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Natural Hazards, Risk Analysis and Emergency Preparedness: Applying Spatial Methods in Disaster Risk Management APPLYING SPATIAL METHODS IN DISASTER RISK MANAGEMENT

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NATURAL HAZARDS, RISK ANALYSIS AND EMERGENCY PREPAREDNESS:
APPLYING SPATIAL METHODS IN DISASTER RISK MANAGEMENT

A Dissertation

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
Requirements for the degree of
Doctor of Philosophy

in

The Department of Geography and Anthropology

by
Henrike Brecht
M.S., Westfaelische Wilhelms-University Muenster, Germany, 2002
December 2012

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ABSTRACT

Losses from natural hazards have been increasing steadily over the last decades. Yet, tools exist that can reduce risks to disasters and prevent hazards from turning into disasters. This study is intended to contribute to a reversal of the staggering economic losses by advancing the application of Geographic Information Systems (GIS) in the field of disaster risk management. Organized as a series of papers for publication, the dissertation first sets the stage by presenting a case study on Louisiana and its vulnerability to hurricanes. Thereafter, it examines and contributes to two fields that have proven to save lives and lower damages following catastrophes: emergency preparedness and risk assessments.

Emergency preparedness, through contingency planning, disaster prediction, and early warning, is critical to reduce disaster impacts. While GIS is increasingly recognized as a key ingredient for successful emergency preparedness, systematic knowledge about how to best use GIS is still in its infancy. This dissertation investigates the status quo of the use of GIS in emergency preparedness and offers recommendations for moving ahead. Based on interviews with emergency responders from three different U.S. states, the bottlenecks and the successes of the use of GIS in the emergency response to Hurricane Katrina are examined.

Risk assessments are tools to identify and understand risk. Given the high loss potential in urban areas, surprisingly little is known about the risk of cities. Oddly, a comprehensive ranking of cities' risk has been lacking. This research addresses this gap by developing, for the first time, a disaster risk ranking of the world's major cities. The ranking measures mortality and economic risks to major natural hazards for the 1,943 main cities in 110 countries. Building on these efforts, the most recent scientific and demographic

information is applied in order to estimate the future impacts of climate change on storm surges that will strike coastal urban populations.

CHAPTER 1

INTRODUCTION

1.1 Setting the Stage

Economic losses from natural hazards have been rising steadily in the past few decades (Figure 1.1). For example, in the period between 1990 and 1999, the costs of disasters, in constant dollars, were more than 15 times higher than during the period 1950-59 (World Bank 2006). The year of 2011 has been no exception to this trend and was the costliest year on record for disasters. Economic losses in 2011 amounted to US$380 billion, far exceeding the previous record set in 2005 (US$220 billion) (Munich Re 2012).

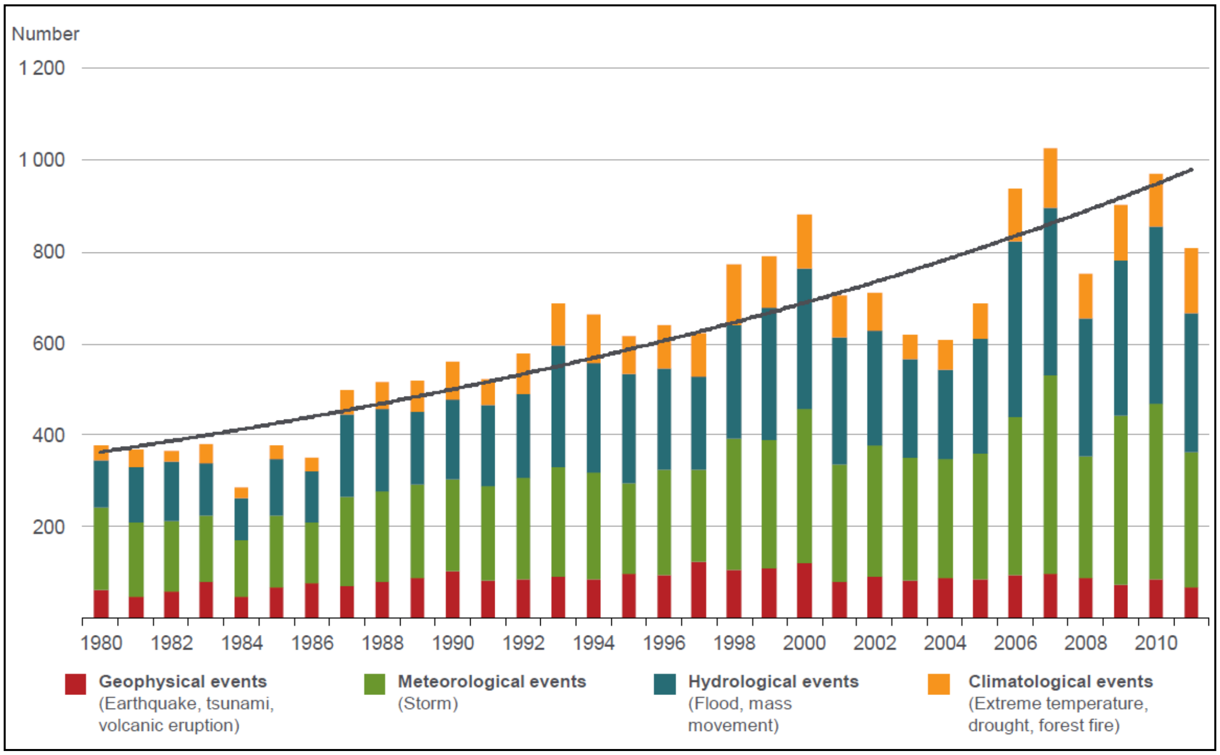

Figure 1.1: Number and type of disasters from 1980 to 2011 (Munich Re 2011)

The main reason for this upward trend is an increased concentration of individuals and assets in hazard prone areas. The world’s population and economic activity have become concentrated in vulnerable locations near earthquake faults, on subsiding river deltas, and along tropical coastal zones. The proportion of the global population living in flood-prone river basins has increased by 114% while those living on cyclone exposed coastlines have grown by 192% over the past 30 years (ISDR 2011). The risks will continue to rise over the next decades as trillions of dollars flow into new public investments in vulnerable areas and as the wealth in flood-prone Manila or earthquake-prone Bogota increases.

Multi-billion-dollar disasters have become more widespread. The 2011 Great Eastern Japanese Earthquake, the 2011 Thai floods, the 2010 Pakistan flooding, and the 2010 Haiti earthquake are some of the most devastating natural hazards on record. Especially developing countries are suffering with more than 95% of disaster deaths occurring in the developing world in the past 25 years (Arnold & Kreimer 2004) and with economic losses being 20 times greater (as a percentage of GDP) than in the developed world (World Bank 2006).

These loss trends may sound gloomy but with the right policies and technical measures, these loss trends can be reversed. Increasing exposure does not necessarily mean increasing disaster risk. In the last two decades, risk reduction efforts have succeeded in reducing the death toll of natural hazards, despite the world’s growing population, through improved early warning, more stringent building codes, and better contingency planning. Economic costs from disasters, however, have risen relentlessly due to the accumulation of wealth in vulnerable areas. Yet, while natural hazards are inevitable, options exist to ensure that they do not become disasters. A range of disaster risk management activities and smart solutions with high cost-benefit ratios exists. These activities and solutions help reduce human and also economic vulnerability to disasters.

Disaster risk management

Disaster Risk Management (DRM) is a set of tools, used to identify, reduce, prepare for, and recover from disasters. Disaster risk management is commonly organized into five main components (e.g., Ghesquiere and Mahul 2010):

- **Risk assessments** provide information on severity, frequency, geographical extent and causes of disasters and give individuals the necessary knowledge to make informed decisions about risk reduction measures.
- **Risk reduction** consists of a blend of hard measures and soft measures. The former include flood control reservoirs, levees, hurricane shutters, and earthquake resilient beams. The latter include institutional arrangements, land use regulation, education, and provision of economic incentives.
- **Financial protection** through insurance and risk transfer reduces the financial challenges of governments in the aftermath of disasters while protecting the long-term fiscal balance.
- **Emergency preparedness** reduces residual risks and includes contingency planning, early warning systems, and crisis management institutions as well as instruments.
- **Recovery and reconstruction** in a post-disaster environment often presents a window of opportunity to rebuild smarter and to mainstream resilience into reconstruction policies.

This dissertation focuses on two of the five components in the realm of disaster risk management; namely on risk assessments and emergency preparedness. It is the aim of the research presented here to enhance the complementary nature of Geographic Information System (GIS) and disaster risk management, which are two disciplines that benefit from further realizing each other's potential. In the area of risk assessments, the thesis presents and analyzes urban risk and thereby aims to raise public awareness and give reference points for investment decisions. In the area of emergency preparedness, the dissertation seeks to advance an improved use of GIS in order to efficiently prepare for, and respond to, disasters.

The Application of Geographic Information Systems in Disaster Risk Management

GIS technology is a tool for understanding vulnerabilities and prioritizing mitigation efforts to reduce the impact of future disasters. It can effectively catalyze the processes of the five DRM components since all of them benefit from access to, and analysis of, complex spatial analysis and maps. The convergence of the two fields of GIS and DRM has increased gradually over the last two decades. In the 1990s, much of the research that integrated GIS and hazard studies was restricted to producing cartographic products rather than spatial modeling. Since 2000, however, the use of GIS has evolved from mapping tools to modeling and simulation instruments. In the last few years, with increasing internet connectivity, mobile phone use, and user-generated content, crowdsourcing has emerged as a dynamic and open way to visualize and map risks and disasters. For example, crisis mapping has been successful in making use of mobile and web-based applications, crowdsourced event data, and satellite imagery to support early warning and rapid response. Nevertheless, significant gaps in using the full GIS potential in disaster risk management remain as this dissertation shows.

1.2 The Problem

1.2.1 Emergency Preparedness

Definition

Emergency preparedness is the last mile of disaster risk management, confronting those residual risks that remain despite risk reduction efforts (Figure 1.2). Emergency preparedness deals with the organization and management of resources and responsibilities for addressing all aspects of emergencies. Preparedness, response, and initial recovery steps are of particular importance in emergency preparedness. The two major components are i) predicting and monitoring hazards as well as issuing warnings to reduce potential damages and ii) being prepared to efficiently respond to and assist in an emergency. Emergency preparedness includes, for example, forecasting, damage modeling, early warning systems, contingency planning, training, response frameworks, and drills.

Problem Statement

Emergency preparedness saves lives and reduces economic damages. In some countries, the enhancement of early warning and disaster management has lead to striking results in reducing mortality risk. Take Bangladesh as an example. In 1970, the Category 3 Cyclone Bhola caused the death of more than 300,000 individuals, the 1991 Category 4 Cyclone Marian killed 138,000 whereas the Category 4 cyclone Sidr in 2007 “only” caused 4,400 deaths. In Europe, to take another example, hydro-meteorological forecasts and early warning systems have avoided between US$560 million and US$3.3 billion of disaster losses per year (Hallegate 2012).

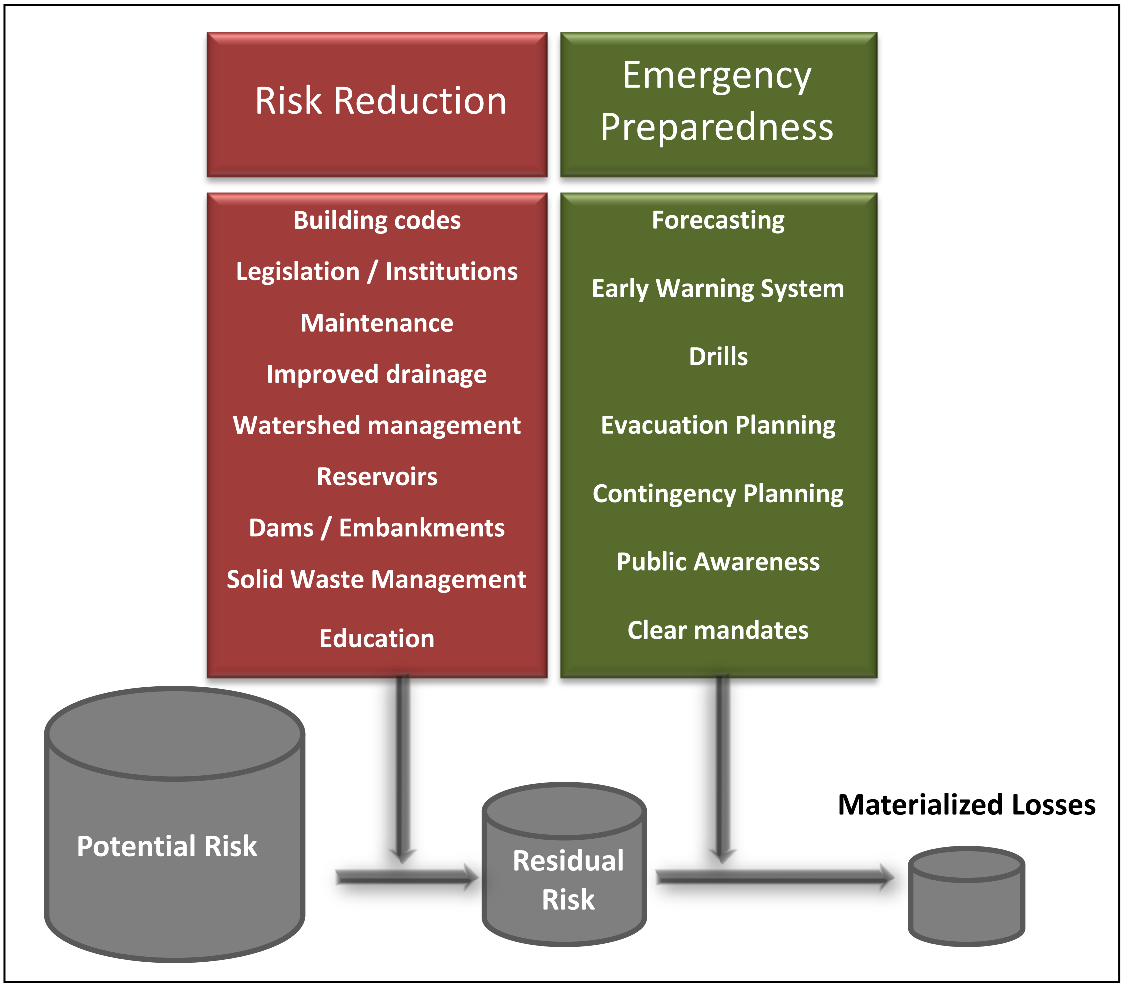

Figure 1.2: Complementary nature of risk reduction and emergency preparedness

In short, continued strengthening of emergency preparedness has well documented benefits. One area, in which emergency preparedness needs to be further improved, is its linkage with GIS. Since most of the information used in emergency preparedness has a geographic dimension, GIS has a large support capacity in this field. The convergence of the two fields of GIS and emergency preparedness is, however, often only rudimentary developed, and little work has been undertaken to enhance the integration of the two fields. This dissertation investigates how GIS can be further harnessed in emergency preparedness, specifically in the two areas of hurricane forecasts and disaster management. In particular, this dissertation poses the following question:

- How can the application of GIS be improved in the emergency response phase?

Objectives

The research presented herein aims at finding methods that enhance the convergence of the two fields of GIS and emergency preparedness. To achieve this goal, a main research objective has been formed:

- Use interviews with GIS emergency responders to analyze the bottlenecks and good practices of the use of GIS in response to Hurricane Katrina and to draw conclusions for enhancing preparedness.

1.2.2 Risk Assessment

Definition

A risk assessment is a method to determine the nature and extent of risks by analyzing hazards, vulnerability, and the extent of human and asset exposure (Figure 1.3). It provides information on severity, frequency, geographical extent, and causes of disasters. This information enables informed decision-making with respect to how risk should be managed and which measures to implement. Quantifying risk and expected future losses is not only the first step in a disaster risk reduction program. The outputs and scenarios of a risk assessment also contribute to the structuring of an overall development project. The Hyogo Framework for Action 2005-2015 (ISDR 2005), signed by 186 nations, characterizes risk assessments as a central activity in defining priorities and building resilience.

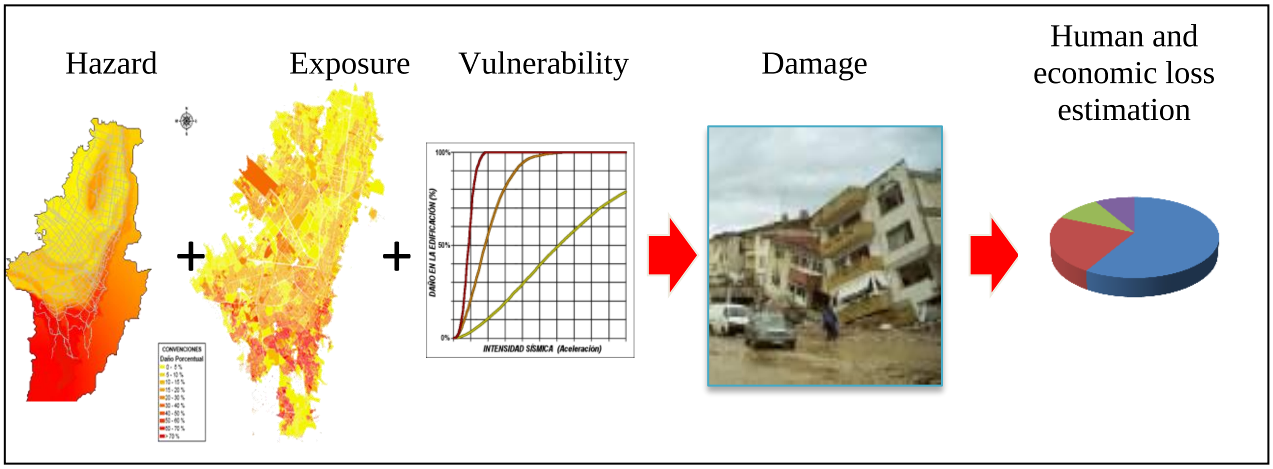

Figure 1.3: Risk assessment methodology

Problem Statement

The potential for losses from natural hazards is particularly high in urban areas. 1.5 percent of the world's land is estimated to produce 50% of worldwide Gross Domestic Product (GDP). The same area accommodates about one sixth of the world's population (World Bank 2009). Population density in urban areas has increased dramatically in recent decades, and since 2008, more than 50% of all individuals reside in urban areas. The United Nations (UN) Population Division estimates that this number will, by 2050, increase to 70%. Because of the enormous risk that has developed and is expanding in urban areas, disaster risk reduction efforts need to be intensified in such places.

Given the high loss potential from natural hazards in urban areas, it comes as a surprise that little is known about the vulnerability and risk potential of cities. Efforts to assess urban risks have so far mainly focused on single megacities, identifying inner-city hotspots. But a comprehensive analysis of the risks to major global cities has been lacking although it is critical guiding priorities in building resilience. This gap is addressed in this research, which seeks to answer the following questions:

- Which cities are likely to be affected by a disaster?
- In which cities is the risk of mortality due to natural hazards the highest?
- Which cities are most at risk of economic losses due to natural hazards?
- Which cities will be highly impacted by climate change and storm surges?

The study will enhance the knowledge of the variation of urban risks. Such knowledge is useful for local and national planners, as well as international donors. Disclosing risks to cities raises awareness, informs the prioritization of resources, inspires further research, particularly at local levels, and promotes a shift towards managing risks rather than emergencies.

Objective

The goal of this study is to present, for the first time, a risk ranking of the world's major cities in 110 less developed countries. I chose to mask out the developed countries in this study since the main intended audience are multilateral and bilateral development institutions, which, in past have often expressed the need for such as study in order to better allocate official development assistance (ODA) funding for disaster risk management where it is most needed. The risks from the four most common types of natural hazards are evaluated for nearly 2,000 cities. The fields of disaster risk management and climate change adaptation have a significant overlap of concepts and shared goals and should therefore be addressed in a joint manner, otherwise policy incoherence, ineffective use of resources, and duplication of efforts can easily occur. I therefore included climate change in the risk assessment by analyzing the impacts of sea level risk and future storm surges on cities. Three fundamental research objectives were established:

- Apply global spatial data layers for the four modules: hazard, exposure, vulnerability, and losses. This is done in order to assess the urban risks in all major cities of the less developed world from four different natural hazards: earthquakes, landslides, floods, and cyclones.

- Present the results in the form of an urban index that allows for the comparison of risk levels worldwide in a self-explanatory manner and that gives reference points for local and national planners as well as international donors for investment decisions.

- Assess the impacts of climate change, in particular sea level rise and storm surges, for nearly 400 cities in coastal areas of developing countries.

1.3 Dissertation Outline

Having made clear what the main questions of the dissertation are and having offered some justification for the criteria by which its objectives have been chosen for examination, it is now appropriate to give an outline of how the dissertation is structured. The dissertation is organized as a series of papers, intended for publication and contains seven chapters. The next chapter is constituted by a case study on Louisiana and its vulnerability to hurricanes, specifically discussing the importance and susceptibility of Louisiana's wetlands. In chapter 3, I focus on the application of GIS in emergency preparedness and suggest ways on how to increase the synergies between GIS and emergency management. This is done by examining challenges and accomplishments of the GIS community in the aftermath of Hurricane Katrina. In chapters 4 and 5, attention is directed towards risk assessments. In chapter 4, I give an account of what a risk assessment is and what components it consists of. The chapter then presents a global urban risk index and gives the results of a comprehensive GIS analysis of risk levels for the main 1,943 major cities in 110 less developed countries. Building upon the results of chapter 4, chapter 5 employs strategies to include the impacts of climate change in an urban risk assessment ranking. The implications of current and future storm surges for 393 cyclone-prone coastal cities in 31 developing countries are thereafter presented. Chapter 6 reviews the main results and conclusions herein and offers suggestions for future research topics.

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CHAPTER 2

LOSING GROUND: HURRICANES AND THE RECEDING LOUISIANA COASTLINE[1]

The U.S. State of Louisiana is losing ground. It is predicted that 1,750 km² could be lost over the next 50 years (Barras et al. 2003), which would mean that about every fifteen seconds, wetlands the size of a tennis court would slip under the water and disappear. Over the past century, 2,430 to 3,650 km² of Louisiana's wetlands vanished from the map due to a number of human activities and natural coastal processes (Finkl and Khalil 2005). The land loss poses many problems. Associated with the degradation of the coastal wetland is not only the destruction of flora and fauna habitats but it also presents a threat to the infrastructure of the oil and fisheries industries that are based in southern Louisiana. Moreover, the local communities and their unique cultures are at risk since their turf is being washed away.

The wetlands have yet another central function: they are Louisiana's natural defense against hurricanes. The marshes act as a buffer that slows hurricanes down and reduces the storm surge height. Just as the likelihood of major storms in the Gulf of Mexico in the near future is increasing and just as Louisiana struggles to recover from the massive destruction of Hurricane Katrina in August 2005, the natural defenses are melting away, leaving southern Louisiana, including New Orleans, even more susceptible to tropical cyclones.

[1]This chapter originally appeared as H. Brecht (2006), Losing Ground: Hurricanes and the Receding Louisiana Coastline, *Westermann Geographische Rundschau International Edition*, 2(02): 51-57. Reprinted by permission of Westermann Geographische Rundschau.

2.1 Hurricanes

Unlike other natural hazards, such as earthquakes, tornadoes, and volcano eruptions, a hurricane can be tracked well in advance of landfall. Via satellites and airplanes, a hurricane can be closely monitored, from its birth as a thunderstorm to a fully developed tropical cyclone. Hurricanes are even given names which adds to the perception that they develop a personality during their life cycle. Their tracks and forces can be predicted rather accurately.

Hurricanes are intense storms in which an extensive system of clouds, heavy rains, and strong winds above 117 km/h rotate around a calm center. These storms are capable of devastating coastal areas and causing massive death tolls.

Origin of Hurricanes

How does a hurricane form and which ingredients are necessary for the formation of a hurricane? Almost all tropical storms form between 10 and 30 degrees of the equator in the Intertropical Convergence Zone (ITCZ). The ITCZ is an area of low pressure that forms where the Northeast Trade Winds meet the Southeast Trade Winds near the Equator. As these winds converge, moist air is forced upward. The Coriolis effect causes a cyclone's rotation. This effect is too weak within 10 degrees of the Equator to initiate the rotary motion.

Another factor that has been determined to be essential for hurricane formation is a sea-surface temperature greater than 26.5°C to a depth of at least 50 m. Over warm oceans, humid air rises and as it reaches the cooler upper atmosphere, the water vapor condenses into water drops. The produced latent heat warms the air, which in turn rises, causing more upward airflow. The latent heat derived from water vapor above warm water is the central energy source of a hurricane.

Other circumstances for hurricane development include quickly decreasing temperatures in the upper atmosphere and high humidity in the troposphere. The high humidity reduces the amount of evaporation in clouds and maximizes the latent heat to be released. Apart from that, a low wind shear, i.e. relative homogenous wind direction and strength at different levels of the atmosphere, contributes to cyclone development. Finally, a trigger for convergence must be present, for example in the form of an easterly wave, which is a westward moving area of convergent winds. Other triggers are a weak frontal boundary and tropical upper tropospheric troughs, both of which produce deep convection.

Life Cycle of a Hurricane

Stage 1 - Tropical Wave: A tropical wave is the birth stage of a hurricane. It has only a slight circulation without closed isobars around a small pressure drop. The wind speeds are less than 40 km/h. These tropical disturbances originate regularly in the intertropical convergence zone and are often accompanied by thunderstorms, cloudiness, and precipitation.

Stage 2 - Tropical Depression: A disturbance is upgraded to a tropical depression when a number of thunderstorms cluster together and an organized circulation in the center of the thunderstorm complex occurs. This circulation is characterized by a wind speed below 65 km/h near the center and by at least one closed isobar that accompanies a lower pressure in the storm center. Tropical depressions are not named but numbered (no. 1, no. 2, etc.).

Stage 3 - Tropical Storm: When a tropical depression intensifies and the maximum sustained winds are between 65 km/h and 115 km/h, it becomes a tropical storm and is assigned a name. Tropical storms are more organized than depressions and they have an intensified circulation. These storms can cause extensive damage even without becoming a hurricane. Slow-moving tropical storms can drop torrential rainfall.

Stage 4 – Hurricane: A tropical storm becomes a hurricane when sustained wind speeds are at least 119 km/h. A pronounced circulation develops around the hurricane eye, an area of relative calm and low atmospheric pressure. The wall that surrounds the eye is about 15 to 80 km thick and is associated with the heaviest winds and strongest thunderstorms. Hurricanes can easily be recognized on satellite images with their white spiral bands around the dark eye.

Stage 5 – Disintegration: A hurricane dissipates when it moves over land where it is deprived of the warm water it needs to power itself. A hurricane can also cease if it enters colder water, if a cold front passes, or if it remains in one area long enough to cool the water down.

Anatomy of a Hurricane

A hurricane consists of three main structural elements. The eye in the center is the calmest section with light winds and partly cloudy or clear skies. The strong surface winds of a hurricane are deflected due to the Coriolis force which causes the winds to rotate around the center. Some of the air, however, is forced towards the center where it converges and descends. The eye wall surrounds the eye and possesses the strongest winds and the heaviest precipitation. The eye wall is a ring of tall thunderstorms. The winds rotate and move upward. Finally, bordering the eye wall are rain bands, which are bands of clouds that produce heavy winds and convective showers. The rain bands spiral inward toward the storm's center.

Hurricane Frequency and Tracks in Louisiana

Hurricanes usually develop between May and November when ocean temperatures are high. Over the past century, the highest incidences in Louisiana occurred in August and September when 80% of all hurricanes made landfall. Figure 2.1 summarizes the areas and time frames of Louisiana hurricanes from 1901 to 1996. Records indicate that the frequency of hurricanes fluctuates in cycles and periods of high hurricane activity that last for several decades, followed by decades of low activity.

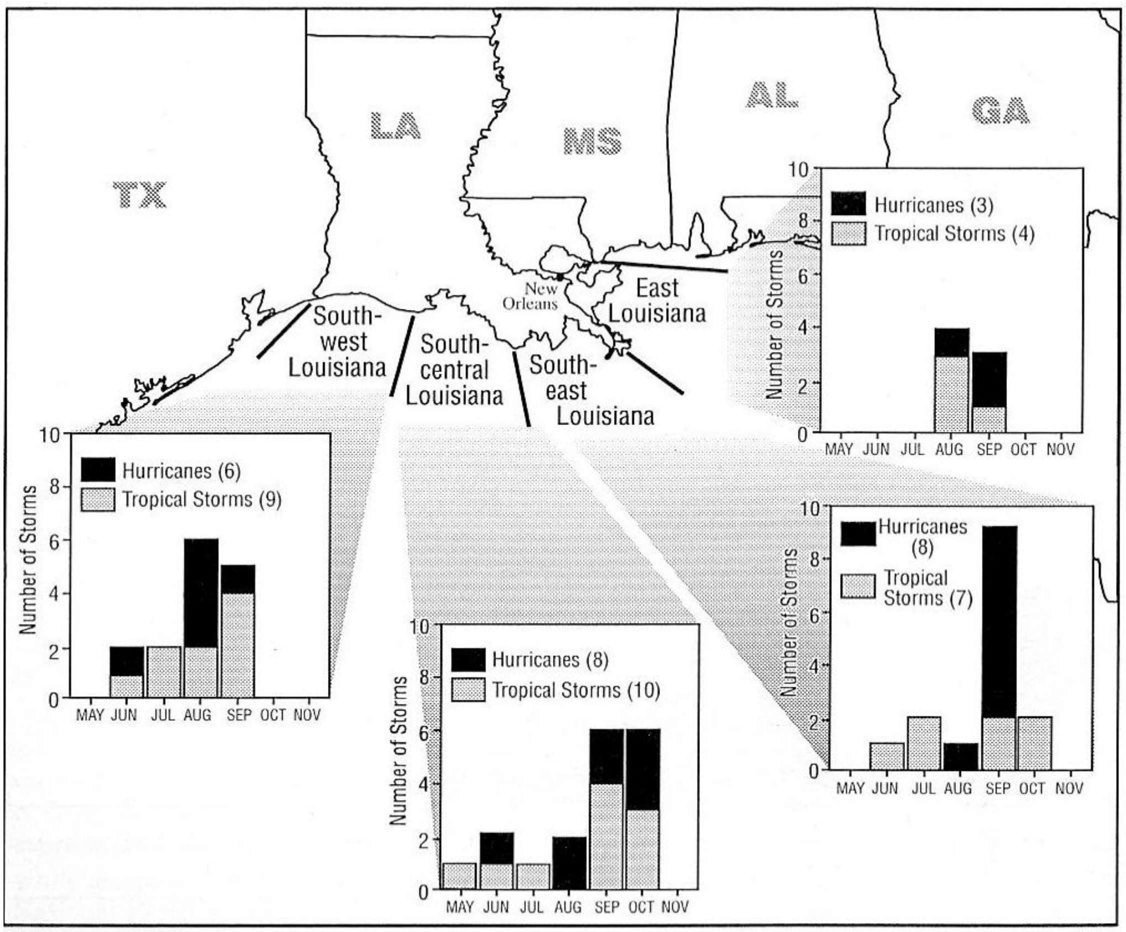

Figure 2.1: Distribution of hurricanes and tropical storms along the Louisiana coast from 1901 to 1996 (Stone et al 1997)

The frequency of major hurricanes appears to rise and fall on a multidecadal time frame. Approximately half of the number of tropical cyclones between 1901 and 1997 made landfall within a 30-year period between 1931 and 1960. The decades before and after that period experienced the landfall of only two hurricanes each (Stone et al. 1997). In the 1970s and 1980s, tropical storm frequencies were low, and it was suggested that this might be related to an intense and prolonged El Niño (Keim et al. 2004). Figure 2.2 shows the tracks of the hurricanes, tropical storms, and tropical disturbances making landfall in Louisiana for the years 1951 to 1996. The average number of hurricanes in the Gulf of Mexico between 1995 and 2005 has been unusually high. It appears that 1995 was the start of the latest natural phase of high hurricane frequency, which is expected to persist for one or two more decades. The hurricane season of 2005 exceeded all previously recorded activity for a single season. 2005 was the year with the most powerful hurricane ever recorded in the Atlantic basin (Wilma) and the most destructive hurricane in U.S. history (Katrina). It also was the first time that three category 5 hurricanes have ever been recorded in the same year in the Atlantic basin.

Hurricane Impacts

The main impacts of hurricanes stem from wind, rain, and storm surge. The most destructive impact of a hurricane is the storm surge which is the fast rise in the water level that occurs when the hurricane approaches the coastline. The reasons for the increase in the sea level are primarily low barometric pressure and strong winds that push the water towards the coast. The storm surge is about one to six meters above sea level, and it is responsible for about 90% of all hurricane related deaths and property damage (Allenstein 1985).

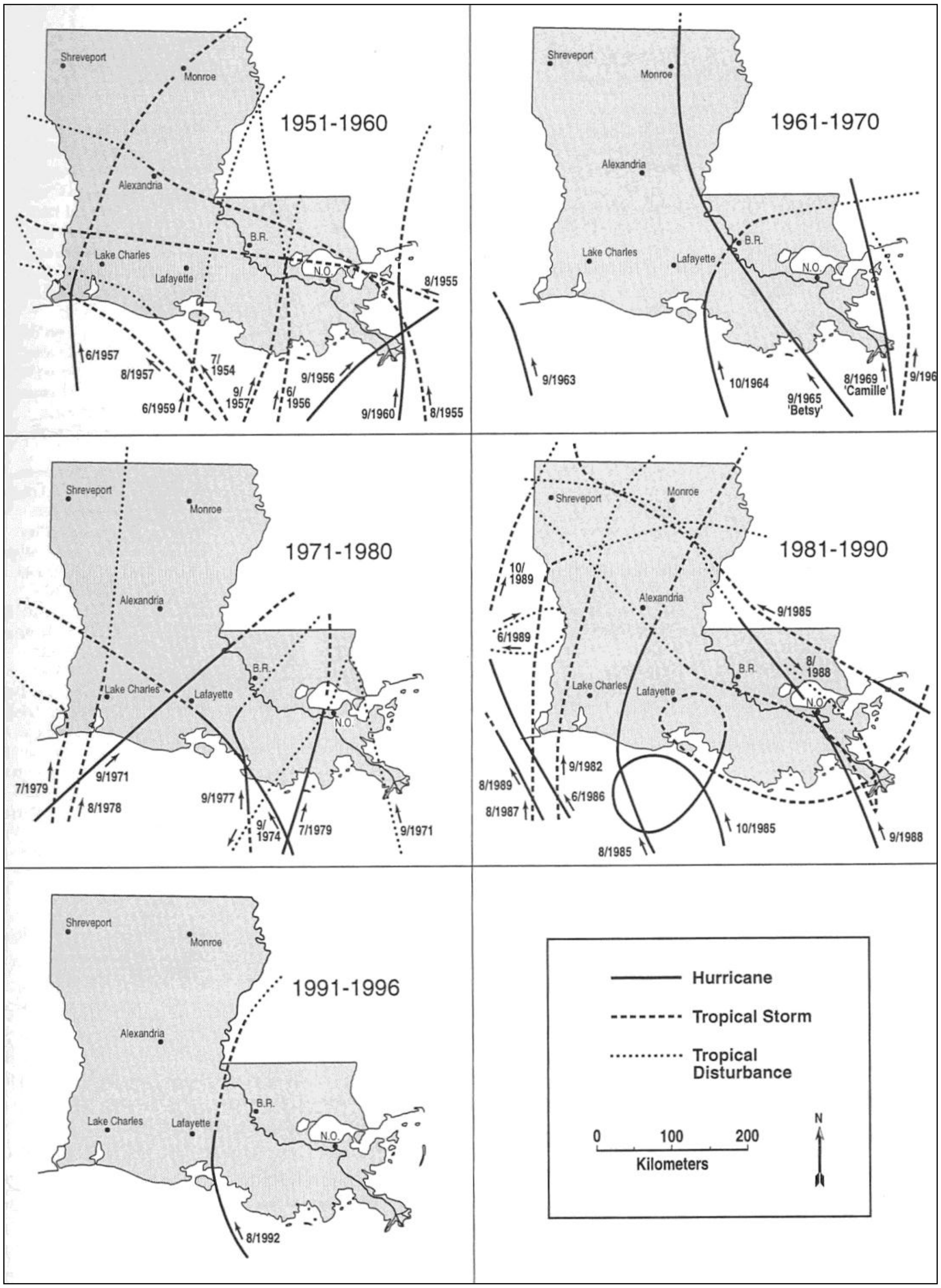

Figure 2.2: Tracks of hurricanes, tropical storms, and tropical disturbances to have made landfall along or near the Louisiana coast from 1951-1996 (Stone et al. 1997)

Another component of a hurricane is the wind, which can cause significant damage. In major hurricanes, flying debris is a hazard. The greatest impacts from winds occur to the east of the eye at landfall since the wind speed on the east side of the storm is added to the forward speed of the storm. Rainfall is another major hurricane effect and can cause heavy flooding of inland areas which in turn leads to crop damage and destruction of highways, bridges, and other structures. The impacts are often extensive if rivers flood their banks. Water runoff can also be devastating in steep landscapes, where it leads to flash floods and mudslides. Finally, hurricanes can create the conditions necessary for tornadoes. A tornado is a violently spinning column of air shaped like a funnel that is in contact with the ground. Tornadoes are relatively small with a diameter of around 100 m but their powerful winds are destructive and life threatening.

Hurricane Forecast

Flood forecasting and warning systems have proven to be a valuable tool to mitigate the adverse effects of a hurricane. Being able to predict hurricanes, disseminate warnings, and evacuate appropriate areas can save lives, and even the economic losses have been shown to be reduced by up to one third due to early warning (Smith 1996). Different hurricane and flood forecast models have been developed. A hurricane model is usually a trajectory model of the eye. The model considers the effects from the pressure gradient force, the centripetal force, the Coriolis force, and surface friction. Based on these physical parameters, as well as the topography and the bathymetry of the considered area, the prediction model calculates the hurricane track, wind speeds, and the point of landfall. For real-time forecasts, meteorological data has to be entered, such as latitude and longitude of the hurricane center, storm central pressure, and radius of the maximum winds (Allenstein 1985). Hurricane models can be coupled with storm surge models which include effects from the surface drag, eddy viscosity, finite amplitude, and bottom slip (Jelesnianski et al. 1992). The National Hurricane Center in Florida is the lead agency in the U.S. in hurricane prediction. The Center issues hurricane watches and warnings if hurricanes become a threat to U.S. territory.

2.2 Louisiana's Wetlands

Louisiana's wetlands lie in flat coastal lowlands that are characterized by marshes, swamps, lakes, levees, bays, and bayous. Not only does the coast present a unique landscape with fabulous scenery and many opportunities for recreational activities revolving around nature, fisheries, and wetland-based culture, but it also protects resources viable to the state and the nation. With the deterioration of the wetlands, these resources are at risk.

