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SCHOOL OF ENGINEERING

Master of Science in Civil Engineering for Environmental Risks Mitigation

Review, Redefinition and Development of Disaster Risk Indices to Rank Countries for International Organizations

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Abbreviations

ADRC	Asian Disaster Reduction Center
CRED	Center for Research on the Epidemiology of Disasters
DDI	Disaster Deficit Index
DRI	Disaster Risk Index
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
ENSURE	Enhancing resilience of communities and territories facing natural and na-tech hazards
ESCAP	Economic and Social Commission for Asia and the Pacific
FAO	United Nations Food and Agriculture Organization
GAR	Global Assessment Report
GDP PPP	Gross domestic product at purchasing power parity
GRID	Global Resource Information Database
HDI	Human Development Index
IDEA	Universidad Nacional de Colombia Instituto de Estudios Ambientales
ITU	International Telecommunication Union
LDI	Local Disaster Index
OCHA	United Nations Office for the Coordination of Humanitarian Affairs
PVI	Prevalent Vulnerability Index
RMI	Risk Management Index
UNDESA	United Nations Department of Economic and Social Affairs
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
UNISDR	United Nations International Strategy for Disaster Reduction
UNISEF	United Nations Children’s Fund
WB	World Bank
WFP	United Nations World Food Program
WHO	World Health Organization

Abstract

Disasters are increasing continuously in the world and so is the risk. For a growing exposure of people and economy, the threats of natural disasters are ominous and ever present ones. The year 2011 has already seen some of the most deadly and devastating disasters like earthquakes in Japan and New Zealand, floods in Pakistan, Australia and Brazil, droughts in East Africa and cyclone "Irene" in United States. Damages are evident but the risk factors that converted these hazards into the disasters are mostly invisible to the public, governments and even to the disaster management and development professionals. It is the need of the future to understand risk and define the policy and strategies to take appropriate actions for disaster risk mitigation. Risk Indices and indicator systems help to identify and bridge the existing gap, prioritize the cost effective actions and to assess the performance of risk management practices in future.

An attempt has been made to review the four different (DRI, Hotspots, Americas Program and ENSURE) existing standard methodologies of risk index systems and to identify the most coherent one. As Local Disaster Index (LDI) of Americas Project provides the dispersion of risk at local scale instead of measuring risk at local level, a separate index complementing to Local Disaster Index and measuring the risk at local scale is developed. Prevalent Vulnerability Index (PVI) is redefined to make it more realistic and relevant to the need. Three countries (Chile, Colombia and El Salvador) are taken as pilot countries to analyze the different methodologies. A critical analysis of the issues affecting the disaster risk management has been done and suggestions are given to improve the indicator systems. This work is aimed to prove future guidelines in the development of risk index and associated indicators.

Keywords:

Risk index, risk, hazard, vulnerability, exposure, disaster, disaster reduction, database, disaster risk management

Introduction

As the world's population increases, and development induces vulnerabilities and exposure, climate change impacts are aggravating the effect of natural disasters. Risk, as the expected loss of life or damage of assets, is present throughout the globe. The varying levels of vulnerability, exposure and hazards define the level of risk. Hence, every country suffers and recovers in a unique manner. Numerous efforts are made to reduce, control, manage, or mitigate risks; the development of disaster risk indices is a tool for these measures. Disaster risk indices, developed for national governments and international organizations, among others, serve as an evaluation of the trend of risks for decision making, for allocation of budgets and for strategic planning. Quantification of risk as indices facilitates the comparison of countries facing disasters, permitting the cultivation of adequate approaches to strengthen their abilities to cope with disaster risks and prepare for future events. Nonetheless, disaster risk indices are a work in progress. The need for a uniform terminology, clear indices with concrete indicators, and improved data recording methodologies, is crucial for the advancement in the field of disaster risk reduction. This advancement is in itself essential for the protection of human lives and assets.

In this work, a review of terminology, databases and indices are developed in an attempt to redefine a measurement of risk applicable to selected countries.

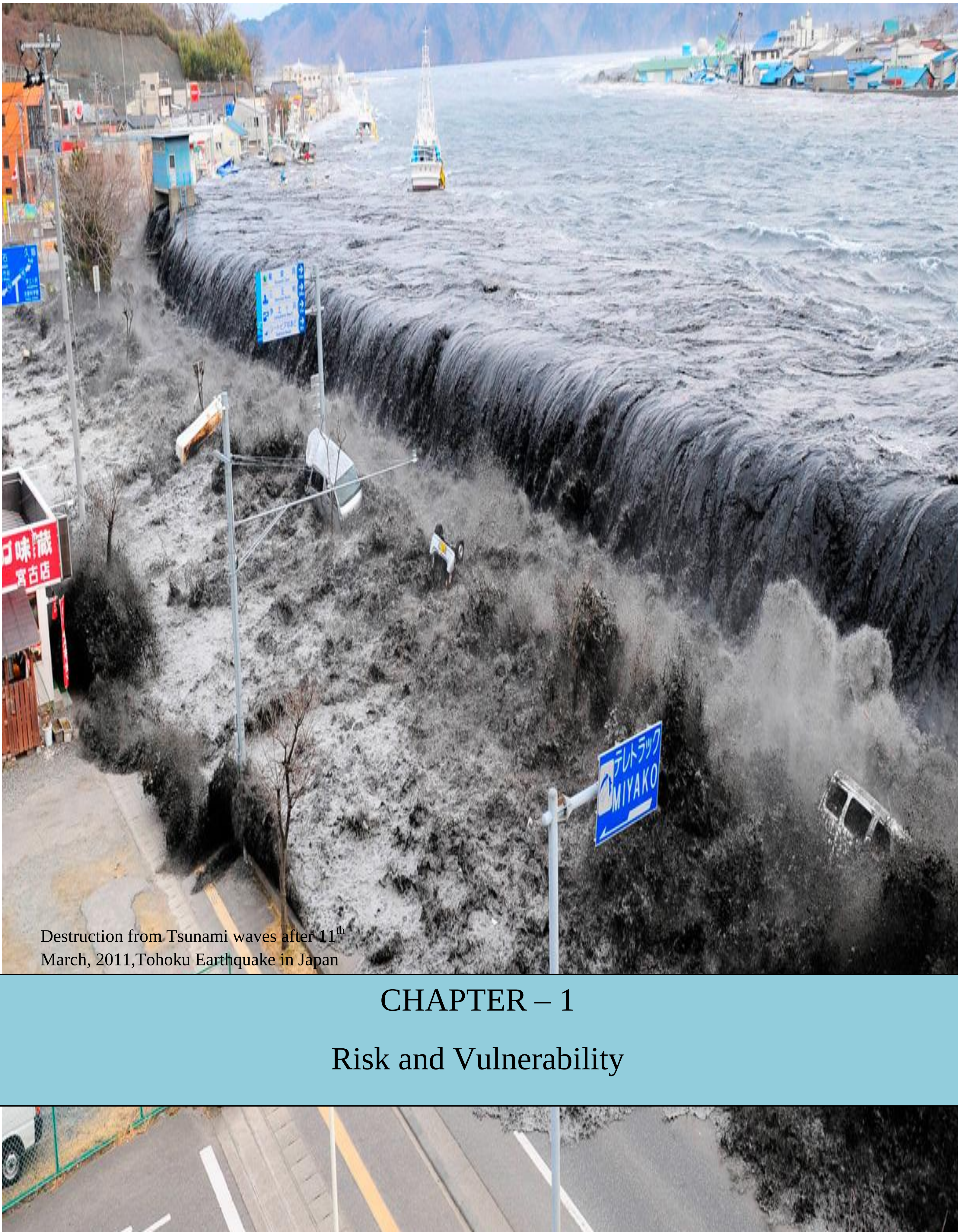
Chapter 1 defines the concepts of risk, vulnerability, exposure and resilience, and how the interpretations of these last three influence the meaning of risk. Global trends of risk are presented, revealing the increase of disaster events. Also, the purposes and limitations of risk indices are described.

Chapter 2 then analyzes the different databases. The differences in the definitions of *disaster* are reviewed, followed by the individual data entry criteria and the recording of the date of the event. Finally, the classification of disasters and the sources of information are presented.

Then, Chapter 3 reviews and compares the methodologies of the Disaster Risk Index from the UNDP, the Hotspots Program from the World Bank and Columbia University, the Americas Program from the Inter-American Development Bank and the Universidad Nacional de Colombia and the ENSURE Program. The pros and cons for each index program are described. Subsequently, the results for the indices applied to Chile, Colombia and El Salvador are presented and compared.

Next, Chapter 4 provides an explanation of the importance and relevance of the Risk Management Index (RMI), followed by the development of a proposed complementary measure to the Local Disaster Index (LDI). This complement, the LDI (2), is calculated using three different datasets for Chile, Colombia and El Salvador. A comparison to the computed LDI (2) for India and United States is also developed. Lastly, the redefinition of the indicators to the Prevalent Vulnerability Index (PVI) is proposed.

Finally, conclusions and reflections on cross cutting issues affecting the global trends of risk are assessed. Recommendations for improvements and future work are proposed.



Destruction from Tsunami waves after 11th March, 2011,Tohoku Earthquake in Japan

CHAPTER – 1

Risk and Vulnerability

Risk and Vulnerability

1.1 Risk

Disaster risk is considered to be a function of hazard, exposure of vulnerability. Disaster risk is expressed as the probability of loss of human life or damaged or destroyed assets in a given period of time. UNISDR defines the risk as the combination of the probability of an event and its negative consequences. The number of natural disasters has been increasing in the last 50 years due to such external changes as the concentration of populations and property in hazardous areas, rapid urbanization and climatic change issues etc. Natural phenomena referred to as "hazards", are not considered to be disasters in themselves. It is the exposure of people and assets and their vulnerability to the event which convert these hazards into the disasters. For example, an earthquake that occurs on a desert island does not trigger a disaster because there is no existing population or property affected. In addition to a hazard, some "vulnerability" to the natural phenomenon must be present for an event to constitute a natural disaster. In general, "risk" is defined as the expectation value of losses (deaths, injuries, property, etc.) that would be caused by a hazard (ADRC, 2005). Following figure explains how natural disasters develop:

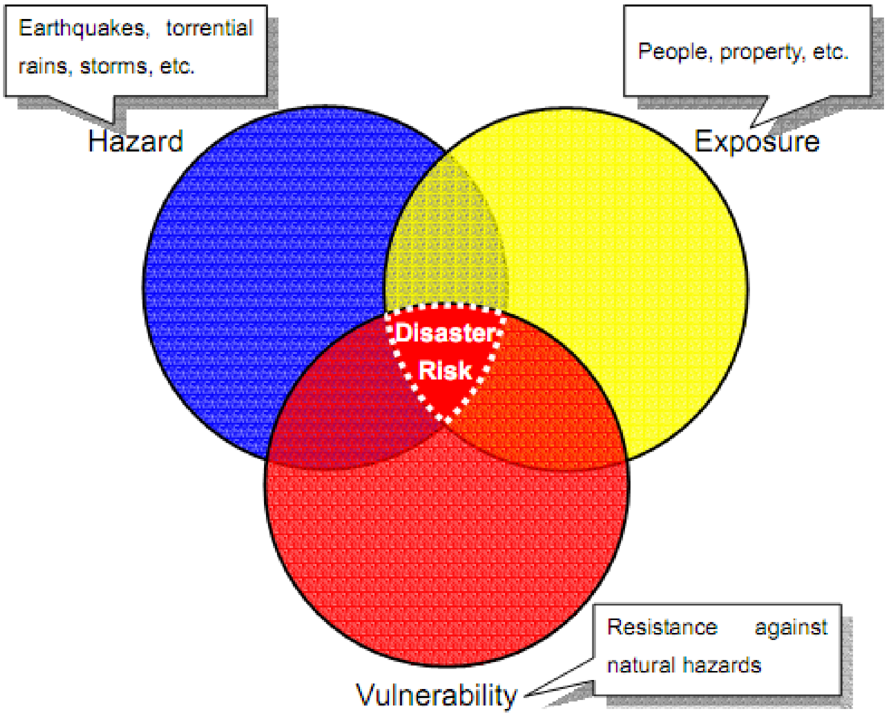


Figure 1: Development of Natural Disasters (ADRC, 2005)

In mathematical terms, risk can be represented by:

Risk= Hazard * Exposure * Vulnerability

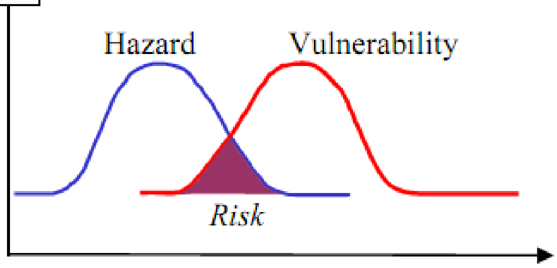


Figure 2: Risk Equation (ADRC, 2005)

It is important to reduce the level of vulnerability and to keep away exposed population and assets by relocating them to a safe location for the disaster risk reduction. The following figure shows the reduced area of risks in comparison to the above figure

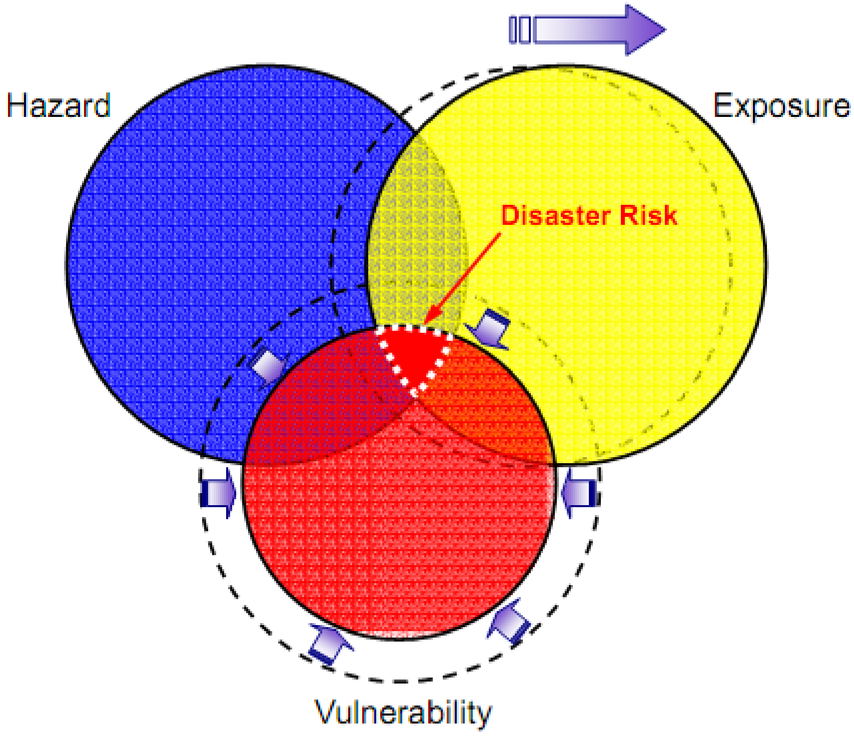


Figure 3: Reducing Disaster Risk (ADRC, 2005)

Disaster risk is geographically highly concentrated. A very small portion area on the world map contains most of the risk and most large scale disaster occurs in these areas only. Except this, most of the areas in the world are affected with low scale and frequent events which may not contribute much in the high mortality but certainly they are linked with the development of local areas in terms of number of people affected and social and economic disruption of life. To get a complete picture of risk, it is better to divide the disaster risk into two parts as intensive and extensive risk.

Intensive risk is defined as the risk associated with the exposure of large concentration of people and economic activities to increased hazard events, which can lead to potentially catastrophic disaster impacts involving high mortality and asset loss (UNISDR 2009). Mortality and direct economic losses are highly geographically concentrated and associated with a very less number of hazards. People and property are exposed to very severe hazards (like earthquake, flood and cyclone) in these areas. It is noted that between January 1975 and October 2008, 0.26 percent of the events recorded accounted for 78.2% of mortality (Global Assessment Report 2009, UNISDR).

Extensive risk is defined as the widespread risk associated with the exposure of dispersed populations to repeated or persistent hazard conditions of low or moderate intensity, often of a highly localized nature, which can lead to debilitating cumulative disaster impacts (UNISDR, 2009). The wide spread low intensity losses related to the hazards like storms, flooding, fires, landslides etc. , may not add up very high to mortality and destruction of economic assets but they have a great impact on the large number of people affected, damage to local infrastructure, crops and particularly affect the low income household and communities. Extensive risk has direct impact on the development of the local areas.

As almost all (97%) of extensive risks are associated with weather related hazards, it also focuses the impact of climate change in the increasing number of disasters. GAR 2011 highlights the point that extensive risk of today can become the disaster loss of tomorrow. For example, low seasonal flooding of Dhaka city is an indicator of growing intensive earthquake risk and areas with manifestation of extensive flood risks are likely to experience intensive risk. Figure 4 explains the difference of mortality in intensive and extensive risk and impact of extensive risk in last 20 years.

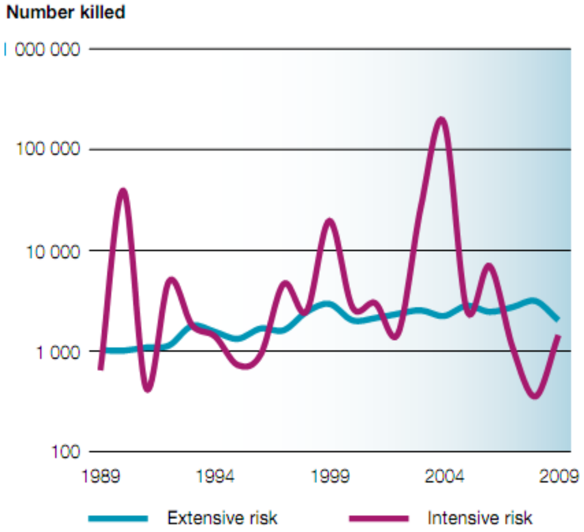


Fig. 1. Mortality from extensive and intensive disasters in 20 countries in Asia, Africa, Latin America and middle east

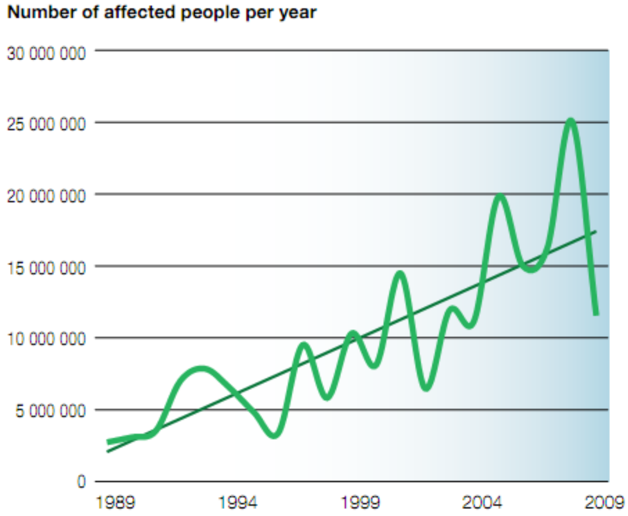


Fig. 2. Number of people affected due to extensive risk in 21 countries

Figure 4: Intensive and Extensive Risk (GAR 2011, UNISDR)

Global Trends of Risk:

More than half of the world population now lives in cities, increasing from 30 % in 1950. In the last two decades, world has seen a rapid increase in the number of disasters. It can be attributed to the better reporting of disasters in comparison to 20 years before or increasing exposure of people and property or both. GAR 2011 reveals the fact that although physical vulnerability has been decreased in the last two decades with the continuous growth of the cities in the world but exposure is continuously increasing and the rate of increase of exposure in much higher than the rate of decrease in the vulnerability and hence the risk is growing continuously in the world. Most of the governments have failed to deal with the complex problems arising with the urbanization. Climate change has also played a vital role in increasing the number of disasters.

Different hazards killed about 3.3 million people between 1970 and 2010, an annual average of 82,500 deaths world-wide in a typical year (World Bank 2010*)*. In 2010, 385 natural disasters killed more than 297 000 people worldwide, affected over 217.0 million others and caused US$ 123.9 billion of damages. A total of 131 countries were hit by these natural disasters, though only 10 countries accounted for 120 of the 385 disasters (31.2%) (EM-DAT, 2010). 87.7 % of global victims of these disasters belong to six countries of Asia. Developing or poor countries contribute most to the number of deaths and maximum economic losses are faced by the rich countries. Figure **5** shows the disaster risk pattern on the world map and also the list of the top 15 countries affected with extreme level of risk which is prepared by global risk advisory firm "Maplecroft".

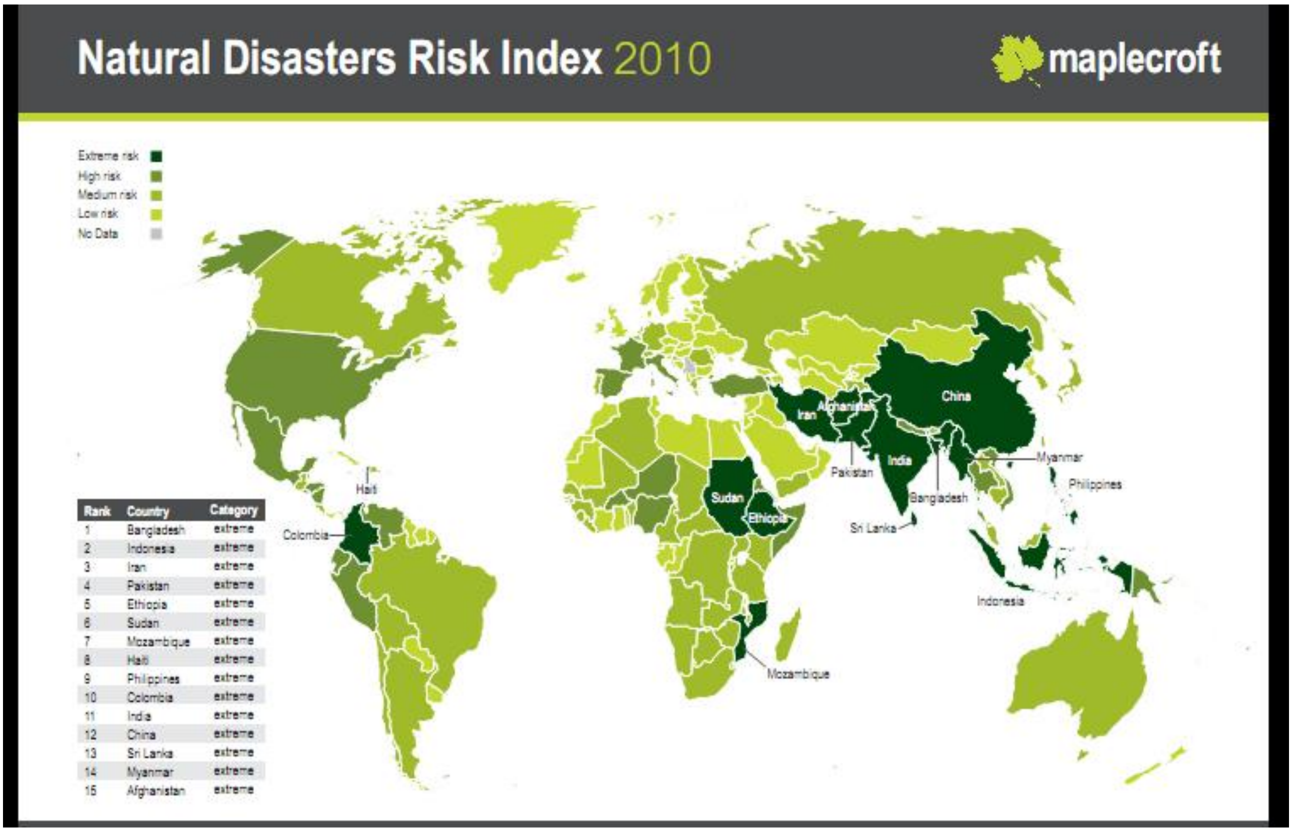


Figure 5: National Disaster Risk Index 2010 (Maplecraft, 2011)

Figure **6** shows the increase in the number of disaster events meeting the EM-DAT criteria. Asia Pacific has been badly hit by maximum number of events followed by Africa and Americas. It is observed that number of disaster events has been increasing continuously after 1985.

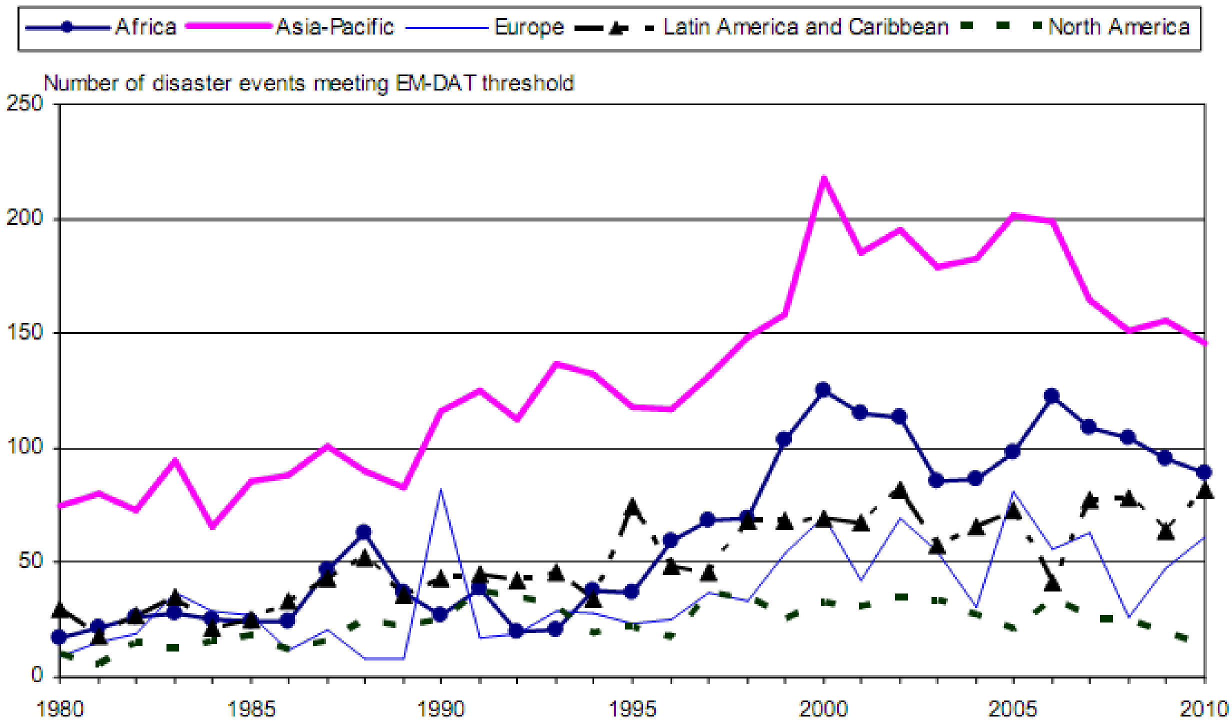


Figure 6: Events Meeting EM-DAT Criteria (ESCAP, 2011)

Figure **7** shows the number of deaths recorded between the period of 1980-2010 due to different disaster events. Asia Pacific region has the maximum number of mortality and there is sharp increase in the number of dead people after year 2000. Higher value of mortality for Latin America and Caribbean in year 2010 is due to the deadly earthquake of Haiti which took the life of more than 200 thousand people. It reflects that poor region like Asia and Africa contribute to maximum number of deaths. This can be attributed to the poor urban planning, badly constructed buildings, poverty and weak governance etc. Although rich countries in Europe and North America face lot of natural hazards but they have very less mortality.

