Agricultural and Forestry Sciences
UNIVERSIDAD DE LA FRONTERA

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February 28, 2018

Dear Reviewer 2

We thank you for taking the time to give this exhaustive review that had helped us to improve our document. We have taken your revision very seriously, and in the following pages, we provide answers to all the comments that you gave us, hoping very much that you feel that we have responded thoroughly.

Sincerely,

Marcelo Somos-Valenzuela
Corresponding author

Comments from reviewer 2

The paper entitled “Response Time to Flood Events using a Social Vulnerability Index (ReTSVI)” seeks to explore a new method to convey the social vulnerable indicators together with evacuation response time under flood threat. Although worth of work, there is a need for significant reworking.

- Comment 1:

The introduction section is very general about the framework of social vulnerability (and sometimes only about vulnerability in general, lines 16-25, page 3) and it fails to interpret the studies in relation to floods hazard (for which a rich literature exists, e.g. Koks et al. 2015; Fekete 2009; Rufat et al. 2015; De Marchi and Scolobig 2012; Zhang and You 2014; Pelling 1997; Roder et al. 2017; De Marchi et al. 2007 among others).

Response to comment 1: We appreciate this suggestion and we modify this text from page 2 line 29-34 which originally read:

“To address this problem, some scholars have mapped physical and social vulnerability to visualize how they overlap. They have also combined them using arithmetic operations such as multiplication or addition of social and physical vulnerability indexes to create a unique indicator that considers both vulnerabilities (Cutter & Emrich, 2006; Hegglin & Huggel, 2008)”.

To this: “To address this problem, some scholars have mapped physical and social vulnerability to visualize how they overlap. They have also combined them using arithmetic operations such as multiplication or addition of social and physical vulnerability indexes to create a unique indicator that considers both vulnerabilities to study evacuation (Chakraborty, Tobin, & Montz, 2005)) or recovery process after hazards occur (Cutter & Emrich, 2006; Hegglin & Huggel, 2008)”

Additionally, after page 3 line 21 after the dot to line 38 we added the following paragraph: “Models of social vulnerability, in this area, have been used to explain the capability of communities to face and recover from disasters (Chakraborty et al., 2005).

Scholars have tried to understand whether socioeconomic and demographic characteristics of the population are relevant to understand why neighborhoods or communities respond differently during an evacuation, why some people evacuate, and others do not evacuate during disasters. The evidence about evacuations during hurricanes shows mixed results. Huang, Lindell, & Prater (2016) analyzed 49 studies linked to evacuations to hurricane warnings conducted since 1991 and concluded that demographics variables have a minor or inconsistent impact on household evacuations. In contrast, others studies show that social vulnerability is a key factor to take into account during emergency management and evacuation planning (Bateman and Edwards, 2002; Chakraborty et al., 2005; Dash and

Gladwin, 2007; Kusenbach et al., 2010). In the case of floods, studies suggest that social vulnerability is an important element to consider in order understanding different behaviors during flooding evacuations. In particular, scholars have found that variables such as low household income, poor housing quality, children (Pelling, 1997), women, housewives, students (De Marchi, 2007), elderly, high population density and population with low level of education (Zhang and You, 2014) are key variables to consider to create a social vulnerability index linked to evacuations during disasters."

- Comment 2: The paper needs extensive restructuring and in its current form fails to analyze the use of mapping social vulnerability for evacuation purposes for emergency management plans. This is a particular application, and the authors were unable to provide a strong bibliography in support of this context.

Response to comment 2: We appreciate this comment and literature suggested by reviewer 1 and 2. We have modified the introduction to narrow our review toward this particular application (see our response above). Regarding restructuring the paper, we have had several native english speaker readers that have helped us to shape this document. Therefore, we feel that, unless the editor thinks otherwise, the paper flow is adequate and it can be easily followed and understood.

- Comment 3: The identification of social vulnerability for effective early warning of disaster-related risks has not been adequately explained. There is no mention of the scale analysis at which mapping social vulnerability can be a usefulness tools for emergency management.

In this work, we do not question if the social vulnerability can be useful for emergency management because it is a normal practice that is widely used. What we identified is that traditionally this process is qualitative where social vulnerability is used to aggregate the population into high, medium and low level of vulnerability. Therefore, we are proposing a methodology to push this use of social vulnerability into a quantifiable unit by including it in the evacuation process. The statistical significance is still an issue that for the number of the first responders we used and we can not solve it in this work and we provide a review for that as well. Please see modified section 3.1 and Table 1.

- Comment 4:

Lines 1-15 page 3 is a repetition of the introduction, and lines 7-1 of the following page bring the reader a bit out of the general content of the manuscript.

Response to comment 4: To avoid redundancy, we deleted page 2 lines 32-35

- Comment 5:

Moreover, the evacuation literature is structurally confused (please consider them disasters and not natural disasters that is quite overlooked) for which I suggest a more focused review and the strongest argumentation.

Response to comment 5: We used the term “natural disaster” instead of “disasters” because the nature of the problems analyzed and the spirit of this work are associated with the environment. These disasters may be trigger by human actions, but they are understood as natural events in the literature. Additionally, we extended our literature review to address the evacuation associated with natural disasters. On the other hand, if the editor suggests that we use the word “disaster” instead of “natural disaster” we will change it in the document.

- Comment 6:

The objectives of the study are also not explained adequately.

Response to comment 6: In section 2.1 Conceptual model of ReTSVI, we implicitly explain the objective of the study “The Response Time by Social Vulnerability Index (ReTSVI) methodology allows for the inclusion of social vulnerability into the traditional evacuation/mobilization models. Figure 1 is a chart of ReTSVI, we use three types of input data, which are: 1) the evacuation curves, one for each level of vulnerability (high, medium and low vulnerability); 2) a model that describes the physical hazard that the population may be exposed to, for example, the time that a flood takes to reach a populated area; and 3) demographic information such as a census data that allows us to categorize the population into different levels of social vulnerability. Then we have two intermediate models. The first one corresponds to the mobilization model that combines the evacuation curves and the inundation model. The result of this step are three maps (one for each level of vulnerability) of the percentage of people that evacuate before the flood strikes a place. The second intermediate model is the calculation of the social vulnerability index (SVI) using the census data, which produces a map of the city in which we can classify each block by social vulnerability. Finally, we combined the results (Integration Model Figure 1) from the mobilization model and the SVI calculations to generate a map with the percentage of people that can evacuate, which considers their social vulnerability level.”

In order to further attend this comment, we modified the paragraph indicate above in the main document and now it reads like this: “The objective of this work is to propose a conceptual model ‘The Response Time by Social Vulnerability Index (ReTSVI)’ methodology that allows for the inclusion of social vulnerability into the traditional evacuation/mobilization models and it moves away from traditional methods that combined social vulnerability and hazard magnitude by ranking in a matrix system that results in qualitative assessment. Figure 1 is a chart of ReTSVI, we use three types of input data, which are: 1) the evacuation curves, one for each level of vulnerability (high, medium and low vulnerability); 2) a model that describes the physical hazard that the population may be exposed to, for example, the time that a flood takes to reach a populated area; and 3) demographic information such as a census data that allows us to categorize the population into different levels of social vulnerability. Then we have two intermediate models. The first one corresponds to the mobilization model that combines the evacuation curves and the inundation model. The results of this step are three maps (one for each level of vulnerability) of the percentage of people that evacuate before the flood strikes a place. The second intermediate model is the calculation of the social vulnerability index (SVI) using the census data, which produces a map of the city in which we can classify each block by social vulnerability. Finally, we combined the results (Integration Model Figure 1) from the mobilization model and the SVI calculations to generate a map with the percentage of people that can evacuate, which considers their social vulnerability level."