Value of the Wetlands

What benefits do the wetlands provide? First, the marshes offer valuable hurricane protection. Wetlands ameliorate the effects of the storms by slowing hurricanes down and by reducing the storm surge. Second, the coastal areas are home to thousands of residents, who live off the wetlands by farming, hunting, shrimping, crabbing, oystering, and fishing. These residents have diverse national and cultural backgrounds. The Cajuns, the largest and oldest immigrant group, were exiled Acadians from what is now Nova Scotia in Canada. Third, the marshes are vital for the fisheries industry, particularly shrimp and oysters. Fisheries are important for Louisiana, contributing over US$3 billion to its economy per year (COFCL 2002). Fourth, wetlands offer protection of oil and gas networks that are critical to U.S. energy security. Fifth, other significant industries in the coastal area include petrochemical processing and manufacturing, shipbuilding and repair, cargo, agriculture, and tourism (Louisiana Coastal Wetlands Conservation and Restoration Task Force and the Wetlands Conservation and Restoration Authority 1998). And finally, Louisiana's swamps represent a unique ecosystem, providing habitat to many endangered species of flora and fauna.

Causes for Wetlands Deterioration

Natural and anthropogenic processes contribute to the land loss (Figure 2.3). One of the main causes is the marsh's subsidence, i.e. the settling, decaying, and sinking of the soils over time. The Mississippi River's spring floods once supplied Louisiana's coastland with fresh layers of sediment which offset the subsidence and resulted in a balance of land loss and gain. These annual floods, however, were often disastrous. The Great Mississippi Flood of 1927, for example, inundated an area of 70,000 km^2, caused millions of dollars in damages, and killed several hundred people. Consequently, the levees were raised along the river and lined with concrete, effectively preventing deluges and stopping the supply of the marsh-building sediments onto the wetlands. Instead, the sediments are now channeled until they are finally lost to the deep waters of the Gulf of Mexico.

The construction of canals through the marsh for oil and gas exploration and ship traffic also contributes to the loss of wetlands. Since the 1950s, engineers have dredged more than 13,000 km of canals, increasing erosion and allowing salt water to infiltrate brackish and freshwater marshes. The salt infiltration destroys flora and fauna. The soils piled up on banks act as barriers to the natural flow of water across the wetland, resulting in the flooding of many areas.

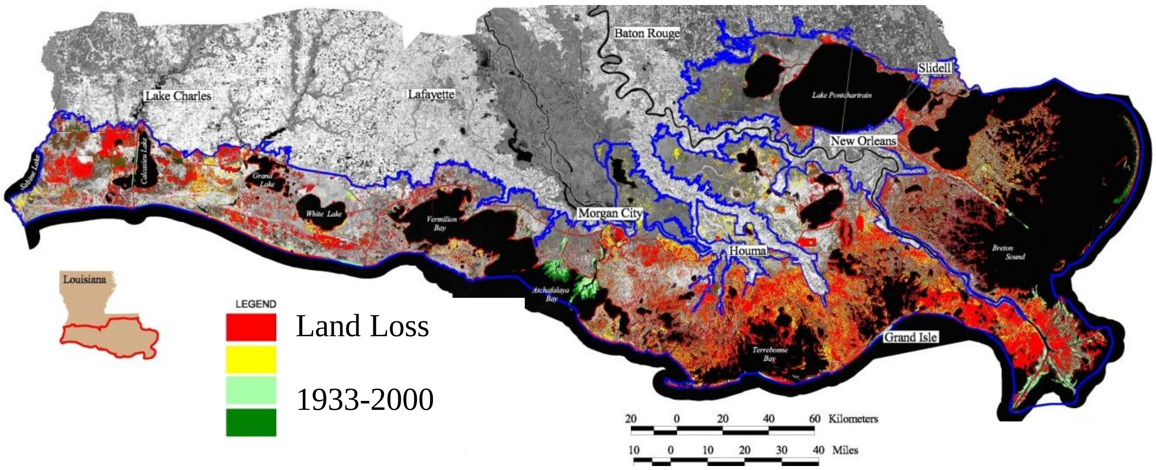

Figure 2.3: More than 100 years of land change in south east Louisiana (1932-2050) (adapted from USGS 2003)

Furthermore, the increased boat traffic produces greater wave action, and the channels accelerate the flow of water thus less plant roots are established along the banks which results in the widening of the channels and further loss of wetlands.

Withdrawal of oil and gas is believed to affect subsidence rates. White and Morton (1997) discovered that high rates of wetland loss in the southeast of the U.S. occurred during or after the period of peak oil and gas production in the 1970s and early 1980s. The removal of millions of barrels of oil, trillions of cubic feet of natural gas, and tens of millions of barrels of saline formation water might have caused a drop in subsurface pressure – a theory known as regional depressurization. Excessive fluid withdrawal from underlying strata by the petroleum industry may have caused nearby underground faults to slip and the land above to slump.

Tropical cyclones and cold fronts are other reasons for wetland loss. The Louisiana coast is affected by a high incidence of tropical storms and hurricanes, which produce strong winds. The resulting elevated water levels and large waves lead to erosion, overwash, and barrier breaching (Stone et al. 2004). For example, early estimates suggest that Hurricane Katrina in August 2005 transformed approximately 80 km^2 of marshes into open water (USGS 2005). Hurricanes can cause sudden and massive tree mortality and secondary damage such as insect infestation and forest wildfires (Cablk et al. 1994). Moreover, Louisiana's high frequency of cold fronts plays a critical role in generating and sustaining higher waves during the winter months which again lead to shoreline erosion (Georgiou et al. 2005).

2.3 The Barrier Islands as Louisiana's First Line of Defense

Barriers are depositional elongated sand features for wave-dominated coasts that extend above sea level (Roy et al. 1994). While they are usually shore-parallel bodies, Louisiana's barriers no longer reside parallel to the shoreline but rather as offshore remnants of former Mississippi delta lobes (Kulp et al. 2005). During tropical storms, these barrier shorelines provide the first line of defense against large waves and storm surges by forming protective structures for marshlands, estuaries, and the human infrastructure behind them. In Louisiana, these features are threatened as they are rapidly degraded due to the above explained reasons for wetlands deterioration. Another anthropogenic cause for the degradation of the barriers is the construction of rigid concrete structures on the islands, which increase erosion by increasing turbulences and velocity (Morton 2002).

Figure 2.4 demonstrates the vulnerability of the Chandeleurs Islands, a barrier chain located just southeast of the Mississippi Delta Plain, to tropical storms. The islands have been labeled "the premier barrier shoreline in Louisiana and the US Gulf coast" (Penland et al. 2005) and have been known for their large sea grass meadow, large marine and shorebird rookeries, and fabulous geomorphology. Last but not least they are the first line of defense for New Orleans and southern Louisiana against tropical storms (Penland et al. 2005).

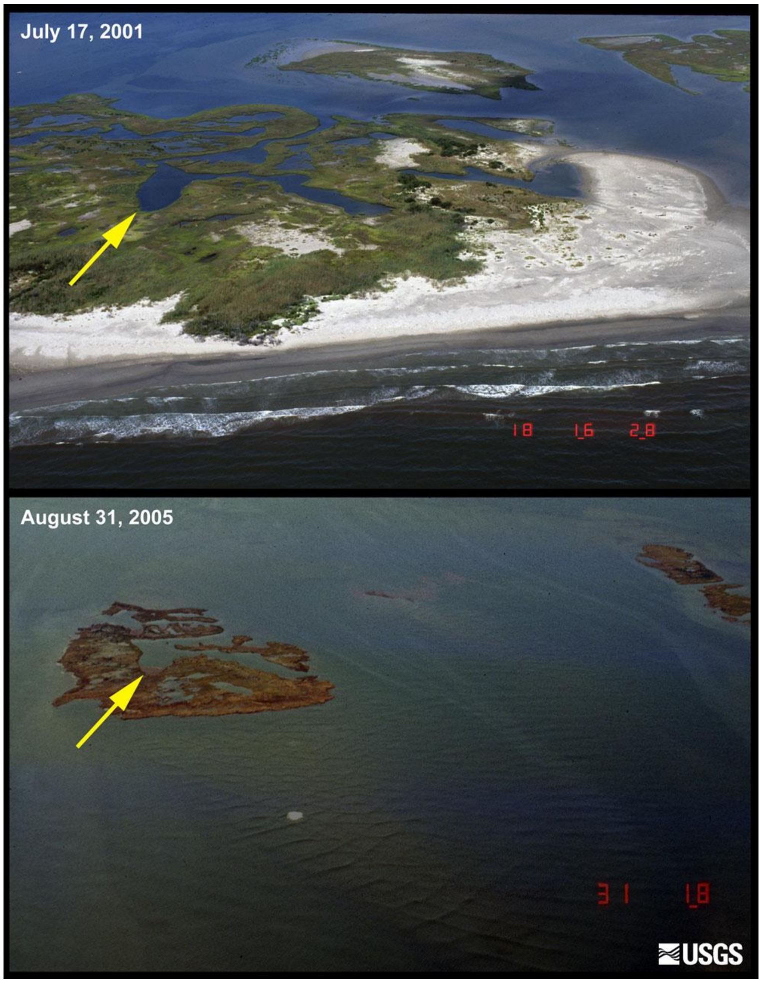

Figure 2.4: Chandeleurs Islands on July 17, 2001 and on August 31, 2005 (USGS 2005)

2.4 Coastal Restoration Efforts

Louisiana has been undertaking efforts to mitigate the wetland loss. The Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA or Breaux Act) Program is a federal grant that provides funding and designs projects to preserve and restore Louisiana's coastal landscape. The legislation was passed in 1990 and grants an average of US$50 million per year. However, despite half a billion dollars spent since 1990 for coastal restoration efforts, Louisiana continues to lose about 65 km^2 of land each year. To fully stop the land loss, early studies suggest that US$14 billion over the next 20 years would be required (Knapp and Dunne 2005). Is it feasible to raise such amounts of money? In November 2005, roughly two months after Hurricane Katrina, the U.S. Senate passed a US$1.2 billion act to fund coastal restoration and hurricane protection in the Gulf states. The money will be raised from auctions of digital broadcast spectrum rights, with the auctions likely to take place in 2010.

Another hope for Louisiana stems from a pending budget bill that would channel a share of federal offshore oil revenue to the coastal restoration efforts in the Gulf states. This bill would provide Louisiana initially with several hundred million dollars a year, and it is projected that the allocation would ultimately rise to US$2 to 3 billion per year (The Times-Picayune 2005). Strategies to restore the marshes are not only costly but also politically sensitive, since they affect communities, agriculture, and the petroleum industry. Numerous mitigation strategies have been proposed. Most ideas include soft engineering solutions such as coastal restoration through controlled flooding which involves cutting crevasses into the levees that allow sediment diversions into the wetlands. Another approach entails distributing dredged materials, which are obtained during channel maintenance, onto wetlands. Sediments can also be captured by means of terracing, fences, and subsurface features (Figure 2.5). Furthermore, erosion control techniques in the form of dikes and levees are applied in Louisiana in order to alter the waves and currents that cause erosion and therefore, to protect frail marsh soils from waves in coastal bays. Other strategies are herbivore control and stabilization of major navigation channels (Louisiana Coastal Wetlands Conservation and

Restoration Task Force and the Wetlands Conservation and Restoration Authority 1998). In order to stop the dramatic loss of the barrier islands, Campbell et al. (2005) propose seaward beach berms, enhanced dunes, marsh platform restoration, and vegetative planting.

The costs and efforts to restore the wetlands are high but without the marshes, Louisiana will lose many benefits, including storm defense, protection of the oil and fishery industries, the conservation of unique cultures, and the preservation of a valuable ecosystem.

Figure 2.5: Terraces encourage sediment deposition and protect existing wetlands by reducing wave action in the shallow waters of Little Vermillion Bay, Louisiana (NOAA 2004)

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CHAPTER 3

THE APPLICATION OF GEO-TECHNOLOGIES AFTER HURRICANE KATRINA[2]

3.1 Introduction

While mainstreaming geo-information in disaster response is becoming increasingly recognized as a key factor for successful emergency management, systematic knowledge about the benefits and bottlenecks of geotechnologies in the response phase is still in fledging stages. In the complex, dynamic, and time-sensitive disaster response situation of Hurricane Katrina, geo-information enhanced decision-making and effectively supported the response but it did not reach its full potential. The overwhelming complexity of the disaster exposed challenges and highlighted good practices. Hurricane Katrina affected an area of nearly the size of the United Kingdom (230,000 square km), it killed more than 1,700 people, and the total cost of damage is estimated at more than $200 billion dollars. The destruction, which has affected primarily the coastal regions of Louisiana, Mississippi, and Alabama, was caused by high-speed winds, storm surge flooding in coastal areas, and, in New Orleans, also by levee failures. Information management is a crucial component of emergency response. The ability of emergency officials to access information in an accurate and timely manner maximizes the success of the efforts. Since most of the information used in disaster management has a geographic dimension (Bruzewicz 2003), geo-technologies have a large capacity to contribute to emergency management. The capabilities of geo-technologies to capture, store, analyze,

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[2]This chapter originally appeared as H. Brecht (2008), The Application of Geo-Technologies after Hurricane Katrina, in *Remote Sensing and GIS Technologies for Monitoring and Prediction of Disasters*, eds. S. Nayak, S. Zlatanova, Springer: 25-26. Reprinted with permission of Springer.

and visualize spatial data in emergency management have been documented in the literature (Cutter 2003; Zlatanova 2006; Carrara and Guzzetti 1996). Paradoxically, in praxis the convergence of the two fields of geo-information and emergency management is only rudimentary developed and little work has been undertaken to enhance the integration.

What were the bottlenecks of using geo-information in the response phase of Hurricane Katrina? Which mapping services were requested frequently? Which workflow procedures streamlined the mapping support? What were the best practices? In the following these questions are addressed focusing on five areas:

- managerial lessons with regard to information flows and staffing issues;
- the perfidies of technology infrastructures in an emergency situation;
- important datasets and best practices of data documentation and access;
- workflows that streamlined the mapping response;
- the "stars" of the mapping products, which were requested or needed the most.

3.2 Lessons Learned

The knowledge about best practices was gained from the experience of GI responders. Input was gathered mainly during the Louisiana Remote Sensing and GIS Workshop (LARSGIS) in Baton Rouge, Louisiana, in April 2006 in which practitioners from the coastal southeastern United States presented and discussed their experiences of using geo-technologies after Hurricane Katrina. The author's own experience in the Emergency Operations Center (EOC) of Baton Rouge after the storm also influenced this paper.

3.2.1 Managerial Lessons

Improving Information Flows

Large amounts of data were acquired and processed after Hurricane Katrina. In the immediate aftermath of the disaster, governmental agencies and private geo-technology companies, realizing the extent of the damage and the gravity of the situation, supported the relief efforts by contributing data. Numerous sets of aerial photographs were taken and distributed to assess flooding and damage, private companies donated satellite images, data, and hardware, and new data layers concerning emergency shelters or power outages were created. Public agencies released and shared existing but previously undisclosed data layers. The usual obstructive administrative barriers caused by competition and conflicts between divisions were abrogated, and instead ad-hoc alliances were built to support the common goal of saving lives and containing the devastation. Data streamed in quickly, resulting in the availability of a multitude of new data layers. The dissemination of the data to the appropriate parties at the desired locations in a timely manner, and in a useful format may have been the biggest challenge for the GI response community. Agencies were not always aware which information was available or where to find certain data. Due to miscommunication, excessive workloads, and general distress, information was distributed only to a limited extent and did not always reach the first responder crews or county governments in remote areas that were in crucial need of this information.

Information flows and structures between the different actors must be identified before the disaster. One possible strategy is to appoint a central data authority that collects and disseminates information, a solution that is effective but difficult to realize due to political and economic reasons. Spatial data infrastructures and web-based solutions have proven to enhance information flows and data accessibility. These tools should to be established before the disaster strikes.

Establishing Geo-Technologies as an Integral Resource

Mapping support often evolved as an ad-hoc component after the storm being triggered by a high demand for maps and geo-information. Impromptu volunteers were engaged or geo-information companies were hired on the spot. Emergency preparedness units need to recognize geotechnology as crucial part of disaster management and incorporate it accordingly into their planning. It is the task of the GI community to increase the awareness of emergency managers towards the value of spatial technology. During the emergency, knowledge gaps became apparent on both sides: governmental emergency staff was unclear about the potential of geo-technologies and the use of maps and the GI community was not informed about governmental disaster plans and strategies. Both parties have to gain an increased understanding of each other's duties and capabilities. Communication and training platforms are means to enhance awareness.

Building Partnerships

Formal and informal partnerships between GI professionals that were established before the disaster proved to be essential in the disaster response. Relationships facilitate coordination and thus the flow of information. One way to strengthen collaboration is the establishment of a workgroup of GI-skilled personnel in governmental agencies, universities, and private industries. Regular meetings foster networks and enable the exchange of news about available data and technologies.

Identifying Staff

GI responders were confronted with many requests for maps and an understaffing in the EOCs. It proved valuable to call on the support of GI colleagues. Volunteers played an important role in the response to Katrina, and it is recommended to integrate them into emergency planning. Staff to support operations during an emergency needs to be identified beforehand. If a disaster occurs, a call-up of pre-defined GI- skilled personnel should be initiated to set up teams. The response teams should include staff from different governmental departments and from academia, assembling specialists from the different fields in geo-technology, such as remote sensing, programming, databases, and GIS. It is helpful to assign staff certain responsibilities pertaining to data collection, logistics, technical support, mapping, distribution, and operational management. Specific staffing challenges are caused by the 24 hours per day, seven days per week operations which require a high staff rotation. For the rotation not to affect efficiency, detailed documentation of requests, actions, files, and file locations are necessary.

3.2.2 Technology Infrastructure Lessons

Ensuring Hardware Resources

The EOCs were not or only rudimentary equipped for geo-technologies prior to Hurricane Katrina. Computers, plotters, printers, and other supplies had to be identified and installed after the storm. Difficulties occurred with regard to finding space in the EOCs not only for large hardware devices and storage systems for hard-copy maps, but also for laptops and workstations. Mapping teams should establish sources and localities of all necessary hardware beforehand and explain their special demands so that physical space in the EOCs can be allocated. In the response to Hurricane Katrina, innovative solutions were found, such as the one from a mapping team in Mississippi that remodeled a bus into office space and equipped it with workstations and printers.

Securing Continuity of Operations

Useful datasets were stored on computers that flooded or that were left behind in the evacuation. Data back-ups at multiple secure locations and mobility of hard- and software are to be established to enable continuous operations under emergency conditions and to avoid loss of data. Data accessibility was not only hampered by disrupted networks and flooded computers but also by logistical issues. In one case, important files were password protected and the responsible administrator could not be reached.

Preparing for Power and Network Disruptions

Power, network, and internet outages were frequently encountered. Ideally, alternative power supply solutions are identified beforehand, including generators and uninterruptible power supplies (UPS) with battery backups that can be added to hardware devices to avoid data losses during power disruptions. Since it is not advisable to rely on network connectivity, sufficient data sharing devices are necessary for an efficient response. Moreover, regular back-up mechanisms proved to be valuable.

Administering Networks

Not only GI skills were vital for successful operations but GI staff installed intermittent network routers, virtual private networks and other network connections. Ideally, a network administrator is appointed who is in charge of connectivity issues.

3.2.3 Data Lessons

Acquiring Relevant Data

Base datasets, for example on pumping stations, utility networks, and power plants, were not always readily available. Especially for rural areas, geo-information was scarce. Information that proved to be of focal interest during the emergency can be divided into two categories: information that should to be collected before the disaster and information that is to be collected after the disaster.

Datasets that were vital during the response and that can be acquired before the disaster include but are not limited to:

Pumping stations	Hazardous materials
Street maps	Building footprints
Elevation models	Helicopter landing places
Points of interest	Special needs population
Fire stations	Evacuation routes
Cadastral data	Population densities
Medical centers	Day and night population
Geomorphology	Utility networks
Land use	Emergency resources
Power plants	Address dataset
Satellite imagery	

Datasets that were frequently requested in the EOCs providing information on the extent of the catastrophe include but are not limited to:

Wind fields	Oil spills
Power outages	Flood depths
Debris estimates	Levee breaks
Daily dewatering	Road restoration
Power restoration	Emergency shelters
Flood fatalities	Flood extent
Satellite imagery	Fire outbreaks
Deceased victim locations	Points of dispensing
Restored power	Pollution
Crime scenes	Damage estimates

Sources need to be established for information that becomes available after the disaster. This can be accomplished with data sharing agreements, which should be set up prior to the emergency. These agreements determine which data will be provided by which organizations and who holds copyrights. For instance, uniform, useful, and complete image datasets were in high demand after Katrina. Therefore, contracts with companies providing aerial photography should be in place, specifying resolutions, area coverage, formats, geo-correction procedures, and accompanying metadata. Agreements need to include how often datasets will be updated since some of the mentioned data layers require daily updates. For instance, shelter locations opened rapidly in the immediate aftermath and then, after a few weeks, closed or moved. Information on flooded roads also needed daily updating, as did the locations of crime scenes.

Clarifying Copyrights

The clarification of data copyrights and privacy laws was time consuming. It was difficult to reach those in charge to get permission for data dissemination because communication networks were interrupted, electronic address books were inaccessible due to flooded and left behind computers, and officials were dispersed because of the evacuation or not available during the weekend and at night. It is of advantage to negotiate data dissemination agreements, data sharing policies, and specifications of data custodianship before the disaster.

Collecting Metadata

After Hurricane Katrina, a multitude of datasets were disclosed and created rapidly. Maps showing the newly available information were requested, produced, and distributed in extremely short time spans. A central problem that arose from this incoming data stream and the stressful situation was that metadata tended to be neglected. However, crucial information is rendered unemployable if datasets are not properly documented.

Moreover, metadata helps to maintain standards for data quality. Finally, missing metadata causes delays since valuable time is spent struggling to find out, for example, on which date an aerial photo set was taken and which area it covers. A metadata standard should be chosen that answers questions of data timeliness, source, accuracy, and coverage. Although metadata collection is time-consuming, GIS staff receiving data must be dedicated to metadata collection, ensuring that a predefined form is completed for all incoming datasets. A data manager should be assigned whose responsibilities include documenting metadata.

Organizing Data

In the response phase, geographic information must flow upstream and downstream between players in real-time. An effective means of accomplishing this dissemination of data is a spatial data infrastructure (SDI) which enables an efficient, reliable, and secure way for the search, exchange, and processing of relevant information. An SDI is a framework that subsumes a collection of geospatial data, technologies, networks, policies, institutional agreements, standards, and delivery mechanisms. Creating an infrastructure subsuming both general and emergency-related data with clearly laid out directory structures and logical names is critical for effective emergency response where many applications occur in real-time. The SDI datasets need to be updated continuously, and data integrity has to be maintained. The responsibility of data creation and maintenance for the SDI cannot lie with one individual organization; it must rather be a joint effort of many organizations.

3.2.4 Operational Lessons and Workflows

Avoiding Duplication of Efforts

Duplication occurred when maps, conveying identical information (e.g. damage levels, road flooding, or power outages), were created by several agencies. Coordination via the implementation of a map depository where central players submit and download maps is a possible solution to this duplication.

Tracking Requests

Keeping track of map requests was conventionally handled by means of paper files. In the Baton Rouge EOC, a team from the Louisiana State University implemented an online tracking system that largely improved the paper system. This tracking system not only documented the actual request but also associated information including contact information of the client, file locations, and map products. The system allowed efficient communication with all members of the response team, which was particularly important due to the high staff turn-over and geographically distributed mapping operations. The documentation of file locations and templates was especially helpful for the preparation of the daily updates of certain maps such as road flooding and emergency shelters. Another feature of the system allowed personnel to be assigned to the various projects. Such a record system for requests, associated files, documents, staff, clients, and products proved to be useful and should be implemented before the disaster strikes.

Preparing Paper Maps

Despite increasing digitalization, paper maps were still essential for the response teams. A high demand of paper maps and only limited printing and plotting capacities caused delays in fulfilling requests and disseminating information. Base maps, especially street maps on different scales, can be prepared beforehand. Ensuring access to sufficient amounts of paper, printers, and plotters is crucial.

Creating Templates

Map templates were found to be useful in the response activities. In the case of daily updated information, consistent templates accelerated the creation of maps and facilitated the comparisons of changes. Predefined map templates containing many data layers, which are turned on and off according to specific needs, saved a considerable amount of time. The templates should be well documented and logically stored within the data structure.

Disseminating GIS Resources

While staff on site in the EOC took requests, promoted geo-technologies, offered solutions, and generated quick maps, staff in remote locations was able to create more sophisticated maps and provide analysis away from the bustle in the EOC. This approach also guaranteed access to hardware, especially printers, that were not backlogged as was often the case in the EOCs.

Using Online Tools

Web-based tools such as Mapquest or Google Earth, were used intensively in the response operations. Not only the GI staff but many of the involved responding agencies and rescue workers applied especially Google Earth for their operations. Google Earth and Google Maps created satellite imagery overlays of the devastation in the affected region, which helped to understand the scope of the disaster. Single houses and addresses could be looked up in Google Earth, and a built-in transparency slider, which allowed to switch between before and after images, enabled to see if and how much damage a place experienced. The accuracy and the ease of use of these online tools that can be operated by non-GIS staff contributed to the wide usage of the tool. This experience highlighted the potential of a web-based community approach to disaster operations.

Promoting Geo-Information

Since rescue workers were often not versed in the potential of geoinformation, it was useful to have a GI staff member attend official EOC meetings to offer GI-based suggestions and solutions. Another way to convey the GI services to officials was by means of fixing frequently requested maps on the walls or collecting them in a map book for display.

3.2.5 Map Products

Requests from Emergency Responders

The large majority of requests from emergency responders were related to street atlases and area overview maps. Commercial maps in stores sold out quickly or flooded and therefore, responders relied on the GI community. Great numbers of street maps were handed out after the storm. The acquisition of digital copies of city maps from commercial companies was helpful. Emergency responders who were not familiar with the area requested maps with photos of landmarks such as the New Orleans Superdome. Checkpoints, which were still standing after the storm, were included in the produced maps. This concept proved to be remarkably helpful for an orientation of the area especially since many street signs were flooded or destroyed. Another crucial orientation and communication means is a grid system for ground reference. After the disaster, some responders considered missing grids in maps as one of the central problems. It would be helpful if map books in compact sizes with the standardized US National Grid, street indices, landmarks, and elevation levels are produced before the disaster. Overlaying street and area maps with satellite inundation maps that outline the extent of the flood and the flood depth was another frequent request. For instance, by means of this data, rescue missions determined whether boats or high-water vehicles are used in a certain area (Figure 3.1).

For the search and rescue operations, mapping of addresses and coordinates of victims was of major importance in the first days after the disaster. Ideally, this process would be automated. Coordinates from a mobile phone placing a 911 call could be tracked automatically and then transferred to handheld computers of emergency responders. Geo-technology can calculate the best routes for accessing victims' locations.

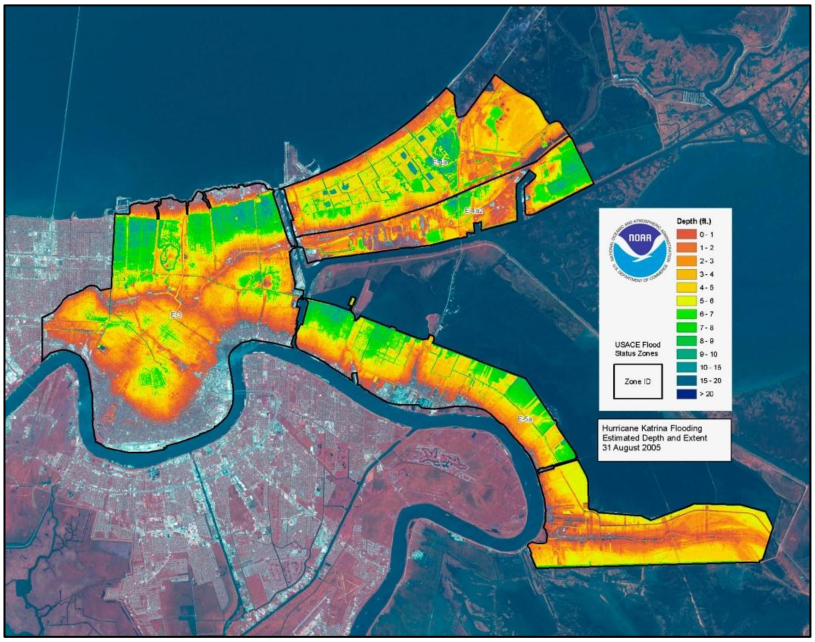

Figure 3.1: Illustration of the depth and extent of the inundation on August 31, 2005, caused by Hurricane Katrina (NOAA 2005)

The Needs of the Public

Accurate and timely information for the public is necessary. The questions of if a house was damaged plagued the evacuees. Days after the disaster, in order to find out if and how deep a house was flooded, the evacuated population relied on photos from television and the Internet to recognize neighborhoods and the levels of flooding and destruction. The uncertainty added to stress and anxiety. This information could be conveyed using web mapping and aerial photographs taken after the disaster.

Vector layers with flood depths and levels of wind damage can complement the information. A system could be established that allows people to enter the address of a building to find out water depths, damage levels, when and how they could travel to the building, and nearest emergency supply centers. Moreover, the public requires detailed knowledge about the assigned evacuation routes and the traffic circumstances, evacuation shelters, kitchens, health facilities, and other public services.

Requests from Government Officials

Government officials asked for maps with various contents, including shelter locations, deceased victim locations, power outages, water systems, maps of state-owned land, pumping locations, and others.

3.3 Conclusions

This paper identifies lessons learned from the application of geotechnologies in the response to Hurricane Katrina. The main challenges in the operations were not related to the often discussed literature themes such as interoperability and semantics but rather to trivial issues such backlogged printers, network disruptions, and missing metadata. Aloof from Virtual Reality applications, one of the most frequent tasks of GI personnel was to print street books and visualize search and rescue coordinates.

Truly analytical GI applications going beyond simple map displays were sparse. Experience shows that the suitability and use of GI technology in the response phase differs from the planning phase because of the urgency, uncertainty, the magnitude of stakeholders, some of whom are unfamiliar with geo-information, and the real-time data needs. Among the most useful GI products created were inundation maps and map books with landmarks, detailed elevation figures, and unified grid systems.

Web-tools such as Google Earth proved to be helpful due to their relevancy, ease of use, and open access. There are reasons to believe that the field of geo-information for disaster management will eventually benefit from further developments of visual environments, semantic interpretations, and other current research topics. Most likely, the future use of geotechnologies will extend beyond mapping and move towards analytical processes. This will especially be the case when emergency managers gain knowledge in geo-information and its capabilities. Currently, however, improvements on the ground are necessary on basic levels. Other analyses of geo-information in disaster management (Kevany 2003; Zerger and Smith 2003; Curtis et al. 2005) report similar experiences, stressing the practical impediments of implementations. Existing knowledge about best practices need to be translated into action, programs, and relevant policies. To enhance the response, the often separate discourses of geo-technology on the one hand and emergency management on the other need to converge.

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CHAPTER 4

A GLOBAL URBAN RISK INDEX

4.1 Introduction

The potential for losses from natural hazards is particularly high in urban areas. 1.5% of the world's land is estimated to produce 50% of worldwide Gross Domestic Product (GDP). The same area accommodates about one sixth of the world's population (World Bank 2009). Concentrations of population, industry, infrastructure, and economic activities in cities contribute to increased exposure and susceptibility to natural hazards. In fact, the ongoing process of urbanization is one of the main reasons for the staggering increase in disaster death tolls and economic losses over the past decades (e.g., Quarantelli 1996, Wisner 2003, Pelling 2003).

The impacts from disasters are on the rise. Statistics show that, even when adjusted for inflation, the losses caused by natural catastrophes have been increasing dramatically and at an ever-quickening pace since 1950. In the period between 1990 and 1999 the costs of disasters in constant dollars were more than 15 times higher than during the period 1950-59 (World Bank 2006). The number of people affected by natural hazards each year nearly quadrupled from 1975-84 to 1996-2005 (EM-DAT 2007). Several factors contribute to this increase, for example land use changes, social inequalities, subsidence, and environmental degradation (e.g., Smith 1996, Mileti 1999, Blaikie et al. 1994). Some scientific studies suggest that a rise in hazardous events can be attributed to climate change (e.g., Emanuel 2005, Bengtsson et al. 2006, Vermeer & Rahmsdorf 2009). But the main driver of risk is population pressure, which is spreading in vulnerable locations, for example, in coastal areas susceptible to cyclones. The world's low lying coastal elevation zone covers 2% of the world's land area but contains 10% of the world's population (McGranahan et al. 2007). Due to the global urbanization process, cities are becoming increasingly predestined for risks. Estimates by the United Nations suggest that over 50% of the world's population already lives in urban areas (UN 2008). Cities are predicted to absorb most of the future growth in the world population: the UN estimates that the urban population share will rise to 70% by 2050 (UN Population Division 2007).

While natural hazards and ongoing urbanization are inevitable, disaster losses can be minimized through adequate disaster risk management. Reducing risks *ex-ante* through risk assessments, land use planning, building codes, early warning systems, adequate watershed management, and contingency planning leads to significantly reduced disaster impacts. The earthquake in Chile in March 2010 was one of the ten most powerful earthquakes recorded in the last century. It released 500 times more energy than the earthquake that struck Haiti in January 2010. Yet, only 521 people died in Chile, whereas Port-au-Prince was catastrophically affected with tens of thousands of deaths. The main reason for this difference is that buildings in Chile are built to codes and are regularly inspected whereas Haiti effectively has no building codes.

Because of the enormous loss potential that has developed and is expanding in the narrowest of urban space, disaster risk reduction efforts need to be intensified in cities. Especially developing countries are suffering from the consequences of disasters with more than 95% of disaster deaths occurring in the developing world in the past quarter century (Arnold & Kreimer 2004) and with economic losses being 20 times greater as a percentage of

GDP in developing countries than in developed ones (World Bank 2006). To secure the steady advances towards poverty alleviation and economic growth in the developing world, suitable risk reduction strategies must be developed and mainstreamed into urban planning and development strategies. Otherwise, years of development and accumulated wealth are repeatedly destroyed and eroded through repeated disasters.

Given the intrinsic high loss potential from natural hazards in urban areas, it comes as a surprise that little is known about the vulnerability and risk potential of cities. Which cities are likely to be affected by a disaster? In which cities is the risk of mortality due to disasters the highest? Which cities are most at risk of economic losses due to natural hazards? Efforts to assess urban risks so far have mainly focused on single cities, identifying inner-city hotspots. But a comprehensive ranking of the global cities' risk to guide priorities in building resilience has been lacking. This study creates, for the first time, a disaster risk ranking of the main cities in the less developed world. Risk levels of 1,943 cities in 110 countries are evaluated and compared. The five following features characterize the index:

- Risks are assessed for urban agglomerations with more than 100,000 inhabitants.
- For each city, mortality risk and economic risk are calculated by taking into account three components of risks: hazard, exposure, and vulnerability.
- The loss potentials are expressed in relative levels.
- Four major natural hazards, namely earthquakes, cyclones, floods, and slides are considered in this study. Urban risks are identified for each of these hazards separately. In addition, a multi-hazard index gives a holistic picture of city risk.

- Expected urban risk exposure in the year 2050 is determined through projections of future city population growth.

By disclosing risks to cities, we hope to raise awareness, inform resource planning, inspire further research, particularly at local levels, and promote the shift towards managing risks rather than emergencies.

4.2 Background

The assessment of risk is highlighted as a central activity in defining priorities and building resilience in the Hyogo Framework for Action 2005-2015 (UN-ISDR 2005), signed by 168 nations and international organizations at the 2005 World Conference on Disaster Reduction. Risk identification supports a wide range of decision-making processes for different actors on how risk should be managed from the public to the private sector (e.g., Cutter & Finch 2008, Birkmann 2006, Fuessel 2007). Quantifying risk and estimating future losses are not only the first steps in any disaster risk reduction program; the resulting scenarios of a risk assessment are increasingly incorporated into sustainable development approaches in different sectors in order to climate- and disaster-proof investments. Once the severity and geographical extent of risks have been assessed and the drivers of risk are better understood, appropriate and cost-effective countermeasures can be systematically identified and implemented. Depending on the scale, risk assessments support multiple applications, for example, urban planning, investment prioritization, land use planning, building codes, and disaster risk financing solutions.

A range of perspectives on risk assessments and indices has emerged, ranging from quantitative calculations on losses to qualitative analysis capturing also intangible impacts.

Interesting initiatives have developed mainly on national level but a few have also been completed on global and urban scale.

Global level: Two main risk assessments initiatives have been undertaken with the goal of identifying multi-hazard risk worldwide on the basis of grid cells with sub-national extent. First, the *Global Disaster Hotspots*, developed by the World Bank and Columbia University (Dilley et al. 2005, Lerner-Lam 2007) produced detailed geospatial data on risks of mortality and economic losses for six major natural hazards. The results enabled a global assessment of risk levels and the identification of areas where the potential for disaster impacts is large. Second, the *Global Assessment Report 2009* (UN-ISDR 2009) is a multiple agencies effort that developed the Global Disaster Hotspots further by using enhanced modeling techniques and improved data layers. An update of this 2009 global risk analysis was released in the *Global Assessment Report 2011* (UN-ISDR 2011).

National level: An example of a comprehensive multi-hazard risk index that assigns overall risk values on a national level is the *Disaster Risk Index* (DRI) (Peduzzi et al. 2009). The DRI calculates three factors on a national resolution for 200 countries: risk of mortality, the relative vulnerability of each hazard type, and the physical exposures of populations to hazard. Another example for a risk assessment on national scale, covering a multitude of countries, is the study by McGranahan et al. (2007), which ranks countries according to their population shares in the low elevation coastal zones.

Urban level: With the rise of megacities, risk assessments have increasingly taken place on city-level, identifying inner-city areas of high risks and loss potential (e.g., World Bank 2010). However, only a few limited initiatives exist which assess the overall risk of numerous cities in the form of an index to compare and rank cities with each other. Efforts in this area to date have been confined to relatively limited sets of locations and hazards. The Munich Reinsurance Group developed the *Natural Hazard Index for Megacities* for 50 cities with high global economic significance (Munich Re 2005). The index has an economic emphasis and is geared towards the risk of material losses which is suitable from an insurance perspective. Hanson et al. (2011) ranked 136 port cities around the world that have more than one million inhabitants. The study examines the risks of coastal areas due to storm surge and high winds, taking into account predictions of climate change, subsidence, and population growth. Brecht et al. (2012) determined the impact of sea level rise and intensified storm surges in developing countries and highlight the major cities worldwide that are located in storm-surge zones. Furthermore, methodologies have been developed that propose indicators to estimate the overall risk of cities. Indicators, include, for example, population density or number of hospital beds (e.g., Davidson 1997, Cardona 2005). These methodologies are frameworks that were selected without regard to data availability and they have been implemented only for a handful of cities.