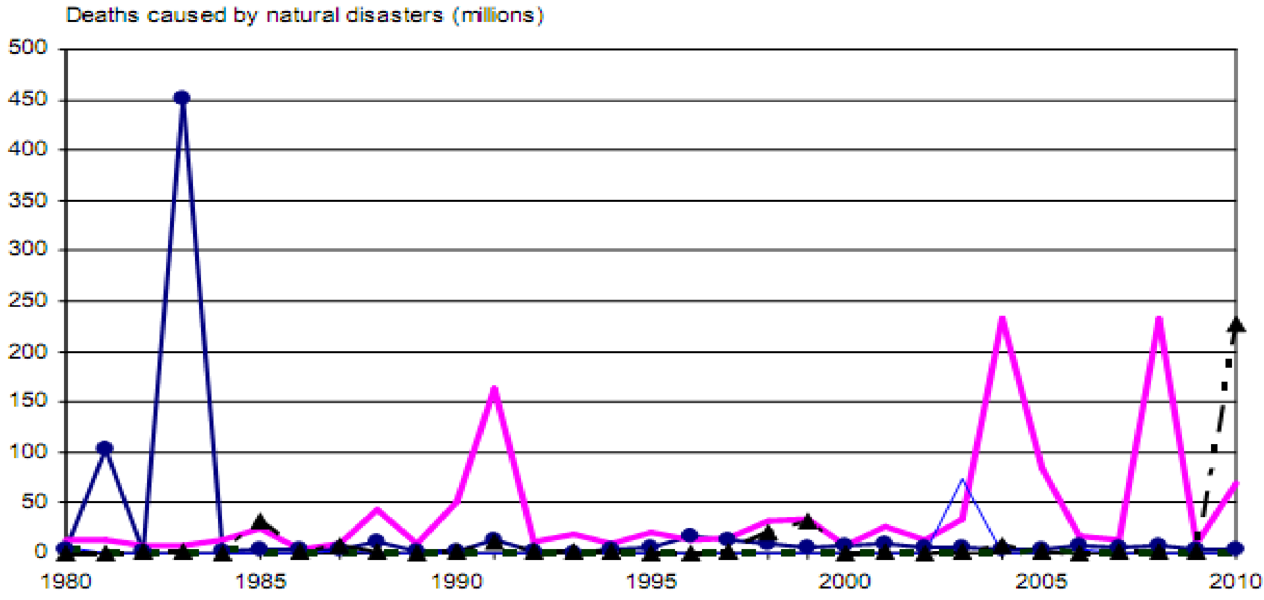


Figure 7: Deaths by Natural Disasters (ESCAP, 2011)

Economic damage caused by natural disasters is also increasing continuously as more and more property is exposed to hazards as countries and cities are developing. Developed countries faced a large part of absolute economic losses but that is not much compare to the GDP of those countries and they are able to absorb this economic shock. Although poor countries have less economic losses in absolute terms but that their relative economic loss (in comparison to GDP) is much higher and for big disasters, they are not able to cope up with those losses and it brings back the economy of the countries to few years.

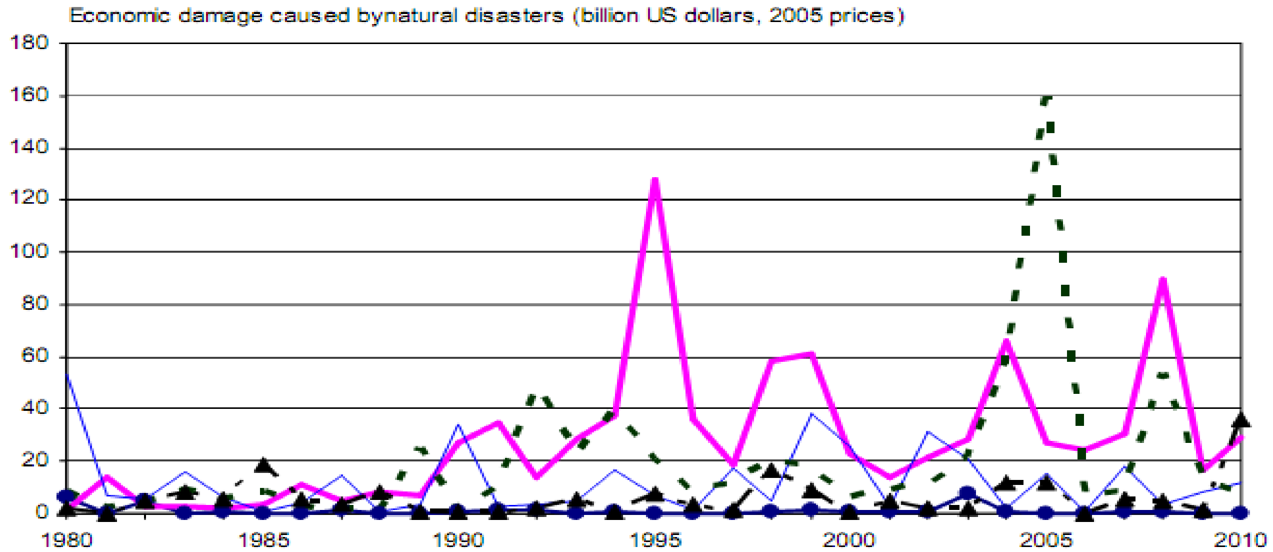


Figure 8: Economic Damage by Natural Disasters (ESCAP, 2011)

1.2 Risk Index: Purpose and Limitations

Formulation of an index of anything is invariably an exercise in generalization, where one is bound to exclude what many may consider important variables, and present a static snapshot of dynamic reality (Vincent, 2004). While impact of full conceptual and analytical weight of risk may be reduced by the quantitative measure, its communicative impact in terms of concrete critical information to non-expert policy-makers cannot be underestimated. Quantification of risk as risk index provides the opportunity to compare the countries facing the disasters and encouraging them to take appropriate measures to strengthen their abilities to cope with disaster risks and bounce back in much stronger way to face the future events.

World disaster conference on Disaster Reduction held in Kobe, Japan in 2005 defines the priorities of developing the indicator system for disaster risks and vulnerability as one of the key activities enabling decision makers to assess the possible impacts of disasters. Risk indices facilitate to convince the parliaments and governments in taking the appropriate actions to reduce disaster risk and provide them an insight to use limited fund efficiently.

Care should be taken while defining the indicators as poor quantitative analysis hamper the government in making right choices in disaster risk management policies. Risk index proved to be very useful for decision makers to take action on priority areas and resource allocation. Risk indices should take into account both physical as well as social and cultural aspects. The index system allows countries or cities to measure their performance in risk management over the years and to identify and fill the gaps in future. Indicators allow reflecting on the potentiality present in a given situation (Cardona, 2003). Indicators are used by the international organizations, NGO, academic institutions, researches and National or local governments to assess the potential risk existing in the country or region which helps them to accelerate their effort in disaster risk management. Measuring risk also allows National governments to allocate their budget to disaster risk issues for the next financial year. International organizations and NGO can also use it for the assessment of their activities and to win the trust of donors for creating funding by showing their achievement in disaster risk management.

Weakness of the indices or indicators is deeply associated with the susceptibility in their estimations, the selection of variables, measurement technique used and aggregating procedures employed (Cardona 2003). As most of the countries are lacking in the systematic data collection, usefulness or reliability of the risk indices depend upon the type of database used. Basic idea behind indicators is to establish a “baseline” assessment of the hazards, exposure and current vulnerabilities and capacities, so that possible future changes can be captured and ideally tied to applied policies and measures (GTZ, 2003).

Indicators defined to calculate the risk index should be chosen carefully and their application of domain should define whether indicators are used in the national, sub-national and local context. Indicators defined in the national scale cannot be applied at the local level because indicators used at macro-level may hide the information at local and regional level. On the other hand if aggregation level is low, information may not be useful enough for national level. Risk assessment at sub-national scales should also be done as indicators defined at local level allow obtaining spatial variability and the dispersion of risk at local level.

The scale at which a risk is evaluated defines not only the purpose but also the outcome of the assessment. When performing a risk assessment at a local scale (i.e. sub-national scale) the uncovered details allow for the identification of the backbone of the issue. Similarly as with the comparison of a city map and the municipal water system plans, the plans identify the details and the components of a system that, when coupled with other systems, generate a city. Likewise, assessments performed at a local scale recognize the individual components and characteristics of vulnerability and exposure that, when aggregated with other local scale assessments, give a more detailed portrait of the situation of risk at a national level. Clearly, such a detail is not always required; some assessments serve the purpose of a general representation, but those that are intended as a complete depiction of the country’s state should consider the aggregation of lower scaled evaluations. Undoubtedly, when a general representation of risk is required, a thorough analysis may be too expensive and time consuming. Different types of vulnerabilities and exposures are identifiable at different scales. Therefore, depending on the aim of the assessment, the appropriate scale is to be employed. The following table is an example of what may be recognized at the different scales.

Scale	Analysis
Micro (ex. municipal)	Structural vulnerability, fragility of lifelines, exposure to individual hazards, domino effects, environmental conditions
Meso (ex. state, department)	Accessibility, systemic vulnerability, exposure to multi-hazard situations, access to resources
Macro (ex. national, multi-national)	Economic systems, resilience (capacities to recover), social vulnerability, access to resources, national risk levels

Table 1: Scales and Assessments

1.3 Vulnerability and Exposure

The term *vulnerability* has many definitions, varying mainly on the field of study. Social sciences, biology, ecology, among others, have unique meanings of vulnerability and risk related terms. The definition of vulnerability and exposure shape the meaning of risk, it is taken from a general potential loss, to a human specific potential loss of life. In general, it can be described through the terms of fragility, susceptibility, or proneness to damage. Exposure, on the other hand, is the state of being accessed by or having the possibility of being impacted by a hazard. A person or an asset is to be both vulnerable and exposed in order to face risk. Being vulnerable but not exposed signifies being fragile but not having the possibility of encountering a hazard event; therefore, it also means not being in risk. Some mistakenly take vulnerability and exposure as synonyms; however, they are two separate characteristics of an individual, a community or an asset in risk. It is important to understand that both vulnerability and exposure are hazard specific. For example, community may be vulnerable to an earthquake but not necessarily be vulnerable to a flood. Vulnerability is a broad term and encompasses several categories. Systemic, structural, environmental, social and physical are just examples of the variations of vulnerabilities. Nonetheless, as different organizations and authors adjust this definition to their own purposes, the meaning of risk is also adjusted. It is clear that risk is a function of hazard, exposure and vulnerability, but the direction vulnerability takes, either exclusive to human lives or encompassing a broader perspective of societies, systems, structures, entities or processes, defines the details of risk.

Inside the field of Disaster Management itself, terminologies also vary; the following are different approaches to the concept of vulnerability and exposure and their effects on the individual visions and descriptions of risk.

The UNISDR defines vulnerability as "the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard" (UNISDR, 2009b). Likewise, it defines *exposure* as "people, property, systems or other elements present in hazard zones that are thereby subject to potential losses". Vulnerability is considered a property of a system and is related to a particular hazard. As discussed before, the UNISDR has two main descriptions of risk, intensive and extensive risk. Along with the broad vulnerability definition, risk is not human being specific. If this organization's view of vulnerability were only as a potential loss of life, then risk would also be restricted to loss of life, however, this is not the case. The disaster risk concepts, according to this agency, are extensive and comprise the loss of assets, services, and functions

On the other hand, the UNDP employs the concept of *human vulnerability* in the DRI program. It is defined as "a human condition or process resulting from physical, social and economic environmental factors, which determine the likelihood and scale of damage from the impact of a given hazard" (UNDP, 2004). This definition is restricted to human beings for its applicability to the DRI, excluding vulnerabilities to economies, structures or others systems and assets. Nonetheless, its use in the DRI includes not only the human conditions, but also the human actions and effects that alter a hazard's impact. As in the UNISDR, the UNDP's definition of vulnerability is hazard specific. Exposure is also separated from vulnerability. *Physical exposure* is defined as "the number of people located in areas where hazardous events occur combined with the frequency of hazard events" (UNDP, 2004). The exclusiveness of vulnerability and exposure to human beings defines the DRI as human specific too. Therefore, the definition of risk in this program entails only the loss of life. Risk, in the DRI, is a function of physical exposure and vulnerability. For this agency, risk is no longer considered as the general expected loss of systems, activities and environments; it is now focused on the human aspects. The definition of vulnerability has transformed the overall risk equation of hazard and vulnerability to a function specifying only vulnerability and exposure, the hazard contribution is consequently embedded in the physical exposure.

Vulnerability is also defined as "the characteristics of a person or group and their situation that influence their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard" (Wisner, et al. 2003). This description is broad and does not have a negative connotation, and is more closely related to *resilience* and *capacity*; nonetheless, it is further explained that "vulnerability can be measured in terms of the damage to future livelihoods". In this situation, vulnerability is again human being specific. A distinction is made between structures and economies, which are unsafe or fragile, but not vulnerable. Vulnerability is time dependent. Risk is composed of the hazard and the number of people, with different vulnerabilities, that are exposed at the time the hazard event occurs. Exposure is, therefore, being at the time and place of the hazard event. The Pressure and Release Model (PAR) explains how risk is the result of a hazard and people, whose vulnerability is a development of a process. It describes the three components of vulnerability, they should not be considered independently, as they are a process which is time and scale dependent. Figure 9, extracted from the book (Wisner, et al. 2003), shows the PAR Model. The first components are the root causes. These root causes are embedded in the idiosyncrasy of the community, they are far from the control by an individual. The three main root causes are the economic, demographic and political systems. The second components of vulnerability, according to the PAR model, are the dynamic pressures. They are the catalyst that triggers the formation of unsafe conditions from the root causes. For example, chronic diseases will make a community more prone to suffer damages, and will make a fragile political system with inefficient health services and no resources a clear unsafe condition for the occurrence of a hazard event. Lastly, the third components of vulnerability are the unsafe conditions. They are "the specific forms in which the vulnerability of a population is expresses in time and space in conjunction with the hazard" (Wisner, et al. 2003). As for the previous example, the unsafe conditions are now a lack of physical resources, medicine or food to deal with the disease when the hazard event occurs.

Lastly, vulnerability is also seen as a proxy of risk, as it refers to the predisposition to damage. The Americas Program considers vulnerability from four different points of view: the social, the physical, the economic and the political. In this vision, the main difference between vulnerability and risk is the fact that vulnerability must be evaluated over time in order to obtain a measure of risk. The spatial and time scales are crucial for dimensioning vulnerability and thus for the understanding of risk.

Vulnerability is sometimes erroneously considered equivalent to poverty. It is true that in some circumstances wealthy communities are less vulnerable than poor communities; however, this is because poverty is a component of vulnerability but they do not have the same meaning. When considering the resources a wealthy community is indeed less vulnerable, given the fact that it may have an easier access to the resources than the less privileged community. Nonetheless, when considering the internal network or laces among people in the case of a calamity, a non-wealthy group may be less vulnerable, as their sense of community, their will of helping each other, or their capacity to adjust to a scarce situation may, for example, be superior. Poor communities may, in some cases, be less vulnerable because of their social networks, their sense of community, or their experience to a previous similar situation. Poverty does not indicate vulnerability; it is to be considered a factor when performing a vulnerability analysis but the two concepts are not to be assumed as equal.

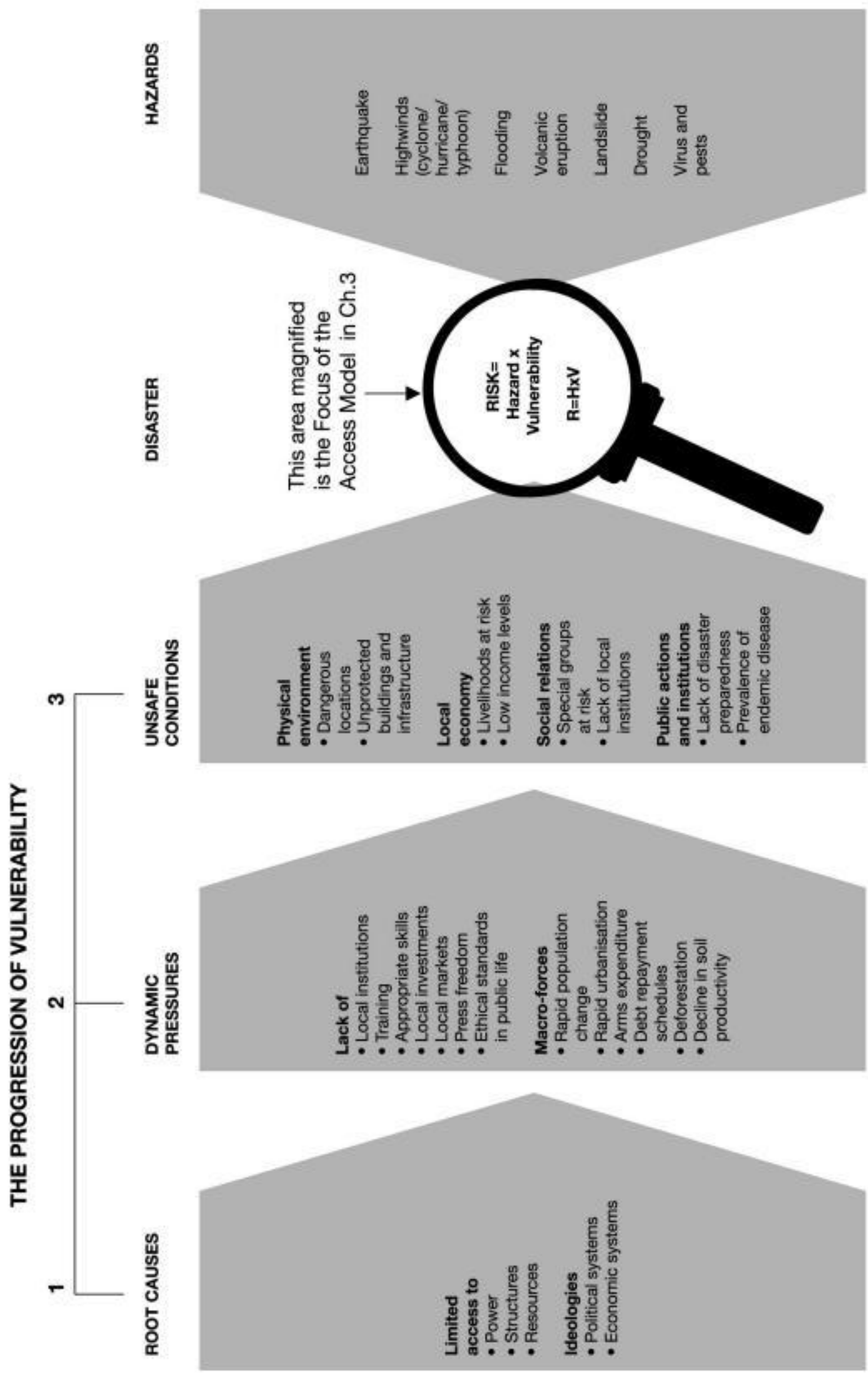


Figure 9: Progression of Vulnerability (Wisner, et al. 2003)

Table 1 summarizes the common usages of vulnerability.

Author	Definition	Specifics
UNISDR	The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard.	Includes population, property, assets. It is not human being specific.
UNDP	A human condition or process resulting from physical, social and economic environmental factors, which determine the likelihood and scale of damage from the impact of a given hazard.	Exclusive to human beings. Risk is thus specific to the loss of human life.
Wisner, Blaikie, Cannon, and Davis (At Risk)	The characteristics of a person or group and their situation that influence their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard. It can be measured in terms of the damage to future livelihoods.	Vulnerability is a process that has root causes which are triggered by dynamic pressures to become unsafe conditions. It is exclusive to human beings. Risk is thus specific to the loss of human life.
O. Cardona	An internal risk factor of the subject or system that is exposed to a hazard and corresponds to its intrinsic predisposition to be affected, or to be susceptible to damage.	Vulnerability is a proxy of risk. It includes the social, physical, economic and political susceptibilities to damage.

Table 2: Definitions of Vulnerability

1.4 Vulnerability and Resilience

When an environmental hazard impacts, some communities have the ability to withstand the effects better than others. This ability to withstand the effects of a catastrophe is *resilience*. As is the case with vulnerability, resilience has different meanings for different authors and organizations. The difference between vulnerability and resilience lies in the fact that vulnerability is measured in a negative sense while resilience is measured in a positive sense of the characteristics of the society. Resilience and vulnerability are very closely related terms but are not necessarily antonyms. One definite common-place definition is not currently established. As opposed to vulnerability, resilience is not commonly measured or calculated, its review, however, is merited through its role in the Disaster Management field.

Resilience is a broad concept. It may be generally described as the ability to recover, absorb or bounce back when facing a natural disaster. Resilience is characterized by the availability of resources. It is not only post disaster specific, as it is also defined by the community's organizing abilities both before of and after an event. It may be enhanced prior to the event by educational campaigns, strengthening the access to resources, availability of means of transportation, among others. The capacity to learn and to adapt will, in theory, allow the community to better withstand a future event, minimizing the catastrophic consequences of the natural hazard.

Some authors interpret resilience as a component of vulnerability. Wisner, et al, defined vulnerability in a general manner that, although not stated, includes the concept of resilience. As previously mentioned, vulnerability is defined as the properties of a community or a situation "that influence their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard" (Wisner, et al. 2003). Coping, resisting and recovering are building blocks of the term *resilience*. In this situation, the relationship between the terminologies is clear: less resilient groups are more vulnerable to future events. Likewise, the Americas Program utilizes "lack of social resilience" as an indicator of vulnerability. Careful attention should be paid to this generalization, as these two concepts are independent and are not antonyms.

The autonomy of these two terms is shown on the following figure. As they vary, the severity of the situation also varies. Ideally, a community with low vulnerability and a high resilience will be best prepared for withstanding risks. A low predisposition to suffer damage and a high capacity to reorganize after an event, characterizes the target situation sought for through disaster reduction measures.

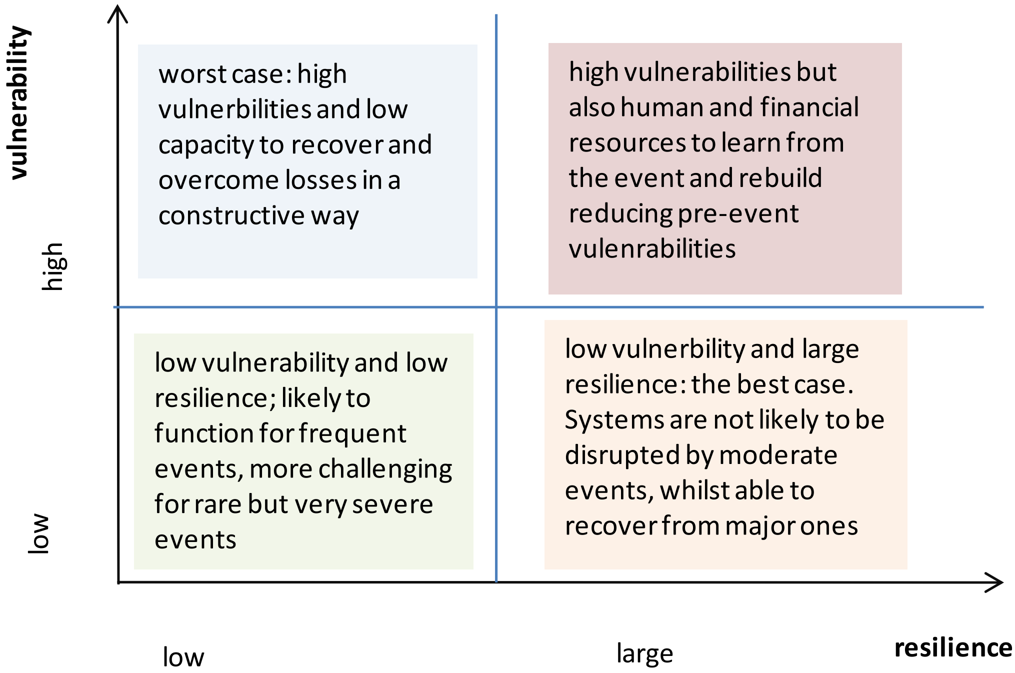
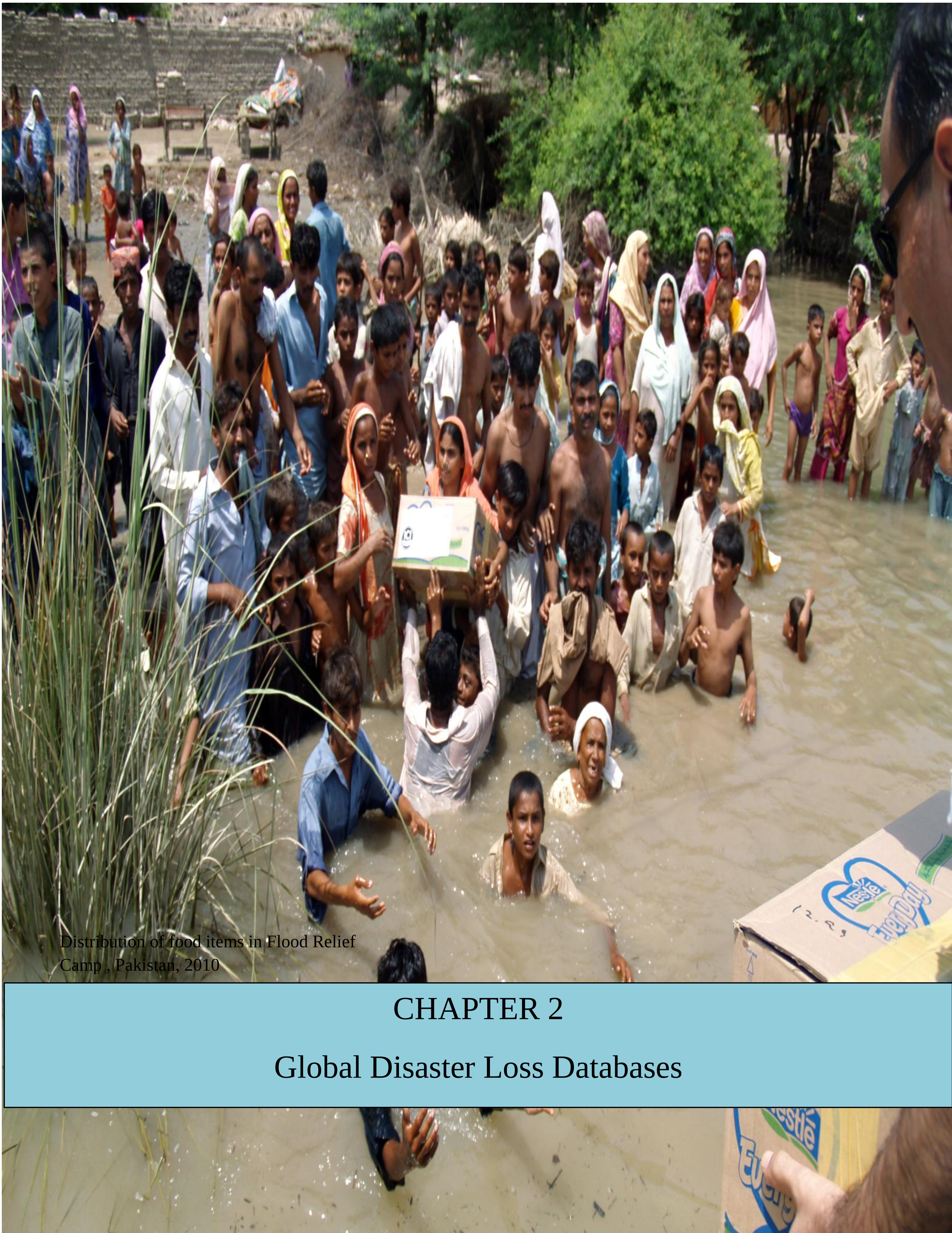


Figure 10: Vulnerability and Resilience (ENSURE, 2011)

Resilience is not exclusively defined by how the negative impacts of an event are handled, but also how the positive aspects, or opportunities, such event may bring are assumed. As stated by Carl Folke, "resilience is not only about being persistent or robust to disturbance. It is also about the opportunities that disturbance opens up in terms of recombination of evolved structures and processes, renewal of the system and emergence of new trajectories" (Folke, 2006).

Measuring resilience is not as widely attempted as measuring vulnerability. A good resilience assessment, though, would complement the evaluation of vulnerability and ultimately the estimation of risk.



Distribution of food items in Flood Relief Camp , Pakistan, 2010

CHAPTER 2

Global Disaster Loss Databases

Global Disaster Loss Databases

2.1 Overview

A well-maintained database of hazards, vulnerabilities and disaster losses provides the strong foundation for risk assessment and helps in the decision making of preventive measures to be taken. It also facilitates in identifying the key areas of development and planning of budget allocations to disaster risk reduction (DRR) activities. Systematic recording of disaster loss data is the crucial step in identifying trends in hazards and vulnerability.

