Agricultural and Forestry Sciences
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February 28, 2018

Dear Reviewer 1

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 1

Summary: This manuscript describes a promising method of incorporating social vulnerability into evacuation analyses. The review of the social vulnerability literature is relatively strong but the review of research on evacuation analysis is rather weak. Two very extensive reviews of research on hurricane evacuation concluded that sociodemographic variables have weak and inconsistent correlations with evacuation decisions (Baker, 1991; Huang et al., 2016) and the research on evacuation departure times is extremely sparse, even for hurricane evacuations. There is a more directly relevant literature on pedestrian evacuation for tsunamis (see the references cited below) but it does not address social vulnerability to any significant extent. In addition, there are also some unanswered questions about the reliability and validity of the evacuation departure time data reported in this study. Overall, the weak empirical foundation in the existing literature and in this study suggests that the authors should be very cautious about any claims about the contribution that social vulnerability indicators can make in improving evacuation analysis.

Response to Summary:
We appreciate the comments from Referee 1, this methodology is intended to help filling the gap that exists in the combination of Physical and Social vulnerability which is traditionally accomplish by ranking them separately and combining them in a matrix generally of 3 by 3. We agree with most of the comments that Anonymous Referee 1 made, and we addressed them in the following pages. We understand the concern that Referee 1 has regarding the lack of empirical foundations which is also true for previous studies. In this work, what we are proposing is a methodology (ReTSVI) to combine Physical and Social Vulnerability by connecting a series of modules that represent processes that occur in an evacuation due to flood hazards; however, we understand that the outcome of this methodology is highly dependent on the definition of the evacuation rate curves. However, we argue that it has to be part of future studies to explain place to place if social vulnerability is statistically significant to describe differences in the evacuation rate. Although with no statistical significance, our results agree with the literature associated to Hurricanes since we found that social vulnerability has less impact after one hour of warning, which is the case in hurricanes where the warn can be given with days in advance. Therefore, we would restrict this work to floods that occurs in a timescale of an hour or less. What we hope this work will be useful for is to define a framework that helps to raise questions related to specific processes associated to social vulnerability that occur in an evacuation due to flood hazards, improve methodologies and integrate/test this new knowledge as modules in this framework.

- Comment 1: Page, Line, Comment 10 L12. The description of the data from the first responders lacks specificity about the process by which the data were collected. One possibility is that each responder was asked to describe the response curve for a specific neighborhood that she or he assisted in evacuating, after which the authors classified the neighborhoods in terms of their social vulnerability. Alternatively, all responders might have been asked to generate separate curves for low, medium, or high vulnerability neighborhoods. The first procedure is much more likely than the second one to generate reliable data. The description of the data also lacks any measures of interrater agreement for the ratings of the percent evacuated at each point in time. The authors should present some measure of variability such as the standard error of the mean for each point in

Figure 5. That information should be accompanied by statistical tests of the differences among the curves for low, medium, or high vulnerability neighborhoods. Given the small sample of responders, it seems quite possible that there are no statistically significant differences among the curves even at 5 minutes. If there are nonsignificant differences among social vulnerability neighborhoods at any given time point, the most appropriate estimate of percentage of evacuees at each point in time would be the median estimate. For example, Figure 5 shows that there is almost certain to be a nonsignificant difference among neighborhoods at 60 minutes. Thus, the median of the three estimates (the estimate of .89 for moderate vulnerability) would be the most appropriate statistical estimate for all three levels of social vulnerability. If there are significant differences at some time points, then those significantly different estimates should be used. However, all time points at which there are nonsignificant differences should have the high and low vulnerability estimates replaced by the median estimate for that time point (the estimate for the moderate vulnerability group).

Response to comment 1:

As the reviewer suggested, there are two possible ways to estimate recollect the data. We tried to use the first procedure (each responder was asked to describe the response curve for a specific neighborhood that she or he assisted in evacuating, after which the authors classified the neighborhoods in terms of their social vulnerability), but it is not possible to do it in Chile due to the lack of data. The most recent data available at household level comes from the census of population conducted in 2002. We checked this dataset, and one of the problems is that many of the new neighborhoods in Coquimbo built after 2002 are not present in the census data. The second option is that all responders might have been asked to generate separate curves for low, medium, or high vulnerability neighborhoods. In the case of Chile, this is the only option available. We use the National Socioeconomic Characterization Survey (CASEN)[1] from 2015, the 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 in Chile. 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. Table 1 shows the variables and levels that we use to define the neighborhoods' social vulnerability in Coquimbo.