4.3 Motivation

Why is a global urban risk index important? There are a number of ingredient questions here. One question is whether an index is useful. Indices consist of a set of indicators, which are derived from extensive datasets that are mathematically combined. An index aggregates information and summarizes a body of knowledge from a wide range of disciplines. It filters information for the reader and translates research into easy to understand results. This makes indices appealing tools, which are widely used.

An additional question is whether a global risk index is of value. A risk index combines complex data of hazards, vulnerabilities, and exposure. One advantage of such an index is that it enables the comparison of risk levels in a self-explanatory manner. As the international development community gradually shifts from financing post-disaster relief towards financing disaster prevention (see for example, Ashdown 2011), a global risk index gives reference points for investment decisions. It enables a comparison of risk levels worldwide and yields the basis for decisions on where funding for disaster risk reduction should be allocated. It allows comparability and the prioritization of programs in areas where hazard risk is greatest and where investment benefits are maximized. Cutter (2001) stresses that geographic comparisons across regions with a systematic approach in methodologies and data are crucial to prioritize risk reduction strategies or poverty reduction goals. Yet, disaster research has usually gravitated toward group or community studies as opposed to large-scale projects (Tierney 2002). Second, by disclosing risks, we intend to raise awareness with regard to potential disaster losses and promote the shift towards managing risks rather than emergencies. A global risk index is helpful for showing planners at which level they are. It gives an understanding of risk and has the innate potential to sensitize the public and encourage officials to take action. And third, we hope that the index will stimulate more detailed research on where the risks are, what the main drivers of risk are, and where to invest to minimize vulnerability.

Finally, another question relates to the advantages of an index that concentrates on urban areas. Urban areas are the fastest growing areas on earth. The world's population became predominantly urban in 2009 with over 50% living in cities, and the UN estimates that the urban population share will rise to 70% by 2050. The urbanization rate is particularly high in the developing world. Cities in East Asia, for instance, absorb two million new urban residents every month (Gill and Kharas 2007) and are projected to triple their built up areas in the coming two decades (Angel et al. 2005). The city ranking creates an evidence base for risk-based decision-making and points to urban hotspots in which integration of risk reduction in urban planning needs to be prioritized.

4.4 Methodology

Risk expresses the possibility of future disaster, that is the possibility that a hazardous event will happen and that exposed and susceptible elements are in the way. It is defined as the probable value of losses that will occur in the event of a disaster. The risk model used in this study is built upon a sequence of four modules: hazard, exposure, vulnerability, and losses (Figure 4.1).

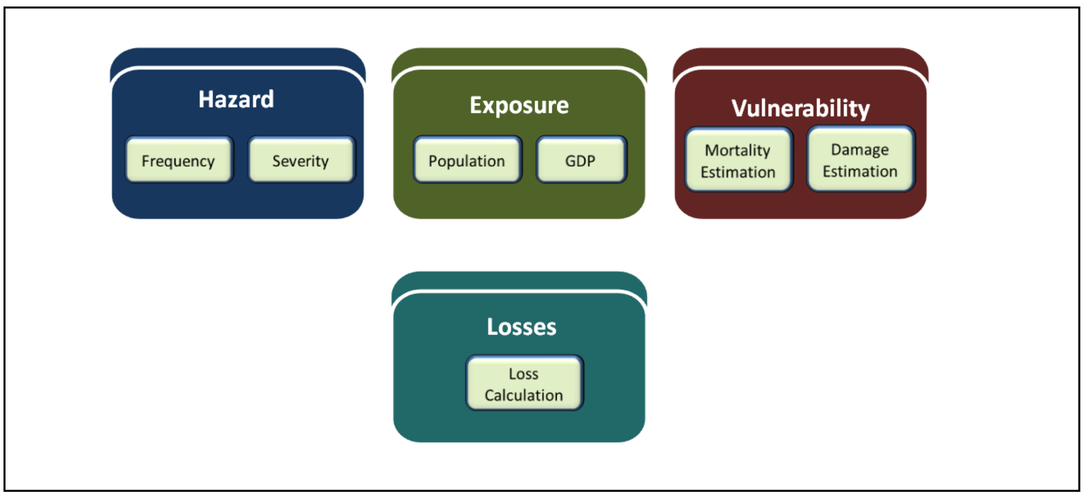

Figure 4.1: The four components of the Global Urban Risk Index

4.4.1 Assessing Hazards

Hazard refers to the possible occurrence of physical events that may have adverse effects on vulnerable and exposed elements (White 1973). The hazard module in this index assesses the risks from four different natural hazards: earthquakes, landslides, floods, and cyclones. Risks are determined for each hazard individually and a multi-hazard index gives an overall picture of city risk. To estimate the likelihood of a hazard striking a given city, this study has taken advantage of global hazard data sets developed by different organizations (Table 4.1).

The data sets depict the geographic distribution of hazard risk in a grid format with resolutions of 1 km^2. Hazard frequency and, when available, severity were derived from historic events, from modeled probabilities or from a combination of both. Historic events have been used to calculate cyclone hazard risk for cities. To estimate cyclone risk, more than 2,800 historic cyclone tracks in the time period from 1975 to 2007 and their modeled wind speed plumes were calculated (Figure 4.2) and combined, resulting in a global grid, that shows how many times each grid cell has been struck by a cyclone (frequency) and with what wind speed (severity) (Figure 4.3).

To calculate landslide hazards, probabilities were applied. The probabilities were derived through a combination of trigger and susceptibility factors defined by various parameters, including slope factor, lithological or geological conditions, soil moisture condition, vegetation cover, precipitation, seismic conditions, and Shuttle Radar Topography Mission (SRTM) elevation data.

Table 4.1: Data sources for the hazard component

Hazard	Description	Unit	Source
Cyclones	Tropical cyclones wind speed buffers based on compilation of tracks (1975-2007) and GIS modelling.	Estimated Saffir-Simpson categories	UNEP/GRID-Europe
Floods	Flood frequencies generated by GIS modelling, observed flood data from 1999 to 2007, obtained from the Dartmouth Flood Observatory (DFO) and the UNEP/GRID-Europe PREVIEW flood dataset.	Expected average number of event per 100 years	UNEP/GRID-Europe/ Dartmouth Flood Observatory
Earthquakes	Modified Mercalli Intensity based on GIS modelling using the Global Seismic Hazard Assessment Program (GSHAP) dataset.	Simulated Modified Mercalli Intensity (MMI)	Center for International Earth Science Information Network (CIESIN), Columbia University
Landslides	Landslide probabilities triggered by earthquakes and precipitation based on GIS modelling taking into account slope factor, lithological (or geological) conditions, soil moisture condition, vegetation cover, precipitation, and seismic conditions.	Expected annual probability and percentage of pixel of occurrence of a potentially destructive landslide event times 1,000,000	Norwegian Geotechnical Institute / International Centre for Geohazards

To calculate earthquake and flood risks, combinations of historic events and modeled probabilities were used. The resulting hazard grids were overlaid with city footprints to identify the maximum hazard probability for each of the cities. This is accomplished by assigning the value of the grid cell with highest hazard denomination within a city footprint as the city's hazard severity.

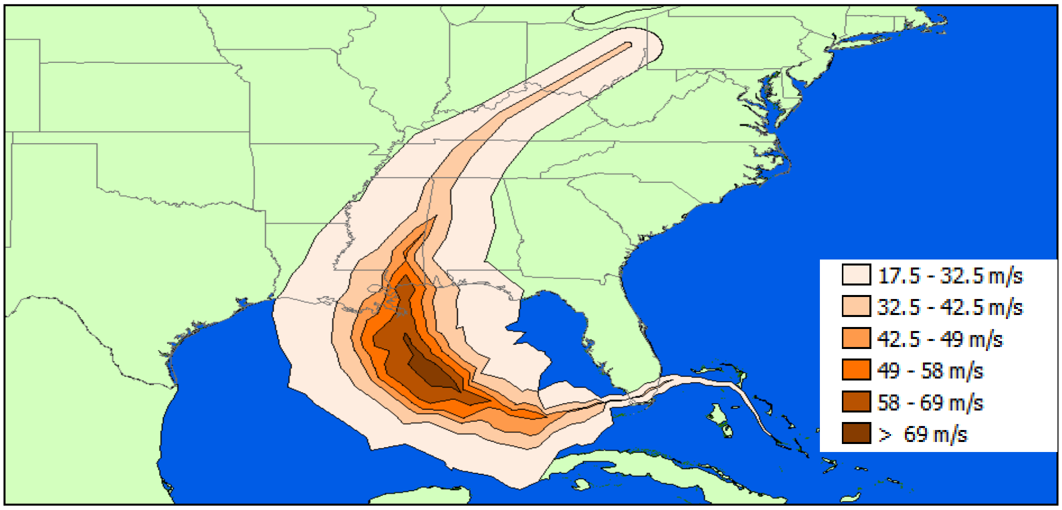

Figure 4.2: Wind field of Hurricane Katrina in 2005

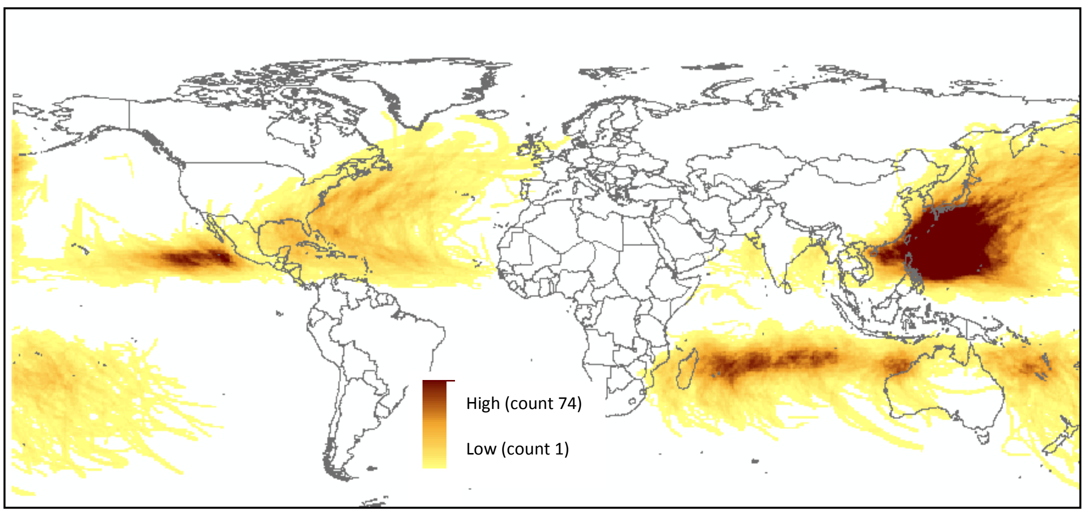

Figure 4.3: Global cyclone frequency 1975-2007

4.4.2 Quantifying Exposure

The exposed elements at potential risk from hazards are people, buildings, transport infrastructure, economies, and communities all of which are greatly concentrated in urban areas. In a rapidly urbanizing world, the increasing concentration of people and economic assets in cities is leading a sharp rise of urban hazard risk and is a main driver for the increase in disaster losses. Growing exposure and delays in reducing vulnerabilities result in an increased number of natural hazards and greater levels of loss.

The impact of a disaster is dependent on the extent of the exposed elements that are in harm's way, i.e. on the number of people and the amount and value of infrastructure that are affected by the disaster. The exposure module in this study is an inventory of assets at risk on city level. Two asset classes are considered: City population and city GDP. City population numbers are based on the Henderson city dataset by Brown University (Table 4.2).

Table 4.2: Data sources for the exposure component

Dataset	Description	Unit	Source
Henderson City Data	Data set of cities worldwide with more than 100,000 inhabitants. The data includes city names, countries, codes, coordinates, and population numbers of the years 1960, 1970, 1980, 1990, and 2000.	Inhabitants per urban agglomeration	Prof. J. Vernon Henderson, Brown University
GRUMP	Global urban footprint grid based largely on NOAA's night-time light satellite data from 1994/5 coupled with settlement information.	Urban population distribution and the global extents of human settlements	Center for International Earth Science Information Network (CIESIN), Columbia University
GDP	Sub-national Gross Regional Product (GRP) and national Gross Domestic Product (GDP) data are allocated in proportion to the population residing in that cell. The approach distinguishes between rural and urban population.	US$/30 arc second	World Bank

All cities in less developed countries with more than 100,000 inhabitants in the year 2000 were selected from this database. This resulted in a city dataset with 1,943 cities. Cities in this context are entire urban agglomerations with suburban fringe and adjacent towns.

To determine urban GDP and hazard severity, a city footprint was defined for each of the city points from the Henderson data. To define a footprint for each city, the city points of the Henderson data were matched with the Global Rural-Urban Mapping Project (GRUMP) raster data by the Center for International Earth Science Information Network (CIESIN) at Columbia University. GRUMP is a global urban footprint grid based largely on NOAA's night-time light satellite data from 1994/5 coupled with settlement information. For each of the 1,943 cities, a corresponding urban area in GRUMP was identified and converted into a polygon, which represented the city's urban footprint. Where multiple city points fell within a large continuous area, Thiessen polygons were used to allocate a portion of the area to each point, creating a unique urban footprint for each city (Figure 4.4).

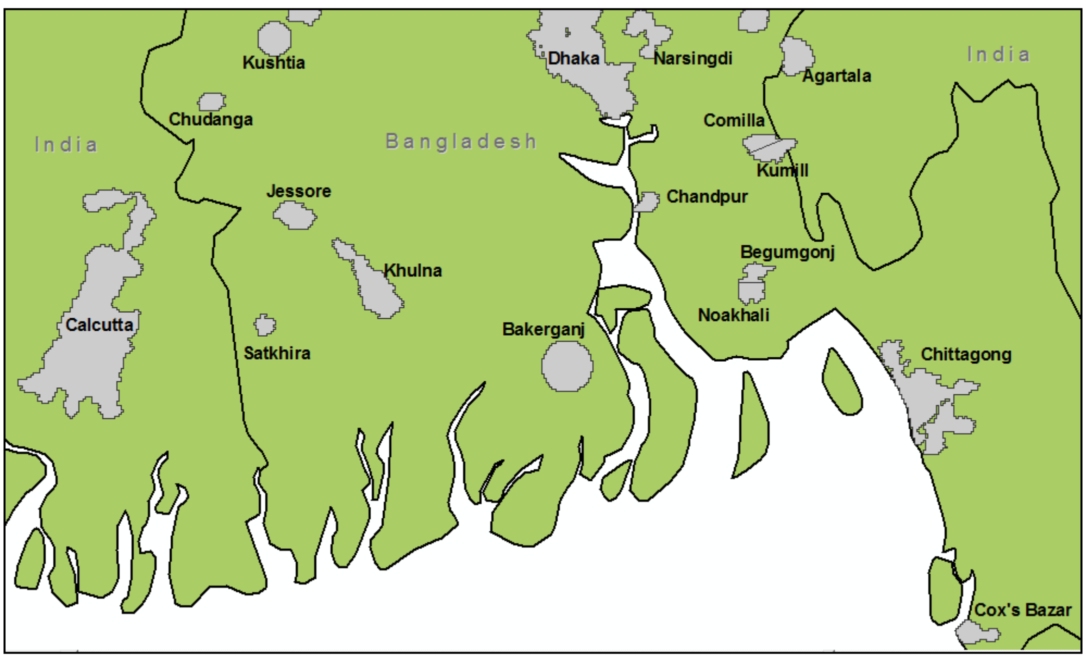

Figure 4.4: Integration of GRUMP data and Henderson Cities

The footprints were used to calculate city GDP by using a global GDP grid with a resolution of approximately $1km^2$. The GDP figures for cells within a city footprint were added up which resulted in the city GDP. By overlying the footprints with the natural hazard grids, the footprints were the basis for identifying if a city was exposed to natural hazards, and if so, to what maximum hazard probability.

4.4.3 Calculating Vulnerability

The term ‘vulnerability’ is derived from the Latin word *vulnerare*, which means 'to wound'. Broadly, vulnerability refers to the extent to which a person, structure, or service is likely to be damaged by the impact of a disaster. It explains why, with a given hazard severity, people and assets are more or less at risk and why they do or do not fail to be robust in the face of a threatening event. For the purpose of a risk assessment, vulnerability is usually disaggregated into categories such as physical, social, economic, or environmental. While physical vulnerability of the built environment, for example, is influenced by building age and construction type, social vulnerability is affected by lack of access to resources or limited access to political power.

Vulnerability reduction is a core element in disaster risk management. The concept of vulnerability has helped to highlight the role of social and physical factors that have an impact on the constitution of risk (Hewitt 1983). By using the notion of vulnerability, disasters are not viewed anymore only as the result of a natural event but rather as the result of the vulnerability of a society, its infrastructure, economy, and environment, all of which are determined by human behavior. Governments and citizens can appreciably reduce vulnerability, and therefore risk, through sensible combinations of prevention, insurance, and preparedness.

Vulnerability is not easily quantifiable and researchers have struggled to develop appropriate metrics for vulnerability (Adgers 2006). Ways to determine vulnerability include deductive, inductive, and combined methods. Deductive approaches use quantitative methods based on historical patterns of past disasters and their damages and losses. Inductive approaches determine risks through combining weighted variables for vulnerability. For example, factors such as GDP, poverty rates, or population density are taken as indicators of how vulnerable a place is. An obstacle to inductive modeling is the lack of accepted procedures for assigning values and weights to the different vulnerability factors that contribute to risk. An obstacle to deductive approaches is that the data on losses during past hazards is insufficient, especially on larger scales, and often not methodologically recorded. Despite this weakness, deductive modeling offers a viable option to risk indexing in many contexts and is helpful, especially for risk comparisons on larger scales.

In this study, two categories of vulnerability are determined using deductive methods. Vulnerability to mortality is calculated based on historical disaster mortality in precedent hazard events and vulnerability to economic losses is determined through past economic losses in disasters. The loss data on number of deaths and amount of economic losses were extracted from the Emergency Events Database (EM-DAT) (http://www.em-dat.net) for the period from 1980 to 2007 (Table 4.3). EM-DAT is maintained by the Centre for Research on the Epidemiology of Disasters (CRED) which classifies an event as a disaster and includes it into EM-DAT if at least one of the following criteria applies: Ten or more people were killed, 100 or more people were affected, a declaration of a state of emergency was made, or an appeal for international assistance was made. EM-DAT records more than 600 disasters globally each year. For each event, the database lists the type of disaster, the country, the date, death tolls, estimated damage, and the number of affected people. Aggregating over more than 8,000 entries in EM-DAT helps compensate for missing data and reporting inaccuracies.

Table 4.3: Data sources for the vulnerability component

Dataset	Description	Unit	Source
EM-DAT (Emergency Events Database)	International disaster database for major hazards across the world, listing country, date, death tolls, estimated damage, number of homeless and affected people. The database contains over 14,000 disasters and is compiled from various sources, including UN agencies, NGOs, insurance companies, research institutes, and press agencies.	Number of fatalities/economic losses per disaster	Centre for Research on the Epidemiology of Disasters (CRED) http://www.em-dat.net/

Different vulnerability coefficients, or loss weights, are calculated for the two vulnerability categories of population and GDP. Weights are obtained for all of the four hazard types for each of the 25 World Bank clusters. Clusters are agglomerations of countries according to standard classifications of the World Bank. They stem from seven geographical regions (Africa, East Asia and the Pacific, Europe and Central Asia, Latin America and the Caribbean, Middle East and North Africa, North America, South Asia) (Figure 4.5) and four different wealth classes (high, upper-middle, lower-middle, and low). The coefficients are calculated on a regional basis rather for each country, or even city, individually due to an insufficient number of hazard and loss events. The weights are an aggregate index of relative losses over a 27 year period. They represent an estimate of the proportion of persons killed during a 27 year period in the area that is exposed to that hazard. For example, to calculate mortality loss weights for a hazard *h* for a certain cluster *c*, the death tolls for that hazard (e.g. earthquakes) in the years from 1980 to 2007 were extracted from EM-DAT for all countries within that cluster and aggregated: M_{ch}.

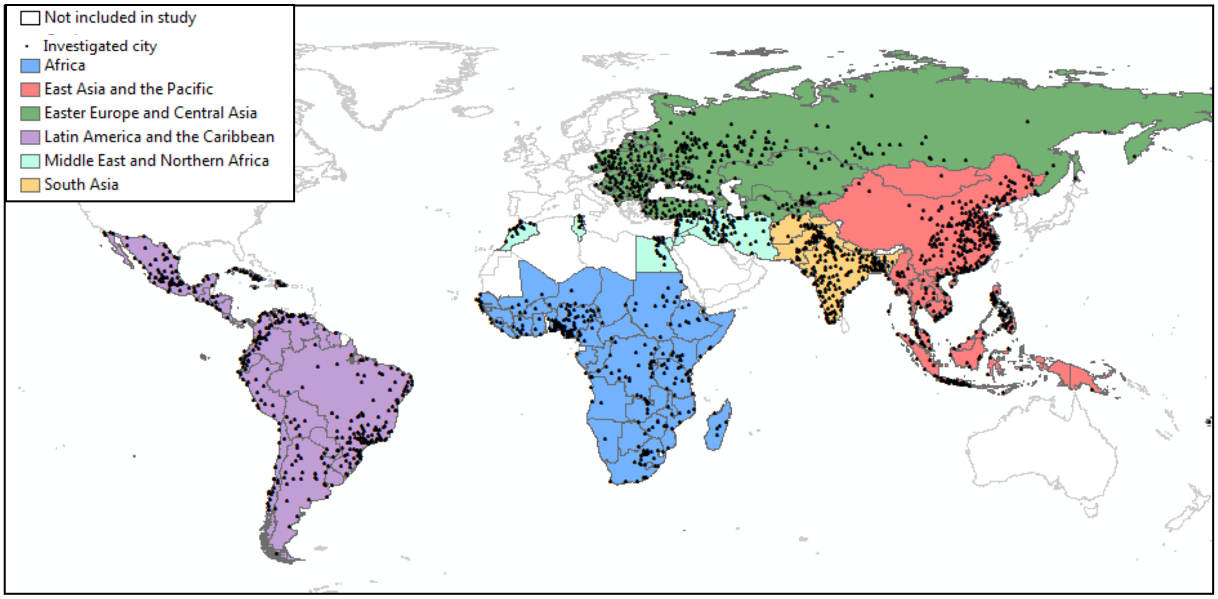

Figure 4.5: The six regions covered in the study

Then, using the raster layers on the extent of each hazard, the population in the earthquake affected areas from the year 2000 was summed up for that cluster: P_{ch}. A simple mortality rate for the hazard is calculated for the cluster:

$$r_{ch} = M_{ch}/P_{ch}$$

4.4.4 Determining Urban Risk

Building upon the first three modules of hazard, exposure, and vulnerability, the probability of mortality and economic losses from catastrophic events for each city is calculated. The vulnerability coefficients are used as weights that are combined with both the exposure data per city and the city-specific hazard severity. For example, for each city *i* that is in an earthquake-prone area, the city-specific earthquake mortality rate M_{ice} is computed by multiplying the cluster-specific earthquake mortality rate r_{ce} by the city population P_i and the city-specific earthquake severity W_{ie}.

$$M_{ice} = r_{ce} P_i W_{ie}$$

To compute a weighted multi-hazard index value for mortality that reflects total estimated impacts from all disaster types for a city, this method is followed for each hazard *h*. Since the degree of hazard (h_d) for each of the five hazards is measured on a different scale (for example, frequency counts for cyclones versus probability index values for landslides), the accumulated mortality numbers are not easily comparable across hazards and simply adding the resulting values would result in an index unduly dominated by a hazard type *h* that happens to be measured on a scale with larger values. Before combining the hazards into a multi-hazard index, a uniform adjustment is applied by deflating the weighted hazard-specific mortality figures, so that the total mortality in each region adds up to the total recorded in EM-DAT.

$$M_{ich}^{*} = M_{ih}' M_{ch} \,/ \sum_{i=1}^{n} M_{ih}'$$

where n is the number of cities per cluster and M'_{ih} is the hazard-specific city mortality rate (h_d P_i r).

The combined, mortality-weighted multi-hazard city risk value Y_i^* is calculated as the sum of the adjusted individual hazard mortality estimates for a given city:

$$Y_i^* = \sum_{h=1}^{4} M_{ih}^{*}$$

Reporting actual mortality numbers would portray an unrealistic impression of precision. To avoid literal interpretation of the disaster index as the number of persons expected to be killed in a 20-year period and in recognition of the many limitations of the underlying data, the resulting measures are converted into index values from one to ten, classifying the global risk distribution into deciles and providing relative presentations of disaster risk.

4.4.5 Interpretation

The calculated risks in the index assign a value to the city as a whole and are based on the three factors of hazard severity in the city, city population, and the vulnerability of the particular World Bank cluster. The mortality risk in a city is the potential extent of total fatality numbers that a city could incur rather than the extent of risk that a single person experiences in that city. Similarly, economic risk mirrors total potential damage extent.

Result interpretation needs to consider that a number of constraints in globally available data limit the sophistication of the methods that were employed to investigate urban risk on a global level. Although I use the best available data, gaps in the data limit our analysis. For example, deductive modeling has weaknesses in determining risk in contexts where disasters occur infrequently and where historical data is scarce. Moreover, disaster loss data in EM-DAT is recorded on country-level and does not allow for a differentiation between urban and rural loss rates and vulnerabilities. The insufficient numbers of disaster events lead us to calculate vulnerability coefficients on regional levels using clusters. Aggregating across more than 8,000 entries in EM-DAT helps compensate for missing data and inaccuracies and reflect broad patterns of vulnerability. It cannot, however, reveal protection mechanisms (land use planning, regulations) that individual cities might have implemented. Another limiting factor is the relatively crude delineation of some hazards. For example, earthquakes with pathological damage patterns are represented incompletely. The cities investigated in this study stem from the Henderson city database (see Table 4.2). This data set contains cities worldwide with more than 100,000 inhabitants. While it has extensive coverage globally, some cities are left out in the database and are consequently not included in the index. Finally, for a few clusters (i.e. Middle East and Northern Africa High Income, Middle East and Northern Africa Lower Middle Income, all clusters in the Africa region, and Eastern Europe and Central Asia Lower Middle Income) insufficient historic loss data was available for landslide hazards, and therefore, the countries belonging to those clusters were not included in the landslide analysis.

In recognition of these limitations, the modest objective of the study is to provide a relative presentation of disaster risk instead of an absolute one. We therefore convert the absolute city risk values, calculated in the risk model, into comparative index values. While the index cannot provide the detail needed to identify concrete risk reduction measures, it assesses the relative importance of risk at regional level and identifies areas where more attention is needed.

4.5 Results

Global Distribution

The number of exposed urban dwellers to certain hazards has implications for the weight given to reduce the risk of specific hazards. In this analysis, by far the greatest number of the investigated urban population in less developed countries is exposed to flood hazards, approximately 1.1 billion. Around half that number (560 million) are at risk to earthquakes and also to landslides (660 million). Finally, nearly 90 million of the study's urban population is exposed to cyclone hazards.

Regional Distribution

Between 1980 and 2006, Pakistan and the US both experienced nineteen major earthquakes (>5.0 on Richter scale). While in Pakistan 74,112 people died during these earthquakes, in the US only 145 people were killed. This enforces the concept that tragedies are not caused by the earthquake itself, but rather by dire construction practices and missing policies. The deaths and devastation in disasters result from human action or inaction. Typically, wealthy regions and countries are higher at risk in terms of economic losses but suffer fewer fatalities whereas poor countries experience high mortality risks and lesser economic risks. The results in Figure 4.6 reflect this trend. This figure shows the accumulated shares of urban economic and mortality risks by region and hazard. Within the individual regions, significant differences can be found in terms risks to mortality and economic loss risks. For example, while urban mortality loss risk to cyclones is greatest in South Asia (68%), the share of urban cyclone economic loss risk in the same region is only 16%. The wealthier East Asia clearly bears the greatest burden of urban economic loss risk (77%) whereas East Asia's urban mortality risk is comparatively lower. Next to wealth, the type of disaster is a decisive factor for overall risk. Fatalities from severe earthquakes, for example, are usually far larger than fatalities from severe floods or cyclones under equal vulnerability conditions.

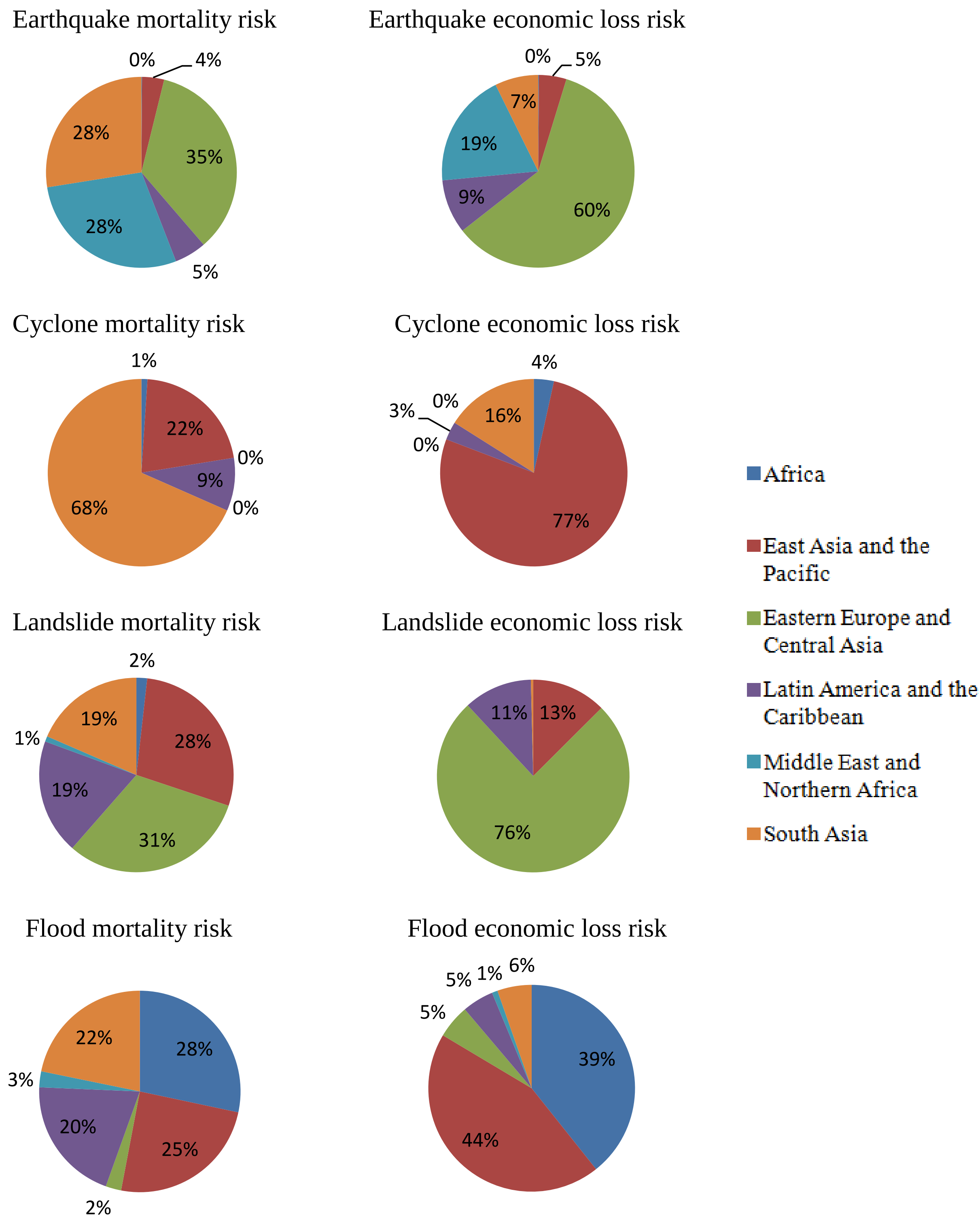

Figure 4.6: Regional shares of urban risks for four different hazards

Ranking Risk by Country

The five most at risk countries for urban mortality and economic loss risk from four investigated hazards are presented in Table 4.4. Some risks are highly concentrated in certain countries. India, Pakistan, and Bangladesh, for example, account for 68% of cumulative urban mortality risk to cyclones out of all investigated cities. Economic loss risk from cyclones, on the other hand is highest in East Asia, where China alone has built up 53% of the cumulative urban economic loss risk for cyclones. Earthquake risk is highly concentrated in Turkey and Iran, both of which together account for 47% of all investigated cumulative urban earthquake risk of economic losses.

Table 4.4: The five most at risk countries for urban mortality and economic loss risk per hazard

	Earthquake Risk		Cyclone Risk	
	Mortality	Economic Loss	Mortality	Economic Loss
1	Turkey	Turkey	India	China
2	Iran	Iran	Pakistan	Myanmar
3	India	Hungary	Bangladesh	Vietnam
4	Pakistan	Romania	China	India
5	Egypt	Russia	Myanmar	Pakistan

	Landslide Risk		Flood Risk	
	Mortality	Economic Loss	Mortality	Economic Loss
1	Turkey	Turkey	South Africa	South Africa
2	Philippines	Philippines	India	Vietnam
3	India	Russia	China	China
4	Guatemala	Guatemala	Argentina	Indonesia
5	Indonesia	China	Bangladesh	India

Ranking Risks by City

The cities with the highest mortality and economic loss risk by hazard are listed in Table 4.5 to Table 4.8. The tables show the five most at risk cities by hazard in each of the six investigated regions. The ranking gives an indication of the cities most worthy of further and more detailed investigation. The data provide for interesting comparisons. For example, Metro Manila, one of the world's most disaster prone cities, is listed in the tables as being highly at risks from the three hazards of earthquakes, floods and landslides. This year, in 2012, the city has again experienced devastating floods with almost two thirds of the city area being submerged after a week of torrential rains. Tehran is also highly at risk, especially from earthquakes and floods. This fact has sparked repeated discussions among the country's leaders about moving the capital to a less risky region. A striking, but also sobering, result is the magnitude of risk in certain cities. In South Asia, the top five ranked cities for cyclone mortality risk bear 62% of all cumulative mortality loss risk in that region. Cumulative economic loss risk for landslides in Eastern Europe and Central Asia amounts to 51% for the top five ranked cities in that category. All of those five cities are in Turkey. In Africa, Addis Ababa accounts for 31% of the cumulative earthquake mortality risk in that region and the top five cities altogether bear 59% of Africa's earthquake mortality risk.

A number of smaller cities with less population and wealth are set to swell with rapid increases in population and asset exposure. These include, for example, Toluca in Mexico and Conakry in Guinea. While the absolute exposure of these cities is currently relatively low, the rapid increase in population growth will pose significant challenges for these cities in the coming years.

Table 4.5: Regional top 5 cities most at risk to earthquakes

	Mortality risk		Economic loss risk	
Region	Country	City	Country	City
Africa	Ethiopia	Addis Ababa	Uganda	Kampala
	Uganda	Kampala	Ethiopia	Addis Ababa
	Malawi	Blantyre	Malawi	Blantyre
	Kenya	Nakuru	Kenya	Kisumu
	Burundi	Bujumbura	Kenya	Nakuru
East Asia	Philippines	Metro Manila	Indonesia	Jakarta
	Indonesia	Jakarta	Philippines	Metro Manila
	China	Tianjin	China	Beijing
	China	Beijing	China	Tianjin
	Indonesia	Bandung	Indonesia	Yogyakarta
Eastern Europe and Central Asia	Turkey	Istanbul	Turkey	Ankara
	Turkey	Ankara	Hungary	Budapest
	Turkey	Izmir	Turkey	Izmit
	Romania	Bucharest	Turkey	Istanbul
	Turkey	Bursa	Turkey	Izmir
Latin America and the Caribbean	Mexico	Mexico City	Peru	Lima
	Peru	Lima	Mexico	Mexico City
	Chile	Santiago	Mexico	Tijuana
	Colombia	Bogota	Colombia	Bogota
	Mexico	Guadalajara	Chile	Santiago
Middle East and Northern Africa	Egypt	Cairo	Iran	Tehran
	Iran	Tehran	Egypt	Cairo
	Iran	Mashhad	Iran	Raja'ishahr
	Iran	Esfahan	Egypt	Shubra El-Kheima
	Tunisia	Tunis	Iran	Ahvaz
South Asia	India	Kolkata	India	Delhi
	Bangladesh	Dhaka	India	Kolkata
	Pakistan	Karachi	Pakistan	Karachi
	India	Delhi	Pakistan	Lahore
	Pakistan	Lahore	Bangladesh	Dhaka

Table 4.6: Regional top 5 cities most at risk to cyclones

	Mortality risk		Economic loss risk	
Region	Country	City	Country	City
Africa	Mozambique	Quelimane	Mozambique	Quelimane
	Mozambique	Beira	Mozambique	Beira
	Madagascar	Toamasina	Madagascar	Toamasina
	Madagascar	Mahajanga	Madagascar	Mahajanga
East Asia	Myanmar	Yangon	China	Shenzhen
	China	Shanghai	Myanmar	Yangon
	Vietnam	Hai Phong	Vietnam	Hai Phong
	China	Fuzhou	China	Shanghai
	China	Dongguan	China	Dongguan
Latin America and the Caribbean	Dominican Republic	Santo Domingo	Mexico	Cancun
	Jamaica	Kingston	Jamaica	Kingston
	Cuba	La Habana	Mexico	Ciudad Madero
	Mexico	Cancun	Dominican Republic	Santo Domingo
	Dominican Republic	La Romana	Mexico	Mazatlan
South Asia	India	Chennai	India	Chennai
	Pakistan	Karachi	Pakistan	Karachi
	Bangladesh	Chittagong	India	Visakhpatnam
	India	Visakhpatnam	Bangladesh	Chittagong
	Bangladesh	Khulna	Bangladesh	Khulna

Note: No cyclone risk was measure in the Middle East, Northern Africa, Eastern Europe, and Central Asia

Urban multi-hazard mortality risk for all 1,943 investigated cities is shown in Figure 4.7. The values are calculated as the sum of the adjusted individual mortality estimates from the four hazards, and the results are grouped into five classes, using quintiles. Mortality risk is significant in regions exposed to repeated severe flooding and storms along the eastern continental shorelines but also in the earthquake prone regions of Eastern Europe and the Middle East. The regional differences in risks are in part due to differences in population size

Table 4.7: Regional top 5 cities most at risk to landslides

	Mortality risk		Economic loss risk	
Region	Country	City	Country	City
Africa	Sierra Leone	Freetown		
	Guinea	Conakry		
	Nigeria	Lagos		
	Côte d'Ivoire	Abidjan		
	Ethiopia	Adis Abeba		
East Asia	Philippines	Metro Manila	Philippines	Metro Manila
	Indonesia	Surabaya	China	Shenzhen
	Philippines	Baguio	Indonesia	Surabaya
	Vietnam	Ho Chi Minh	Indonesia	Yogyakarta
	Indonesia	Padang	China	Hong Kong
Eastern Europe and Central Asia	Turkey	Manisa	Turkey	Izmit
	Turkey	Izmir	Turkey	Manisa
	Russia	Petropavlovsk-Kamatskij	Turkey	Kahramanmaras
	Turkey	Kahramanmaras	Turkey	Izmir
	Turkey	Erzurum	Turkey	Erzurum
Latin America and the Caribbean	Guatemala	Guatemala City	Guatemala	Guatemala City
	Ecuador	Quito	Brazil	Vitoria
	Colombia	Bogota	Peru	Lima
	Peru	Lima	Ecuador	Quito
	Brazil	Vitoria	El Salvador	San Salvador
Middle East and Northern Africa	Iran	Tehran	Bahrain	Al-Manamah
	Iran	Rasht	Djibouti	Djibouti
	Iran	Shiraz	Iran	Tehran
	Iran	Tabriz	Iran	Mashhad
	Iran	Khorramabad	Iran	Esfahan
South Asia	India	Imphal	India	Imphal
	India	Mumbai	India	Srinagar
	India	Srinagar	India	Thane
	Pakistan	Peshawar	India	Bhiwandi
	Pakistan	Islamabad	India	Chandigarh

Note: Due to lack of data, economic loss risk for landslides could not be calculated in Africa.