- Comment 7:

The methodology part is a bit confused due to the presence of several small chapters that mix up the methods, data collection and the study area, also lacking a chronological sequence. Please organize the chapter is the simplest format to increase the readability (I suggest to start from the study area, data collection and methods at last).

Response to comment 7: We adressed this question above "Regarding restructuring the paper, we have had several native English speaker readers that have helped us to shape this document. Therefore, we feel that, unless the editor thinks otherwise, the paper flow is adequate and it can be easily followed and understood". Aditionally, we feel like Reviewer 2 suggest that the area of study and Huaraz is the center of this work; however, we used this place as an example of application of the methodology proposed ReSTVI. Therefore, the importance of the "area of study" or "the case study" is secondary and it needs to go after we explain the methodology not to confuse the readers.

- Comment 8:

For the study area selection, there is a need to strongly justify the decision to study GLOF hazards in Peru providing some inundation zone maps and probability of occurrence details.

Response to comment 8: The reason to use this GLOF hazards is that one of the authors did the simulation for a potential inundation in Huaraz as part of a project that was funded by United States Agency for International Development (USAID), Interamerican Development Bank (IBD) and The ministry of environment of Peru. During this work in Peru, we also wanted to evaluate the implication of installing an early warning system. Then, we realized that the population exposed to the potential hazard was completely different in terms of social vulnerability, and we worked with the Ministry of Environment to have access to the Census data, which is not publicly available, to determine the different levels of social vulnerability and which group was going to be affected more or less. This work was published in Somos-Valenzuela (2014). During the work described, we realized that there was not a formal methodology to combine social vulnerability into the evacuation process, which is confirmed from our literature review and the literature recommended for both reviewers, we may still miss publications and examples from others part of the world though. Then we try to generate data on the evacuation rate and the differences in social vulnerability in the evacuation process in Huaraz; however, although there were a couple of evacuation drills organized by the civil defense of Peru in Huaraz, we were not allowed to access the information collected, if there were any information collected. After this, we decided to collect data after a tsunami in Coquimbo knowing that the hazard and the population are different; however, our goal is to provide a methodology and we provide an example of how the methodology should be applied.

For the second part of the question, the inundation maps were published in Somos-Valenzuela et al., (2016), we used the result of that work in this paper (Figure 5). The probability of occurrence is irrelevant for this work because we want to know the evacuation rate given the inundation scenario selected. Therefore, for the sake of this example, the probability of the inundation is 100% since it is the condition that has to happen to have the scenario presented as the application example in this paper. Additionally, calculating the probability of an inundation generated due to GLOF events is not straightforward given the nature of the hazard. There is not enough data to determine the frequency, location, and magnitude of those events. Additionally, the research frontier in GLOF is looking into the calculation of the probability of occurrence of GLOF, which is far from the scope of this paper, although, we are aware of the importance of the frequency of any hazard in a proper risk analysis which is not what we present in this work.

- Comment 9:

The utility of having 22 interviews is not properly set. The four institutions have been not described and the questions are not well explained, as well as the type of those (quantitative, qualitative?). How could respondents define low, medium and high social vulnerability? Why are stakeholders assumed to know the average evacuation time and the percentage of the population that usually evacuates? Was it related to their personal experiences or have the data in support of it? Another critical error is made in creating the social vulnerability index.

Response to comment 9:

The four institutions have been not described and the questions are not well explained, as well as the type of those (quantitative, qualitative?).

We explain in more detail who are the first responders that participated in the survey and how we recollect the data.

The original text from page 6 line 36 to page 7 line 7 reads as follow:

“Four institutions that work directly to help the population during the evacuation process participated in this study: the navy, the police, firefighters and the municipality of Coquimbo. Each institution selected at least five employees to respond to our questionnaire, these employees work directly during the emergency to help people evacuate their houses. The survey was completed with the help of a research assistant that conducted a personal interview with each participant. We asked first responders to estimate the average evacuation time and the percentage of the population that evacuates their households from 0 to 5 minutes, 0 to 15 minutes, 0 to 30 minutes, 0 to 45 minutes, 0 to 60 minutes in neighbourhoods with low, medium and high social vulnerability in Coquimbo.”

We replace this text with the paragraph below:

“Four institutions that work directly to help the population during the evacuation process participated in this study: the navy, the police, firefighters and the emergency office from the municipality of Coquimbo. First, we contacted by phone with each institution to explain the purpose of the study and asked them if they agree to participate in the research, all of them agree. Then, a research assistant visited each institution and asked them to select at least five emergency experts to respond to our questionnaire. The main requirement was that the participants worked directly during the emergency to help people evacuate their houses. The research assistant conducted a personal interview with each participant. We asked the first responders “In your opinion and based on your experience during the tsunami of 16th of September. Since the evacuation alarm was active, what is the evacuation time of population who live in areas of low/medium/high social vulnerability?” They needed to estimate the average evacuation time in neighborhoods with low, medium and high social vulnerability. Then, we asked “what is the percentage of the population that evacuate in the first X minutes? (X=5, 15, 30, 45, 60)” The first responders write down the percentage of the population that evacuates their households from 0 to 5 minutes, 0 to 15 minutes, 0 to 30 minutes, 0 to 45 minutes, 0 to 60 minutes in neighborhoods with low, medium and high social vulnerability in Coquimbo. The answers were recollected into two scales: percentages and average time (in minutes)

- Comment 10: How could respondents define low, medium and high social vulnerability?

Response to comment 10:

We use the National Socio-economic Characterization Survey (CASEN)[1] from 2015, same year that the earthquake/tsunami occurred, to calculate a social vulnerability index at the municipality level, following the same procedure identify in the section 2.2.3. This way we were able to identify the socioeconomic and demographic characteristics of the neighborhoods with high, medium and low social vulnerability. We incorporate this information in the survey, so the first responders could identify what neighborhood belongs to each category; all responders generate separate curves for low, medium, or high vulnerability neighborhoods."

- Comment 11: Why are stakeholders assumed to know the average evacuation time and the percentage of the population that usually evacuates? Was it related to their personal experiences or have the data in support of it?

Response to comment 11: Their information provide by first responders is base on their personal experience during the evacuation to the tsunami. This group of first responders participated actively and directly during the evacuation process; we asked them to estimate, based on their experience during the tsunami, what would be the percentage of evacuation, and an average time of the evacuation of the population of Coquimbo.

- Comment 12:

The authors used the receipt of Cutter without acknowledging properly the acronym (SoVI and not SVI as stated), the trademark and the complete receipt.

