South Asia Disaster Risk Management Programme:

Synthesis Report on SAR Countries Disaster Risks

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PREFACE

South Asia Region (SAR) nations have a history of devastating earthquakes, floods, landslides, droughts and cyclones that have caused economic and human losses. The physiographic settings and the climatic characteristics of the region is favorable towards the high incidence of both geological and hydro-metrological hazards. As per the World Bank classification, most of the countries in the region are in the low or lower middle income category. Like any other part of the world, in SAR also natural hazards hurt the poor the most, both in terms of life and livelihood.

SAR countries are diverse in terms of size, population density and topography. A country like India has a vast geography, diverse climatic condition and topography whereas a country like Maldives has its own uniqueness as an island country with the majority of its land close to sea level. Due to geographical characteristics, some of the natural hazards are trans-boundary in nature. Sometimes, hazard occurrence in one country has more impact on the neighboring country. Another characteristic of this region is that some of the countries like Bhutan and Nepal are mountainous and in the event of any major disaster can only be accessed through its neighboring country, India. This also necessitates regional cooperation for disaster risk reduction planning. Many of the countries in SAR, being signatory of the Hyogo Framework for Action (HFA 2005 – 2015) have initiated to disaster risk reduction. Multilateral agencies, Government agencies, Non Governmental Organization and private organizations are contributing towards reducing disaster risk in the region.

In addition, high population density coupled with high population growth and economic development in this region necessitates disaster risk reduction planning. As a result, UNISDR and the World Bank have initiated disaster risk reduction activities in this region. As part of this initiative under the South Asia Disaster Risk Management Program, UNISDR has awarded a consultancy project to RMSI, India to prepare a synthesis report on the risk assessment of SAR countries. This is the final report submitted by RMSI as part of the assignment.

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ABBREVIATION USED

AAL	Average Annual Loss
APN	Asia-Pacific Network
ADRC	Asian Disaster Reduction Centre
CRED	Centre for Research on the Epidemiology of Disasters
EM-DAT	Emergency Events Database, developed by the Office of US Foreign Disaster Assistance and the Centre for Research on the Epidemiology of Disasters
ESCAP	Economic and Social Commission for Asia and the Pacific
EV	Economic Vulnerability
GDP	Gross Domestic Product
GCM	Global Circulation Model
GSHAP	Global Seismic Hazard Program
HDI	Human Development Index
HFA	Hyogo Framework for Action
IFRC	International Federation of Red Cross and Red Crescent Societies
MMI	Modified Mercalli Intensity
MSL	Mean Sea Level
MRI	Meteorological Research Institute
NGDC	National Geophysical Data Centre
NGI	Norwegian Geotechnical Institute
OFDA	Office of the US Foreign Disaster Assistance
PRECIS	Providing Regional Climates for Impact Studies
POK	Pakistan Occupied Kashmir
RCM	Regional Circulation Model
SAARC	South Asia Association of Regional Cooperation
SAR	South Asia Region
SV	Social Vulnerability
UN	United Nations
UNOCHA	United Nations Office for the Coordination of Humanitarian Affairs
UNISDR	United Nations International Strategy for Disaster Reduction
UNDP	United Nations Development Programme
USAID	United States Agency for International Development
WB	World Bank
WMO	World Meteorological Organization

Executive Summary

1.1 Background

This report has been prepared as part of the UNISDR and the World Bank initiative towards disaster risk reduction in SAR countries in line with the Hyogo Framework of Action (HFA 2005 – 2015). The objective is to prepare a simplified quantitative risk assessment to determine the social and economic loss potential and likelihood of occurrence of the different hazards at country and regional level. This involved conducting a desk review of existing reports, studies, analyses and assessments related to disaster risk (hazards and vulnerability) at the country and regional levels.

This report analyses and assesses disaster risk at country and regional levels with focus on earthquake, flood, drought, landslide, cyclone and volcano hazards. The SAR countries assessed are Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka. This assessment involved review of reports and literature available at country, regional and global levels to understand the hazard and vulnerability.

A review of the existing hazard, vulnerability and economic loss data at country level was performed. The main data sources consulted include the World Bank, CRED EM-DAT, UN, UNOCHA, SAARC, DesInventar, NGDC, GSHAP, ADRC, ESCAP, Swiss Re and Munich Re. National level data and country specific reports and research papers were also reviewed.

The socio-economic data were analyzed along with the mortality risk for various hazards to quantify the vulnerability (ISDR, 2009). As most of the data available in the public domain are related to disasters rather than hazard risk, this study relied on the Global Assessment Report (GAR) preview platform database (ISDR, 2009) for mortality risk for various hazards such as earthquake, flood, landslide, cyclone and drought; GSHAP hazard data for earthquake and NGI hazard data for landslide. The GAR preview platform (http://preview.grid.unep.ch) has created spatial data for the entire world using simplified modeling techniques. The hazard risk data for the region was extracted from this global data and graded into four/five categories of very high, high, medium and low/very low for earthquake, flood, landslide, cyclone and drought. The hazard risk data were analyzed along with grid based population data to assess the population exposed to various hazard risks.

To analyze the risk profile at country level, reported economic disaster loss data were used. Economic loss potential for different probabilities of exceedance were calculated using the historical economic loss data. For countries like Bhutan and Maldives, where economic loss data were not adequate, economic loss potential for different probabilities of exceedance were not calculated.

1.2 Key Findings

South Asia Region is highly vulnerable to earthquake, flood, landslide, drought and cyclone. During the last 40 years (1967 – 2006), the reported 784 disasters have caused 0.80 million deaths. Out of the reported disasters, 50 percent were floods and 25 percent cyclones. Cyclones however were the cause of about 0.5 million deaths. Flood and drought affected the largest number of people (2 billion). The total economic loss was about $ 80 billion, with flood alone causing about $ 49 billion loss. The number of deaths and economic losses due to earthquakes are also very significant in the region (196,400 deaths and $ 11.6 billion loss). About half of the population is exposed to high flood hazard and more than 10 percent of the population is exposed to high earthquake hazard. This indicates that, in addition of being severe, the hazards are geographically wide spread making any mitigation action unwieldy.

Afghanistan is highly vulnerable to flood and earthquake. The number of disasters related to flood are very high (47 out of 87; 54 percent) as compared to 27 (31 percent) for earthquake. Earthquake, however, caused more deaths (9,300) than flood (3,100). Flood contribute to the largest economic loss ($ 376 million) followed by earthquake ($ 183 million).

Bangladesh is highly prone to flood and cyclone. The number of disasters related to cyclone is very high (100 out of 182; 55 percent) as compared to flood (70; 38 percent). Cyclone caused more deaths (0.47 million) than flood (0.04 million). Flood affected the largest population and is the main contributor to loss (0.29 billion people and $ 12 billion). Cyclone also contributes to significant economic losses of the order of $ 2.9 billion.

Bhutan is highly vulnerable from earthquake, flood and landslide. Insufficient data are available over the last 40 years to summarize deaths and economic losses.

India is highly vulnerable to flood, earthquake and cyclone. In terms of geographic area, India is larger than all the other SAR countries put together. For the same reason, the population affected as well as the occurrence of disasters and their impacts are high in the country. There were 162 floods (52 percent) and 73 cyclones (23 percent) out of 313 disasters events reported during the last 40 years. Earthquake caused the largest number of deaths (106,900) followed by flood (52,300). The economic loss due to flood was $ 33.3 billion followed by earthquake ($ 5.3 billion). Total number of population affected by drought is the largest (961 million) followed by flood (730 million).

Maldives is highly vulnerable to tsunami, cyclone, storm surge and sea level rise. The southern and eastern portions of the island are highly vulnerable compared to the rest of the country because of its low elevation. Due to the size and elevation of the country, Maldives would be highly vulnerable to the expected sea level rise due to climate change.

Nepal is highly vulnerable to flood, earthquake and landslide. Flood are most common (28; 54 percent) followed by landslides (14; 27 percent) out of the 52 reported disasters. Flood caused the highest number of deaths (5,400) and economic losses ($ 975 million) although drought affected more population (4.6 million). Damaging earthquakes have been reported in the past and the country is highly vulnerable to earthquake.

Pakistan is highly vulnerable to flood, earthquake, and cyclone. Flood are most common (48; 51 percent) followed by earthquake (27; 29 percent) out of 94 reported disasters events. Earthquake caused the larger number of deaths (78,800) and the largest economic loss ($ 5.3 billion). Flood affected the largest population (41.8 million).