Table 4.8: Regional top 5 cities most at risk to floods

	Mortality risk		Economic loss risk	
Region	Country	City	Country	City
Africa	South Africa	Cape Town	South Africa	Cape Town
	South Africa	Pretoria	South Africa	Durban
	South Africa	Durban	South Africa	Pretoria
	South Africa	Port Elizabeth	South Africa	Port Elizabeth
	Nigeria	Lagos	South Africa	Alberton
East Asia	Indonesia	Jakarta	Vietnam	Ho Chi Minh
	China	Wuhan	Indonesia	Jakarta
	Philippines	Metro Manila	Philippines	Metro Manila
	Vietnam	Ho Chi Minh	Vietnam	Hanoi
	Vietnam	Hanoi	Cambodia	Phnom Penh
Eastern Europe and Central Asia	Uzbekistan	Tashkent	Russia	Moscow
	Uzbekistan	Namangan	Poland	Warszawa
	Uzbekistan	Andijan	Uzbekistan	Tashkent
	Russia	Moscow	Poland	Kattowitz
	Tajikistan	Khujand	Turkey	Ankara
Latin America and the Caribbean	Argentina	Buenos Aires	Argentina	Buenos Aires
	Venezuela	Caracas	Brazil	Sao Paulo
	Brazil	Sao Paulo	Uruguay	Montevideo
	Argentina	Rosario	Venezuela	Caracas
	Venezuela	Maracaibo	Mexico	Mexico City
Middle East and Northern Africa	Iran	Tehran	Iran	Ahvaz
	Iran	Ahvaz	Iran	Tehran
	Iraq	Al-Basrah	Iran	Rasht
	Iran	Shiraz	Iran	Shiraz
	Morocco	Casablanca	Iran	Abadan
South Asia	Bangladesh	Dhaka	India	Kolkata
	India	Kolkata	India	Delhi
	India	Delhi	Bangladesh	Dhaka
	Bangladesh	Chittagong	India	Surat
	Pakistan	Karachi	Pakistan	Karachi

but also the degree of hazard severity and frequency across regions. Additionally, the differences reflect the variation in vulnerability. Similarly, economic risk is shown on Figure 4.8.

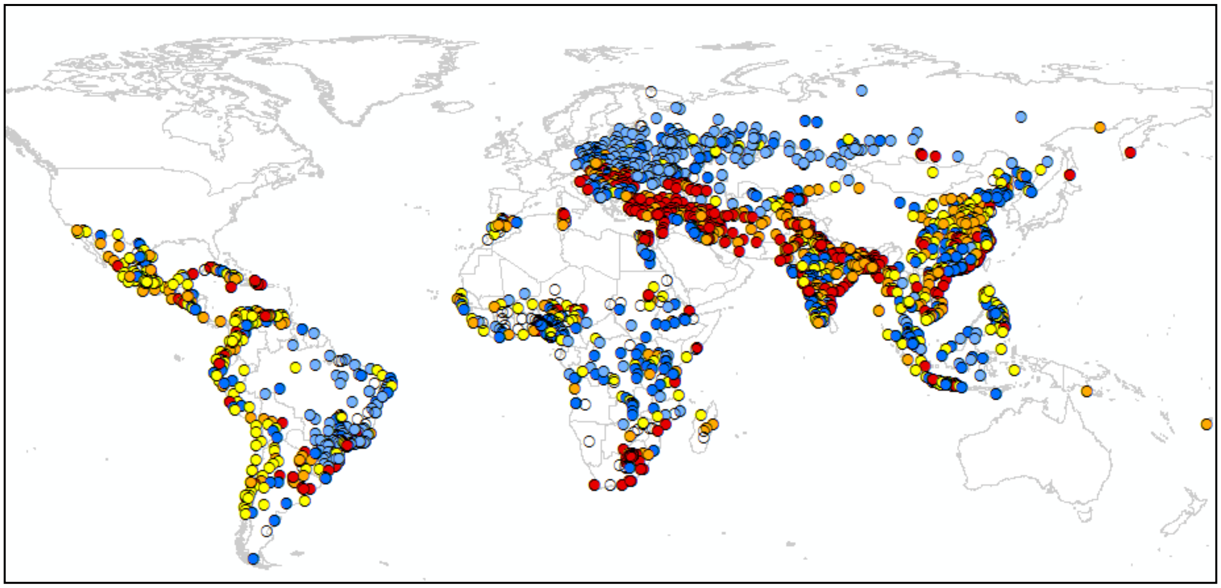

Figure 4.7: Urban mortality risk

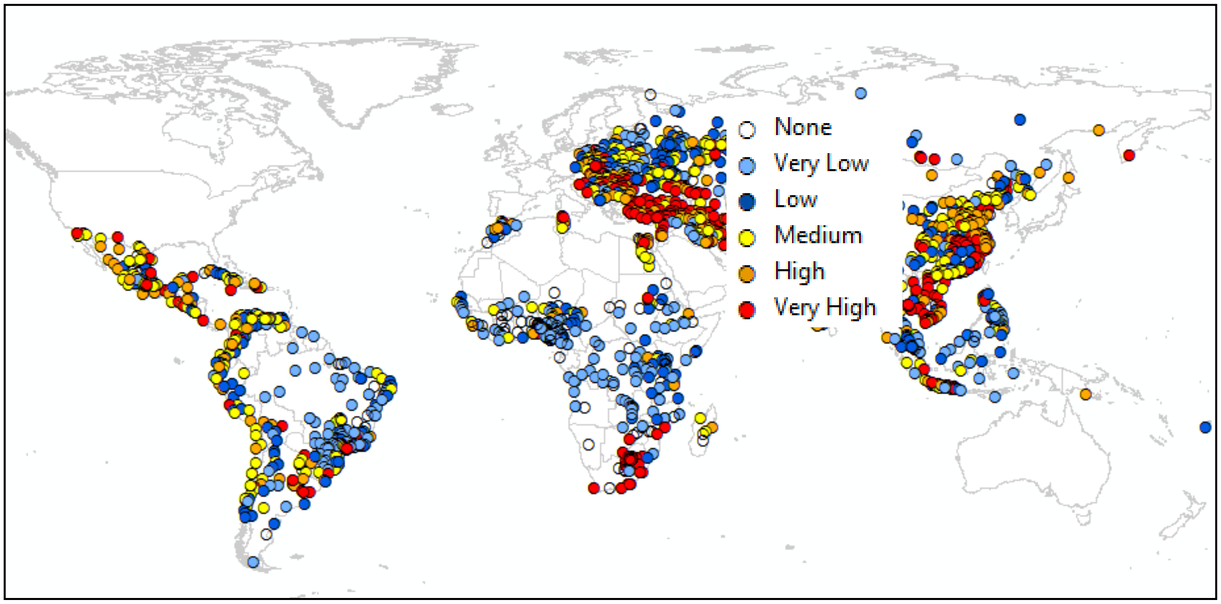

Figure 4.8: Urban economic loss risk

Figure 4.9 shows the cities most at risk, taking into account both economic and mortality risk from all hazards. To determine these, percentiles of the hazard-specific mortality of all the cities are calculated using 15 classes (6.66 percentile, 13.33 percentile, etc.). The same was done for economic risk. Cities that fall the class above the highest percentile (93.33) for both mortality and economic risk are included in the maps. Of these highest ranked thirty cities, eleven are in East Asia, five are in South Asia, five are in Eastern Europe and Central Asia, three in Latin America, three in Sub Saharan Africa and three in the Middle East and Northern Africa. Some of these city results are closely tied with high hazard risk from several hazards (for example, Tehran), others are particularly at risk due their size (for example, Metro Manila) and yet others are in the top 30 list due to their high vulnerability (for example, Ankara).

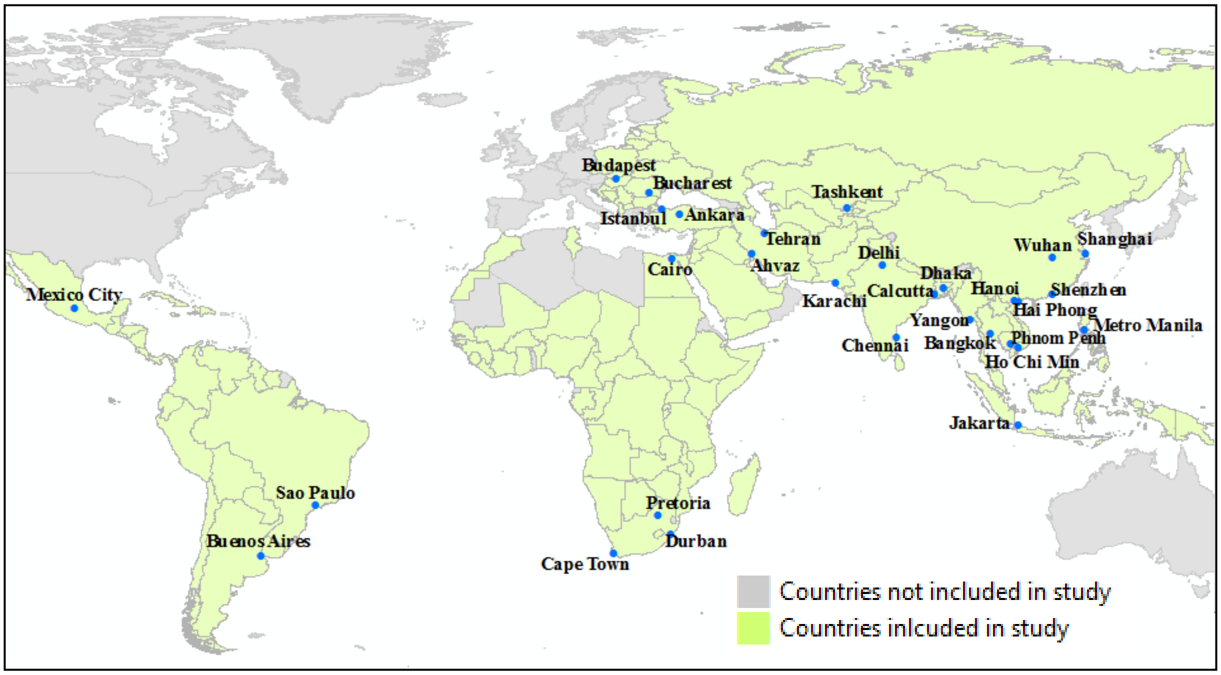

Figure 4.9: 30 cities most at risk

In another approach, I compare current risks with future risks in the year 2050. To do this, I use data generated in a study by Uwe Deichmann and Hyoung Gun Wang (World Bank), who estimated city population projections for the cities used in the global urban risk index. This was accomplished through a growth model that uses the Ordinary Least Square estimation. Combining my results for the geographic patterns of hazard events representative of the 1975–2008 period with the Deichmann and Wang's city-specific population projections to 2050 allows for the estimation of future risks. The analysis suggests that the number of people at risk from tropical cyclones and earthquakes in large cities in 2050 more than doubles (Figure 4.10).

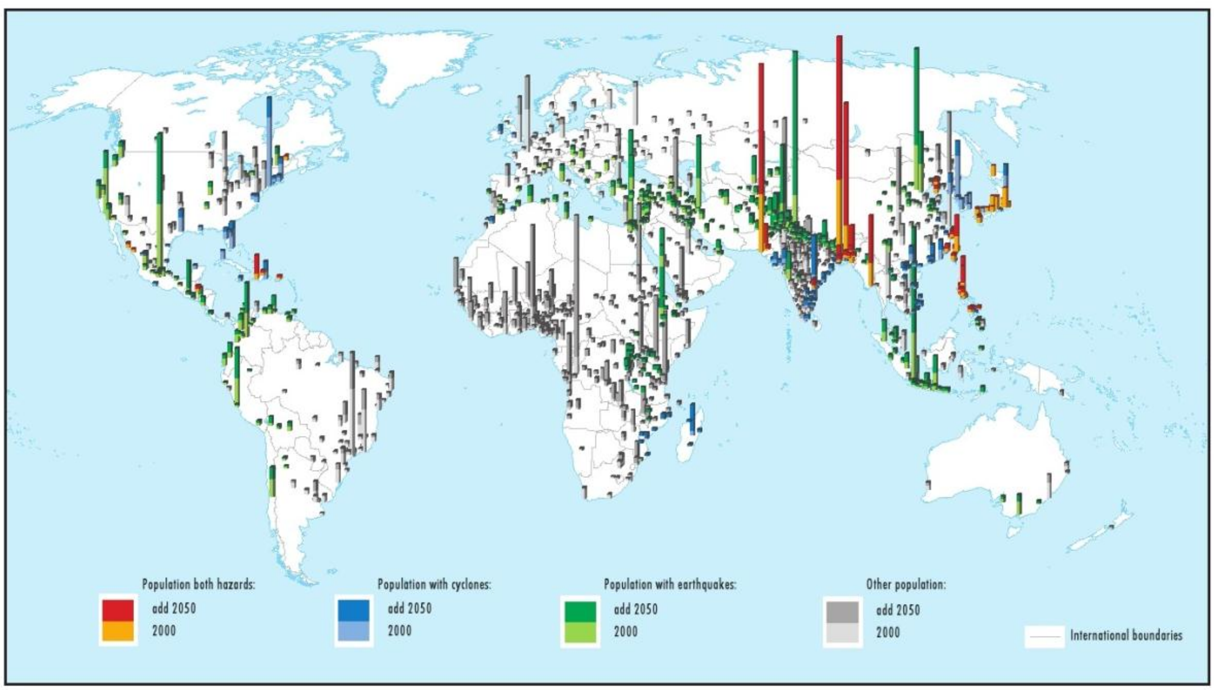

Figure 4.10: Exposure to cyclones and earthquakes in large cities in 2000 and 2050

4.6 Sensitivity Analysis

Sensitivity analysis, applied to a risk assessment, is a method used to understand how risk estimates depend on the variability and uncertainty of the factors used in the analysis. It determines how the different factors used in the index construction process affect the outputs, and it plays an important role in the verification and validation of the model. According to Saltelli at al. (2000) a sensitivity analysis is conducted to determine, for example, a) if the model resembles the system under study; b) the factors that most influence the output variability and therefore require special attention; c) the model parameters that are insignificant and that can be omitted; and d) which factors interact with each other. It is the final step in index development analysis, which examines the sensitivity of the model to changes in its inputs, and that gives an indication on the level of confidence or uncertainty. In existing risk and vulnerability indices, this last step has often been omitted.

In the Urban Risk Index, sources of uncertainties include: a) the underlying hazard models, b) the delineation of cities, c) the global grids for GDP and population, and d) the vulnerability coefficients. Future work on the index could conduct local sensitivity analysis by varying these input factors one at a time and examine the impact, while the other factors remain constant. Since the index measures relative values, the sensitivity of the relative, not absolute, values would need to be examined. These analyses could be developed for the individual four single hazard indices.

For the multi-hazard index, which simply adds the values of the single hazard indices, it would be interesting to determine which of the four indices have the largest influence in the overall urban multi-hazard risk. The percentage values to which the single hazard indices contribute to the overall index vary largely from 0-100% for all four hazards. A preliminary analysis was carried that investigates how the top 20 cities of the multi-hazard mortality index change if one single hazard value is removed. If the landslide results are omitted from the overall index, only one city out of the top 20 cities changes. If the flood index values are omitted, three cities change in the top 20. Removing the cyclones from the overall index, results in a change of six cities and, finally, excluding earthquakes results in a change of seven cities in the top 20 cities. This corresponds to the fact that earthquakes, on average, cause large fatality numbers.

4.7 Conclusion

This study assesses the risk of mortality and economic loss from catastrophic events in cities of less developed countries worldwide with a population greater than 100,000. Risk is calculated by combining the three modules of hazard, exposure, and vulnerability. The urban hazards are determined by overlaying the city locations with hazard severity grids; regional vulnerability coefficients are based on loss data from past events; and exposure is defined through city population and city GDP. Four single hazard risk indices are developed and in addition, a multi-hazard index gives a holistic picture of city risk. The absolute risk values are converted into index values, classifying the results into relative presentations of risk. Expected urban risk exposure in the year 2050 is determined through projections of future city population growth.

By revealing risk levels, I hope to contribute to the knowledge on the variation of urban risks. Such knowledge is useful for local and national planners, as well as international donors. Disclosing risks to cities raises awareness, informs the prioritization of resources, inspires further research, particularly at local levels, and promotes a shift towards managing risks rather than emergencies.

The index also provides a baseline for channeling international interest and funding for detailed urban multi-hazard risk assessments. These detailed assessments of the hazards, elements at risks, and the present vulnerabilities are required to gain a deep understanding for effective risk reduction and financial risk transfer mechanisms. Once the underlying risks in a city are known, the key drivers of risk can be addressed through a range of policy options, for instance, through building codes, environmental rehabilitation, land use planning, and early warning. Since the current lack of integration of urban development and risk reduction increases vulnerabilities and expected future losses, a shift to proactive and preventive urban planning underpinned with the principle of diminishing risk is needed. This increased role of urban planning as a tool for reducing disaster is perhaps the most important public policy recommendation from this paper.

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CHAPTER 5

SEA-LEVEL RISE AND STORM SURGES: HIGH STAKES FOR A SMALL NUMBER OF DEVELOPING COUNTRIES[3]

5.1 Introduction

Large tropical cyclones create storm surges that can strike crowded coastal regions with devastating force. During the past 200 years, 2.6 million people may have drowned during surge events (Nicholls, 2003). These disasters have continued to inflict heavy losses on the people of developing countries. Cyclone Sidr struck Bangladesh in November 2007, killing more than 3,000 people, injuring more than 50,000, damaging or destroying more than 1.5 million homes, and affecting the livelihoods of more than 7 million people (Bangladesh Disaster Management Information Centre, 2007; United Nations [UN], 2007). Cyclone Nargis struck Myanmar's Irrawaddy delta in May 2008, creating the worst disaster in the country's recorded history. It killed more than 80,000 people and affected the livelihoods of more than 7 million (UN, 2009).

The scientific evidence indicates that climate change will intensify storm surges for two reasons. First, they will be elevated by a rising sea level as thermal expansion and ice cap melting continue. The most recent evidence suggests that sea-level rise could reach 1 m or more during this century (Hansen, 2006, 2007; Hansen & Sato, 2011; Overpeck et al., 2006;

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Pfeffer, Harper, & O'Neel, 2008; Rahmstorf, 2007; Vermeer & Rahmstorf, 2009). These results include estimates significantly beyond the upper limit of the range cited by the Intergovernmental Panel on Climate Change's (IPCC, 2007) Fourth Assessment Report: A 90% confidence interval of 18 to 59 cm based principally on thermal expansion, with an additional 10 to 20 cm allowed for a potential dynamic response from the Arctic and Antarctic ice sheets. The more recent research cited above has focused on the dynamic implications of ice sheet instability.

Second, the current scientific consensus, summarized by IPCC (2011), holds that a warmer ocean is likely to intensify cyclone activity and heighten storm surges. As storm surges increase, they will create more damaging flood conditions in coastal zones and adjoining low-lying areas. The destructive impact will generally be greater when the surges are accompanied by strong winds and when surges make landfall during high tide.

Larger storm surges threaten greater future destruction, because they will move further inland, threatening larger areas than in the past. In addition, both natural increase and internal migration are increasing the populations of coastal areas in many developing countries. Table 5.1 shows that coastal population shares increased in all developing regions from 1980 to 2000. Population growth is particularly strong in coastal urban areas, whose growth also reflects continued rural–urban migration in many developing countries.

Rising storm surges in a changing climate and growing population in coastal urban areas may collide with disastrous consequences during the 21st century. As average effects increase, variations in coastal morphology may magnify the effects in some areas, while largely insulating others. In this article, combining the most recent scientific and demographic information, we explore the implications of intensified storm surges for 393 coastal cities with populations greater than 100,000, in 31 developing countries that have experienced tropical storms in the past. We focus on the distribution of heightened impacts, because we believe that greater knowledge of their probable variation will be useful for local and national planners, as well as international donors. In addition, we believe that realistic projections of the scale of these disasters will inform the current debate about the appropriate timing and strength of carbon emissions mitigation.

Table 5.1: Percent of national population in coastal cities, 1980 – 2000

World Bank region	1980	1990	2000
Sub-Saharan Africa	7.19	9.12	11.98
East Asia and Pacific	7.09	8.55	9.36
Latin American and Caribbean	15.58	16.61	17.53
South Asia	4.19	4.80	5.55

Source: CIESIN, Global Rural Urban Mapping Project GRUMPv1.
Note: Population in coastal urban zone, defined as elevation < 10 m

The remainder of the article is organized as follows. The section on global warming, tropical cyclone intensity, and disaster preparedness section reviews recent scientific evidence on global warming and tropical cyclone intensity, and motivates the article. The section on research strategy and data sources describes our research strategy and data sources, whereas the next section describes our methodology. In the section on city results, we present our results for coastal cities. The last section summarizes and concludes the article.

5.2 Global Warming, Tropical Cyclone Intensity, and Disaster Preparedness

Some recent scientific studies suggest that observed increases in the frequency and intensity of tropical cyclones in the last 35 years can be attributed in part to global climate change (Bengtsson, Hodges, & Roeckner, 2006; Emanuel, 2005; Webster et al., 2005). Others have challenged this conclusion, citing problems with data reliability, regional variability, and appropriate measurement of sea surface temperature and other climate variables (e.g., Landsea, Harper, Hoarau, & Knaff, 2006). Although the science is not yet conclusive (International Workshop on Tropical Cyclones, 2006; Pielke, Landsea, Mayfield, Laver, & Pasch, 2005), the World Meteorological Organization (2006) has recently noted that "it is likely that some increase in tropical cyclone peak wind-speed and rainfall will occur if the climate continues to warm. Model studies and theory project a 3-5% increase in wind speed per degree celsius increase of tropical sea surface temperatures" and "if the projected rise in sea level due to global warming occurs, then the vulnerability to tropical cyclone storm surge flooding would increase."

IPCC (2007, 2011) cite a trend since the mid-1970s toward longer duration and greater intensity of storms and a strong correlation with the upward trend in tropical sea surface temperatures. In addition, IPCC (2007) notes that hurricanes/cyclones occur in places where they have never been observed before. Overall, using a range of model projections, the report asserts a probability greater than 66% that continued sea surface warming will lead to tropical cyclones that are more intense, with higher peak wind speeds and heavier precipitation (IPCC, 2007; Emanuel, Sundararajan, & William, 2008; see also Hansen & Sato, 2011; Woodworth & Blackman, 2004; Woth, Weisse, & von Storch, 2006).

These projections from the global scientific community point to the need for greater disaster preparedness in countries that are vulnerable to storm surges. Some adaptation has already occurred, and many lives have been saved by improvements in disaster forecasting, evacuation, and emergency shelter procedures (Shultz, Russell, & Espinel, 2005; Keim, 2006). At the same time, as the recent disasters in Bangladesh and Myanmar have demonstrated, storm-surge losses remain huge in many areas. Such losses could be reduced by allocating more resources to increased disaster preparedness, especially given the likelihood that storms and storm surges will intensify. However, setting a new course requires a better understanding of expected changes in storm-surge patterns.

5.3 Research Strategy and Data Sources

Previous research on storm-surge impacts on coastal cities has been confined to relatively limited cases. For example, Hanson et al. (2011) assessed the exposure associated with surge-induced flood events in 136 port cities with populations of more than one million in 2005. The impacts of storm surges have been assessed for Bangladesh (Dasgupta et al., 2010), Copenhagen (Hallegatte et al., 2011), Southern Australia (McInnes, Hubbert, Macadam, & O'Grady, 2008), the Irish Sea (Wang et al., 2008), and Shanghai (Wang, Gao, Xu, & Yu, 2010). In this article, we broaden the assessment to 393 coastal cities with populations greater than 100,000, located in 31 coastal countries that have experienced tropical storms. These cities are located in four developing regions: East Asia and Pacific, Latin America and Caribbean, South Asia, and Sub-Saharan Africa. We consider the potential exposure of these cities to a storm surge that is large (1 in 100 years) by contemporary standards, and then compare it with a more intense storm surge later in the century. In modeling future conditions, we take account of sea-level rise, geological uplift, and subsidence along the world's coastlines.

At the outset, we acknowledge several limitations in the analysis. Although we use the best available data for estimating the relative exposure of various coastal segments to increased storm surge, several gaps in the data limit our analysis. First and foremost, the absence of a global database on shoreline protection (e.g., coastal embankments), and coastal-zone management (e.g., land-use planning, regulations, relocation) has prevented us from incorporating the effect of existing man-made protection measures (e.g., sea dikes), natural underwater coastal protective features (e.g., mangroves) and coastal zone management policies on exposure estimates. Incorporation of existing or planned protective measures might significantly alter our exposure estimates, but the requisite information is not available. Second, we have not been able to include small island states because the best available satellite system cannot accurately measure ground elevation over small areas. Third, among the developing countries included in this analysis, we restrict our analysis to coastal segments where historical storm surges have been documented.

5.4 Method

To quantify the implications of intensified storm surges for coastal cities in a changing climate, we have used geographic information system (GIS) software to overlay the city locations with the inundation zones projected for three cases: a current 1-in-100-year tropical storm surge, a 10% intensification over the next 100 years, and a 15% intensification. Table 5.2 summarizes our data sources for assessments of inundation zones and impacts.

Table 5.2: Summary of data sources

Dimension	Dataset Name	Unit	Res-olution	Source(s)
Coastline	SRTM v2 Surface Water Body Data			NASA
Elevation	Hydrosheds conditioned SRTM 90m DEM	km^2	90m	http://gisdata.usgs.net/Website/HydroSHEDS/viewer.php.
Watersheds	Hydrosheds Drainage Basins	km^2		http://gisdata.usgs.net/Website/HydroSHEDS/viewer.php.
Coastline Attributes	DIVA GIS database			http://diva.demis.nl/files/
Cities	City Polygons with Population Time Series			Urban Risk Index*, Henrike Brecht, 2007

*Urban extents from GRUMP (alpha) (http://sedac.ciesin.org/gpw/) joined with World Cities Data (J. Vernon Henderson 2002).
http://www.econ.brown.edu/faculty/henderson/worldcities.html

Our analysis involves a multistep procedure. First, we use a base hydrologically conditioned elevation data set to identify inundation zones and subject them to alternative storm-surge scenarios. Second, we construct a surface for the location of major cities. Third, we overlay the city surface with the inundation zone layers to determine the spatial exposure of each city under alternative storm-surge conditions.

The height of a tropical storm-induced surge in a changing climate will depend on sea-level rise and the power of the future storm, as determined by the change in ocean surface temperature and nonclimate effects: uplift and subsidence of land caused by natural processes (tectonics and glacial-isostatic adjustments) and anthropogenic processes (e.g., ground water withdrawal). Taking all these factors into account, in estimating future storm surges we follow the method outlined by Hanson et al. (2011):

$$\text{Future storm surge} = S100 + SLR + (UPLIFT \times 100\ \text{year}) / 1000 + SUB + S100 \times x$$

where, S100 = 1-in-100-year current storm surge height (m), SLR = sea-level rise (m), UPLIFT = continental uplift/ natural subsidence (mm/year), SUB = anthropogenic subsidence (m) applies to deltas only, x = increase in storm-surge height (%), applied only in coastal areas that have been affected by cyclones/hurricanes.

More detailed descriptions of the steps followed are provided below:

For elevation, we use a recently released hydrologically conditioned version of 90 m Shuttle Radan Topography Mission (SRTM) data, part of the hydrosheds data set (Lehner, Verdin, & Jarvis, 2008). We have downloaded all 5°× 5° coastal tiles of the 90 m SRTM data, and conditioning of the SRTM data in this case involves steps that alter elevation values to produce a surface that drains to the coast, including filtering, lowering of stream courses and adjacent pixels, and carving out barriers to stream flow.

We extract vector coastline masks from SRTM Version 2, and download coastline information from the Dynamic Interactive Vulnerability Assessment (DIVA) coastal GIS database. In the calculation of storm surges in a changing 2100 climate, we use the following attributes drawn from the DIVA database:

S100: 1-in-100-year surge height, based on tidal levels, barometric pressures, wind speeds, seabed slopes and storm-surge levels from monitoring stations;

DELTAID: coastline segments associated with river deltas;

UPLIFT: estimates of continental uplift/subsidence in mm/year from the geophysical model of Peltier (2000), including a measure of natural subsidence (2 mm/year) for deltas.

In addition, to approximate conditions in 2100, we assume a SLR of 1 m, 0.5 m anthropogenic subsidence (SUB) applicable to deltas only, and x = (0.1, 0.15): alternative increases of 10% and 15% in storm-surge height in coastal areas where tropical cyclones have occurred.

We compare surges associated with current and future storms with the elevation values of inland pixels with respect to a coastline, to delineate potential inundation areas.

Each inland pixel could be associated with the nearest coastline segment in a straight-line distance. However, to better capture the movement of water inland, we use hydrological drainage basins. We apply the surge height calculated for the coastline segment closest to the basin outlet to inland areas within that basin.

As a surge moves inland, its height is diminished. The rate of decay depends largely on terrain and surface features, as well as factors specific to the storm generating the wave. In a case study on storm surges, Nicholls (2006) uses a distance decay factor of 0.2 to 0.4 m per kilometer that can be applied to wave heights in relatively flat coastal plains. For this analysis, we use an intermediate value (0.3 m per 1 km distance from the coastline) to estimate the wave height for each inland cell.

We delineate surge zones by comparing projected surge heights with SRTM values in each cell. A cell is part of the surge zone if its elevation value is less than the projected wave.

Following McGranahan, Balk, & Anderson (2007), we delineate low elevation coastal zones using inland pixels with less than 10 m elevation near coastlines.

For identifying major coastal cities, we have considered all urban agglomerations containing suburbs and adjacent towns with more than 100,000 inhabitants in the year 2000 from the World Cities database. The city points were then matched with the Center for International Earth Science Information Network (CIESIN) information on global urban extent based largely on NOAA's night-time satellite data from 1994 to 1995. For each city a corresponding raster urban area was identified and converted into a polygon. Where multiple city points fell within a large contiguous area, Thiessen polygons were used to allocate a portion of the area to each point, creating a unique urban footprint for each city.

Calculating exposure indicators: We overlay our delineated inundation zones with locations of cities with more than 100,000 inhabitants in 2000 to determine exposure of 393 coastal cities to storm-surge conditions under current and future climate scenarios.

It should be noted that our estimates may be conservative because (a) the analysis is based on a sea-level rise estimate of 1 m by 2100, although the previously cited scientific literature suggests that multi-meter sea-level rise is possible in this century and (b) the estimates do not take future shoreline erosion into account. As we noted previously, the absence of a global database on shoreline protection has prevented us from modeling likely changes in shorelines associated with a 1 m sea-level rise. Even a 1 m rise in sea level will change shorelines considerably in many coastal segments, if shorelines are not protected (Dasgupta, Laplante, Murray, & Wheeler, 2011). Coastal morphology will change with receding shorelines, and potential inundation areas for storm surges will be determined by the characteristics of the changed coastlines. To improve coastal security, future research and adaptation planning should consider such likely shoreline changes.

5.5 City Results

5.5.1 Exposure of Coastal Area

In this section, we consider measures of coastal urban exposure. The measure summarized in Table 5.3 lists cities in each developing region whose coastal areas will be most affected by future increases in storm surges. This computation is done in three steps. First, we rank cities in each region by percent increase in the future inundation area relative to the current inundation area. To weight for current exposure, we rank cities in each region by percent of coastal area in the current inundation zone. Then, we compute the average for the two ranks and reorder the cities by their average ranks. Table 5.3 includes the highest ranking cities in each region, using future inundation increase weighted by current exposure.

We tabulate results for 10 cities in East Asia, Latin America and the Caribbean, and South Asia. In Sub-Saharan Africa, there are fewer than 10 cities whose coastal characteristics match our criteria for inclusion in the analysis. We provide results for future wave height increases of 10% and 15%. To illustrate, Nacala, Mozambique has the highest future exposure in Sub-Saharan Africa in both the 10% and 15% cases. In the 21st century, 25% of its coastal area will be added to its inundation zone (Pct 2). This is a 50% increase in its current inundation zone, which is already 50% of its coastal area (Pct 1).

Using the same calculations, we identify the top-ranked cities in the other three regions as Rach Gia, Vietnam; Acapulco de Juarez, Mexico; and Cox's Bazar, Bangladesh. These cities join the other top-ranked cities as potentially deadly locales, as storm water drainage infrastructure is often outdated and inadequate in low-income urban centers.

Table 5.3: Exposure to future storm surge: Wave height increases of 10% and 15%

Region	Subregion	Country	City	Rank 10%	Rank 15%	Ratio 10%	Ratio 15%	Pct1	Pct2 10%	Pct2 15%
AFR	Southern Africa	Mozambique	Quelimane	1	2	34	38	56	19	21
AFR	Southern Africa	Mozambique	Nacala	2	2	50	50	50	25	25
AFR	Madagascar	Madagascar	Mahajanga	3.5	4	13	13	67	8	8
AFR	Southern Africa	Mozambique	Beira	3.5	2	33	42	51	17	21
AFR	Southern Africa	Mozambique	Maputo	5	5	21	21	41	9	9
EAP	Southeast Asia	Vietnam	Rach Gia	1	2	46	46	60	27	27
EAP	Southeast Asia	Indonesia	Tegal	2	3	60	60	48	29	29
EAP	Northeast Asia	Korea, Rep	Ansan	3	1	27	33	70	19	23
EAP	Southeast Asia	Vietnam	Nha Trang	4	6	27	27	67	18	18
EAP	China	China	Dandong	5	4.5	39	43	51	20	22
EAP	Southeast Asia	Vietnam	Hue	7	7	26	26	68	18	18
EAP	Southeast Asia	Philippines	Cotabato	7	9	22	22	73	16	16
EAP	Southeast Asia	Indonesia	Cirebon	7	9	69	69	35	24	24
EAP	Southeast Asia	Philippines	Butuan	9	4.5	63	67	38	24	25
EAP	China	China	Zhuhai	10	9	32	34	53	17	18
LCR	Central America	Mexico	Acapulco	1	1	45	47	44	20	21
LCR	Carib. Islands	Dom. Rep	La Romana	2	2	50	50	35	17	17
LCR	Central America	Mexico	Ciudad del Carmen	3	3	24	24	73	18	18
LCR	Northern South America	Venezuela	Barcelona	5.5	5.5	55	55	29	16	16
LCR	Northern South America	Venezuela	Cumana	5.5	5.5	69	69	26	18	18
LCR	Central America	Mexico	Mazatlan	5.5	5.5	52	55	30	15	16
LCR	Andean South America	Colombia	Barranquilla	5.5	5.5	109	109	14	15	15
LCR	Andean South America	Colombia	Cartagena	8	8.5	59	59	25	15	15
LCR	Northern South America	Venezuela	Puerto Cabello	9.5	10	37	38	32	12	12
LCR	Central America	Mexico	Tampico	9.5	8.5	87	95	18	16	17
SAR	Southern Asia	Bangladesh	Cox's Bazar	1	1	42	47	47	20	22
SAR	Southern Asia	Bangladesh	Khulna	2	2.5	88	95	35	31	33
SAR	Southern Asia	Bangladesh	Bakerganj	3	2.5	28	30	70	20	21
SAR	Western Asia	Pakistan	Karachi	4	4	30	32	44	13	14
SAR	Southern Asia	India	Jamnagar	5	5	32	37	43	13	16
SAR	Southern Asia	India	Vadodara	6	6	40	40	36	14	14
SAR	Southern Asia	Sri Lanka	Moratuwa	7	7.5	74	76	21	16	16
SAR	Southern Asia	India	Thane	8.5	9	19	19	43	8	8
SAR	Southern Asia	Bangladesh	Chandpur	8.5	7.5	50	58	24	12	14
SAR	Southern Asia	India	Bhavnagar	10	10	14	14	58	8	8

Note: Pct 1 = Current Inundation Zone as Percent of Coastal Area; Pct 2 = Future Increase in Indundation Zone as Percent of Coastal Area; Ratio = 100 x [Pct2 / Pct 1].

The risks may be particularly severe in poor neighborhoods and slums, where infrastructure is often nonexistent or poorly designed and ill-maintained. Within regions, exposures are clearly far from balanced across countries. In each region, at least half of the top 10 cities are in only 2 countries: Mozambique (4) and Madagascar (1) in Sub-Saharan Africa; Indonesia (or the Philippines) (2) and Vietnam (3) in East Asia; Mexico (4) and Venezuela (3) in Latin America; and Bangladesh (4) and India (4) in South Asia.

5.5.2 Exposure of Population

In an alternative approach, we compare cities by estimating the exposure of their populations to intensified storm surges in the 21st century. We consider the combined effects of projected population change, sea-level rise and storm intensification on the distribution of exposures by the end of the century. We use the UN's medium population projections for 2100, as reported by IIASA (2009), and conservatively assume that all coastal cities in each country retain their current share of the national population. In addition, we assume that coastal cities' populations are uniformly distributed across their coastal and noncoastal areas. From the work reported in Exposure of Coastal Area section above, we draw the percent of coastal areas in inundation zones now, and in 2100 after a 1 m sea-level rise. For 2100, we generate results for 10% and 15% increases in the intensity of a 1-in-100-year storm. Combining the area and demographic information, we estimate populations in the current and future inundation zones, and the implied increase in affected populations. Table 5.4 displays the 25 cities with the largest population exposures, expressed as changes in affected populations and cumulative percents of the total change for all cities. Although the 10% and 15% cases have slightly different rankings, the same cities are in the top 25 in both cases.