There are very few global disaster loss databases and only one of them is publically freely available. EM-DAT is the only global disaster loss database available publically which is managed by CRED (Centre for research on Epidemiology of Disasters), University of Louvain, Belgium. Other global disaster databases are NatCat and Sigma, managed by Munich Re and Swiss Re reinsurance companies respectively, but they are either partially available or not available. The quality of the data in all these databases varies as they use different sources and methodologies to collect the data. DesInventar database is also discussed here although it is not really global and it contains the disaster loss data of primarily Latin American and Caribbean countries. But this database provides the information on a finer resolution which helps in identifying the impact of local hazards. DesInventar database is maintained by LA-RED.

For many countries, relevant data is unavailable or inaccurate. 90% of the countries that endorsed the Hyogo Framework for action (HFA) do not currently have functioning and institutionalized system for disaster losses (GAR, 2011). Data regarding disaster impact, especially for small scale disasters and environmental consideration of impact as well as long term effect of the disasters, is still lacking. Generally national databases are heterogeneous, dispersed and inaccessible. Being adopted different methodologies and selection criteria, it makes rather a very difficult job to compare the information available in different database systems. There is a need to work towards the standardization of all issues related to the technical soundness, political neutrality, methodologies and process related to the collection, analysis, storage, maintenance and dissemination of data (UNISDR, 2004).

Resolution level of disaster loss data also affects the interpretation of risk. All three global databases has a very large scale resolution which will not help in identification and classification of risk at sub-national and local level. There is a need of data inventory system to be set up in each and every country which will assist them to measure the disaster risk at local level and to adopt the more effective risk sensitive planning for taking mitigation measures.

2.2 Comparison among EM-DAT, NatCat, Sigma and DesInventar:

Accurate accounting of disaster loss is a very important aspect for improving disaster risk management. There is no thumb rule to compare the dataset as they have been prepared under different methodologies, using different criteria and for specific purposes and clients. EM-DAT focuses mainly on the humanitarian approach taking into account the number of people dead, affected or missing while NatCat and Sigma have been prepared with respect to the insurance industry concentrating on the economic losses. Although being publically available, EM-DAT has been most widely used in the applied and researches context. The following table provides the overview of all four databases:

Parameters	EM-DAT	NatCat	Sigma	DesInventar
Access	Public	Partially Public	Partially Public	Public
Geographical Scale Covered	Global	Global	Global	Regional
Period Covered	1900-present	79AD-present	1970-present	Mostly 1970 onwards
Number of entries	>17000 (May 2008)	>28000 (800 entries/ year)	>8000 (300 entries/ year)	>44000
Type of disasters	Natural (including epidemics) and man made disasters + conflict	Natural Disasters (excluding drought and man made, i.e. technological disasters)	Natural and Man made disasters (excluding drought)	Natural + Technological disasters including epidemics
Methodology	Country entry	Country and event entry (all disasters geo-coded for GIS evaluations)	Event entry	Country entry
Entry Criteria	10 or > deaths and/or 100 or > affected and/or Declaration of a state of emergency/call for	· Entry if - any property damage, any person sincerely affected (injured, dead) · before 1980, only	> 20 deaths and/or > 50 injured and/or > 2000 homeless and/or insured losses	a set of adverse effects caused by social-natural and natural phenomena on human life, properties and

	international assistance	major event	>14 million US$ (Marine), >28 million US$ (Aviation), >35 million US$ (all other losses)and/or total losses in excess of 70 million US$ * does not report affected only homeless	infrastructure within a specific geographic unit during a given period of time
Priority Sources	UN Agencies	Priority given to Lloyd's list, Reuters, Reports from clients and branch offices, Insurance press	Not Specified	News Media

Table 3: Overview of Databases

Differences in the Definition of disaster in EM-DAT, NatCat, Sigma and DesInventar:

Difference in the definition of *disaster* in all these databases itself creates the difference in the data collection criteria. EM-DAT defines the disaster as "a situation or event, which overwhelms local capacity, necessitating a request to national or international level for external assistance, an unforeseen and often sudden event that causes great damage, destruction and human suffering" (CRED, 2006).

NatCat made a distinction between geophysical, meteorological, hydrological and climatological events Figure 11 which are then further subdivided into event groups (e.g. windstorms) and event types (e.g. tropical storms). The data are additionally structured according to catastrophe classes reflecting the impact of a catastrophe in financial and human terms. They are classified on a scale from 0 to 6. Catastrophe class 0 comprises natural events without financial or human losses; these are included in the database, but are not used for evaluation. Catastrophe classes 5 and 6 comprise the great and devastating natural catastrophes, and play a special part in the entire system.

According to Sigma, "a natural catastrophe is a harmful event determined by natural forces. Usually, this event produces many single accidents involving a lot of insurance contracts" (Swiss Re, 2007).

DesInventar defined *"disaster"* as the set of adverse effects caused by social-natural and natural phenomena on human life, properties, infrastructure and environment (an *"Event"*) within a specific geographic unit during a given period of time. DesInventar attempts to collect the more standard variables of number killed, injured, and estimated economic costs, but also attempts to collect less easily quantifiable variables surrounding infrastructure damage as a means of detailing the social effects of disasters. Because of the national level of data collection DesInventar is able to collect detailed information of small and medium scale disasters that are often not represented in larger scale databases, though it has been recognized that this level of resolution contributes to the exaggerated numbers of people affected (CRED,2006).

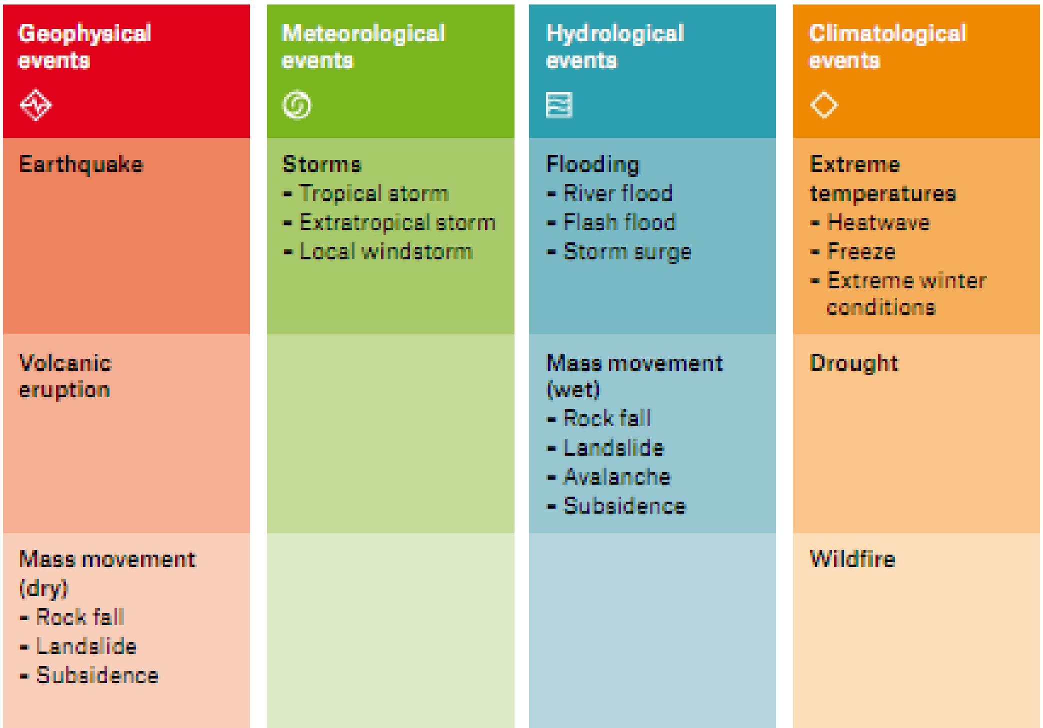


Figure 11: NatCat Events (Munich Re, 2011)

Difference in the data entry criteria:

Events to be included in EM-DAT should fulfill at least one of the following criteria:

- 10 or more people reported killed
- 100 or more people reported affected
- Declaration of state of emergency
- Call for international assistance

NatCat database concentrates on loss events due to natural hazards resulting in property damage or bodily injury. Natcat provides much more scientific data such as such as wind speed, magnitude, and geocoding, along with the mortality and economic losses but it has no thresholds to include a event. NatCat include an item in the database entry for each loss declared in a given event.

One of the following criteria must be met in order to include an event in the Sigma database:

- 20 or more deaths
- 50 or more people injured
- 2000 or more people homeless
- Economic criteria such as insured losses exceed more than $14m in respect of marine and $28m in respect of aviation or $35m in respect of all other losses and /or total losses in excess of $70m

DesInventar also does not have any threshold to include an event in the database. Absence of such criteria in NatCat and DesInventar explain the large amount of data in these two databases.

Difference in recording the date of event:

Problem occurs even in the recording the date of an event. Same even can be reported at different dates, especially for disasters like flood and drought that continue for a long time. In this case, event has to be verified with respect to the location where disaster occurs. Generally NatCat and Sigma record a period for the disaster (start/end) while EM-DAT records the day it was declared as an humanitarian emergency by one of the priority sources (*CRED, 2005*). Reported economic damages are always attributed to the end year of the disaster because only after the disaster has concluded can the full amount of damages can be reasonably estimated (*Menoni 2011*).

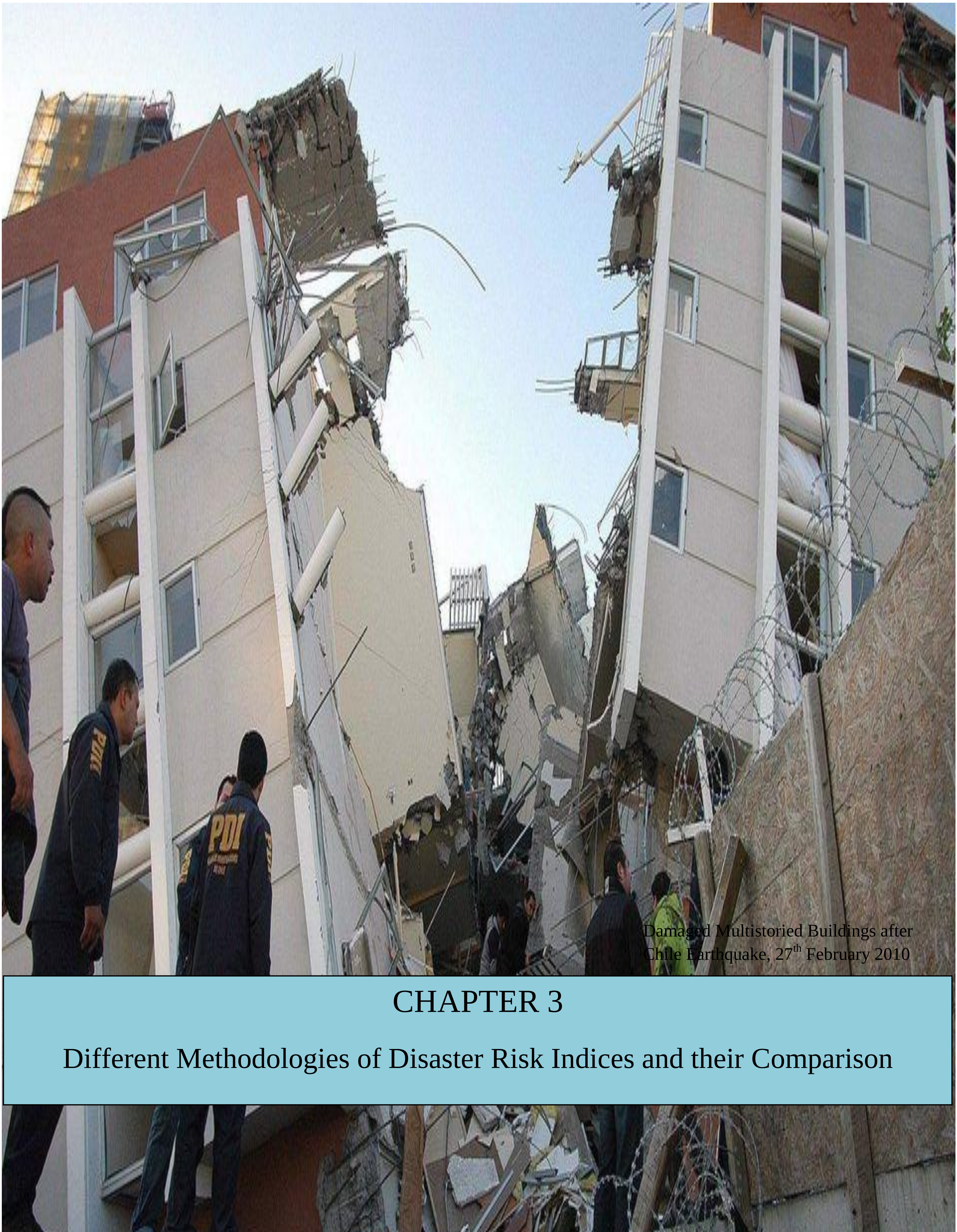
Difference in the Classification of Disasters:

There can be differences between the classification of disasters too. It happens particularly to the associated or secondary disasters. The flood can be consequences of tropical cyclone or Tsunami and similarly landslide can be initiated due to the earthquake. There can be discrepancies in the recorded event as loss due to disaster may be reported twice under two different disasters (primary and secondary) in the same time period and it has to be verified.

Difference in the Information Sources:

Sources of EM-DAT include governments, UN agencies (UNEP, OCHA, WFP, and FAO), NGOs (IFRC), research institutions, insurance institutions (Lloyds) and press agencies, although priority is given to UN agencies because of EM-DAT's humanitarian interests. Amongst disaster databases, EM-DAT provides one of the most comprehensive and transparent explanations of the methodology employed (CRED, 2006). NatCat database include national insurance agencies, Lloyds, press and media, UN agencies, NGOs, world weather services, clients and subsidiaries but priority is given to clients and branches, and insurance industry reports.

Sigma's sources of information include newspapers, Lloyds, primary insurance and reinsurance periodicals, internal reports, and online databases although no primary source is suggested. Lack of public accessibility to the Sigma database makes it difficult to report on the ability to search the database. Though DesInventar utilizes government agencies, NGOs, and research institutes for source data, it relies heavily on news media as a priority source which remains controversial. Disaggregating the data for individual events provided in the DesInventar database continues to be a challenge.



Damaged Multistoried Buildings after Chile Earthquake, 27th February 2010

CHAPTER 3

Different Methodologies of Disaster Risk Indices and their Comparison

Different Methodologies of Disaster Risk Indices and their Comparison

3.1.1 DRI Program

Background and Aim: Disaster Risk Index (DRI) of the United Nations Development Programme (UNDP), in collaboration with the UNEP-GRID was the first effort to measure the disaster risk quantitatively. The main objective of the DRI was to improve the understanding of the relationship between development and disaster risk. DRI enables the comparison of relative levels of physical exposure, vulnerability and risk between countries. DRI also provides the quantitative fact to redefine development plan and policies to mainstream the disaster risk reduction and risk management. DRI has a global coverage and a national scale of resolution. DRI allows to make the comparison of disaster risk between countries for three different hazards: earthquake, tropical cyclone and floods.

Database Used: Mortality rate (number of people killed or number of people killed per million population) is used as the risk indicator for the computation of DRI for different countries. Economic loss is not taken into account as a risk indicator because less data is available on it. Mortality data is used from EM-DAT which is the largest and the only global disaster dataset available publically. EM-DAT takes into account the medium and large scale disasters only as it includes the information of those disasters which fulfill the following criteria: 10 or more people killed, 100 people reported affected or a call for international assistance/ declaration of state of emergency.

Methodology: DRI is calculated for the specific hazards. The following are the steps for calculating the DRI of different countries:

1. All the required geophysical data is collected to produce the hazard maps for the earthquakes, cyclones, drought and flooding.
2. The different hazards are modeled for calculating the frequency of hazards for each location of the world. The event frequency is computed by the following relation:

   Event Frequency = $\frac{number\ of\ events\ for\ the\ given\ area}{number\ of\ years\ of\ observation}$

3. The exposed population is obtained by overlaying the population maps in a GIS system.
4. The physical exposure is obtained by multiplying the frequency of hazard of given magnitude with the population affected.

5. In DRI, vulnerability includes the indicators which reduce the absorbing and recovery capacity of people prone to risk. Indicators of vulnerability index also include those indicators which can increase the frequency, severity, unpredictability of hazard and decrease the vulnerability like early warning system etc. DRI measures the human vulnerability in two ways. The first is the relative vulnerability:

$$\text{Relative Vulnerability} = \frac{\text{number of people killed}}{\textit{number} \text{ of people exposed to particular hazard type}}$$

The second measure of vulnerability includes the 24 socio-economic variables to represent eight categories of vulnerability. Table 1 represents all the 24 variables and their data sources:

Table 1: Vulnerability Indicators

Categories of Vulnerability	**Indicators**	**Source**
Economic	GDP per inhabitant at purchasing power parity	**WB**
	Human Poverty Index	**UNDP**
	Total Debt Service (% of the exports of goods and services)	**WB**
	Inflation, food prices (annual %)	**WB**
	Unemployment, total (% of total labour force)	**ILO**
Type of Economic Activities	Arable land (in thousands hectares)	**FAO**
	% of Arable land and permanent crops	**FAO**
	% of Urban Population	**UNPOP**
	% of Agriculture's dependency for GDP	**WB**
	% of labour force in agriculture sector	**FAO**
Dependency and Quality of Environment	Forests and woodland (in % of land area)	**FAO**
	Human Induced Soil degradation	**FAO/UNEP**
Demography	Population growth	**UNDESA**
	Urban Growth	**GRID**
	Population Density	**GRID**
	Age Dependency ratio	**WB**
Health and Sanitation	% of people with access to improved water supply (total, urban, rural)	**WHO/UNICEF**
	No. of Physicians (per 1000	**WB**

	inhabitants)	
	No. of hospital beds	**WB**
	Life expectancy at birth for both sexes	**UNDESA**
	Under five years old mortality rate	**UNDES**
Early Warning Capacity	No. of radios (per 1000 inhabitants)	**WB**
Education	Illiteracy rate	**WB**
Development	Human Development Index (HDI)	**UNDP**

Table 4: Vulnerability Indicators (UNDP, 2004)

6. Risk is calculated by the following equation:
   Risk = Hazard × Exposed Population × Vulnerability
   Or Risk = Physical Exposure × Vulnerability

Pros and Cons - DRI Program

1. The DRI represents the number of deaths due to a particular hazard. Although Mortality rate is one of the aspects of disaster risk, it is still used as the indicator of risk, as it is the most widely available data in global databases for comparison. Even injured people cannot be used as comparison as it depends upon the number of health facilities to register this record. Disasters like flood and drought may cause very few deaths but they produce a huge economic loss and social disruption. Deaths do not reflect the human development loss. Inclusion of economic loss data will strengthen the DRI.

2. DRI deals with medium and large scale risks only. If included, small scale and everyday disaster can produce a different picture of losses.

3. DRI should not be used to predict the future risk because it uses the past hazards exposure and past data to calculate the risk values. It is assumed that the event will occur most likely in the same nature in the future, which is not a reality at a finer resolution.

4. DRI uses the mortality rate in the calculation of vulnerability. Mortality is the most reliable indicator of human loss at global level. It provides a hard figure but has a little impact on the policy itself. Drought is associated with more loss of life than any other hazard. However, it is actually more affected by other cross cutting issues like armed conflict, corruption, chronic diseases, poverty and poor governance etc. In the case of drought, deaths alone do not represent actual loss.

5. The DRI represents risks associated with earthquakes, tropical cyclones and floods (also drought but work in progress) which account 94% of total mortality. DRI do not consider the secondary hazards triggered by the primary one which can also produce a substantial amount of loss.

6. As DRI used the data between 1980-2000, countries who faced less frequency but sever intensity hazards outside this period do not necessary represent the true picture of risk.

7. DRI used vulnerability factors which are output oriented instead of input taken. Vulnerability indicators for which sufficient data was not available, have been omitted from final calculations. In future there may be some other important indicators also for which data was not present at the time of DRI study.

8. Governance and management to deal with the disaster risk in a country change over time. Present DRI do not take into account the indicators based on disaster risk management. Risk management indicators should be considered as it reduce the vulnerability of the system. In future, it can also be used as a strong tool to compare the risk reduction strategies of different countries.

3.1.2 HOTSPOTS Program

The Hotspots program, developed by the World Bank and Columbia University, has the aim of mapping the areas that have a high risk, not considering national boundaries but considering instead a gridded world map. The project's objectives are to generate a global risk assessment using spatial distribution of hazards, vulnerability and exposure, rather than national statistics and national boundaries, with a clear definition of the hazard and vulnerability components of risk. The program is targeted for international organizations that work with risk related issues, national and local governments.

The word Hotspot is defined as "a specific area or region that may be at relatively high risk of adverse impacts from one or more natural hazards" (Dilley, et al, 2005).

The three indices developed as part of this program are the following:

1. Mortality risk
2. Risk of total economic loss
3. Risk of economic losses as a proportion of the GDP.

The hazards considered are earthquakes, cyclones, floods, landslides, droughts and volcano eruptions. The hazard figures are obtained from historical data; however, a significant amount of data is not available for many countries; therefore, the gridded, spatially uniform approach is beneficial. The program recognizes that it is not an absolute representation of risk, instead, it is a representation of the relative levels of risk per geographical area.

The three elements of risk are the hazard, represented by its probability of occurrence, the exposure and the vulnerability to a specific hazard. Hotspots are divided in two categories: single-hazard hotspots and multi-hazard hotspots. Since there is no measure to quantify physical fragility and social vulnerability, some proxies of vulnerability have been used. The masked population density, GDP, and transportation network density are normalized to the total losses reported. The grid used in this project is of 2.5 minutes by 2.5 minutes, creating approximately 8.7 million cells. Cells with less than five residents per square kilometer have not been included; therefore, approximately 4.1 million cells remain after the population exclusion is performed. Additionally, the land area is divided into seven regions and four wealth ranks, creating twenty-eight loss rates.

The following are the steps followed for the risk assessment of mortality, a similar procedure is followed for the risk assessment of economic losses (Dilley, 2005):

1. The total casualties are obtained from the EM-DAT (M_h).
2. The total population estimated to live in the area affected by the particular hazard is obtained using GIS (P_h).
3. Mortality rate per hazard is calculated by $r_h = M_h / P_h$
4. The location specific mortality is calculated (per grid cell) by multiplying the location's population by the previously calculated mortality rate:
   $M_{hi} = r_h * P_h$
   This is calculated for the six hazards and then a mortality weighted multi-hazard index value for each grid cell, i, is calculated:

   $$Y_i = \sum_{h=1}^{6} P_{hi}$$

5. The estimated mortality in a given cell is $M_{hij} = r_{hj} * P_i$, where j represents the twenty-eight combinations of region and wealth rank, the loss rates.
6. The accumulated mortality is $M'_{hij} = r_{hj} * W_{hi} * P_i$ where W_{hi} represents the hazard degree in terms of the frequency (during the 20-year period analyzed).
7. The weighted mortality per hazard h in a grid cell i is:

$$M^*_{hij} = \frac{M'_{hij} \times M_{hj}}{\sum_{i=1}^{n} M'_{hij}}$$

8. A mortality-weighted multi-hazard disaster risk hotspot index is:

$$Y^*_i = \sum_{h=1}^{6} M^*_{hij}$$

9. The Y^*_i is transformed to a scale of 1 to 10, to avoid having an index in terms of fatalities, by classifying the unmasked grid cells into deciles.

Pros and Cons - Hotspots Program

The Hotspots program benefits from the data gathering technique used. The spatially uniform grid cells permit the risk analysis per region, as opposed to per country. Since some countries fail to effectively record losses, a regional analysis allows for a clearer view of the areas at high risk.

The Hotspots program recognizes that it is not an absolute measure of risk, but more a relative representation of risk levels. There is no extreme value usable as reference.

The risk analysis computations are based on historical data obtained from the past 20 years. Many hazards have not materialized into events in these past 20 years; however, the potential for a natural disaster still exists. Risk levels between different hazards are therefore not comparable. Also, when using historical data, it is assumed that the event will occur most likely in the same nature in the future, which is not a reality at a finer resolution.

Internal armed conflict, corruption and chronic diseases are examples of what may considerably affect mortality rate during a natural disaster. These aspects are not considered nor included in the global databases used in this program.

Local recurring events that generate a considerable amount of loss are not included in the risk analysis, as it focuses on six major type of events.

3.1.3 Americas Program

The IDB-IDEA program developed four indices with the purpose of providing "national decision makers with access to the information that they need to identify risk and propose adequate disaster risk management policies and actions" (Cardona, 2005). The four indices are the Disaster Deficit Index (DDI), the Local Disaster Index (LDI), the Prevalent Vulnerability Index (PVI) and the Risk Management Index (RMI). The main database used for development of these indices is the DesInventar database. Other data is obtained at a national level.

The DDI is an economic index that measures the possible loss of a country when dealing with a catastrophe. Exposure times utilized are 50, 100, and 500 years (meaning events with a probability of exceedance of 18, 10 and 2 percent, respectively, in a 10 year exposure period), in which the significant possible impacts of the events are considered. By relating the availability and the demand of funds required for the Maximum Considered Event (MCE), the DDI captures the financial exposure. This index is based on historical data, using the event's intensity as a measure of the hazard and does not consider the number of casualties of past events.

The DDI is defined with the following equation:

$$DDI = \frac{MCE\ Loss}{Economic\ Resilience}$$

The numerator is obtained by relating the hazards and the physical vulnerability of the exposed elements and "represents the maximum direct economic impact in probabilistic terms on public and private stocks" (Cardona, 2005). The denominator, the economic resilience, is calculated with the following indicators:

F_1^p: Insurance and reassurance payments
F_2^p: Reserve funds for disasters
F_3^p: Aid and donations
F_4^p: New taxes
F_5^p: Budgetary reallocations

F_6^p: External credit
F_7^p: Internal credit

Clearly, as the calculated DDI increases, the difference between the potential losses and the availability of funds also increases. The DRI above 1.0 shows that the expected losses are higher than the country's economic capacity to face them.

The LDI is an index that measures the distribution of social and economic risk to low intensity events. National environmental catastrophes are not considered, instead, the more frequent local level events are accounted for. The data used for calculating this index is obtained from the DesInventar database. The general equation is the following:

$$LDI = LDI_{Deaths} + LDI_{Affected} + LDI_{Losses}$$

Where the $LDI_{Deaths,}$ $LDI_{Affected}$ and LDI_{Losses} are sub-indices representing, respectively, the number of deaths, the number of affected and the direct losses in terms of the economic value of crops and housing. The affected housing and the destroyed housing are summed, as so are the number of people affected and the number of homeless. The LDI is comparable from country to country as it is not influenced by the amount of municipalities nor amount and type of events. The data obtained from the database are normalized with respect to the area of the municipality, allowing for the comparison of the concentration of damages. The four types of events considered are landslides and debris flows, seismo-tectonic (low intensity), floods and storms, and others.

Colloquial denomination	Phenomena
Landslides and debris flows	External geodynamic phenomena
	Landslides, rock falls, debris flows, avalanche, mass removal, subsidence, land sinks
Seismo-tectonic	Internal geodynamic phenomena
	Earthquake volcanic eruption, tsunami, fault, liquefaction
Floods and storms	Hydrological phenomena
	Flood, river bore, sedimentation, erosion, flood tide, overflow, water table depletion, drought
	Atmospheric phenomena
	Storms (electric and tropical), tempests, whirlwinds, hurricanes, rain, fog, hail, snow-storm, frost and freezing spells, heat waves, forest fires
Other	Technological phenomena
	Fires, accidents, explosions, escapes, pollution, collapse,

	structures
	Biological phenomena
	Epidemics, biological, plague

Table 5: Classifications of Events for LDI (Cardona, 2005)

The LDI also shows the distribution of the effects, deaths, affected and losses. A high LDI represents well spatially distributed effects of the event, whereas a lower value shows a non-uniform distribution.