Sri Lanka is highly vulnerable to flood, drought and cyclone. The total number of flood disasters events reported during the 40 years is 38 (72 percent) with 1,090 deaths. Flood affected the population most (9.7 million people) followed by drought and cyclone (8.2 million and 1.38 million respectively). Flood contributes most to the economic loss ($ 370 million).

Global Circulation Models addressing climate change do not present a uniform view of the impact of climate change on SAR as they have limited capability to forecast the present meteorological patterns. A high resolution climate change model of the region appears to be more stable and predicts a temperature increase of 3 to 4 ^{0}C over the next 80 years and a significant increase in rainfall in the eastern part of SAR.

Developing countries are especially vulnerable to climate change because of their geographic exposure, low incomes, and greater reliance on climate sensitive sectors such as agriculture.

The cost of climate change in India and South East Asia could be as high as a 9-13% loss in GDP by 2100 compared with what could have been achieved in a world without climate change. Up to an additional 145-220 million people could be living on less than $2 a day and there could be an additional 165,000 to 250,000 child deaths per year in South Asia and sub-Saharan Africa by 2100, due to income loss alone.

Social vulnerability was analyzed using mortality data from past disasters. The relative SV analysis shows that Bangladesh ranks first followed by Pakistan, Afghanistan, Nepal, India and Sri Lanka. Due to paucity of data, relative SV of Bhutan and Maldives could not be assessed.

Economic vulnerability analysis shows that India, Pakistan and Bangladesh exhibit the largest losses, which is due to large exposure at risk and the high level of hazards. When expressing the relative economic vulnerability in terms of economic loss corresponding to 0.5 percent probability of exceedance (corresponds to 200 year return period) as a function of the GDP, Nepal ranks first followed by Bangladesh, Afghanistan, Pakistan, India, and Sri Lanka. Due to paucity of economic loss disaster data, the analysis could not be carried out for Bhutan and Maldives.

Dhaka, Kolkata, Delhi, Mumbai, and Karachi are the five mega-cities in SAR with a total population of about 80 million. These cities are experiencing high population growth and intense economic activities. All the mega-cities are highly vulnerable to earthquake and flood. Dhaka, Kolkata and Karachi are also vulnerable to cyclone and storm surge. In a simple risk assessment taking into account the mega-city hazard zonation and population, Delhi ranks first for earthquake risk followed by Kolkata and Dhaka; for flood and cyclone Kolkata ranks first followed by Dhaka and Karachi, for all hazards combined Kolkata ranks first followed by Dhaka and Karachi. Besides mega-cities, highly populated low elevation coastal areas, highly vulnerable to floods and cyclone, present a significant risk.

1.3 Way Forward

Based on the analyses carried out in this study, the following recommendations are presented to reduce disaster risks in SAR.

1.3.1 Additional analyses

Three levels of analyses are envisioned to refine the result presented in the report. These analyses first focus on flood (either monsoon or cyclone generated) and earthquake as they are the most damaging quick onset disasters.

Level 1: An analysis similar to this one based only on historical records should be repeated at a higher level of resolution. Instead of limiting the resolution of the analysis at the country level, a high resolution grid should be considered, 100 km grid for example. Risk aggregation by hazard type and area would provide, at low cost, a much more refined picture of the risk than the present analysis.

Level 2: As a second step, using the same methodology, worst case scenarios should be run for the mega-cities. This simple analysis would provide a reasonable quantification of the loss given the occurrence of a scenario. The uncertainty around the risk could then be bracketed by scientifically estimating the range of probability of occurrence of such scenarios.

Level 3: As a third step, fully probabilistic analyses containing all the elements of standard risk analysis should be performed for the hazards and regions identified as high risk in step 1 and 2.

Drought hazard should be addressed in the context of climate change. Being a slow onset hazard, response is readily available in the near term. Only long-term adaptation strategies should be considered.

1.3.2 Response to disaster

Considering the trans-boundary nature of hazards in SAR, a coordinated approach among countries towards disaster response is required. The terrain characteristics of Himalayan Mountains, for example, demands that planned and coordinated response programs be in place for rescue and support operations. Nodal organizations such as SAARC can play a key role in coordination among SAR countries to reduce trans-boundary hazards.

1.3.3 Centralized database

Any analysis or program gains from having access to high quality data. Data gathering particularly hydro-meteorological data should be centralized and coordinated not only within countries but also among countries. The presence of many trans-boundary rivers whose flow or dam management has direct impact on neighboring countries makes the coordination even more imperative.

Except for earthquake, all major hazards provide some warning time before they strike. Simple measures such as public education and warning could significantly reduce the number of deaths. Implementation of flood early warning systems not only within a country, but also across boundaries has the potential of reducing the social impact of the disaster.

1.3.4 Ensuring participation and Institutional strengthening

Regional cooperation and institutional strengthening are crucial for developing strategies towards hazards of trans-boundary nature. Institutional strengthening should be carried out in a coordinated approach under common framework and be implemented in a decentralized manner.

To ensure participation of all stakeholders, hazard management strategies must be judiciously selected considering the local and regional situational factors as well as the developmental needs of the region. Considering the terrain characteristics and size of the nations, different strategies need to be blended with the development planning process towards disaster risk reduction at country and regional levels.

1.3.5 Improvement in disaster risk assessment

Many of the SAR countries have district level disaster management plans in place. These plans should be refined as they often lack the details necessary to reflect ground realities. They should be based on the level 2 or level 3 types of analyses recommended in section 1.3.1, reflecting realistic scenarios and associated responses. In addition, the disaster risk management plans should be integrated into local development plans. Such plans should further be assimilated within regional and national programs.

Disaster risk management activities should be carried out within a common framework that, if required, could be integrated at the national level or across boundaries.

1.3.6 Coordinated approach

Presently disaster response activities of most SAR countries are coordinated under institutions such as SAARC. ADRC is coordinating at a higher level with more countries party to it. The coordination and efficiency of these types of networks should be improved and their focus expanded to address disaster risk reduction. Human and financial resource augmentation, skill improvement and infrastructure development are required to achieve such goals. These efforts should be carried out with the participation of all the SAR countries to ensure future sustainable use of the networks.

1.3.7 Poverty alleviation and awareness generation

Poverty significantly exacerbates the impact of hazards both on the human and economic levels. Poverty usually implies that constructions are inadequate to resist earthquake resulting both in large numbers of casualties and devastating damages. Poverty is also associated with inadequate land use planning to avoid the impact of flood resulting in massive flood devastation. Finally poverty is connected to a lack of preemptive response to local hazards either because the authorities do not have the appropriate information to warn the population of the imminence of the hazard or because of the unwillingness or incapability of the locals to evacuate and leave behind their land and livelihood. Poverty reduction is indeed an issue with much broader ramifications than hazard response that is clearly outside the scope of this study, but increased awareness to the hazards can be handled at a local level with limited resources and direct results. The level of awareness to the danger of tsunami has increased significantly throughout the world after the December 26, 2004 tsunami. Continuous efforts should be made to increase the awareness of populations to less damaging but more frequent events to take some simple and effective steps to mitigate their impact. Storm surge can be handled well by using simple measures such as providing biological shield using mangrove plantation.

1.4 Organization of the Report

This report is organized into the following sections:

1. Executive Summary.
2. Methodology: This section presents the methodological steps adopted to perform this study.
3. SAR Vulnerability and Risk Assessment: This section covers the SAR regional analysis. As a background, the geographic settings and socio economic statistics of the region are presented. The section concludes with the analysis of potential climate change and its impact in SAR.
4. Country Profile: This section analyses vulnerability and risk assessment at the country level. Salient findings and basic statistical data related to each country are presented in a concise format for easy and quick reference.
5. Priority Areas for Detailed Risk Assessment: In this section, a simplified risk assessment is developed for demonstration purposes to identify priority areas requiring detailed risk assessment.
6. Summary and Recommendations
7. Annexure: The details of the methodologies used for economic loss analysis are presented in this annexure.

   Reference: This section lists the materials referred to in this study along with useful websites for further reference.

Methodology

This report presents a hazard and vulnerability risk assessment for the following eight countries of the South Asia Region (SAR): Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka. The hazards analyzed are earthquake, flood, drought, landslide, cyclone, and volcano. Technology related disasters are excluded. The report analyzes and estimates the hazard, vulnerability and loss based on the historical events that impacted the region over the last 40 years (1967 to 2006). The risk assessment is reported at both the country and regional levels. This section describes the methodology adopted in carrying out the hazard and risk assessment estimation.