Table 5.4: Top 25 City population exposure: Wave height increases of 10% and 15%

Rank by wave height increase				Change in affected population		Cumulative %		Global city population rank 2000
10%	15%	Country	City	10%	15%	10%	15%	
1	1	Philippines	Manila	3,438,334	3,438,334	25.7	24.8	12
2	2	Pakistan	Karachi	1,417,639	1,460,948	36.2	35.3	9
3	3	Indonesia	Jakarta	836,130	836,130	42.5	41.3	11
4	4	Bangladesh	Khulna	635,950	678,217	47.2	46.2	190
5	5	India	Calcutta	547,004	657,439	51.3	50.9	5
6	6	Thailand	Bangkok	546,157	546,157	55.4	54.8	21
7	7	Bangladesh	Chittagong	489,789	545,826	59	58.8	47
8	8	Vietnam	Ho Chi Minh	433,176	433,176	62.2	61.9	36
9	9	Myanmar	Yangon	384,381	384,381	65.1	64.7	37
10	10	Philippines	Taguig	232,703	251,844	66.9	66.5	623
11	11	Philippines	Kalookan	212,853	212,853	68.4	68	251
12	12	Colombia	Barranquilla	181,864	181,864	69.8	69.3	136
13	13	India	Chennai	156,149	168,705	71	70.5	25
14	14	Mozambique	Maputo	137,977	137,977	72	71.5	63
15	16	Philippines	Davao	119,101	126,434	72.9	72.4	244
16	15	Mozambique	Beira	111,202	129,417	73.7	73.4	650
17	18	Indonesia	Ujungpandang	107,612	107,612	74.5	74.1	291
18	17	Philippines	Butuan	102,901	108,203	75.3	74.9	981
19	19	Bangladesh	Bakerganj	97,056	100,112	76	75.6	1018
20	20	Philippines	Malabon	89,497	91,420	76.7	76.3	803
21	21	Philippines	Iloilo	87,548	91,369	77.3	77	756
22	23	Venezuela	Maracaibo	82,628	82,628	77.9	77.6	118
23	25	Indonesia	Surabaya	81,921	81,921	78.6	78.1	87
24	24	Madagascar	Mahajanga	80,353	80,353	79.2	78.7	1659
25	22	Mozambique	Quelimane	77,646	83,375	79.7	79.3	1371

The most striking feature of our results is the extreme concentration of effects in a handful of cities. In both the 10% and 15% cases, about 25% of the increase in developing-country urban population exposed to future storm surges is in only one city, Manila (3.4 million). The top 10 cities account for 67% of total exposures, and the top 25 for 79%. The other 368 coastal cities in our data set account for only 21% of the total. Of the top 25, 13 are in Southeast Asia, 4 in Sub-Saharan Africa, 6 in South Asia, and 2 in South America. We should emphasize that our results are not closely tied to the current distribution of coastal city populations. As Table 5.4 shows, many of the cities with top 25 changes in vulnerable populations are not among the world's most populous urban areas at present. Their future top 25 status stems from two factors: future urban growth and coastal characteristics that make them particularly exposed to greater storm surges.

Table 5.5 provides context by displaying our overall results for countries with coastal cities in the top 25 group. We present countries in descending order of percentage impacts from sea-level rise. Our results assign the highest rank in both absolute and percent terms to Philippines, with projected exposure of 16 million people to storm surge risk by 2100. This is 41.7% of the projected population in coastal cities over 100,000. The projected change in population-at-risk from 2000 to 2100 is 5.4 million, or 14% of projected population in 2100. Other countries with notably high-percentage exposures in 2100 include Myanmar (43.5%), Vietnam (32.2%), India (20.1%), Mozambique (19.1%), Indonesia (18.6%) and Madagascar (16.9%). After Philippines, the countries with highest percent changes in exposed populations are Madagascar (11%), Mozambique (7.9%), Thailand (7.9%) and Myanmar (7.4%).

5.6 Conclusions

In this article, we have assessed the exposure of coastal cities with 2000 populations greater than 100,000 in developing countries to larger storm surges associated with global warming and a 1 m sea-level rise. After identifying future inundation zones, we have overlaid the city locations. Our results indicate large effects that are much more concentrated in some regions, countries and cities than others. We have also incorporated population projections for the 21st century and computed the exposures of coastal urban populations as conditions worsen.

Table 5.5: Projected national totals (‘000) for 2100: Coastal cities with populations greater than 100,000

Country	Population	Population affected by storm surges	% affected	Change in population affected, 2000-2100	Percentage of population in 2100
Philippines	38,400	16,000	41.7	5,357	14
Madagascar	763	129	16.9	84	11
Mozambique	4,928	943	19.1	390	7.9
Thailand	7,289	854	11.7	576	7.9
Myanmar	5,745	2,499	43.5	427	7.4
Colombia	4,869	495	10.2	293	6
Indonesia	25,700	4,786	18.6	1,464	5.7
Bangladesh	26,800	2,447	9.1	1,404	5.2
Vietnam	12,400	3,997	32.2	643	5.2
Pakistan	28,200	2,252	8	1,461	5.2
Venezuela	12,200	441	3.6	204	1.7
India	55,600	11,200	20.1	858	1.5

Note: For projected wave height increase of 15%.

Our results suggest a huge asymmetry in the burden of sea-level rise and storm intensification, with only 1 of 393 cities accounting for 25% of the future coastal population exposure and 10 cities for 67% of the future exposure. Our results suggest that the residents of a small number of developing-country cities will bear the additional brunt of heightened storm surges, whereas many other coastal cities will experience little change in population exposure. In light of the huge asymmetries in our country- and city-level results, we believe that careful targeting of international assistance will be essential for the effective and equitable allocation of resources for coastal protection and disaster prevention. In addition, the large magnitudes of potential exposures of people, economies, and ecosystems to storm-surge-induced inundation, even in a small number of countries, provide strong evidence in support of rapid action to reduce global warming by mitigating greenhouse gas emissions.

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CHAPTER 6

CONCLUSION

6.1 Summary and Main Conclusions

The primary goal of this study was to contribute to a reversal of the staggering disaster losses by advancing the application of GIS in the field of disaster risk management.

In Chapter 2, I set the stage for this dissertation by introducing its topic using the example of Louisiana and its vulnerability to hurricanes. The formation and anatomy of hurricanes along with their frequency near the Louisiana coast were described. The chapter outlined the importance but also the unprecedented loss of the Louisiana wetlands and discusses coastal restoration efforts as a means to reduce hurricane risks.

With a clearer understanding of the concepts of disasters, vulnerability, and risk reduction, this dissertation then examined four case studies that implement GIS methodologies in disaster risk management, specifically in the fields of emergency preparedness and risk assessments. A set of research questions was posed corresponding to the two fields above.

Emergency Preparedness

In chapter 3, I focused on the application of GIS in emergency preparedness with the goal to promote the use of GIS in disaster response and thereby enhance decision making in the aftermath of catastrophes. The research question was:

1. How can the application of GIS be improved in the emergency response phase?

Chapter 3 addressed the second research question. Through interviews with GIS responders in the three U.S. States of Louisiana, Alabama, and Mississippi after Hurricane Katrina in 2005, the successes and failures of using geographic information to support the response were investigated and lessons were drawn. The study showed that the use of GIS in the emergency phase differs from that in the planning phase due to the urgency, uncertainty, and the fast coordination of a multitude of stakeholders. Truly analytic GIS applications going beyond simple mapping were sparse. The main challenges in the operations were not related to the prominent literature themes of Virtual Reality and semantics but rather trivial issues had to be solved such as missing metadata and the lack of a platform to effectively distribute the data to emergency responders. The intensive use of web tools, such as Google Earth, proved to be successful due to their ease of use. Such web tools could be operated by non-GIS specialists and allowed for straightforward and helpful applications, such as the overlay of imagery before and after the disaster. One main takeaway is that a GIS contingency plan, drafted before the disaster, is critical for a successful emergency response. The plan should address a multitude of issues including the work of volunteers, data readiness through GIS clearinghouses, and tools for information dissemination.

Risk Assessments

In chapters 4 and 5, attention was directed towards risk assessments as instruments for determining the likelihood of an extreme hazard event and climate change impacts. The main research questions were:

1. Which cities are likely to be affected by a disaster?
2. In which cities is the risk of mortality due to a natural hazard the highest?

3. Which cities are most at risk of economic losses due to natural hazards?
4. Which cities will be highly impacted by climate change and storm surges?

To seek answers to these questions, I have made use of global data layers for cities, hazards, vulnerability, exposure, and watersheds and analyzed them in a novel GIS process. To address the first three questions, I developed a ranking of the major cities in 110 countries. Risk levels of 1,943 cities with more than 100,000 inhabitants in the year 2000 were evaluated and compared for the four major hazards of cyclones, earthquakes, floods, and landslides. Urban risks were identified for each of these hazards separately, and, in addition, a multi-hazard index gave a holistic picture of city risk. The index showed that risk is highly concentrated in a number of cities in certain regions. Asia is particular prone to disasters. Out of the most at risk 30 cities, eleven are in East Asia and five in South Asia. In Latin America, Mexico City, Sao Paulo, and Buenos Aires have the highest disaster risks. In Sub-Saharan Africa, cities in South Africa are at high risk, especially to floods.

Chapter 5 contained a discussion of the fourth question as stated above, where, building upon the results of chapter 4, I considered the strategies that can be employed to include the impacts of climate change in the urban risk assessment. The implications of storm surges for coastal cities were quantified both for contemporary conditions and for expected future conditions in a changing climate. The exposure to today’s and future storm surges were explored for 393 of cyclone-vulnerable coastal cities in 31 developing countries. To model the future conditions, sea-level rise, geological uplift, and subsidence of coastlines were taken into account. The most striking feature of the results was the extreme concentration of effects in a handful of cities. The analysis suggested gross inequality in the heightened impact of future disasters, with 50% of the burden falling on the residents of ten Asian cities and 40% falling on Manila, Karachi, and Jakarta alone. In light of these huge asymmetries, careful targeting of international assistance will be essential for the effective and equitable allocation of resources for coastal protection and disaster prevention.

This dissertation thus presented several case studies that demonstrated how geospatial methods can be applied in disaster risk management. There are reasons to believe that the cooperation between these two fields will continue to expand and deepen which will no doubt lead to more effective and efficient disaster risk management with direct consequences for a safer life.

6.2 A Short Glance Ahead

Emergency Preparedness

Further research is necessary to investigate how promising new technologies can be applied to best save lives and property. For example, Web 2.0, as a technology that provides a platform for information sharing, interoperability, user interaction, and collaboration on the World Wide Web, has large potential to enhance disaster preparedness. It allows for viewers of content to become active contributors and creators in a virtual community. In the last few years, we have seen an exciting shift in how GIS paired with Web 2.0 technologies can support disaster risk management programs. An interesting study could document how Web 2.0 tools are being used in emergencies and investigate further applications. Empowered by cloud-, crowd-, and SMS-based technologies, remote technological communities can now engage in disaster response at an unprecedented level. Especially the year 2010 marked a change in how GIS supports humanitarian emergencies: After the 2010 earthquakes in Haiti and Chile and the floods in Pakistan, volunteer communities, often with extensive expertise in GIS, mobilized and processed imagery, created detailed maps, and geocoded an abundance of houses, streets, and critical infrastructure. Using open source and cloud-based tools, these humanitarian technologists applied their skills to help affected communities and reduce risks. Prominent applications include OpenStreetMap, an open collection of data being gathered by currently over 300,000 members, Ushahidi, an open-source crowd sourcing crisis information platform, and GoogleMapMaker, which allows its members to collaboratively create maps. The outputs support the humanitarian response and help to provide speedy and efficient aid to the ones most in need. We are only at the beginning of using the full potential of these technologies, and a study on this development could provide great insights on where to go from here.

But also public institutions are moving towards fully embracing GIS as a basis for emergency preparedness. Another worthy research effort could document the best practices in GIS applications used in emergency centers around the world. During my employment at the World Bank, I have enjoyed working, for example, in the Emergency Operations Coordination Centers of Queensland, Australia, and Shanghai, China. Both centers have anchored their operations fully in GIS and have developed GIS customized applications as the main platform for the emergency centers with a plethora of baseline data and pre-defined automated ways to add data in emergencies. Armed with this system, emergency services personnel can effectively carry out its task, including evacuating communities and strategically positioning their crews and resources, where they are clear of rising waters or burning fires.

Risk Assessments

This dissertation is only a first step in creating an integrated framework for assessing urban disaster risk. Much work needs to be done both on local and global levels to complete the picture. Since the most limiting factor is the lack of accurate and systematic loss data, the improvement and refinement of the underlying loss databases are essential. Several regional initiatives are already ongoing to build capacity for assessing damages and losses and developing regional databases for post-event loss data. For instance, the Association of Southeast Asian Nations (ASEAN) has included the development of damage and loss databases into its work program 2010–2015 (ASEAN 2010) and is currently supporting its member states to set up uniform systems for recording post-event event data. To scale up these initiatives, the World Bank and the Global Facility for Disaster Reduction and Recovery have been providing training for Governments in damage and loss assessments for more than 50 countries. Yet, further studies and efforts are needed to complete the picture of historic losses.

Another restrictive factor to develop accurate urban risk assessments is the approximations used for the hazard layers. Future versions of the index will be able to make use of advanced hazard models, such the one being currently developed by the Global Earthquake Model (GEM) foundation and for the Global Assessment Report 2013, which is currently being developed by the United Nations International Strategy for Disaster Reduction (UN-ISDR).

Additional research could also provide greater insights into how to increase the use and application of risk assessments in development and land use planning. Sharing risk information, such as maps of flood plains and seismic fault lines, widely and in a form that is readily understood is an easy and effective measure to reduce risk. Open risk information would, for instance, facilitate holding officials accountable in the case they do not address known risks. Also, real estate markets could better reflect risk information in housing prices, which would depreciate house prices in risky areas and lead to incentives to not invest in new development in hazardous locations. While the importance of sharing data is increasingly being recognized, there are still many obstacles to achieving open data practices. Future research can investigate how to best publicize risk information and incentivize its use in planning. This could include studies on fostering government commitments to open data for promoting transparency, accountability, and improved decision making and also research on open source software tools to share, source and create disaster risk data.

APPENDIX 1: GLOBAL URBAN RISK INDEX - CITY RANKING

City	Country	Population	City GDP (in millions)	Natural Hazards Exposure				Mortality				Economic Damage				Multi-haz. Econom. Risk	Multi-haz. Mortality Risk
				Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide		
				High				High				High					
				Medium				Medium				Medium					
				Low				Low				Low					
								no data				no data					
Buenos Aires	Argentina	12,600,000	35,850.84													15	15
Dhaka	Bangladesh	12,300,000	3,585.74													15	15
Sao Paulo	Brazil	17,800,000	99,670.73													15	15
Phnum Penh	Cambodia	984,000	1,028.08													15	15
Changsha	China	1,775,000	2,694.36													15	15
Shanghai	China	12,900,000	57,036.31													15	15
Shenzhen	China	1,146,000	147,285.14													15	15
Wuhan	China	5,169,000	6,927.32													15	15
Budapest	Hungary	1,825,000	16,131.99													15	15
Chennai	India	6,648,000	6,170.48													15	15
Delhi	India	11,700,000	19,855.42													15	15
Calcutta	India	12,900,000	13,846.13													15	15
Bandung	Indonesia	3,409,000	5,796.80													15	15
Jakarta	Indonesia	11,000,000	37,310.15													15	15
Surabaya	Indonesia	2,461,000	7,193.75													15	15
Tehran	Iran	7,225,000	22,170.62													15	15
Mexico City	Mexico	18,100,000	96,147.86													15	15
Yangon	Myanmar	4,196,000	1,677.65													15	15
Karachi	Pakistan	11,800,000	7,754.09													15	15
Cape Town	South Africa	2,993,000	12,237.79													15	15
Durban	South Africa	1,335,000	12,722.68													15	15
Pietermaritzburg	South Africa	413,200	2,896.99													15	15
Port Elizabeth	South Africa	1,186,000	4,435.25													15	15
Pretoria	South Africa	1,508,000	7,670.72													15	15
Vereeniging	South Africa	379,000	1,975.57													15	15
Bangkok	Thailand	7,281,000	22,060.82													15	15
Adana	Turkey	1,294,000	3,653.47													15	15
Ankara	Turkey	3,203,000	14,830.89													15	15
Istanbul	Turkey	9,451,000	4,274.31													15	15
Izmir	Turkey	2,409,000	3,781.57													15	15
Toshkent (Taskent)	Uzbekistan	2,148,000	2,241.30													15	15
Hai Phong	Vietnam	1,679,000	619.17													15	15
Hanoi	Vietnam	3,734,000	3,778.94													15	15
Ho Chi Minh (Saigon)	Vietnam	4,615,000	19,139.88													15	15
Belo Horizonte	Brazil	4,170,000	18,806.11													14	15
Beijing	China	10,800,000	33,565.86													14	15
Dongguan	China	1,319,000	10,392.21													14	15
Jiaojiang	China	471,500	4,771.41													14	15
Nanjing	China	2,740,000	8,046.54													15	14
Shantou	China	1,176,000	4,710.08													14	15
Tianjin	China	9,156,000	15,723.72													14	15
Wenzhou	China	1,611,000	8,842.44													14	15
Xiantao	China	1,614,000	812.88													14	15
Zagreb	Croatia	1,060,000	2,271.79													14	15
Cairo	Egypt	10,600,000	12,439.74													14	15
Shubra Al-Khaymah	Egypt	1,033,000	8,549.87													14	15
Guatemala City	Guatemala	3,242,000	5,091.44													14	15
Surat	India	2,344,000	3,337.39													14	15
Ahvaz	Iran	997,000	4,563.46													14	15
Esfahan (Isfahan)	Iran	2,589,000	4,831.07													14	15
Quelimane	Mozambique	169,100	102.14													14	15
Mandalay	Myanmar	1,037,300	516.24													14	15
Lahore	Pakistan	6,040,000	3,709.32													14	15
Lima	Peru	7,443,000	23,547.02													14	15
Buceresti	Romania	2,054,000	3,231.49													14	15

City	Country	Population	City GDP (in millions)	Natural Hazards Exposure				Mortality				Economic Damage				Multi-haz. Econom. Risk	Multi-haz. Mortality Risk
				Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide		
				High Medium Low				High Medium Low				High Medium Low					
Krasnodar	Russia	639,000	1,181.70													14	15
Alberton	South Africa	161,700	3,153.83													15	14
Newcastle	South Africa	240,100	1,438.78													15	14
Vanderbijlpark	South Africa	276,800	2,022.19													15	14
Welkom	South Africa	222,200	1,631.21													15	14
Bursa	Turkey	1,304,000	1,805.41													14	15
Diyarbakir	Turkey	558,600	1,436.64													14	15
Erzurum	Turkey	326,200	833.20													14	15
Gaziantep	Turkey	930,000	2,462.68													14	15
Kahramanmaras (Maras)	Turkey	331,500	1,054.46													14	15
Kayseri	Turkey	544,000	1,996.97													14	15
Kocaeli (Izmit)	Turkey	216,400	6,589.36													15	14
Konya	Turkey	680,500	2,457.38													14	15
Malatya	Turkey	437,000	1,094.97													14	15
Manisa	Turkey	219,800	265.46													14	15
Mersin (Icel)	Turkey	547,400	3,463.71													14	15
Caracas	Venezuela	3,153,000	6,111.20													14	15
Chittagong	Bangladesh	3,581,000	894.32													13	15
Santiago	Chile	5,538,000	15,572.46													13	15
Chongqing	China	5,312,000	6,422.66													14	14
Fuzhou	China	1,397,000	4,421.99													13	15
Hangzhou	China	1,780,000	10,677.57													15	13
Nanchang	China	1,722,000	2,660.51													14	14
Xiaogan	China	858,900	1,222.07													14	14
Yiyang	China	1,343,000	1,140.09													14	14
Yueyang	China	1,213,000	1,170.36													14	14
Bogota	Colombia	6,288,000	8,476.22													13	15
Ostrava (Ostrau)	Czech Republic	320,900	2,865.55													14	14
Santo Domingo	Dominican Republic	3,599,000	5,585.87													13	15
Guwahati (Gauhati)	India	808,021	839.02													13	15
Hyderabad	India	6,842,000	4,738.94													13	15
Mashhad (Meschhed)	Iran	2,328,000	3,187.54													13	15
Rasht	Iran	417,748	2,201.21													13	15
Shiraz	Iran	1,090,000	2,074.80													13	15
Tabriz (Taebris)	Iran	1,590,000	2,189.31													13	15
Amman	Jordan	1,430,000	3,276.26													13	15
Vientiane	Lao P.D.R.	632,200	232.24													13	15
Akyab	Myanmar	161,200	73.49													13	15
Irkutsk	Russia	593,700	712.91													13	15
Petropavlovsk-Kamatskij	Russia	194,100	290.53													13	15
Vladikavkaz	Russia	310,100	487.05													13	15
Bratislava	Slovak Republic	448,900	2,717.39													14	14
Kosice	Slovak Republic	244,400	1,229.15													14	14
Carltonville	South Africa	179,600	857.18													14	14
EastÿLondon	South Africa	232,000	1,030.17													14	14
Klerksdorp	South Africa	150,100	1,420.49													15	13
Mdantsane	South Africa	200,000	929.10													14	14
Nelspruit	South Africa	103,500	1,151.04													15	13
Rustenburg	South Africa	114,200	1,368.08													15	13
Witbank	South Africa	182,700	948.98													14	14
Halab	Syria	1,850,900	2,662.88													13	15
Antalya	Turkey	559,100	697.44													13	15
Elazig	Turkey	273,500	932.85													14	14
Sakarya (Adapazari)	Turkey	200,100	967.28													14	14
Samsun	Turkey	369,400	1,270.31													14	14
Sanliurfa (Urfa)	Turkey	390,000	753.93													13	15

City	Country	Population	City GDP (in millions)	Natural Hazards Exposure				Mortality				Economic Damage				Multi-haz. Econom. Risk	Multi-haz. Mortality Risk
				Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide		
				High Medium Low				High Medium Low				High Medium Low					
Tarsus	Turkey	207,600	2,259.49													14	14
Montevideo	Uruguay	1,236,000	11,885.27													14	14
Da Nang	Vietnam	439,500	98.20													13	15
Rosario	Argentina	1,278,000	1,729.28													12	15
Khulna	Bangladesh	1,426,000	822.40													12	15
Gaborone	Botswana	213,400	318.02													13	14
Porto Alegre	Brazil	3,708,000	20,099.63													13	14
Dalian	China	2,628,000	3,907.36													12	15
Ezhou	China	1,031,700	759.86													13	14
Harbin	China	2,928,000	4,545.57													14	13
Huangshi	China	642,100	1,166.77													14	13
Jinan	China	2,568,000	4,535.06													14	13
Leshan	China	1,137,000	801.21													13	14
Quanzhou	China	640,000	5,163.37													13	14
Tianmen	China	1,779,000	730.73													13	14
Zhuhai	China	407,000	10,652.42													13	14
Zibo	China	2,654,200	3,076.60													13	14
San Salvador	El Salvador	1,408,000	5,874.56													13	14
Ahmedabad	India	4,160,000	4,437.39													13	14
Chandigarh	India	808,796	1,093.46													12	15
Ludhiana	India	1,655,000	1,122.15													12	15
Patna	India	1,291,000	487.37													12	15
Pune (Poona)	India	3,489,000	3,208.42													12	15
Vijayawada	India	1,237,000	1,365.68													13	14
Visakhpatnam	India	1,705,000	1,434.09													12	15
Malang	Indonesia	803,900	2,251.16													14	13
Abadan	Iran	206,073	1,334.27													13	14
Mehrshahr	Iran	413,299	3,031.35													13	14
Raja'ishahr	Iran	134,848	8,479.43													14	13
Kingston	Jamaica	912,500	2,905.77													12	15
Cancun	Mexico	397,191	1,353.62													12	15
Lagos	Nigeria	13,400,000	6,817.79													12	15
Hyderabad	Pakistan	1,304,000	902.15													12	15
Multan	Pakistan	1,500,000	857.98													12	15
Angarsk	Russia	264,700	895.53													13	14
Machaakala	Russia	304,000	570.88													13	14
Moscow	Russia	9,321,000	50,060.86													15	12
Nigel	South Africa	100,200	709.47													14	13
Potchefstroom	South Africa	111,100	540.97													14	13
Al-Harum	Sudan	2,731,000	2,310.31													12	15
Dimashq	Syria	1,747,200	2,325.14													12	15
Tunis	Tunisia	1,897,000	1,886.72													12	15
Eskisehir	Turkey	496,200	529.58													12	15
Kirikkale	Turkey	222,200	1,176.87													13	14
Trabzon	Turkey	199,300	793.41													13	14
Van	Turkey	247,800	524.27													13	14
Barquisimeto	Venezuela	923,000	1,862.64													12	15
Petare	Venezuela	520,982	3,967.79													13	14
Can Tho	Vietnam	244,900	284.25													14	13
Hue	Vietnam	261,700	83.08													13	14
Nha Trang	Vietnam	260,700	139.10													13	14
Narsingdi	Bangladesh	253,700	462.14													12	14
Changchun	China	3,093,000	2,897.09													13	13
Haikou	China	527,900	1,545.29													11	15
Xian	China	3,123,000	3,778.43													13	13
Yichang	China	595,800	1,255.70													14	12

City	Country	Population	City GDP (in millions)	Natural Hazards Exposure				Mortality				Economic Damage				Multi-haz. Econom. Risk	Multi-haz. Mortality Risk
				Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide		
				High Medium Low				High Medium Low				High Medium Low					
Zhengzhou	China	2,070,000	2,315.55													13	13
Medellin	Colombia	2,951,000	5,534.74													12	14
Rijeka	Croatia	147,709	964.68													13	13
Split	Croatia	173,692	1,018.89													13	13
Allahabad	India	1,062,000	772.74													12	14
Ghaziabad	India	968,521	2,288.17													12	14
Kanpur	India	2,450,000	550.40													11	15
Nellore	India	378,947	375.47													11	15
Pondicherry	India	505,715	947.85													11	15
Srinagar	India	971,357	750.61													11	15
Varnasi	India	1,291,000	755.39													12	14
Palembang	Indonesia	1,422,000	2,289.22													13	13
Bakhtaran (Kermanshah)	Iran	692,986	1,028.58													11	15
Dezful	Iran	202,639	1,785.72													13	13
Qazvin	Iran	291,117	1,373.17													12	14
Qom	Iran	777,677	1,185.52													11	15
Tijuana	Mexico	1,167,000	29,495.84													14	12
Gujranwala	Pakistan	2,051,000	792.31													11	15
Peshawar	Pakistan	2,098,000	983.60													11	15
Asuncion	Paraguay	1,262,000	3,888.71													12	14
Kattowitz	Poland	3,487,000	6,460.53													14	12
Rybnik	Poland	144,200	1,401.20													13	13
Warszawa	Poland	2,269,000	15,529.34													15	11
Bacau	Romania	212,800	338.46													12	14
Braov	Romania	311,300	485.75													12	14
Constanta	Romania	339,300	587.25													12	14
Galati	Romania	340,200	432.48													12	14
Iasi	Romania	353,600	433.30													12	14
Piteoti	Romania	190,600	403.24													12	14
Timioara	Romania	338,900	630.55													12	14
Novorossijsk	Russia	203,300	399.61													12	14
Sodi	Russia	358,600	508.12													12	14
Stavropol	Russia	343,300	510.73													12	14
Ulan-Ude	Russia	370,400	488.56													12	14
Hims	Syria	698,800	1,220.32													11	15
Adiyaman	Turkey	232,000	332.76													12	14
Aydin	Turkey	146,000	187.93													12	14
Batman	Turkey	232,200	608.86													12	14
Denizli	Turkey	255,100	315.79													12	14
Hatay (Antakya)	Turkey	144,910	691.26													13	13
Osmaniye	Turkey	175,600	389.70													12	14
Andijon (Andizan)	Uzbekistan	342,200	468.26													13	13
Namangan	Uzbekistan	413,600	508.21													13	13
Maracaibo	Venezuela	1,901,000	2,256.95													11	15
Cam Pha	Vietnam	136,300	51.14													12	14
LongÿXuyen	Vietnam	150,900	224.92													14	12
Vinh	Vietnam	100,400	242.35													14	12
La Plata	Argentina	556,308	1,288.84													11	14
Santa Fe	Argentina	400,000	803.75													11	14
Bakerganj	Bangladesh	255,800	232.51													10	15
Cox's Bazar	Bangladesh	104,700	128.89													10	15
Rajshahi	Bangladesh	1,016,000	236.19													10	15
Santa Cruz	Bolivia	1,065,000	1,828.07													11	14
Francistown	Botswana	101,700	143.26													12	13
Anyang	China	718,200	1,810.54													13	12
Jingzhou	China	1,065,100	786.74													12	13

City	Country	Population	City GDP (in millions)	Natural Hazards Exposure				Mortality				Economic Damage				Multi-haz. Econom. Risk	Multi-haz. Mortality Risk
				Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide		
					High				High				High				
					Medium				Medium				Medium				
					Low				Low				Low				
Jiujiang	China	496,500	713.26													13	12
Wuhu	China	628,000	1,011.02													13	12
Xuanzhou	China	2,730,000	560.09													11	14
Yibin	China	740,400	655.87													12	13
Yingkou	China	646,900	2,176.51													13	12
Zhangzhou	China	490,500	2,923.26													12	13
Zhenjiang	China	592,700	2,666.03													14	11
Barranquilla	Colombia	1,736,000	2,933.99													11	14
San Jose	Costa Rica	988,000	8,487.40													12	13
Miskolc	Hungary	181,900	440.49													12	13
Asansol	India	1,425,000	663.63													11	14
Surakarta	Indonesia	579,600	1,156.42													13	12
Arak	Iran	380,755	920.89													11	14
Babol	Iran	158,346	844.24													12	13
Bandar-e Abbas	Iran	273,578	859.66													11	14
Kerman	Iran	384,991	909.57													11	14
Yazd	Iran	326,776	913.36													11	14
Al-Mawsil	Iraq	1,034,000	781.86													10	15
Ar-Rusayfah	Jordan	184,300	3,079.33													13	12
Savannakhet	Lao P.D.R.	154,900	133.24													13	12
Guadalajara	Mexico	3,908,000	5,289.00													10	15
Mexicali	Mexico	549,873	8,647.26													13	12
Reynosa	Mexico	403,718	3,112.49													12	13
Fez	Morocco	900,900	1,063.92													10	15
Tetouan	Morocco	323,100	1,310.88													11	14
Beira	Mozambique	447,600	267.50													11	14
Faisalabad	Pakistan	2,232,000	1,394.19													10	15
Islamabad	Pakistan	1,068,000	564.44													10	15
Bielsko-Biala	Poland	179,600	531.94													12	13
Braila	Romania	232,100	338.61													11	14
Cluj-Napoca	Romania	332,400	391.45													11	14
Craiova	Romania	316,700	329.09													11	14
Ploieoti	Romania	251,200	369.90													11	14
Armavir	Russia	164,900	430.14													12	13
Nalchik	Russia	233,400	376.55													11	14
Pyatigorsk	Russia	133,100	652.39													12	13
Umm Durman	Sudan	1,599,300	1,034.21													11	14
Balikesir	Turkey	207,400	297.42													11	14
Corum	Turkey	160,600	575.46													12	13
Karabuek	Turkey	113,300	399.25													12	13
Chirchiq	Uzbekistan	183,300	460.08													13	12
Hong Gai	Vietnam	141,200	36.83													11	14
Nam Dinh	Vietnam	187,100	178.13													13	12
Qui Nhon	Vietnam	192,700	115.03													13	12
Rach Gia	Vietnam	188,800	166.26													13	12
Thanh Hoa	Vietnam	103,000	298.33													14	11
Cordoba	Argentina	1,434,000	2,111.50													10	14
Corrientes	Argentina	325,628	586.29													10	14
Sylhet	Bangladesh	302,000	218.75													10	14
Hefei	China	1,242,000	1,862.72													12	12
Huangzhou	China	366,000	558.97													12	12
Jilin	China	1,435,000	1,677.00													12	12
Taian	China	1,503,000	2,028.69													12	12
Victoria (Xianggang)	China	6,927,000	37,260.21													10	14
Yangjiang	China	521,400	766.31													9	15
Cali	Colombia	2,710,000	4,226.73													11	13

City	Country	Population	City GDP (in millions)	Natural Hazards Exposure				Mortality				Economic Damage				Multi-haz. Econom. Risk	Multi-haz. Mortality Risk
				Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide		
					High Medium Low				High Medium Low				High Medium Low				
Quito	Ecuador	1,754,000	1,480.49													10	14
Al-Mansurah (Mansura)	Egypt	369,621	855.15													10	14
As-Suways (Suez)	Egypt	417,610	886.13													10	14
Bani Suwayf (Beni Suef)	Egypt	172,032	2,268.28													12	12
Szeged	Hungary	170,600	276.15													11	13
Brahmapur (Berhampur)	India	289,724	290.04													9	15
Dhanbad	India	961,000	1,002.25													11	13
Durgapur	India	492,996	491.87													11	13
Gorakhpur (Gorakhpoor)	India	624,570	272.46													10	14
Imphal	India	245,967	348.30													9	15
Kochi (Cochin)	India	1,762,000	1,494.24													11	13
Vadodara (Baroda)	India	1,608,000	1,345.20													11	13
Madiun	Indonesia	190,200	1,336.15													13	11
Semarang	Indonesia	787,000	1,994.45													12	12
Yogyakarta	Indonesia	450,000	11,664.13													13	11
Amol	Iran	159,092	741.80													11	13
Ardabil	Iran	340,386	505.33													10	14
Hamadan	Iran	401,281	654.17													10	14
Orumiyeh (Reza Iyeh)	Iran	435,200	674.27													10	14
Sari	Iran	195,885	681.45													11	13
Al-Basrah	Iraq	1,004,800	247.40													9	15
As-Sulaymaniyah	Iraq	721,700	425.27													9	15
Irbil	Iraq	1,042,700	567.81													9	15
Irbid	Jordan	253,000	1,158.50													11	13
Biskek	Kyrgyz Republic	217,000	443.09													11	13
Puebla	Mexico	1,968,000	7,014.45													11	13
Quetta	Pakistan	560,307	401.71													10	14
Rawalpindi	Pakistan	1,531,000	793.12													9	15
Sukkur	Pakistan	329,176	261.24													10	14
Jastrzebie-Zdroj	Poland	101,900	491.32													12	12
TarguMureo	Romania	163,300	329.34													11	13
Groznyj	Russia	135,100	273.38													11	13
Al-Lathiqiyah	Syria	391,300	839.51													10	14
Hama	Syria	350,900	633.24													10	14
Nonthanburi	Thailand	291,307	3,053.37													14	10
Phra Pradaeng	Thailand	166,828	20,926.99													15	9
Ariana	Tunisia	178,600	1,251.65													11	13
Alanya	Turkey	128,100	264.63													11	13
Erzincan	Turkey	111,700	269.86													11	13
Kuetahya	Turkey	177,200	168.57													10	14
Siirt	Turkey	116,900	218.90													11	13
Zonguldak	Turkey	115,900	276.25													11	13
My Tho	Vietnam	118,000	142.89													13	11
Parana	Argentina	256,602	670.19													10	13
Batdambang	Cambodia	183,600	154.54													12	11
Anqing	China	566,100	545.28													11	12
Putian	China	350,200	1,921.01													10	13
Puyang	China	464,900	1,544.70													12	11
Shanwei	China	409,100	986.88													9	14
Shijiazhuang	China	1,603,000	4,170.57													11	12
Xiangfan	China	706,400	1,011.82													12	11
Zhongshan	China	1,300,800	1,799.58													9	14
La Habana	Cuba	2,256,000	6,497.96													8	15
Kinshasa	Dem. Rep. of Congo	5,064,000	878.45													8	15
Djibouti	Djibouti	503,200	461.25													9	14
Santiago	Dominican Republic	1,539,000	956.40													9	14

Natural Hazards Exposure (Earthquake, Cyclone, Flood, Slide): High / Medium / Low

Mortality (Earthquake, Cyclone, Flood, Slide): High / Medium / Low

Economic Damage (Earthquake, Cyclone, Flood, Slide): High / Medium / Low

City	Country	Population	City GDP (in millions)	Multi-haz. Econom. Risk	Multi-haz. Mortality Risk
Al-Isma'iliyah (Ismailia)	Egypt	254,477	817.66	10	13
Al-Mahallah Al-Kubra	Egypt	395,402	464.26	9	14
Gyoer	Hungary	132,000	294.53	10	13
Agartala	India	189,327	239.18	10	13
Agra	India	1,169,000	628.88	9	14
Bhavnagar (Bhaunagar)	India	517,578	378.37	9	14
Faizabad (New Township)	India	1,051,000	142.71	8	15
Guntur	India	514,707	487.55	9	14
Gwalior	India	898,000	390.14	10	13
Jalandhar (Jullundur)	India	701,223	645.30	9	14
Kakinada	India	368,672	356.35	8	15
Rajahmundry	India	408,341	641.71	11	12
Sangli (-Miraj)	India	447,632	1,410.14	10	13
Shiliguri (Siliguri)	India	470,275	386.08	9	14
Medan	Indonesia	1,879,000	4,800.28	11	12
Bander-e Bushehr	Iran	143,641	527.13	10	13
Borujerd	Iran	217,804	292.70	9	14
Gorgan	Iran	188,710	591.75	10	13
Kashan	Iran	201,372	539.67	10	13
Khorramshahr (Khuninshahr)	Iran	105,636	610.53	11	12
Qa'emshahr	Iran	143,286	721.39	10	13
Zahedan	Iran	419,518	479.96	9	14
Zanjan	Iran	286,295	459.04	9	14
Az-Zubayr	Iraq	153,200	378.92	10	13
Tuxtla Gutierrez	Mexico	424,579	1,370.91	10	13
Villahermosa	Mexico	330,846	1,866.60	11	12
Casablanca	Morocco	3,541,000	3,351.21	10	13
Meknes	Morocco	545,800	523.56	9	14
Sialkot (incl. Cantonment)	Pakistan	417,597	325.27	9	14
Ciudad de Panama	Panama	1,173,000	5,144.91	10	13
Dagupan	Philippines	130,328	423.85	11	12
Davao	Philippines	1,202,000	199.37	9	14
Arad	Romania	181,900	199.51	10	13
Buzau	Romania	147,600	175.50	10	13
Piatra Neamt	Romania	122,800	143.45	10	13
Satu Mare	Romania	127,900	209.96	10	13
Berkessk	Russia	121,700	182.82	10	13
Juano-Sachalinsk	Russia	179,200	283.13	10	13
Kislovodsk	Russia	110,000	186.89	10	13
Nevinnomyssk	Russia	132,600	246.73	10	13
Beograd (Belgrad)	Serbia and Monten.	1,482,000	613.40	12	11
Khujand (Leninabad)	Tajikistan	205,200	156.09	11	12
Dar es Salaam	Tanzania	2,347,000	1,517.74	9	14
Thanya Buri	Thailand	113,818	3,813.30	14	9
Bismil	Turkey	110,700	161.94	10	13
Karaman	Turkey	113,700	417.17	11	12
Kiziltepe	Turkey	122,300	223.50	10	13
Ordu	Turkey	128,500	213.99	10	13
Viransehir	Turkey	116,100	228.04	10	13
Kabul	Afghanistan	2,590,000	228.26	7	15
Concordia	Argentina	131,716	837.57	10	12
Baki (Baku)	Azerbaijan	1,936,000	2,445.84	13	9
Brahman Baria	Bangladesh	202,400	120.88	9	13
Chandpur	Bangladesh	119,900	65.41	8	14
Mymensingh (Nasirabad)	Bangladesh	328,400	90.06	8	14
Rangpur	Bangladesh	262,300	210.94	9	13

