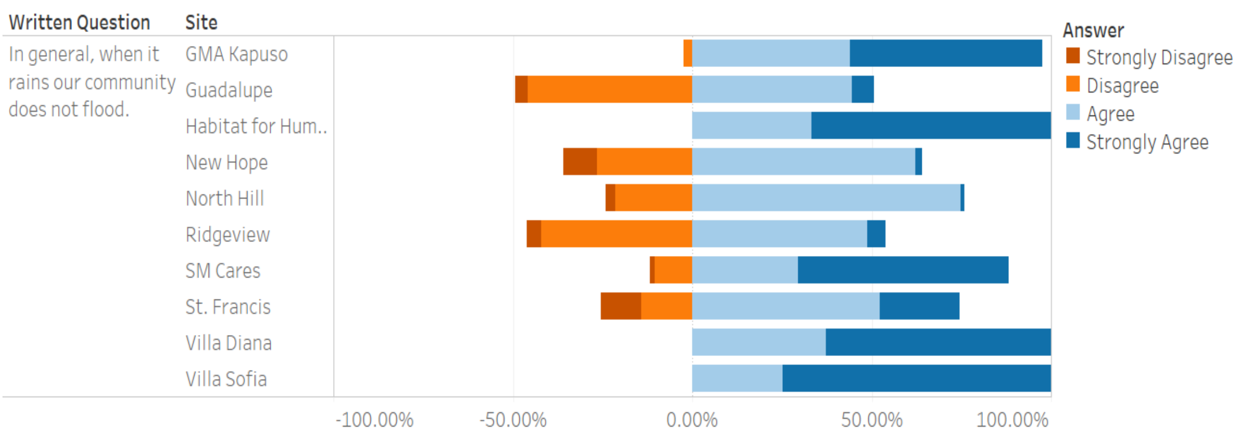

Figure 2: Responses per site "In general, when it rains our community does not flood."

For earthquake exposure, I looked at the question "During the earthquake, the houses in my community were affected." Communities reported being affected with the highest response being 50 percent of Ridgeview respondents. St. Francis had the most positive response, with only 1.46 percent agreeing community houses were affected.

An interesting comparison can be made between NHA and non-NHA sites. In response to whether their site flooded during Tropical Storm Urduja, 62 percent of NHA community respondents said there was flooding and 28 percent of non-NHA community respondents said there was flooding. However, for the earthquake question, 18 percent of NHA respondents said they were affected and 28 percent of non-NHA respondents said they were affected.

3.3 Integration of Both Methods

Overlapping survey responses and actual hazard maps revealed interesting correlations and discrepancies between the data. For flooding, at least 55 percent of respondents at sites within flood zones reported flooding (Figure 3). The color gradient for each site is based on the percentage of respondents agreeing with the survey statement, with darker being a larger percentage of respondents agreeing. The strongest correlation between survey respondents and mapped flood risk was with Habitat for Humanity and GMA Kapuso. Despite both being very close, GMA Kapuso does overlap with the flood zone and Habitat for Humanity does not, which was reflected in the survey responses, as 85 percent of GMA Kapuso respondents did report flooding compared to only 3 percent of Habitat for Humanity respondents.

The overlap of survey responses about past earthquake experience with the ground shaking hazard map revealed more discrepancies than similarities (Figure 4). Despite most sites being within the VII zone, sites ranged from 2 (St. Francis) to 50 percent (Ridgeview) of respondents reporting affected houses. Even between Habitat for Humanity and GMA Kapuso, which are in the same area, there was a discrepancy in responses.

