Title: Do Disasters Exacerbate Vulnerabilities More for the Already Vulnerable? A Case Study of Cyclone Pam's Influence on Social Vulnerability in Vanuatu
Author: Hugh Roland

Extended abstract:

Research questions:

Climate models predict that tropical cyclones will grow in intensity in the years to come and that sea-level rise will increase risks from storm surges (Walsh et al., 2016). Understanding how a cyclone affects a population's social vulnerability is thus both important and pressing. Do more vulnerable populations experience a greater change in their level of social vulnerability compared to populations less vulnerable at baseline? What aspects of social vulnerability are most affected?

Vulnerability includes both exposure sensitivity and adaptive capacity (Adger, 2006; Smit and Wandel, 2006), and much of the literature divides vulnerability into physical and social components (Borden, Schmidtlein, Emrich, Piegorsch, & Cutter, 2007). Physical vulnerability is tied to potential hazards of a location while social vulnerability is associated with community and individual capacities to withstand and respond to threatening conditions (Levine, Esnard, & Sapat, 2007; Zahran, Brody, Peacock, Vedlitz, & Grover, 2008). Scholars emphasize social components to various extents, stressing the importance of local characteristics and larger social and economic forces (Myers, Slack, & Singelmann, 2008), with some arguing that all aspects of disasters are determined by a social calculus (Smith, 2006). Vulnerability cannot be described by a simple wealth metric or level of exposure to an environmental condition. Rather, vulnerability might be defined as "a combination of factors that determine the degree to which someone's life, livelihood, property and other assets are put at risk by a discrete and identifiable event (or series or 'cascade' of such events) in nature and in society" (Wisner, Blaikie, Cannon, & Davis, 2003, p. 11, 12).

This study compares social vulnerability in the South Pacific country Vanuatu before and after Cyclone Pam, which struck in 2015, by examining indicators likely to dictate the extent that individual life, livelihood, and assets were put at risk by the shock. Cyclone Pam, a category five storm, is the worst disaster known to have hit Vanuatu (Robertson, 2015). I use demographic variables and environmental health, housing, and economic indicators relevant to largely subsistence Vanuatu, including asset measures like livestock ownership, to create an index of relevant social vulnerability indicators. Whether higher baseline levels of vulnerability are associated with greater increases in vulnerability following the cyclone—as I hypothesize—is determined by first reducing indicators using a principal component analysis (PCA), after which remaining indicators are compared pre- and post-cyclone using data from the 2009 census and 2016 mini census.

Few studies have compared social vulnerability before a disaster with social vulnerability directly after, particularly in rural and largely subsistence contexts like Vanuatu where populations already face considerable environmental risks. Most research on social vulnerability and natural disasters compares pre-disaster social vulnerability with disaster outcomes such as property damage, injury and death, and disaster recovery (Finch, Emrich, & Cutter, 2010; Schmidtlein, Shafer, Berry, & Cutter, 2011; Yoon, 2012; Zahran et al., 2008). The availability of post-disaster data in Vanuatu allows for changes in social vulnerability to be assessed, which this study examines to explore whether pre-disaster social vulnerability is related to degree of change in social vulnerability and what aspects of social vulnerability changed most.

Relevant literature on social vulnerability:

Disaster recovery increases socioeconomic inequality, particularly along the lines of race, education, and homeownership, which suggests close linkages between two increasingly prominent social problems, wealth inequality and damages resulting from natural disasters (Howell & Elliott, 2018; Schultz & Elliott, 2013). Research on social vulnerability focuses on social and economic stratification and levels of access to resources and typically finds that places with greater social vulnerability are positively associated with greater disaster damages and take longer to recover (Borden et al., 2007; Cutter

& Emrich, 2006; Finch et al., 2010; Wisner et al., 2003, p. 93; Yoon, 2012). Some research has found that while relative losses are highest among populations of high social vulnerability and thus the impact of losses greatest for these populations, total losses may be higher among populations of low social vulnerability since they are wealthier and have more material goods at risk (Schmidtlein et al., 2011). Nevertheless, the wealthy suffer less loss of life, avoid many hazards entirely, and quickly recover from events catastrophic for others. For example, the 1976 earthquake in Guatemala disproportionately affected Guatemala City slum dwellers and Mayan Indians living in poor towns compared to the middle class whose homes were better sited and constructed, reflecting a physical vulnerability with a strong social component. The Guatemalan poor's high level of baseline social vulnerability was exacerbated by the earthquake that left them even more vulnerable to future disasters (Wisner et al., 2003).