City	Country	Population	City GDP (in millions)	Natural Hazards Exposure				Mortality				Economic Damage				Multi-haz. Econom. Risk	Multi-haz. Mortality Risk
				Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide		
					High				High				High				
					Medium				Medium				Medium				
					Low				Low				Low				
Cochabamba	Bolivia	607,129	768.38													9	13
Rio de Janeiro	Brazil	10,600,000	50,420.75													10	12
Vitoria	Brazil	1,336,521	6,131.02													10	12
N'Djamena	Chad	1,043,000	285.05													8	14
Chengdu	China	3,294,000	2,190.70													9	13
Handan	China	1,996,000	3,412.41													10	12
Jingmen	China	1,153,000	466.67													10	12
Kaifeng	China	761,500	992.42													11	11
Linyi	China	2,498,000	2,070.41													9	13
Luzhou	China	1,390,900	663.19													10	12
Maanshan	China	504,500	558.87													11	11
Nanping	China	486,800	517.97													11	11
Neijiang	China	1,365,400	1,500.11													10	12
Ningbo	China	1,173,000	4,938.70													10	12
Qinhuangdao	China	673,100	4,845.56													11	11
Qinzhou	China	1,138,300	424.51													8	14
Quzhou	China	261,200	1,034.09													12	10
Taiyuan	China	2,415,000	3,647.13													10	12
Tongling	China	331,100	570.99													11	11
Wanxian	China	1,759,000	515.79													10	12
Xiangtan	China	653,700	836.52													11	11
Xuzhou	China	1,873,000	3,926.55													10	12
Yangzhou	China	513,500	1,932.14													12	10
Zaozhuang	China	2,048,000	2,543.77													10	12
Bucaramanga	Colombia	940,200	2,140.74													10	12
San Pedro de Macoris	Dominican Republic	159,000	424.91													8	14
Guayaquil	Ecuador	2,293,000	2,099.55													9	13
Banha	Egypt	145,792	1,122.84													10	12
Bur Sa'id (Port Said)	Egypt	469,533	322.30													8	14
Shibin Al-Kawm	Egypt	159,909	820.49													10	12
Tanta	Egypt	371,010	352.72													8	14
Amritsar	India	830,000	556.28													8	14
Cuttack	India	587,637	415.41													10	12
Dehra Dun	India	527,859	348.85													8	14
Jabalpur	India	1,027,000	513.54													9	13
Jammu	India	607,642	302.19													8	14
Lucknow	India	2,568,000	903.39													9	13
Meerut	India	1,261,000	278.96													7	15
Muzaffarpur	India	305,465	188.51													9	13
Rohtak	India	286,773	327.21													9	13
Sabzevar	Iran	170,738	322.59													9	13
Sanandaj	Iran	277,808	350.30													8	14
Sirjan	Iran	135,024	315.46													9	13
Al-Amarah	Iraq	323,200	246.36													8	14
Az-Zarqa (Serka)	Jordan	471,200	294.64													8	14
Ciudad Madero	Mexico	182,325	3,059.53													11	11
Mazatlan	Mexico	327,989	1,095.09													9	13
Tlaquepaque	Mexico	458,674	6,639.71													11	11
El-Jadida	Morocco	129,600	936.68													10	12
Monywa	Myanmar	162,400	69.57													11	11
Myingyan	Myanmar	121,300	51.81													11	11
Pathein	Myanmar	215,500	91.06													11	11
Larkana	Pakistan	270,366	204.16													9	13
Mardan	Pakistan	244,511	308.58													9	13
Baia Mare	Romania	149,400	136.57													9	13
Botosani	Romania	129,300	136.96													9	13

City	Country	Population	City GDP (in millions)	Natural Hazards Exposure				Mortality				Economic Damage				Multi-haz. Econom. Risk	Multi-haz. Mortality Risk
				Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide		
					High				High				High				
					Medium				Medium				Medium				
					Low				Low				Low				
Drobeta-Turnu Severin	Romania	116,200	167.80													10	12
Ramnicu Valcea	Romania	120,700	205.83													10	12
Sibiu	Romania	167,400	137.82													9	13
Suceava	Romania	119,800	139.39													9	13
Majkop	Russia	167,300	125.15													9	13
Al-Qamishli	Syria	172,600	514.15													9	13
Pak Kret	Thailand	141,788	7,475.67													14	8
Susah	Tunisia	145,900	695.55													10	12
Afyon	Turkey	123,900	117.64													9	13
Aksaray	Turkey	110,500	263.98													10	12
Corlu	Turkey	134,600	105.36													9	13
Isparta	Turkey	146,600	134.07													9	13
Usak	Turkey	135,800	125.12													9	13
Angren	Uzbekistan	155,400	154.29													11	11
Olmaliq (Almalyk)	Uzbekistan	131,100	201.97													11	11
Guarenas	Venezuela	170,204	933.20													10	12
Cam Ranh	Vietnam	139,000	16.87													9	13
Mendoza	Argentina	946,000	2,604.76													9	12
San Nicolas de los Arroyos	Argentina	132,909	464.50													9	12
Bogra	Bangladesh	220,100	134.73													8	13
Comilla	Bangladesh	307,400	63.48													7	14
Kumill	Bangladesh	307,400	75.75													7	14
Minsk	Belarus	1,772,000	1,448.88													12	9
Cotonou	Benin	704,900	652.58													9	12
Siemreap	Cambodia	135,200	76.73													11	10
Anshan	China	1,453,000	2,370.22													9	12
Beihai	China	497,000	673.53													9	12
Daqing	China	1,077,500	1,619.63													11	10
Dongying	China	721,900	687.47													10	11
Guangzhou	China	3,893,000	8,370.04													11	10
Hebi	China	476,500	677.74													10	11
Jiamusi	China	874,000	519.33													10	11
Kunming	China	1,701,000	1,689.38													9	12
Zhuzhou	China	723,400	1,022.07													11	10
Cartagena	Colombia	837,600	1,046.43													9	12
Santiago de Cuba	Cuba	534,600	1,105.00													8	13
La Romana	Dominican Republic	182,500	413.96													7	14
Az-Zaqaziq (Sagasig)	Egypt	267,351	343.01													8	13
San Pedro Sula	Honduras	616,500	906.18													9	12
Szekesfehervar	Hungary	110,200	191.47													9	12
Aligarh	India	667,732	280.02													7	14
Bareilly	India	729,800	280.00													7	14
Bhubaneswar	India	657,477	380.14													9	12
Bokaro Steel City	India	497,855	369.17													9	12
Darbhanga	India	266,834	92.14													8	13
Kolhapur	India	497,554	520.53													8	13
Moradabad	India	641,240	253.94													7	14
Cirebon	Indonesia	294,400	1,190.17													11	10
Kudus	Indonesia	117,400	877.55													12	9
Pekalongan	Indonesia	249,200	959.36													11	10
Bojnurd	Iran	134,835	248.68													8	13
Khorramabad	Iran	272,815	210.39													7	14
Khvoy	Iran	158,346	214.02													8	13
Maragheh	Iran	132,318	383.44													9	12
Neyshabur	Iran	159,092	292.18													8	13
Saveh	Iran	111,245	409.57													9	12

City	Country	Population	City GDP (in millions)	Natural Hazards Exposure				Mortality				Economic Damage				Multi-haz. Econom. Risk	Multi-haz. Mortality Risk
				Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide		
				High Medium Low				High Medium Low				High Medium Low					
Al-Kut	Iraq	352,800	216.02													7	14
Almaty	Kazakhstan	1,248,000	2,018.05													10	11
Toamasina	Madagascar	166,000	26.83													8	13
Chihuahua	Mexico	657,876	2,761.67													9	12
Ciudad Juarez	Mexico	1,168,000	22,370.13													11	10
Minatitlan	Mexico	109,193	2,370.64													11	10
Monterrey	Mexico	3,416,000	9,864.26													9	12
Zapopan	Mexico	910,690	3,223.01													9	12
Rabat	Morocco	1,496,000	1,796.62													9	12
Pakokku	Myanmar	111,100	46.30													10	11
Pyay	Myanmar	123,800	49.94													10	11
Kathmandu	Nepal	701,499	213.07													7	14
Kano	Nigeria	3,169,100	1,102.87													8	13
Gujrat	Pakistan	250,121	181.11													8	13
Jhang Sadar	Pakistan	292,214	213.48													8	13
Arequipa	Peru	720,400	2,329.58													10	11
Angeles	Philippines	263,971	277.25													10	11
San Fernando	Philippines	102,082	337.26													11	10
Magadan	Russia	121,000	88.84													8	13
Usolje-Sibirskoje	Russia	103,500	118.99													9	12
Al-Hasakah	Syria	185,800	289.42													8	13
Dushanbe	Tajikistan	691,600	499.35													10	11
Edirne	Turkey	125,600	91.16													8	13
Tekirdag	Turkey	109,800	66.69													8	13
Samarqand (Samarkand)	Uzbekistan	371,800	536.92													11	10
Ciudad Guayana	Venezuela	704,168	1,888.81													9	12
Puerto Cabello	Venezuela	169,959	529.72													9	12
Ca Mau	Vietnam	101,900	75.85													11	10
Phan Thiet	Vietnam	139,200	45.09													10	11
Formosa	Argentina	197,057	199.26													7	13
Posadas	Argentina	250,000	456.13													8	12
Kushtia	Bangladesh	114,100	141.86													9	11
Naogaon	Bangladesh	143,700	123.39													8	12
Nawabganj	Bangladesh	149,200	131.99													8	12
La Paz	Bolivia	1,480,000	1,062.17													8	12
Moji das Cruzes	Brazil	116,117	16,073.25													13	7
Baotou	China	1,319,000	2,324.51													9	11
Chuzhou	China	468,600	243.82													9	11
Fangchenggang	China	464,400	218.37													7	13
Heze	China	1,600,000	2,471.32													9	11
Hohhot	China	978,000	1,564.91													9	11
Jieyang	China	624,700	2,629.93													10	10
Lanzhou	China	1,730,000	1,405.31													8	12
Sanya	China	446,000	219.09													6	14
Shenyang	China	4,828,000	4,810.10													10	10
Weifang	China	1,287,000	2,198.55													9	11
Weinan	China	861,000	620.93													9	11
Zhanjiang	China	1,368,000	1,265.00													6	14
Aizawl	India	229,714	157.15													6	14
Bhilai (Bhilai Nagar)	India	925,000	660.37													9	11
Gandhinagar	India	195,891	1,392.37													11	9
Kharagpur	India	296,323	354.92													9	11
Patiala	India	323,309	297.19													7	13
Raipur	India	605,131	653.11													9	11
Shillong	India	267,881	240.10													7	13
Thane	India	1,484,000	8,944.18													10	10

City	Country	Population	City GDP (in millions)	Natural Hazards Exposure				Mortality				Economic Damage				Multi-haz. Econom. Risk	Multi-haz. Mortality Risk
				Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide		
				High Medium Low				High Medium Low				High Medium Low					
Yamunanagar	India	189,587	369.69													8	12
Birjand	Iran	127,608	248.61													8	12
Emamshahr (Shahrud)	Iran	104,765	217.49													8	12
Gonbad-e Qabus	Iran	111,253	267.02													8	12
Ilam	Iran	126,346	273.57													8	12
Marv Dasht	Iran	103,579	207.22													8	12
Bamako	Mali	1,131,000	406.49													7	13
Acapulco (de Juarez)	Mexico	620,656	1,318.19													8	12
Hermosillo	Mexico	545,928	2,775.37													9	11
Jiutepec	Mexico	142,459	2,492.72													10	10
Los Mochis	Mexico	200,906	1,906.21													9	11
Naucalpan	Mexico	835,053	5,218.70													9	11
Tonala	Mexico	315,278	2,191.14													9	11
Valle de Chalco	Mexico	322,784	15,052.52													11	9
Bago	Myanmar	223,700	95.05													10	10
Hintada	Myanmar	122,600	52.11													10	10
Meiktila	Myanmar	151,900	69.30													10	10
Lalitpur	Nepal	157,475	312.73													8	12
Kaduna	Nigeria	1,409,100	966.13													8	12
Maiduguri	Nigeria	950,000	373.19													7	13
Bahawalpur	Pakistan	403,408	304.18													7	13
Chiniot	Pakistan	169,282	162.23													8	12
Kemoke	Pakistan	150,984	243.11													8	12
Sargodha	Pakistan	455,360	308.27													7	13
Shekhapura	Pakistan	271,875	198.47													7	13
Weh	Pakistan	198,431	244.81													8	12
Trujillo	Peru	590,200	1,758.60													9	11
Baguio	Philippines	252,386	411.68													7	13
Dakar	Senegal	2,079,000	740.07													7	13
Ljubljana	Slovenia	290,600	4,180.35													11	9
Sivas	Turkey	253,700	29.03													6	14
Jizzakh (Dzizak)	Uzbekistan	126,400	75.23													9	11
Catia La Mar	Venezuela	118,466	554.70													9	11
Valencia	Venezuela	1,893,000	747.01													6	14
Jamalpur	Bangladesh	145,100	111.12													7	12
Sirajganj	Bangladesh	140,500	76.82													7	12
Jundiai	Brazil	299,669	3,904.12													10	9
Concepcion	Chile	373,000	1,783.73													8	11
Lianyungang	China	604,500	1,829.53													9	10
Liaoyang	China	698,200	1,976.26													9	10
Qingdao	China	2,316,000	5,647.01													10	9
Qiqihar	China	1,435,000	1,241.28													9	10
Rizhao	China	1,136,200	1,250.15													8	11
Urumqi	China	1,391,900	1,035.76													8	11
Xianyang	China	753,300	1,391.60													10	9
Xintai	China	1,325,000	1,466.05													8	11
Xinxiang	China	721,300	1,757.34													9	10
Zigong	China	1,072,000	1,069.50													8	11
Mit Ghamr	Egypt	101,801	392.59													8	11
Tegucigalpa	Honduras	950,000	996.80													8	11
Barddhaman (Burdwan)	India	285,871	170.46													8	11
Jodhpur	India	847,000	443.25													8	11
Kurnool	India	320,619	192.22													8	11
Muzaffarnagar	India	316,452	132.49													6	13
Panipat	India	261,665	341.24													7	12
Saharanpur	India	452,925	182.38													6	13

City	Country	Population	City GDP (in millions)	Natural Hazards Exposure				Mortality				Economic Damage				Multi-haz. Econom. Risk	Multi-haz. Mortality Risk
				Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide		
				High				High				High					
				Medium				Medium				Medium					
				Low				Low				Low					
Shimla	India	142,161	228.08													7	12
Thiruvananthapuram (Trivand	India	1,229,000	1,062.78													8	11
Padang	Indonesia	611,900	1,067.11													7	12
Andimeshk	Iran	106,923	175.26													7	12
Mahabad	Iran	107,799	145.93													7	12
Malayer	Iran	144,373	229.34													7	12
Shahr-e Kord	Iran	100,477	203.32													7	12
Bacqubah	Iraq	256,000	132.83													6	13
Bagdad	Iraq	4,797,000	4,903.21													8	11
Oskemen	Kyrgyz Republic	793,100	71.01													6	13
Luang Prabang	Lao P.D.R.	116,000	116.81													10	9
Culiacan	Mexico	540,823	2,053.19													8	11
Oaxaca	Mexico	251,846	1,824.15													8	11
San Nicolas de los Garzas	Mexico	496,879	16,448.71													10	9
Tlalnepantla	Mexico	714,735	4,050.99													8	11
Ulan-Bator	Mongolia	738,000	375.14													9	10
Wiratnagar	Nepal	168,544	100.04													7	12
Dera Ghozi Khan	Pakistan	188,149	140.77													7	12
Marpur Khas	Pakistan	184,465	129.06													7	12
Port Moresby	Papua New Guinea	300,200	175.80													8	11
Chiclayo	Peru	481,100	1,346.22													9	10
Batangas	Philippines	247,588	275.73													8	11
Krakow	Poland	857,000	2,105.92													11	8
Chelyabinsk	Russia	1,185,000	2,959.30													11	8
Kazan	Russia	1,137,000	3,221.42													11	8
Samara (Kujbysev)	Russia	1,260,000	3,374.71													11	8
Ufa	Russia	1,139,000	2,545.87													11	8
Tartus	Syria	141,500	226.79													7	12
Kampala	Uganda	1,212,000	1,217.07													8	11
Kharkiv (Kharkov, Charkov)	Ukraine	1,526,000	1,669.36													12	7
Mazar-i Sharif	Afghanistan	232,800	83.98													5	13
Resistencia	Argentina	280,000	274.76													6	12
San Miguel de Tucuman	Argentina	519,252	1,534.21													7	11
Chudanga	Bangladesh	107,900	155.22													7	11
Pabna	Bangladesh	154,500	125.62													7	11
Araraquara	Brazil	173,086	372.46													5	13
Criciuma	Brazil	152,903	1,779.91													6	12
Sofija (Sofia)	Bulgaria	1,192,000	828.17													10	8
Antofagasta	Chile	249,000	2,086.14													8	10
Baoji	China	554,000	632.79													8	10
Datong	China	1,165,000	1,050.11													7	11
Dezhou	China	510,000	1,474.43													8	10
Laiwu	China	1,218,800	1,018.55													7	11
Lengshuitan	China	1,040,400	395.68													8	10
Nanchong	China	1,197,000	644.33													8	10
Panjin	China	539,400	1,614.89													8	10
Shangqiu	China	1,435,300	1,089.28													7	11
Taizhou (J+H)	China	1,408,300	1,663.02													9	9
Xingtai	China	489,000	1,232.32													8	10
Xining	China	822,700	1,269.07													8	10
Zhangjiakou	China	880,000	969.24													7	11
Zhoushan	China	683,100	700.88													5	13
Abidjan	Côte d'Ivoire	3,305,000	2,591.89													7	11
Kafr ash-Shaykh	Egypt	124,819	141.31													6	12
Santa Ana	El Salvador	241,266	580.98													8	10
Adis Abeba	Ethiopia	2,639,000	949.22													7	11

City	Country	Population	City GDP (in millions)	Natural Hazards Exposure				Mortality				Economic Damage				Multi-haz. Econom. Risk	Multi-haz. Mortality Risk
				Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide		
				High Medium Low				High Medium Low				High Medium Low					
Kecskemet	Hungary	107,700	53.94													6	12
Bangalore	India	5,561,000	2,429.28													7	11
Cuddapah	India	260,899	258.92													8	10
Hisar	India	263,070	367.58													8	10
Latur	India	299,828	239.00													6	12
Warangal	India	528,570	173.98													7	11
Banda Aceh	Indonesia	253,700	751.60													9	9
Tegal	Indonesia	278,000	288.96													8	10
Yogyakarta	Indonesia	470,800	1,315.31													8	10
Bukan	Iran	120,020	170.02													6	12
Saqqez	Iran	115,394	153.78													6	12
Zabol	Iran	100,887	109.56													6	12
Kisumu	Kenya	266,300	233.86													7	11
Antananarivo (Tananarive)	Madagascar	1,507,000	660.07													6	12
Campeche	Mexico	190,813	1,694.54													8	10
Cheturnal	Mexico	121,602	1,126.47													8	10
Metepec	Mexico	158,695	3,265.94													9	9
Morelia	Mexico	549,996	1,084.28													7	11
San Pablo de las Salinas	Mexico	150,000	5,702.38													10	8
Tampico	Mexico	295,442	1,538.16													8	10
Pokhara	Nepal	168,806	58.72													6	12
Managua	Nicaragua	959,000	493.58													6	12
Kasir	Pakistan	241,649	188.21													6	12
Cabanatuan	Philippines	222,859	145.03													8	10
Gdansk (Danzig)	Poland	712,900	2,376.46													11	7
Niznij Novgorod	Russia	1,458,000	2,919.55													10	8
WadÿMadani	Sudan	265,900	323.96													7	11
Khon Kaen	Thailand	141,034	193.05													9	9
Odesa	Ukraine	1,012,000	777.42													11	7
Bukhoro (Buchara)	Uzbekistan	263,500	271.80													9	9
Quqon (Kokand)	Uzbekistan	190,100	518.32													10	8
Baruta	Venezuela	213,373	4,331.30													9	9
Santa Teresa (del Tuy)	Venezuela	126,930	208.66													7	11
Valera	Venezuela	116,036	739.40													8	10
SocÿTrang	Vietnam	106,500	64.87													9	9
Begumgonj	Bangladesh	103,700	80.80													6	11
Dinajpur	Bangladesh	178,200	96.27													5	12
Jessore	Bangladesh	219,800	130.85													7	10
Americana	Brazil	181,650	3,389.54													9	8
Pelotas	Brazil	300,952	2,285.86													8	9
Recife	Brazil	3,315,000	9,375.09													7	10
Quilpue	Chile	119,000	1,512.68													8	9
Rancagua	Chile	209,000	1,212.75													7	10
Vina del Mar	Chile	338,500	1,130.36													7	10
Chaozhou	China	335,300	1,504.02													8	9
Fuling	China	300,000	99.09													7	10
Fuyu	China	1,025,000	237.52													7	10
Hegang	China	695,400	270.45													7	10
Jincheng	China	230,600	1,183.13													10	7
Langfang	China	683,300	971.47													7	10
Linqing	China	891,000	992.79													7	10
Liupanshui	China	2,023,000	411.71													5	12
Yangquan	China	620,000	854.58													7	10
Yantai	China	2,080,000	1,921.16													8	9
Yining	China	430,000	917.99													7	10
Ibague	Colombia	398,900	676.85													7	10

City	Country	Population	City GDP (in millions)	Natural Hazards Exposure				Mortality				Economic Damage				Multi-haz. Econom. Risk	Multi-haz. Mortality Risk
				Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide		
				High / Medium / Low				High / Medium / Low				High / Medium / Low					
Palmira	Colombia	278,409	928.80													8	9
Pasto	Colombia	346,700	301.93													6	11
Pereira	Colombia	580,900	661.48													7	10
Santa Marta	Colombia	367,900	510.32													7	10
Manzanillo	Cuba	119,900	281.20													5	12
Ambato	Ecuador	170,500	441.62													7	10
Bilbays	Egypt	113,608	164.02													6	11
Suva	Fiji	174,700	188.15													5	12
Bhagalpur	India	349,709	30.82													5	12
Bhiwandi	India	621,390	2,468.59													7	10
Mathura	India	319,235	143.87													5	12
Rampur	India	281,549	125.09													5	12
Shahjahanpur	India	323,166	117.94													5	12
Kediri	Indonesia	293,200	1,235.73													8	9
Probolinggo	Indonesia	158,100	938.36													9	8
Tanjungkarang (T.-Telukbetun	Indonesia	743,000	844.62													7	10
Kirkuk	Iraq	688,500	18.23													2	15
Tall Afar	Iraq	141,600	119.88													5	12
Leon	Mexico	1,050,000	4,540.60													7	10
Tapachula	Mexico	179,839	420.35													6	11
Texcoco	Mexico	101,711	6,642.28													10	7
Toluca	Mexico	1,184,000	705.93													5	12
Torreon	Mexico	953,000	3,267.63													7	10
Chioinou	Moldova	657,300	246.83													9	8
Mawlamyine	Myanmar	360,400	136.06													7	10
Birganj	Nepal	103,880	74.89													6	11
Sokoto	Nigeria	488,600	249.40													6	11
Zaria	Nigeria	868,300	524.63													6	11
Jhelum	Pakistan	145,847	149.28													6	11
Mingoora	Pakistan	174,469	131.58													5	12
Muridike	Pakistan	108,578	89.62													6	11
Okara	Pakistan	200,901	141.57													5	12
Rahamyar Khan	Pakistan	228,479	157.42													5	12
Sahawal	Pakistan	207,388	140.78													5	12
Tando Adam	Pakistan	103,363	80.28													6	11
Piura	Peru	350,600	595.45													7	10
Butuan	Philippines	267,279	75.33													6	11
Cotabato	Philippines	163,849	62.29													7	10
Perm	Russia	1,118,000	2,973.40													10	7
Vladivostok	Russia	606,200	563.86													9	8
Mogadishu	Somalia	1,219,000	89.87													4	13
Udon Thani	Thailand	220,493	174.95													8	9
Al-Qayrawan	Tunisia	113,100	163.80													6	11
Gabes	Tunisia	106,600	167.00													6	11
Qarshi (Karsi)	Uzbekistan	194,100	239.60													9	8
Acarigua	Venezuela	166,720	547.63													7	10
Cabimas	Venezuela	214,000	428.86													6	11
Ciudad Ojeda	Venezuela	103,835	502.05													7	10
Turmero	Venezuela	226,084	1,064.32													7	10
Da Lat	Vietnam	123,000	44.82													8	9
Vung Tau	Vietnam	178,600	579.26													10	7
San Juan	Argentina	120,000	1,127.52													7	9
Saidpur	Bangladesh	114,000	130.24													5	11
Tangail	Bangladesh	148,300	51.69													5	11
Porto-Novo	Benin	234,900	248.75													6	10
Brasilia	Brazil	1,990,000	13,046.10													7	9

City	Country	Population	City GDP (in millions)	Natural Hazards Exposure				Mortality				Economic Damage				Multi-haz. Econom. Risk	Multi-haz. Mortality Risk
				Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide		
				High Medium Low				High Medium Low				High Medium Low					
Curitiba	Brazil	2,525,000	12,465.23	0	0		0	0	0		0	0	0		0	7	9
Fortaleza	Brazil	3,014,000	6,397.61	0	0			0	0			0	0			6	10
Santa Maria	Brazil	230,464	1,680.27	0	0			0	0			0	0			7	9
Talcahuano	Chile	277,000	694.87		0		0		0		0		0		0	6	10
Temuco	Chile	260,000	642.35		0				0				0			6	10
Cangzhou	China	440,400	954.57		0		0		0		0		0		0	7	9
Changzhi	China	593,500	114.76		0				0				0			5	11
Changzhou	China	886,000	4,501.09	0	0		0	0	0		0	0	0		0	10	6
Foshan	China	468,400	6,261.63	0	0			0	0			0	0			10	6
Fushun	China	1,411,300	2,469.52	0	0		0	0	0		0	0	0		0	8	8
Guiyang	China	2,533,000	982.21	0	0			0	0			0	0			6	10
Nanyang	China	1,613,700	1,389.06	0	0			0	0			0	0			7	9
Panzhihua	China	635,500	471.30		0				0				0			6	10
Suzhou	China	1,183,000	3,973.22	0	0			0	0			0	0			9	7
Wuxi	China	1,127,000	2,806.50	0	0		0	0	0		0	0	0		0	9	7
Xiamen	China	1,265,900	338.00	0			0	0			0	0			0	4	12
Yinchuan	China	586,000	586.26		0		0		0		0		0		0	6	10
Armenia	Colombia	294,300	669.98		0	0			0	0			0	0		7	9
Barrancabermeja	Colombia	183,300	314.03		0				0				0			6	10
Buenaventura	Colombia	324,207	423.40		0				0				0			6	10
Neiva	Colombia	312,300	434.75		0				0				0			6	10
Holguin	Cuba	305,000	636.95		0	0			0	0			0	0		7	9
La Vega	Dominican Republic	106,200	667.86		0				0				0			8	8
Cuenca	Ecuador	271,400	812.65		0				0				0			7	9
Alappuzha (Alleppey)	India	177,079	271.70	0	0			0	0			0	0			7	9
Jaipur	India	2,145,000	1,318.87	0	0		0	0	0		0	0	0		0	6	10
Kollam (Quilon)	India	379,975	589.40	0	0			0	0			0	0			7	9
Nagpur	India	2,062,000	2,193.80	0	0		0	0	0		0	0	0		0	7	9
Cilacap	Indonesia	254,900	271.23		0		0		0		0		0		0	7	9
Pasuruan	Indonesia	160,600	547.42		0				0				0			8	8
Taman (Jawa Tengah)	Indonesia	102,800	462.88		0				0				0			9	7
Aguascalientes	Mexico	594,092	3,329.57	0	0			0	0			0	0			7	9
Boca del Rio	Mexico	123,891	578.67		0		0		0		0		0		0	6	10
Colima	Mexico	119,639	920.14		0				0				0			7	9
Huixquilucan	Mexico	107,951	9,817.37		0	0			0	0			0	0		10	6
Merida	Mexico	662,530	2,590.20	0	0		0	0	0		0	0	0		0	6	10
Nuevo Laredo	Mexico	308,828	8,864.70	0	0		0	0	0		0	0	0		0	9	7
Poza Rica de Hidalgo	Mexico	151,441	1,244.91		0				0				0			7	9
Puerto Vallarta	Mexico	151,432	536.29													6	10
Queretaro	Mexico	536,463	3,377.44	0	0			0	0			0	0			7	9
San Luis Rio Colorado	Mexico	126,645	1,093.79		0		0		0		0		0		0	7	9
Veracruz	Mexico	411,582	1,381.21		0	0			0	0			0	0		6	10
Mohammedia	Morocco	188,619	1,526.15	0	0		0	0	0		0	0	0		0	8	8
Daska	Pakistan	101,500	86.84		0		0		0		0		0		0	5	11
Jacobabad	Pakistan	137,733	91.82		0		0		0		0		0		0	5	11
Khairpur	Pakistan	102,188	132.75		0	0	0		0	0	0		0	0	0	5	11
Kohat	Pakistan	125,271	94.88		0		0		0		0		0		0	5	11
Nawabshah	Pakistan	183,110	132.36		0	0	0		0	0	0		0	0	0	5	11
Sadiqabad	Pakistan	141,509	117.97		0		0		0		0		0		0	5	11
Shikarpur	Pakistan	133,259	97.55		0		0		0		0		0		0	5	11
Huancayo	Peru	282,400	765.31		0				0				0			7	9
Naga	Philippines	137,810	148.97		0				0				0			7	9
Olongapo	Philippines	194,260	63.07		0				0				0			6	10
Stettin	Poland	416,600	1,502.76	0	0		0	0	0		0	0	0		0	10	6
Chabarovsk	Russia	614,000	535.37	0	0			0	0			0	0			8	8
Chimki	Russia	133,500	10,212.53	0	0		0	0	0		0	0	0		0	13	3

City	Country	Population	City GDP (in millions)	Natural Hazards Exposure				Mortality				Economic Damage				Multi-haz. Econom. Risk	Multi-haz. Mortality Risk
				Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide		
				High Medium Low				High Medium Low				High Medium Low					
Kemerovo	Russia	492,700	783.13	0	0		0	0	0		0	0	0		0	9	7
Naberednyje Delny	Russia	514,700	1,537.37	0	0		0	0	0		0	0	0		0	10	6
Simbirsk	Russia	667,400	375.89	0	0		0	0	0		0	0	0		0	8	8
Tula	Russia	506,100	835.65	0	0		0	0	0		0	0	0		0	9	7
Volgograd	Russia	1,020,000	1,683.13	0	0		0	0	0		0	0	0		0	9	7
Hat Yai	Thailand	185,557	764.03	0	0			0	0			0	0			9	7
Ubon Ratchathani	Thailand	106,552	130.01	0	0		0	0	0		0	0	0		0	8	8
Binzart	Tunisia	108,900	53.44		0	0	0		0	0	0		0	0	0	4	12
Farghona (Fergana)	Uzbekistan	212,800	155.36		0				0				0			8	8
Margilon (Margilan)	Uzbekistan	144,900	253.27		0				0				0			9	7
Nawoiy (Navoi)	Uzbekistan	141,500	239.15		0		0		0		0		0		0	9	7
Ciudad Bolivar	Venezuela	312,691	258.31		0				0				0			5	11
Coro	Venezuela	158,763	211.92		0				0				0			5	11
San Cristobal	Venezuela	307,184	1,209.42		0	0			0	0			0	0		6	10
Jalalabad	Afghanistan	154,200	30.71		0				0				0			3	12
Santiago del Estero	Argentina	202,876	296.03		0		0		0		0		0		0	5	10
Gomel	Belarus	503,400	250.75	0	0		0	0	0		0	0	0		0	9	6
Campinas	Brazil	1,862,000	7,507.88	0	0			0	0			0	0			6	9
Mossoro	Brazil	197,067	602.46		0		0		0		0		0		0	7	8
Teresina	Brazil	676,596	1,044.52	0	0			0	0			0	0			5	10
Uruguaiana	Brazil	118,181	853.64	0	0		0	0	0		0	0	0		0	7	8
Arica	Chile	183,000	835.78		0				0				0			6	9
Copiapo	Chile	120,000	715.08		0				0				0			6	9
La Serena	Chile	127,000	653.21		0				0				0			6	9
Guigang	China	1,633,200	685.39	0	0			0	0			0	0			5	10
Hengshui	China	398,700	356.06		0		0		0		0		0		0	5	10
Hengyang	China	784,300	123.37	0	0		0	0	0		0	0	0		0	5	10
Jining	China	1,019,000	2,230.91	0	0			0	0			0	0			8	7
Jinxi	China	2,771,000	924.96	0	0		0	0	0		0	0	0		0	6	9
Luoyang	China	1,451,000	1,782.24	0	0			0	0			0	0			7	8
Meizhou	China	326,500	675.56		0				0				0			6	9
Nanning	China	1,311,000	1,398.60	0	0			0	0			0	0			7	8
Qujing	China	590,700	317.73		0				0				0			5	10
Sanmenxia	China	254,200	162.30		0				0				0			6	9
Tianshui	China	1,165,900	277.78		0				0				0			4	11
Yancheng	China	1,562,000	1,386.39	0	0		0	0	0		0	0	0		0	7	8
Yulin	China	1,558,000	1,023.35	0	0			0	0			0	0			6	9
Yuyao	China	848,000	2,466.34	0	0			0	0			0	0			8	7
Florencia	Colombia	113,100	936.66		0				0				0			8	7
Manizales	Colombia	341,200	414.88		0	0			0	0			0	0		6	9
Monteria	Colombia	252,000	471.19		0				0				0			6	9
Camagueey	Cuba	342,900	631.61		0	0	0		0	0	0		0	0	0	6	9
Cienfuegos	Cuba	165,800	490.95	0			0	0			0	0			0	3	12
Guantanamo	Cuba	264,100	578.67		0	0			0	0			0	0		6	9
San Cristobal (Benementa de	Dominican Republic	133,500	319.44		0				0				0			6	9
Machala	Ecuador	211,300	405.18		0				0				0			6	9
Papeete (Tahiti)	French Polynesia (Fr.)	106,100	797.08	0		0	0	0		0	0	0		0	0	4	11
El Progreso	Honduras	106,500	276.00		0				0				0			6	9
Mumbai (Bombay)	India	18,100,000	5,823.26	0	0	0		0	0	0		0	0	0		1	14
Cilegon - Merak	Indonesia	144,100	1,008.32		0				0				0			8	7
Jambi	Indonesia	408,600	601.42		0		0		0		0		0		0	6	9
Shymkent	Kazakhstan	360,100	155.13		0				0				0			8	7
Mombasa	Kenya	685,000	70.24	0	0		0	0	0		0	0	0		0	3	12
Mahajanga	Madagascar	128,600	28.84	0			0	0			0	0			0	5	10
Cuautla Morelos	Mexico	136,932	945.58		0				0				0			6	9
Cuernavaca	Mexico	327,162	698.73		0	0			0	0			0	0		5	10

City	Country	Population	City GDP (in millions)	Natural Hazards Exposure				Mortality				Economic Damage				Multi-haz. Econom. Risk	Multi-haz. Mortality Risk
				Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide		
				High / Medium / Low				High / Medium / Low				High / Medium / Low					
Saltillo	Mexico	562,587	2,295.52													6	9
Tehuacan	Mexico	204,598	858.70													6	9
Tepic	Mexico	265,817	727.20													5	10
Xalapa	Mexico	373,076	823.09													5	10
Safi	Morocco	103,100	77.23													4	11
Tanger	Morocco	578,800	529.80													5	10
Maputo	Mozambique	3,025,000	744.08													4	11
Niamey	Niger	182,450	215.48													5	10
Katsina	Nigeria	377,400	219.81													5	10
Abbottabad	Pakistan	105,999	82.76													4	11
Bahawalnagar	Pakistan	109,642	96.75													4	11
Barewala	Pakistan	149,857	104.16													4	11
Gojra	Pakistan	114,967	80.86													4	11
Hafizabad	Pakistan	130,216	90.19													4	11
Jaranwala	Pakistan	103,308	73.06													4	11
Khanewal	Pakistan	132,962	91.53													4	11
Pakpattan	Pakistan	107,791	79.10													4	11
Cusco	Peru	279,600	412.23													6	9
Iquitos	Peru	340,200	489.49													6	9
Cagayan de Oro	Philippines	461,877	292.67													5	10
Cebu	Philippines	718,821	719.16													5	10
Legazpi	Philippines	157,010	97.57													6	9
San Pablo	Philippines	207,927	76.79													5	10
Tarlac	Philippines	262,481	41.16													5	10
Bydgoszcz	Poland	386,300	830.56													9	6
Wroclaw	Poland	636,800	1,225.04													9	6
Lyubercy	Russia	163,900	7,259.96													12	3
Odincovo	Russia	127,400	8,505.17													12	3
Morogoro	Tanzania	235,200	149.88													5	10
Tabora	Tanzania	1,703,000	121.13													3	12
Rayong	Thailand	106,585	2,397.71													11	4
Puerto la Cruz	Venezuela	205,635	625.19													5	10
Asadabad	Afghanistan	101,600	30.41													3	11
Herat	Afghanistan	161,700	61.72													3	11
Mehtar Lam	Afghanistan	118,500	30.50													3	11
Quandahar	Afghanistan	329,300	4.22													1	13
Qunduz	Afghanistan	111,200	32.06													3	11
Luanda	Angola	2,571,600	1,482.51													3	11
Salta	Argentina	457,223	427.19													4	10
San Salvador de Jujuy	Argentina	226,961	335.57													4	10
Noakhali	Bangladesh	103,700	112.08													4	10
Satkhira	Bangladesh	100,800	60.26													5	9
Bujumbura	Burundi	315,000	38.93													3	11
Garoua	Cameroon	313,000	203.26													3	11
Calama	Chile	124,000	953.02													6	8
Chillan	Chile	167,000	530.90													5	9
Iquique	Chile	170,000	820.04													5	9
Talca	Chile	179,000	626.49													5	9
Valparaiso	Chile	285,000	444.72													4	10
Baoding	China	701,500	1,901.74													8	6
Benxi	China	957,000	1,377.60													7	7
Changde	China	1,374,000	998.26													6	8
Chifeng	China	1,087,000	1,372.56													7	7
Dandong	China	700,200	1,891.79													8	6
Huainan	China	1,349,100	1,003.02													6	8
Huzhou	China	1,077,000	1,543.86													7	7