1.5 Data Review

A simple and straight forward approach to estimate risk is to base it simply on the historical record. If the databank is relatively complete and covers a period long enough to include several return period cycles of the events under consideration, reliable estimates can be derived from this simplified approach. More robust approaches model the physics of event generation and introduce geophysical parameters to supplement the incompleteness of the historical record. The development and implementation of such models require significant time and budget resources way beyond the scope of this effort.

In this analysis, most hazards considered have short return periods such that a window of 40 years provides a reliable picture of the characteristics of the phenomena. Earthquakes and volcanic eruption, that have long to very long return periods, require special treatment. For earthquakes, a period of 100 years of data has been reviewed and analyzed but the results have been re-normalized to the standard 40 years window to provide consistency with the other hazards. Volcanic activity has not been explicitly addressed since insufficient data are available in the record to derive meaningful estimates.

Since data quality and completeness are critical in the implementation of the proposed approach, particular effort has been made to identify, document, verify and process the data. The remainder of this section addresses the data resources, their use and limitations in the context of this study.

1.5.1 Data Sources

Since 1980, significant efforts have been made by various academic and multilateral development agencies to compile historical disaster data and generate standardized data across the globe for disaster risk mitigation activities. As a result, numerous databases are accessible in the literature and on the Internet. This section describes a few of the most relevant data sources used in this study.

Centre for Research on the Epidemiology of Disaster (CRED) maintains EM-DAT global database on disasters (natural and technological hazards) one of exhaustive data available in the public domain.

Asian Disaster Reduction Centre (ADRC) has compiled data from various sources like UN/OCHA, DesInventar, US Government: OFDA, reinsurance, private, government of Japan, IFRC, UN/WMO. The data is available for India, Bangladesh, Nepal and Sri Lanka in SAR for the period 1901-2000.

DesInventar has data mostly of Central America along with data for Sri Lanka, Nepal and a small portion of Orissa state in India. DesInventar covers all natural as well as man-made hazards including epidemics and also documents deaths, affected population, damaged and affected houses and losses in local dollars for the period 1972 to 2006. The DesInventar database for Sri Lanka primary contains events from EM-DAT and ADRC and has surveyed the events for accuracy and its disaggregation.

National Geophysical Data Centre (NGDC) database contain earthquake events since 1900 for all countries in the world. The database is exclusively on earthquake events and is an exhaustive database.

United Nation Office for the Coordination of Humanitarian Affairs (OCHA) is an UN body principally focusing on humanitarian action in partnership with national and international actors in disaster risk management.

South Asia Association of Regional Cooperation (SAARC) is an association of all the eight countries of SAR to provide a platform for the South Asia countries to work together in a spirit of friendship, trust and understanding.

Dartmouth Observatory has compiled flood data across the world for major events since 1980. The site has documented the flood extent for different period using satellite data. Dartmouth data has recorded Glide number for each event which is a unique identifier, a standard practice many international organizations are now following. The site is exclusively for flood data and economic loss is sparsely documented.

Norwegian Geotechnical Institute (NGI, 2008) has prepared landslide hazard map for the entire world and is available in GIS format. In addition, there are various hazard specific studies analyzing particular events at country level. However, these comprehensive reports fall short in providing country level risk information.

The World Bank under the Global Risk Analysis has developed a methodology and modeled the hazard and vulnerability and calibrated it using data from EM-DAT. The results are published as a report: Natural Disaster Hot Spots, Disaster Risk Management series No.5, World Bank (Dilley et al., 2005).

The recently launched Global Assessment Review (GAR) preview platform (ISDR, 2009; (***http://preview.grid.unep.ch***) have improved upon the previous studies and developed a methodology and modeling hazard risk mortality index for earthquake, flood, landslide and cyclone hazards.

Apart from the data from these sources, reports from other sources, such as United States Agency for International Development (USAID), UNOCHA, United Nations International Strategy for Disaster Reduction (UNISDR), SAARC, Munich Re and Swiss Re were also reviewed. Published hazard maps and data available in public domain were also referred to at various stages.

1.5.2 Data Issues

In spite of the efforts of data gathering organizations, historical data on disasters have a lot of inherent problems. Guha-Sapir and Hargitt (2004) have highlighted several issues on the availability of disaster-related data in the report “Thirty Years of Natural Disasters 1974-2003: The Numbers”. The key problems highlighted in the report include:

1. Lack of a single organization performing data collection and compilation, which can lead to lack of standardization in data collection methodologies and definitions.
2. Biased data can occur because of the rationale behind data gathering.

3. Prolonged disaster events (like famine over many years) may be recorded as multiple events.
4. Regional events which spread across different political boundaries (like flood, earthquake) can be recorded in all the affected countries, and may be counted as different events.
5. Change in national boundaries can also cause ambiguities and difficulties in comparing historical data.
6. Fragmented jurisdiction within a country over the different types of disasters can lead to inconsistencies in loss and social impact estimation.

In addition to these, there are concerns regarding the lack of standardized methods for assessing damage across the globe. Most of the database managers gather data from a variety of public sources, such as newspapers, insurance reports or aid agencies. The original information is not specifically gathered for analytical purposes, so even if the compiling organization applies strict definitions, there are still inherent shortcomings in the data.

There are other issues in disaster data gathering like the impact diffusion of a drought event extending far beyond the visible physical damage, often affecting livelihood issues. Hazard such as drought do not have clear cut start and end dates as the occurrence starts slowly and the impact lingers long after the official end of the drought.

In view of these issues, the steps taken to resolve at least some of them to the extent possible are presented in the next section.

1.5.3 Data Selection and Cleaning

As described in the previous section, a large number of sources contain data gathered by different agencies and under different programs. An important part of the risk assessment effort is to identify the most reliable sources, cross check them with other sources, identify and resolve inconsistencies in order to create a best estimate database to be used in the study. Table 1 presents the data sources used for each hazard listed in order of importance.

The rest of this section presents some of the steps followed to assure that the most reliable data were gathered and used.

Along with the inherent data issues identified in the previous section, a specific problem faced in this study is regarding the disaster spreading across countries. Many events (flood, earthquake and drought) spread across countries and the events are recorded in more than one country thereby resulting in duplication of event and impact values, when used for analysis at regional level. Some data sources like Dartmouth have documented the data by event and not by country. For such cases, individual country losses were identified, correlated and recorded as per CRED database format.

To handle these anomalies, the data from different sources were compared on an event by event basis. If the event was not reported in any of the said sources, it was ignored. If an event was only recorded in one data source, it was cross checked using published reports, papers and even media news; particularly if there were major variations in the reported number of deaths, affected population and economic loss.

The earthquake, flood, landslide, drought and cyclone hazard mortality risk maps were extracted from the GAR preview platform (ISDR, 2009). These datasets were created on a coarser grid for analyzing the global scenario. While using these data for calculating the geographic area under different hazard risks and for extracting the potential population exposed, a skewed picture is projected for small countries due to the coarse grid size. For this reason, Maldives is not considered in this exercise. RMSI has conducted an exclusive study for assessing disaster risk for Maldives in 2006 (UNDP, 2006). This study focused on earthquakes, windstorms (including cyclone) and tsunami. As there is no other data available both in terms of hazards and disasters for Maldives, the findings of RMSI study are presented in the Maldives country profile section. There is also a paucity of data for Bhutan, particularly economic loss data. For these two countries, the economic risk assessment could not be performed. Similarly, economic loss data for landslides for several countries were not sufficient to perform the disaster economic loss risk assessment.

Table 1 Details on data source used and vintage for each hazard for the study

<table>
<tr><th>Hazard</th><th>Vintage</th><th>Source</th><th>Comments</th></tr>
<tr><td>Earthquake</td><td>1967 - 2006</td><td>NGDC, GSHAP, CRED, ADRC, ISDR</td><td rowspan="5">Data compared and cleaned using different sources including individual research papers.

For regional analysis, damaging earthquakes from 1900 to 2006 were considered.