Social and physical vulnerability are closely connected and are both influenced by a wide range of climate and non-climate stressors (Adger and Barnett, 2009; O'Brien et al., 2009). Respondents in a study in Tuvalu, for example, placed environmental conditions in local historical, socioeconomic, and cultural contexts. Water shortages were linked, not only to unpredictable weather and droughts, but also overcrowding, and land insecurity was linked, not only to sea-level rise and storms, but also increasing population size and changing land use that prompted greater settlement of low-lying areas (McCubbin, Smit, & Pearce, 2015). Health vulnerabilities such as increases in diarrheal and respiratory diseases are similarly linked to both poverty and climate change (Haines, Kovats, Campbell-Lendrum, & Corvalan, 2006). Outbreaks in fish contamination, frequently associated with stressed coral reef environments and lagoons, are more common in poor areas. Like cases of crop damage resulting from droughts or salt-water intrusion, affected households with financial resources buy food while the poor either go without or consume contaminated foods (McCubbin et al., 2015). This type of vulnerability may be particularly significant in rural areas where food alternatives are not an option. Rural places are especially vulnerable to environmental changes and disasters because of highly subsistence economies (Bach, 2017), dependence on a single economic base (Cutter & Emrich, 2006), and strong positive associations with social vulnerability indicators, including low employment and education levels, poor housing quality, high poverty, and large numbers of minority groups (Chen, Cutter, Emrich, & Shi, 2013).

Researchers have argued that the international discourse on climate change and sea-level rise in low-lying Pacific island countries places too much emphasis on the physical hazard and physical vulnerability rather than social frameworks that determine hazards' human impacts (Kelman et al., 2015; Wisner, Gaillard, & Kelman, 2012). They argue that this focus overlooks communities' social environments, misrepresents local realities, and distracts from important challenges. This case study contributes to debates concerning the influence of social vulnerability on disasters' human impacts, emphasizing locally important social and economic conditions and related vulnerability indicators to provide an empirical analysis of social vulnerability in the Pacific, where there have been few such studies despite longstanding recognition of severe climate change vulnerability (Barnett & Campbell, 2010, p. 80).

Operationalizing vulnerability:

Questions of how to measure health status have long been a focus of economics literature, and justifying measures of social vulnerability may be approached similarly. Good measures follow several desirable measurement properties: variability and roughly symmetrical score distributions across populations, reliability, and validity (Manning, Newhouse, & Ware, 1981). There has been substantial development in research operationalizing social vulnerability in the last fifteen years, primarily focused on establishing measurement validity. The 42-item Social Vulnerability Index (SoVI), which includes demographic indicators like socioeconomic status and occupation and land use characteristics like the extent of infrastructure, was proposed by Cutter et. al. in 2003 (Cutter, Boruff, & Shirley, 2003). This vulnerability scoring system has since been widely used to assess vulnerability (Borden et al., 2007; Finch et al., 2010; Holand, Lujala, & Rød, 2011; Levine et al., 2007; Myers et al., 2008; Zahran et al., 2008). Many new indexes focusing on different aspects of vulnerability have since been developed (Ahsan & Warner, 2014) and applied in developing contexts (Ahsan & Warner, 2014; Hahn, Riederer, & Foster, 2009; Pandey & Jha, 2012; Shah, Dulal, Johnson, & Baptiste, 2013; Vincent, 2004). Indexes applied in developing countries often emphasize socioeconomic and livelihood indicators (Ahsan & Warner, 2014; Hahn et al., 2009), and studies using these indexes in natural resource-dependent contexts may give greater attention to variables related to health and resource availability (Hahn et al., 2009; Pandey & Jha, 2012; Shah et al., 2013).

This study creates a unique index that considers indicators from indexes operationalizing social vulnerability in developing countries and focuses on subsistence-related indicators highly applicable in Vanuatu and for which there is rich data. The indicators included in any study are of course subject to data availability. Due to data limitations, some vulnerability indicators more applicable in developed countries, like SoVI indicators of commercial and industrial development, are left out of this study. Other studies have similarly omitted variables found in common indexes like Cutter et. al., 2003's SoVI because data is unavailable and instead focused on types of indicators most relevant to the study site (Finch et al., 2010).