City	Country	Population	City GDP (in millions)	Natural Hazards Exposure				Mortality				Economic Damage				Multi-haz. Econom. Risk	Multi-haz. Mortality Risk
				Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide		
				High / Medium / Low				High / Medium / Low				High / Medium / Low					
Jiangmen	China	427,900	1,761.45													8	6
Jiaxing	China	791,000	2,077.39													8	6
Liuzhou	China	928,000	1,528.26													7	7
Sucheng	China	237,000	512.25													6	8
Suining	China	1,428,000	914.02													6	8
Taicheng	China	950,000	1,446.51													7	7
Tangshan	China	1,671,000	67.95													2	12
Cucuta	Colombia	723,200	129.21													3	11
Valledupar	Colombia	274,300	292.80													5	9
Villavicencio	Colombia	284,600	266.18													5	9
Matanzas	Cuba	140,200	299.29													2	12
Praha (Prague, Prag)	Czech Republic	1,226,000	10,593.07													10	4
Eloy Alfaro (Alfaro)	Ecuador	137,800	792.34													7	7
Ibarra	Ecuador	122,200	193.03													5	9
San Miguel	El Salvador	227,414	343.40													5	9
Accra	Ghana	1,976,000	1,031.18													4	10
Bilaspur	India	330,291	190.96													5	9
Coimbatore	India	1,292,000	784.19													5	9
Indore	India	1,428,000	896.10													5	9
Korba	India	315,695	75.02													4	10
Nashik (Nasik)	India	1,136,000	978.54													5	9
Pemalang	Indonesia	109,300	171.38													7	7
Masjed-e Soleyman	Iran	116,883	16.02													2	12
Cordoba	Mexico	133,807	1,116.13													6	8
Matamoros	Mexico	376,279	2,456.22													6	8
Orizaba	Mexico	118,552	1,093.84													6	8
Santa Catarina	Mexico	225,976	3,879.31													7	7
Tultilan (Buenavista)	Mexico	190,000	1,510.80													6	8
Uruapan	Mexico	225,816	585.54													5	9
Taunggyi	Myanmar	154,100	59.96													5	9
Jimeta	Nigeria	213,300	125.73													4	10
Mubi	Nigeria	194,000	101.94													4	10
Chishtian Mandi	Pakistan	101,659	81.59													4	10
Ica	Peru	183,700	416.87													6	8
Sullana	Peru	180,400	410.31													6	8
Antipolo	Philippines	470,866	155.75													3	11
General Santos	Philippines	411,822	290.59													5	9
Iloilo	Philippines	365,820	654.58													5	9
San Jose	Philippines	108,254	53.30													5	9
Urdaneta	Philippines	111,582	42.99													5	9
Astrachan	Russia	486,100	934.76													8	6
Krasnojarsk	Russia	977,000	2,551.57													8	6
Mytisci	Russia	155,700	2,851.53													11	3
Saratov	Russia	915,000	1,177.52													8	6
Tomsk	Russia	482,100	1,767.23													9	5
Saint-Louis	Senegal	144,100	82.10													4	10
Novi Sad	Serbia and Monten.	182,778	113.91													9	5
Kassala	Sudan	295,100	307.76													5	9
Kusti	Sudan	218,400	73.48													4	10
Musoma	Tanzania	131,500	88.94													4	10
Barinas	Venezuela	228,598	305.22													4	10
Cumana	Venezuela	269,428	305.28													4	10
Guacara	Venezuela	137,816	574.76													5	9
Los Teques	Venezuela	183,142	1,365.65													6	8
Maracay	Venezuela	1,100,000	216.07													2	12
Maturin	Venezuela	283,318	379.80													4	10

City	Country	Population	City GDP (in millions)	Natural Hazards Exposure				Mortality				Economic Damage				Multi-haz. Econom. Risk	Multi-haz. Mortality Risk
				Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide		
				High Medium Low				High Medium Low				High Medium Low					
Merida	Venezuela	230,101	366.72													4	10
Qaleh-ye Naw	Afghanistan	115,200	17.44													2	11
Neuquen	Argentina	327,374	1,730.86													5	8
Oruro	Bolivia	232,311	192.69													4	9
Foz do Iguacu	Brazil	256,349	1,663.14													6	7
Osorno	Chile	129,000	451.84													5	8
Valdivia	Chile	124,000	498.78													5	8
Baiyin	China	445,200	262.05													3	10
Fuxin	China	785,000	1,544.34													7	6
Fuyang	China	1,729,500	573.40													5	8
Guilin	China	611,200	1,038.19													6	7
Huaiyin	China	521,800	2,376.73													8	5
Jinzhou	China	834,000	1,516.09													7	6
Mianyang	China	1,065,000	869.48													6	7
Pingdingshan	China	723,000	1,340.23													7	6
Pingxiang	China	1,502,000	542.37													5	8
Shaoxing	China	324,300	3,637.83													9	4
Songyuan	China	502,100	88.09													4	9
Taizhou	China	588,000	1,947.96													8	5
Wuhai	China	391,000	238.87													4	9
Yanan	China	332,000	132.85													5	8
Sincelejo	Colombia	231,500	377.44													5	8
Sogamoso	Colombia	111,800	412.01													6	7
Tulua	Colombia	157,300	266.10													5	8
Bayamo	Cuba	181,900	372.97													5	8
Esmeraldas	Ecuador	129,900	224.76													5	8
Riobamba	Ecuador	125,100	269.54													5	8
Bhopal	India	1,576,000	659.67													4	9
Jamshedpur	India	1,002,000	659.80													4	9
Kozhikode (Calicut)	India	1,115,000	596.85													4	9
Madurai	India	1,275,000	1,105.93													5	8
Manado	Indonesia	344,100	462.89													4	9
Tasikmalaya	Indonesia	221,500	886.55													5	8
Nakuru	Kenya	319,200	224.70													4	9
Blantyre	Malawi	518,800	287.40													4	9
Kota Baharu	Malaysia	233,673	2,110.38													5	8
Sungai Petani	Malaysia	170,000	1,377.01													5	8
Chilpancingo	Mexico	142,746	476.82													4	9
Ciudad del Carmen	Mexico	126,024	183.53													4	9
Ciudad Valles	Mexico	105,721	427.53													5	8
Durango	Mexico	427,135	1,352.39													5	8
Ensenada	Mexico	223,492	1,158.09													5	8
Pachuca	Mexico	231,602	643.39													4	9
Mergui	Myanmar	143,700	52.03													5	8
Masaya	Nicaragua	110,000	327.62													6	7
Maradi	Niger	503,061	39.60													2	11
Muzaffargarh	Pakistan	121,641	5.32													1	12
Pucallpa	Peru	227,500	335.30													5	8
Bacolod	Philippines	429,076	564.68													4	9
San Carlos (Pangasinan)	Philippines	154,264	41.19													4	9
Surigao	Philippines	118,534	40.45													2	11
Plock	Poland	130,900	525.17													9	4
Jaroslavl	Russia	616,700	1,160.67													8	5
Maribor	Slovenia	100,900	1,274.70													8	5
Ashgabad (Aschabad)	Turkmenistan	605,000	708.01													8	5
Barcelona	Venezuela	311,475	207.81													3	10

City	Country	Population	City GDP (in millions)	Natural Hazards Exposure				Mortality				Economic Damage				Multi-haz. Econom. Risk	Multi-haz. Mortality Risk
				Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide		
					High				High				High				
					Medium				Medium				Medium				
					Low				Low				Low				
El Limon	Venezuela	119,602	438.08		0				0				0			5	8
Baglan	Afghanistan	114,200	2.07		0				0				0			1	11
Catamarca	Argentina	140,000	210.86		0		0		0		0		0		0	3	9
Mar del Plata	Argentina	579,483	610.85	0	0			0	0			0	0			3	9
Bobrujsk	Belarus	227,700	146.78	0	0		0	0	0		0	0	0		0	8	4
Mahileu	Belarus	372,700	189.06	0	0		0	0	0		0	0	0		0	7	5
Goiania	Brazil	1,106,000	5,353.07	0	0		0	0	0		0	0	0		0	5	7
Burgas	Bulgaria	192,900	203.14		0		0		0		0		0		0	8	4
Ruse	Bulgaria	165,400	133.75		0		0		0		0		0		0	8	4
Varna	Bulgaria	293,600	280.83		0				0				0			8	4
Douala	Cameroon	1,670,000	812.60	0	0			0	0			0	0			2	10
Bengbu	China	747,600	851.48	0	0			0	0			0	0			6	6
Huaibei	China	762,700	843.26	0	0			0	0			0	0			6	6
Jiaozuo	China	717,100	1,042.20	0	0			0	0			0	0			6	6
Jixi	China	949,000	655.41	0	0		0	0	0		0	0	0		0	5	7
Maoming	China	663,700	1,114.84	0	0			0	0			0	0			6	6
Shaoguan	China	494,600	1,694.61	0	0			0	0			0	0			7	5
Shizuishan	China	323,900	157.09		0		0		0		0		0		0	3	9
Zhaoqing	China	459,100	1,130.00	0	0			0	0			0	0			6	6
Popayan	Colombia	204,900	251.36		0	0			0	0			0	0		4	8
Brazzaville	Congo	1,234,000	518.20	0	0			0	0			0	0			2	10
Las Tunas	Cuba	144,300	310.84		0	0	0		0	0	0		0	0	0	5	7
Bukavu	Dem. Rep. of Congo	231,800	78.80		0		0		0		0		0		0	3	9
Goma	Dem. Rep. of Congo	142,900	55.20		0				0				0			3	9
Portoviejo	Ecuador	180,300	125.15		0				0				0			3	9
Santo Domingo de los Colorad	Ecuador	189,800	83.43		0				0				0			3	9
Al-Uqsor (Luxor)	Egypt	360,503	3,035.52	0	0		0	0	0		0	0	0		0	6	6
Skopje	FYR Macedonia	520,500	1,022.04		0				0				0		0	8	4
Port Blair	India	100,186	0.63		0	0			0	0			0	0		1	11
Rajkot	India	913,000	798.31	0	0		0	0	0		0	0	0		0	5	7
Tiruchirppalli	India	820,000	879.53	0	0		0	0	0		0	0	0		0	5	7
Adiwerna	Indonesia	101,800	529.42		0				0				0			6	6
Blitar	Indonesia	137,600	292.73		0				0				0			5	7
Jember	Indonesia	231,800	547.20		0	0			0	0			0	0		4	8
Celaya	Mexico	277,750	1,477.27	0	0			0	0			0	0			5	7
Iguala	Mexico	104,759	306.10		0				0				0			4	8
Irapuato	Mexico	319,148	826.74	0	0			0	0			0	0			4	8
La Piedad	Mexico	162,954	256.71		0				0				0			3	9
Zamora de Hidalgo	Mexico	122,881	385.37		0				0				0			4	8
Bama	Nigeria	100,500	40.51	0	0		0	0	0		0	0	0		0	3	9
Gashua	Nigeria	107,100	56.07	0	0		0	0	0		0	0	0		0	3	9
Chincha Alta	Peru	125,200	241.74		0		0		0		0		0		0	5	7
Huanuco	Peru	137,900	180.65		0				0				0			4	8
Lapu-Lapu	Philippines	217,019	883.76		0	0			0	0			0	0		5	7
Mandaue	Philippines	259,728	449.13		0	0			0	0			0	0		4	8
Zamboanga	Philippines	601,794	81.75		0	0	0		0	0	0		0	0	0	2	10
Kielce	Poland	211,700	485.44	0	0		0	0	0		0	0	0		0	8	4
Torun (Thorn)	Poland	206,100	533.13	0	0		0	0	0		0	0	0		0	8	4
Wloclawek	Poland	123,400	426.10	0	0		0	0	0		0	0	0		0	8	4
Oradea	Romania	220,700	298.03	0	0		0	0	0		0	0	0		0	7	5
Beboksary	Russia	459,200	411.46	0	0		0	0	0		0	0	0		0	7	5
Berepovec	Russia	324,400	1,064.48	0	0		0	0	0		0	0	0		0	8	4
Jekaterinburg	Russia	1,431,000	3,351.89	0	0		0	0	0		0	0	0		0	8	4
Kurgan	Russia	364,700	278.03	0	0		0	0	0		0	0	0		0	6	6
Podolsk	Russia	194,300	9,102.64	0	0		0	0	0		0	0	0		0	10	2
Tver	Russia	454,900	604.68	0	0		0	0	0		0	0	0		0	7	5

City	Country	Population	City GDP (in millions)	Natural Hazards Exposure				Mortality				Economic Damage				Multi-haz. Econom. Risk	Multi-haz. Mortality Risk
				Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide		
					High				High				High				
					Medium				Medium				Medium				
					Low				Low				Low				
Kaolack	Senegal	221,400	95.62													3	9
Mtwara	Tanzania	131,400	69.56													3	9
Kyyiv (Kiev, Kiew)	Ukraine	2,670,000	1,364.94													7	5
Termiz (Termez)	Uzbekistan	124,100	59.83													5	7
Harare	Zimbabwe	1,752,000	320.60													2	10
San Carlos de Bariloche	Argentina	105,093	448.33													4	7
San Rafael	Argentina	111,066	153.67													3	8
Sucre	Bolivia	192,238	148.88													3	8
Tarija	Bolivia	135,679	152.97													4	7
Natal	Brazil	1,038,830	2,998.95													4	7
Coquimbo	Chile	133,000	292.08													3	8
Puerto Montt	Chile	134,000	488.75													4	7
Chengde	China	417,200	61.26													2	9
Deyang	China	594,400	762.81													6	5
Guangyuan	China	867,100	329.12													4	7
Huizhou	China	358,700	1,344.60													7	4
Mudanjiang	China	801,000	601.67													5	6
Tieling	China	419,700	835.33													6	5
Zaoyang	China	1,121,000	450.12													4	7
Cartago	Colombia	130,500	186.63													4	7
Girardot	Colombia	117,000	199.29													4	7
Tunja	Colombia	109,600	169.64													4	7
Palma Soriano	Cuba	108,400	199.21													4	7
Sancti Spiritus	Cuba	120,800	339.35													5	6
Manta	Ecuador	168,800	95.97													3	8
Asyut (Assiut)	Egypt	343,498	1,770.74													5	6
Mallawi	Egypt	119,283	3,796.70													7	4
Qina (Kena)	Egypt	171,275	3,288.59													7	4
Mangalore	India	538,560	643.96													4	7
Mysore	India	742,261	478.65													4	7
Banjarmasin	Indonesia	553,000	874.75													6	5
Palu	Indonesia	175,900	196.94													4	7
Pematangsiantar	Indonesia	240,800	321.86													3	8
Sukabumi	Indonesia	140,700	437.15													4	7
Talang	Indonesia	131,800	419.40													5	6
Riga	Latvia	775,000	3,104.57													8	3
Monrovia	Liberia	1,347,600	60.82													1	10
Kuantan	Malaysia	283,041	920.63													2	9
Kuching	Malaysia	152,310	437.89													1	10
Ciudad Acuna	Mexico	108,159	2,420.17													6	5
Nicolas Romero	Mexico	216,192	468.44													3	8
Nogales	Mexico	156,854	1,722.09													5	6
Piedras Negras	Mexico	126,386	2,248.93													6	5
Marrakech	Morocco	736,500	762.79													3	8
Thaton	Myanmar	101,300	41.50													4	7
Chinandega	Nicaragua	120,400	143.48													4	7
Leon	Nicaragua	153,200	113.90													3	8
Jos	Nigeria	722,900	300.00													2	9
Ciudad del Este	Paraguay	254,300	556.40													4	7
Ayacuchu	Peru	110,600	158.21													4	7
Cajamarca	Peru	101,200	160.21													4	7
Tarapoto	Peru	105,900	202.08													4	7
Iligan	Philippines	285,061	67.26													2	9
Santiago	Philippines	110,531	58.54													4	7
Grudziadz	Poland	102,500	251.90													7	4
Radom	Poland	231,600	506.97													7	4

City	Country	Population	City GDP (in millions)	Natural Hazards Exposure				Mortality				Economic Damage				Multi-haz. Econom. Risk	Multi-haz. Mortality Risk
				Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide		
				High Medium Low				High Medium Low				High Medium Low					
Dzerdinsk	Russia	277,100	746.49													7	4
Nidnekamsk	Russia	223,400	559.55													7	4
Novokujbysevsk	Russia	116,200	700.47													8	3
Novosibirsk	Russia	1,478,000	2,100.85													7	4
Syzran	Russia	186,900	572.79													7	4
Voloskij	Russia	286,900	688.19													7	4
Freetown	Sierra Leone	1,013,400	190.27													0	11
Abarah	Sudan	110,500	174.57													4	7
Mwanza	Tanzania	1,155,000	240.40													2	9
Carupano	Venezuela	121,892	278.62													3	8
Cua	Venezuela	101,868	216.71													3	8
Mariara	Venezuela	101,115	182.18													3	8
Thai Nguyen	Vietnam	131,500	58.12													5	6
La Rioja	Argentina	138,074	161.85													2	8
Brest	Belarus	304,200	153.33													6	4
Mazyr	Belarus	109,000	106.92													7	3
Sarajevo	Bosnia and Herzeg.	360,000	330.96													6	4
Juazeiro	Brazil	132,796	522.16													4	6
Petropolis	Brazil	270,489	8,335.14													6	4
Rio Grande	Brazil	179,422	760.43													4	6
Sao Jose dos Campos	Brazil	952,000	1,886.27													3	7
Sorocaba	Brazil	487,907	4,185.90													5	5
Plovdiv	Bulgaria	344,500	373.38													6	4
Ouagadougou	Burkina Faso	1,130,000	63.64													1	9
Bangui	Central African Republi	636,300	140.32													2	8
Los Angeles	Chile	113,000	57.84													2	8
Chaoyang	China	450,300	624.01													5	5
Chenzhou	China	617,200	331.32													4	6
Jinchang	China	190,200	104.63													3	7
Liaoyuan	China	451,700	671.25													5	5
Longyan	China	451,100	487.38													5	5
Qingyuan	China	521,300	567.71													5	5
Xinyu	China	775,800	417.47													4	6
Yichun	China	871,000	317.71													4	6
Zhaodong	China	851,000	380.47													4	6
Maicao	Colombia	114,300	197.32													4	6
Ciego de Avila	Cuba	118,400	258.35													4	6
Lubumbashi	Dem. Rep. of Congo	967,000	37.40													1	9
Mbuji-Mayi	Dem. Rep. of Congo	874,700	76.68													1	9
Loja	Ecuador	124,000	155.07													3	7
Milagro	Ecuador	130,800	139.88													3	7
Quevedo	Ecuador	126,900	103.49													3	7
Al-Minya (Minje)	Egypt	201,360	2,596.67													6	4
Aswan (Assuan)	Egypt	219,017	1,688.48													5	5
Sawhaj (Sohag)	Egypt	170,125	2,218.10													6	4
Conakry	Guinea	1,824,000	425.75													0	10
La Ceiba	Honduras	108,900	162.22													4	6
Ranchi	India	862,850	449.11													3	7
Ambon	Indonesia	261,300	92.05													2	8
Pontianak	Indonesia	492,300	527.59													5	5
Samarinda	Indonesia	494,800	648.87													5	5
Ipoh	Malaysia	566,211	2,022.51													3	7
Kelang	Malaysia	563,173	2,099.42													3	7
Petaling Jaya	Malaysia	438,084	4,500.55													4	6
Segou	Mali	132,400	54.13													2	8
Ciudad Victoria	Mexico	249,029	479.37													3	7

City	Country	Population	City GDP (in millions)	Natural Hazards Exposure				Mortality				Economic Damage				Multi-haz. Econom. Risk	Multi-haz. Mortality Risk
				Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide		
					High Medium Low				High Medium Low				High Medium Low				
San Cristobal de las Casas	Mexico	112,442	292.37													3	7
Soledad Diez Gutierrez	Mexico	169,574	41.69													1	9
Dawei	Myanmar	113,400	40.71													4	6
Lashio	Myanmar	126,100	46.19													5	5
Abeokuta	Nigeria	516,700	426.46													3	7
Onitsha	Nigeria	496,300	335.55													2	8
Lipa	Philippines	218,447	70.66													2	8
Lodz	Poland	1,055,000	1,859.95													6	4
Poznan	Poland	578,900	2,579.35													7	3
Omsk	Russia	1,216,000	1,934.98													6	4
Rostov-na-Donu	Russia	1,049,000	1,588.16													6	4
Surgut	Russia	274,900	385.66													6	4
Voronesh	Russia	940,000	1,356.43													6	4
Zel'onodol'sk	Russia	100,200	561.23													7	3
Ziguinchor	Senegal	200,700	67.31													2	8
Dnipropetrovsk	Ukraine	1,129,000	1,298.97													7	3
Donetsk	Ukraine	1,075,000	1,176.70													7	3
Zaporizhzhya	Ukraine	878,000	1,055.17													7	3
Guanare	Venezuela	112,000	115.80													2	8
Ocumare del Tuy	Venezuela	101,707	136.41													2	8
Punto Fijo	Venezuela	109,362	24.46													1	9
Tirana	Albania	299,300	199.93													3	6
Bahia Blanca	Argentina	281,161	388.34													2	7
San Luis	Argentina	146,885	204.71													2	7
Baranavici (Baranovici)	Belarus	175,700	111.84													6	3
Pinsk	Belarus	134,700	88.26													6	3
Soligorsk	Belarus	101,200	70.05													6	3
Potosi	Bolivia	147,351	84.19													2	7
Cuiaba	Brazil	475,632	3,261.39													4	5
Jacarei	Brazil	183,444	847.09													4	5
Joao Pessoa	Brazil	896,345	1,882.61													3	6
Londrina	Brazil	433,264	3,777.73													4	5
Maceio	Brazil	919,128	2,084.50													3	6
Manaus	Brazil	1,436,000	371.99													1	8
Ribeirao Preto	Brazil	502,333	3,826.89													4	5
Timon	Brazil	111,967	302.85													3	6
Punta Arenas	Chile	122,000	149.79													2	7
Dongchuan	China	293,200	28.89													1	8
Hanzhong	China	491,900	391.70													4	5
Jiayuguan	China	142,900	74.10													2	7
Jinhua	China	338,100	561.87													5	4
Luohe	China	328,700	632.88													5	4
Qitaihe	China	469,500	346.46													4	5
Shaoyang	China	587,600	311.67													4	5
Shiyan	China	464,500	477.24													4	5
Shuozhou	China	528,200	252.44													4	5
Tongchuan	China	441,600	394.64													4	5
Yuxi	China	365,100	178.71													4	5
Zunyi	China	583,700	482.74													4	5
Brno (Bruenn)	Czech Republic	382,800	1,550.96													6	3
Kolwezi	Dem. Rep. of Congo	776,300	0.01													1	8
Kafr ad-Dawwar	Egypt	231,978	1,013.25													4	5
Tallinn	Estonia	403,981	2,008.13													6	3
Dire Dawa	Ethiopia	309,600	76.37													2	7
Ichalkaranji (Ichaikaroji)	India	257,572	615.46													4	5
Jamnagar	India	558,462	395.85													3	6

City	Country	Population	City GDP (in millions)	Natural Hazards Exposure				Mortality				Economic Damage				Multi-haz. Econom. Risk	Multi-haz. Mortality Risk
				Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide		
				High / Medium / Low				High / Medium / Low				High / Medium / Low					
Kota	India	695,899	382.45													3	6
Nanded	India	430,598	387.25													3	6
Thrissur	India	330,067	391.12													3	6
Tiruppur	India	542,787	305.87													3	6
Banyuwangi	Indonesia	110,700	204.85													3	6
Bengkulu	Indonesia	253,000	60.25													1	8
Al-Hillah	Iraq	489,300	310.48													2	7
An-Najaf	Iraq	529,400	363.62													2	7
An-Nasiriryah	Iraq	497,200	312.13													2	7
Karbala	Iraq	516,000	303.52													2	7
Taraz	Kazakhstan	330,100	224.72													5	4
Eldoret	Kenya	234,400	153.79													3	6
Lilongwe	Malawi	473,000	209.87													2	7
Ampang	Malaysia	126,459	6,322.82													5	4
Coatzacoalcos	Mexico	225,973	32.95													1	8
Xai-Xai	Mozambique	112,000	81.71													2	7
Calabar	Nigeria	418,600	265.81													2	7
Oshogbo	Nigeria	412,700	177.80													2	7
Roxas	Philippines	126,352	116.82													3	6
Silay	Philippines	107,722	247.05													3	6
Tacloban	Philippines	178,639	146.32													2	7
Tagum	Philippines	179,531	83.64													2	7
Balakovo	Russia	206,000	260.04													5	4
Engels	Russia	189,000	465.94													6	3
Joskar-Ola	Russia	249,200	359.37													5	4
Korolov	Russia	132,400	304.78													6	3
Kostroma	Russia	288,100	368.31													5	4
Lipeck	Russia	521,000	1,536.56													6	3
Nachodka	Russia	157,700	153.41													5	4
Novodeboksarsk	Russia	123,400	351.08													6	3
Orenburg	Russia	523,600	1,310.15													6	3
Toljatti	Russia	722,900	1,848.24													6	3
Podgorica (Titograd)	Serbia and Monten.	130,875	90.07													5	4
Kismayu	Somalia	195,900	17.26													1	8
Juba	Sudan	144,600	101.98													3	6
Mbeya	Tanzania	204,200	166.20													3	6
Chiang Mai	Thailand	167,776	913.91													6	3
Chaerjew (Chardzhou)	Turkmenistan	203,000	336.55													6	3
Chernivtsi	Ukraine	255,900	82.53													5	4
Krovy Rig	Ukraine	693,500	914.48													6	3
Rivne	Ukraine	244,500	77.07													5	4
Calabozo	Venezuela	102,000	139.51													2	7
El Tigre	Venezuela	119,609	125.12													2	7
Guatire	Venezuela	115,264	105.44													2	7
Kitwe	Zambia	762,700	73.51													1	8
Rio Cuarto	Argentina	150,000	234.51													2	6
Trelew	Argentina	101,425	521.44													3	5
Ganca	Azerbaijan	294,700	499.36													5	3
Aracaju	Brazil	460,898	1,816.20													3	5
Juiz de Fora	Brazil	443,359	2,005.51													3	5
Uberlandia	Brazil	487,887	2,292.79													3	5
Badaojiang	China	320,000	449.97													4	4
Heyuan	China	247,500	468.25													4	4
Jingdezhen	China	403,100	377.06													4	4
Sanming	China	269,900	426.68													4	4
Shuangyashan	China	502,800	173.28													3	5

City	Country	Population	City GDP (in millions)	Natural Hazards Exposure				Mortality				Economic Damage				Multi-haz. Econom. Risk	Multi-haz. Mortality Risk
				Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide		
				High Medium Low				High Medium Low				High Medium Low					
Tonghua	China	428,700	439.65													4	4
Wuzhou	China	328,400	452.02													4	4
Kisangani	Dem. Rep. of Congo	497,800	39.72													1	7
Uvira	Dem. Rep. of Congo	182,300	9.55													1	7
Debrecen	Hungary	209,600	142.00													4	4
Dhule	India	341,473	307.74													3	5
Gaya	India	394,185	185.01													2	6
Junagadh	India	252,138	147.79													2	6
Malegaon	India	409,190	392.26													3	5
Raurkela (Rourkela)	India	484,292	294.59													3	5
Shimoga	India	274,105	307.62													3	5
Ujjain	India	429,933	208.26													2	6
Kupang	Indonesia	159,300	163.77													2	6
Magelang	Indonesia	138,100	199.55													2	6
Mertoyudan	Indonesia	119,000	89.87													2	6
Tebingtinggi	Indonesia	139,400	189.01													2	6
Ar-Ramadi	Iraq	388,300	210.06													2	6
Aqtobe	Kazakhstan	253,100	781.36													6	2
Astana	Kazakhstan	313,000	609.35													6	2
Earaoanda	Kazakhstan	436,900	875.44													6	2
Oskemen	Kazakhstan	311,000	707.92													6	2
Pavlodar	Kazakhstan	300,500	719.50													6	2
Kaunas	Lithuania	414,200	1,120.69													5	3
Vilnius	Lithuania	578,300	1,252.39													5	3
Bukit Mertajam	Malaysia	210,000	4,208.76													4	4
Shah Alam	Malaysia	319,612	2,818.36													3	5
San Pedro Garza Garcia	Mexico	125,945	556.57													3	5
Kenitra	Morocco	330,200	403.24													2	6
Talara	Peru	100,600	45.07													2	6
Bago	Philippines	141,721	91.67													2	6
Ormoc	Philippines	154,297	37.47													1	7
Pagadian	Philippines	142,515	14.26													1	7
Opole	Poland	129,500	357.25													5	3
Arkhangelsk	Russia	361,800	849.02													5	3
Dimitrovgrad	Russia	137,000	191.85													5	3
Magnitogorsk	Russia	427,900	1,025.49													5	3
Miass	Russia	166,200	333.55													5	3
Nidnij Tagil	Russia	390,900	975.91													5	3
Nikolo-Berjozovka	Russia	115,700	243.97													5	3
Serov	Russia	132,000	228.35													5	3
T'umen'	Russia	503,800	941.95													5	3
Ustinov	Russia	652,800	1,236.13													5	3
Kigali	Rwanda	351,400	229.74													2	6
Arusha	Tanzania	160,100	137.35													3	5
Kigoma	Tanzania	120,500	55.29													2	6
Moshi	Tanzania	188,300	118.55													3	5
Dashhowuz (Tasauz)	Turkmenistan	165,000	196.54													5	3
Mary	Turkmenistan	123,000	321.87													6	2
Dniprodzerzhynsk	Ukraine	266,300	649.47													6	2
Kerch	Ukraine	160,900	240.65													5	3
Luhansk (Vorosilovgrad)	Ukraine	459,700	633.69													6	2
Lutsk	Ukraine	216,800	86.12													5	3
Makiyivka	Ukraine	377,500	743.43													6	2
Mariupol' (Zdanov)	Ukraine	484,400	654.85													6	2
Sevastopol	Ukraine	344,400	359.61													5	3
Urgench	Uzbekistan	165,400	63.02													4	4

City	Country	Population	City GDP (in millions)	Natural Hazards Exposure				Mortality				Economic Damage				Multi-haz. Econom. Risk	Multi-haz. Mortality Risk
				Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide		
				High / Medium / Low				High / Medium / Low				High / Medium / Low					
Chitungwiza	Zimbabwe	390,600	148.07													2	6
Elbasan	Albania	101,300	75.11													3	4
Orsa	Belarus	124,500	73.82													4	3
Banja Luka	Bosnia and Herzeg.	160,000	133.78													4	3
Blumenau	Brazil	241,987	2,108.89													3	4
Cabo Frio	Brazil	106,326	2,434.30													4	3
Feira de Santana	Brazil	431,458	2,029.02													3	4
Ipatinga	Brazil	210,777	1,668.76													3	4
Limeira	Brazil	237,959	1,436.95													3	4
Piracicaba	Brazil	316,518	1,571.99													3	4
Ponta Grossa	Brazil	266,552	1,541.01													3	4
Volta Redonda	Brazil	242,773	2,096.55													3	4
Huaihua	China	301,500	293.36													3	4
Yichun	China	904,000	53.69													1	6
Plzen (Pilsen)	Czech Republic	167,100	882.65													5	2
Boma	Dem. Rep. of Congo	341,100	15.80													1	6
Bunia	Dem. Rep. of Congo	123,700	1.08													1	6
Likasi	Dem. Rep. of Congo	364,700	16.03													1	6
Tshikapa	Dem. Rep. of Congo	302,300	5.22													1	6
Nazret	Ethiopia	161,800	62.01													2	5
Bissau	Guinea-Bissau	279,900	42.02													1	6
Georgetown	Guyana	223,900	41.62													1	6
Aurangabad	India	1,012,000	793.90													1	6
Chandrapur	India	297,612	364.64													3	4
Erode	India	391,169	217.03													2	5
Jalgaon	India	368,579	99.94													2	5
Jhansi	India	463,281	165.26													2	5
Nizamabad	India	286,956	202.50													2	5
Sagar	India	309,164	111.54													2	5
Tirunelveli	India	431,603	196.22													2	5
Udaipur	India	389,317	214.55													2	5
Vellore	India	388,211	200.14													2	5
Lhokseumawe	Indonesia	135,000	43.26													1	6
Al-Fallujah	Iraq	221,600	150.35													2	5
Kostanay	Kazakhstan	221,400	595.28													5	2
Semey	Kazakhstan	269,600	547.03													5	2
Uralsk	Kazakhstan	195,500	462.15													5	2
Nairobi	Kenya	2,310,000	2,809.10													0	7
George Town	Malaysia	180,573	2,312.07													3	4
Kuala Terengganu	Malaysia	250,528	1,484.40													2	5
Salamanca	Mexico	137,000	391.38													2	5
Tighina	Moldova	148,100	61.95													4	3
Tiraspol'	Moldova	214,700	57.25													4	3
Bauchi	Nigeria	283,700	111.08													1	6
Ede	Nigeria	234,100	173.75													2	5
Cadiz	Philippines	141,954	5.43													1	6
Calapan	Philippines	105,910	7.68													1	6
Dumaguete	Philippines	102,265	126.36													2	5
Gingoog	Philippines	102,379	6.55													1	6
Sagay	Philippines	129,765	31.77													1	6
Toledo	Philippines	141,174	39.10													1	6
Lublin	Poland	356,000	814.27													4	3
Barnaul	Russia	580,100	617.25													4	3
Belgorod	Russia	342,000	727.66													4	3
Kaluga	Russia	339,300	625.33													4	3
Kamysin	Russia	124,600	161.27													4	3

City	Country	Population	City GDP (in millions)	Natural Hazards Exposure				Mortality				Economic Damage				Multi-haz. Econom. Risk	Multi-haz. Mortality Risk
				Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide		
				High Medium Low				High Medium Low				High Medium Low					
Kirov	Russia	466,200	800.51													4	3
Kursk	Russia	443,500	709.09													4	3
Nidnevartovsk	Russia	233,900	78.25													3	4
Novokuzneck	Russia	561,600	781.54													4	3
Penza	Russia	532,200	656.09													4	3
Ryazan	Russia	529,900	750.11													4	3
Sarapul	Russia	105,700	192.90													4	3
Vladimir	Russia	337,100	578.34													4	3
Niyala	Sudan	285,800	88.70													1	6
Shinyanga	Tanzania	102,100	64.14													2	5
Zanzibar	Tanzania	247,500	199.76													2	5
Nakhon Ratchasima	Thailand	204,391	451.97													4	3
Surat Thani	Thailand	111,276	398.83													4	3
Bathurst	The Gambia	200,000	150.57													2	5
Kherson	Ukraine	351,700	500.23													5	2
Kremenchuk	Ukraine	234,000	476.25													5	2
Lviv	Ukraine	813,000	239.95													4	3
Mykolayiv	Ukraine	518,200	594.97													5	2
Simferopol	Ukraine	330,600	385.21													4	3
Nuqus (Nukus)	Uzbekistan	246,500	30.14													3	4
Tuzla	Bosnia and Herzeg.	160,000	79.64													3	3
Zenica	Bosnia and Herzeg.	146,000	77.75													3	3
Governador Valadares	Brazil	235,881	1,022.34													2	4
Itajai	Brazil	141,932	2,227.08													3	3
Itu	Brazil	123,881	1,918.02													3	3
Porto Velho	Brazil	273,496	987.59													2	4
Rio Branco	Brazil	226,054	496.00													2	4
Taubate	Brazil	229,810	641.73													2	4
Maroua	Cameroon	238,200	121.65													1	5
Nkongsamba	Cameroon	106,800	23.84													0	6
Yingtan	China	166,200	205.64													3	3
Zhangjiajie	China	449,400	47.28													1	5
Butembo	Dem. Rep. of Congo	143,300	3.49													1	5
Kalemie	Dem. Rep. of Congo	107,400	11.20													1	5
Kikwit	Dem. Rep. of Congo	217,100	6.56													1	5
Matadi	Dem. Rep. of Congo	219,500	35.60													1	5
Mbandaka	Dem. Rep. of Congo	201,800	1.64													1	5
Gambella	Ethiopia	223,600	8.70													1	5
Harar	Ethiopia	161,200	35.98													1	5
Jimma	Ethiopia	112,500	41.93													1	5
Mekele	Ethiopia	122,700	80.62													2	4
Nyiregyhaza	Hungary	118,500	94.92													3	3
Pecs	Hungary	162,700	348.58													3	3
Alwar	India	265,850	140.84													2	4
Bhilwara	India	280,185	157.50													2	4
Firozabad	India	278,801	211.67													2	4
Salem	India	693,236	635.71													1	5
Samarra	Iraq	305,900	80.77													1	5
Petropavl	Kazakhstan	203,500	319.82													4	2
Rudny	Kazakhstan	109,500	431.30													5	1
Temirtau	Kazakhstan	170,500	515.97													5	1
Alor Setar	Malaysia	114,949	2,122.45													3	3
Kota Kinabalu	Malaysia	145,000	1,611.91													0	6
Sibu	Malaysia	155,000	698.24													2	4
Oujda	Morocco	163,000	237.44													2	4
Gusau	Nigeria	196,400	108.77													1	5