Therefore, we added a new Table 1, and the former Table 1 now is 2 and the same happens to the next tables. Alsoo, we added on page 7 line 21 the following paragraph:
"We use the National Socioeconomic Characterization Survey (CASEN)[1] from 2015, the same year that the earthquake/tsunami occurred, to calculate a social vulnerability index at the municipality level, following the same procedure identified 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 in Chile. We incorporate this information in the

[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).

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.”

Aditionally, we have modified Figure 5 and the section 3.1 and now it reads as follow:

3.1 Survey to first responders

Figure 5 shows the percentage of the 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), the 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.

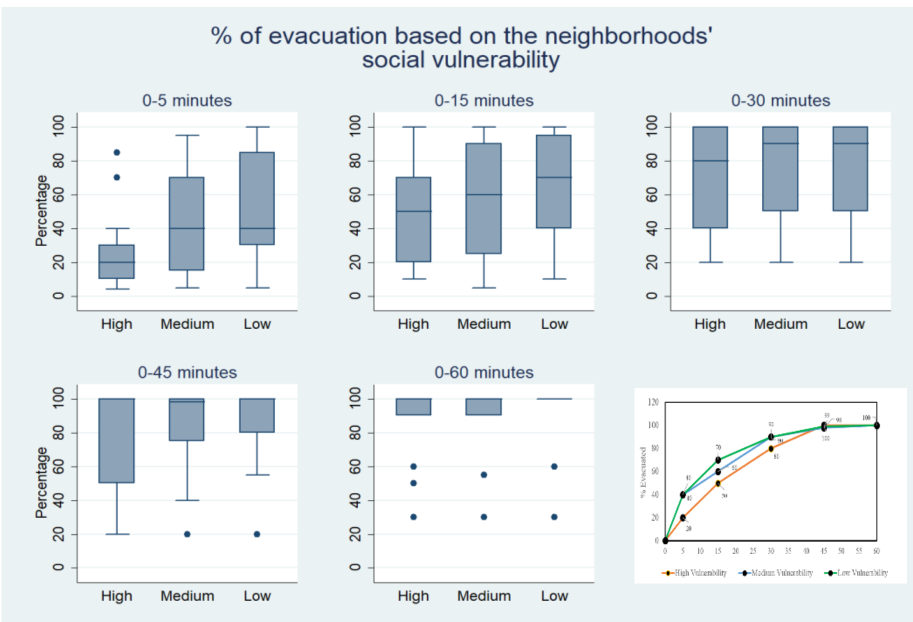


Figure 5: First responder’s results by social vulnerability group. Bottom right figure show the median value.

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 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.

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 2: Page 11 L8. If all six components were included in the SVI, what is the justification for believing that all of them are relevant to evacuation vulnerability? This issue of evacuation vulnerability (as distinct from general social vulnerability) is important because most of the Cutter et al. (2003) examples of social vulnerability in their Table 1 refer to disaster recovery rather than evacuation. There are some authors that have addressed evacuation vulnerability but, to the best of my knowledge, only Chakraborty et al. (2005) and Kusenbach et al. (2010) have examined social vulnerability in evacuation. (Cova's papers on evacuation vulnerability examine vulnerability due to evacuation route system geometry and link capacity.) Even the Chakraborty and Kusenbach studies assumed that their measures of social vulnerability would actually make a difference in evacuation rather than demonstrated it empirically. There is a broader literature on household evacuation, but the available data show no evidence that any of the sociodemographic variables measured in these studies is consistently related to evacuation (Baker, 1991; Huang et al., 2016), let alone evacuation departure time distributions. The only evacuation review to cite evidence in support of any relationships of sociodemographic variables with household evacuation only cited positive instances and ignored reports of nonsignificant correlations (Dash & Gladwin, 2007).