The PVI represents the socio-economic vulnerability of a country. It is a composite indicator and measures three aspects of vulnerability: the exposure and physical susceptibility, the socio-economic fragility, and the lack of resilience (assumed as vulnerability). These types of vulnerability are averaged to obtain the PVI:

$$PVI = \frac{PVI_{ES} + PVI_{SF} + PVI_{LR}}{3}$$

Each sub-index has its own set of indicators, obtained from available databases or individually in each country.

Table 5 Indicators of Exposure and Susceptibility (Cardona, 2005)

Indicator	Source
ES 1. Population growth, average annual rate (%)	UNDESA WB
ES 2. Urban growth, average annual rate (%)	UNDESA WB GEO HABITAT
ES 3. Population density, people per 5 km^2	UNEP/GRID GEO
ES 4. Poverty- population below US$1 per day	WB UNICEF
ES 5. Capital stock, million US$ per 1000 km^2	WB Ministries of Finance and Planning
ES 6. Imports and exports of goods and services, % of GDP	WB
ES 7. Gross domestic fixed investment, % of GDP	WB
ES 8. Arable land and permanent crops, % of land area	FAO GEO

Table 6: Indicators of Exposure and Susceptibility (Cardona, 2005)

Table 6 Indicators of Socio-economic Fragility (Cardona, 2005)

Indicator	Source
SF 1. Human Poverty Index	UNDP
SF 2. Dependents as proportion of working age population (15-64)	WB
SF 3. Social disparity, concentration of income measured using Gini index	WB
SF 4. Unemployment, as % of total labor force	ILO WB
SF 5. Inflation, food prices, annual %	UNICEF WB
SF 6. Dependency of GDP growth of agriculture, annual %	WB
SF 7. Debt servicing, % of GDP	WB
SF 8. Human-induced soil degradation	FAO/UNEP GEO

Table 7: Indicators of Socio-economic Fragility (Cardona, 2005)

Table 7 Indicators of Lack of Resilience (Cardona, 2005)

Indicator	Source
LR 1. Human Development Index (inv)	UNDP
LR 2. Gender-related Development Index (inv)	UNDP
LR 3. Social expenditure; on pensions, health, and education, % of GDP (inv)	WB
LR 4. Governance Index (inv)	WBI
LR 5. Insurance of infrastructure and housing, % of GDP (inv)	Ministries of Finance and Planning
LR 6. Television sets per 1000 people (inv)	WB
LR 7. Hospital beds per 1000 people (inv)	WB
LR 8. Environmental Sustainability Index, ESI (inv)	WEF

Table 8: Indicators of Lack of Resilience (Cardona, 2005)

The RMI is a qualitative measure of the risk management performance at the national level. It is composed of four sub-indices that evaluate the country's policies. Each sub-index has six indicators, each one having five performance levels. The performance levels correspond to low, incipient, significant, outstanding, and optimal. Nonetheless, each indicator can also be calculated numerically with the corresponding value from 1 to 5 each performance level. The four sub-indices are Risk Identification (RI), Risk Reduction (RR), Disaster Management (DM), and Financial Protection (FP). The general equation for the RMI is:

$$RMI = \frac{RMI_{RI} + RMI_{RR} + RMI_{DM} + RMI_{FP}}{4}$$

Table 8 Indicators of Risk Identification (Cardona, 2005)

Indicator and Performance Level
RI1 Systematic disaster and loss inventory 1. Some basic and superficial data on the history of events. 2. Continual registering of current events, incomplete catalogues of the occurrence of some phenomena and limited information on losses and effects. 3. Some complete catalogues at the national and regional levels, systematization of actual events and their economic, social and environmental effects. 4. Complete inventory and multiple catalogues of events; registry and detailed systematization of effects and losses at the national level. 5. Detailed inventory of events and effects of all types of existing hazards and data at the sub-national and local levels.
RI2 Hazard monitoring and forecasting 1. Minimum and deficient instrumentation of some important phenomena 2. Basic instrumentation networks with problems of updated technology and continuous maintenance. 3. Some networks with advanced technology at the national level or in particular areas; improved prognostics and information protocols established for principal hazards. 4. Good and progressive instrumentation cover at the national level, advanced research in the matter of the majority of hazards and some automatic warning systems working. 5. Wide coverage of station and sensor networks for all types of hazard in all parts of the territory; permanent and opportune analysis of information and automatic early warning systems working continuously at the local, regional and national levels.
RI3 Hazard evaluation and mapping 1. Superficial evaluation and basic maps covering the influence and susceptibility of some phenomena. 2. Some descriptive and qualitative studies of susceptibility and hazard for principal phenomena at the national scale and for some specific areas. 3. Some hazard maps based on probabilistic techniques for the national level and for some regions. Generalized use of GIS for mapping the principal hazards. 4. Evaluation is based on advanced and adequate resolution methodologies for the majority of hazards. Microzonification of some cities based on probabilistic techniques. 5. Detailed studies for the vast majority of potential phenomena throughout the territory. Microzoning of the majority of cities and hazard maps at the sub-national and municipal level.
RI4 Vulnerability and risk assessment 1. Identification and mapping of the principal elements exposed in prone zones in principal cities and river basins. 2. General studies of physical vulnerability when faced with the most recognized hazards, using GIS in some cities and basins. 3. Evaluation of potential damage and los scenarios for some physical phenomena in the principal cities. Analysis of the physical vulnerability of some essential buildings. 4. Detailed studies of risk using probabilistic techniques taking into account the economic and social impact of the majority of hazards in some cities. Vulnerability analysis for the majority of essential buildings and lifelines. 5. Generalized evaluation of risk, considering physical, social, cultural and environmental factors. Vulnerability analysis also for private buildings and the majority of lifelines.
RI5 Public information and community participation 1. Sporadic information on risk management in normal conditions and more frequently when

disasters occur. 2. Press, radio and television coverage oriented towards preparedness in case of emergency. Production of illustrative materials on dangerous phenomena. 3. Frequent opinion programs on risk management issues at the national and local levels. Guidelines for vulnerability reduction. Work with communities and NGO's. 4. Generalized diffusion and progressive consciousness; conformation of some social networks for civil protection and NGO's that explicitly promote risk management issues and practice. 5. Wide scale participation and support from the private sector for diffusion activities. Consolidation of social networks and notable participation of professional and NGO's at all levels.
RI6 Training and education in risk management 1. Incipient incorporation of hazard and disaster topics in formal education and programs for community participation. 2. Some curricular adjustments at the primary and secondary levels. Production of teaching guides for teachers and community leaders in some places. 3. Progressive incorporation of risk management in curricula. Considerable production of teaching materials and undertaking of frequent courses for community training. 4. Widening of curricular reform to higher education programs. Specialization courses offered at various universities. Wide ranging community training at the local level. 5. Generalized curricular reform throughout the territory and in all stages of education. Wide ranging production of teaching materials. Permanent schemes for community training.

Table 9: Indicators of Risk Identification (Cardona, 2005)

Table 9 Indicators of Risk Reduction (Cardona, 2005)

Indicator and Performance Level
RR1 Risk consideration in land use and urban planning 1. Some basic and superficial data on the history of events. 2. Continual registering of current events, incomplete catalogues of the occurrence of some phenomena and limited information on losses and effects. 3. Some complete catalogues at the national and regional levels, systematization of actual events and their economic, social and environmental effects. 4. Complete inventory and multiple catalogues of events; registry and detailed systematization of effects and losses at the national level. 5. Detailed inventory of events and effects of all types of existing hazards and data at the sub-national and local levels.
RR2 Hydrographic basin intervention and environmental protection 1. Inventory of basins and areas of severe environmental deterioration or those considered to be most fragile. 2. Promulgation of national level legal dispositions and some local ones that establish the obligatory nature of reforestation, environmental protection and river basin planning. 3. Formulation of some plans for organization and intervention in strategic water basins and sensitive zones taking into account risk and vulnerability aspects. 4. Appreciable number of regions and water basins with environmental protection plans, impact studies and ordering of agricultural areas that consider risk a factor in determining investment decisions. 5. Intervention in a considerable number of deteriorated basins, sensitive zones and strategic ecosystems. Majority of municipalities have environmental intervention and protection plans.
RR3 Implementation of hazard-event control and protection techniques

1. Some structural control and stabilization measures in some more dangerous places. 2. Channeling works, water treatment in major cities all constructed following security norms. 3. Establishing of measures and regulations for the design and construction of hazard control and protection works in harmony with territorial organization dictates. 4. Wide scale intervention in mitigable risk zones using protection and control measures in the principal cities as required. 5. Adequate design and construction of cushioning, stabilizing, dissipation and control works in the majority of cities in order to protect human settlements and social investment.
RR4 Housing improvement and human settlement relocation from prone-areas 1. Identification and inventory of marginal human settlements located in hazard prone areas. 2. Promulgation of legislation establishing the priority of dealing with deteriorated urban areas at risk in the large cities. 3. Programs for upgrading the surroundings, existing housing, and relocation from risk areas in principal cities. 4. Progressive intervention of human settlements at risk in the majority of cities and adequate treatment of cleared areas. 5. Notable control of risk areas in all cities and relocation of the majority of housing constructed in non mitigable risk zones.
RR5 Updating and enforcement of safety standards and construction codes 1. Voluntary use of norms and codes from other countries without major adjustments. 2. Adaptation of some requirements and specifications according to some national and local criteria and particularities. 3. Promulgation and updating of obligatory national norms based on international norms that have been adjusted according to the hazard evaluations made in the country. 4. Technological updating of the majority of security and construction code norms for new and existing buildings with special requirements for special buildings and lifelines. 5. Permanent updating of codes and security norms: establishment of local regulations for construction in the majority of cities based on microzonations, and their strict control and implementation.
RR6 Reinforcement and retrofitting of public and private assets 1. Retrofitting and sporadic adjustments to buildings and lifelines; remodeling, changes of use or modifications. 2. Promulgation of intervention norms as regards the vulnerability of existing buildings. Strengthening of essential buildings such as hospitals or those considered indispensable. 3. Some mass programs for evaluating vulnerability, rehabilitation and retrofitting of hospitals, schools, and the central offices of lifeline facilities. Obligatory nature of retrofitting. 4. Progressive number of buildings retrofitted, lifelines intervened, some buildings of the private sector retrofitted autonomously or due to fiscal incentives given by government. 5. Massive retrofitting of principal public buildings. Permanent programs of incentives for housing rehabilitation lead to lower socio-economic sectors.

Table 10: Indicators of Risk Reduction (Cardona, 2005)

Table 10 Indicators of Disaster Management (Cardona, 2005)

Indicator and Performance Level
DM1 Organization and coordination of emergency operations 1. Different organizations attend emergencies but lack resources and various operate only with

voluntary personnel.

2. Specific legislation defines an institutional structure, roles for operational entities and coordination of emergency commissions through out the country.
3. Considerable coordination exists in some cities, between organizations in preparedness, communications, search and rescue, emergency networks, and management of temporary shelters.
4. Permanent coordination for response between operational organizations, public services, local authorities and civil society organizations in the majority of cities.
5. Advanced levels of interinstitutional organization between public, private and community based bodies. Adequate protocols exist for horizontal and vertical coordination at all territorial levels.

DM2 Emergency response planning and implantation of warning systems

1. Basic emergency and contingency plans exist with check lists and information on available personnel.
2. Legal regulations exist that establish the obligatory nature of emergency plans. Some cities have operational plans and articulation exists with technical information providers at the national level.
3. Protocols and operational procedures are well defined at the national and sub-national levels and in the main cities. Various prognosis and warning centers operate continuously.
4. Emergency and contingency plans are complete and associated with information and warning systems in the majority of cities.
5. Response preparedness based on analysis.

DM3 Endowment of equipments, tools and infrastructure

1. Basic supply and inventory of resources only in the operational organizations and emergency commissions.
2. Center with reserves and specialized equipment for emergencies at the national level and in some cities. Inventory of resources in other public and private organizations.
3. Emergency Operations Center (EOC) which is well stocked with communication equipment and adequate registry systems. Specialized equipment and reserve centers exist in various cities.
4. EOC's are well equipped and systematized in the majority of cities. Progressive complimentary stocking of operational organizations.
5. Interinstitutional support networks between reserve centers and EOC's are working permanently. Wide ranging communications, transport and supply facilities exist in case of emergency.

DM4 Simulation, updating and test of inter institutional response

1. Some internal and joint institutional simulations between operational organizations exist in some cities.
2. Sporadic simulation exercises for emergency situations and institutional response exist with all operational organizations.
3. Desk and operational simulations with the additional participation of public service entities and local administrations in various cities.
4. Coordination of simulations with community, private sector and media at the national level, and in some cities.
5. Testing of emergency and contingency plans and updating of operational procedures based on frequent simulation exercises in the majority of cities.

DM5 Community preparedness and training

1. Informative meetings with community in order to illustrate emergency procedures during disasters.
2. Sporadic training courses with civil society organizations dealing with disaster related themes.

3. Community training activities are regularly programmed on emergency response in coordination with community development organizations and NGO’s. 4. Courses are run frequently with communities in the majority of cities and municipalities on preparedness, prevention and reduction of risk. 5. Permanent prevention and disaster response courses in all municipalities within the framework of a training program in community development and in coordination with other organizations and NGO’s.
DM6 Rehabilitation and reconstruction planning 1. Design and implementation of rehabilitation and reconstruction plans only after important disasters. 2. Planning of some provisional recovery measures by public service institutions and those responsible for damage evaluation in some cities. 3. Diagnostic procedures, reestablishment and repairing of infrastructure and production projects for community recovery are available at the national level and in various cities. 4. Ex ante undertaking of recovery plans and programs to support social recovery, sources of employment and productive means for communities in the majority of cities. 5. Generalized development of detailed reconstruction plans dealing with physical damage and social recovery based on risk scenarios. Specific legislation exists and anticipated measures for reactivation.

Table 11: Indicators of Disaster Management (Cardona, 2005)

Table 11 Indicators of Governance and Financial Protection (Cardona, 2005)

Indicator and Performance Level
FP1 Interinstitutional, multisectoral and decentralizing organization 1. Basic organizations at the national level arranged in commissions, principally with an emergency response approach. 2. Legislation that establishes decentralized, interinstitutional and multisectoral organization for the integral management of risk and the formulation of a general risk management plan. 3. Interinstitutional risk management systems active at the local level in various cities. Inter-ministerial work at the national level in the design of public policies for vulnerability reduction. 4. Continuous implementation of risk management projects associated with programs of adaptation to climate change, environmental protection, energy, sanitation, and poverty reduction. 5. Expert personnel with wide experience incorporating risk management in sustainable human development planning in major cities. High technology information systems available.
FP2 Reserve funds for institutional strengthening 1. Existence of a national disaster fund and some local funds in some cities. 2. Regulation of exiting reserve funds or creation of new sources to co-finance local level risk management projects. 3. National economic support and search for international funds for institutional development and strengthening of risk management in the whole country. 4. Progressive creation of reserve funds at municipal level to co-finance projects, institutional strengthening and recovery in times of disaster. 5. Financial engineering for the design of retention and risk transfer instruments at the national level. Reserve funds operating in the majority of cities.
FP3 Budget allocation and mobilization 1. Limited allocation of national budget to competent institutions for emergency response. 2. Legal norms establishing budgetary allocations to national level organizations with risk management objectives.

3. Legally specified specific allocations for risk management at the local level and the frequent undertaking of inter administrative agreements for the execution of prevention projects. 4. Progressive allocation of discretionary expenses at the national and municipal level for vulnerability reduction, the creation of incentives and rates of environmental protection and security. 5. National orientation and support for loans requested by municipalities and sub national and local organizations from multilateral loan organizations.
FP4 Implementation of social safety nets and funds response 1. Sporadic subsidies to communities affected by disasters or in critical risk situations. 2. Permanent social investment funds created to support vulnerable communities focusing on the poorest socio-economic groups. 3. Social networks for the self protection of means of subsistence of communities at risk and undertaking of post disaster rehabilitation and reconstruction production projects. 4. Regular micro-credit programs and gender oriented activities oriented to the reduction of human vulnerability. 5. Generalized development of social protection and poverty reduction programs integrated with prevention and mitigation of activities throughout the territory.
FP5 Insurance coverage and loss transfer strategies of public assets 1. Very few public buildings are insured at the national level and exceptionally at the local level. 2. Obligatory insurance of public goods. Deficient insurance of infrastructure. 3. Progressive insurance of public goods and infrastructure at the national level and in some cities. 4. Design of programs for the collective insurance of buildings and publically rented infrastructure in the majority of cities. 5. Analysis and generalized implementation of retention and transfer strategies for losses to public goods considering reinsurance groups, risk titles, bonds, etc.
FP6 Housing and private sector insurance and reinsurance coverage 1. Low percentage of private goods insured. Incipient, economically weak and little regulated insurance industry. 2. Regulation of insurance industry controls over solvency and legislation for insurance of house loan and housing sector. 3. Development of some careful insurance studies based on advanced probabilistic estimates of risk , using microzoning, auditing and optimum building inspection. 4. Design of collective housing insurance programs and for small businesses by the majority of local governments and insurance companies with automatic coverage for the poorest. 5. Strong support for joint programs between government and insurance companies in order to generate economic incentives for risk reduction and mass insurance.

Table 12: Indicators of Governance and Financial Protection (Cardona, 2005)

Pros and Cons - Americas Program

The Americas Program allows for the adaptation of its indices to the national and local level, satisfying the needs of different stakeholders.

The use of composite indicators permits the inclusion of details that an individual indicator does not allow. The value of the indicator represents the influencing aspects of a complex problem. However, the AHP technique employed in the PVI and in the RMI cannot be easily duplicated nor can results be compared if the index is to be calculated by a different group of experts.

The RMI is an innovative and unique method for monitoring the performance of a government's policies towards risk management. Improvements and deficiencies of governmental strategies can be controlled with time. It is crucial for decision-makers when renovating or confirming risk reduction policies. Although it is a very useful indicator, it is difficult to compute. The fact that it is a self assessment makes the results very subjective, as evaluations may be exaggerated to generate international recognition and may also be understated in order to request international monetary assistance or resources.

The DDI calculation is based on historical events; nonetheless, that a region has not suffered from a particular event does not guarantee that the near future will also be event-free. The DDI does not include a count of victims and casualties, and is also missing an inclusion of small scale events, which aggregate to produce a great impact at a sub-national level and eventually hinder the national level as well.

A low value of the LDI, not being sensitive to quantity, does not represent a low level or risk; instead it represents a concentration of the risks in one geographical area. This may be misleading as the name of the index implies a measurement of the level of risk and not a description of the distribution. The inclusion of large size events is not totally clear, given the fact that the effects of these large events at a local scale are considered.

The PVI includes existing indices as part of its indicators. In doing so, the drawbacks and limitations of the existing indices are carried on by the PVI as well. Chapter 4 describes the limitations of the indicators composing the PVI.

3.1.4 ENSURE Program

The ENSURE project, "Development of a new methodological framework for an integrated multi-scale vulnerability assessment", is aimed at constructing a vulnerability and resilience evaluation taking into account the temporal and spatial scales that define these two concepts. This methodology is primarily hazard specific, as vulnerability, social, physical, or systemic, is also hazard specific.

Figure 12 is a detail of the framework of the integrated multi-scale assessment of vulnerability and resilience to natural hazards. It shows two sets of axes, one for the hazard and the other one for the vulnerability. The meaning being that the scale and the timing at which a hazard is analyzed is not automatically the same scale and timing at which vulnerability and resilience are analyzed. As seen on the figure, physical vulnerability is considered at a local scale, resilience is considered at a macro scale, and systemic vulnerability connects the micro and the macro scales.

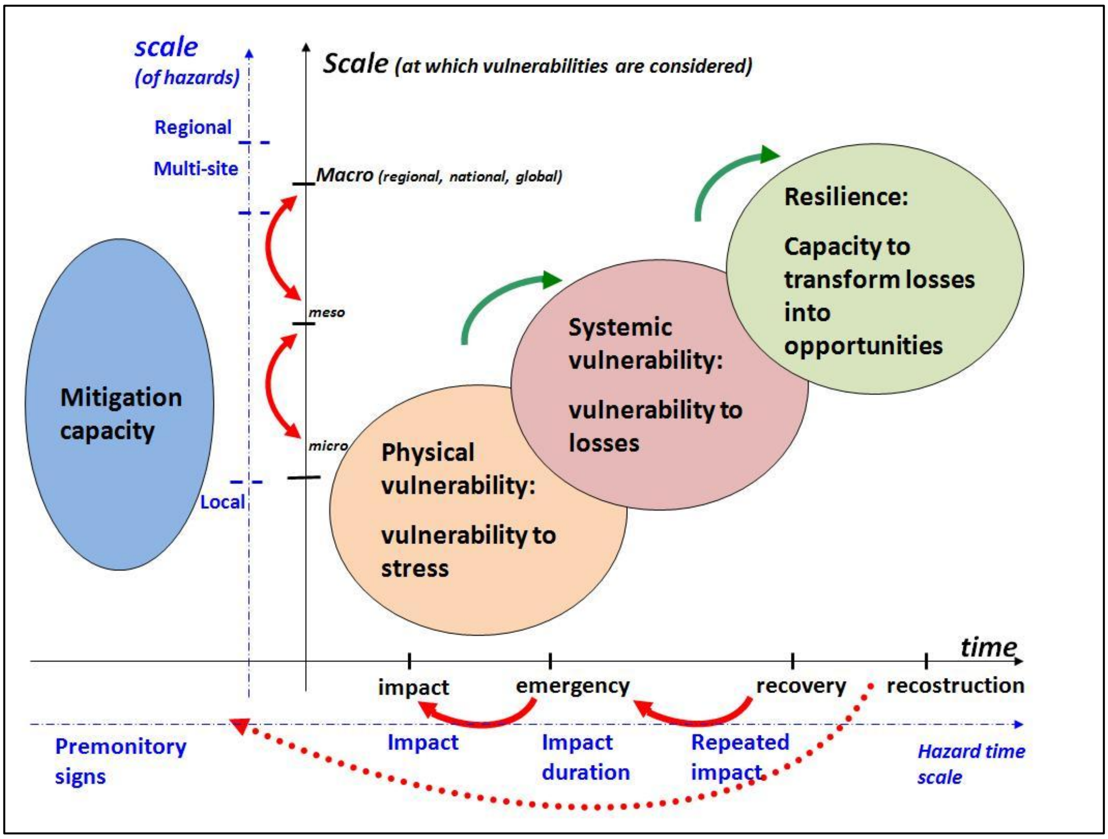


Figure 12: Multi-scale Assessment of Vulnerability and Resilience to Natural Hazards (ENSURE, 2011)

The two main objectives of the ENSURE project are first to define the relationship between vulnerability, resilience, adaptation, coping capacity, etc. within a preventive scheme, that is, before a hazard event impacts, to prevent the dependence to the post-disaster analysis. The second objective was to pursue advancement within the vulnerability assessments through the development of the matrices.

The methodology consists of four matrices, which are the definition of each of the four ellipsoids in the figure above. The first matrix includes the items to be considered before the event impacts; it is devoted to the capacity to mitigate. The second includes those items related to the time of the event and measures the physical vulnerability to the specific hazard. The third matrix defines the aspects that immediately follow the event, the systemic vulnerability and the vulnerability to losses is assessed, the secondary effects to the natural environment and the capacity to maintain functions of critical facilities are measured. Finally, the fourth matrix defines those that are to be considered in the recovery phase, it is defined as the resilience or response capabilities in the long term. This matrix evaluates the resilience of the natural environment (in case of fires or droughts), the resilience of structures, and access to resources, among others. Each matrix is divided into four sections or systems: natural environment, built environment, infrastructure and production sites, and social system. Each of these systems described in terms of its components, aspects (or indicators) and criteria for assessment. Furthermore, a weight is given to each indicator. It is noted, as for the other programs described earlier, that indicators are not to be considered individually, but instead as part of a whole. Although each set of matrices should be developed per each hazard, a multi-risk view is not excluded. As noted below, some of the indicators refer to the possibility of enchained events, meaning a hazard triggering another hazard (for example an earthquake triggering a landslide) or a technological disaster.

Indicators have been verified for measurability, specificity, representativeness, and verifiability.

The following are extractions of the matrices for the system, component, and aspect (indicator) portions:

First Matrix – Resilience: Mitigation Capacity		
System	*Component*	*Aspect*
Natural Environment	Natural hazards	Natural hazards identification and mapping
		Hazards monitoring
		Integration of monitoring systems forecasting modeling systems
		Structural defense measures
Built Environment	Exposure and vulnerability of built environment	Inclusion of vulnerability and exposure assessments in land use plans
	Rules and tools for risk mitigation	Availability, quality and efficacy of mitigation rules
Infrastructure and Production Sites	Critical infrastructure	Existence of vulnerability assessments for critical facilities; level of consideration of vulnerability in programs regarding critical facilities
	Production sites	Existence of vulnerability assessments for production sites; consideration of na-techs
Social System (agents)	People/ individuals	Evaluation of the capacity of individuals living in prone hazard areas of coping with hazardous events
	Community and institutions	Involvement of a community into decision-making processes related to risk prevention and mitigation, the capacity of institutions of improving risk awareness and the level of cooperation among different institutions in charge of risk prevention/ mitigation

Table 13: Resilience - Mitigation Capacity Matrix (ENSURE, 2011)

Second Matrix – Physical Vulnerability: Vulnerability to stress		
System	*Component*	*Aspect*
Natural Environment	Natural ecosystems	Fragility of natural ecosystem to hazard
		Possibility of enchained effects due to the interaction of natural systems with the triggering hazard
		Vulnerability of ecosystem to mitigation measures taken during emergency
Built Environment	Exposure and vulnerability of built environment	Factors that make buildings, the urban fabric, and the public facilities, vulnerable to the stress
Infrastructure and Production Sites	Critical infrastructure	Factors that make critical infrastructures vulnerable (mainly lifelines)
	Production sites	Factors that make production sites vulnerable (including na-tech potential)
Social System (agents)	People/ individuals	Factors that may lead to injuries and fatalities
	Community and institutions	Factors that may lead to large number of victims

Table 14: Physical Vulnerability - Vulnerability to Stress Matrix (ENSURE, 2011)

Third Matrix – Systemic Vulnerability: Vulnerability to losses		
System	*Component*	*Aspect*
Natural Environment	Natural ecosystems	Fragility of natural ecosystem to potential secondary effects of hazard
		Possibility of enchained effects due to the interaction of natural systems with the triggering hazard
		Vulnerability of ecosystem to mitigation measures taken during emergency
Built Environment	Exposure and vulnerability of built environment	Factors that make buildings, the urban fabric, and the public facilities, vulnerable to the stress
Infrastructure and Production Sites	Critical infrastructure	Factors that make critical infrastructures stop functioning
	Production sites	Factors that may lead to halting production
Social System (agents)	People/ individuals	Factors that may reduce coping capacity during crisis
	Community and institutions	Factors that may hamper effective crisis management

Table 15: Systemic Vulnerability - Vulnerability to Losses Matrix (ENSURE, 2011)

Fourth Matrix – Resilience: Response capability in the long run		
System	*Component*	*Aspect*
Natural Environment	Natural ecosystems	Ecosystem capacity to recover from damages
		Ecosystem capacity to recover from secondary negative effects of emergency mitigation measures
Built Environment	Exposure and vulnerability of built environment	Urban fabric/ built environment capacity to recover reducing pre-event vulnerability
Infrastructure & Production Sites	Critical infrastructure	Availability of tools to recover critical infrastructures rapidly and at low costs
	Production sites	Availability of tools to recover production sites rapidly and at low costs
Social System (agents)	People/ individuals	People's resilience in the face of the catastrophe induced trauma
	Community	Affected community's resilience to the consequences of a catastrophe
	Institutions	Transparency, reliability and trustworthiness of institutions in charge of reconstruction
	Economic stakeholders	Capacity and willingness of stakeholders to reinvest in affected areas

Table 16: Resilience - Response Capability in the Long Run (ENSURE, 2011)

Pros and Cons – ENSURE Project

The employed matrices are comprehensive, including the most representative aspects of the different types of vulnerability. Economic vulnerability, which has been a focus point for other projects, is not considered fully developed. Although this approach allows for an understanding of the locality's vulnerability situation and response capabilities, it does not measure actual risk. The ENSURE project views vulnerability and resilience as proxies of risk. Nonetheless, it does not include the hazard's frequency dimension, nor the exposure variables that define risk.