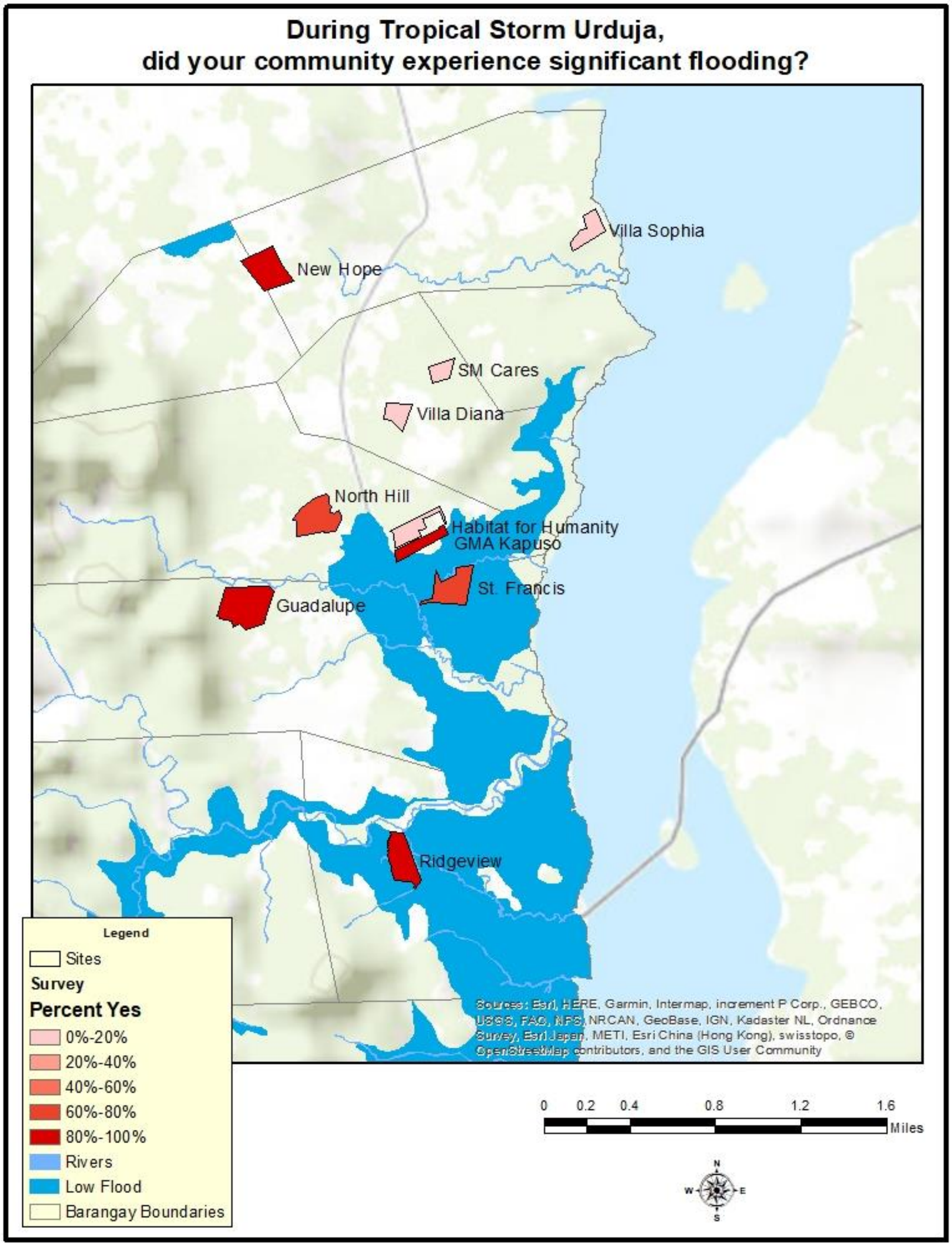

Figure 3: Percentage of respondents who stated "Yes" to the question "During Tropical Storms Urduja - Did your community experience significant flooding?" overlaid with the low flood hazard map.