For Bhutan and Maldives, there is not enough loss data to compute AAL and economic loss potential.</td></tr>
<tr><td>Flood</td><td>1967 - 2006</td><td>Dartmouth Observatory, CRED, ADRC, OCHA, SAARC, World Bank, ISDR</td></tr>
<tr><td>Drought</td><td>1967 - 2006</td><td>CRED, ADRC, OCHA, SAARC, World Bank, ISDR</td></tr>
<tr><td>Landslide</td><td>1967 – 2006</td><td>CRED, ADRC, OCHA, NGI, SAARC, World Bank, ISDR</td></tr>
<tr><td>Cyclone</td><td>1967 - 2006</td><td>CRED, ADRC, OCHA, SAARC, World Bank, ISDR</td></tr>
<tr><td>Volcano</td><td>1967 - 2006</td><td>International Association of Volcanology and Chemistry of the Earth’s Interior, Global Volcanism Program, Smithsonian Institution</td><td>No disaster events reported</td></tr>
</table>

1.6 Hazard Risk and Vulnerability Estimates

The hazard risk and vulnerability at the regional and country levels were derived from the sets of data presented in the previous section. The hazard risks were estimated semi-quantitatively rather than fully probabilistically. They were further investigated to assess their geographical commonality and overlap. Vulnerability was defined as being proportional to the population at risk. For vulnerability assessment, quantitative techniques were used to relate the hazard risk with the socio-economic indicators of the region.

1.6.1 Hazard Risk Analysis

Short of presenting a fully probabilistic estimate of hazard risk, this study regionally classifies the hazard risks as low, medium, high and very high. A more quantitative definition of these descriptors is given by hazard in their respective sections.

The earthquake, flood, landslide, cyclone and drought hazard risks maps were derived from the GAR Preview platform (ISDR, 2009; ***http://preview.grid.unep.ch***) along with country specific disaster data.

1.6.2 Vulnerability Analysis

The assessment and mapping of human vulnerability is less advanced than the hazard assessment work (UNISDR, 2004). There is no straight forward methodology for human vulnerability modeling due to reasons such as the lack of observational data on the hazard, the lack of proper estimate of hazard impact as it propagates into the livelihood of the society and the lack of mechanism to assess the lingering impact of the aftermath of some events. Methodologies for modeling physical vulnerability have been developed and are in are an advanced stage. However, as social vulnerability is society specific, depending on factors such as life style, its quantification is more involved and at present there are efforts to develop methods for assessing social vulnerability using participatory methods at the local level (Douglas, 2007).

In this study the social vulnerability was estimated based on the average number of people killed per year at country level. The social vulnerability ranking at country level was estimated based on the average number people killed per year per million (relative vulnerability). Hazard risk mortality maps and gridded population data were analyzed using Geographic Information System (GIS) to identify the population at risk to the various hazards.

Countries were compared based on population at risk for a single hazard as well as multiple hazards. Average number of people killed per year per million were calculated to compare all countries on a consistent scale. Economic and social indicators such as Gross Domestic Product (GDP) and population density were also considered to describe the social vulnerability.

1.7 Risk Assessment

Risk is commonly quantified as the product of hazard by exposure. In this study, the intent has been to quantify the risk directly based on the historical loss records. Such approach, much simpler that the standard probabilistic methods, provides reliable estimates as long as the length of record is sufficient as explained in the data section. This condition is clearly met as the analysis is based on 40 years of data (1967-2006).

In addition to the general data issues identified in section 2.1.2, the following remarks apply to this section. The use of historical data for loss computation may have some shortcomings. Often damage estimates of large, catastrophic events tends to be overestimated, while those of more frequent, less severe events are often underestimated. Moreover, smaller events, particularly those that individually cause relatively little damage, are often not reported at all. In general, when two sources of data were available, the one with the more conservative estimate was considered. Also, the severity of reported damage often depends on the economy of the affected area, even though the intensity of hazard may be similar. For example, floods in developed countries tend to cause higher economic losses per unit area flooded than floods in parts of Bangladesh.

The methodology for loss analysis was adopted from Pusch (2004) “Preventable Losses: Saving Lives and Property through Hazard Risk Management, A Comprehensive Risk Management Framework for Europe and Central Asia, Working Paper series no. 9, The World Bank”. This method is presented in Annexure 1.

Statistical methods were applied to determine the probability and frequency of a hazard occurrence and the level of economic loss it can cause. Deaths, death per million population, affected population, affected population per million were also estimated. Economic loss potential for different probabilities of exceedance and Average Annual Loss (AAL) were calculated.

For regional analysis, damaging earthquakes from 1900 to 2006 were considered since earthquakes have longer return periods. NGDC data were extensively used along with some published reports. Economic losses for landslides for several countries were not sufficient and the hazard analysis could not be performed. For Bhutan and Maldives, there is a dearth of loss data primarily due to low frequency of hazards and non availability of loss data. For this reason, the risk assessment could not be performed. Volcanic hazard is insignificant in the study region and its risk assessment was not carried out.

1.8 Presentation of Results

The results are first presented at regional and country level. For clarity of understanding of hazard risk distribution, regional hazard risk maps for all hazards except volcano are presented. At country level, data are presented to capture the composition of hazard risks within country, relation between events and their impact and trend over the period of 40 years.

Natural hazards are strongly linked to biophysical settings while vulnerability is a factor of socio-economic conditions of the region. Therefore, in this report, a brief overview of each country is provided as background information prior to the risk assessment. Disaster events and their impact at the country and regional levels were analyzed in the context of biophysical and socio-economic settings of the country and the region.

SAR Hazard Risk and Vulnerability Assessment

1.9 Overview

The World Bank Natural Disaster Hotspot Study (Dilley et al., 2005) reports that about 25 million sq km (19 percent of earth's land area) and 3.4 billion people (more than half of the world's population) are relatively highly exposed to at least one hazard. About 3.8 million sq km and 790 million people are relatively highly exposed to at least two hazards. About 0.5 million sq km and 105 million people are relatively highly exposed to three or more hazards. The statistics also suggest that future disasters will continue to impose high costs on human and economic development.

Though the disasters affect all, irrespectively of economic status, they have a much deeper impact on poor people. The reasons being that poor people often occupy the environmentally marginal areas that are susceptible to disasters and do not have the means to protect themselves or to escape the area even if they are warned of its imminence. For these reasons, the impact of hazards is significantly different in developed and developing nations. In developed nations disasters cause higher economic damage and loss to infrastructure while they generate large number of casualties in developing countries (Pusch, 2004). In the case of India and its neighboring countries, however, with high population density coupled with a fast growing economy, the impact of disasters can be of the nature of both developed and developing countries, high economic as well as high social impact. Of great concern is the fact that reported disaster occurrences almost doubled between 1995 and 2005. This increase may be a result of better information coupled with population growth, increasing exposure of population and economic assets, and a growth in the number of reported small-scale disaster events with relatively low mortality impact.

SAR is exposed to many recurring natural hazards, including earthquake, flood, drought, landslide, cyclone and tsunami; earthquake, cyclone and flood being the most devastating ones. The Asia region has the highest frequency of reported disasters compared to rest of the world. As per CRED EM-DAT, about 50 percent of the reported disasters in the world between 2000 and 2006 occurred in the Asia region and accounted for 78 percent of the total affected population. Earthquake and wave surge (including tsunami) caused the highest casualty while flood and drought affected the largest number of people.

As per CRED EM-DAT statistics in SAR during the period 1967 – 2006, a total of 0.8 million deaths were reported (an annual average of 20,000 deaths) and the physical exposure in the region is 56.4 million people, which is more than one third of the total population in the region. During this period, cumulative direct economic losses in the region were about $ 80 billion. Although there are some discrepancies among the various sources regarding these estimates, still they give a broad picture of the risk and vulnerability in this region. In addition, the region is heavily dependent on primary activities such as agriculture; fishing and the disasters not only affect the lives but also livelihood of the people. The impact on people's livelihood is not quantified or accounted for in these numbers.

SAR has recently experienced major disasters from different hazards. On December 26, 2004, the Asian tsunami displaced about 1.2 million people, many of whom lost their livelihoods. Over 50,000 people died or were declared missing, with Sri Lanka suffered with highest number of deaths in SAR. The economic loss in India, Sri Lanka and Maldives was estimated at $2.5 billion mostly in housing, fisheries and tourism sector. On October 8, 2005, a magnitude 7.6 earthquake occurred 100 km north-northeast of Islamabad with tremors felt across a wide swath of South Asia – from central Afghanistan to western Bangladesh. Pakistan was most impacted with approximately 73,000 fatalities, over 2.8 million people left without shelter, and the overall cost for reconstruction and recovery estimated at $ 5.2 billion (Munich Re, 2005).

1.10 Regional Setting

The SAR countries included in this study are Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka. There is a lot of physical, social and cultural continuity as well as diversity in this region. India is the largest of the SAR countries both in terms of geographic extent and population. Maldives and Sri Lanka are small island countries while Nepal, Bhutan and Afghanistan are land locked with Bhutan and Nepal totally located in the mountain ranges of the Himalayas. A map of the region is shown in Figure 1 and a summary of the basic statistics is provided in Table 2.