Data:

Changes in vulnerability are compared using aggregated data of the country's entire population from the 2009 census (Vanuatu National Statistics Office, 2009) and 2016 mini census, which directly followed Cyclone Pam in 2015 (Vanuatu National Statistics Office, 2016). The mini census is a population and household count but with fewer progress indicators than the regular census. In addition to comparing demographic indicators between censuses, this study compares locally important environmental health, housing, and economic variables. Demographic indicators include age, sex, ethnicity, household size, number of dwellings in town and region, and education attendance level. Housing and environmental health indicators include type of living quarters, land tenure type, main toilet type, main source of lighting, main source of drinking water, source of cooking fuel, phone access, and main materials used for walls, floor, and roof. Economic indicators include whether households fished in the last 12 months, whether families planted cash crops, main sources of household income, total number of livestock owned, and households with cattle, poultry, pigs, and goats. These subsistence indicators are particularly relevant in developing and largely rural contexts like Vanuatu where only a quarter of the total population of 234,023 live in two urban local divisions, Port Vila and Luganville (Vanuatu National Statistics Office, 2009). Census data are aggregated by urban-rural classification, province (of which there are 6), and local division (of which there are 66). Provinces and local divisions are administrative boundaries that vary in geographic area and population size. Analysis will focus on aggregate local division level data.

Methods:

I use a two-stage analytical approach to answer my main research question: are higher baseline levels of social vulnerability associated with greater increases in social vulnerability following the cyclone? The first part of this analysis will be to arrange variables based on whether they are positively or negatively related to vulnerability and, similar to other studies applying vulnerability indexes, conduct a PCA to reduce indicators to those that are most influential (Borden et al., 2007; Finch et al., 2010; Holand et al., 2011; Myers et al., 2008). A PCA is useful because many indicators correspond to certain aspects of a population's vulnerability, and indicators frequently overlap or are highly correlated. A large number of indicators like this is unsuitable for analysis, and a PCA is conducted to determine which variables are most relevant in explaining differences and to create groups of indicators for later analysis that control for the percentage of the variance that each indicator explains. Similar to other studies that group reduced indicators into categories like race and class or employment in a particular sector (Finch et al., 2010), I will group variables based on broad category of vulnerability. These groups will follow three categories of census data: demographic indicators, housing and environmental health indicators, and economic indicators that focus on subsistence measures. Creating three reduced groups of indicators is more useful than lumping reduced indicators together since it allows my analysis to better identify the factors of social vulnerability most affected by the cyclone. The PCA will be conducted using baseline measures of social vulnerability from the 2009 census.

Once indicators have been reduced through the PCA to groups of influential vulnerability indicators specifying the variance explained by each indicator, data will comprise, for each indicator within the groups, a baseline measure for each local division and the change in vulnerability for each local division, calculated by subtracting post-cyclone vulnerability from baseline vulnerability. The 66 local divisions in the census means that there are 66 observations at two time periods. I will present descriptive statistics of average baseline vulnerability and average change in vulnerability across the 66 local divisions for the three reduced groups and for each of the indicators in the groups.

To examine how changes in vulnerability are associated with baseline vulnerability, linear regressions will be run for the three reduced groups of vulnerability indicators, accounting for the percentage of variance explained by each indicator within the groups. Results from this regression analysis will also answer questions of which group of vulnerability indicators changed most following the cyclone. To explore which specific indicators changed most and whether certain items are driving differences, I plan to run sensitivity tests, since repeating the analysis on individual items may uncover differences masked in results for the groups.

There are several important assumptions in this study, most notably that the magnitude of the natural force was similar across the 66 local divisions. This assumption is supported by government statements following the cyclone that the entire country was drastically affected (Robertson, 2015). I will, however, run a sensitivity analysis based on the cyclone's path to determine whether changes in vulnerability are associated with island location relative to the cyclone. Geographic differences will also be explored in spatial visualizations of baseline vulnerabilities for the groups of indicators determined by the PCA as well as spatial visualizations of changes in vulnerability. Should I find differences based on the cyclone's path, this will suggest the need for further analysis based on differential influences across both time and location. I also assume that the importance of a change in vulnerability is equal regardless of the population's baseline vulnerability: an increase in vulnerability in a population more vulnerable at baseline is just as important as the same level increase in vulnerability in a population less vulnerable at baseline. However, increases in vulnerability are more drastically felt among the already highly vulnerable, and since I hypothesize that populations more vulnerable at baseline experience a greater increase in vulnerability, this is a conservative assumption.

It's also important to remember that this study is correlational not causal and that there are many variables that cannot be isolated and considered. For example, because this study uses a pre-post design, rather than many observation points before and after, we cannot track and account for differences in variables over longer periods of time. More longitudinal data would allow us to examine trends and whether the cyclone's impacts on vulnerability are long or short term patterns.