3.2 Limitations to use DRI, Hotspots, Americas Program and ENSURE Methodologies

DRI produce the global view of disaster risk and vulnerability with national resolution while Hotspot and Americas Program map the risk at national and sub national level. Flood and drought proved to be the most difficult hazards to be mapped as there is the lack of sufficient availability of global database over these hazards. Flood risk was overestimated in DRI project as it took the whole watershed as flooded area while flood risk was underestimated in Hotspot project as it used the satellite imagery. It is possible in case of Hotspot project that many of local flash flood events may have been ignored.

Hotspot and DRI should not be used to predict the future risk as both of them used past data to calculated vulnerability and risk under the assumption that the places will experience similar hazards in future. Rapid Urbanization and local environment change have the capacity to change the distribution of population, hazard and vulnerability over the short time period.

Drought was found to be more affected by armed conflicts, chronic disease, and weak governance than disasters caused by other hazards. It was the reason that drought was left out of the final analysis of DRI.

DRI provides death risk as risk index while Hotspot measures risk of mortality, risk of economic loss and risk of economic loss as a proportion of GDP. DRI mainly includes earthquakes, floods, cyclones and drought and Hotspot also include landslides and volcanoes in addition to the hazards used in DRI project. Americas Program adopt a different methodologies considering different hazards for calculation of local disaster index and maximum considered event based on most important sudden onset hazard type for the calculation of disaster deficit index.

Americas Program was applied to 12 Latin American countries instead of global scale. It has to be verified in other regions also. Americas Program is the first project taking into account risk management issues in risk management index (RMI). Although risk management index measured performance of government for disaster risk management and it is self-evaluated by the national experts so it may raise a question on reliability of data but definitely it helps in identifying the gaps between risk management and good governance and filling those gaps in future. Local disaster index (LDI) is also difficult to measure as most of the countries are lacking in terms of local disaster loss data.

The following table, adapted from M. Pelling's Visions of Risk, is an overall summary of the four programs previously described:

	DRI	**Hotspots**	**Americas Program**	**ENSURE**
Objective	To demonstrate the ways in which development contributes to human vulnerability and risk.	To identify geographical areas in the world with high multi- hazard risk.	To reveal national socio-economic vulnerability and risk due to natural hazards, and risk management performance.	To evaluate vulnerability and resilience to natural hazards considering the temporal and spatial scales.
Unit of analysis	National	Sub-national (2.5' grid cells)	National and sub-national	Sub-national
Key contributions	Maps hazards worldwide. Identifies independent hazard specific socio-economic indicators of national vulnerability. Proposes a simple measure of relative vulnerability.	Maps hazards worldwide. Identifies relative risks of mortality and economic loss for populations and economic assets exposed to single and multiple hazards. Estimates relative risks of mortality and economic losses.	Provides a group of four independent but related indices covering local disaster loss, economic exposure and financial preparedness, socio-economic vulnerability and national disaster risk management program performance.	Generates comprehensive matrices to define four aspects of vulnerability and resilience: mitigation capacity, physical vulnerability, systemic vulnerability and long term resilience.
Hazard	Earthquake, cyclone, flood, and drought. Landslide has been partly studied through work coordinated by NGI.	Earthquake, cyclone, flood, landslide, drought and volcano.	LDI: landslides and debris flows; seismo-tectonic; floods and storms; other (biological, technological) DDI: flood, cyclone or earthquake (maximum	All types of hazards can be included.

Vulnerability	1) The ratio between mortality and population exposed. 2) Derived from socio- economic indicators calibrated against disaster mortality.	Represented by historical disaster mortality and economic loss rates for 28 groups of regions and country wealth classes for each hazard type.	In the DDI vulnerability is a function of financial exposure and resiliency. In the PVI vulnerability was not hazard specific and is characterized by social and economic sub- indicators.	Vulnerability is hazard specific, but enchained events are considered. Vulnerability (resilience, systemic and physical) is defined through indicators.
Risk	Disaster mortality calculated as a product of hazard, population exposed and vulnerability variables.	Disaster mortality and economic losses calculated as products of hazard, elements exposed and vulnerability.	Expressed through four independent indices covering: financial exposure and capacity to finance reconstruction, local risk accumulation, socio-economic vulnerability and risk management performance.	n.a. Vulnerability can be considered as a proxy of risk
Limitations	Short time-span for mortality loss data compared to hazard frequency (volcano and earthquake). Limited availability of appropriate socio-economic variables.	Lack of sub-national data on mortality and economic loss. Does not identify specific vulnerability factors.	As the indices are inductive the results are not verifiable against specific disaster-related outcomes. Selection of sub-index components (and their valuation in the RMI) rests on the judgment of national experts, making international comparison difficult. National level resources and support for data collection and dissemination are required.	As it is applied at a local level, an overall national evaluation is not feasible. Local resources and support for data collection are required. Indicator weights are subjective, require experts opinions, and thus results cannot be easily duplicated.
Comparative Advantage	National dimensioning of vulnerability factors and disaster risk. Focus on large and medium events.	Sub-national dimensioning of hazard exposure and disaster risk. Focus on large and medium events.	National dimensioning of vulnerability factors and disaster risk. Characterization of risk management performance at the national level. Includes large and medium as well as small (locally significant) events.	Relates vulnerability and resilience to individual hazards, considering the individual time and space dependencies.

Future Possibilities	Measuring disaster risk to ecological and environmental systems that impact of human welfare. National and sub-national case-study ground verification. Time-series analysis. Dynamic risk assessment. Contribution to benchmarking.	Measuring disaster risk to ecological and environmental systems that impact of human welfare. National and sub-national case study ground verification. Temporal comparisons. Dynamic risk assessment.	Benchmarking for disaster risk reduction performance. A family of indicators could be developed for individual economic and social sectors at the national and sub-national levels. LDI could be further developed to provide a country to country comparable measure of risk, not only the identification of the internal distribution.	Providing an integrated assessment of vulnerability. Generating an aggregation method for a national assessment.

Table 17: Comparison of DRI, Hotspots, Americas Program and ENSURE

3.3 Comparison of Results

After a review of the mostly used disaster risk indices, a comparison was made by through their application to three countries. The aim was to analyze the relative positions of the indices for countries having different GDPs per capita (for 2010) and evaluate how these vary from one index to the next. The calculated indices were readily available from reports and publications. Since the Americas Program framework was developed, tested and calculated for Latin America region, Chile, Colombia and El Salvador were analyzed.

The World Bank reported that Chile has a GDP per capita of US$11,888 and a population of approximately 17.2 million, is prone mainly to fires, storms, earthquakes, and droughts (as per the DesInventar database). Colombia has a GDP per capita of US$6,225; 42.9 million inhabitants, and is affected by floods, landslides, fires, and earthquakes. Lastly, El Salvador has the lowest GDP per capita of the three selected countries, US$3,519; with 5.7 million inhabitants, and the main hazards being floods, landslides, fires, and earthquakes.

Country	GDP per capita (US$)
Chile	11,888
Colombia	6,225
El Salvador	3,519

Table 18: GDP per capita (Data from World Bank)

The Hotspots program listed the three countries in the list of the top sixty countries, based on land area, with two or more hazards.

Country	% of Total Area Exposed	% of Population Exposed	Max Number of Hazards
El Salvador	32.4	39.7	3
Chile	26.2	62.6	4
Colombia	8.9	7.5	3

Table 19: Description of Exposure and Hazards (Data from Dilley, et al, 2005)

3.3.1 Americas Program Results

For the event having 18% probability of exceedance in a 10 year exposure period, that is, a 50 year return period, Figure 13 shows the DDI comparison for the year 2000. Chile, Colombia and El Salvador appear to be economically capable of handling the situation. Nonetheless, Colombia and El Salvador do not have the economic ability to deal with the 10% and 2% (100 and 500 year return period, respectively). The most critical case is for Colombia in the 500 year return period event, where the DDI is greatly higher than the other two, with 5.4.

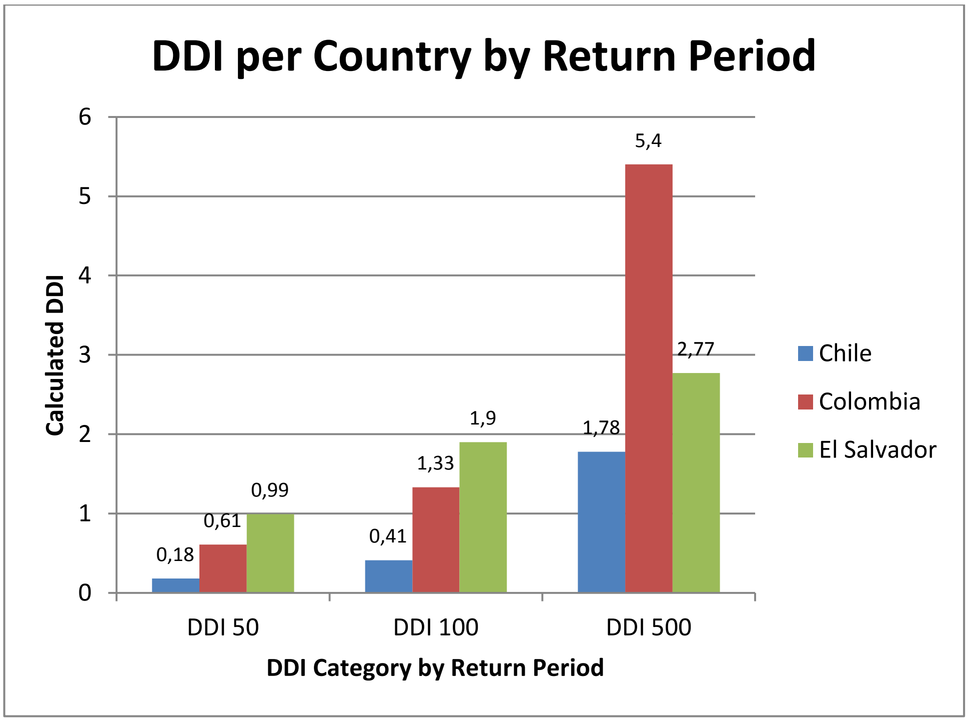


Figure 13: DDI per Country by Return Period

Likewise, the results for the LDI are shown on Figure 14 and Figure 15, for the period from 1996 through 2000. Figure 14 shows the LDI per component of deaths (k), affected (a), and losses (l). Figure 15 shows the total LDI, with the accumulated values of the sub-indices. Colombia and El Salvador show a more uniform distribution of the effects than Chile. It is important to point out that the lower value of the LDI represents a non-uniform distribution of the effects of an event, and does not represent a lower quantity of events or a lower intensity of the effects.

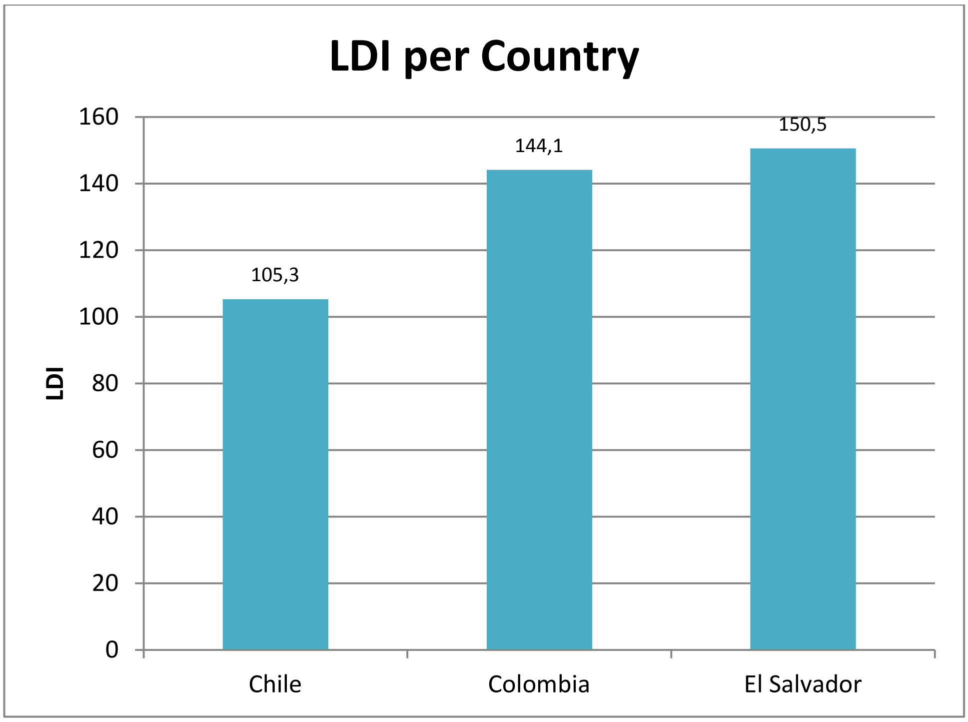


Figure 14: LDI per Country

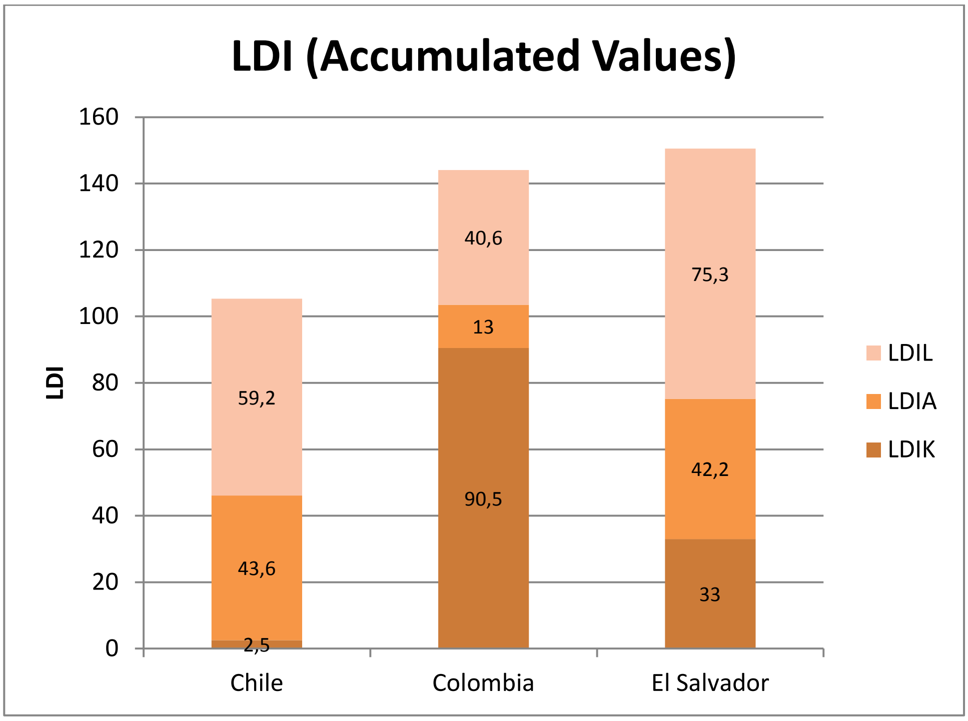


Figure 15: LDI per Country (Accumulated Values)

Since the PVI is a composite indicator, different weighing techniques are used to calculate the index: the equal weighing of the components of each sub-indicator, the budget allocation, the Analytic Hierarchy Process (AHP) and the unify technique which averages the AHP allocations. The budget allocation and the AHP require expert knowledge for the determination of the weighing factors. The budget allocation is performed by distributing an amount X of weights to each indicator. The AHP is done by pair wise comparing each of the sub-indicators and determining which is more important and by how much. The results of the weighing techniques are consistent, showing that Chile has the lowest PVI and El Salvador has the highest PVI. Figure 16 shows the calculated PVI, by weighing technique, for the year 2000. Figure 17 shows the aggregated values for the indicators, using the AHP method. A clear view of the results of each component indicator, the exposure and physical susceptibility (ES), the socio-economic fragility (SF), and the lack of resilience (LR), is presented. Colombia has a higher socio-economic fragility than exposure susceptibility and lack of resilience. El Salvador has a greater value for each indicator than the three aggregated values of Chile, showing, once again, how much more prone it is to disasters.

These results are consistent with those of the DDI (with the exception of the 500 year return period event) in which Chile has the lowest value and El Salvador the highest. Chile has the lowest vulnerability and is the most capable of economically withstanding the effects of a disaster.

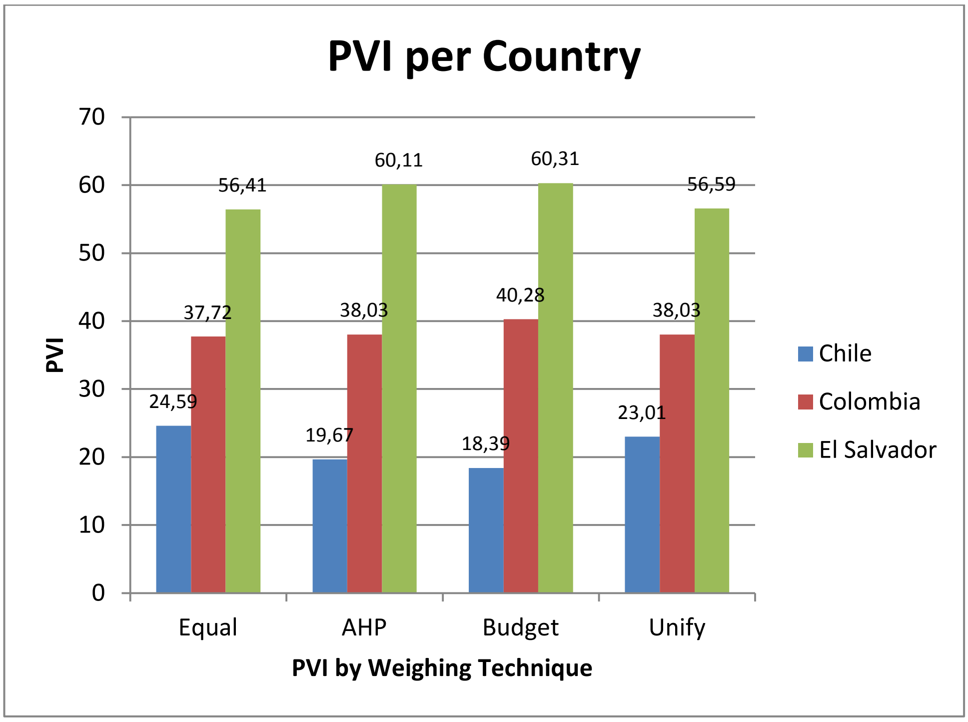


Figure 16: PVI per Country by Weighing Technique

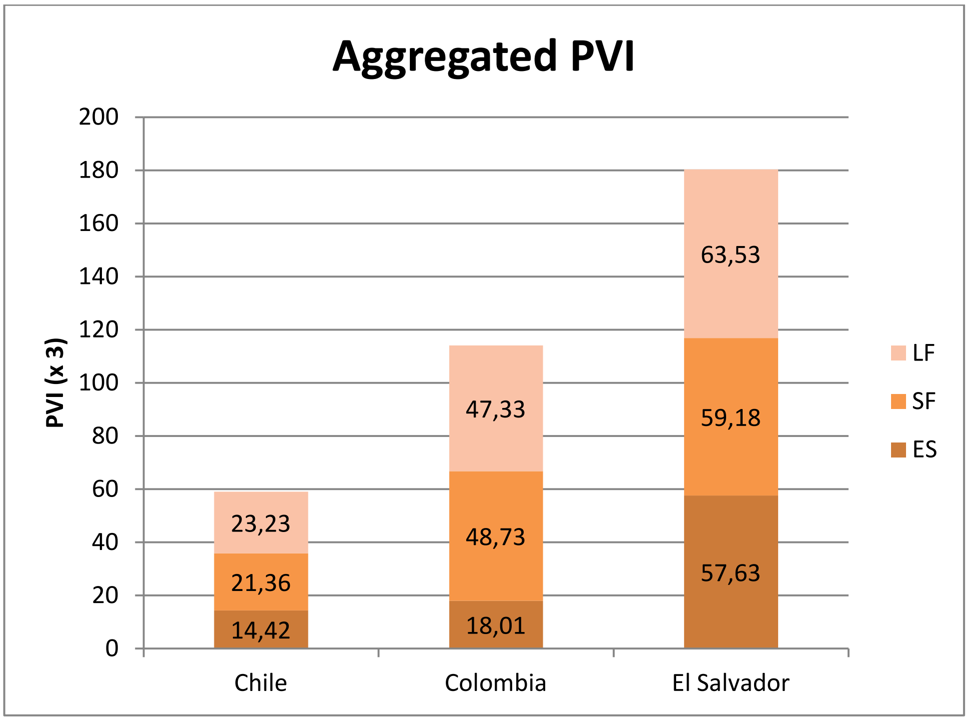


Figure 17: PVI per Country (Aggregated Values)

Lastly, the RMI, for the year 2003, for these three countries is shown in Figure 18, using the AHP, budget allocation and equal weighing techniques described above. Figure 0.0 shows the aggregated values using the AHP technique for the composite indicators: risk identification (RI), risk reduction (RR), disaster management (DM), and governance and financial protection (FP).

While the disaster management indicator is the greatest for Chile, it is the area in which Colombia needs to improve the most. Colombia's risk reduction policies are more effective than those from El Salvador, even though, overall El Salvador has better risk management practices. Results show that Chile has superior risk management practices. This can be observed in the fact that it has low values of DDI and of PVI. The vulnerability and the expected damages can be reduced by employing risk management practices.

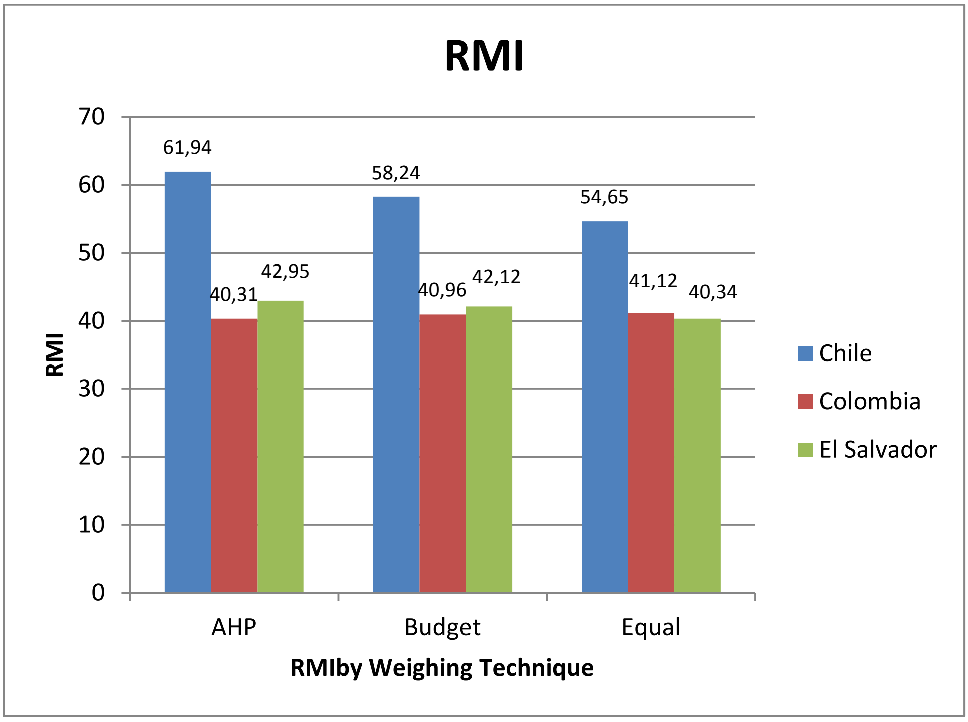


Figure 18: RMI per Country by Weighing Technique

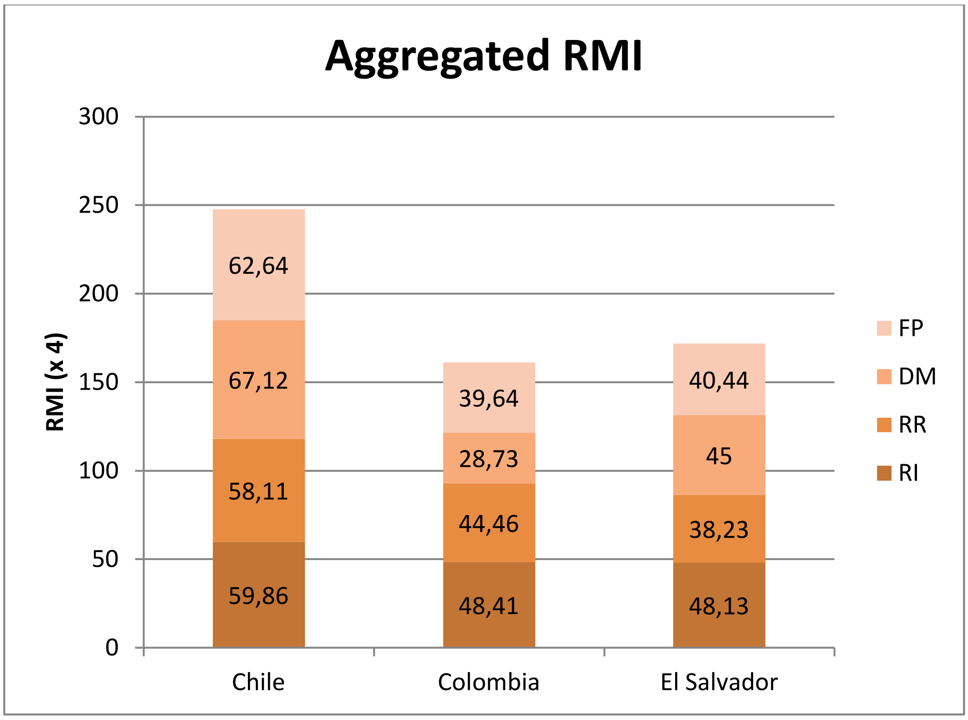


Figure 19: RMI per Country (Aggregated Values)

3.3.2 DRI Results

DRI uses the mortality as a risk indicator but this alone cannot provide the true picture of the losses occurred in a country. It is good indicator of human loss but it does not take into account the human development loss. For most of the hazards, death risk can be proved to be only a fine crack in the deep crevasse. But DRI proved to be a good tool to co-relate between death risks and development in the country. The following graphs represent the comparison between Chile, Colombia and El Salvador about the number of people killed and number of people killed per million inhabitants.

Colombia has the highest number of people killed in a year followed by El Salvador and Chile but situation is more alarming to El Salvador which has the highest number of deaths per million people. It means that large population of El Salvador is under the threat of death due to disaster risk.

Other factors like GDP and Human Development Index also described the link between the disaster risk and development issues. Cross cutting issues like corruption level, population affected to HIV/AIDS and population affected due to armed conflict also reduce the risk management capabilities of government.