Figure 1 Location map of South Asia Region

The location and physiographic setting of the SAR countries has a domain influence on the socio-economic and development activities as well as on the occurrence of natural hazards.

1.11 Physical Setting

The Himalayan Mountains form a prominent physical feature spreading across many of the SAR countries. This physiographic unit also has a great influence on the climate of the region. There are major rivers originating from this mountain range mostly fed by the glaciers, namely: the Ganges River, which flows across northern India and into Bangladesh, the Indus River, which flows across India and Pakistan and the Brahmaputra River that flows across India and Bangladesh.

Climatically, the region is heavily influenced by monsoonal phenomena: a seasonal reversal of wind flow due to changing low and high-pressure in the sub-continent. Monsoonal phenomena have a weaker influence toward the north western region – northwest of India, part of Pakistan and most part of Afghanistan. There is a wide variation in the weather condition such as temperature, rainfall, humidity within SAR with equatorial and tropical characteristics in the southern region – Sri Lanka, Maldives and part of India. Portions of India and Pakistan have semi-arid to arid climatic conditions while Afghanistan is predominantly arid. India, due to its vast extent and diverse physiography, has varied weather conditions that range from marine to arid and tropical to alpine. The variation in rainfall in the region contributes to hydro-meteorological hazards like flood and drought.

The climatic conditions of the region have influenced its socio-economic development as well as hazards which are of geological and hydro-meteorological origin.

1.12 Socio-economic Setting

The population of SAR is heavily concentrated in the fertile river valleys of the Ganges and the deltas of Indus, Brahmaputra and along the coastlines. The population density distribution is shown in Figure 2. Even though SAR has some of the world's most populous mega urban cities, the majority of the people still live in rural areas. The population of SAR is more than 1.5 billion out of which about 1.1 billion is in India alone.

Table 2 Socio-economic profile of SAR countries (2006 statistics)

Country	Area (sq km)	Population*	Population density (per sq km)	% population below poverty level*	Population growth (annual) *	Urban population %**	GDP growth (annual %)*	GNI per capita, PPP (current international $)*
Afghanistan	652,090	31,889,923**	49	53	2.6**	28.0	6.1	-
Bangladesh	144,000	155,463,091	1,080	50	1.5	23.9	6.6	1,230
Bhutan	47,000	663,964	14	32	2.2	8.2	8.5	3,530
India	3,287,260	1,109,811,147	338	29	1.4	28.1	9.7	2,470
Maldives	300	300,292	1,001	21	1.7	19.9	23.5	4,580
Nepal	147,180	27,641,362	188	42	2.0	21.1	2.8	1,010
Pakistan	796,100	159,002,039	200	33	2.1	33.7	6.9	2,390
Sri Lanka	65,610	19,886,000	303	25	1.1	30.9	7.7	3,840

*Source: * World Bank statistics:*
(http://web.worldbank.org/WBSITE/EXTERNAL/DATASTATISTICS/0,,contentMDK:20535285~menuPK:1192694~pagePK:64133150~piPK:64133175~theSitePK:239419,00.html)
** http://saarc-sdmc.nic.in/index.asp

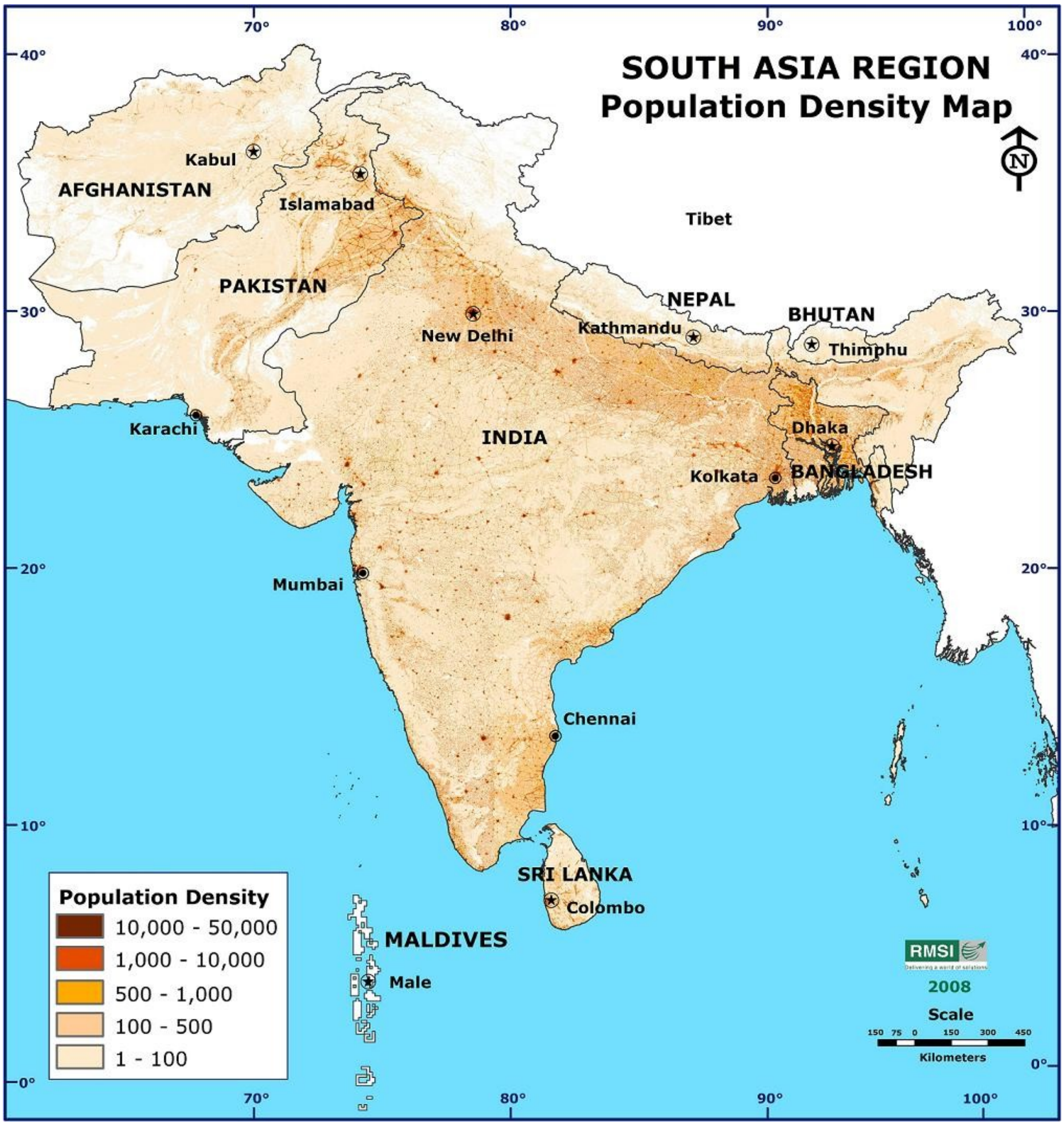


Figure 2 Population density map

Source: Landscan, 2005

1.13 Disaster Overview

All six hazards: earthquake, flood, drought, landslides, cyclone and volcano are analyzed in this section. The hazard wise list of disasters that affected each country in SAR is presented in the disaster matrix (Table 3). This matrix does not capture the frequency or severity of the events in each country but provides an understanding of the common risks, the region is subjected to.

The disaster matrix indicates that flood is a common disaster and is present in all SAR countries. Cyclone, earthquake, landslide and drought are the next most prevalent disasters in the region. Disasters caused by volcanoes are not prominent in SAR compared to other disasters and has not been studied in detail.

Table 3 Disaster matrix by country

Country	Hazards					
	Earthquake	Flood	Drought	Landslides	Cyclone	Volcano
Afghanistan	x	x	x	x		
Bangladesh	x	x	x	x	x	
Bhutan	x	x	x	x		
India	x	x	x	x	x	
Pakistan	x	x	x	x	x	
Maldives		x	x		x	
Nepal	x	x	x	x		
Sri Lanka		x	x	x	x	

Based on the CRED EM-DAT database, SAR experienced 937 disasters during the period 1967 – 2006. India, due to its size, is the focus of the majority of these disaster events. Of the 937 events, 43 percent are flood related with India and Bangladesh subjected to a majority of them. Even though, earthquakes constitute only 13 percent of the total number of disaster events, they have affected a large number of people and caused huge economic losses.

