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A global exposure model for disaster risk assessment

Andrea De Bono [a,b,*], Miguel G. Mora [c]

[a] Institute for Environmental Sciences, University of Geneva, Geneva, Switzerland
[b] United Nations Environment Programme, Global Resources Information Database, Geneva, Switzerland
[c] International Centers for Numerical Methods in Engineering (CIMNE), Universitat Politècnica de Catalunya, Barcelona, Spain

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ABSTRACT

The Global Exposure database is being produced for the Global Risk Assessment 2013, part of the Global Assessment Report 2013 (GAR 2013). It aims to map at a granular geographical level the world's capital stock in urban areas. It is designed primarily to assess the risk of economic losses as consequence of natural hazards at a global scale.

The Global Exposure database for GAR 2013 (GEG-2013) is an open exposure global dataset at 5 km spatial resolution which integrates population and country-specific building typology, use and value. It is currently suitable mainly for earthquakes and cyclones probabilistic risk modeling using the CAPRA platform (http://www.ecapra.org).

This paper describes the development of the GEG-2013. The database is based on a top-down or "downscaling" approach of national/regional socio-economic and building type information. These information are transposed onto a regular raster dataset (grid format) using a geographic population distribution model as a proxy.

1. Background

Exposure is the collection of the elements at risk to potential losses [1] or that may suffer damage due to a hazard impact. This paper describes how a global exposure database was generated and used for the quantification of both the exposure and the vulnerability, to support the earthquakes and cyclones probabilistic risk modeling in the Global Assessment Report on Disaster Risk Reduction (GAR) process [2].

Models for assessing quantitative risk from natural hazards use building counts, as well as statistic aggregations of buildings at different areal units, to estimate physical damages. The exposed elements include people, resources, infrastructures, production, goods, services or ecosystems and coupled social–ecological systems. In the Global Exposure database for GAR 2013 (GEG-2013) the physical exposures is represented through the inventory of buildings in urban areas, called here "the building stock".

During the last ten years, various remarkable products, related to exposure at a global level, have been released into the public domain.

Among those, HAZUS is multi-hazard loss estimation software [3]. It mainly focuses on the United States environment, assigning structural classes to a grid representing the occupancy. These structural classes are then directly linked to damage functions.

The PAGER inventory database [4] provides the distribution of housing/dwelling units rather than the distribution of buildings types.

The Global Exposure Database for Global Earthquake Model [5], as yet still unpublished, will certainly be the most advanced global exposure database for earthquake risk assessment. GED4GEM is a global, multi-scale, and regionally/locally driven exposure database [6]. The GED will feature data at four different geographical scales:

- Level 0 (at country-level), the GED is a gridded dataset, at 30″ resolution, including data compiled through

* Corresponding author at: International Environment House (IEH) 11, chemin des Anémones 1219 Châtelaine Switzerland.
E-mail address: debono@unepgrid.ch (A. De Bono).

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national census surveys. It contains statistical information about the number and distribution of dwellings and/or buildings fractions in a country, classified by building type and residential/non-residential. Where available, the information about the value of buildings per meter square is also provided.

- Level 1 (at sub-country level) the GED is a gridded dataset, at 30″ resolution, including comparable information to level 0, but with data coming from sub-national or district-level surveys. Where available, the information about the value of buildings per meter square is also provided.
- At Level 2 (the local level), the GED consists of a gridded dataset based on datasets obtained by aggregating sub-grid/finer data, coming from building-by-building surveys.
- At Level 3 (single buildings) a vector GIS dataset includes single buildings/dwellings level information that is provided when available.

At a regional level, the Pacific risk exposure database[1] co-funded by the Global Facility for Disaster Reduction and Recovery (GFDRR, World Bank), and the Japanese Government, provides a comprehensive geo-referenced catalog of facilities for 15 Pacific countries. It includes, besides population distribution, more than 400,000 high-resolution satellite images, including building footprints for structural classification and use. The database also includes information on main infrastructures such as roads, bridges, dams, ports and airports, as well as on utilities and major crops.

More recently, the GFDRR is working on an exposure model for natural catastrophe risk assessment in Latin America and the Caribbean Region [7]. The aim is to produce a global open exposure dataset based upon population, country specific building type distribution and other global/economic indicators such as World Bank indices that are suitable for natural catastrophe risk modeling purposes.

The most accurate way to produce an inventory of exposed assets consists in collecting individual georeferenced data within the economic evaluation of each asset: this is a classical bottom-up approach. It is usually applied for local (sub-city–city level) models and partially for larger scaled models (OpenDRI [8], GED 4GEM levels 2 and 3) which consider the characteristic of each of the exposed components such as buildings and more generally critical infrastructures. Many datasets have been and are constantly produced, by the World Bank's staff especially at a local scale, throughout the Bank's regions' projects; however, these projects have not produced, or yet made available, global scale datasets i.e. dataset covering the entire world. Even putting together the existing high resolution datasets, they would not provide a global coverage. Furthermore, these dataset does not present a uniform spatial distribution that would allow the buildup of bottom-up global exposure grids [9].

An exposure database that includes a global inventory of critical facilities based on a pure bottom up approach would require considerable human and economic efforts, and is beyond the scope of this project.

As the bottom-up approach is not available, we employed a spatial disaggregation, which consists in downscaling the available data (e.g. by administrative units) by means of auxiliary information and statistical techniques.

The development of GEG-2013 is based on a top-down or "downscaling" approach, where information including socio-economic, building type and capital stock at a national scale are transposed onto a regular grid, using geographic population and Gross Domestic Product (GDP) distribution models as proxies.

The exposure indicator is the number of persons subdivided by socio-economic class living in a specific construction type in a determined geographical location. This is used as a base for distributing the exposed economic value of the building stock.

2. Objectives

The objective of the GAR global risk assessment is to provide comparable disaster risk metrics for all countries and territories in the world, through a set of risk classes representing the likely order of magnitude of loss.

The GEG-2013 is a key element in the estimation of the risk developed in the GAR 2013 process. Disaster risk is considered to be a function of hazard, exposure and vulnerability, expressed as the probability of loss of life, injury or destroyed or damaged capital stock in a given period of time [2].

The purpose of GEG-2013 is to generate a global evaluation of exposed assets, in urban areas, in order to provide specific exposure input data to be used in further, coarse grain type, risk assessments [10]. It only considers the direct physical damage to urban buildings, combining both national socio-economic information, as well as a geographic population and GDP distribution models, as the main sources of information. The GEG-2013 top-down approach has the advantage to guarantee comparability across all countries and territories worldwide.

In order to develop a consistent framework for the GEG-2013 three essential aspects of the exposed assets are analyzed, by responding to the following questions:

1. What are the "exposed assets"?
2. How can we classify them?
3. How we can establish a monetary evaluation of the exposed assets?

2.1. What are the "exposed assets"?

The exposed assets considered in GEG-2013 are the building stock including both dwellings and buildings, and the population living or working inside them.

In the 2013 edition of GAR, the global probabilistic risk analyses will include only the economic component of the losses affecting urban agglomerations; hence the exposure database will cover urban areas with generally more than 2000 inhabitants. This limitation can be justified by the fact that urban human settlements are the pivot point of

[1] PCRAFI: http://pcrafi.sopac.org/.