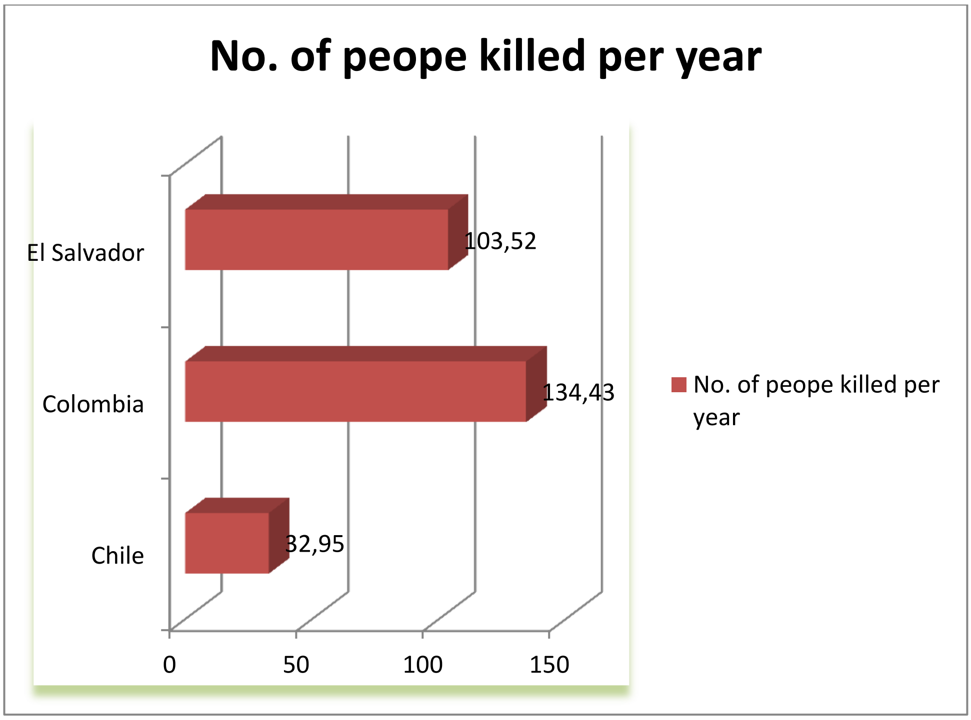


Figure 20: Casualties per Year (DRI)

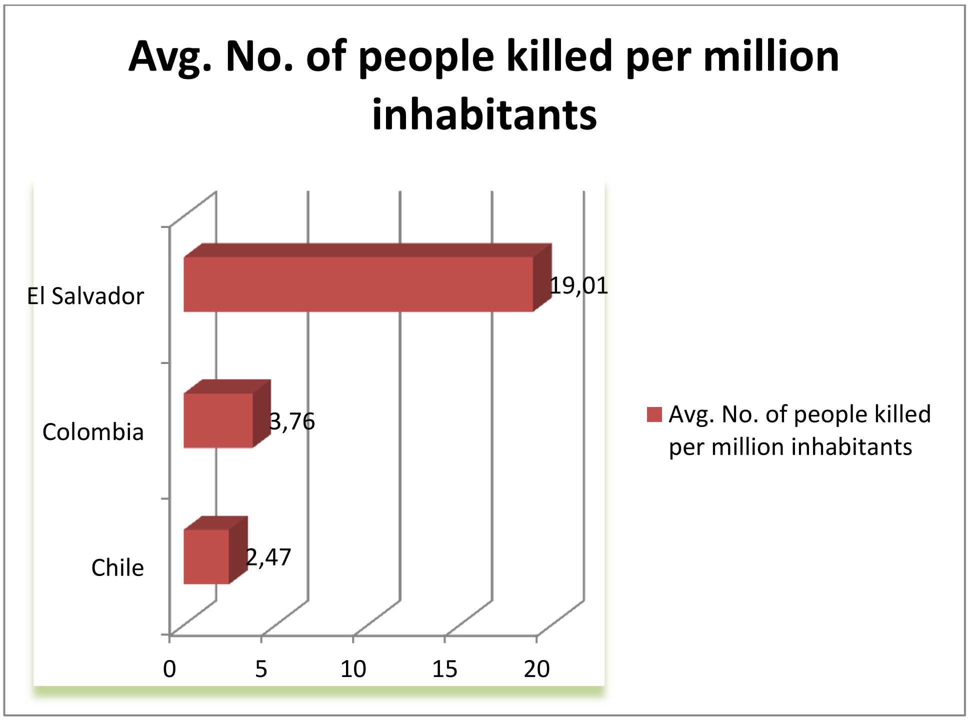


Figure 21: Casualties per Million Inhabitants (DRI)

In comparison to the other two countries (Chile and El Salvador), Colombia enjoys a very high GDP (PPP) but high GDP alone cannot guarantee a strong governance which is reflected by the fact that still after having less GDP (PPP), performance of Chile in managing risk is better than other Colombia. Countries whose economies based on energy exposed are characterized by high GDP per capita but most of them lack of good risk governance. Chile with high human development index (HDI) strengthens the need of risk sensitive development in future for managing risk.

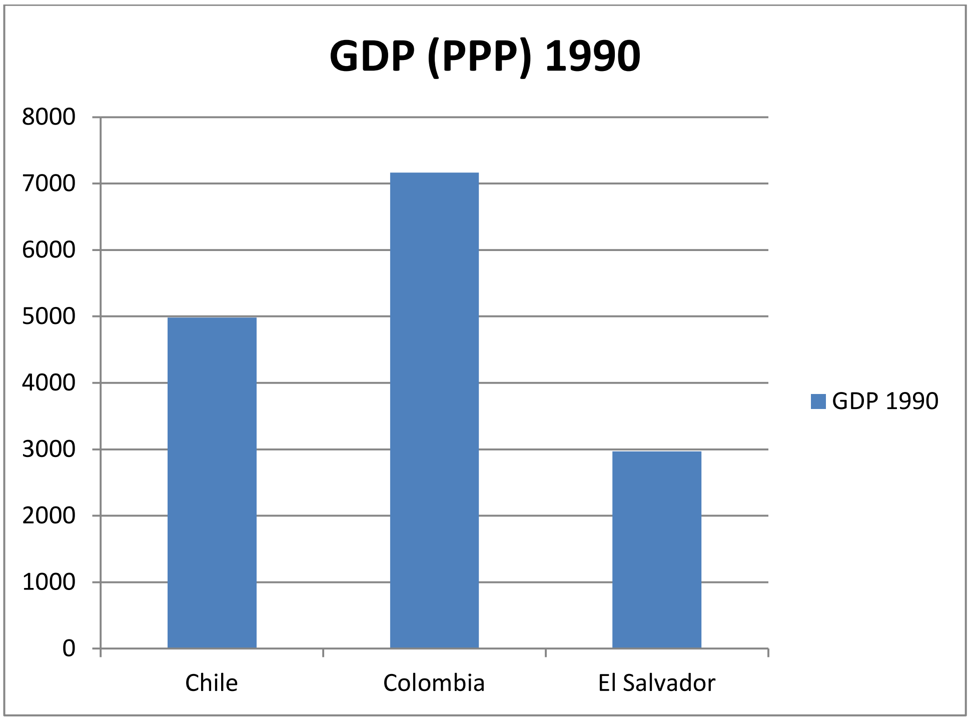


Figure 22: GDP PPP 1990 (DRI)

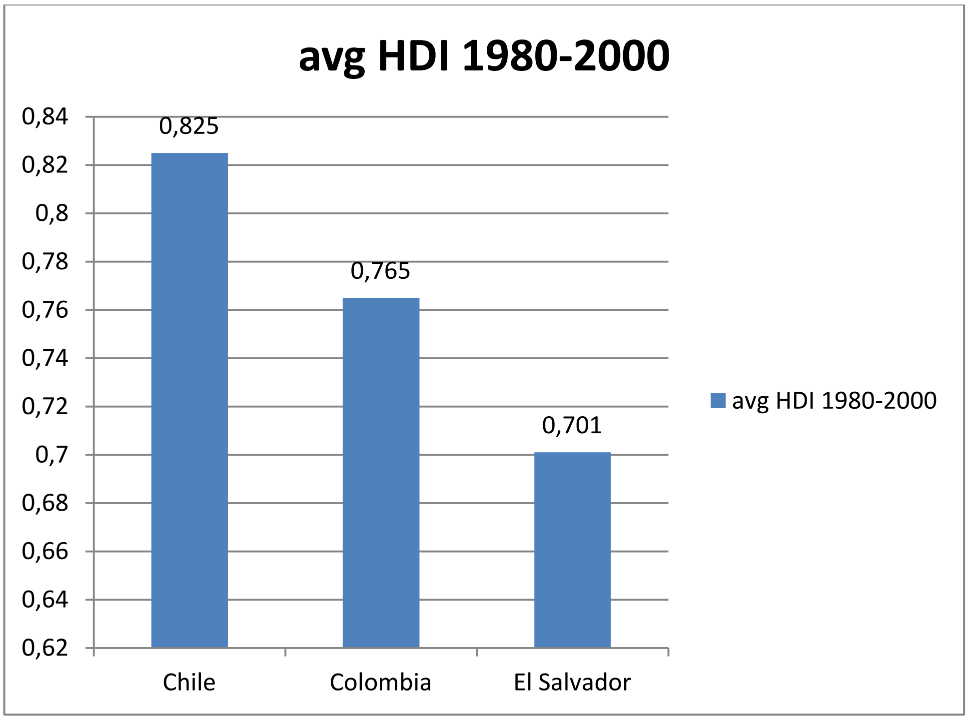


Figure 23: HDI per Country (DRI)

From the above analysis, it is proved that El Salvador is having a high mortality rate. El Salvador is also suffering with low HDI and low GDP which are weakening the capability of that nation to reduce the disaster risk. Effects of above mentioned cross cutting issues were analyzed and it was found that corruption increased in Colombia and El Salvador while whole Colombia and almost half of the El Salvador are affected by violence and armed conflicts. Internally displaced people due to these conflicts are often forced to occupy the hazardous site and most of the displaced people include women and children which are more susceptible to any risk. People affected by HIV/AIDS have low disaster coping capacities to the disease brought by climate change, flood etc. Chile has a low HIV/AIDS patient while Colombia and El Salvador have three times more population affected with HIV/AIDS in comparison to Chile.

DRI gives a good understanding of importance of development issues in managing disaster risk.

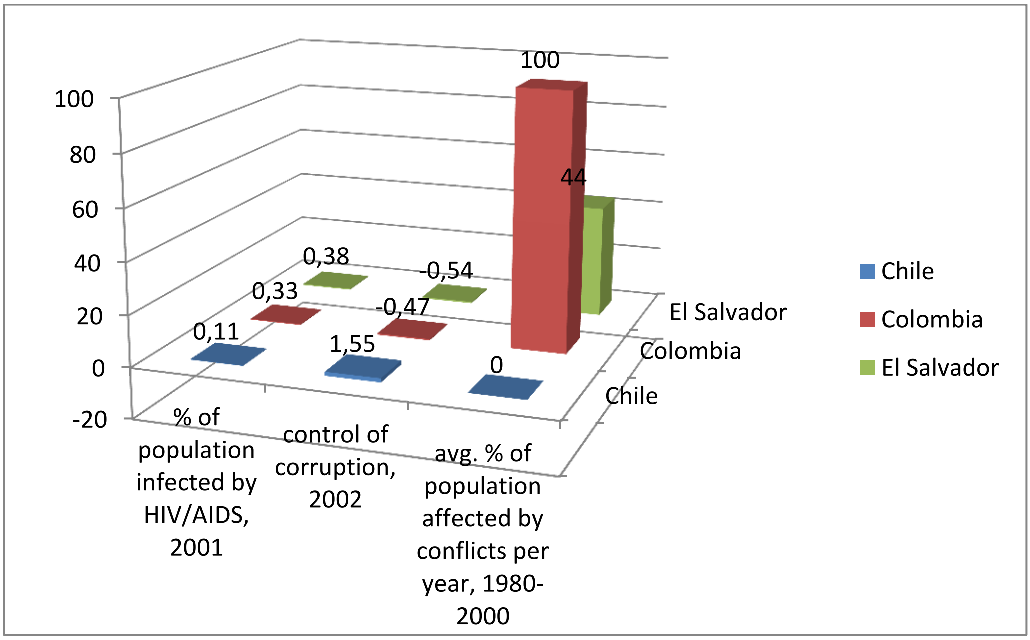


Figure 24: Factors for DRI

Disaster risk index of Chile, Colombia and El Salvador is 0.63, 0.52 and 0.69 which is reported by UNEP in 2008. These values of DRI are obtained by taking the average of risk index with respect to the number of people killed and number of people killed per million. It shows that El Salvador has the highest disaster risk present followed by Chile and Colombia.

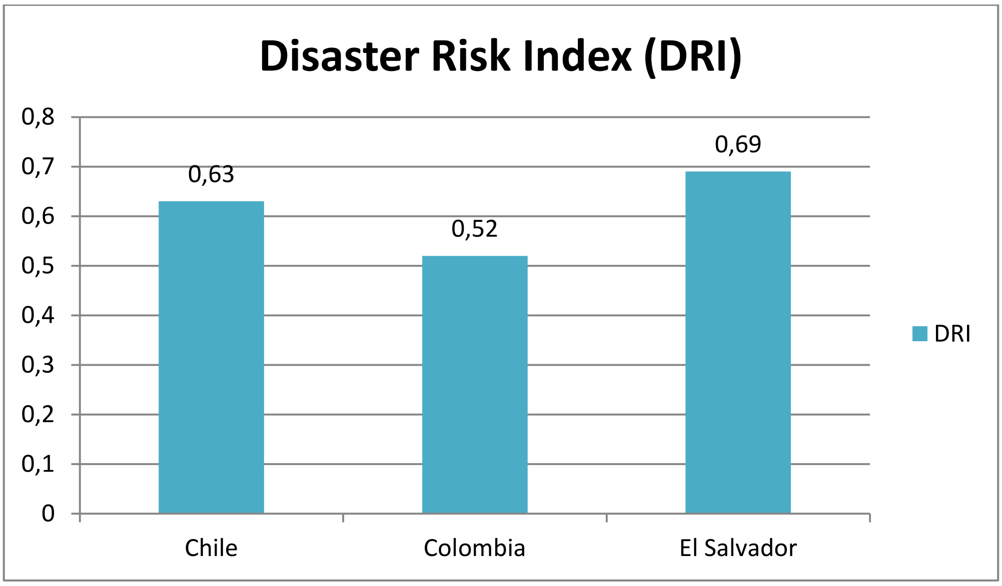


Figure 255: DRI of Chile, Colombia and El Salvador (UNEP,2008)

3.3.3 Hotspots Results

The hotspots program produces maps showing the areas at high mortality risk and high economic risk. The following maps are zoomed-in portions of the maps for global disruption of disaster risk hotspots for all hazards, available on the Natural Disaster Hotspots: A Global Risk Analysis Report.

First, Figure 25 below, represents the mortality risk. Almost all of El Salvador is in the top deciles, showing the highest risk. Colombia and Chile do not show suck a high risk as El Salvador, nonetheless they are mostly on the 5th to 7th deciles. As seen on Figure 26, 51.7% of the total area of El Salvador is at high risk of mortality, and 77.7% of its population lives in these areas. Even though only 1% of the land area in Chile is in high risk of mortality, 18.7 of its population lives there; the high population density, one of the proxies of vulnerability, puts this population at high risk.

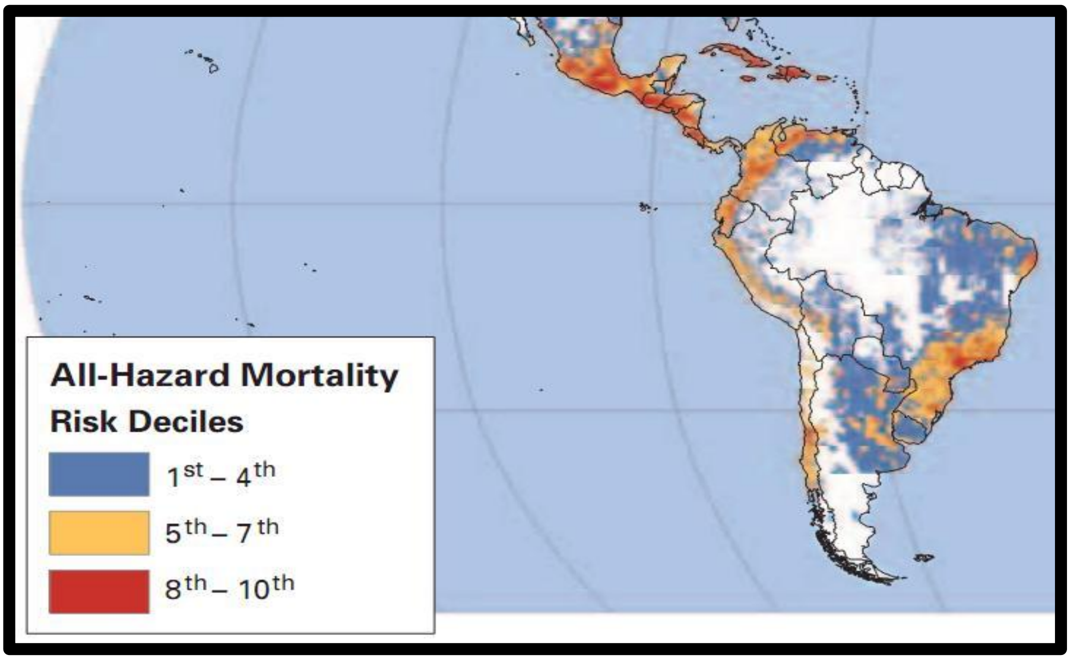


Figure 266: Map for Mortality Risk (Dilley, et al, 2005)

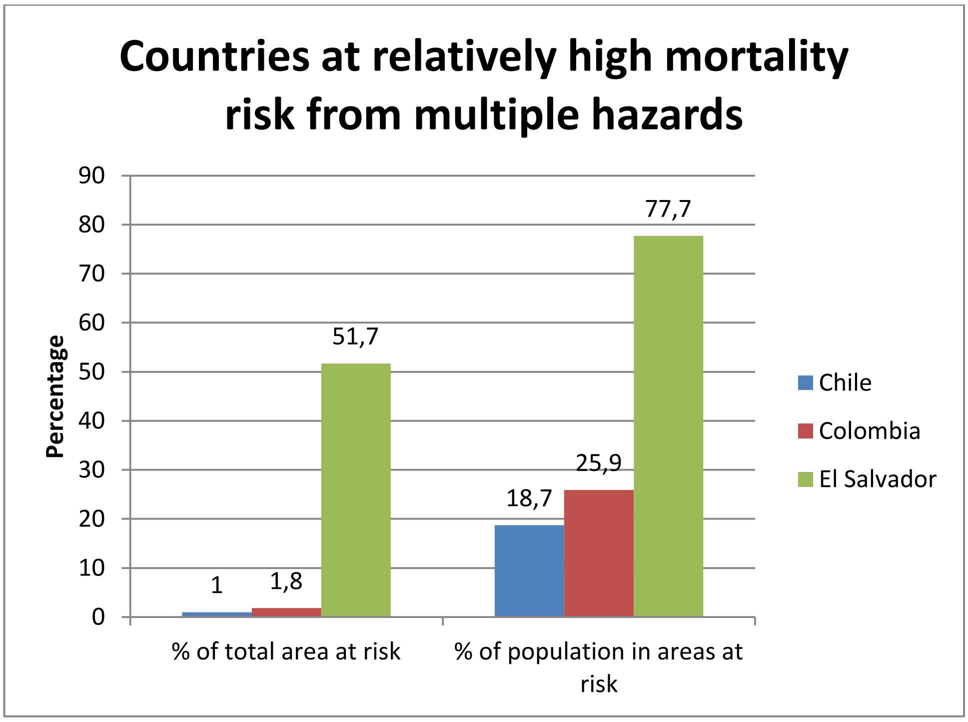


Figure 277: Countries at Relatively High Mortality Risk from Multiple Hazards (data from Dilley, et al, 2005)

Next, Figure 27 shows the global distribution of disaster risk hotspots for all hazards based on the total economic loss and Figure 29 represents the economic loss as a proportion of the GDP density. Again, El Salvador is in the top deciles, and, as shown on Figure 28, 85.4% of its GDP is in the area at risk. Colombia has a considerable portion of its territory in high risk as well, with 73% of its GDP concentrated in these areas. Chile, with only 2.9% of its area at risk, has 62.9% of its GDP at risk. GDP, as previously mentioned, is another proxy of vulnerability used in the Hotspots program.

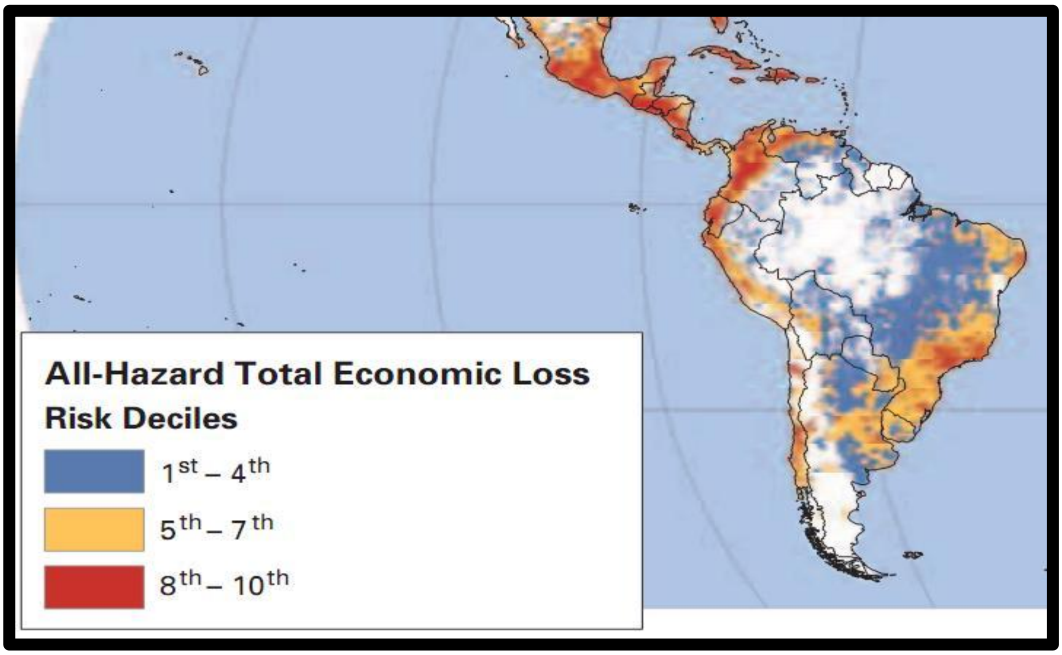


Figure 288: Map of Total Economic Loss (Dilley, et al, 2005)

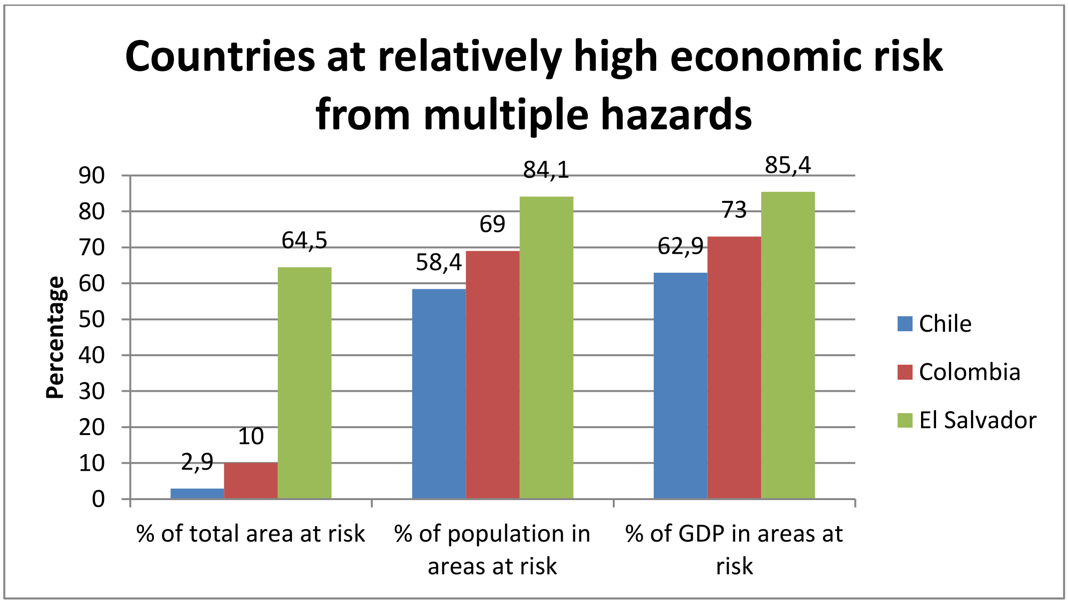


Figure 299: Countries at Relatively High Economic Risk from Multiple Hazards (data from Dilley, et al, 2005)

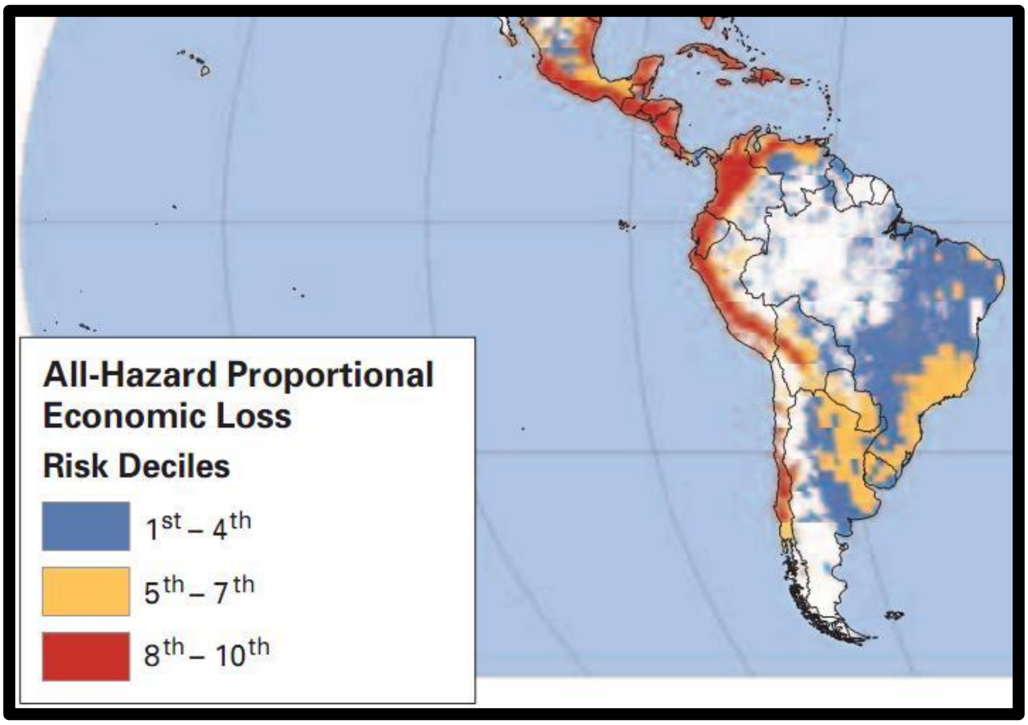
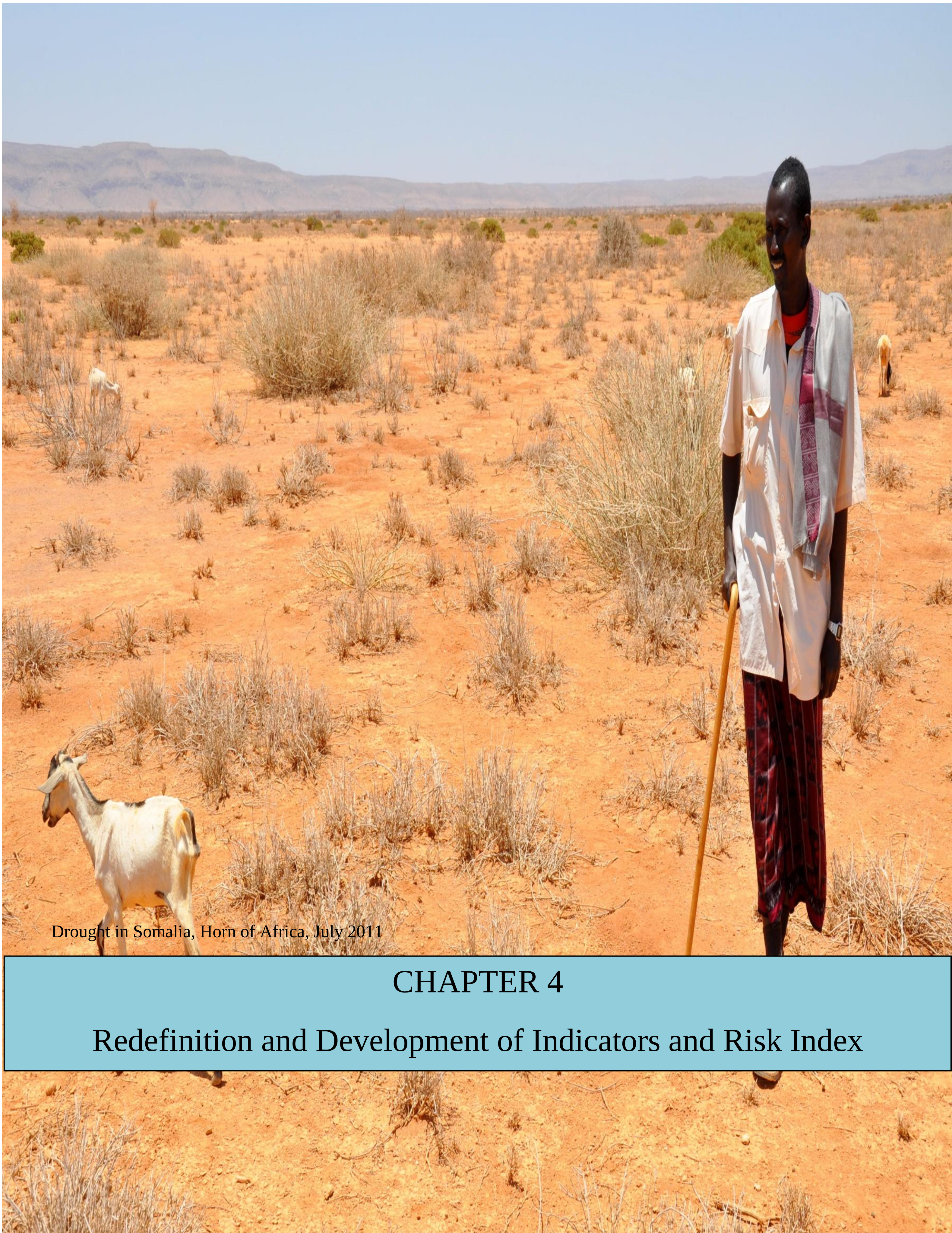


Figure 30: Map of Proportional Economic Loss to GDP (Dilley, et al, 2005)



Drought in Somalia, Horn of Africa, July 2011

CHAPTER 4

Redefinition and Development of Indicators and Risk Index

Redefinition and Development of Indicators and Risk Index

4.1 Redefinition of Index: LDI (2)

The main advantage of the Local Disaster Index (LDI) is that it provides an indication of how dispersed risk is inside a country. As previously mentioned, this index, however, does not provide an indication of the actual level of risk. A complement to this LDI is therefore proposed: an index that accompanies the distribution by presenting a measurement of risk. It is important to note that the complement of the LDI (referred to as the LDI (2)) is not to be used individually; both indices should be used together, as they both offer correlated information. With these two indices an identification of the relative levels of risk between countries is possible and the distribution of this risk inside the individual countries is also given.