1.14 Disaster Risk Profile

The country level risk analysis is presented in section 4. Compilation of damaging disaster events along with associated losses is also reported in the section.

The reported disaster data (Figure 3) show a steady increase of event incidence in SAR. The reported number of deaths was highest during 1967 – 1971 followed by 1987 – 1991 and 2002 – 2006. Since 1992 there is a consistent increase in number of deaths. The large number of deaths reported during 1967-1971 was due to the 1970 cyclone in Bangladesh. The average annual incidence rate had increased from 1 to 5 over this period.

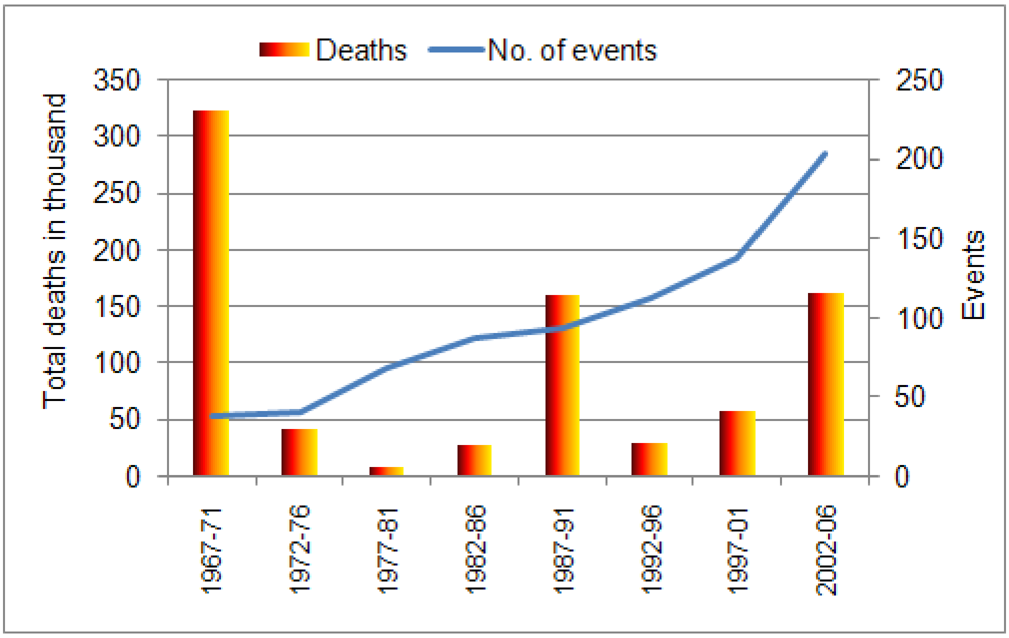


Figure 3 Reported disasters and deaths in SAR during 1967 – 2006

The reported total affected population (Figure 4) shows a steady increase along with the number of disaster events. The large number of affected population reported during 1987 – 1991 was mainly caused by the 1988 and 1991 cyclones in Bangladesh and the 1991 earthquake in India. The large number of reported affected population in 2002 – 2006 was due to the 2004 tsunami.

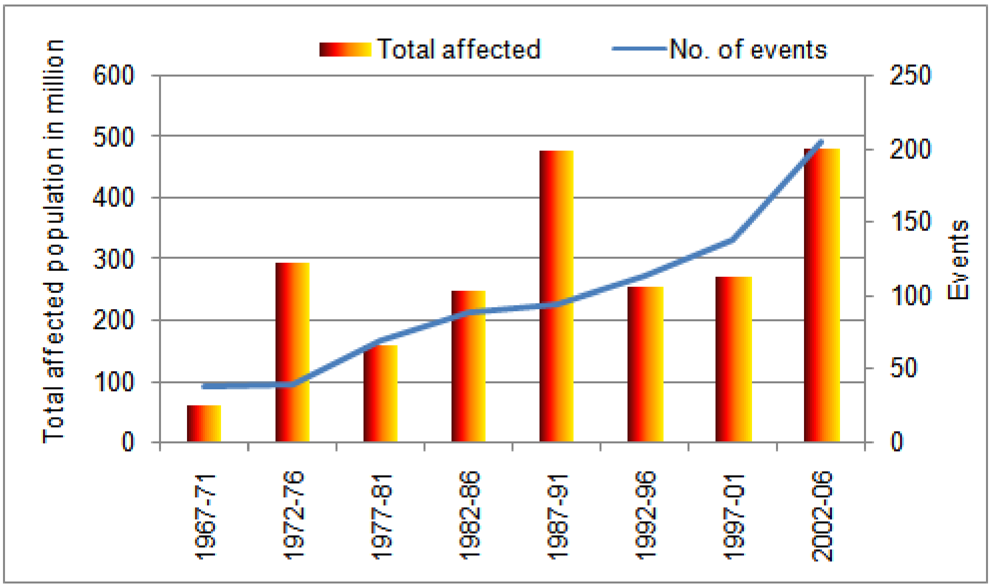


Figure 4 Reported disasters and total affected population in SAR during 1967 – 2006

The economic losses also show a steady rise over the years. Figure 5 plots the reported events against the economic loss losses they caused. This rise can be attributed to the increase in the number of disaster events, their unusual severity, and an increase in exposure. The lack of adequate mitigation measures further accentuates the problem. The economic loss shows a sudden increase in the period 1987 – 91, which was due to the 1988 and 1991 cyclones in Bangladesh and the 1991 earthquake in India.

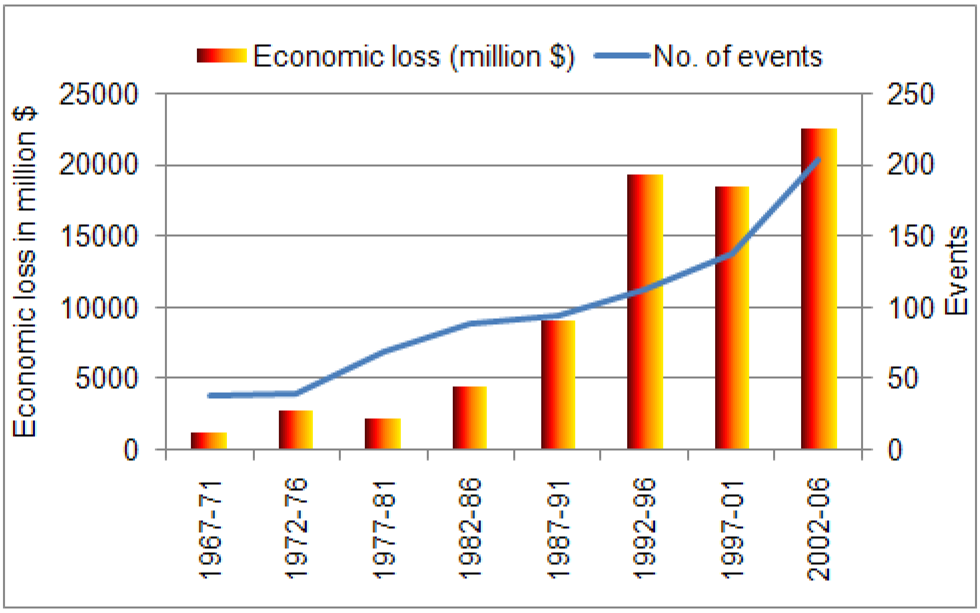


Figure 5 Reported disasters and economic loss in SAR during 1967 – 2006

To understand hazard wise disasters distribution and their impact in SAR, the reported disaster data of 40 years (1967 – 2006) were analyzed with respect to hazard and time. The data show that 50 percent of the disaster events reported was due to flood alone. Cyclone and earthquake account to 25 and 13 percent respectively (Figure 6).