Response to comment 12: We use the methodology developed by Susan Cutter (2003) to construct the Social Vulnerability Index (SVI). However, we do not use the same variables to run the Principal Component Analysis because the census in Peru has different variables that the US census. Other authors, see Koks et al., (2015), Fekete (2009), also use Cutter's methodology to construct a social vulnerability index calling their indexes SVI. In consequence, we called the name SVI and not SoVI because they are created with a similar process but they are different indexes with different variables.

- Comment 13:

Do the authors transformed the variables to be able to compare them (e.g., z-score normalization)? Do the authors made a multicollinearity analysis to prove that none of the variables was predictive of others? Which threshold for component selection (referring to Eigenvalues.)?

[1] CASEN is a tool to describe and analyze the socio-economic situation of Chilean families, including housing, education, and labour characteristics. This is a cross-sectorial survey, whose periodicity yields a time based picture of the evolution of individual/household welfare (Contreras 2001).

Response to comment 13:

We did not include the methodology in the original text because we considered that the citation was enough. However, we are glad to provide an extensive explanation of what we did. Therefore, in the document in Page 10 line 9 after the dot we included the following paraphaph:

"To construct a Social Vulnerability Index (SVI), we analyzed census data using Principal Component Analysis(PCA). PCA is a multivariate technique "that analyzes a data table in which observations are described by several inter-correlated quantitative dependent variables"(Abdi and Williams, 2010). The main objective of a PCA is to extract information from the variables in a new set of orthogonal variables called principal components. For example, PCA "provides an approximation of a data table, a data matrix, X, regarding the product of two small matrices T and P', These matrices, T, and P,' capture the essential data pattern of X" (Wold et al., 1987). The use of this technique allows for robust and consistent numbers of variables that can be analyzed to estimate changes in social vulnerability over time (Cutter et al., 2003).
First, we identify the variables that were linearly correlated using the Variance Inflation Factors (VIF), those variables with VIF higher than 10 points were excluded from the model. Then, we followed Schmidtlein et al. (2008), who list seven steps to calculate the Social Vulnerability Index (SVI): (1) Normalize all variables as a percentage, per capita or density functions. For this paper, we normalized all variables as percentages; for example, the percentage of independent houses per block or the percentage of older adults per block. Then standardize all input (census) variables to z-scores $z = \frac{x-\mu}{\sigma}$. This creates variables with mean 0 and standard deviation 1. (2) Perform the PCA with the standardized input variables (z-scores). Select the number of components based on eigenvalues greater than one. (3) Rotate the initial PCA solution. In our work we used a normal Kaiser varimax rotation for component selection. (4) Calculate the Kaiser-Meyer-Olkin measure of sampling adequacy (KMO) and Bartlett's test of sphericity. (5) Interpret the resulting components as to how they may influence (increase or decrease) social vulnerability and allocate signs to the components accordingly. (6) Combine the selected component scores into a univariate score using a predetermined weighting scheme. The factors are named based on variables with significant factor loading, usually greater than .3 or less than -.3. (7) Finally, we standardized the resulting SVI scores to mean 0 and standard deviation 1. All the steps but step 6 are straightforward. In step 6, we must decide how we want to combine the different components. The first criterion is to use the scores from the PCA, adding them but assuming that all the components have the same contribution to the SVI (Cutter et al., 2003). The second criterion uses the scores from the PCA but assigns different weights to the principal components according to the fraction of variability they explain (Schmidtlein et al. 2008). The third method also does not assume that each component contributes equally to social vulnerability, but in contrast to the second method,

it multiplies each z-score by the factor load, and then its explained variance multiplies each component (Schmidtlein et al. 2008). We use the first criterion; we gave the same weight to all components. The same was done by Chakraborty et al., (2005); Chen et al., (2013); Cutter et al., (2003); Fekete, (2009) and Zhang and You, (2014). Fekete (2012) page 1167 provide a solid argument that explains the reason of using equal weighting which avoids adding assumptions that are qualitative and mostly not empirically supported, although it may sound intuitive to use the loading factor or the variance explained by the factor to combine the variables selected. Moreover, Roder et al., (2017) argue that there is no appropriate methodology for the calculation of the index."

- Comment 14: Which the adjusted directionality of the components (Table 1)?. The directionality is the most important part in the creation of the equation and thus the resulted index for each block. Also, in this regard, how factors have been weighted? (e.g., equally, Pareto rankings or with the variance each factor explained).

Response to comment 14: For the directionality, we indicate this with the sign in front of the variable name following Table 1 from Fekete (2009). However, for the sake of clarity, we modify Table one to clarify the directionality of the component and added a new column with the sign adjustment of the components.

Original Table 1:

Selected Census variables after PCA analysis to estimate Social Vulnerability Index (SVI) + more vulnerable – less vulnerable	Components					
	1	2	3	4	5	6
- Household with 5 or more rooms	.31					
- Population with health insurance	.40					
+ Population with primary education	-.37					
- Population with college education	.43					
- Population with "white collar jobs"	.40					
+ Indigenous population	-.35					
+ Population with disabilities		.53				
+ Population older than 65 years old		.53				
+ Women		.44				
+ Informal settlement			.74			
+ Household without electricity			.41			
+ Illiterate population			.33			
- Independent houses				.56		
+ House rented				.53		
+ Adult population divorced				-.57		
+ Jobs in the commerce sector					.61	
+ Jobs in the construction sector					-.33	

	1	2	3	4	5	6
+ Number of people per square kilometer					.52	
+ Children less than 1 year old						.59
+ Jobs in the manufacturing sector						.66
% of variance explained by component	20%	9%	8%	7%	7%	6%
Cumulative explained variance	20%	29 %	37 %	44 %	51 %	57 %

New version of Table 1

Selected Census variables after PCA analysis to estimate Social Vulnerability Index (SVI)	Sign Adjustment	Components 1	2	3	4	5	6
Household with 5 or more rooms	-	.31					
Population with health insurance		.40					
Population with primary education		-.37					
Population with college education		.43					
Population with "white collar jobs"		.40					
Indigenous population		-.35					
Population with disabilities	+		.53				
Population older than 65 years old			.53				
Women			.44				
Informal settlement	+			.74			
Household without electricity				.41			
Illiterate population				.33			
Independent houses	-				.56		
House rented					.53		
Adult population divorced					-.57		
Jobs in the commerce sector	+					.61	
Jobs in the construction sector						-.33	
Number of people per square kilometer						.52	
Children less than 1 year old	+						.59
Jobs in the manufacturing sector							.66
% of variance explained by component		20%	9%	8%	7%	7%	6%
Cumulative explained variance		20%	29 %	37 %	44 %	51 %	57 %

- Comment 15:

The selection of social vulnerability indicators is only based on the work of Cutter et al. (2003) and this step is very reductive in relation to the objective of the research that is focused in evacuation rather than recovery. There is salient need to criticize construction of indicators to flood hazards looking at those variables that really would have an effect on peoples' capacity to evacuate. It will add important value to the paper and ensure an advancement in understanding social vulnerability for this specific hazard for Peru.

