EVALUATING RISK FROM A HOLISTIC PERSPECTIVE TO IMPROVE RESILIENCE: THE UNITED NATIONS EVALUATION AT GLOBAL LEVEL

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ABSTRACT

Disaster risk is not only associated with the occurrence of intense hazard events but also with the vulnerability conditions that facilitate disasters when such events occur. Vulnerability is closely linked to social processes and governance weaknesses in disaster-prone areas, and is usually related to a set of fragilities, susceptibilities, and issues regarding the lack of resilience of the exposed human settlements. The holistic risk assessment aims to reflect risk from a comprehensive perspective by using, in one hand, the physical risk or potential physical damage directly linked to the occurrence of hazard events and, on the other hand by capturing how underlying risk drivers or amplifiers –social, economic, environmental issues, non-hazard dependent elements, worsen the current existing physical risk conditions in terms of lack of capacity to anticipate or resist, or to respond and recover from adverse impacts. This article presents the results of the holistic evaluation of risk as well as of the implications of risk for development obtained at global level in the framework of the *UN Atlas-GAR: Unveiling Disaster Risk*, using the probabilistic physical risk results, obtained from the multi-hazard Global Risk Assessment 2015, socioeconomic indicators and macroeconomic flow variables available in worldwide databases for more than 200 countries and territories. These results are useful to identify risk drivers that are associated not only to the physical vulnerability of countries' assets but also to social, economic and financial issues that should be examined and tackled in a comprehensive way.

Keywords: Holistic approach; exposure and susceptibility; socio-economic fragility; lack of resilience; probabilistic risk assessment; indicators.

1. INTRODUCTION

Nowadays it is accepted that disaster risk is the result of the combination of the potential occurrence of hazard events and the fragility of the elements susceptible to be damaged, which consequently will result on direct and indirect losses for the exposed communities. It is also accepted that there is currently a lot of knowledge and a clear understanding in terms of building codes to ensure resilient infrastructure. Therefore, it can be said that natural events are "destructive because man has made them so, by investing his wealth with a disregard for the hazards that nature may have in store for him" (Ambraseys, 2010).

Physical vulnerability of the exposed elements is the result of inadequate practices and activities in a community as part of unplanned development processes that lead to the construction of susceptible elements and, in several cases, to the generation of new hazards (anthropogenic hazards). It is worth noting that current physical vulnerability of exposed elements is the result of past decisions driven by social, cultural, economic, institutional and environmental factors. Hence, although in many cases good decisions, policies, practices and actions have been taken and applied in this regard, it is very difficult, if not impossible, to lessen current physical risk in the short term; it implies a steady long-term process that will be reflected over time. This situation will inevitably result on a yet greater number of damages and losses in the next several decades. On the other hand, current intrinsic characteristics of society define either worse or better conditions that amplify or reduce the impact and the ability to recover from adverse events and create an either stronger or weaker new build environment. By improving socio-economic conditions of the society, two issues can be addressed: a higher capacity to recover from the impact of the events, as well as, after disaster, the capacity to build back better to avoid future disasters.

Risk assessments can improve the level of risk understanding and perception, helping main actors to realize the importance of considering risk into development processes. Public concern has been increasing in the last few decades and nowadays it is widely accepted that actions can be and should be taken to prevent and reduce risk. But the lack of understanding of disaster risk can lead to its underestimation and therefore to a lack of will or motivation to undertake initiatives to reduce it or prevent it. What is not dimensioned cannot be managed; to decide it is necessary to measure. Therefore, to develop a robust risk management strategy, risk must be properly evaluated.

Although risk evaluations and highly technical risk assessments fill a gap on the understanding of risk and they have been used for years within specific sectors, such as the insurance market, they have not been widely used by the public sector. Consequently, in many cases, decisions have been based primarily on ordinary knowledge, trial and error, or non-scientific knowledge and beliefs. Unfortunately, there is still incipient understanding of what the results of risk assessments are and what they mean.

Development actions in favor of the poorer do not automatically reduce risk (TEARFUND 2003), thus signifying that risk management should be made explicit as a development goal, the recognition of risk through the characterization of inherent vulnerability conditions (Briguglio 2003) serves to reiterate the relationship between risk and development (UNDP 2004). This is so to the extent that the vulnerability conditions that underlie the notion of risk are, on the one hand, problems caused by inadequate economic growth and, on the other hand, deficiencies that may be intervened via adequate development processes. Therefore, although the indicators proposed reflect recognized development aspects (Holzmann and Jorgensen, 2000; Holzmann 2001) they are presented here in order to capture the different circumstances that favor the direct physical impacts (exposure and susceptibility) and indirect and at times intangible impacts (socio-economic fragility and resilience) of probable physical phenomena (Masure 2003; Davis 2003)" (Cardona et al. 2004)

As result of abovementioned, to attempt an effective communication of risk assessment outcomes and considering that the purpose of composite indicators is to describe a problem or a complex system in simple terms, a holistic risk assessment approach has been selected to be applied at global level to 216 countries, in the framework of the *UN Atlas-GAR: Unveiling Disaster Risk* (UNISDR, 2017). The methodology and some results are presented herein attempting to illustrate how is possible to reveal hidden risk, integrating physical risk results, using probabilistic metrics, and a comprehensive set of indicators or risk drivers, to give account the socioeconomic conditions that aggravate the potential losses.

2. RISK LANDSCAPE AT GLOBAL LEVEL

Risk management decision-making should focus on a comprehensive risk management strategy which must be based on a multidisciplinary approach that considers not only the physical damage and the direct impact but also a set of socioeconomic factors that favour second order effects and consider the intangible impact in case an event occurs (Cardona 1990, 2001, 2005; Cardona and Hurtado 2000; Cutter et al. 2003; Carreño et al. 2007; 2012, 2014; Barbat et al. 2010; Khazai et al. 2014).