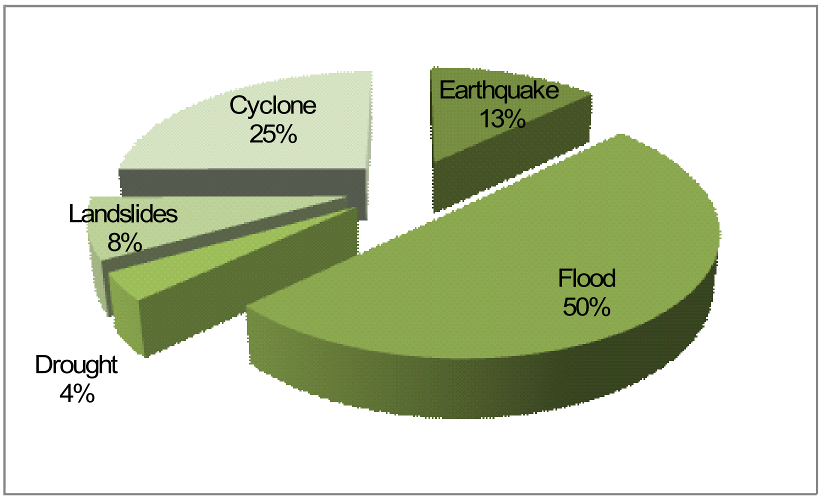


Figure 6 Percentage distribution of reported disaster SAR (1967-2006)

Number of deaths reported is highest due to disasters caused by cyclones (Figure 7). During the 40 year period, 197 cyclone events were reported in SAR. In the same period there were 100 reported earthquake events causing death to 196,351 people. Even though the flood disaster events are more than the cyclone and earthquake events, death reported are much lower than due to cyclone and earthquake.

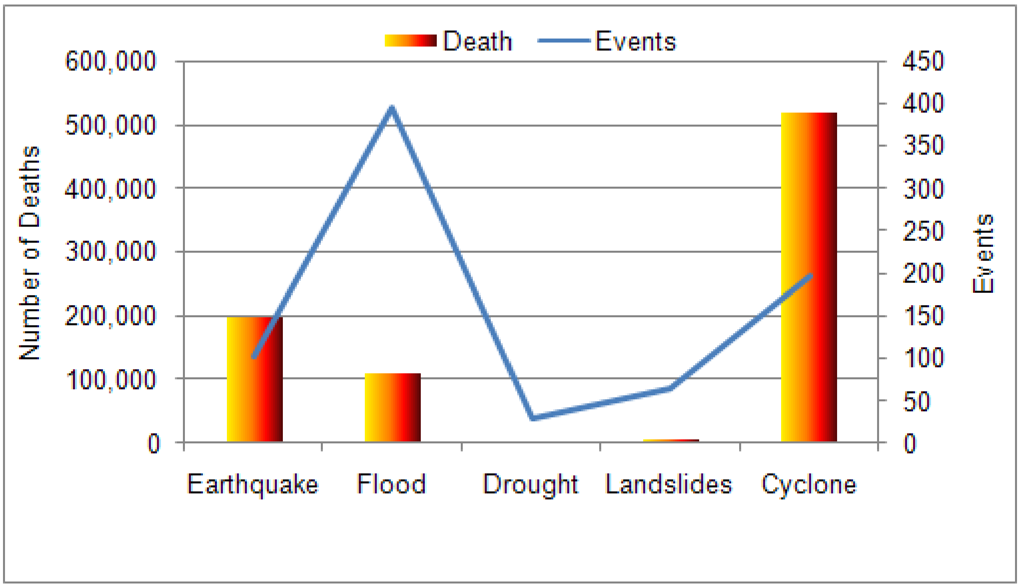


Figure 7 Reported disasters and deaths by hazard in SAR during 1967 - 2006

To understand the hazard wise distribution and their impact in SAR, the reported disaster data (1967-2006) was analyzed with respect to hazard and time. Out the 784 reported disaster events, 50 percent are floods (394), 13 percent earthquakes (100) and 25 percent cyclones (197) (Figure 6).

Cyclone caused the largest number of deaths (520,000) as shown in Figure 7. The 1970 Bangladesh cyclone alone caused 300,000 deaths. Earthquakes caused 196,000 deaths. Even though the number of reported floods is higher than either cyclones or earthquakes, the number of deaths caused by flood disasters is much lower (100,000); the reason probably being that it is easier to escape flood then either cyclone or an earthquake.

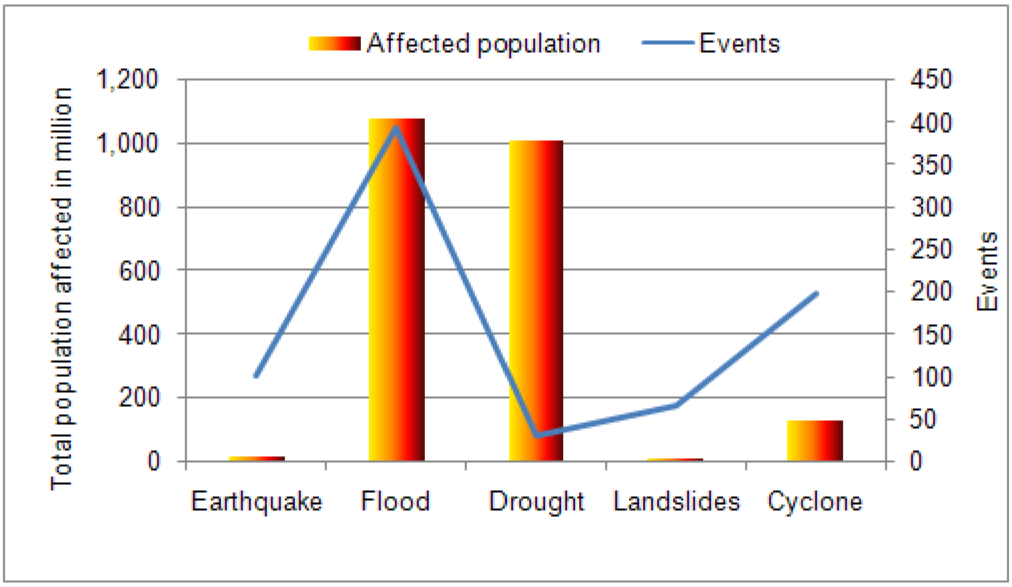


Figure 8 Reported disasters and affected population by hazard in SAR during 1967 - 2006

Flood and drought have affected about the same population, approximately one billion (Figure 8). The number is extremely large because the same population got affected several times over the 40 year period, and it is the cumulative figure that is reported.

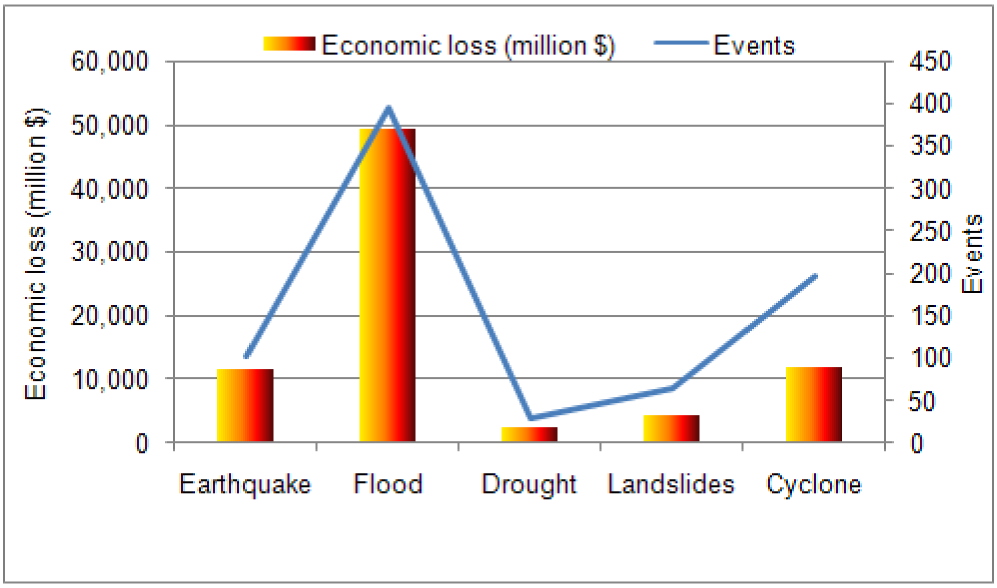


Figure 9 Reported disasters and economic loss by hazard in SAR during 1967 – 2006

Flood although causing the least amount of deaths has the largest economic impact. The economic loss due to flood over the last 40 years is about $ 49 billion or an average annual loss of more than $ one billion. Cyclones and earthquakes generated economic losses of approximately $ 12 billion each.

1.15 Major natural hazard risk overview and vulnerability assessment

Earthquakes, floods, droughts, landslides and cyclones are the five major natural hazards that cause disasters in the SAR region. This section provides a high level picture of the regional hazards in the form of mortality risk maps and tables charting the percentage areas and population under different categories of low, moderate, high and very high (ISDR, 2009) depending upon the availability of database.