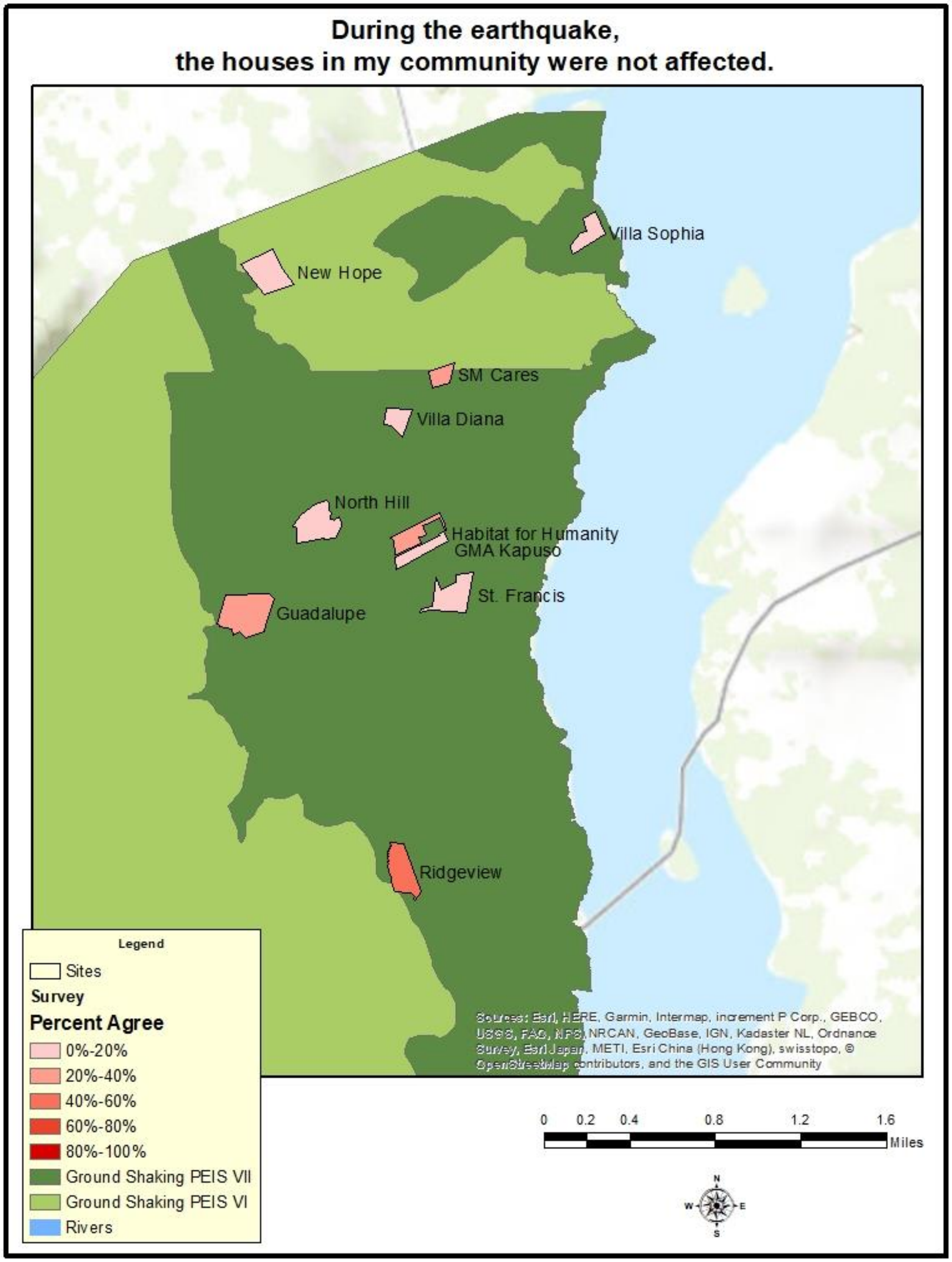

Figure 4: Percentage of respondents who agreed with the statement "During the earthquake, the houses in my community were affected." overlaid with the hazard map for ground shaking.