Risk should be presented and explained in a way that attracts stakeholders' attention. In that scenario, one of the main challenges is to find the right ways to communicate complex issues from science to politics or the public. The holistic risk assessment approach aims to reflect risk from a comprehensive perspective by using, in one hand, the physical vulnerability or potential physical damage which is directly linked to the occurrence of hazard events and, on the other hand by capturing how underlying risk drivers or amplifiers –social, economic, environmental factors–, which are mainly non-hazard dependent, worsen the current existing physical risk conditions in terms of lack of capacity to anticipate or resist, or to respond and recover from adverse impacts. Holistic evaluations of risk at urban level have been performed in recent years for different cities worldwide (Cardona 2001, 2007; Birkmann et al. 2013; Cardona et al. 2012; Carreño et al. 2007; Jaramillo 2014; Marulanda et al. 2013; Salgado-Gálvez et al. 2016) as well as at country level (Burton and Silva 2014) and have proven to be a useful way to evaluate, compare and communicate risk while promoting effective actions toward the intervention of vulnerability conditions measured at its different dimensions. See also Cardona at al. (2018) in the proceedings of this conference.

Figure 1 presents the conceptual framework of the holistic risk approach, used for this initiative, where it is shown that risk is a function of hazard and vulnerability (physical vulnerability and socioeconomic factors). The holistic approach states that to reduce existing risk or to prevent the generation of new risk it is required a comprehensive risk management system, based on an institutional structure accompanied by the implementation of policies and strategies to intervene not only susceptible elements but also diverse factors of the society that may create or increase risk, as well as to intervene, when possible, created hazards (anthropogenic, technological, etc.). In the same way, in the case a hazard event is materialized, resulting in a disaster, emergency response and recovery actions should be conducted as part of the risk management framework.

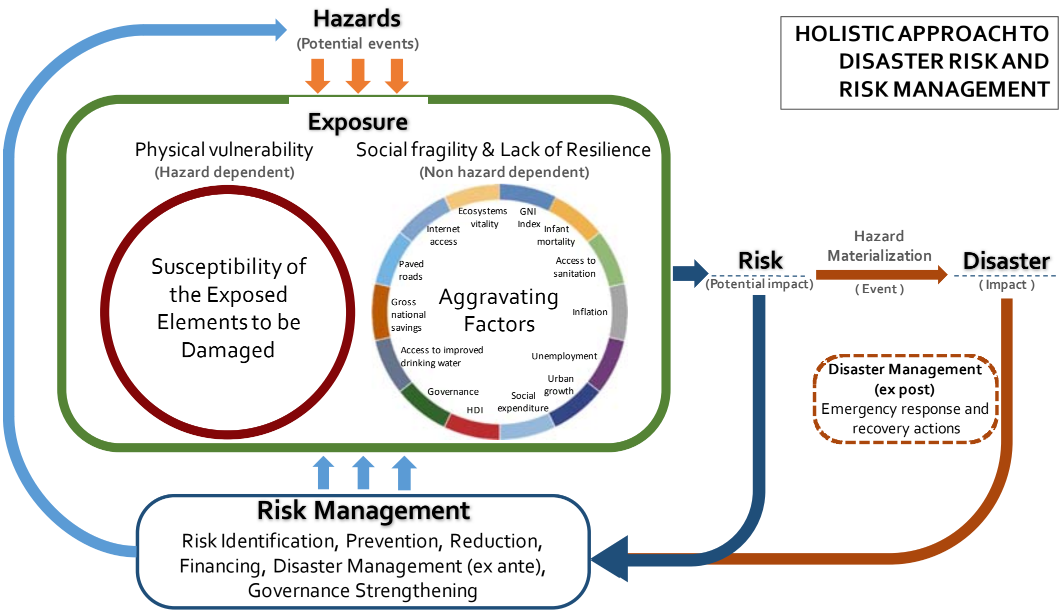

Figure 1. Conceptual framework of the holistic approach to disaster risk. Adapted from Cardona & Barbat (2000).

For this evaluation, "physical vulnerability" values were obtained using vulnerability functions of the exposed assets of countries. These functions relate the intensity of the hazard event with the mean damage ratio of each building class of the exposed assets. The fully probabilistic risk assessment, which is basically the convolution of the hazard with the physical vulnerability, is used to obtain the main risk metric: The Loss Exceedance Curve, LEC. From the LEC, other useful metrics can be obtained such as the Average Annual Loss, AAL or the Probable Maximum Loss for any chosen return period. The physical component of risk used for the holistic risk evaluation, was estimated using the multi-hazard[1] AAL from the Global Risk Assessment 2015 (Cardona et al. 2015).

The aggravating factors are aimed to represent in a numerical way, a society context from different dimensions. Actually, it is not conceived to measure how each of the characteristics chosen are going to increase or reduce due to the occurrence of an event, but to show, with indicators, how the conditions of a society can make it more susceptible to the impact of an event. These characteristics are non-hazard dependent. That is, the social context exists, and it is like it is, independent on the occurrence of an external shock. The physical losses (damage of the exposed elements) are not influenced by current conditions of the society. What this Holistic Risk Evaluation shows, in a very simplified form, is that, when better societal conditions exist, it is assumed that the impact will not worsen because people (in a general context) has the capacity to react and to recover faster. Worse condition of the society will affect the capacity of a country to cope with disasters, increasing –for example– the incapability to absorb consequences, to respond efficiently and to recover from the impact.

For the aggravating factors, fourteen variables were chosen. A limited number of variables to represent said context are chosen to make it easier to interpret and to use. The fact that the evaluation is done at national level implies using, inevitably, aggregated and gross variables that cannot capture the spatial variability at local level. With a few variables we intend to represent different dimensions (i.e. social, economic, environmental, governmental) at national level. These variables or indicators were sought to cover a wide spectrum of issues that underlie the notion of risk in terms of predominating vulnerability conditions of physical susceptibility and beyond; i.e. factors related to social fragility and lack of resilience that favor indirect and intangible impacts in case of occurrence of a hazardous event.