City	Country	Population	City GDP (in millions)	Natural Hazards Exposure				Mortality				Economic Damage				Multi-haz. Econom. Risk	Multi-haz. Mortality Risk
				Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide		
					High				High				High				
					Medium				Medium				Medium				
					Low				Low				Low				
Iwo	Nigeria	206,600	104.59	0	0		0	0	0		0	0	0		0	1	5
Makurdi	Nigeria	243,900	91.70	0	0			0	0			0	0			1	5
Minna	Nigeria	262,000	69.55	0	0		0	0	0		0	0	0		0	1	5
Bialystok	Poland	285,000	604.64	0	0		0	0	0		0	0	0		0	4	2
Czestochowa	Poland	256,500	553.96	0	0		0	0	0		0	0	0		0	4	2
Abakan	Russia	169,200	523.51	0	0		0	0	0		0	0	0		0	4	2
Balasicha	Russia	132,900	602.42	0	0		0	0	0		0	0	0		0	4	2
Berezniki	Russia	181,900	526.61	0	0		0	0	0		0	0	0		0	4	2
Bijsk	Russia	225,000	118.80	0	0		0	0	0		0	0	0		0	3	3
Bratsk	Russia	457,400	387.24	0	0		0	0	0		0	0	0		0	3	3
Ivanovo	Russia	459,200	369.11	0	0		0	0	0		0	0	0		0	3	3
Orel	Russia	344,500	502.16	0	0		0	0	0		0	0	0		0	3	3
Orsk	Russia	273,900	560.17	0	0		0	0	0		0	0	0		0	4	2
Petrozavodsk	Russia	282,100	644.26	0	0		0	0	0		0	0	0		0	4	2
Prokopjevsk	Russia	237,300	577.17	0	0		0	0	0		0	0	0		0	4	2
Staryj Oskol	Russia	213,800	646.02	0	0		0	0	0		0	0	0		0	4	2
Syktyvkar	Russia	229,700	766.31	0	0		0	0	0		0	0	0		0	4	2
Ussurijsk	Russia	157,300	140.80	0	0		0	0	0		0	0	0		0	3	3
Nis	Serbia and Monten.	182,583	69.07		0				0				0			3	3
Pristina	Serbia and Monten.	186,611	65.43		0		0		0		0		0		0	3	3
Ar-Raqqah	Syria	207,900	405.07	0	0		0	0	0		0	0	0		0	2	4
Dayr az-Zawr	Syria	204,900	340.93	0	0		0	0	0		0	0	0		0	2	4
Geita	Tanzania	135,100	156.86	0	0		0	0	0		0	0	0		0	2	4
Tanga	Tanzania	202,900	110.69	0	0			0	0			0	0			1	5
Kirovohrad	Ukraine	261,700	322.57	0	0		0	0	0		0	0	0		0	4	2
Lysychansk	Ukraine	114,300	472.15	0	0		0	0	0		0	0	0		0	5	1
Poltava	Ukraine	311,000	351.92	0	0		0	0	0		0	0	0		0	4	2
Sumy	Ukraine	292,300	324.43	0	0		0	0	0		0	0	0		0	4	2
Kabwe	Zambia	208,200	43.29	0	0		0	0	0		0	0	0		0	1	5
Benguela	Angola	129,800	250.75	0	0		0	0	0		0	0	0		0	1	4
Lobito	Angola	133,100	409.93	0	0		0	0	0		0	0	0		0	1	4
Grodno	Belarus	311,500	158.71	0	0		0	0	0		0	0	0		0	3	2
Vitebsk	Belarus	356,000	216.62	0	0		0	0	0		0	0	0		0	3	2
Barra Mansa	Brazil	164,963	983.04	0	0		0	0	0		0	0	0		0	2	3
Boa Vista	Brazil	196,942	479.37	0	0			0	0			0	0			2	3
Cachoeiro de Itapemirim	Brazil	154,771	918.90	0	0			0	0			0	0			2	3
Campos dos Goytacazes	Brazil	363,489	304.18	0	0			0	0			0	0			1	4
Caruaru	Brazil	217,084	632.64	0	0		0	0	0		0	0	0		0	2	3
Divinopolis	Brazil	177,729	739.38	0	0		0	0	0		0	0	0		0	2	3
Ilheus	Brazil	161,898	496.97	0	0		0	0	0		0	0	0		0	2	3
Itabuna	Brazil	190,888	867.79	0	0		0	0	0		0	0	0		0	2	3
Itapetininga	Brazil	111,774	673.70	0	0			0	0			0	0			2	3
Jau	Brazil	106,954	641.16	0	0			0	0			0	0			2	3
Jequie	Brazil	130,207	501.24	0	0			0	0			0	0			2	3
Macae	Brazil	125,118	734.95	0	0		0	0	0		0	0	0		0	2	3
Macapa	Brazil	270,077	259.26	0	0		0	0	0		0	0	0		0	1	4
Nossa Senhora do Socorro	Brazil	130,255	1,048.17	0	0		0	0	0		0	0	0		0	2	3
Patos de Minas	Brazil	111,159	505.08	0	0			0	0			0	0			2	3
Pindamonhangaba	Brazil	118,793	1,193.67	0	0			0	0			0	0			2	3
Pocos de Caldas	Brazil	130,594	646.46	0	0			0	0			0	0			2	3
Rio Claro	Brazil	163,341	1,013.25	0	0			0	0			0	0			2	3
Rondonopolis	Brazil	141,660	630.88	0	0			0	0			0	0			2	3
Santarem	Brazil	186,518	558.23	0	0			0	0			0	0			2	3
Santos	Brazil	1,260,000	6,256.16	0	0	0		0	0	0		0	0	0		2	3
Teresopolis	Brazil	114,688	804.61	0	0			0	0			0	0			2	3
Varginha	Brazil	103,499	494.96	0	0		0	0	0		0	0	0		0	2	3

City	Country	Population	City GDP (in millions)	Natural Hazards Exposure				Mortality				Economic Damage				Multi-haz. Econom. Risk	Multi-haz. Mortality Risk
				Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide		
					High				High				High				
					Medium				Medium				Medium				
					Low				Low				Low				
Varzea Grande	Brazil	210,849	1,299.82	0	0		0	0	0		0	0	0		0	2	3
Pleven	Bulgaria	118,700	98.76		0		0		0		0		0		0	3	2
Sliven	Bulgaria	103,900	69.75		0				0				0		0	3	2
Ngaoundere	Cameroon	167,100	99.96	0	0		0	0	0		0	0	0		0	1	4
Moundou	Chad	111,200	71.29	0	0		0	0	0		0	0	0		0	1	4
Karamay	China	263,100	8.14	0	0		0	0	0		0	0	0		0	1	4
Divo	Côte d'Ivoire	140,300	51.70	0	0		0	0	0		0	0	0		0	1	4
Gagnoa	Côte d'Ivoire	156,800	64.31	0	0		0	0	0		0	0	0		0	1	4
San-Pedro	Côte d'Ivoire	129,800	52.07	0	0		0	0	0		0	0	0		0	1	4
Bandundu	Dem. Rep. of Congo	112,900	10.36	0	0		0	0	0		0	0	0		0	1	4
Ilebo	Dem. Rep. of Congo	101,100	4.94	0	0			0	0			0	0			1	4
Kindu	Dem. Rep. of Congo	115,400	7.75	0	0		0	0	0		0	0	0		0	1	4
Belgaum	India	506,235	301.62	0	0	0		0	0	0		0	0	0		1	4
Ujungpandang	Indonesia	1,051,000	1,594.93	0	0	0		0	0	0		0	0	0		1	4
Atyrao	Kazakhstan	142,500	309.17	0	0		0	0	0		0	0	0		0	4	1
Maseru	Lesotho	164,700	55.80	0	0		0	0	0		0	0	0		0	1	4
Klaipoda	Lithuania	202,500	425.04	0	0		0	0	0		0	0	0		0	3	2
Panevooys	Lithuania	133,600	304.17	0	0		0	0	0		0	0	0		0	3	2
Siauliai	Lithuania	146,800	304.55	0	0		0	0	0		0	0	0		0	3	2
Gao	Mali	104,700	17.06	0	0		0	0	0		0	0	0		0	1	4
Mopti	Mali	114,400	36.34	0	0		0	0	0		0	0	0		0	1	4
Boloi	Moldova	179,400	60.68		0		0		0		0		0		0	2	3
Ksar-el-Kebir	Morocco	124,600	126.49	0	0			0	0			0	0			1	4
Nador	Morocco	110,000	141.11	0	0		0	0	0		0	0	0		0	1	4
Abakaliki	Nigeria	118,600	59.63	0	0		0	0	0		0	0	0		0	1	4
Benin	Nigeria	1,021,900	644.57	0	0	0		0	0	0		0	0	0		0	5
Bida	Nigeria	154,100	99.54	0	0		0	0	0		0	0	0		0	1	4
IfonÿOsun	Nigeria	103,300	46.69	0	0		0	0	0		0	0	0		0	1	4
Otukpo	Nigeria	134,000	1.02	0	0		0	0	0		0	0	0		0	1	4
Sapele	Nigeria	146,800	11.77	0	0		0	0	0		0	0	0		0	1	4
Marawi	Philippines	131,090	73.17	0	0			0	0			0	0			2	3
Gorzow Wielkopolski	Poland	126,400	397.88	0	0		0	0	0		0	0	0		0	3	2
Kalisz	Poland	106,600	587.51	0	0		0	0	0		0	0	0		0	4	1
Olsztyn	Poland	172,600	375.54	0	0		0	0	0		0	0	0		0	3	2
Rzeszow	Poland	162,300	419.06	0	0		0	0	0		0	0	0		0	3	2
Tarnow	Poland	121,400	303.12	0	0		0	0	0		0	0	0		0	3	2
Almetyevsk	Russia	140,700	367.14	0	0		0	0	0		0	0	0		0	3	2
Bratsk	Russia	277,600	475.28	0	0		0	0	0		0	0	0		0	3	2
Dita	Russia	309,900	279.04	0	0		0	0	0		0	0	0		0	3	2
Elektrostal'	Russia	147,000	453.95	0	0		0	0	0		0	0	0		0	3	2
Jakutsk	Russia	195,400	394.95	0	0		0	0	0		0	0	0		0	3	2
Jelec	Russia	119,700	298.34	0	0		0	0	0		0	0	0		0	3	2
Kaliningrad	Russia	424,400	271.43	0	0		0	0	0		0	0	0		0	2	3
Kamensk-Uralsky	Russia	190,600	394.04	0	0		0	0	0		0	0	0		0	3	2
Kinesma	Russia	100,000	64.77	0	0		0	0	0		0	0	0		0	2	3
Komsomolsk-na-Amure Dzen	Russia	291,600	282.26	0	0		0	0	0		0	0	0		0	3	2
Novomoskovsk	Russia	138,100	489.09	0	0		0	0	0		0	0	0		0	3	2
Oktyabraskiy	Russia	111,500	528.93	0	0		0	0	0		0	0	0		0	4	1
Pervouralsk	Russia	136,100	405.37	0	0		0	0	0		0	0	0		0	3	2
Rybinsk	Russia	239,600	433.23	0	0		0	0	0		0	0	0		0	3	2
Saransk	Russia	314,800	508.08	0	0		0	0	0		0	0	0		0	3	2
Serpuchov	Russia	229,300	307.26	0	0		0	0	0		0	0	0		0	3	2
Smolensk	Russia	353,400	243.23	0	0		0	0	0		0	0	0		0	2	3
Sterlitamak	Russia	265,200	418.75	0	0		0	0	0		0	0	0		0	3	2
Taganrog	Russia	284,400	452.73	0	0		0	0	0		0	0	0		0	3	2
Tambov	Russia	312,000	423.89	0	0		0	0	0		0	0	0		0	3	2

City	Country	Population	City GDP (in millions)	Natural Hazards Exposure				Mortality				Economic Damage				Multi-haz. Econom. Risk	Multi-haz. Mortality Risk
				Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide		
				High				High				High					
				Medium				Medium				Medium					
				Low				Low				Low					
Zelenograd	Russia	207,100	415.88	0	0		0	0	0		0	0	0		0	3	2
Zlatoust	Russia	196,900	355.44	0	0		0	0	0		0	0	0		0	3	2
Wau	Sudan	105,700	62.20	0	0		0	0	0		0	0	0		0	1	4
Paramaribo	Suriname	213,800	869.70	0	0		0	0	0		0	0	0		0	2	3
Iringa	Tanzania	137,900	112.62	0	0		0	0	0		0	0	0		0	1	4
Korogwe	Tanzania	101,200	58.79	0	0		0	0	0		0	0	0		0	1	4
Cherkasy	Ukraine	307,100	216.95	0	0		0	0	0		0	0	0		0	3	2
Horlivka	Ukraine	292,500	232.64	0	0		0	0	0		0	0	0		0	3	2
Nikopol	Ukraine	147,300	343.25	0	0		0	0	0		0	0	0		0	4	1
Stakhanov	Ukraine	100,400	290.26	0	0		0	0	0		0	0	0		0	4	1
Syeverodonets'k	Ukraine	124,100	293.69	0	0		0	0	0		0	0	0		0	4	1
Chingola	Zambia	149,900	29.89	0	0		0	0	0		0	0	0		0	1	4
Livingstone	Zambia	105,200	28.25	0	0			0	0			0	0			1	4
Luanshya	Zambia	124,300	37.17	0	0		0	0	0		0	0	0		0	1	4
Mufulira	Zambia	130,400	26.98	0	0		0	0	0		0	0	0		0	1	4
Barysau	Belarus	154,400	207.87	0	0		0	0	0		0	0	0		0	3	1
Araguaina	Brazil	105,701	249.39	0	0		0	0	0		0	0	0		0	1	3
Barreiras	Brazil	115,331	431.12	0	0			0	0			0	0			1	3
Braganca Paulista	Brazil	110,982	103.30	0	0		0	0	0		0	0	0		0	1	3
Caxias	Brazil	103,276	181.49	0	0			0	0			0	0			1	3
Imperatriz	Brazil	218,555	348.03	0	0		0	0	0		0	0	0		0	1	3
Maraba	Brazil	134,258	439.38	0	0		0	0	0		0	0	0		0	1	3
Nova Friburgo	Brazil	151,820	105.54	0	0			0	0			0	0			1	3
Parnaiba	Brazil	124,942	150.22	0	0		0	0	0		0	0	0		0	1	3
Petrolina	Brazil	166,113	339.43	0	0		0	0	0		0	0	0		0	1	3
Salvador	Brazil	3,187,000	5,750.45	0	0	0		0	0	0		0	0	0		1	3
Sao Luis	Brazil	950,000	1,383.86	0	0	0		0	0	0		0	0	0		1	3
Sobral	Brazil	134,371	227.87	0	0		0	0	0		0	0	0		0	1	3
Stara Zagora	Bulgaria	147,000	112.18		0	0			0	0			0	0		2	2
Bafoussam	Cameroon	217,100	129.91	0	0	0		0	0	0		0	0	0		0	4
Heihe	China	180,500	36.00	0	0		0	0	0		0	0	0		0	1	3
Yunfu	China	275,000	229.72	0	0	0		0	0	0		0	0	0		1	3
Olomouc (Olmuetz)	Czech Republic	102,800	387.21	0	0		0	0	0		0	0	0		0	3	1
Tirupati	India	302,678	215.83	0	0	0		0	0	0		0	0	0		1	3
Balikpapan	Indonesia	419,400	3,049.83	0	0	0		0	0	0		0	0	0		1	3
Palangkaraya	Indonesia	112,300	0.10	0	0		0	0	0		0	0	0		0	1	3
Kokshetao	Kazakhstan	123,400	224.55	0	0		0	0	0		0	0	0		0	3	1
Daugavpils	Latvia	114,829	262.75	0	0		0	0	0		0	0	0		0	2	2
Elblag	Poland	130,000	242.96	0	0		0	0	0		0	0	0		0	2	2
Koszalin	Poland	112,700	249.82	0	0		0	0	0		0	0	0		0	2	2
Legnica	Poland	109,200	472.96	0	0		0	0	0		0	0	0		0	3	1
Slupsk	Poland	102,200	285.37	0	0		0	0	0		0	0	0		0	3	1
Adinsk	Russia	121,600	227.85	0	0		0	0	0		0	0	0		0	2	2
Blagovesdensk	Russia	222,000	243.98	0	0		0	0	0		0	0	0		0	2	2
Kolomna	Russia	150,700	218.38	0	0		0	0	0		0	0	0		0	2	2
Kovrov	Russia	159,900	188.77	0	0		0	0	0		0	0	0		0	2	2
Leninsk-Kuzneckij	Russia	113,800	273.11	0	0		0	0	0		0	0	0		0	2	2
Meauredensk	Russia	104,400	399.57	0	0		0	0	0		0	0	0		0	3	1
Miaurinsk	Russia	120,700	127.55	0	0		0	0	0		0	0	0		0	2	2
Murom	Russia	142,400	148.07	0	0		0	0	0		0	0	0		0	2	2
Noginsk	Russia	117,200	220.32	0	0		0	0	0		0	0	0		0	2	2
Novgorod	Russia	231,700	161.95	0	0		0	0	0		0	0	0		0	2	2
Novoderkassk	Russia	184,400	274.97	0	0		0	0	0		0	0	0		0	2	2
Novotroick	Russia	109,600	345.21	0	0		0	0	0		0	0	0		0	3	1
Orechovo-Zujevo	Russia	124,900	214.24	0	0		0	0	0		0	0	0		0	2	2
Rubcovsk	Russia	162,600	119.45	0	0		0	0	0		0	0	0		0	2	2

City	Country	Population	City GDP (in millions)	Natural Hazards Exposure				Mortality				Economic Damage				Multi-haz. Econom. Risk	Multi-haz. Mortality Risk
				Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide		
				High Medium Low				High Medium Low				High Medium Low					
Selkovo	Russia	104,900	296.66	0	0		0	0	0		0	0	0		0	3	1
Sergijev Posad	Russia	111,100	341.34	0	0		0	0	0		0	0	0		0	3	1
Volgodonsk	Russia	178,200	171.45	0	0		0	0	0		0	0	0		0	2	2
Zeleznodorodnyj	Russia	100,100	521.13	0	0		0	0	0		0	0	0		0	3	1
Kragujevac	Serbia and Monten.	154,489	55.03		0	0	0		0	0	0		0	0	0	2	2
Nebitdag	Turkmenistan	119,000	90.77		0	0			0	0			0	0		2	2
Berdyansk	Ukraine	129,100	125.80	0	0		0	0	0		0	0	0		0	3	1
Bila Tserkva	Ukraine	209,600	61.31	0	0		0	0	0		0	0	0		0	2	2
Chernihiv	Ukraine	304,900	93.51	0	0		0	0	0		0	0	0		0	2	2
Ivano-Frankivs'k	Ukraine	237,800	75.22	0	0		0	0	0		0	0	0		0	2	2
Khmelnytskyi	Ukraine	258,000	76.69	0	0		0	0	0		0	0	0		0	2	2
Kommunarsk	Ukraine	116,100	225.67	0	0		0	0	0		0	0	0		0	3	1
Kramatorsk	Ukraine	183,200	237.38	0	0		0	0	0		0	0	0		0	3	1
Krasnyy Luch	Ukraine	100,400	144.83	0	0		0	0	0		0	0	0		0	3	1
Melitopol'	Ukraine	166,800	183.53	0	0		0	0	0		0	0	0		0	3	1
Oleksandriya	Ukraine	103,856	149.37	0	0		0	0	0		0	0	0		0	3	1
Pavlohrad	Ukraine	126,000	133.69	0	0		0	0	0		0	0	0		0	3	1
Slavyansk	Ukraine	124,500	188.76	0	0		0	0	0		0	0	0		0	3	1
Ternopil'	Ukraine	234,400	79.02	0	0		0	0	0		0	0	0		0	2	2
Uzhhorod	Ukraine	125,300	47.97		0		0		0		0		0		0	2	2
Vinnytsya	Ukraine	386,000	119.90	0	0		0	0	0		0	0	0		0	2	2
Yenakiyeve	Ukraine	104,400	195.81	0	0		0	0	0		0	0	0		0	3	1
Yevpatoriya	Ukraine	109,100	115.41		0	0	0		0	0	0		0	0	0	2	2
Zhytomyr	Ukraine	292,900	72.95	0	0		0	0	0		0	0	0		0	2	2
Buon Me Thuot	Vietnam	130,300	138.09	0	0	0		0	0	0		0	0	0		0	4
Lusaka	Zambia	1,640,000	307.38	0	0	0		0	0	0		0	0	0		0	4
Angra dos Reis	Brazil	114,237	351.57	0	0	0		0	0	0		0	0	0		1	2
Campo Grande	Brazil	654,832	3,047.59	0	0	0		0	0	0		0	0	0		1	2
Yaounde	Cameroon	1,444,000	868.77	0	0	0		0	0	0		0	0	0		0	3
Huangshan	China	401,700	89.10	0	0	0		0	0	0		0	0	0		1	2
Tartu	Estonia	101,246	250.08	0	0		0	0	0		0	0	0		0	2	1
Ekibastuz	Kazakhstan	127,200	64.85	0	0		0	0	0		0	0	0		0	2	1
Sandakan	Malaysia	220,000	828.90		0	0			0	0			0	0		0	3
Maymyo	Myanmar	100,400	41.40		0	0	0		0	0	0		0	0	0	1	2
Enugu	Nigeria	578,000	353.36	0	0	0		0	0	0		0	0	0		0	3
Umuahia	Nigeria	225,600	142.68	0	0	0		0	0	0		0	0	0		0	3
Calbayog	Philippines	147,187	6.37	0	0	0		0	0	0		0	0	0		1	2
Lucena	Philippines	196,075	144.60	0	0	0		0	0	0		0	0	0		1	2
Arzamas	Russia	110,700	254.89	0	0		0	0	0		0	0	0		0	2	1
Glazov	Russia	106,300	188.94	0	0		0	0	0		0	0	0		0	2	1
Kansk	Russia	107,400	226.08	0	0		0	0	0		0	0	0		0	2	1
Noril'sk	Russia	140,800	0.00	0	0	0		0	0	0		0	0	0		1	2
Novosachtinsk	Russia	101,900	141.19	0	0		0	0	0		0	0	0		0	2	1
Obninsk	Russia	108,300	245.60	0	0		0	0	0		0	0	0		0	2	1
Pskov	Russia	201,500	90.94	0	0		0	0	0		0	0	0		0	1	2
Severodvinsk	Russia	118,600	4.23	0	0		0	0	0		0	0	0		0	1	2
Solikamsk	Russia	106,000	210.98	0	0		0	0	0		0	0	0		0	2	1
UstIlimsk	Russia	105,200	109.62	0	0		0	0	0		0	0	0		0	2	1
Velikije Luki	Russia	116,300	31.54	0	0		0	0	0		0	0	0		0	1	2
Votkinsk	Russia	101,700	185.98	0	0		0	0	0		0	0	0		0	2	1
Prizren	Serbia and Monten.	115,711	43.74		0	0			0	0			0			1	2
Apucarana	Brazil	100,241	639.99	0	0	0		0	0	0		0	0	0		1	1
Bauru	Brazil	310,208	1,781.15	0	0	0		0	0	0		0	0	0		1	1
Botucatu	Brazil	103,793	556.72	0	0	0		0	0	0		0	0	0		1	1
Cascavel	Brazil	228,340	1,304.09	0	0	0		0	0	0		0	0	0		1	1
Catanduva	Brazil	104,195	622.77	0	0	0		0	0	0		0	0	0		1	1

City	Country	Population	City GDP (in millions)	Natural Hazards Exposure				Mortality				Economic Damage				Multi-haz. Econom. Risk	Multi-haz. Mortality Risk
				Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide		
					High				High				High				
					Medium				Medium				Medium				
					Low				Low				Low				
Caxias do Sul	Brazil	333,201	2,511.78	0	0	0		0	0	0		0	0	0		1	1
Chapeco	Brazil	134,210	877.07	0	0	0		0	0	0		0	0	0		1	1
Dourados	Brazil	149,679	608.03	0	0	0		0	0	0		0	0	0		1	1
Florianopolis	Brazil	321,778	1,661.16	0	0	0		0	0	0		0	0	0		1	1
Franca	Brazil	281,869	1,820.09	0	0	0		0	0	0		0	0	0		1	1
Guarapuava	Brazil	141,575	743.94	0	0	0		0	0	0		0	0	0		1	1
Joinville (Joinvile)	Brazil	414,350	2,364.16	0	0	0		0	0	0		0	0	0		1	1
Lajes	Brazil	152,320	976.35	0	0	0		0	0	0		0	0	0		1	1
Marilia	Brazil	189,533	1,141.14	0	0	0		0	0	0		0	0	0		1	1
Maringa	Brazil	283,792	1,932.85	0	0	0		0	0	0		0	0	0		1	1
Palmas	Brazil	133,471	171.51	0	0	0		0	0	0		0	0	0		1	1
Passo Fundo	Brazil	163,748	1,063.56	0	0	0		0	0	0		0	0	0		1	1
Presidente Prudente	Brazil	185,150	1,496.75	0	0	0		0	0	0		0	0	0		1	1
Rio Verde	Brazil	106,109	414.44	0	0	0		0	0	0		0	0	0		1	1
Santa Barbara d'Oeste	Brazil	167,574	85.44	0	0	0		0	0	0		0	0	0		1	1
Sao Carlos	Brazil	183,369	1,027.02	0	0	0		0	0	0		0	0	0		1	1
Sao Jose	Brazil	167,268	2,294.45	0	0	0		0	0	0		0	0	0		1	1
Sao Jose do Rio Preto	Brazil	336,998	2,807.22	0	0	0		0	0	0		0	0	0		1	1
Sete Lagoas	Brazil	180,211	717.45	0	0	0		0	0	0		0	0	0		1	1
Uberaba	Brazil	243,406	1,127.04	0	0	0		0	0	0		0	0	0		1	1
Bamenda	Cameroon	271,800	181.29	0	0	0		0	0	0		0	0	0		0	2
Pointe Noire	Congo	511,600	463.38	0	0	0		0	0	0		0	0	0		0	2
Gonder	Ethiopia	142,100	71.93	0	0	0		0	0	0		0	0	0		0	2
Aktan	Kazakhstan	143,400	14.91	0	0		0	0	0		0	0	0		0	1	1
Meru	Kenya	136,800	74.68	0	0	0		0	0	0		0	0	0		0	2
Nyeri	Kenya	199,700	64.60	0	0	0		0	0	0		0	0	0		0	2
Johor Baharu	Malaysia	384,613	3,045.69	0	0	0		0	0	0		0	0	0		0	2
Miri	Malaysia	140,000	469.69	0	0	0		0	0	0		0	0	0		0	2
Selayang Baru	Malaysia	170,000	2,529.96		0	0			0	0			0	0		0	2
Seremban	Malaysia	246,441	1,613.06		0	0			0	0			0	0		0	2
Ciudad Obregon	Mexico	250,790	165.06	0	0	0		0	0	0		0	0	0		1	1
Awka	Nigeria	148,300	133.88	0	0	0		0	0	0		0	0	0		0	2
Nnewi	Nigeria	171,500	296.10	0	0	0		0	0	0		0	0	0		0	2
Obosi	Nigeria	120,900	286.43	0	0	0		0	0	0		0	0	0		0	2
Okpoko	Nigeria	148,900	0.40	0	0	0		0	0	0		0	0	0		0	2
Owerri	Nigeria	183,400	117.15	0	0	0		0	0	0		0	0	0		0	2
Shagamu	Nigeria	186,800	154.50	0	0	0		0	0	0		0	0	0		0	2
Uyo	Nigeria	100,600	97.51	0	0	0		0	0	0		0	0	0		0	2
San Carlos (Negros Occ.)	Philippines	118,259	8.72	0	0	0		0	0	0		0	0	0		1	1
Nakhon Si Thammarat	Thailand	118,764	191.28	0	0	0		0	0	0		0	0	0		1	1
Kam'yanets'-Podol's'kyy	Ukraine	105,200	35.85	0	0		0	0	0		0	0	0		0	1	1
Man	Côte d'Ivoire	155,200	67.13	0	0	0		0	0	0		0	0	0		0	1
Gemena	Dem. Rep. of Congo	115,900	4.18	0	0	0		0	0	0		0	0	0		0	1
Malacca	Malaysia	180,671	2,886.78		0	0			0	0			0	0		0	1
Taiping	Malaysia	183,320	1,073.31		0	0			0	0			0	0		0	1
Tawau	Malaysia	145,000	712.43		0	0			0	0			0	0		0	1
Gurue	Mozambique	111,900	53.92	0	0	0		0	0	0		0	0	0	0	0	1
Nacala	Mozambique	178,200	111.00	0	0	0		0	0	0		0	0	0	0	0	1
Amaigbo	Nigeria	108,500	48.13	0	0	0		0	0	0		0	0	0		0	1
Gboko	Nigeria	163,000	67.00	0	0	0		0	0	0		0	0	0		0	1
Ijebu Ode	Nigeria	182,100	150.06	0	0	0		0	0	0		0	0	0		0	1
Ugep	Nigeria	181,500	61.82	0	0	0		0	0	0		0	0	0		0	1
Makeni	Sierra Leone	101,300	23.74	0	0	0		0	0	0		0	0		0	0	1
Songea	Tanzania	123,500	62.12	0	0	0		0	0	0		0	0	0		0	1
Huambo	Angola	165,700	301.69	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Comodoro Rivadavia	Argentina	144,074	906.19	0	0	0	0	0	0	0	0	0	0	0	0	0	0

City	Country	Population	City GDP (in millions)	Natural Hazards Exposure				Mortality				Economic Damage				Multi-haz. Econom. Risk	Multi-haz. Mortality Risk
				Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide		
					High				High				High				
					Medium				Medium				Medium				
					Low				Low				Low				
Mercedes	Argentina	100,876	33.44	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bohicon	Benin	107,200	69.23	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Djougou	Benin	177,300	20.38	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Parakou	Benin	141,100	72.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aguas Lindas de Goias	Brazil	105,216	3,675.63	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alagoinhas	Brazil	112,339	424.62	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anapolis	Brazil	279,752	1,109.69	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aracatuba	Brazil	164,440	1,393.41	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arapiraca	Brazil	152,281	323.72	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Barbacena	Brazil	103,522	499.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Belem	Brazil	1,638,000	4,931.85	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Campina Grande	Brazil	336,218	1,002.15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Castanhal	Brazil	121,174	239.24	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Garanhuns	Brazil	103,283	340.55	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Juazeiro do Norte	Brazil	201,950	842.76	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Luziania	Brazil	129,905	2,262.38	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Montes Claros	Brazil	288,534	1,340.09	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Paranagua	Brazil	122,179	267.24	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Teofilo Otoni	Brazil	102,500	455.93	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vitoria da Conquista	Brazil	225,430	910.76	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bobo Dioulasso	Burkina Faso	474,300	128.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baicheng	China	471,300	421.13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nantong	China	639,600	1,393.92	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Siping	China	463,000	587.96	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Weihai	China	496,400	803.61	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Xuchang	China	350,200	784.29	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bouake	Côte d'Ivoire	578,400	232.79	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Daloa	Côte d'Ivoire	184,300	88.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Korhogo	Côte d'Ivoire	164,400	80.36	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Yamoussoukro	Côte d'Ivoire	165,000	73.80	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pinar del Rio	Cuba	172,300	333.55	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Santa Clara	Cuba	243,900	479.40	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Isiro	Dem. Rep. of Congo	131,700	10.92	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kananga	Dem. Rep. of Congo	521,900	53.55	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mwene-Ditu	Dem. Rep. of Congo	189,900	5.13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Al-Fayyum (El-Fajum)	Egypt	260,964	1,291.97	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Al-Iskandariyah (Alexandria)	Egypt	4,113,000	5,134.51	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Damanhur	Egypt	212,203	179.64	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Libreville (incl. Peripherie)	Gabon	526,100	1,331.45	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kumasi	Ghana	906,400	301.82	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tamale	Ghana	259,200	75.20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ahmadnagar	India	307,455	257.45	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ajmer	India	490,138	270.54	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Akola	India	399,978	357.30	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amravati	India	549,370	511.76	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bellary	India	317,000	230.82	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bijapur	India	245,946	182.37	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bikaner	India	529,007	247.29	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Davanagere	India	363,780	258.64	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gulbarga (Gulburga)	India	435,631	306.48	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hubli-Dharwar	India	786,018	201.70	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Parbhani	India	259,170	233.56	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solapur	India	873,037	589.17	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thoothukkudi (Tuticorin)	India	242,860	308.14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ad-Diwaniyah	Iraq	388,300	207.21	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Al-Kufah	Iraq	105,600	120.92	0	0	0	0	0	0	0	0	0	0	0	0	0	0

City	Country	Population	City GDP (in millions)	Natural Hazards Exposure				Mortality				Economic Damage				Multi-haz. Econom. Risk	Multi-haz. Mortality Risk
				Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide		
					High Medium Low				High Medium Low				High Medium Low				
As-Samawah	Iraq	118,300	0.76	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Machakos	Kenya	173,700	59.09	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Antsirabe	Madagascar	151,800	10.35	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fianarantsoa	Madagascar	131,600	3.10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sikasso	Mali	125,400	39.21	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Monclova	Mexico	192,554	1,877.68	0	0	0	0	0	0	0	0	0	0	0	0	0	0
San Luis Potosi	Mexico	931,000	3,115.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Zacatecas	Mexico	113,947	419.34	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Agadir	Morocco	599,300	437.49	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beni-Mellal	Morocco	153,600	193.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Khouribga	Morocco	164,600	265.48	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chimoio	Mozambique	192,700	126.30	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nampula	Mozambique	341,700	200.40	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Windhoek	Namibia	192,300	662.58	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Agadez	Niger	107,000	9.41	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Zinder	Niger	195,595	50.43	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aba	Nigeria	766,800	273.56	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Abuja	Nigeria	154,200	43.70	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ado	Nigeria	235,600	138.96	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Akure	Nigeria	361,200	198.68	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bugama	Nigeria	119,700	67.73	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Damaturu	Nigeria	218,000	47.07	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Efon Alaye	Nigeria	239,900	45.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ejigbo	Nigeria	114,100	64.57	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Funtua	Nigeria	119,500	65.37	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gbongan	Nigeria	115,000	76.97	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gombe	Nigeria	224,600	99.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ibadan	Nigeria	1,731,000	2,045.19	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ife	Nigeria	307,300	168.94	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Igboho	Nigeria	112,800	75.40	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ijero	Nigeria	143,900	66.66	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ikare	Nigeria	156,800	70.21	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ikire	Nigeria	183,300	83.77	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ikirun	Nigeria	125,900	77.59	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ikot Ekpene	Nigeria	205,700	144.18	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ila	Nigeria	147,800	64.20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ilawe	Nigeria	157,000	88.11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ilesha	Nigeria	229,300	0.19	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ilorin	Nigeria	732,700	436.23	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Inisa	Nigeria	135,400	45.88	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ise	Nigeria	163,200	70.40	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Iseyin	Nigeria	281,100	137.48	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jalingo	Nigeria	101,200	2.57	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kishi	Nigeria	128,200	101.64	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lafia	Nigeria	112,500	61.27	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Offa	Nigeria	102,300	63.27	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ogbomosho	Nigeria	712,100	245.56	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Okene	Nigeria	430,900	371.36	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Okrika	Nigeria	117,800	88.17	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ondo	Nigeria	220,600	122.55	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Owo	Nigeria	237,400	113.94	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oyo	Nigeria	608,300	310.46	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Port Harcourt	Nigeria	1,016,200	73.73	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Shaki	Nigeria	147,300	90.35	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Suleja	Nigeria	145,500	38.20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Warri	Nigeria	486,700	11.59	0	0	0	0	0	0	0	0	0	0	0	0	0	0

City	Country	Population	City GDP (in millions)	Natural Hazards Exposure				Mortality				Economic Damage				Multi-haz. Econom. Risk	Multi-haz. Mortality Risk
				Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide	Earthquake	Cyclone	Flood	Slide		
					High Medium Low				High Medium Low				High Medium Low				
Khanpur	Pakistan	117,764	87.94	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Waldenburg	Poland	135,700	471.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Zielona Gora (Gruenberg)	Poland	118,800	410.15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Elista	Russia	103,300	72.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kolpino	Russia	141,200	618.44	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leningrad	Russia	5,133,000	3,756.63	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Murmansk	Russia	376,300	1,390.32	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sachty	Russia	221,800	381.93	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Salavat	Russia	156,800	347.96	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vologda	Russia	302,500	994.71	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mbour	Senegal	122,400	32.44	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thies	Senegal	255,200	84.79	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Koidu	Sierra Leone	109,900	2.90	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Singapore	Singapore	3,567,000	80,516.77	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hargeisa	Somalia	197,100	44.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Merca	Somalia	168,200	5.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Benoni	South Africa	399,400	2,076.47	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bloemfontein	South Africa	364,700	1,640.85	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Boksburg	South Africa	285,100	1,675.58	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Brakpan	South Africa	187,300	1,348.13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
George	South Africa	102,900	534.61	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Johannesburg	South Africa	2,335,000	9,219.15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kimberley	South Africa	186,200	853.92	0	0	0	0	0	0	0	0	0	0	0	0	0	0
King Williams Town	South Africa	101,900	718.65	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Krugersdorp	South Africa	222,000	2,866.14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Randfontein	South Africa	107,100	2,205.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Springs	South Africa	175,700	710.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tembisa	South Africa	308,500	2,906.26	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Westonaria	South Africa	124,500	1,481.80	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Al-Fasir	Sudan	178,500	56.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Al-Junaynah	Sudan	116,800	83.31	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Al-Qadarif	Sudan	240,500	249.07	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Al-Ubayyid	Sudan	288,600	105.72	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bur Sudan	Sudan	384,100	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dodoma	Tanzania	159,100	102.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sfax	Tunisia	257,800	420.12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Play Cu	Vietnam	102,000	35.51	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ndola	Zambia	568,600	72.08	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bulawayo	Zimbabwe	794,600	123.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gweru	Zimbabwe	163,900	36.64	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mutare	Zimbabwe	168,100	139.91	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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Internet: www.geographischerundschau.de

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Die Geographische Rundschau International Edition, Volume 2, No. 02 / 2006, hat den Artikel "Losing Ground: Hurricanes and the Receding Louisiana Coastline" veroeffentlicht, von dem ich Autorin bin.

Ich wuerde diesen Artikel gerne in die Dissertation, die ich momentan an der Louisiana State University im Bereich Geographie schreibe, miteinbringen. Ich wuerde Sie bitten, die Veroeffentlichung dieses Artikels in meiner Dissertation stattzugeben.

Bitte melden Sie sich, fall Sie Fragen haben.

Mit freundlichen Gruessen,
Henrike Brecht

Henrike Brecht
Disaster Risk Management Specialist
East Asia and Pacific Infrastructure Unit (EASIN)
The World Bank
1818 H Street, NW • Washington, DC 20433 USA
T: +1 202 458 7473 • F: +1 202 477 1205
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VITA

Henrike Brecht was born in Bad Gandersheim, Germany. She was awarded a M.S. in Environmental Science from Westfaelische Wilhelms-University in Muenster, Germany, in 2002. During her M.S. studies, she was a research assistant at the Institute for Geoinformatics in Muenster. After graduation, Henrike worked for the United Nations High Commissioner for Refugees (UNHCR) in Switzerland, Kenya and Sudan. In 2004, she started her doctoral studies at Louisiana State University (LSU) in Geography and Anthropology under the advisorship of Dr. Michael Leitner and with financing from the Economic Development Scholarship through the LSU Hurricane Center. In 2007, she took a position as a Disaster Risk Management Specialist at the World Bank, where she has enjoyed implementing risk reduction projects predominantly in Southeast Asian countries. She expects to receive her Doctor of Philosophy degree in December 2012.