Response to comment 15: Reducing this study just to the work by Cutter (2003) is not accurate, which is demonstrated by the many authors cited in this paper that used social vulnerability indexes. The basic idea is to use census data to shed some light to a very complex process which is understanding social vulnerability interactions. Advancing the research in social vulnerability is by no means an objective of this paper. Therefore we believe that although this is an interesting question it is out of the scope of this work.

- Comment 16: It is not understood how the authors selected the variables (from 245 to 20). This is one of the most critical points in this part of the analysis.

Response to comment 16: The selection of the variables to construct the SVI is explained in our respond to comment 13.

- Comment 17: How the economic status affects people capacity to evacuate? How being divorced? Or renting a house?

Response to comment 17: First of all, the goal of using the methodology selected to construct a social vulnerability index is to generate an index that is driven by Census data and the selection of variables is controlled by the results of the multicollinearity and PCA analyses. The major intervention is the assignment of the contribution sign to the vulnerability, and we support this from the literature revised. According to previous work that link social vulnerability and evacuation process due to disasters, the literature shows that socioeconomic status of families (in particular income and education) (Kusenbach et al., 2010), marital status of the household head and house ownership (Pelling, 1997) affect the ability of people and communities to respond or evacuate during a disaster. In this sense, we use variables to construct our Social Vulnerability Index (SVI). The specificity of the how this variables affect the evacuation is not studied in this paper and we rely on the information provided in previous work to do this selection.

- Comment 18:

In addition, there have not been justified in accordance with the real vulnerability Peruvian people might face in this century.

Response to comment 18: Knowing the real vulnerability of Peruvian people might face in this century is a task that we do not intent to answer. We understand that this is a titanic task that would need a specific project and expertise to be answered and we anticipate that the results of that task would be subjected to scrutiny and qualitative criticism due to the multidimensional nature of human condition and therefore social vulnerability. Therefore, we selected this general methodology, which is well accepted, to estimate social vulnerability and to provide an example of application of the methodology proposed in this study. The advantage of the methodology is that if there is a better alternative to estimate social vulnerability it can be used replacing what we have shown here. We do not intent to claim success nor authorship on the social vulnerability index, we just used a well-known and accepted methodology.

- Comment 19:

Why are women more vulnerable in Peru? Another issue emerges for gender. The impact of gender on social vulnerability to floods hazard is not unambiguous. As mentioned by Rufat et al., (2015) "women are also assigned more coping-capacities, greater commitment to knowledge of risk, and social relations. The case studies reveal that it is difficult to make generalizations about women's social vulnerability and that women's dependency and needs within the context of vulnerable populations might have been overemphasized. Even in developing countries with the most inequitable societies, gender alone is not predictive of social vulnerability because women's everyday living conditions vary across socioeconomic status, household structures, and geographic locations. Within this context, some studies found that gender had no impact on the social vulnerability in the face of floods at all". Some further discussion may seek to explore this factor. This is valid for all the variables. In this regard, Roder et al. 2017 address this specific problem of variables contextualization.

Response to comment 19: This analysis is very important because it is key to identify if the components selected contribute or not to increase social vulnerability. In our study, we select the variables using a multicollinearity test and PCA; and we assign the contribution to the index based on the literature available. In some studies women are identified as more vulnerable to hurricane evacuation than men in Kusenbach et al., 2010. De Marchi (2007) recognizes women and household wives as "the most vulnerable responders in therm of anticipation defined as prior awareness of flood risk, evaluation of personal preparedness, precautionary measures adopted, knowledge of warning systems and codes"

- Comment 20:

Concerning the evacuation curves, are they different statistically? Without this understanding, the related results seem not supported at all.

Response to comment 20:

We test if the mean response time to the evacuation alarm between the three types of neighborhoods was statistically significant using two methods: Anova (parametric method) and Kruskal-Wallis (non-parametric method). Table 1 shows that the differences are not statistically significant (p>0.05) between neighborhoods using both methods; this could be due to the limited size of the sample. In consequence, we decide to use the median rather than the mean as the middle point of the distribution of the mean response time and added Table 1 to the document.

Table 1: Parametric and non-parametric statistical difference test between level of social vulnerability.

Time	Anova	Kruskal-Wallis
0-5 minutes	0.13	0.09
0-15 minutes	0.44	0.39
0-30 minutes	0.67	0.60
0-45 minutes	0.85	0.87
0-60 minutes	0.87	0.52

- Comment 21:

The mapping of the social vulnerability (Figure 6) is meaningless without an understanding of the classification method used to show the three vulnerability classes (e.g. SD, Jenks Natural Breaks), in fact one could conclude that it is quite easy to play with those classes without knowing the distribution curve. Also, which is the minim, maximum and the average value of the index? Again the components have been just mentioned roughly for which is impossible to understand to their contribution to the vulnerability in the evacuation processes during a GLOF and specifically in Peru. I suggest strongly to provide a table with some basic statistics of the number of blocks in the three categories. Also, provide some spatial statistics to relate to the proximity to the river and to analyze the outcome map of social vulnerability overlapped with the flood hazard map.

Response to comment 21:

For the classification, we used three quantiles as it is shown in the figure below. The maximum value is 1.365, the minimum is -1.3425, the mean is 0.03, and the standard deviation is 0.4367

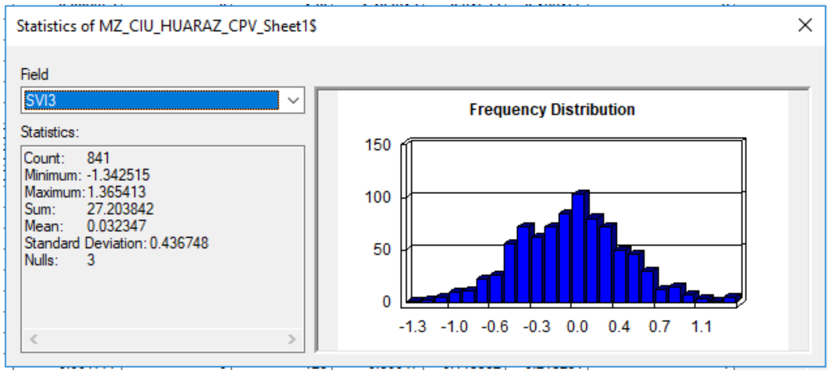

Figure 1 comments: Social Vulnerability Index statistics calculated in ArcGIS

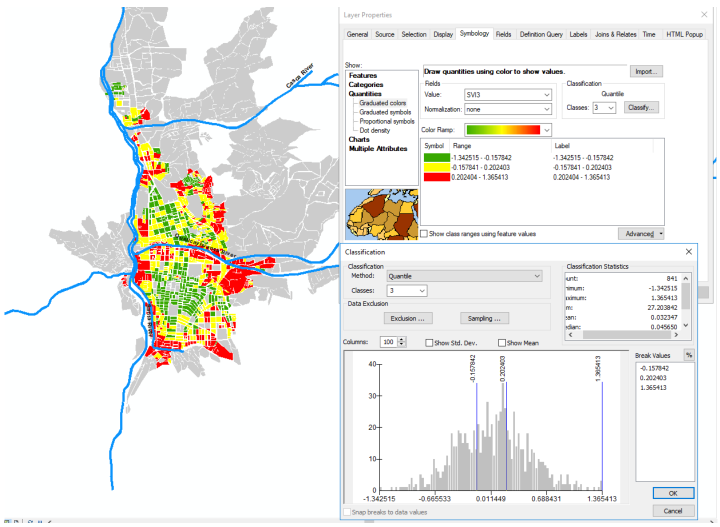

Figure 2 comments:: Social Vulnerability Index classification calculated in ArcGIS.