The criteria to choose them were that they together could capture a wide understanding of the conditions of the societies, coverage of most of the countries included in the global risk assessment and confidence of the sources of information. Figure 2 presents the structure of indicators used to evaluate the total risk or the Country Disaster Risk Index from a holistic perspective.

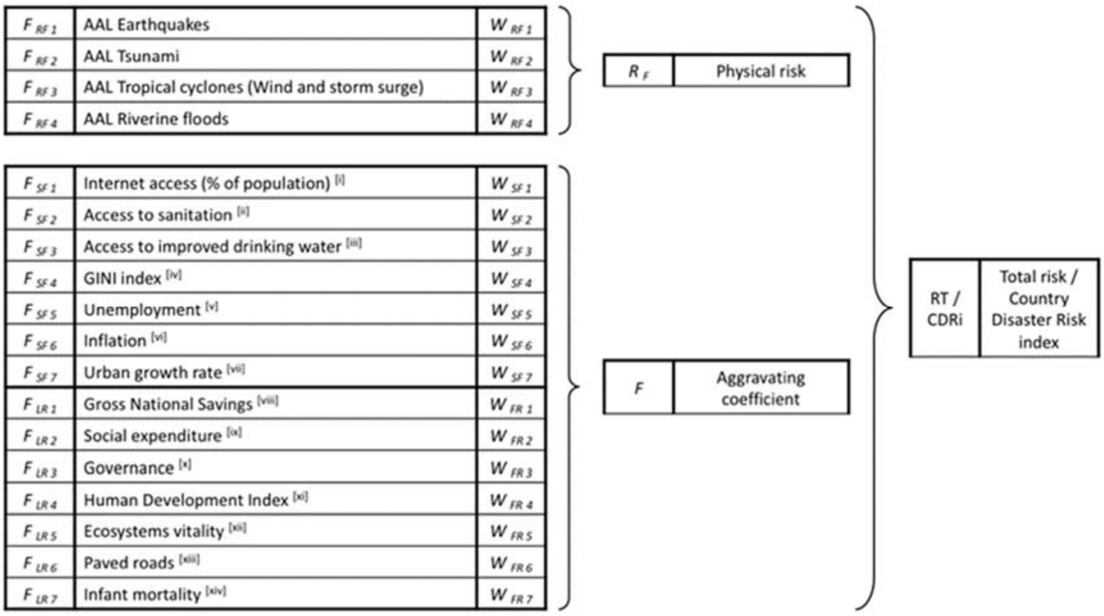

Figure 2. Structure of indicators used in the global holistic evaluation of risk.

This is the first time that a study following the abovementioned approach is conducted considering hazard, exposure and socioeconomic descriptors for more than 200 countries. The results are useful to identify risk

[1] The hazards calculated in the Global Risk Assessment were: Earthquakes, Tropical cyclones (wind and storm surge), Tsunami and Riverine Floods. Details of the methodology can be found in Cardona et al. (2014), Rudari et al. (2015), NGI (2014), UNISDR (2015, 2017).

drivers that are not only associated to the physical vulnerability of buildings and infrastructure but also to social issues that should be examined and tackled in a comprehensive way.

This approach demonstrates, with numbers, how poverty conditions (which is usually the main risk driver) increase the impact of disasters. Some countries such as Japan can have high values of total risk. But in a disaggregated way, it can be seen it has higher physical risk due to its location in very active areas for specific hazards. Other countries, where physical risk is similar among them or even low, can see the increase on total risk due to the aggravating factors. Our holistic risk evaluation at global level gives numbers at national level but does not separate poor people from non-poor people. This is seen more as a tool of communication for the national government, where it would be necessary to analyze in a deeper way how conditions are distributed within the country and which are the areas that should be improved to achieve equality and more sustainable development. Hallegate et al., 2017, in their document "unbreakable" describes different conditions on how disasters exacerbate poverty and how poverty can lead to disasters.

2.1 Adaptation of the holistic risk assessment methodology

Applying the holistic risk evaluation methodology proposed by Cardona (2001) and Carreño et al. (2007), the holistic risk assessment index or Total Risk (R_T) is calculated by using the equation:

$$R_T = R_F\,(1 + F) \qquad (1)$$

This expression, known in the literature as the Moncho's Equation (Carreño et al. 2007), is defined as a combination of a physical risk index, R_F, and an aggravating coefficient, F. Where R_F and F are composite indicators (Carreño 2006; Carreño et al. 2007). R_F is obtained from the probabilistic risk results –such as the average annual loss or pure premium– while F, which accounts for the socioeconomic fragility and lack of resilience of the area under analysis, is obtained from available data regarding political, institutional and community organization aspects which usually reflect weak emergency response, lack of compliance of existing codes, economic and political instability and other factors that contribute to the risk creation process and related to the capacity to cope or recover (Carreño et al. 2007; Renn 2008). In this approach, potential physical damage is affected or aggravated by a set of socioeconomic conditions that may worsen the negative effects when an event occurs. Detailed information about this methodology can be found in Carreño (2006), Carreño et al. (2007) and Barbat et al. (2011). This approach has also been applied at different resolution levels (Daniell et al. 2010; Burton and Silva 2014) and has been integrated in toolkits, guidebooks and databases for earthquake risk assessment (Khazai et al. 2014; 2015; Burton et al. 2014). Descriptors are selected according to the availability and relevance of indicators for the area under study. In these proceedings see also Cardona at al. (2018).