4.0 Discussion

Based on the results, there are multiple strengths and weaknesses of each method. Mapping on the surface is effective in showing where high risk areas are, but once integrated could be found to possibly be inaccurate. Survey data is effective in determining site-specific exposure but had discrepancies with the hazard maps. If anything, the discrepancies shown by comparing and combining each method revealed a deeper analysis that can be performed, and that each method leads to a richer understanding of the exposure to hazards at these sites.

4.1 Mapping

Hazard maps are useful in showing where high-risk areas are, however the integration of surveys and maps indicates that hazard maps alone show an incomplete picture of exposure relocation sites post-construction. When planning for risk, analysis of the overlap of hazards and site development is a useful visual aid in assessment of potential exposure to hazards and how to prevent sites from being exposed. As my results show, it seems that decision makers were effective in selecting relocation sites outside of the flood zone but not effective in avoiding more destructive ground shaking. Only three sites are within the flood zone, and only are in the low flood zone at that, however all sites are exposed to PEIS VII levels of ground shaking.

Hazard spatial analysis can also show where and to what magnitude events are likely to occur. The overlap with ground shaking and sites (Figure 5) revealed that most sites are exposed to destructive scale earthquake shaking. When creating a risk reduction plan, the magnitude of each ground shaking zone would need to be considered. Based on the hazard maps alone, flood management plans and flood preparedness training should also be considered at St. Francis, Ridgeview, and GMA Kapuso.

Though spatial analysis of hazard maps is effective for inspecting where hazards may occur, in terms of where hazards have occurred, this method is incomplete. It is critical to note that flooding and earthquake damage could still occur at low exposure sites, since these maps only show probability of exposure. The true effects of a hazard cannot be measured either, such as how infrastructure may be damaged or what populations are most susceptible to exposure, and so risk cannot be fully measured. Finally, Tacloban City's hazard maps were determined before the construction of relocation sites and significant concomitant land use changes. It is feasible that the extent of water-related hazards (flooding, storm surge) across the landscape changed due to major infrastructure developments.

4.2 Survey

Variations between type of hazard and even question highlighted what differences there are between sites due to each type of risk. In reflecting upon their past experience with both flooding and an earthquake, respondents at Ridgeview, Guadalupe, and New Hope tended to have more negative responses, while Villa Diana, Villa Sophia, and Habitat for Humanity, tended to have more positive responses. The responses suggest Ridgeview, Guadalupe, and New Hope are more exposed to risk.

The discrepancy between responses about flooding during Tropical Storm Urduja and general exposure to floods highlight the potential issues with survey analysis itself. Perhaps respondents felt that the tropical storms were more severe than general storms and thus flooding during Urduja was out of the ordinary. Or respondents are more likely to give stronger answers when asked about a specific event. These discrepancies highlight the fault in surveys: that they are based on people's perceptions and opinions. The weakness in surveying as data is a perfect example of where integrating both mapping and surveys can be helpful to see if people's perceptions of risk to hazards match with known hazards.

4.3 Integration of Both Methods

Integrating survey responses with hazard maps aids in resolving weaknesses that each method has alone and enhancing the strengths of each method. Surveys are weak in their accuracy in measuring exposure to hazards, but by comparing the answers visually to the exposure as measured by the maps, the validity of respondents' perceptions can be confirmed. Indeed, the highest responses for exposure did visually correlate with the hazard map zones for flooding and earthquakes. There were definite discrepancies that could be affected by the variability of responses, but if anything, they highlighted where there might be issues other than just geographic exposure that lead to risk, such as drainage and site infrastructure issues or structurally weak housing construction. For example, the survey suggested NHA sites experienced more flooding than non-NHA sites (62 percent compared to 28 percent), and the three sites that reported flooding that are outside of the flood zone (New Hope, North Hill, and Guadalupe) are all NHA sites. This could suggest that non-NHA sites took more care in drainage infrastructure. Hazard maps are weak in their inability to show the actual effects of a hazard or the magnitude in which they affect communities. Maps developed before land use changes are also void of the impact relocation development projects have and how hazards interact with the changed landscape. By overlapping the survey data and considering a direct comparison of communities' past experience, the actual effects of flooding and earthquakes hazards can be better understood.