The proposed LDI (2) is calculated by using a geometric mean average of the overall country population and a weighted geometric mean average for the number of casualties, affected and economic losses. The geometric averages are used to properly represent the exponential growth in the population and in the GDP during the analyzed periods of time; an arithmetic mean average does not capture the exponential growth and instead calculates a linear growth. Geometric averages are commonly used by the United Nations in the calculations involving population growth. The weighted average is used in order to give importance to the relationship between the overall value and its result, for example, having 200 casualties in a population of 5 million is not the same as having 200 casualties in a population of 15 million. This index is based on historical data; therefore, it is not a true measurement of future risk, but is instead a trend of what the risk has been for a period of 25 years.

The basic meaning of the LDI (2) is a ratio of the effects of a natural disaster to the total population, in the case of casualties or affected people, or to the GDP PPP in the case of economic losses. This was defined as relevant vulnerability by the DRI. The relevant vulnerability is taken as an indication of risk, due to the /fact that the hazard event has already occurred and those that were initially at risk (people and assets) have indeed suffered the consequences of the disaster, as the risk has already materialized into a negative outcome. The overall population and the overall GDP are used as opposed to the exposed population or the exposed assets since the LDI itself determines the distribution of the risk inside the country being analyzed. Therefore, the specification of the exposed was not deemed necessary. The overall highest value of the LDI (2) is, theoretically, 100. The highest value of the LDI (2) would represent the hypothetical situation in which there was a complete destruction of assets and the complete population was either killed or affected. A value of zero is not possible, as the equation clearly represents it; if there were no deaths, no affected people or no economic losses, the risk for that period is does not exist. Nonetheless, the fact that the total country population and the total GDP are used as a reference force the values of the calculated LDI (2) to be very low.

GDP PPP is the gross domestic product converted in international dollars using purchasing power parity rates. The GDP PPP is used as reference because it represents the value of the local currency, given the fact that what may be acquired with a dollar in El Salvador is completely different than what can be purchased with the same dollar in Chile.

The overall equations for the LDI (2) are the following:

$$LDI\ (2)_{k,a,l} = \frac{exp^{\frac{\sum_{i=1}^{n} w_i\, ln(x_i)}{\sum_{i=1}^{n} w_i}}}{\sqrt[n]{y_1 y_2 \cdots y_n}}$$

$$LDI\ \ 2\ = \frac{LDI\ (2)_k\ + LDI\ (2)_a\ + LDI\ (2)_l}{3}$$

The weighted geometric mean average of deaths, affected, or losses is defined by:

$$exp^{\frac{\sum_{i=1}^{n} w_i\, ln(x_i)}{\sum_{i=1}^{n} w_i}}$$

Where x_i is the number of casualties, affected people or economic losses for each period i, and w_i is the corresponding weight. For the case of the casualties and the affected people, the weight is defined by the ratio of effects in a given period to the population of that same period. On the other hand, the weight of the economic losses is the ratio of the economic loss of a given period with respect to the GDP PPP of that same period.

The geometric mean of the total population and of the GDP PPP is defined by:

$\sqrt[n]{y_1 y_2 \ldots y_n}$ where y_i represents the population for each of the five year periods. The calculations of these equations are shown in Appendix A.

4.2 Application of the LDI (2)

The proposed LDI (2) is applied to the subject countries of Chile, Colombia and El Salvador. As a comparison, three different datasets were used for this calculation, as the results are totally dependent on the quality and availability of data. First, the data from the Americas Program Report was used, then data was obtained directly from the DesInventar database, and lastly, EM-DAT was accessed for their representation of the effects of the disasters.

The overall population and GDP PPP were obtained from the World Bank Database. The same values were used for the three sets of calculations:

POPULATION			
YEAR	***Chile***	***Colombia***	***El Salvador***
1981 – 1985	*11,718,040*	*28,720,784*	*4,863,246*
1986 – 1990	*12,737,614*	*31,902,170*	*5,192,232*
1991 – 1995	*13,919,938*	*35,136,911*	*5,577,438*
1996 – 2000	*15,029,685*	*38,427,276*	*5,871,765*

Table 20: Population per Period (Data from World Bank)

GDP PPP			
YEAR	***Chile***	***Colombia***	***El Salvador***
1981 - 1985	*33,416,978,173*	*86,293,028,498*	*10,080,507,214*
1986 - 1990	*50,890,883,076*	*123,868,151,882*	*12,481,473,412*
1991 - 1995	*86,565,866,045*	*175,657,958,347*	*18,159,810,619*
1996 - 2000	*130,588,102,726*	*221,223,056,673*	*24,823,147,862*

Table 21: GDP PPP per Period (Data from World Bank)

The first calculation of the LDI (2) was performed utilizing the exact data used in the Americas Program Report for the calculation of the LDI. The report cited the DesInventar database as the source for the data. Some inconsistencies, however, were found. For the period of 1981 – 1985, Colombia has reported 25,390 deaths, the majority of these casualties (more than 22,000) were from a volcano eruption in 1985. The subsequent period, 1986 – 1990, reports 57 deaths for El Salvador; nonetheless, in 1986 the capital city of this country suffered from an earthquake that took approximately 1,200 human lives. These discrepancies are accompanied by the corresponding difference in affected people and in the amount of losses. The criteria used for obtaining the data are not consistent from country to country, hence, the risk results are not consistent with the overall trend presented in Chapter 3, and Colombia portrays a significantly higher risk level, followed by Chile and lastly El Salvador. Additionally, the Americas Program Report computed the LDI for a period of 20 years. It should be noted that in 2001, El Salvador was shaken by an earthquake that had, once again, approximately 1,200 casualties with the corresponding affected people and economic losses. This event, not included in this dataset, would greatly alter the results of the computed index. Restricting historical based calculations to a short time period (in this case 20 years) does not provide a clear view of the location's risk, as one considerable hazard event may have stricken in the years following the analyzed time frame, as was the case in this situation with El Salvador. The following table shows the dataset obtained from the Americas Program Report, used for the calculations in the subsequent table.

Period	Accumulated Values Unit	Chile	Colombia	El Salvador
1981 - 1985	Deaths	627	25,390	674
	Affected	294,926	1,876,213	62,122
	Losses	168,808	384,976	6,123
1986 - 1990	Deaths	663	1,864	57
	Affected	481,594	1,300,795	9,923
	Losses	102,974	200,832	731
1991 - 1995	Deaths	620	1,626	118
	Affected	510,088	1,676,522	55,935
	Losses	113,017	417,849	2,715
1996 - 2000	Deaths	344	2,540	126
	Affected	321,079	4,573,352	53,055
	Losses	78,366	985,085	598
Losses are in USD 1000 Table from Americas Program Report				

Table 22: Accumulated Values of Effects (Data from Cardona, 2005)

	Chile	Colombia	El Salvador
geometric weighted average of deaths	587	16,859	401
geometric average of population	13,293,292	33,350,698	5,362,545
avg % of deaths to total population	**0.004%**	**0.051%**	**0.007%**
geometric weighted average of affected	411,954	2,568,964	52,030
geometric average of population	13,293,292	33,350,698	5,362,545
avg % of affected to total population	**3.099%**	**7.703%**	**0.970%**
geometric weighted average of losses	135,339,977	497,970,032	4,272,595
geometric average of GDP PPP	66,216,216,645	142,760,610,700	15,432,244,752
avg % of losses to GDP PPP	**0.204%**	**0.349%**	**0.028%**
overall risk index	**1.10%**	**2.70%**	**0.34%**

Table 23: Overall LDI (2) based on Americas Program Report Data

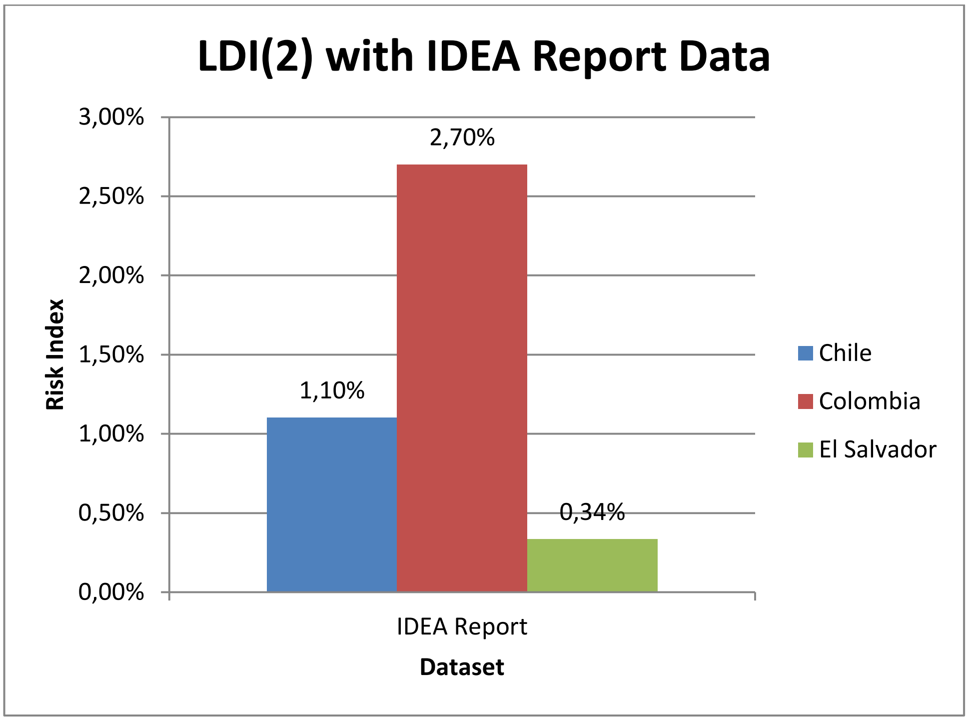


Figure 301: LDI (2) with Americas Program Report Data

The second calculation of the LDI (2) was performed using data directly from the DesInventar database. The casualties were computed by adding the number of dead people plus the number of missing people, as it was considered that the missing people have most probably died. The amount affected people was computed by adding the number of injured, victims, affected, relocated and evacuated. All of these people have been affected by the hazard event, and are thus summed into one quantity. The economic losses reported on the DesInventar database are not consistent throughout the years or through countries. Therefore, for consistency, a ratio of the affected to the economic losses for the LDI in the Americas Program Report was calculated and then applied to this new dataset for the calculation of the economic losses. The Americas Program Report calculated the economic losses by adding the affected houses, destroyed houses and affected crops, each multiplied by a given economic value obtained from the national government's minimum salary for the corresponding year or from a group of experts. It is important to note that the amount of recorded entries for each country is significantly different. A greater amount of entries may signify a greater detail and thus a higher quantity of effects. The following table shows the amount of entries for each country:

Recorded Entries per Period			
Period	**Chile**	**Colombia**	**El Salvador**
1981 - 1985	1,677	2,890	172
1986 - 1990	1,864	2,477	152
1991 - 1995	1,644	2,544	414
1996 - 2000	1,721	4,232	641
2001 - 2005	955	3,838	1,206
Total	**7,861**	**15,981**	**2,585**

Table 24: Recorded Entries per Period by Country (Data from DesInventar)

An additional period was included in this calculation. Data from 2001 through 2005 was added for a clearer view of the results.

The following tables show the data set and the results for this calculation:

Accumulated Values				
Period	**Unit**	**Chile**	**Colombia**	**El Salvador**
1981 - 1985	Deaths	716	26,672	338
	Affected	353,546	2,679,906	2,735
	Losses	94,063	535,834	82
1986 - 1990	Deaths	846	1,998	1,241
	Affected	601,687	4,234,109	26,902
	Losses	160,082	846,590	809
1991 - 1995	Deaths	690	2,013	102
	Affected	1,162,559	3,014,768	42,161
	Losses	309,304	602,788	1,268
1996 - 2000	Deaths	487	3,252	502
	Affected	952,527	7,401,048	104,449
	Losses	253,424	1,479,804	3,140
2001 - 2005	Deaths	590	1,088	2,513
	Affected	3,113,055	3,761,287	1,890,686
	Losses	828,243	752,051	56,844
Losses are in USD 1000				
Table from DesInventar Database				

Table 25: Accumulated Values of Effects (Data from DesInventar)

	Chile	Colombia	El Salvador
geometric weighted average of deaths	686	16,220	1,376
geometric average of population	13,658,877	34,426,745	5,467,220
avg % of deaths to total population	**0.005%**	**0.047%**	**0.025%**
geometric weighted average of affected	1,544,297	4,409,223	1,398,183
geometric average of population	13,658,877	34,426,745	5,467,220
avg % of affected to total population	**11.306%**	**12.808%**	**25.574%**
geometric weighted average of losses	311,668,872	825,708,856	38,411,089
geometric average of GDP PPP	76,611,646,081	156,754,480,098	17,136,339,783
avg % of losses to GDP PPP	**0.407%**	**0.527%**	**0.224%**
overall risk index	**3.91%**	**4.46%**	**8.61%**

Table 26: Overall LDI (2) based on DesInventar Data

The results for the overall risk index are consistent with the trend portrayed in Chapter 3. El Salvador has the highest risk level, followed by Colombia and lastly Chile. Although the values of the effects are higher for Colombia, the overall population and the overall GDP are also higher than for El Salvador; therefore, the effects, with proportion to the whole, are not as severe for Colombia as they are for El Salvador. The following chart shows the results:

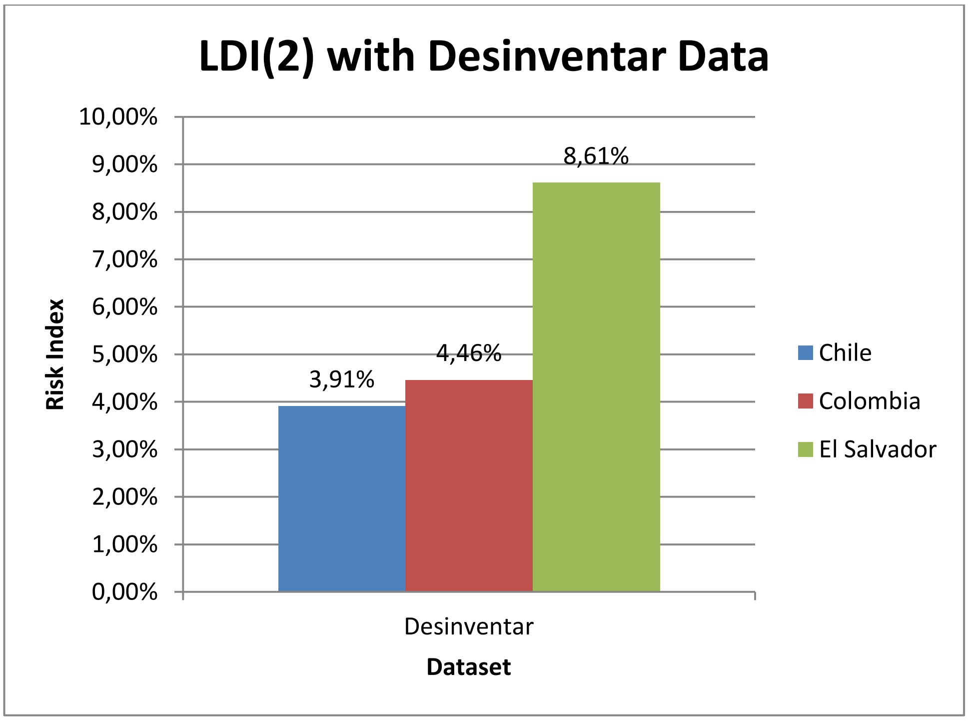


Figure 312: LDI (2) with DesInventar Data

Lastly, the LDI (2) was calculated using data from EM-DAT. This third scenario also includes the fifth period, 2001 – 2005. The EM-DAT database has records for casualties, affected and economic losses. Their definition of affected is "People requiring immediate assistance during a period of emergency, i.e. requiring basic survival needs such as food, water, shelter, sanitation and immediate medical assistance..." (EM DAT, 2009). The economic impact includes damages to infrastructure, housing and crops, as well as indirect effects on the local economy. Although these definitions are not exact to those used above, they are comprehensive and provide a complete view of the consequences of the hazard event.

The following tables summarize the effects and the calculations:

Accumulated Values				
Period	**Unit**	**Chile**	**Colombia**	**El Salvador**
1981 - 1985	Deaths	311	22,556	520
	Affected	1,192,356	56,700	80,000
	Losses	1,500,000	1,415,900	280,000
1986 - 1990	Deaths	224	1,124	1,165
	Affected	205,772	535,325	539,060
	Losses	195,200	52,500	1,500,000
1991 - 1995	Deaths	290	1,087	170
	Affected	140,583	137,825	24,771
	Losses	386,660	106,800	1,000
1996 - 2000	Deaths	60	1,576	525
	Affected	279,616	1,183,630	91,831
	Losses	550,400	1,860,869	559,610
2001 - 2005	Deaths	89	621	1,590
	Affected	307,262	1,349,282	2,113,650
	Losses	293,900	10,000	2,226,600
Losses are in USD 1000				
Table from EM-DAT				

Table 27: Accumulated Values of Effects (Data from EM-DAT)

	Chile	Colombia	El Salvador
geometric weighted average of deaths	235	15,081	969
geometric average of population	13,658,877	34,426,745	5,467,220
avg % of deaths to total population	**0.002%**	**0.044%**	**0.018%**
geometric weighted average of affected	637,935	909,042	1,242,928
geometric average of population	13,658,877	34,426,745	5,467,220
avg % of affected to total population	**4.670%**	**2.641%**	**22.734%**
geometric weighted average of losses	1,043,779,224	1,368,250,827	1,305,815,197
geometric average of GDP PPP	76,611,646,081	156,754,480,098	17,136,339,783
avg % of losses to GDP PPP	**1.362%**	**0.873%**	**7.620%**
overall risk index	**2.01%**	**1.19%**	**10.12%**

Table 28: Overall LDI (2) based on EM-DAT Data

The LDI (2) computed with the EM-DAT data portrays different results from the previous computations. In this case, El Salvador has a significantly highest risk than the other two countries. The difference between Colombia and Chile is not major; even so, Chile appears to be in greater risk than Colombia.

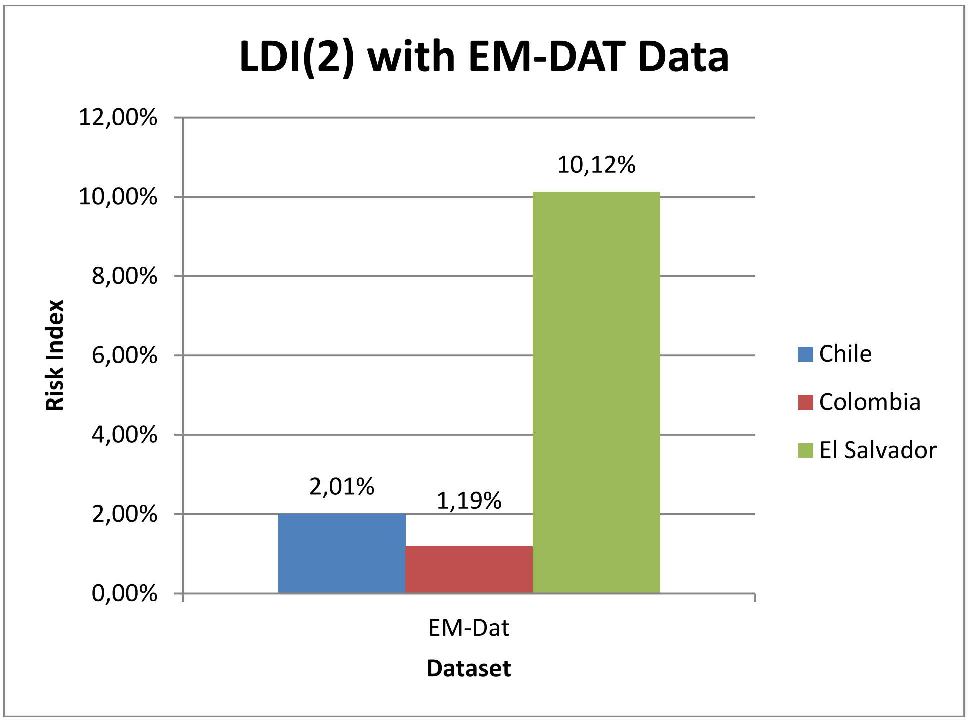


Figure 323: LDI (2) with EM-DAT Data

The following chart represents the three calculations for the proposed LDI (2). It leads to conclude that the quality and type of data used in the calculations of indices are crucial in the interpretation of the results.

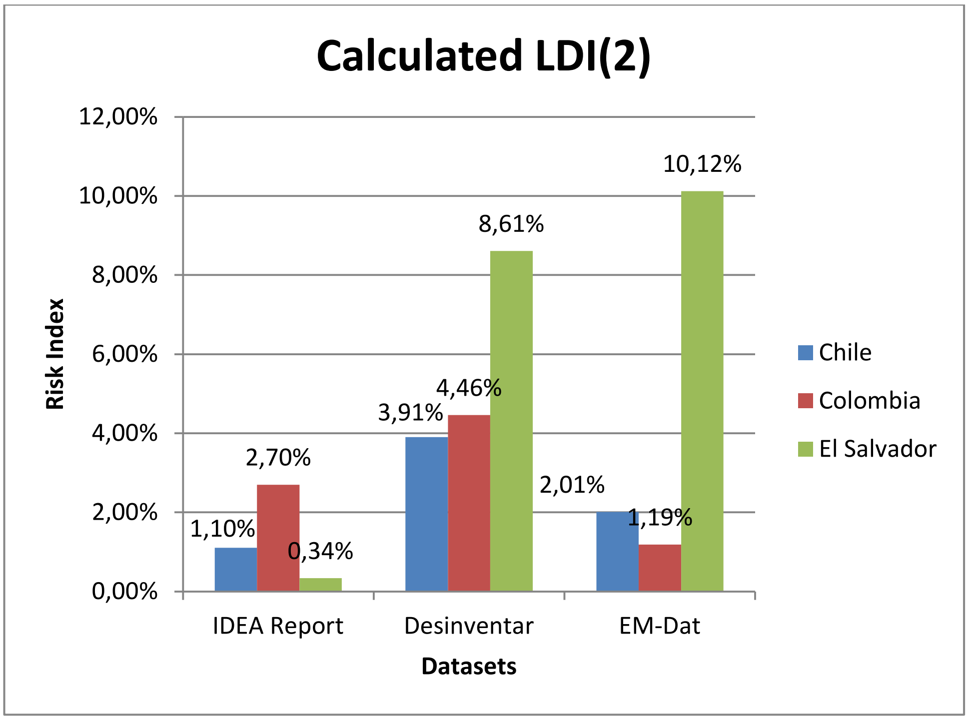


Figure 334: Calculated LDI (2) - Database Comparison

As a further comparison, the LDI (2) was calculated for the United States and for India, with the data available from the EM-DAT database. It is worth noting that the LDI should also be calculated, as these two indices complement each other.

The fact that India is not only highly populated but has also a very high population density makes it more prone to suffering from severe consequences during natural disasters. Although India has a well off economy, its wealth is concentrated and not distributed throughout the country. Not all of the population has access to resources, as the ideal situation should be, making them more vulnerable to natural hazards. A significant portion of India's population is in fact poor. Therefore, an analysis at a sub-national level, for example, the calculation of the LDI, would produce a clearer picture of the risk inside the country. Disaggregating data in country where the population and exposure are so diverse would be beneficial. On the other hand, the United States depicts a very low risk level. A closer look at the economic losses reported on the databases would probably alter the results of the computed LDI (2).

Period	Unit	India	United States
Accumulated Values			
1981 - 1985	Deaths	15,798	2,426
	Affected	188,074,089	1,057,050
	Losses	3,365,420	15,495,850
1986 - 1990	Deaths	15,083	801
	Affected	373,775,800	22,038
	Losses	5,124,543	16,479,420
1991 - 1995	Deaths	20,711	1,924
	Affected	185,790,650	733,600
	Losses	9,014,102	109,095,100
1996 - 2000	Deaths	29,486	1,625
	Affected	222,675,937	3,801,729
	Losses	7,995,980	51,483,950
2001 - 2005	Deaths	49,021	2,998
	Affected	307,262	1,349,282
	Losses	15,598,634	252,846,830
Losses are in USD 1000			
Table from EM-DAT			

Table 29: Accumulated Values of Effects for India and United States (Data from EM-DAT)

	India	United States
geometric weighted average of deaths	27,672	2,101
geometric average of population	879,889,375	257,964,696
avg % of deaths to total population	**0.003%**	**0.001%**
geometric weighted average of affected	254,785,094	2,064,517
geometric average of population	879,889,375	257,964,696
avg % of affected to total population	**28.956%**	**0.800%**
geometric weighted average of losses	7,484,238,564	116,129,334,716
geometric average of GDP PPP	799,210,377,136	5,885,561,028,935
avg % of losses to GDP PPP	**0.936%**	**1.973%**
overall risk index	**9.97%**	**0.92%**

Table 30: Overall LDI (2) for India and United States

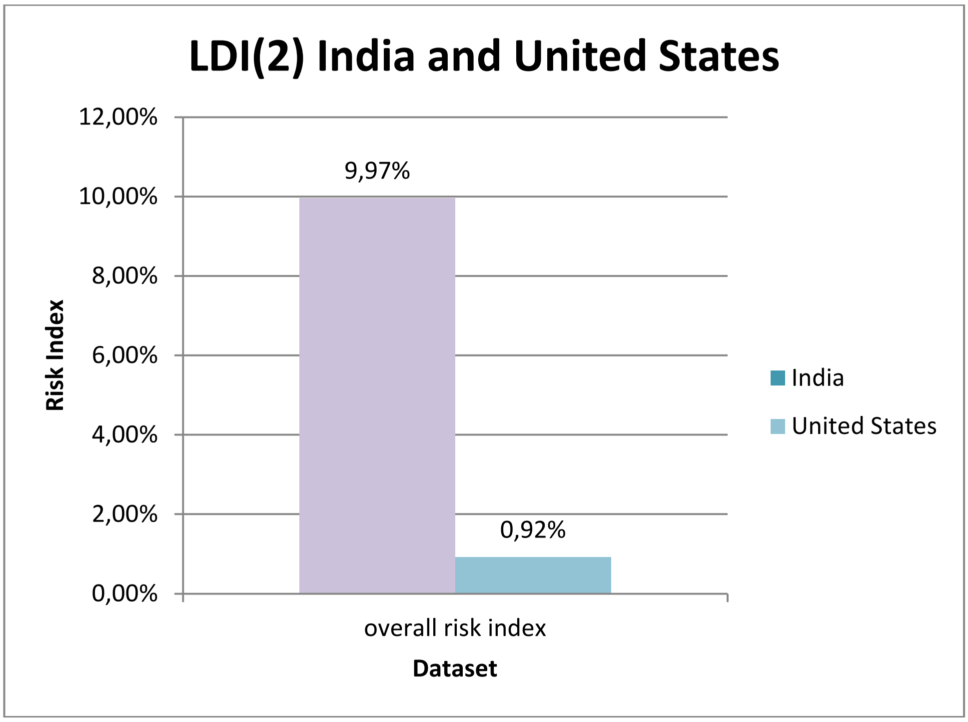


Figure 345: LDI (2) for India and United States

Lastly, as shown on Figure 35, El Salvador and India present the highest levels of risk. These two countries, however, are totally different in their size, economies, population, etc. As seen on the Hotspots analysis presented in Chapter 3, El Salvador is completely exposed to natural hazards. Both countries portray a high population density: India has approximately 390 inhabitants per square kilometer and El Salvador has roughly 300, population density, as previously mentioned, is an indication of vulnerability.