In case of this evaluation, it is assumed that Total Risk (R_T) can be maximum two times the physical risk of the affected area. It means that, if in a hypothetic case, where socioeconomic characteristics are optimal and there is neither fragility nor lack of resilience, the aggravating factors would be zero and then, the total risk would have the same value of physical risk. While if society characteristics are as bad as to obtain the maximum value of the aggravating coefficient (1.0), total risk would be twice the physical risk value. This assumption is made with the aim to reflect that socioeconomic characteristics can influence the impact of a disaster. Whether it is twice, three, four or more times higher than the physical damage is not defined here and different proposals exist with relation to this, but the objective in the context of the holistic evaluation is to make the impact of these characteristics manifested and show that they can really influence the most direct effects of a disaster (physical damage).

Risk addressed from a physical point of view is the starting point to analyse the subsequent impacts of a disaster on the society. Disasters resulting from natural and anthropogenic events are the damage on the built environment or on the physical assets affecting people and their activities in different ways. This means, when earthquakes occur, if buildings collapse, people in them shall die, when floods occur if houses are inundated people will be affected in terms of being displaced from their houses and lose their properties, when droughts occur, crops are lost, and it will be translated on lack of food.

2.1.1. Physical

risk, R_F

In this initiative, the physical risk index, R_F, has been calculated based on the results of the global probabilistic multi-hazard risk assessment made for the Global Assessment Report 2015 (UNISDR, 2015a; Cardona, et al. 2015), the multi-hazard[2] Average Annual Economic Loss[3]. [4]

The probabilistic risk assessment methodology used in the Global Risk Assessment for GAR15 is composed by three major components: hazard, exposure and vulnerability.

- Hazard assessment: for each phenomenon considered, a set of events is defined along with their respective frequencies of occurrence, forming an exhaustive representation of hazard. Each scenario contains the spatial distribution of the probability parameters to model the intensities as random variables.
- Exposure assessment: Creation of an inventory of exposed elements, specifying the geographical location of the asset, its replacement value and its building class.
- Vulnerability assessment: for each building class a vulnerability function is defined, for each type of hazard. This function characterizes the structural behavior of the asset during the occurrence of the hazard event. Vulnerability functions provide the probability distribution of the loss as a function of increasing hazard intensity.

The main risk metric obtained from fully probabilistic risk assessments is the Loss Exceedance Curve, LEC, which is recognized to be the most robust tool for representing catastrophe risk (Cardona 1986, Ordaz, 2000). From the LEC different metrics are obtained, such as the Average Annual Loss, AAL and the Probable Maximum Loss, PML. The AAL is a compact metric with a low sensitivity to uncertainty. It expresses the expected average loss per year considering all the events that could occur over a long timeframe, including very intense losses over long return periods. The AAL integrates into a single value the effect, in terms of loss, of the occurrence of hazard scenarios over vulnerable exposed elements. The average annual loss considers the losses in each building for all the events that can occur on the assumption that the process of occurrence of hazard events is stationary and that the damaged structures are reinforced immediately after an event.
Details on the probabilistic risk assessment methodology can be found in (Ordaz, 2000; CIMNE & Ingeniar, 2015).

The AAL, as a single value, is the metric used to obtain the R_F, which allows comparing physical risk among countries. For obtaining the R_F, the AAL is transformed to values between 0.0 and 1.0 using 1.0 as the maximum value which corresponds to those AAL greater than 10 per thousand (or the same 1 per cent). The calculation of R_F was made conveniently for numerical values following the equation:

$$R_F = \frac{\log(AAL)}{\log\,(AAL_{max}) - \log\,(AAL_{min})} \quad (2)$$

where *max* value is 100 and the *min* value is 0.01.

[2] The hazards considered in GAR15 were earthquakes, tsunami, tropical cyclones (wind and storm surge) and riverine floods.

[3] In the Global Risk Assessment 2015, it is only considered the Average Annual Loss related to economic losses and does not consider any other direct physical impacts such as death or injured people.

[4] In this approach, we consider intensive risk only. Small and moderate disasters do not make part of this analysis.

2.1.2. Aggravating coefficient, F

The aggravating coefficient, F, is calculated as follows:

$$F = \sum_{i=1}^{m} F_{SF_i} \cdot W_{SF_i} + \sum_{j=1}^{n} F_{LR_j} \cdot W_{LR_j} \qquad (3)$$

where F_{SFi} and F_{LRj} are the aggravating factors, W_{SFi} and W_{LRj} are the associated weights of each i and j factor.

Due to robustness and sensitivity considerations (Marulanda et al. 2009) and because the global scope of this assessment, where a consensus process is not feasible, to avoid discussions about relevance of each aspect, it was assumed conveniently that the weight of each factor is the same; m and n are the total number of factors for social fragility and lack of resilience, respectively.

For this case, seven descriptors were used to capture the social fragility conditions and other seven to capture the lack of resilience. Most of the descriptors were obtained using data from worldwide databases[5]. Each of the factors used in the calculation of the Total Risk (R_T), or Country Disaster Risk Index, captures different aspects of the society and is quantified in different units. For this reason, certain normalizing procedures are needed to standardize the values of each descriptor and convert them into commensurable factors.

In this case, transformation functions were used to standardize the social fragility and lack of resilience factors selected. Some of them are shown in Figure 3. The factors and their units, as well as the [*min, max*] values are shown on the abscissa. Depending on the nature of the descriptor, the shape and characteristics of the functions vary. It means that functions related to descriptors of social fragility have an increasing shape while those related to resilience have a decreasing one to give account indeed lack of resilience. Thus, in the first case, a high value of an indicator means greater contribution to aggravation (i.e. corruption indicator, if this value is high, it will contribute more to aggravate or worsen conditions to cope or respond in an adverse situation). In the second case, a high value of the indicator means a lower negative influence on the aggravation (i.e. access to education, a high value is a positive characteristic for more resilient societies, therefore, it will contribute less to aggravating an adverse situation). The transformation functions can be understood as risk and aggravating probability distribution functions or as the membership functions of the linguistic benchmarking of high risk or high aggravation.