Response to comment 2: First of all, we would like to explain why we use 6 components instead of 10 or 11 or any number in between. To determine the number of components that will be part of the social vulnerability index, we selected those components with eigenvalues values greater than one, as the graph below shows. This criterion has been used by previous studies (Schmidtlein et al., 2008) and the methodology to construct the social vulnerability index was added, step by step, in the page 11 lines 21-40 and page 12 from lines 1-10

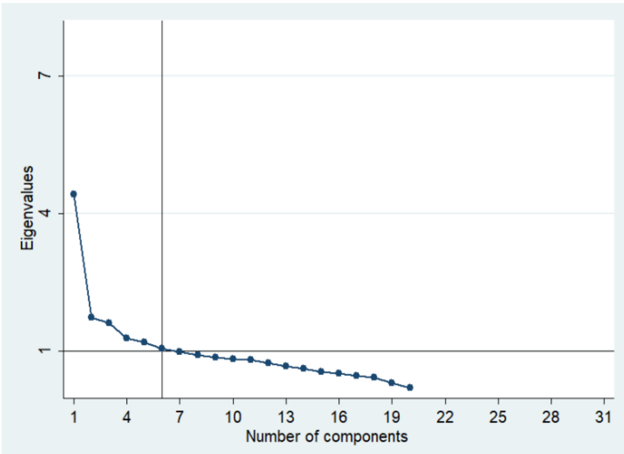


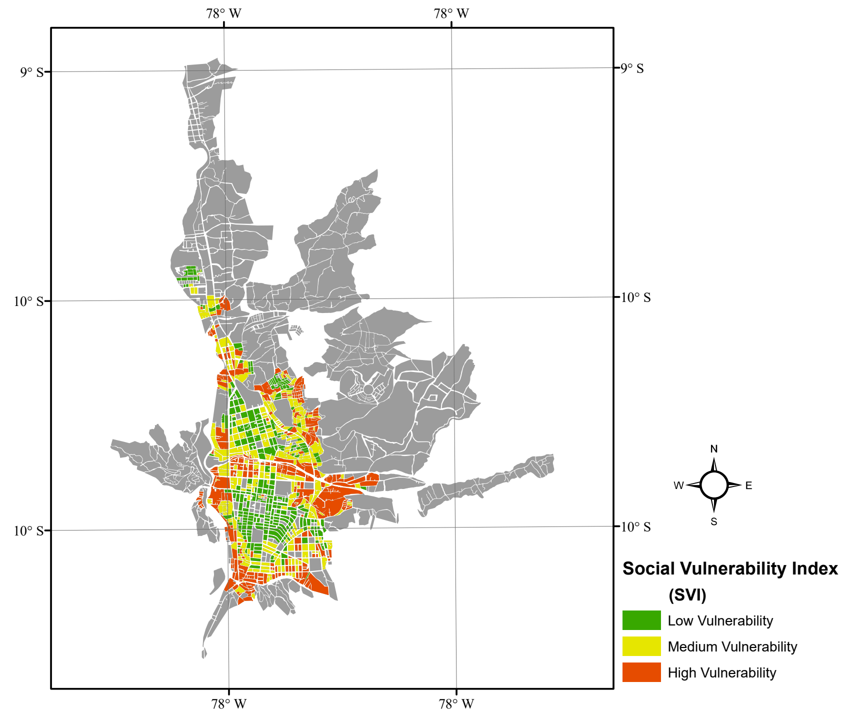
Figure 1 reviewer 1: Eigenvalues calculated using PCA analysis.

As the reviewer mentioned, 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 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. 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.

We added this previous paragraph into the discussion section.

- Comment 3: Page 11 L11. Figure 6 does indeed show that there are many blocks of high social vulnerability located close to the river, but there are also blocks of medium and low vulnerability there as well. The authors' argument would be more persuasive if they would overlay the expected inundation zone onto the map and calculate the proportion of high, medium, and low vulnerability blocks within the inundation zone.

Response comment 3:
We agree with this comment and we have change Figure 6



For this new Figure 6:

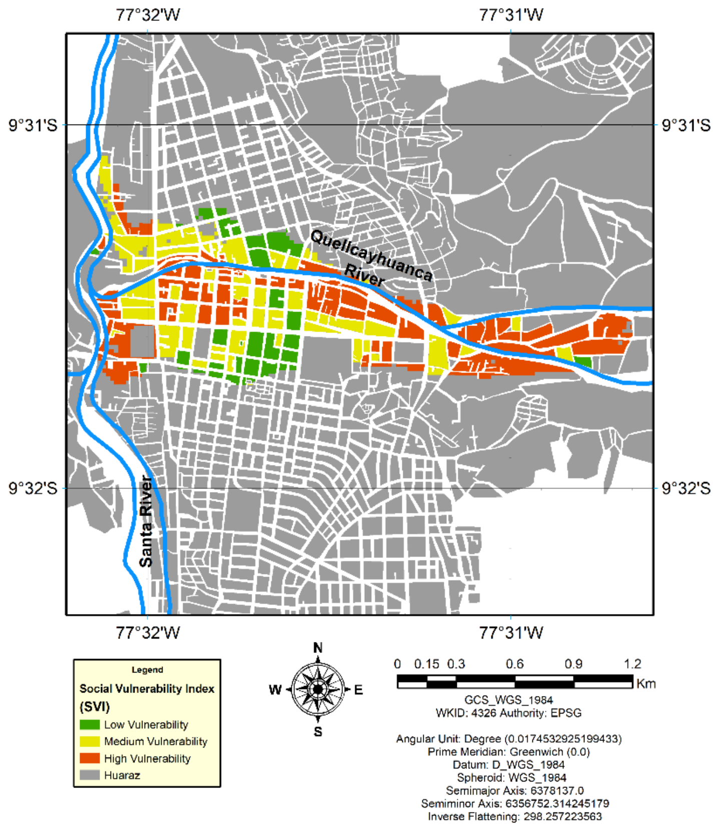


Figure 6: Comparative Vulnerability of Blocks in Huaraz using Social Vulnerability Index (SVI)

And we added in the text after inserting Figure 6: "The proportion of high, medium and low vulnerability blocks within the inundation zone are 15%, 35 %, and 50% respectively."

- Comment 4: Page 11 L27. The differences among the neighborhoods with respect to the outcomes of the evacuation model are necessarily a direct result of the presumed differences among the three evacuation rate curves. If the differences among the three curves are not significantly different from each other, then a single departure time curve should be used and the differences among the neighborhoods with respect to the outcomes of the evacuation model will vanish.

Response comment 4:
The reviewer is right here. If all the curves are not significantly different from each other, at the end the result will be the same to what it is traditionally used, which is a single curve that does not discriminate the population by the social vulnerability. Therefore, this methodology is building from what it is already out there, and it proposes a framework to incorporate information on the evacuation as a function of vulnerability level when it is available.

- Comment 5: Page 11 L29. The finding that evacuations were completed more rapidly with the earth-quake/tsunami response data than with the LIFESim equations is due to the fact that, as long as the local population recognizes earthquake shaking as a tsunami warning cue, the shaking is an instantaneous broadcast mechanism (see Lindell et al., 2015; Wei et al., 2017). In those situations, k = 1 in Equation 3, which makes the time-consuming contagion process unnecessary.

Response comment 5:

We have included the two references and the paragraph suggested in our text and from Page 11, Line 30 after the dot it reads "The finding that evacuations were completed more rapidly with the earthquake/tsunami response data than with the LIFESim equations is due to the fact that, as long as the local population recognizes earthquake shaking as a tsunami warning cue, the shaking is an instantaneous broadcast mechanism (see Lindell et al., 2015; Wei et al., 2017). In those situations, k = 1 in Equation 3, which makes the time-consuming contagion process unnecessary."

- Comment 6: Page 12 L7 would be more accurate if restated with the following qualifications. 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. Moreover, 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. One imitation of the available research is that Baker (1991) and Huang et al. (2016) âˇAˇ Tthe two most relevant literature reviewsâˇAˇTaddressed (primarily vehicular) hurricane evacuation in the Unites States. It is unclear if these results would generalize to pedestrian evacuation in other countries.

Response comment 6:

We modified accordingly to the reviewer suggestion on page 12, from line 7-10

- Comment 7: Page 12 L29. Morss et al. (2011) did not address any studies of evacuation, let alone the effects of social vulnerability on evacuation departure times, so the claim in this sentence about the comparability of the sample size is unsupported.

Response comment 7:

We apologize for this mistake, and we delete the sentence and reference.

- Comment 8: Page 13 L4. This study does not "estimate the percentage of people that evacuate an inundation hazard zone" (my emphasis); it estimates the rate at which people evacuate an inundation zone.

Response comment 8:

The first part of the methodology proposed is to estimate the rate at which people evacuate an inundation hazard zone for three level of social vulnerability (Figure 1). However, when it is combined with the arrival time of the flood and the evacuation mechanism (in our case walking), it is possible to calculate the percentage that departs and reach a safe area before the flood arrives. Therefore, the result of this methodology is the percentage of people that evacuate an inundation hazard zone. Figure 7 and 8 show this, the only difference between the different frames in each figure is that we highlight the effect of delaying the warning, but all of them show the percentage of people evacuated in each scenario according to the assumptions and simplifications we made.

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