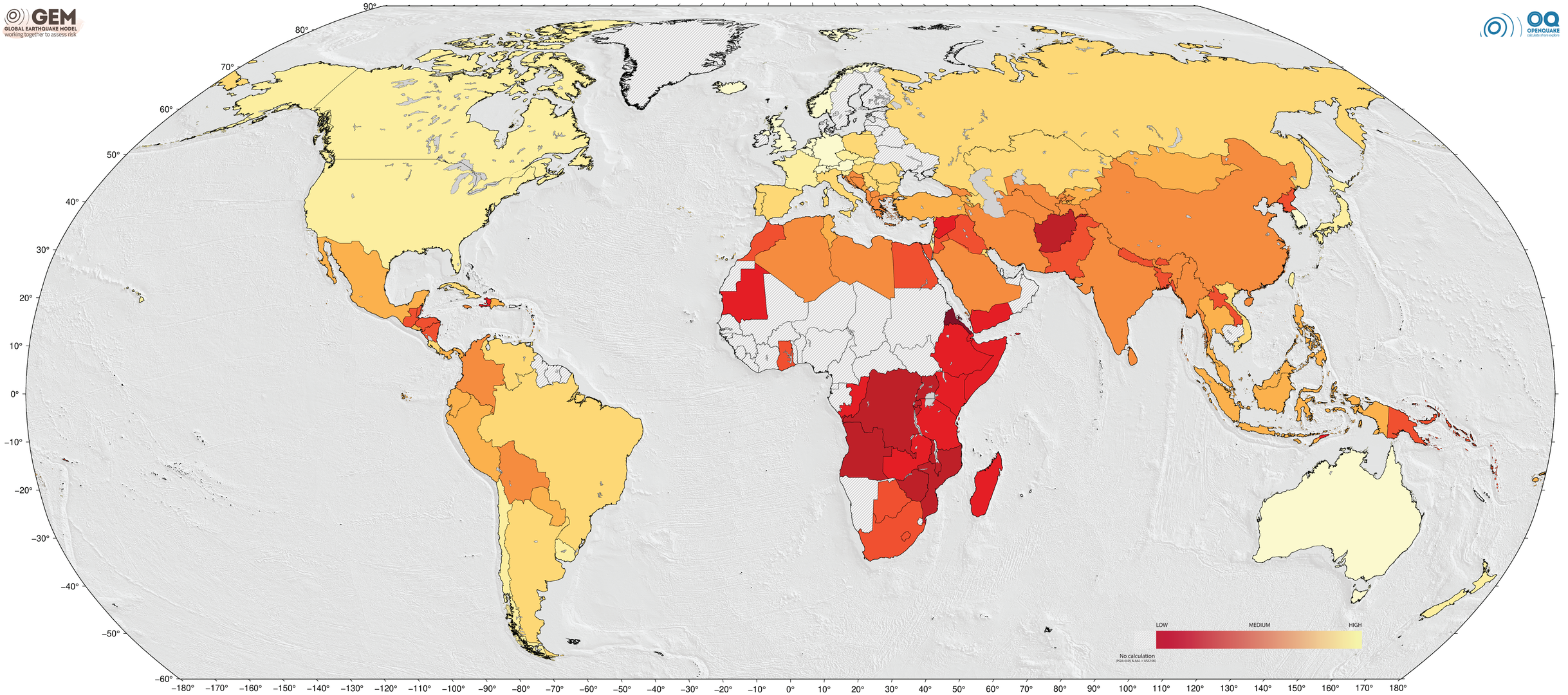
Global Earthquake Model

Reconstruction and Recovery Map



Global Earthquake Model (GEM) Social Vulnerability Map

Earthquakes can have adverse impacts that extend beyond physical damage or casualties and can severely damage economies and negatively influence societies and social well-being. The addition of the Social Vulnerability component into GEM's scientific framework provides the means to analyze and better understand the various socio-economic factors that may exacerbate the impact of an earthquake, or that may affect the ability of communities to fully recover from damaging earthquake events. The global modelling of socio-economic vulnerability consists of three maps that depict spatially varying characteristics that affect the impact and recovery potential of populations from damaging earthquakes.

Socio-Economic Vulnerability Maps

The first map is the *Global Social Vulnerability Map*, which is a composite index that was developed to measure characteristics or qualities of social systems that create the potential for loss or harm. Here, social vulnerability helps to explain why some countries will experience adverse impacts from earthquakes differentially where the linking of social capacities with demographic attributes suggests that communities with higher percentages of age dependent populations, homeless, disabled, under-educated, and foreign migrants are likely to exhibit higher social vulnerability than communities lacking these characteristics. Other relevant factors that affect the social vulnerability of populations include in-migration from foreign countries, population density, an accounting of slum populations, and international tourist arrivals.

The second map is the *Global Economic Vulnerability Map*, which is a composite index that was designed primarily to measure the potential for economic losses from earthquakes due to a country's macroeconomic exposure. This index is also an appraisal of the ability of countries to respond to shocks to their economic systems. Relevant indicators include the density of exposed economic assets such as commercial and industrial infrastructure. Metrics used to measure the ability of a country to withstand shocks to its economic system include reliance on imports/exports, government debt, and purchasing power. The economic vulnerability category also considers the economic vitality of countries since the economic vitality of a country can be directly related to the vulnerability and resilience of its populations. The latter includes measurements of single-sector economic dependence, income inequality, and employment status.