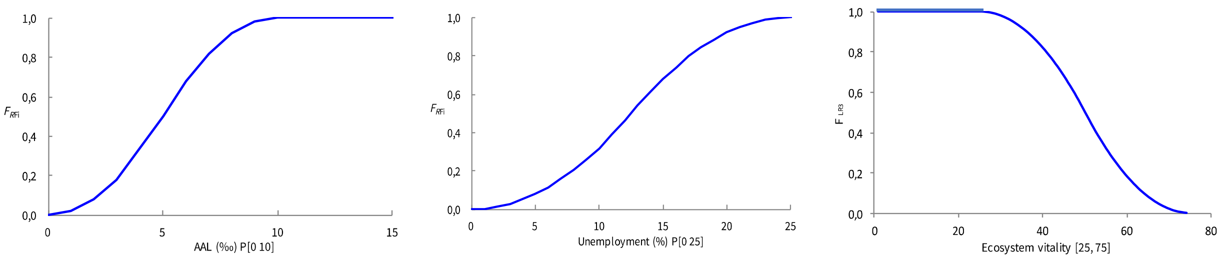

Figure 3. Examples of transformation functions.

The values on the abscissa of the transformation functions correspond to the values of the descriptors or raw indicators (as found in the international databases) while the ordinate corresponds to the final value of each factor, either related to the physical risk or to the aggravating factor. In all cases, values of the factor lie between 0.0 and 1.0. Since the transformation functions are membership functions, for high risk and aggravating coefficient levels, 0.0 corresponds to non-membership (or zero contribution to risk and aggravating coefficient) while 1.0 means full membership (or full contribution to risk and aggravating coefficient). Limit values denoted as X_{MIN} and X_{MAX} are defined by using expert criteria and information about previous disasters. Relative weights W_{FSi} and W_{FRj} that associate the importance of each of the factors on the

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[5] International Telecommunication Union ITU, World Health Organization WHO, the World Bank, CIA US Central Intelligence Agency, World Urbanization Prospects WUP, International Labor Office ILO, United Nation Development Program UNDP, Yale University, Food and Agriculture Organization FAO, Organization for Economic Co-operation and Development OECD.

index calculation are defined in this specific evaluation as equal, that is, it is assigned the same importance or contribution to each of the indicators that intend to characterize the socio-economic dynamics of the society.

In this application of the methodology at global level, for the selection of the aggravating factors, besides considering the availability of data and country coverage, an effort was made to specify relevant issues that reflect social fragility and lack of resilience of the countries. Indicators representing social fragility such as: internet access (% of population), access to sanitation and access to improved drinking water, are functions of economic development as living standards rise along with disposable income levels. These indicators reflect a comparatively unfavorable situation that reflect a notion of susceptibility of a community when faced with hazardous events, whichever its nature or severity. The relation of distribution of population and the trend towards greater concentration in the cities is portrayed by the urban growth indicator, which reflects the exposure of population as a condition of susceptibility whenever the growth has been disorderly, lacking land use regulations that result not only in fragile constructions but also in serious impacts on the environment. Differences in vulnerability of the exposed social and physical context, determines the selective nature of the severity of the effects of the natural phenomenon (Cardona, 2001).

The other indicators of social fragility selected have been the GINI Index, unemployment and inflation, which in general represent income inequality, since high inflation has been found to counteract the income-equalizing effect of fiscal distribution. Poverty constrains the capacity of the society to cope with disasters, rendering its functioning particularly fragile, a vulnerability condition that reflects, in general, an adverse and intrinsic predisposition to be affected when faced with a hazardous event.

The indicators selected representing (lack of) resilience have been: gross national savings, social expenditure, governance, Human Development Index HDI, ecosystems vitality, paved roads and infant mortality. They capture at a macro level the capacity to recover from or absorb the impact of hazardous events. When these indicators are adverse, means that necessities of the society are not being covered, accounting for a deficit in the quality of life, thus reflecting a notion of susceptibility and an incapacity to adequately face disasters.

2.2 Results of risk at global level from holistic approach

This section presents some results obtained using the methodology in terms of R_F, F and R_T. Detailed information about the results can be found in Cardona et al. (2015, 2017) and UNISDR (2015a, 2017): *UN Atlas-GAR: Unveiling Disaster Risk*.

As it can be seen in Figure 4, displaying the bottom ten and top ten countries for the R_F index, the highest R_F values are generally found in Small Islands Development States, SIDS, where in many cases the area affected by an event represents virtually the whole area of the country. In these cases, exposure plays an important role in risk, given the intensity of the events and the small countries that in relative terms are more affected. On the other hand, when excluding the SIDS from the results, as shown in the right, the R_F results show that the highest values usually correspond to developing countries prone to hazardous events that might affect greater areas of the country. These high values of potential losses can be given by the disorganized urbanization process and the lack proper building codes. Usually, the larger the event and the smaller or the weaker the economy, the more significant is the impact. From the socio-economic perspective, as shown in Figure 5, highest values belong to weaker economies countries, where organizational, institutional, environmental and social conditions are also weaker, and it is reflected in this evaluation by the high values of susceptibility and lack of resilience indicators. Opposite to the R_F values, in the aggravating coefficient ranking, SIDS did not obtain the worst results, even being small economies, due specially to their geographical size that does not allow a diversification of the economy, the socio-economic indicators for SIDS reflect good and balanced conditions.