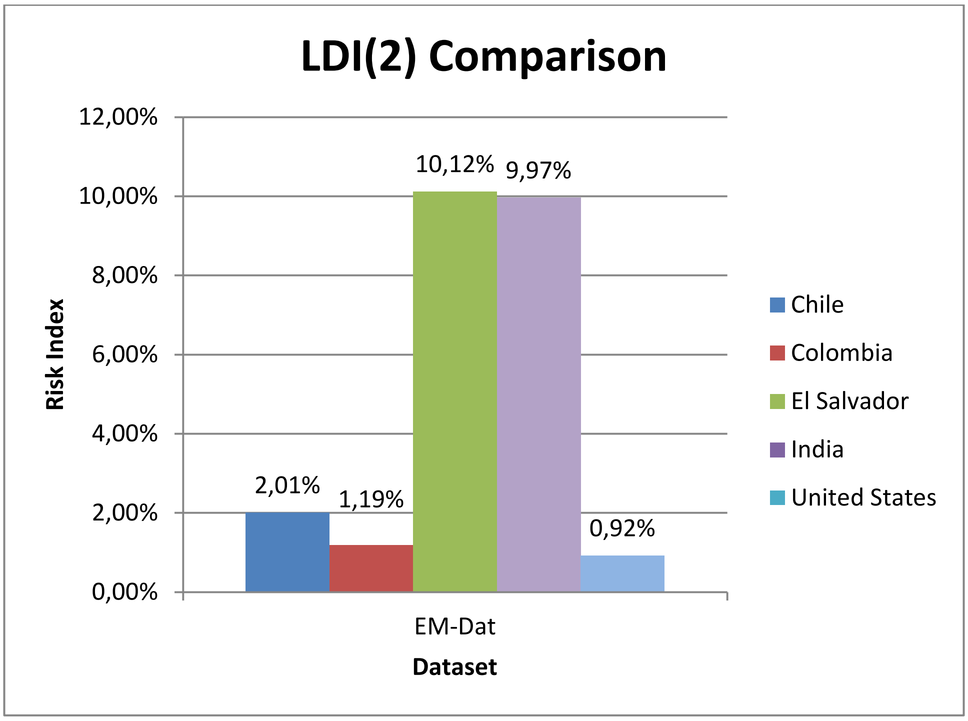


Figure 356: LDI (2) Country Comparison

4.3 Redefinition of Indicators: PVI

PVI portrays prevailing vulnerability conditions by measuring exposure in prone areas, socio-economic fragility and lack of social resilience. Identifying the vulnerable part of the system is the key issue of disaster risk management. Vulnerability can be directly related to the development of countries. Risk is a situation that demands the dimensioning of vulnerability over time (Cardona, 2004).

An attempt has been made here to look into more detail of the all the indicators used in all three component of PVI and their feasibility and reliability have been assessed. While proposing the new indicators, it has been kept into mind that indicators should be measurable, relevant to the topic, analytically and statistically sound, understandable, easy to interpret, reproducible and appropriate to scope. Already existing data is also key criteria in the selection of data because available global information allows to compare different countries, although self assessment regarding vulnerability and coping capacity do not account for available data rather these approaches focus on the people's knowledge and policy recommendations. (*Wisner & Walter, 2005*).

It is required to check if exposure is relevant to each potential type of event. Although most of the indicators taken in $PVI_{ES,}$ are common to any type of event but few indicators can have more importance over the others in a specific hazard. For an example, percentage of arable land is very important indicator for flood and drought events but not really affected by the earthquake. It's a important decision need to be made in future whether indicators should be hazard specific or common for all events.

Poverty is measured as population below US$ 1 per day PPP which do not look to be a consistent value applying to all countries of the world. As the quality of life and criteria for poor differ from country to country and national standard has been set in every country to count the people living below poverty line, it is proposed here to include percentage of people living below poverty line as an indicator for the physical exposure instead of people earning below US$ 1 per day.

Physical susceptibility of assets is measured in terms of value of capital stock million US$ dollar/1000 km^2. 1000 km^2 seemed to be very big resolution in small countries like Switzerland, Sri Lanka etc. This parameter need to be reviewed. If results has to be disaggregated at sub national level, it may not provide the true picture of risk. It is proposed to use the resolution of 500 km^2.

Imports and exports of goods and services as % of GDP do not provide any correlation across countries between trade as a % of GDP and vulnerability. For larger countries level of openness of economy and vulnerability to natural hazards depend upon the diversification of the export market. For smaller countries with very few key exports, vulnerability of those particular export needs to be considered. If a major flood occurs to a country whose major part of economy is based on agriculture then it will bring down the economy and will increase the economic burden over the society. There is a need of an indicator to link the composition of economy showing the relative importance of industry, agriculture etc.

ES8 "Arable land and permanent crops as % of land area" is also a weak indicator as it does not give any economic significance of agriculture sector. Including "Agriculture as a percentage of GDP" as a variable can be a much better option.

Number of people affected by chronic disease or HIV AIDS etc. as a percentage of total population should be considered as important indicator in the category of social fragility of PVI. There is a large population of HIV infected people particularly in Africa and Asia. It reduces the capacity of the society to fight with the post disaster consequences and chances of survival are less for these people.

Number of hospitals beds per 100 people and television sets per 1000 people do not seem to be very realistic parameter to assess the vulnerability in terms of lack of resilience. PVI_{LR} use indicators which show the capacity to recover from or absorb the shock and play a key role in faster response and recovery. Number of medical facilities per 500 km^2 area or number of medical staff per 1000 people can be a more useful indicator instead of number of beads. There can be more than one telephone set in a single home with one telephone connections. So it is proposed to measure number of mainland telephone connections per 100 people.

The following tables provide the redefined indicators of prevalent vulnerability indicators

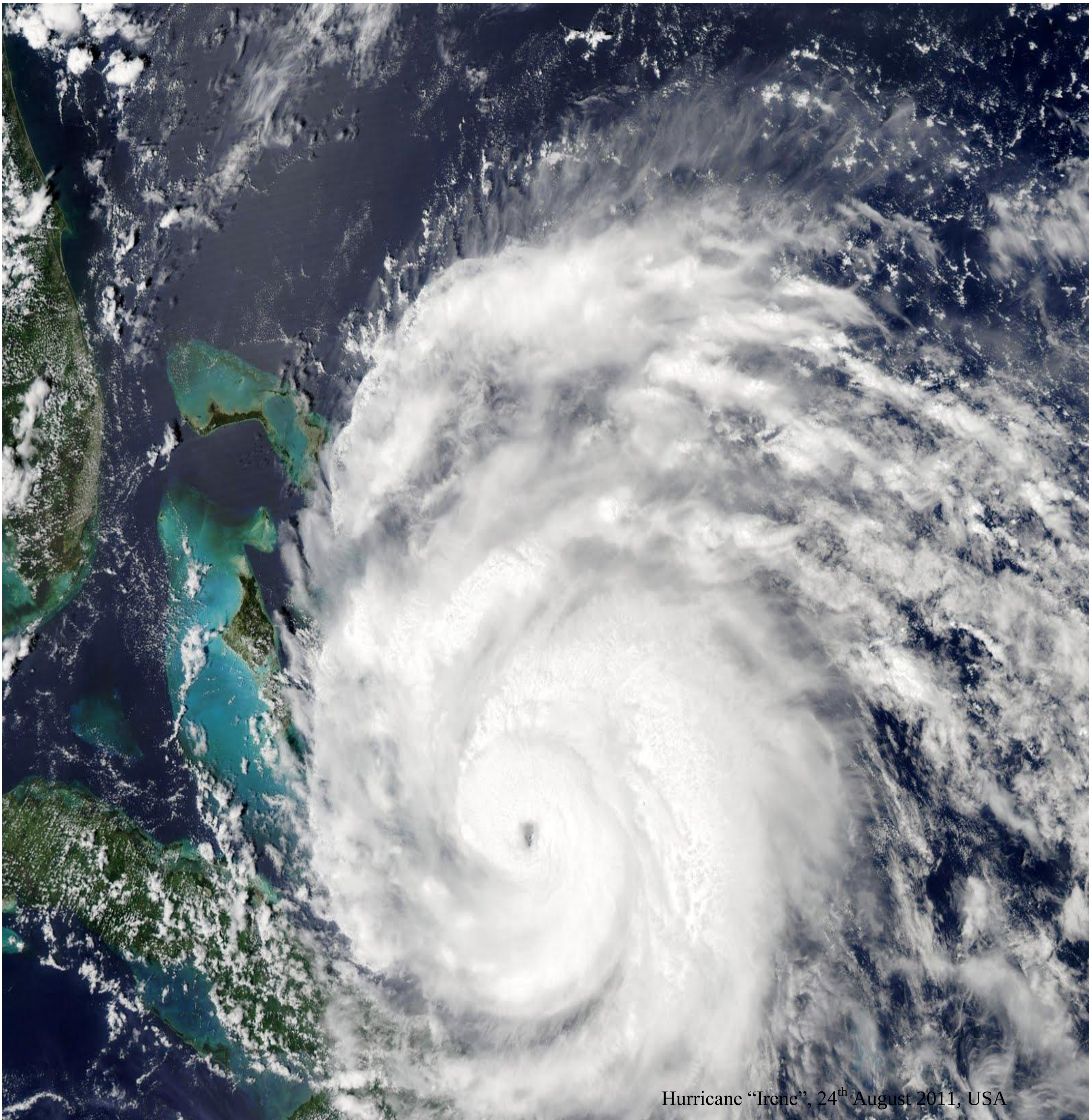
EXPOSURE AND SUSCEPTIBILITY	
Indicator	Source
ES 1. Population growth, average annual rate (%)	UNDESA / WB
ES 2. Urban growth, average annual rate (%)	UNDESA / WB / GEO / HABITAT
ES 3. Population density, people per 5 km^2	UNEP/GRID / GEO
ES 4. Number of people living below poverty line	WB / UNICEF or National Government
ES 5. Capital stock, million US$ per 500 km^2	WB Ministries of Finance and Planning
ES 6. Imports and exports of goods and services, % of GDP	WB
ES 7. Gross domestic fixed investment, % of GDP	WB
ES 8. Agricultural as % of GDP	WB

SOCIO-ECONOMIC FRAGILITY	
Indicator	Source
SF 1. Human Poverty Index	UNDP
SF 2. Dependents as proportion of working age population (15-64)	WB
SF 3. Social disparity, concentration of income measured using Gini index	WB
SF 4. Unemployment, as % of total labor force	ILO / WB
SF 5. Inflation, food prices, annual %	UNICEF / WB
SF 6. Dependency of GDP growth of agriculture, annual %	WB
SF 7. Debt servicing, % of GDP	WB
SF 8. Human-induced soil degradation	FAO/UNEP / GEO
SF9. Iliteracy rate %	UNICEF
SF.10 % of Population affected by HIV-AIDS	UNAIDS, WHO

LACK OF RESILIENCE	
Indicator	Source
LR 1. Human Development Index (inv)	UNDP

LR 2. Gender-related Development Index (inv)	UNDP
LR 3. Social expenditure; on pensions, health, and education, % of GDP (inv)	WB
LR 4. Governance Index (inv)	WBI
LR 5. Insurance of infrastructure and housing, % of GDP (inv)	Ministries of Finance and Planning
LR 6. Number of mainland telephone lines per 1000 people	ITU
LR 7. Number of medical staff per 1000 people	WHO
LR 8. Environmental Sustainability Index, ESI (inv)	WEF

Table 31: Revised table of indicators of PVI



Hurricane “Irene”, 24th August 2011, USA

CONCLUSIONS

Conclusions

The effects of natural hazards continue to increase over time. Risk, as a combination of vulnerability, exposure and hazard, is not only present, but also alarmingly high in various areas of the world. Reasons for these levels of risk vary from increasing population, densely populated areas, and dynamic climatological conditions, among others. As national governments and international organizations attempt to mitigate risks and reduce the total disaster risk, much needed new strategies continue to flourish. With these, the use of risk indices is becoming more frequent.

Disaster risk management (DRM) is the systematic process of using administrative decisions, organization, operational skills and capacities to implement policies, strategies and coping capacities of the society and communities to lessen the impacts of natural hazards and related environmental and technological disasters. This comprise all forms of activities including structural and non structural measures to avoid (prevention) or to limit (mitigation and preparedness) adverse effects of the hazards (*Living with Risk, 2004*). Risk reduction should be priority for all risk prone countries but still developing and poor countries find it difficult to make risk reduction a priority. Low income countries tend to invest less on prevention and risk reduction and more on post disaster response and recovery. It may be due to the fact that positive effects of investing in DRR may not be realized for many years which make it difficult to justify the mobilization of funds and resources to DRR in comparison to other sectors such as rural health where benefits are more upfront and visible.

Computation of a risk index faces many obstacles such as uniform terminology, standard methodologies of data collection, lack of disaster loss data, the unavailability of existing database system to public, and the choice of an appropriate scale for the assessment. There is still a great cacophony exist in the definition of technical terms of disaster risk management field. There should be standard terminology which can be unanimously adopted in the international community to talk about the disaster risk issues. Interpretation of vulnerability, hazard, risk and disasters in a different way for everyone leads to an ambiguous picture of global risk which does not provide a good comparison about the level of risk between different countries. Poor data collection can mislead the government or policy makers to take decision on sustainable development issues. The world is still lacking a standard methodology of data collection. Different databases like EM-DAT, NatCat, and Sigma have their own method of collection of data according to their needs. For example, Munich Re and Swiss Re only consider the insured losses. EM-DAT has set a particular threshold to consider events into disasters. National governments should be encouraged by International Organizations (United Nations, World Bank etc.) to establish disaster loss databases which will help them to identify risk in their territory.

Currently, some countries have better practices than others in the data collection, impeding a true uniform comparison of relative risks. Additionally, in some cases the disaster loss data is inexistent. The appropriate collection of data and monitoring of disasters would allow the identification of those countries that require additional international assistance, others that need improvement in their strategies, and finally those that have an outstanding performance and could serve as examples to follow. The public has limited access to disaster databases. Today, only EM-DAT and DesInventar are accessible to the public, while NatCat and Sigma have very limited or no access at all. Allowing the propagation of information facilitates future studies in the field of disaster risk reduction. A public accessible database would not only force countries to be transparent with regards to their reported losses, but would also generate a consciousness in the population that would hopefully lead them to take action on disaster reduction measures.

The choice of an adequate scale for a risk assessment is crucial. An assessment at a national scale, needless to say also at a global scale, disregards essential details of the composition of risk. These details become visible when an evaluation is performed at a micro or sub-national scale. Micro scaled assessments can be aggregated to portray a clearer and truer vision of risk at a national level. When a micro scale is utilized, the building blocks of vulnerability and exposure are identified. A detailed appraisal is obviously not always required, for example, when a general estimate to compare countries in the same continent is sought; but it is definitely essential when analyzing the situation of a region inside a country or when a national government intends to use such an assessment to allocate resources or to distribute its national budget. As with risk, different aspects of vulnerability are revealed at different scales. Structural fragility and the vulnerability of lifelines may be in evidence at a micro scale assessment. Systemic vulnerability, availability of resources, or accessibility may be analyzed at a medium based scale. Lastly, economic vulnerability, resilience, capacity to recover, and social vulnerability may be assessed at a national scale. The scale of an assessment determines its output and is to be cautiously selected.

Selection of scale is also directly related to the availability of data, methods used to collect those data and the construction and presentation of that output. Except availability of data, compilation of data is a further constraint in this regard. Risk analysis based on local level also helps to identify the roots of the vulnerability. But it should be kept in the mind that sometimes indicators based on local scale are too local and although they provide the clear picture of the associated risk drivers, the results cannot be compared to the others. Local scale is important to conduct the in depth household surveys to collect information about vulnerability of people. The following example in the Box 1 provides the evidence how local scale risk analysis improved the better data collection by putting informal settlements in the risk map which were missing from the city map and also helped city to get funding from central government for city wide upgrading program.

Box 1: Data collection and risk mapping for urban development planning – Cuttack, India

Mahila Milan is a group of women taking leadership roles for informal settlers. The mapping process in Cuttack, a city in India, is carried out by community organizations formed by the inhabitants of informal settlements and other districts through a partnership between local Mahila Milan groups and local slum dweller federations. This community data gathering includes the preparation of digital maps at the city scale for the city authorities. Theses maps and the data gathered about each informal settlements are being used to negotiate support needed by local authorities to upgrade or relocate houses, hence reducing disaster risks.

This process is applied to all informal settlements and from this comes an accurate, detailed and disaggregated data base on risk and vulnerability for the whole city that is combined with a city wide map showing the boundaries of all informal settlements.

City authorities in Cuttack have been supportive of this initiative, which also helped producing the information base the city needed to get central government funding for a city wide upgrading program.

Source: *"What Role for Low-income Communities in Urban Areas in Disaster Risk Reduction?". David Satterthwaite - 2011. IIED*

The proposed Local Disaster Index LDI (2) strengthens the existing Local Disaster Index of Americas Project. As it measures the disaster risk at local level, it should be used as a complementary function to the already existing LDI which provides information of dispersion of risk at local level. Although disaster affects the economy and development of the whole nation, impact is more severely felt at local level; therefore, it should be priority for the future to conduct risk assessments and maintain a good database at local level to address the development issues to national governments which are generally overshadowed in a large scale. Prevalent Vulnerability Index (PVI) is redefined to meet the future needs of risk assessment and it should be counted as a dynamic variable over space and time. It is strongly recommended to review and revise the indicators of risk indices as more hidden underlying risk drivers are identified in future and better information is available of the data required.

The effect of the quality of data and use of different methodologies for data collection is obvious from the result of the analysis conducted while calculating the LDI (2) for three different countries Chile, Colombia and El Salvador. LDI (2) is computed using the three data from three different sources. In one case, data is directly picked up from the Americas project and the other two cases are based on DesInventar and EM-DAT database. Results based on Americas Program shows that risk is higher in Colombia followed by Chile and El Salvador which seems to be a wrong interpretation in general. This result can be explained on the basis of the time frame for which data has been used. In this case, data is available from 1981-2000 only. It should be noted that a big earthquake in El Salvador took approximately 2000 lives which are not included here. If it is taken into account, it can increase the overall risk many folds. It justifies the need of a long duration of available data to interpret the risk more accurately. It could also be possible due to the inclusion of local events only. The other two cases present a much higher risk in El Salvador in comparison to the Chile and Colombia. In these two cases, data is taken from 1981-2005 which include more events. DesInventar based result of LDI (2) provides the risk index in Chile, Colombia and El Salvador as 3.91, 4.46 and 8.61 respectively while EM-DAT based LDI (2) for the above mentioned countries is given as 2.01, 1.19 and 10.12 respectively. EM-DAT based results are higher than DesInventar as it has better accountability of mortality and affected people with respect to the other databases.

LDI (2) is also computed for India and USA, representing the nationalities of the authors. Facts were found interesting as India, even after being the 9^{th} largest economy in terms of nominal GDP and 4^{th} largest economy in terms of PPP, is engulfed in the disaster risk. LDI (2) computed for India and United States are 9.97 and 0.92 respectively. The reasons behind these results can be attributed to the large population and higher population density of India even though when economic losses in terms of absolute terms are less in comparison to United States.

Physical impact of global climate change proved to be more dangerous for hydro-meteorological hazards like flood, hurricane, cyclones, wildfires and typhoons etc. Climate change is expected to influence future disaster risk in three ways: first, through the likely increase in weather and climate related hazards such as global warming, sea-level rise and erratic precipitation, second, through the degradation of ecosystems such as deforestation, coastal erosion and third, through the exposure of large number of people to more severe hazards. Disaster risk management practices should be part of development of the cities and only then disaster risk can be reduced to a substantial amount. Ecosystem based disaster management are gaining importance as it is found that it can reduce the substantial amount of financial burden in comparison to the structural measures. Examples given in Box 2 show cases of Hubei province in China and New York city in USA where upgrading of ecosystem reduces the possibility of seasonal floods and also the 30-40% of the cost of the required structural mitigation measures.

Box 2: Ecosystem-based disaster risk management – Hubei Province, China and New York

1. In Hubei Province, China, a wetland restoration program reconnected lakes to the Yangtze river and rehabilitated 448 km^2 of wetlands with a capacity to store up to 285 million m^3 of floodwater. The local government subsequently reconnected a further eight lakes covering 350 km^2. Sluice gates at the lakes have been re-opened seasonally and illegal aquaculture facilities have been removed or modified. The local administration has designated lake and marshland areas as natural reserves. In addition to contributing to flood prevention, restored lakes and floodplains have enhanced biodiversity, increased income from fisheries by 20-30 percent and improved water quality to potable levels.

2. In New York, untreated storm water and sewage regularly flood the streets because the ageing sewerage system is no longer adequate. After heavy rains, overflowing water flows directly into rivers and streams instead of reaching water treatment plants. In New York city, it is estimated that traditional pipe and tank improvements would cost US$6.8 billion. Instead, New York City will invest US$5.3 billion in green infrastructure on roofs, streets and sidewalks. This promises multiple benefits. The new green spaces will absorb more rainwater and reduce the burden on the city's sewage system, air quality is likely to improve, and water and energy cost may fall.

Source: *"Global Assessment Report on Disaster Risk Reduction", 2011*

There are other issues like HIV-AIDS and people affected by armed conflict which play a key role indirectly to increase the risk of the society under the threat of natural disasters. Two important aspects are to be considered when a nation is immersed in, for example, an internal war. First, the priorities of the government towards its people are focused on preventing the loss human lives to the armed conflicts. Therefore, disaster risk reduction initiatives are secondary in importance, even if the country's geography is very prone to suffering from natural hazards. Second, when facing a catastrophe triggered by a natural hazard event, the recorded amount of victims or of those affected may be altered by the addition of those that have previously gone missing because of the armed conflict or by the addition of those who have been displaced by the war and not by the natural disaster itself. There is still not much reliable data available related to these issues but the building up of these data is recommended in order to consider the effects of parallel crisis in the overall risk to natural disasters.

International organizations have been continuously involved in the development of indicators and disaster risk indices. Until now , they have been using indicators to monitor and manage their investments and program activities in disaster risk reduction (DRR). They have also been using the risk index to rank countries according to their risk profile. In future, International organizations such as UN, NGO and WB etc. can use the indicators for the monitoring the institutional performance and showing their achievements in DRR which can eventually help them to convince the donors to get funding. At national level, governments can assess their DRR related policies and strategies using indicators and it will also encourage them to divert more budget in DRR activities instead of post disaster incentives. By using indicators and systematically monitoring and reviewing achievements, national and other authorities will also greatly facilitate the discharge of obligations to prepare status reports related to disaster risk reduction.

Development and application of indicators is a complex task that must involve many actors, including individual states, regional and international organizations, local governments, non-governmental organizations and community-based groups. It requires the blending of technical expertise and political and social realities in order to achieve good, usable indicator sets that can remain relevant for a reasonably long term. Long term monitoring is a challenge in the use of indicators as benefits of disaster risk reduction initiatives may not become apparent for many years. Future work in the development of risk indicators could be to solve the complexity multi-hazard environments, where the vulnerabilities vary by hazard, location, and human circumstances. The technical demands of indicator implementation will always remain a challenge. Most of the countries find it a tedious task to maintain the essential disaster loss data for use in indicators due to lack of man power and resources. The data and methodologies upon which indicators and benchmarks depend are inevitably limited and imperfect. Indicators must be recognized as only indicative of the real world, and not the reality itself.

The indicator system provides a good insight into the current situation of the country or community regarding the risk drivers and allows to trace changes in those risk factors. Risk Index helps to consolidate the large amount of technical and conceptual information of risk factors into a single numeric value. Although if it is not able to capture the whole information, indeed it can prove to be a good tool to make policy-makers understand the disaster risk issues and it can motivate them to direct their efforts for mitigating those risks for future generations.

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World Wide Web

United Nations International Strategy for Disaster Reduction, Geneva, Switzerland
http:// www.unisdr.org

United Nations Environment Programme, Geneva, Switzerland
http:// www.unep.org

EM-DAT, The International disaster database, Belgium
http:// www.emdat.be

DESINVENTAR, Inventory System of the effects of the Disasters
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Chapter 1
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Chapter 4
http://www.flickr.com/photos/46434833@N05/5758400938

Conclusions
http://quibb.blogspot.com/2011/08/tropical-storm-irene-2011.html

Appendix

Calculation of the ratio of average deaths to average population in a period of twenty years in Chile (using the Americas Program Report dataset):

Following table shows the average population of Chile in each five years since 1981 until 2000:

Period	average mean population
1981 - 1985	11718039.55
1986 - 1990	12737613.78
1991 - 1995	13919937.83
1996 - 2000	15029685.11

The average population of the country during the period of twenty years is estimated as a geometric mean of given population average in each five years.

$$Average\ mean\ population = \sqrt[4]{11718039.55 \times 12737613.78 \times 13919937.83 \times 15029685.11} = 13293292$$

The following table gives the number of deaths in each five year period.

Period	average mean population	Deaths
1981 - 1985	11718039.55	627
1986 - 1990	12737613.78	663
1991 - 1995	13919937.83	620
1996 - 2000	15029685.11	344

The average value of deaths in twenty years is calculated by considering the relative importance of this item in each period of five years. This calculation is done by first obtaining the importance or weight (w) of each value as the ratio of the number of deaths (x) to the total population (y) in that same period.

$$w_i = \frac{x_i}{y_i}$$

The mentioned calculation is shown in the following table:

Period	average mean population (y)	Deaths (x)	Weight (w)
1981 - 1985	11718039.55	627	0.0054%
1986 - 1990	12737613.78	663	0.0052%
1991 - 1995	13919937.83	620	0.0045%
1996 - 2000	15029685.11	344	0.0023%

Then the average is calculated as a weighted geometric mean average of weighted deaths amount.

$$geometric\ weighted\ average\ of\ deaths = exp\left(\frac{\sum_{i=1}^{4} w_i\, ln(x_i)}{\sum_{i=1}^{4} w_i}\right) = 587$$

Finally, the ratio of average deaths to average population for the twenty year period is calculated by the following equation:

$$LDI\ (2)_k = \frac{exp\left(\frac{\sum_{i=1}^{4} w_i\, ln(x_i)}{\sum_{i=1}^{4} w_i}\right)}{\sqrt[4]{y_1 y_2 y_3 y_4}} = \frac{587}{13293292} = 0.004\%$$

Likewise the LDI (2) for the affected and the economic losses are computed.

$LDI\ (2)_a = 3.099\%$

$LDI\ (2)_l = 0.204\%$

The overall LDI (2) is then obtained with the following equation:

$$LDI\ (2) = \frac{LDI\ (2)_k + LDI\ (2)_a + LDI\ (2)_l}{3} = \frac{0.004\% + 3.099\% + 0.204\%}{3}$$

$$LDI\ (2) = 1.10\%$$