Implications:

This study provides one of few empirical analyses of social vulnerability in the Pacific, proposes and assesses vulnerability indicators applicable to developing countries and subsistence economies, and offers a rare comparison of social vulnerability before and after a disaster. Should results indicate, as hypothesized, that populations with higher levels of baseline vulnerability experience a greater increase in vulnerability following Cyclone Pam compared to less vulnerable populations, this would lend support to arguments that stress the importance of social factors in determining how hazards impact populations. Finding that social and economic factors are a major determinant in populations' vulnerability to hazards also has implications for how to approach development (Cannon & Müller-Mahn, 2010) and might lend support to strategies that address root causes over those that focus on technological solutions and "managing risk" (Wisner et al., 2003, p. 24).

Bibliography:

Ahsan, M. N., & Warner, J. (2014). The socioeconomic vulnerability index: A pragmatic approach for assessing climate change led risks–A case study in the south-western coastal Bangladesh.

International Journal of Disaster Risk Reduction, *8*, 32–49. https://doi.org/10.1016/J.IJDRR.2013.12.009
Bach, J. L. (2017). *Perceptions of Environmental Change: Nikutoru, Tabiteuea Maiaki, Kiribati*. University of Montana.
Barnett, J., & Campbell, J. R. (2010). *Climate change and small island states : power, knowledge, and the South Pacific*. Earthscan. Retrieved from https://books.google.com/books/about/Climate_Change_and_Small_Island_States.html?id=f4ZuUkv5ZhIC
Borden, K. A., Schmidtlein, M. C., Emrich, C. T., Piegorsch, W. W., & Cutter, S. L. (2007). Vulnerability of US cities to environmental hazards. *Journal of Homeland Security and Emergency Management*, *4*(2), 1547–7355. Retrieved from https://www.degruyter.com/view/j/jhsem.2007.4.2/jhsem.2007.4.2.1279/jhsem.2007.4.2.1279.xml
Cannon, T., & Müller-Mahn, D. (2010). Vulnerability, resilience and development discourses in context of climate change. *Natural Hazards*, *55*(3), 621–635. https://doi.org/10.1007/s11069-010-9499-4
Chen, W., Cutter, S. L., Emrich, C. T., & Shi, P. (2013). Measuring social vulnerability to natural hazards in the Yangtze River Delta region, China. *International Journal of Disaster Risk Science*, *4*(4), 169–181. https://doi.org/10.1007/s13753-013-0018-6
Cutter, S. L., Boruff, B. J., & Shirley, W. L. (2003). Social Vulnerability to Environmental Hazards*. *Social Science Quarterly*, *84*(2), 242–261. https://doi.org/10.1111/1540-6237.8402002
Cutter, S. L., & Emrich, C. T. (2006). Moral Hazard, Social Catastrophe: The Changing Face of Vulnerability along the Hurricane Coasts. *The ANNALS of the American Academy of Political and Social Science*, *604*(1), 102–112. https://doi.org/10.1177/0002716205285515
Finch, C., Emrich, C. T., & Cutter, S. L. (2010). Disaster disparities and differential recovery in New Orleans. *Population and Environment*, *31*(4), 179–202. https://doi.org/10.1007/s11111-009-0099-8
Hahn, M. B., Riederer, A. M., & Foster, S. O. (2009). The Livelihood Vulnerability Index: A pragmatic approach to assessing risks from climate variability and change—A case study in Mozambique. *Global Environmental Change*, *19*(1), 74–88. https://doi.org/10.1016/J.GLOENVCHA.2008.11.002
Haines, A., Kovats, R. S., Campbell-Lendrum, D., & Corvalan, C. (2006). Climate change and human health: Impacts, vulnerability and public health. *Public Health*, *120*(7), 585–596. https://doi.org/10.1016/J.PUHE.2006.01.002
Holand, I. S., Lujala, P., & Rød, J. K. (2011). Social vulnerability assessment for Norway: A quantitative approach. *Norsk Geografisk Tidsskrift - Norwegian Journal of Geography*, *65*(1), 1–17. https://doi.org/10.1080/00291951.2010.550167
Howell, J., & Elliott, J. R. (2018). Damages Done: The Longitudinal Impacts of Natural Hazards on Wealth Inequality in the United States. *Social Problems*. https://doi.org/10.1093/socpro/spy016
Kelman, I., Stojanov, R., Khan, S., Gila, O. A., Duží, B., & Vikhrov, D. (2015). Viewpoint paper. Islander mobilities: any change from climate change? *International Journal of Global Warming*, *8*(4), 584. https://doi.org/10.1504/IJGW.2015.073056
Levine, J. N., Esnard, A.-M., & Sapat, A. (2007). Population Displacement and Housing Dilemmas Due to Catastrophic Disasters. *Journal of Planning Literature*, *22*(1), 3–15. https://doi.org/10.1177/0885412207302277
Manning, W., Newhouse, J., & Ware, J. (1981). *The status of health in demand estimation*. Retrieved from https://www.rand.org/pubs/reports/R2696-1.html
McCubbin, S., Smit, B., & Pearce, T. (2015). Where does climate fit? Vulnerability to climate change in the context of multiple stressors in Funafuti, Tuvalu. *Global Environmental Change*, *30*, 43–55. https://doi.org/10.1016/j.gloenvcha.2014.10.007
Myers, C. A., Slack, T., & Singelmann, J. (2008). Social vulnerability and migration in the wake of disaster: the case of Hurricanes Katrina and Rita. *Population and Environment*, *29*(6), 271–291. https://doi.org/10.1007/s11111-008-0072-y
Pandey, R., & Jha, S. (2012). Climate vulnerability index - measure of climate change vulnerability to communities: a case of rural Lower Himalaya, India. *Mitigation and Adaptation Strategies for*