1	Finland	0,02	207	Tonga	0,88	159	Ecuador	0,74
2	Singapore	0,05	208	Guadeloupe	0,88	160	Tajikistan	0,74
3	Norway	0,15	209	New Caledonia	0,89	161	Peru	0,75
4	Maldives	0,18	210	Anguilla	0,89	162	Bangladesh	0,78
5	Andorra	0,23	211	Virgin Islands	0,90	163	Cambodia	0,79
6	Kiribati	0,25	212	Dominica	0,91	164	Laos	0,80
7	Denmark	0,25	213	Antigua and Barbuda	0,93	165	Honduras	0,80
8	Cape Verde	0,29	214	Cayman Islands	0,93	166	Myanmar	0,80
9	Sao Tome And Principe	0,29	215	The Bahamas	0,94	167	Madagascar	0,81
10	Western Sahara	0,32	216	Montserrat	0,94	168	Philippines	0,83

Figure 4. Ranking Physical Risk (R_F) bottom 10 and top 10 countries. (left and middle). Top 10 countries excluding SDIS (right); total 168 countries. *Source:* UN Atlas-GAR, UNISDR 2017

1	Cayman Islands	0,04	207	Kenya	0,88
2	Gibraltar	0,05	208	Sierra Leone	0,88
3	Réunion	0,06	209	Madagascar	0,89
4	Denmark	0,08	210	Liberia	0,89
5	Germany	0,09	211	Nigeria	0,90
6	Norway	0,09	212	Guinea	0,91
7	Austria	0,10	213	Eritrea	0,92
8	Netherlands	0,10	214	Angola	0,94
9	Switzerland	0,10	215	Yemen	0,95
10	Monaco	0,12	216	Somalia	0,97

Figure 5. Ranking aggravating factor (F). Bottom 10 and top 10 countries. *Source*: UN Atlas-GAR

As it can be seen in Figure 6, total risk (R_T) results evidence the important influence that the aggravating factors have on the physical effects after an event. The results depict how most of the countries in the bottom list are lower and weaker economies countries. These results reflect susceptibility in terms of physical, organizational and attitudinal factors that may lead to generate or increase vulnerability faced with the occurrence of hazard events.

1	Finland	0,02	207	Belize	1,34
2	Singapore	0,06	208	Cambodia	1,35
3	Norway	0,16	209	Somalia	1,37
4	Maldives	0,26	210	Bahamas	1,38
5	Denmark	0,26	211	Haiti	1,40
6	Andorra	0,28	212	Lao People's Dem Rep	1,41
7	Sweden	0,38	213	Dominica	1,42
8	Kiribati	0,42	214	Vanuatu	1,46
9	Cabo Verde	0,45	215	Solomon Islands	1,49
10	Luxembourg	0,47	216	Madagascar	1,53

Figure 6. Ranking Total Risk (R_T) or CDRi. *Source*: UN Atlas-GAR, UNISDR 2017

Complete rankings of countries and world maps are available in the *UN Atlas-GAR: Unveiling Disaster Risk* (UNISDR, 2017). In addition, this Atlas includes country's risk profiles using augmented reality; therefore, it is possible to have more details, indicators, graphics, and values for each country, such as the curves of Probable Maximum Loss, PML, taking into account all evaluated hazards. The Figure 7 displays the world map with the results of physical risk in terms of pure premium based on the relative AAL, including six perils (earthquakes, tsunamis, riverine floods, tropical cyclone -wind and storm surge). The Figure 8 displays the map of the aggravating factor as composite indicator that reflects social fragilities and lack of resilience (as amplifiers and risk drivers). The Figure 9 displays the world map of the total risk or Country Disaster Risk Index, CDRi, as the integrated outcome of the holistic risk assessment at global level.

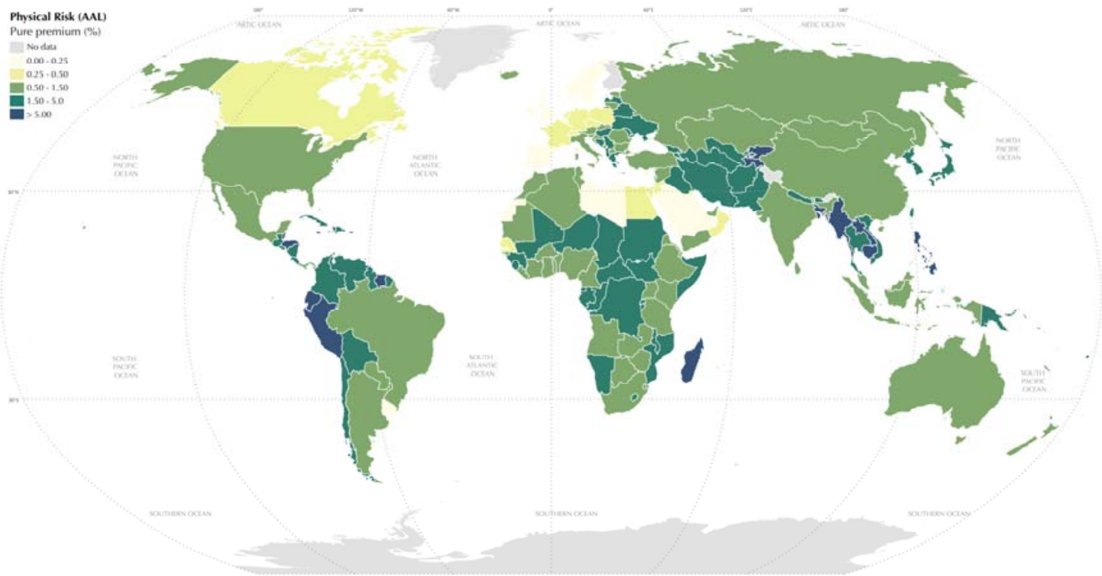

Figure 7. Map of physical risk (risk pure premium AAL ‰)