The proportion of high, medium and low vulnerability blocks within the inundation zone is 15%, 35 %, and 50% respectively.

- Comment 22: The discussion chapter is not adequately addressed. There is a lengthy introduction that sum up the justification of the research and the methodology undertaken and that present new results never presented before. I suggest entirely rearrange this chapter, enrich it and provide some consideration to flood management and early warning system. I suggest improving the quality of all the figures. All the other comments are made through the file.
- Regarding Result and Discussion, these chapters are very general. I would have expected a more depth analysis.

Response to comment 22:

Figure 9 in the discussion does not provide new information, instead it presents the same results than Figure 5, which is in the result section, but in a different format. We also improved the figures, adding new feature to many of them and improving the resolution.

In the results we rewrite section 3.1 and now it reads as follow: "Figure 5 shows the percentage of population that evacuate after the tsunami alarm was activated in neighborhoods with high, medium and low social vulnerability. Each box presents the 75th percentile (upper hinge), the median (center), 25th percentile (lower hinge) and the outlier values. Figure 5 indicates that neighborhoods with high social vulnerability systematically evacuate fewer people than areas with medium or low social vulnerability, for example, the first 5 minutes after the alarm is activated, the median (percentage of evacuation) for neighborhoods with high social vulnerability is the 20%, and 40% for medium and low social vulnerability. Figure 5 also shows that the differences in term of the percentage of evacuation decrease over time and eventually disappear after an hour since the alarm was activated.

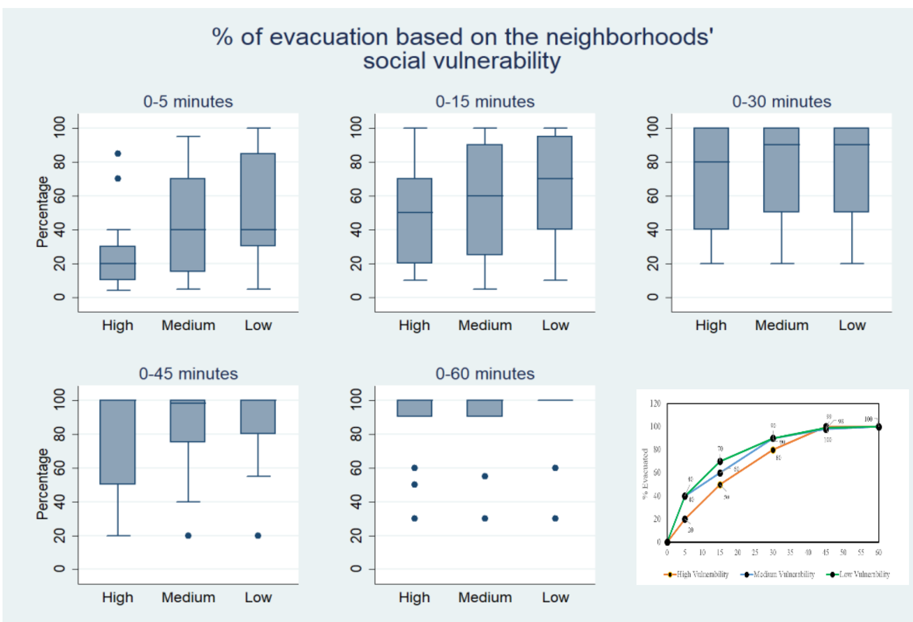

Figure 5: First responder's results by social vulnerability group.

We test if the mean response time to the evacuation alarm between the three types of neighborhoods was statistically significant (p>0.05) using two methods: Anova (parametric method) and Kruskal-Wallis (non-parametric method). Table 1 shows that the differences are not statistically significant between neighborhoods using both methods; this could be due to the limited size of the sample. In consequence, we decide to use the median rather than the mean as the middle point of the distribution of the mean response time.

Table 1: Parametric and non-parametric statistical difference test between level of social vulnerability.

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0-30 minutes	0.67	0.60
0-45 minutes	0.85	0.87
0-60 minutes	0.87	0.52

”

We also rearrange the Discussion and Conclusions which now read as follow:

“4. Discussion

The literature indicates that social vulnerability has a large influence on how people respond to natural disasters. There is agreement that more vulnerable inhabitants not only suffer the most during a natural disaster but also are less resilient, which affects their ability to recover afterward. Social vulnerability is thought to be an important factor that needs to be included in evacuation analyses but there are no systematic frameworks to do so. This paper deals with this problem by proposing a methodology to integrate social vulnerability into the calculation of how people evacuate after an EWS is activated. We develop the *Response Time by Social Vulnerability Index* (ReTSVI) methodology, which is a three-step process to determine the percentage of people that would leave an area that could be potentially inundated. For doing this, we used the methods from the LIFESim model and replaced the evacuation curves to reflect the differences in the time response according to social vulnerability level.

The findings from the surveys are in agreement with the theory since the time that people take to respond increases as the vulnerability moves from low to high levels. An interesting result is shown in Figure 9, where we compare the aggregate survey responses with the evacuation responses categorized by social vulnerability level, finding that people at a medium level of vulnerability respond similarly to the aggregated values. Then, people with low and high vulnerability behave almost symmetrically around the average. If we extrapolate these results to areas where we just know from first responders the aggregated evacuation rate in time, we can apply the factors indicated in Figure 9 to make a first order approximation of the difference in the evacuation rate by the social vulnerability.

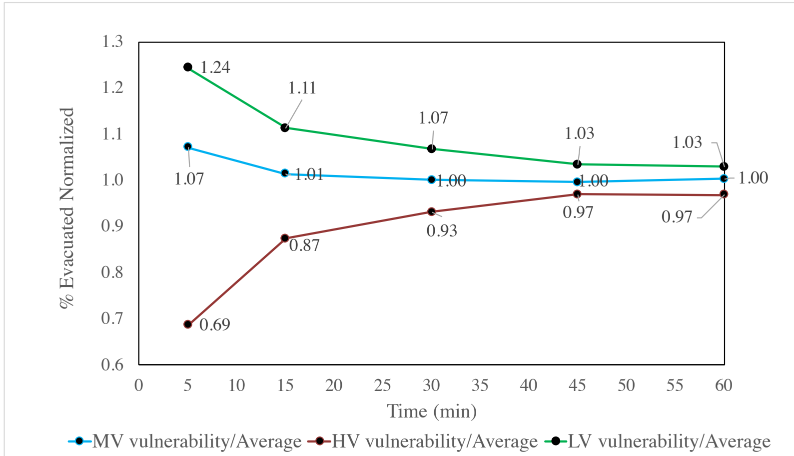

Figure 9: People evacuated per social vulnerability level normalized by the average number of people evacuated.