The third map is the *Recovery/Reconstruction Potential Map*, which is closely aligned with the concept of disaster resilience. Enhancing a country's resilience to earthquakes is to improve its capacity to anticipate threats, to reduce its overall vulnerability, and to allow its communities to recover from adverse impacts from earthquakes when they occur. The measurement of recovery and reconstruction potential includes capturing inherent conditions that allow communities within a country to absorb impacts and cope with a damaging earthquake event, such as the density of the built environment, education levels, and political participation. It also encompasses post event processes that facilitate a population's ability to reorganize, change, and learn in response to a damaging earthquake.

Criteria for indicator selection

To choose indicators contextually exclusive for use in each map, the starting point was an exhaustive review of the literature on earthquake social vulnerability and resilience. For a variable to be considered appropriate and selected, three equally important criteria were met:

1. variables were justified based on the literature regarding its relevance to one or more of the indices.
2. variables needed to be of consistent quality and freely available from sources such as the United Nations and the World Bank; and
3. variables must be scalable or available at various levels of geography to promote sub-country level analyses.

This procedure resulted in a 'wish list' of approximately 300 variables of which 78 were available and fit for use based on the three criteria.

Process for indicator selection

For variables to be allocated to an index, a two-tiered validation procedure was utilized. For the first tier, variables were assigned to each of the respective indices based on how each variable was cited within the literature, i.e., as being part of an index of social vulnerability, economic vulnerability, or recovery/resilience. For the second tier, machine learning and a multivariate ordinal logistic regression modelling procedure was used for external validation. Here, focus was placed on the statistical association between the socio-economic vulnerability indicators and the adverse impacts from historical earthquakes on a country by country basis.

The Global Significant Earthquake Database provided the external validation metrics that were used as dependent variables in the statistical analysis. To include both severe and moderate earthquakes within the dependent variables, adverse impact data was collected from damaging earthquake events that conformed to at least one of five criteria: 1) caused deaths, 2) caused moderate damage (approximately $1 million USD or more), 3) had a magnitude 7.5 or greater 4) had a Modified Mercalli Intensity (MMI) X or greater, or 5) generated a tsunami. This database was chosen because it considers low magnitude earthquakes that were damaging (e.g., MW >=2.5 & MW<=5.5) and contains socio-economic data such as the total number of fatalities, injuries, houses damaged or destroyed, and dollar loss estimates in $USD.

Countries not demonstrating at least a minimal earthquake risk, i.e., seismicity <0.05 PGA (Pagani et al. 2018) and <$10,000 USD in predicted average annual losses (Silva et al. 2018) were eliminated from the analyses as not to include countries with minimal to no earthquake risk. A total study area consists of N=136 countries.

The Global Earthquake Model (GEM) Foundation

The Global Socio-Economic Vulnerability Maps 2020 is a product of the GEM Foundation's collaborative work with the Department of Geography at the University of Connecticut, USA. GEM is a non-profit foundation in Pavia, Italy funded through a public-private sponsorship with a vision to create a world that is resilient to earthquakes. Formed in 2009 through the initiative of the Organization for Economic Co-operation and Development (OECD) Global Science Forum in 2006, GEM participants represent national research and disaster management institutions, the private sector, the academia and international organizations.

GEM's OpenQuake Platform website (platform.openquake.org) provides access to all data, models, tools and software behind the maps. GEM's open-source OpenQuake engine enables probabilistic hazard and risk calculations worldwide and at all scales, from global down to regional, national, local, and site-specific in a single software package.

GEM supports the Sendai Framework for Disaster Risk Reduction (SFDRR) goals by contributing openly accessible products for hazard and risk assessment and capacity development through risk reduction projects. GEM also serves as a baseline or exemplar for the development of a broader multi-hazard framework for risk assessment in support of a holistic and comprehensive approach to disaster risk reduction.

Technical details on the development and compilation of the socio-economic vulnerability maps, underlying models and the list of contributors can be found at: www.globalquakemodel.org/global-social-vulnerability.

How to use and cite this work

Please cite this work as: C Burton, M. Toquica (September 2020). Global Earthquake Model (GEM) Social Vulnerability Map (version 2020.1)
DOI: https://doi.org/10.13117/gem-reconstruction-recovery-map. This work is licensed under the terms of the Creative Commons Attribution - Non Commercial-Share Alike 4.0 International License (CC BY-NC-SA).

Acknowledgements

This map is the result of a collaborative effort and extensively relies on the enthusiasm and commitment of various organisations to openly share and collaborate. The creation of this map would not have been possible without the support provided by several public and private organisations during GEM's second and third working programmes, 2014-2018 and 2019-2021 respectively. None of this would have been possible without the extensive support of all GEM Secretariat staff. These key contributions are profoundly acknowledged. A complete list of the contributors can be found at: www. globalquakemodel.org/global-social-vulnerability.

Legal statements

This map is an informational product created by the GEM Foundation for public dissemination purposes. The information included in this map must not be used for the design of seismic socio-economic policies or to support any important decisions involving human life, capital and movable and immovable properties. The values of social vulnerability and risk values used in this map do not constitute an alternative nor do they replace any national government policy or actions defined in national codes or earthquake risk estimates derived nationally. Readers seeking this information should contact the national authorities tasked with socio economic and risk assessment. The socio-economic vulnerability maps are based on the results of an integration process that is solely the responsibility of the GEM Foundation.

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