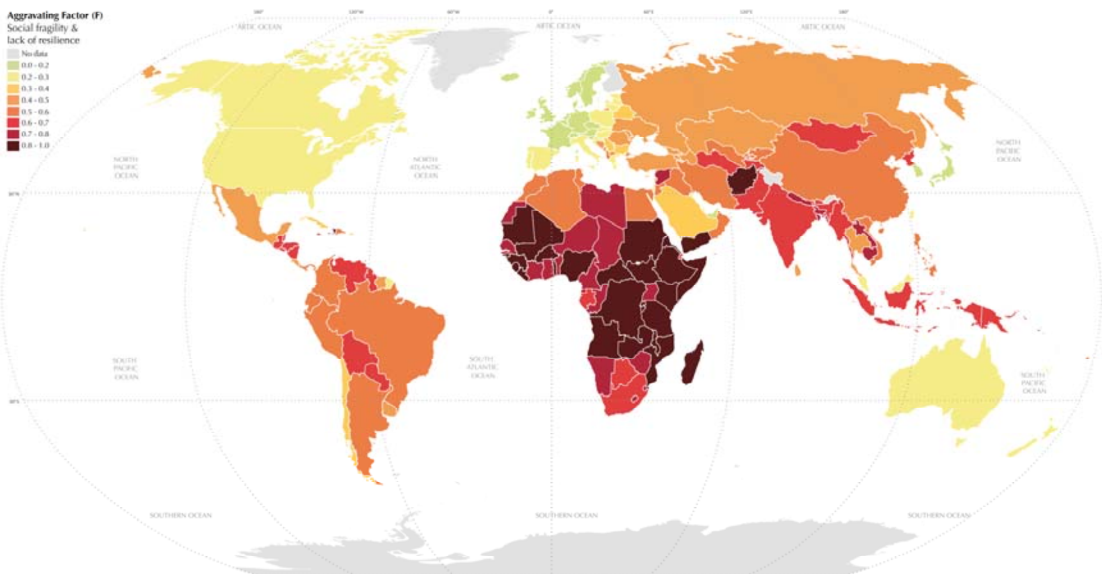

Figure 8. Map of aggravating factor (*F*) regarding social fragility and lack of resilience

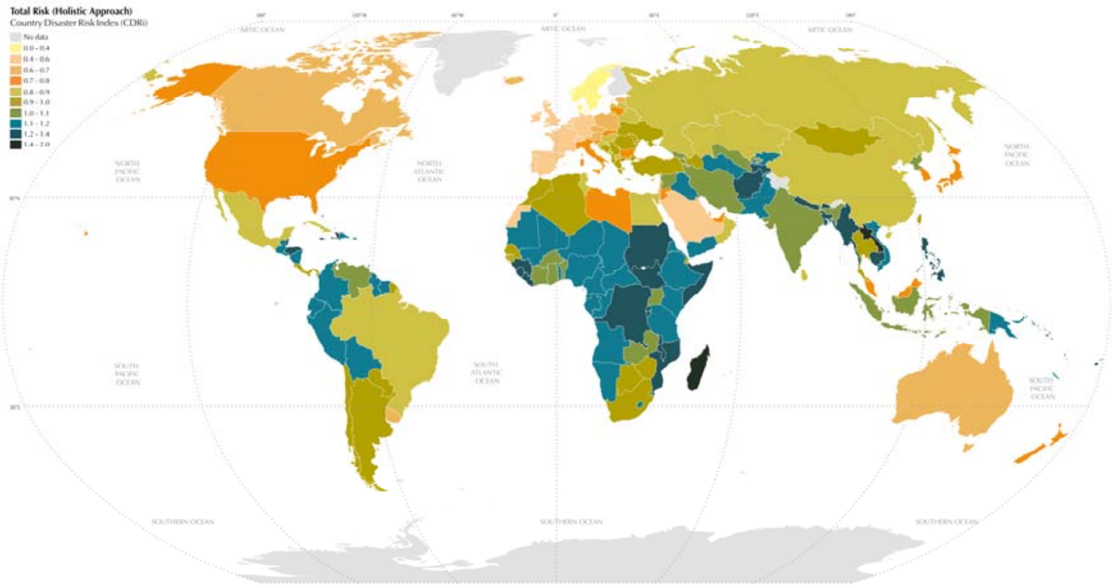

Figure 9. Map of total risk from holistic perspective (Country Disaster Risk Index, CDRi)

2.3 Risk implications for sustainable development

In addition, it is worth noting that the pure premium, besides of being the metric used to represent the physical risk, once compared against a set of macroeconomic flow variables, it reflects social and economic growth constraints for the country as a result of potential future disasters. Such approach has been developed in the Disaster Risk Development Implications index (DRDIi), which attempts to reveal the proportion of the country's AAL on the social annual expenditure (health, education, and social protection); the capital formation and savings (domestic investment) and reserves (financial capacity) of each country. Detailed information on this index, methodology and results can be found in Cardona et al. (2015, 2017) and UNISDR (2015a, 2017): *UN Atlas-GAR: Unveiling Disaster Risk.*

This index, proposed by Mabel C. Marulanda, Omar D. Cardona and Andrew Maskrey (originally call as the MCMi) is a simple and practical composite indicator, useful to provide a ranking of the countries based on the tacit implications of latent disasters for socioeconomic development and the countries' sustainability. The index is calculated based on three sub-indicators: The Disaster Risk Social Implications (DRSI), obtained from the ratio of the AAL with the Social Expenditure; the Disaster Risk Growth Implications (DRGI), obtained from the average of the ratio of the AAL with Gross Fixed Capital Formation and the Gross Savings; and the Disaster Risk Economic Implications (DREI), obtained from the average of the ratio of the AAL with the Reserves. The indexes range from 0 to 100. When these indexes are high, means potential constrains and future stress for the sustainable development.