It is important to keep in mind that the surveys were taken in one location where people are highly trained to deal with tsunamis, which may present limitations applying this model in other locations. Regardless, this is an important advancement in our ability to quantify a process that is normally only addressed with qualitative methodologies. Certainly, we need to collect more data to come up with more general approximations of the importance of social vulnerability in the evacuation.

On the other hand, there is a body of literature that does not find a connection between social vulnerability and evacuation process (i.e. Baker, 1991; Huang, Lindell, & Prater, 2016). However, this literature has been conducted during evacuation process due to Hurricanes, where the population is informed to evacuate their home with hours or days in advance. According to our result, although with no statistical significance, social vulnerability is only relevant during the first 30 minutes after the evacuation alarm is activated, after that, the response time is almost the same among neighborhoods from different levels of social vulnerability. In the case of floods, the literature suggests that social vulnerability is an important element to consider in order to understanding different behaviours during flooding evacuations. In particular, scholars have found that variables such as low household income, poor housing quality, children (Pelling, 1997), women, housewives, students (De Marchi, 2007), elderly, high population density and population with low level of education (Zhang and You, 2014) are key variables to consider to create a social vulnerability index linked to evacuations during disasters. On the other hand, we wanted to use a methodology that make use of census information without major intervention. Therefore, we extend the application of the findings from Fekete (2009) , even though this research was conducted disaster recovery rather than evacuation, who demostrate that "social vulnerability indices are a means for generating information about people potentially affected by disasters that are e.g. triggered by river-floods." Coincidently, the components selected by the criterion used and explained in this work are similar if not the same to what the literature review indicated. Therefore, we felt encouraged to use the 6 components to first explain the responder what we mean by high, medium, and low social vulnerability and to do the exercise of application in Huaraz.

5 Conclusion

This article proposes a methodology to incorporate social vulnerability into current methodologies to estimate the percentage of people that evacuate an inundation hazard zone. Previous research recognizes the relevance of social vulnerability; however, it fails to connect the physical vulnerability or the characteristics of an inundation event with social vulnerability. Consequently, we propose a three-step methodology to include social vulnerability that we call Response Time by Social Vulnerability Index (ReTSVI).

We provide an example of the application of ReTSVI where we surveyed first responders to estimate the aggregated time of response and the time of response by social vulnerability. Then we used census data to calculate the SVI and applied into the evacuation process to inundation in Huaraz that was estimated in a study by Somos-Valenzuela and colleagues (2016).

The survey shows that in the first five minutes there is the larger difference in time response between social groups. In this initial period 27% of the population living in neighbourhoods with high social vulnerability evacuated, whereas 42% and 49% of people with medium and low vulnerability escape in the same period. This tendency smooths out after 15 minutes where the distances between the different groups get closer. We use the Principal Component Analysis to construct the SVI, six factors explain social vulnerability among all blocks in Huaraz (Perú) and 57% of the variance is captured by these components. Socioeconomic status, age, gender, marital status, labour sector, education level, home-ownership, population density, poverty, and quality of dwelling materials explain the differences in social vulnerability in Huaraz.

The results of the example of ReTSVI in Huaraz highlight the relevance of including social vulnerability in the planning process. There are distinct differences in the percentage of people evacuated in Huaraz for blocks that are close to each other, which could be explained by SVI since their exposure to the physical hazard and the distance to escape are similar. The same is true when the alarm is delayed, the longer it takes for the authorities to warn people, the larger the influence of SVI. However, we have to mention that although it seems intuitively plausible that people with different levels of social vulnerability would differ in their evacuation rates and departure times, there are no empirical data that support this assumption. Differences in evacuation rate associated to level of social vulnerability needs further study because with the current state of the art and the data collected in this study, we cannot answer this question with statistical significance.”

Extra Supplementary Comments (SC)

- SC1: Page 2 line 5, worldwide, where?

Response to comment SC1: yes, worldwide. Now page 2 line 5 reads as follow:

"For example, worldwide natural disasters caused around 3.5 trillion US dollars in damages from 1980 5 to 2011,…"

- SC2: Page 2 line 8, Preparedness of whom? communities? rescue officers? policy makers.

Response to comment SC2: Preparedness of communities. Now page 2 line 8 before the dot, it reads as follow:

"A key strategy to reduce the loss of human life during a disaster is to improve preparedness of communities"

- SC3: Page 2 line 12, repeated work "age" and add "and gender"

Response to comment SC3: Now page 2 line 12 after the dot reads as follow "Individual characteristics such as race, age, gender,…"

- SC4: Page 5 line 3. Can you please explain how class would affect people's decision to evacuate?

Response to comment SC4: we provided an extra reference that support the statement (Kusenbach et al. 2010). Our work is not to study the mechanisms to understand why class, gender or another variable could increase or decrease vulnerability instead we based the selection in the literature available.

- SC5: Page 6 line 6 "2.1 Conceptual model of ReTSVI." Is this chapter useful at all?

Response to comment SC5:

Yes, this is probably the most important section of this paper. The reason for this is that we are proposing a methodology ReTSVI that combines a series of modules which are pieces of information such us evacuation rate curves, mobilization, inundation models and social vulnerability indexes to create an integrated map of evacuation in a given location. We also provided an application example of this, which is important but it is not as relevant as the methodology proposed.

- SC6: Page 6 line 21 "There is the need for a strong and supported justification of the study area selection."

Response to comment SC6: We already addressed this point in this document, and we copy our answer here.

“The reason to use this GLOF hazards is that one of the authors did the simulation for a potential inundation in Huaraz as part of a project that was funded by USAID, BID and The ministry of environment of Peru. During this work in Peru, we also wanted to evaluate the implication of installing an early warning system. Then, we realized that the population exposed to the potential hazard was completely different in terms of social vulnerability, and we worked with the Ministry of Environment to have access to the Census data, which is not publicly available, to determine the different levels of social vulnerability and which group was going to be affected more or less. This work was published in Somos-Valenzuela (2014). During the work described, we realized that there was not a formal methodology to combine social vulnerability into the evacuation process, which is confirmed from our literature review and the literature recommended for both reviewers, we may still miss publications and examples from others part of the world though. Then we try to generate data on the evacuation rate and the differences in social vulnerability in the evacuation process in Huaraz; however, although there were a couple of evacuation drills organized by the civil defense of Peru in Huaraz, we were not allowed to access the information collected, if there were any information collected. After this, we decided to collect data after a tsunami in Coquimbo knowing that the hazard and the population are different; however, our goal is to provide a methodology, and we provide an example of how the methodology should be applied.”

- SC7: Page 6 line 22 “I suggest to define what a GLOF is.”

Response to comment SC7: The definition of GLOF is provided on the same line. GLOF stands for Glacier Lakes Outburst Flood.

- SC8: Page 8 line 5-7 “To estimate the percentage of people that evacuate we use the LIFESim model as a base framework. The Army Corps of Engineering incorporated this model into the HEC-Fia model (Lehman and Needham, 2012; USACE, 2012) to evaluate how flood events affect the evacuation during flood events.” This sentence sounds odd. Please revise.