However, overlapping hazard maps with survey responses about exposure to those hazards cannot show the cause of discrepancies between hazard maps and surveys. The differences may be driven by inaccuracy in either the maps or the surveys, or by much deeper issues, such as the biases in the perceptions of community members or problems with the way these sites were built. For example, consider Guadalupe, North Hill, and New Hope, which all had above 60% of respondents who reported flooding despite not being in a flood zone. New Hope is near a low flood zone; it is possible the flood zone was not drawn correctly in the hazard map and should be extended to encompass New Hope as well. However, Guadalupe and North Hill are not near the existing flood zone line, indicating other issues, such as poor drainage infrastructure, are contributing to flooding during rain events. Overlapping surveys and hazard maps highlight overalls discrepancies and where there could be failures or successes in mitigating risk. Further data collection and analysis would need to be done to discover direct correlations.

5.0 Further Research

The nature of combining survey data with hazard maps is such that it creates more questions than it necessarily solves. Why are there differences between surveys and mapping? What causes the discrepancies among sites within the same hazard zones? What other factors lead to increased or decreased exposure to natural hazards? In my opinion this is a strength of the methodology. Researchers and local decision makers alike are driven by the primary goal of selecting an approachable method to better understand the risk of natural hazards. Community surveys, hazard mapping, and their combination provide a wealth of data on exposure and risk. In particular, overlaying survey data with hazard maps reveals surprises in how physical risk to natural hazards manifests and calls attention to where further research and analysis is needed.

The discrepancies among sites highlighted where factors other than geographic exposure to natural hazards could be affecting the relative risk to sites. For example, New Hope, which was not in a flood zone, had a large portion of respondents stating they experienced flooding in the past. Though the simple comparison of survey responses to hazard maps cannot explain this difference, it does call attention to where additional research is needed, such as the quality and capacity of drainage infrastructure at relocation sites. Another study could explore the built environment and contemplate what indicators or survey responses could reveal infrastructure impacts or other issues on a hazard map.

Analysis of survey responses revealed an interesting fault in human-based assessment. People’s responses do not necessarily reflect exactly what has happened to them. Instead, there are discrepancies that could not explained by hazard maps. For example, differences between responses for the particular tropical storm question and the general question on flooding exposure could indicate a difference in perception of overall flood risk and flood risk in certain areas. Indeed, people’s perceptions of risk is a major factor in how they will respond to a certain question. An interesting study would be to look into how relocation community member’s perception of risk compares with the actual risk they face to natural disasters, and how those perceptions align or contrast with the relevant hazard map. Overall, the beauty of this research subject is its ability to create the first steps in a more in-depth analysis of natural hazard risk.

6.0 Conclusions

Risks to natural hazards is a very prevalent and pressing issue. As the severity of climate related natural disasters and world population increases, we must work to mitigate risk as much as possible. To mitigate risks, we must understand each element: exposure, vulnerability, and capacity. In my research I focused in on effectively determining exposure and illuminated a novel methodological comparison between community surveys and hazard maps for the evaluation of exposure at relocation sites. By combining survey responses and hazard maps I analyzed the exposure to two local natural hazards, flooding and earthquakes, and uncovered implications for the overall exposure at relocation sites. However, survey and mapping should not be used as the only methods to assess risk. Instead, they provide a way to test the waters and better understand the context in which natural hazard risks occur. To use these methods in an analysis of risk to natural hazards, I recommend combining methods as the strengths of each dampen the other method’s weaknesses. The combination can aid in the larger assessment of holistically measuring and mitigating risk to natural hazards.

References

Ahmed, I., McEvoy, D., 2014. Post-tsunami resettlement in Sri Lanka and India: site planning, infrastructure and services. International Journal of Disaster Resilience in the Built Environment 5(1), 53–65.

Anuradha Mukherji, N. Emel Ganapati, Guitele Rahill, 2014. Expecting the Unexpected: Field Research in Post-Disaster Settings. Natural Hazards.