In case of a disaster (which could be much higher than the AAL), what wants to be expressed is that, if economic resources to cope with losses are taken from a specific budget, they could mean that no resources are available to invest on development. Of course this is an assumption, because no country would take whole resources from a single expenditure, but measuring in this way gives a more tangible idea of how relevant the proportion that losses (in this case AAL) represent can be for the expenditures and investment on development of a country. Indeed, intensive disasters are not annual and when they occur the losses can be even many times the AAL. In addition, they would mean the reallocation of resources from other and different budgets.

This approach is simple and, in any case, provide a general view of the implications of disaster risk for socioeconomic development of countries and the need to implement an integrated risk reduction financial strategy. Figure 10 displays the map of the Disaster Risk Development Implications Index at global level.

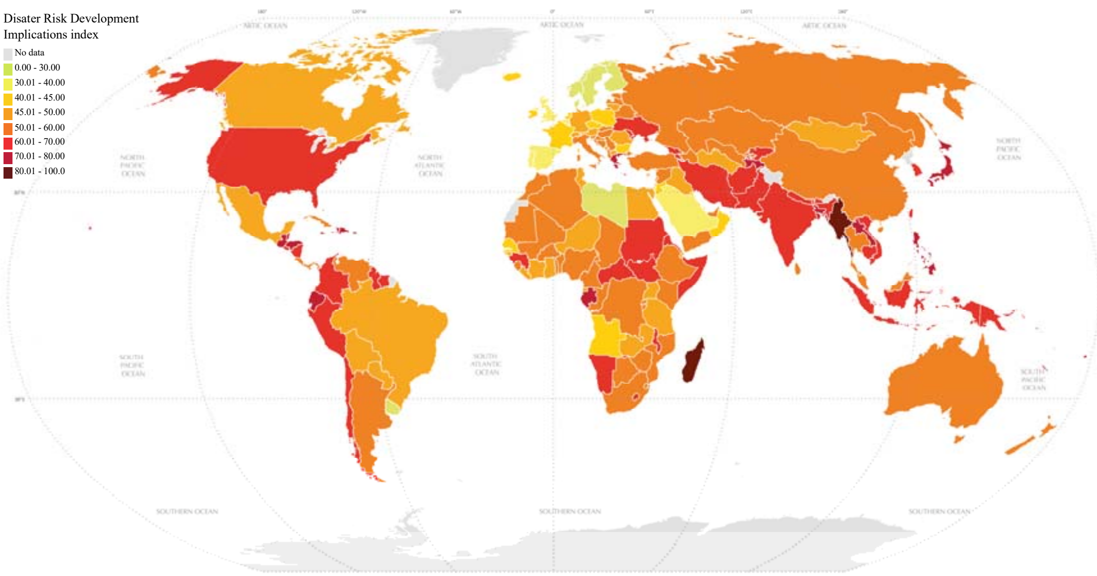

Figure 10. Map of the Disaster Risk Development Implications Index (MCM index)

3. CONCLUSIONS

This is the first time that a study following the abovementioned methodologies is conducted in all aspects (hazard, exposure and socioeconomic descriptors) for 216 countries. Measuring risk with the same methodologies in all countries allows a direct and appropriate comparison of the obtained results and they can help in prioritizing the countries for developing higher detail disaster risk analysis. The holistic evaluation also allows the disaggregation of results to highlight the main risk drivers, by identifying the descriptors, that are contributing the most in each of the indexes (physical risk, social fragility and lack of resilience). Finally, results are useful to identify underlying risk drivers that are not only associated to the physical vulnerability of buildings and infrastructure, but also to social factors that should be examined in more depth.

The holistic evaluation and the implications index are based on probabilistic risk assessment methodologies and socioeconomic indicators. Probabilistic risk assessments are models that intend to represent a reliable order of magnitude of potential losses, they do not predict events nor exact amounts of damage and losses. Therefore, these models consider the different uncertainties related to the occurrence of natural phenomena and generation of losses. On the other hand, socioeconomic indicators are a way to represent and quantify the situation of a country; they are approximations and many details might be lost in condensing in a single number what wants to be measured. Nevertheless, this figure can give a good approximation of risk drivers and allows to set more specific achievements. Indicators allow also comparison among different periods or among different areas, identifying weaknesses and strengths which serve as a starting point to take concrete actions to improve socioeconomic conditions. Although the uncertainties related to the physical risk assessment have been accounted for, research is needed to incorporate the ones existing in the considered socioeconomic characteristics (Burton and Silva 2014). Those cannot be handled by means of probability distributions. Nevertheless, it is important to highlight that sensitivity tests have been made in the past to demonstrate the robustness of risk rankings and risk level ranges derived from the composite indicator (Marulanda et al. 2009).

It is important to bear in mind that indicators in general, are not aimed to identify risk management measures, which must be identified using integrated models and comprehensive analysis. Indicators are gross and overall operating pictures that allow easier interpretation of multi-dimensional issues instead of trying to find a trend in many separate indicators, and they mainly serve to highlight some aspects of risk; therefore, more detailed information, i.e. disaggregated values, should exist to draw suitable conclusions and define courses of action. Despite the shortfalls indicators may have, they are useful to attract public interest and raise awareness towards risk, as well as to compare and prioritize areas for action and to promote the improvement of risk management capabilities.

This kind of evaluations can be periodically updated to evaluate the changes in physical risk and in development. The results obtained from this evaluation allow measuring the progress towards the goals established in the Sendai Framework for Disaster Risk Reduction 2015-2030, and the Sustainable Development Goals, SDGs, without waiting for disasters to happen. It is possible to measure progress in reducing future negative effects in the occurrence of events, without having to experience a disaster (Muir-Wood 2016).

The indexes presented in this document are complementary to other indexes such as the one proposed by Hallegate et al. (2017) which focus on the impacts of disasters on well-being. This approach has a different perspective to the one presented here but takes into account also the socioeconomic context. We consider that in decision-making related to disaster risk management, a single indicator is not enough to cover all the angles of a complex system and to identify risk management options in countries.

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