Global Change, *17*(5), 487–506. https://doi.org/10.1007/s11027-011-9338-2
Robertson, J. (2015, March 15). Cyclone Pam: Vanuatu awaits first wave of relief and news from worst-hit islands. *The Guardian*. Retrieved from https://www.theguardian.com/world/2015/mar/15/cyclone-pam-death-toll-may-reach-50-in-port-vila-alone-as-full-impact-still-unknown
Schmidtlein, M. C., Shafer, J. M., Berry, M., & Cutter, S. L. (2011). Modeled earthquake losses and social vulnerability in Charleston, South Carolina. *Applied Geography*, *31*(1), 269–281. https://doi.org/10.1016/J.APGEOG.2010.06.001
Schultz, J., & Elliott, J. R. (2013). Natural disasters and local demographic change in the United States. *Population and Environment*, *34*(3), 293–312. https://doi.org/10.1007/s11111-012-0171-7
Shah, K. U., Dulal, H. B., Johnson, C., & Baptiste, A. (2013). Understanding livelihood vulnerability to climate change: Applying the livelihood vulnerability index in Trinidad and Tobago. *Geoforum*, *47*, 125–137. https://doi.org/10.1016/J.GEOFORUM.2013.04.004
Smith, N. (2006). *There's No Such Thing as a Natural Disaster*. Retrieved from http://understandingkatrina.ssrc.org/Smith/
Vanuatu National Statistics Office. (2009). *2009 National Population and Housing Census*.
Vanuatu National Statistics Office. (2016). *Vanuatu 2016 Post Pam Mini-Census Report*.
Vincent, K. (2004). Creating an index of social vulnerability to climate change for Africa. *Tyndall Center for Climate Change Research. Working Paper*, *56*. Retrieved from http://disaster-sts-network.org/content/creating-index-social-vulnerability-climate-change-africa
Walsh, K. J. E., McBride, J. L., Klotzbach, P. J., Balachandran, S., Camargo, S. J., Holland, G., … Sugi, M. (2016). Tropical cyclones and climate change. *Wiley Interdisciplinary Reviews: Climate Change*, *7*(1), 65–89. https://doi.org/10.1002/wcc.371
Wisner, B., Blaikie, P., Cannon, T., & Davis, I. (2003). *At Risk: Natural Hazards, People's Vulnerability, and Disasters* (2nd edition). New York: Routledge. Retrieved from http://www.preventionweb.net/files/670_72351.pdf
Wisner, B., Gaillard, J., & Kelman, Il. (2012). Framing disaster: theories and stories seeking to understand hazards, vulnerability and risk. In B. Wisner, J. Gaillard, & Il. Kelman (Eds.), *Handbook of Hazards and Disaster Risk Reduction* (pp. 47–62). Routledge. https://doi.org/10.4324/9780203844236-13
Yoon, D. K. (2012). Assessment of social vulnerability to natural disasters: a comparative study. *Natural Hazards*, *63*(2), 823–843. https://doi.org/10.1007/s11069-012-0189-2
Zahran, S., Brody, S. D., Peacock, W. G., Vedlitz, A., & Grover, H. (2008). Social vulnerability and the natural and built environment: a model of flood casualties in Texas. *Disasters*, *32*(4), 537–560. https://doi.org/10.1111/j.1467-7717.2008.01054.x