Response to comment SC8:

We modify this sentence and now it reads: “To estimate the percentage of people that evacuate we use the LIFESim model as a base framework. The Army Corps of Engineering incorporated this model into the HEC-Fia model (Lehman and Needham, 2012; USACE, 2012) to evaluate the evacuation during flood events.”

- SC9: Page 10 line 2-3 "One of the main critics of the use of indexes to quantify social vulnerability is the limited number of variables and the lack of connection and interrelationship among variables used by the indexes." Already stated

Response to comment SC9:

We intentionally state this again, because it is important to present the information that follows. If the editor considers that it should not be there, we can certainly modify it.

- SC10: Page 10 line 4-5: If you'd followed the methodology of cutter 2003 you should name the index SoVI and acknowledge it properly.

Response to comment SC10: We already addressed this point in this document, and we copy our answer here.

"We use the methodology developed by Susan Cutter (2003) to construct the Social Vulnerability Index (SVI). However, we do not use the same variables to run the Principal Component Analysis because the census in Peru has different variables that the US census. Other authors, see Koks et al., (2015), also use Cutter's methodology to construct a social vulnerability index and also Koks et al., (2015) called their index SVI. In consequence, we called the name SVI and not SOVI because they are different indexes with different variables."

- SC11: Page 11 line 30-33"The explanation for this may be that we took the surveys in Chile after an earthquake struck and produced a tsunami, and the population of Chile is well trained and experienced in knowing what to do in case an alarm is sounded warning of an imminent inundation."

This is true, so why using evacuation curve for a different hazard?

Response to comment SC11:

We have two reasons to do this; the first one is that we do not know any other source of data where the evacuation curves are discriminated by social vulnerability indexes. The second reason is that we wanted to provide an example of the methodology proposed and we used this tsunami hazard with the characteristic of the population similar to Peru (or at least closer than using curves from the US or Europe) as a proxy of flood generated by a GLOF.

- SC12: Page 20 line 6-7 **Figure 1: ReTSVI chart**

Integrated map of..? Why the three classes of the mobilization model have been named as SVI low-medium and high? There should not have anything in common with the social vulnerability outcomes and the inundation model and the evacuation curves.

Response to comment SC12:

The reason to name them like that is that to create those maps, we used the evacuation curves that correspond to the vulnerability level. For example, if the evacuation map is SVI low, it means that we assumed that all the population evacuation rate follows the curve for low social vulnerability index. Then when we have the three maps (because we decided to aggregate the population in three groups), with the result of the SVI from the Census data we determined which evacuation rate should be used in each neighbor.

- SC13: Page 21 line 4 **Figure 3: This image corresponds to Figure 9 from (Somos-Valenzuela et al., 2016). Preliminary hazard map of Huaraz due to a potential GLOF originating from Lake Palcacocha with the lake at its current level (0 m lowering) and for the two mitigation scenarios (15 m lowering, and 30 m lowering).**

What low-medium-high stand for? Any reference to return period? What's the percentage of each level of hazard?

Response to comment SC13:

As the figure indicated it corresponds to flood hazard, for more information on how that was constructed, I would suggest referring to Somos-Valenzuela et al. (2016)

- SC14: Page 23 line 5 **Figure 8: Evacuation using Social Vulnerability Index.**

Spatial reference is missing

Response to comment SC14 :

We modified Figure 5, 6 and 7. Please see below.

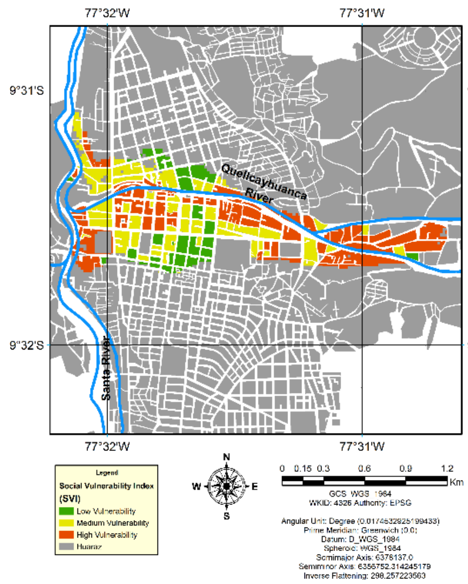

Figure 6: Comparative Vulnerability of Blocks in Huaraz using Social Vulnerability Index (SVI)

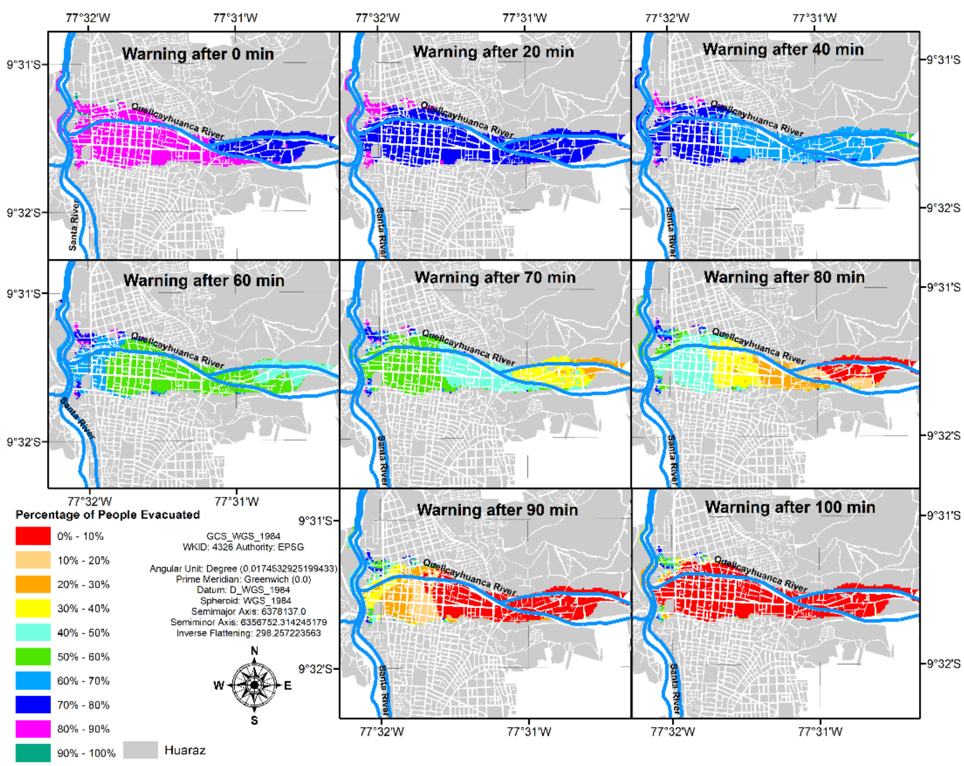

Figure 7: Evacuation using empirical equations.