Bier, V.M., 2017. Understanding and Mitigating the Impacts of Massive Relocations Due to Disasters. EconDisCliCha 1, 179–202.

City Profile | City of Tacloban, 2016. . Tacloban City Government.

Costas Amernakis, N. Nirupama, 2012. Prioritization of Disaster Risk in a Community Using GIS. Natural Hazards.

CPO, 2016. Tacloban City Comprehensive Land Use Plan. The Government of Tacloban City.

European Space Agency, 2016. Sentinel-2 - Missions - Sentinel Online [WWW Document]. URL https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-2 (accessed 5.2.18).

Guzzetti, F., Carrara, A., Cardinali, M., Reichenbach, P., 1999. Landslide hazard evaluation: a review of current techniques and their application in a multi-scale study, Central Italy. Geomorphology 31, 181–216.

IDMC, 2017. 2017 Global Report on Internal Displacement [WWW Document]. International Displacement Monitoring Centre. URL http://www.internal-displacement.org/global-report/grid2017/ (accessed 3.29.18).

Jethro Mullen, 2013. Super Typhoon Haiyan, one of strongest storms ever, hits central Philippines [WWW Document]. CNN. URL http://www.cnn.com/2013/11/07/world/asia/philippines-typhoon-haiyan/index.html (accessed 4.15.18).

JICA, 2015. The Urgent Development Study on the Project on Rehabilitation and Recovery from Typhoon Yolanda in The Philippines. Final Report (II) Appendix Technical Supporting Report 2 (Volume 1, Chapter 3 and 4). Japan International Cooperation Agency.

Jick, T.D., 1979. Mixing Qualitative and Quantitative Methods: Triangulation in Action. Administrative Science Quarterly 24, 602. https://doi.org/10.2307/2392366

Kevin J.E. Walsh, John L. McBride, Philip J. Klotzbach, Sethurathinam Balachandran, Suzana J. Camargo, Greg Holland, Thomas R. Knutson, James P. Kossin, Tsz-cheung Lee, Adam Sobel, Masato Sugi, 2016. Tropical Cyclones and Climate Change. Wiley Periodicals, Inc. 7.

Klein, R.J.T., Nicholls, R.J., Thomalla, F., 2003. Resilience to natural hazards: How useful is this concept? Global Environmental Change Part B: Environmental Hazards 5, 35–45.

Luc Anselin, 1988. What Is Special About Spatial Data? 9.

Micheal Bueza, 2016. IN NUMBERS: 3 years after Super Typhoon Yolanda. Rappler.

Norén, V., Hedelin, B., Nyberg, L., Bishop, K., 2016. Flood risk assessment – Practices in flood prone Swedish municipalities. International Journal of Disaster Risk Reduction 18, 206–217.

Official Gazette of the Republic of the Philippines, 2016. Making sense of the PHIVOLCS earthquake intensity levels | [WWW Document]. URL https://web.archive.org/web/20161014122559/http://www.gov.ph/laginghanda/phivolcs-earthquake-intensity-scale/ (accessed 4.29.18).

Palliyaguru, R., Amaratunga, D., Haigh, R., 2012. Impact of integrating disaster risk reduction philosophies into infrastructure reconstruction projects in Sri Lanka. Journal of Civil Engineering and Management 18(5).

Sanderson, D., 2000. Cities, Disasters and Livelihoods. Risk Management 10.

Smith, K., 2004. Hazard, Risk and Disaster, in: Environmental Hazards. pp. 11–12.

Sullivan-Wiley, K.A., Short Gianotti, A.G., 2017. Risk Perception in a Multi-Hazard Environment. World Development 97, 138–152.

Tacloban City, 2016. Tacloban City Housing & Community Development Office 46.

Tumamao-Guittap, G., Castro, J., Ezra Mallari, A., Niňo Punay, K., 2015. Hydro-Meteorological Risk Assessment of Tacloban City, Philippines.