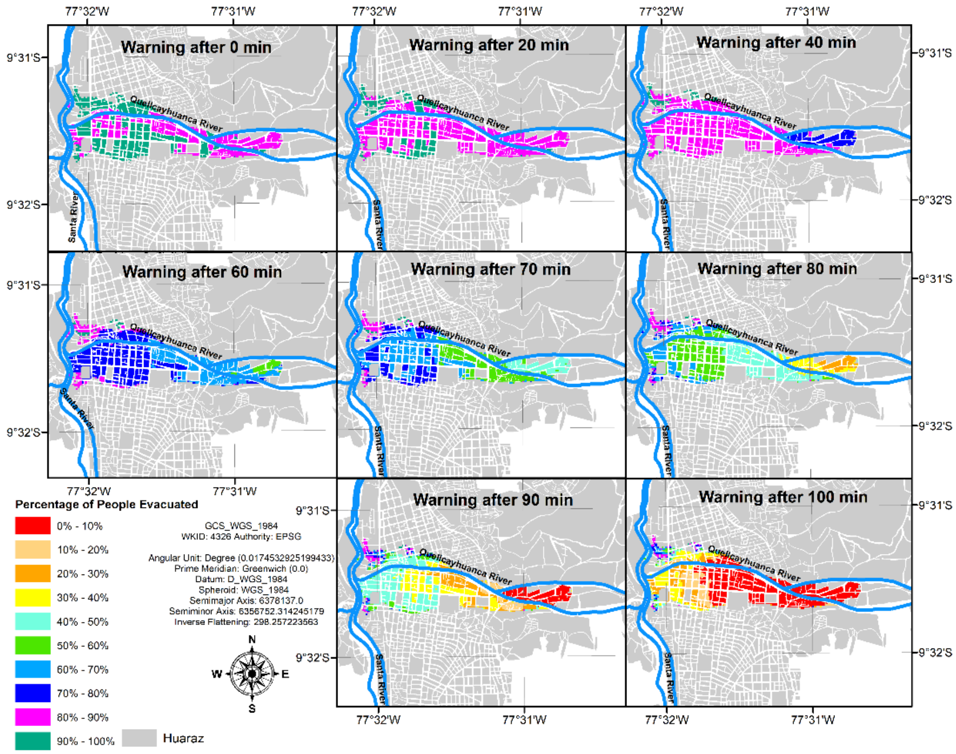

Figure 8: Evacuation using Social Vulnerability Index.

References

Abdi, H. and Williams, L. J.: Principal component analysis, Wiley Interdiscip. Rev. Comput. Stat., 2(4), 433–459, doi:10.1002/wics.101, 2010.

Baker, E.: Hurricane evacuation behavior, Int. J. Mass Emerg. Disasters, 9(2), 287–310, 1991.

Bateman, J. and Edwards, B.: Gender and evacuation: A closer look at why women are more likely to evacuate for hurricanes, Nat. Hazards Rev., 3(3), 107–117, 2002.

Chakraborty, J., Tobin, G. a. and Montz, B. E.: Population Evacuation: Assessing Spatial Variability in Geophysical Risk and Social Vulnerability to Natural Hazards, Nat. Hazards Rev., 6(1), 23–33, doi:10.1061/(ASCE)1527-6988(2005)6:1(23), 2005.

Chen, W., Cutter, S., Emrich, C. and Shi, P.: Measuring social vulnerability to natural hazards in the Yangtze River Delta region, China, Int. J. Disaster Risk Sci., 4(4), 169–181, 2013.

Cutter, S. and Emrich, C.: Moral Hazard, Social Catastrophe: The Changing Face of Vulnerability along the Hurricane Coasts, Ann. Am. Acad. Pol. Soc. Sci., 604(1), 102–112, doi:10.1177/0002716205285515, 2006.

Cutter, S., Boruff, B. and Shirley, L.: Social Vulnerability to Environmental Hazards, Soc. Sci. Q., 84(2), 242–261, 2003.

Dash, N. and Gladwin, H.: Evacuation Decision Making and Behavioral Responses: Individual and Household, Nat. Hazards Rev., 6988(August 2007), 69–77, doi:10.1061/(ASCE)1527-6988(2007)8, 2007.

Fekete, A.: Validation of a social vulnerability index in context to river-floods in Germany, Nat. Hazards Earth Syst. Sci., 9(2), 393–403, doi:10.5194/nhess-9-393-2009, 2009.

Fekete, A.: Spatial disaster vulnerability and risk assessments: challenges in their quality and acceptance, Nat. Hazards, 61(3), 1161–1178, doi:10.1007/s11069-011-9973-7, 2011.

Hegglin, E. and Huggel, C.: An Integrated Assessment of Vulnerability to Glacial Hazards, Mt. Res. Dev., 28(3–4), 299–309, doi:10.1659/mrd.0976, 2008.

Huang, S.-K., Lindell, M. K. and Prater, C. S.: Who leaves and who stays? A review and statistical meta-analysis of hurricane evacuation studies, Environ. Behav., 48(8), 991–1029, 2016.

Koks, E., Jongman, B., Husby, T. and Botzen, W.: Combining hazard, exposure and social vulnerability to provide lessons for flood risk management, Environ. Sci. Policy, 47, 42–52, 2015.

Kusenbach, M., Simms, J. and Tobin, G.: Disaster vulnerability and evacuation readiness: coastal mobile home residents in Florida, Nat. Hazards, 52(1), 79, 2010.

De Marchi, B.: Risk construction and social vulnerability in an italian alpine region. Country report Italy, ISIG., 2007.

Pelling, M.: What determines vulnerability to floods; a case study in Georgetown, Guyana, Environ. Urban., 9(1), 203–226, 1997.

Roder, G., Sofia, G., Wu, Z. and Tarolli, P.: Assessment of Social Vulnerability to Floods in the Floodplain of Northern Italy, Weather. Clim. Soc., 9(4), 717–737, 2017.

Schmidtlein, M., Deutsch, R., Piegorsch, W. and Cutter, S.: A sensitivity analysis of the social vulnerability index., Risk Anal., 28(4), 1099–114, doi:10.1111/j.1539-6924.2008.01072.x, 2008.

Somos-Valenzuela, M. a., Chisolm, R. E., Rivas, D. S., Portocarrero, C. and McKinney, D. C.: Modeling a glacial lake outburst flood process chain: the case of Lake Palcacocha and Huaraz, Peru, Hydrol. Earth Syst. Sci., 20(6), 2519–2543, doi:10.5194/hess-20-2519-2016, 2016.

Somos-Valenzuela, M. A.: PhD Dissertation: Vulnerability and Decision Risk Analysis in Glacier Lake Outburst Floods (GLOF). Case Studies: Quillcay Sub Basin in the Cordillera Blanca in Peru and Dudh Koshi Sub Basin in the Everest Region in Nepal, , 255, 2014.

Wold, S., Esbensen, K. and Geladi, P.: Principal component analysis, Chemom. Intell. Lab. Syst., 2(1–3), 37–52, doi:10.1016/0169-7439(87)80084-9, 1987.

Zhang, Y.-L. and You, W.-J.: Social vulnerability to floods: a case study of Huaihe River Basin, Nat. hazards, 71(3), 2113–2125, 2014.