In detailed risk analyses performed for economic loss estimation or emergency response planning, vulnerability is usually disaggregated into loss to buildings and infrastructure, business interruption loss, and social impact quantified in terms of number of fatalities and casualties. In this analysis, a rapid assessment approach was followed where a simple proxy was used to quantify the vulnerability. The selected proxy was the population at risk. This assumption is robust for two reasons: Firstly, most of the buildings and the infrastructure are concentrated in populated areas and, secondly, the population itself is quite vulnerable to hazards in CAC. The mortality risk maps (available from GAR preview platform) were overlaid with gridded population data and analyzed using GIS to identify the population at risk from various hazards. The vulnerabilities are presented in tables, identifying the percentage of the populations in each country under different hazard risk mortality category.

1.15.1 Earthquake

The seismicity in SAR is generated by the collision between three tectonic plates. The Indian plate is moving northward at a speed of about five cm per year and in doing so collides with the Eurasian Plate. Due to this collision, the Himalayan Mountains are uplifted and a large number of earthquakes are being generated. This is the cause of earthquakes from the Himalayas to the Arakan-Yoma- one of the most seismically active belts on the earth. The same process involving the Indian plate and the Burmese Micro-plate results in earthquakes in the Andaman and Nicobar Islands. Smaller earthquakes have also occurred within Peninsular India. They are referred to as intra-plate earthquakes and arise from localized systems of forces in the crust sometimes associated with the reactivation of ancient geological structures such as in the Rann of Kachchh.

The inter-plate boundary regions, Himalayan Arc and intra-plate regions are the most important contributor to the earthquake risk in SAR. The Himalayan belt extending across Afghanistan, Pakistan, India, Nepal and Bhutan is identified as the very high seismic hazard area in SAR (Figure 10 and Figure 11). SAR is considered to be one of the highest seismically active regions in the world. Earthquakes have a severe impact in terms of number of people killed compared to other natural hazard in SAR.

The very high seismic risk in the region was recently emphasized by the October 2005, magnitude 7.6 Kashmir (POK) earthquake that caused more than 70,000 deaths both in India and Pakistan. The largest number of deaths as a direct result of an earthquake in SAR was caused by this event. It supersedes the number of fatalities in SAR directly caused from the Sumatra earthquake of magnitude 9.1 in 2004, which generated a highly damaging Tsunami. These are followed by the 1935 Quetta (Balochistan, Pakistan) earthquake of magnitude 7.5 with 30,000 fatalities, the 1905 Kangra (Himachal Pradesh, India) earthquake of magnitude 7.8 with 20,000 fatalities and the 2001 Bhuj, (Gujarat, India) earthquake of magnitude 7.7 with about 20,000 fatalities. Apart from the 2004 Sumatra and 1945 Makran tsunamigenic earthquakes, most deaths were caused as a result of building collapse due to ground shaking.

The Indian peninsula was generally thought to be seismically safe; however, large earthquakes such as 1967 Koyna earthquake of magnitude 6.5, 1993 Latur/ Killari earthquake of magnitude 6.3 and 1999 Jabalpur earthquake of magnitude 6.0 have proven otherwise. Several other damaging earthquakes have also affected this region in historical past.

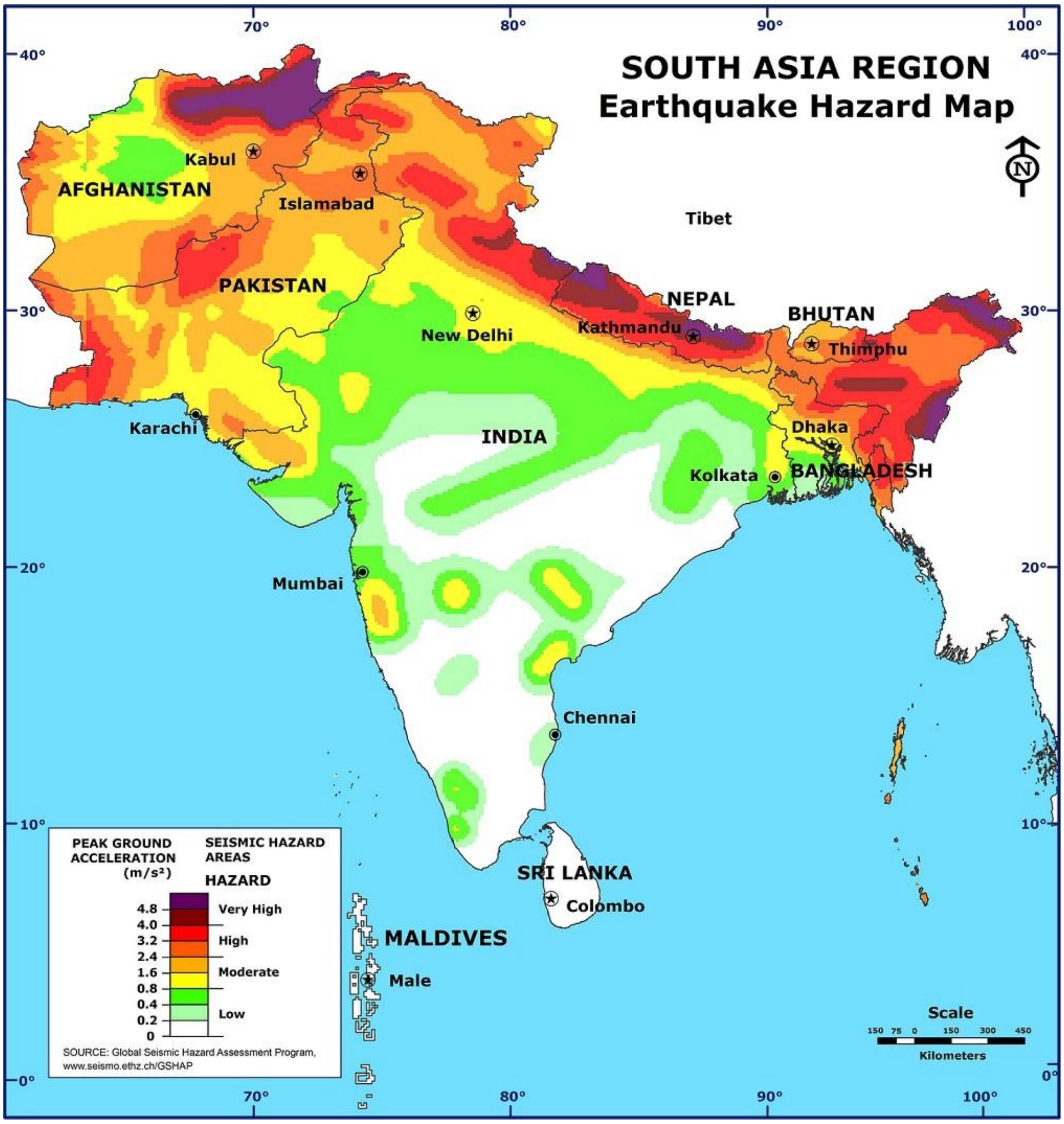


Figure 10 Earthquake hazard map of SAR

Source: Bhatia et al. (2000). A probabilistic hazard map of India and adjoining region, Global Seismic Hazard Program), http://www.seismo.ethz.ch/GSHAP/

Note: Based on peak ground acceleration for 10% probability of exceedance in 50 years. This equates to a return period of 475 years for a specific level of ground acceleration at a specific location. Seismic hazard zone are classified into low (0 -0.08 g); moderate (0.08 g – 0.24 g); high (0.24 g – 0.40 g); very high (0.40 g or greater).

In terms of magnitude, the largest recorded earthquake that affected SAR is the 2004 Sumatra earthquake of magnitude 9.1 (3rd largest in the world since 1900). Even though the epicenter of the event is outside SAR, many countries in SAR have experienced its deadly impact. The earthquake was felt as far as Ahmedabad in western India. The resulted tsunami decimated entire coastal communities in India, Sri Lanka, and caused significant damage and deaths in the Bangladesh, and Maldives. However, the largest earthquake that occurred within SAR is the 1950 Great Assam earthquake of magnitude 8.6 (8th largest earthquake in the world). Ground motions from this earthquake were felt strongly as far as Kolkata, near 1,000 km away from the epicenter. The 1945 Makran, Pakistan earthquake of magnitude 8.0 rocked the coastal areas of the Balochistan and Sindh Province of Pakistan including the city of Karachi and was felt as far as Kanpur in Uttar Pradesh, India. This earthquake also generated a major tsunami in the Arabian Sea, killing several people as far as Mumbai. Prior to 1900, several large damaging earthquakes reportedly occurred in SAR.

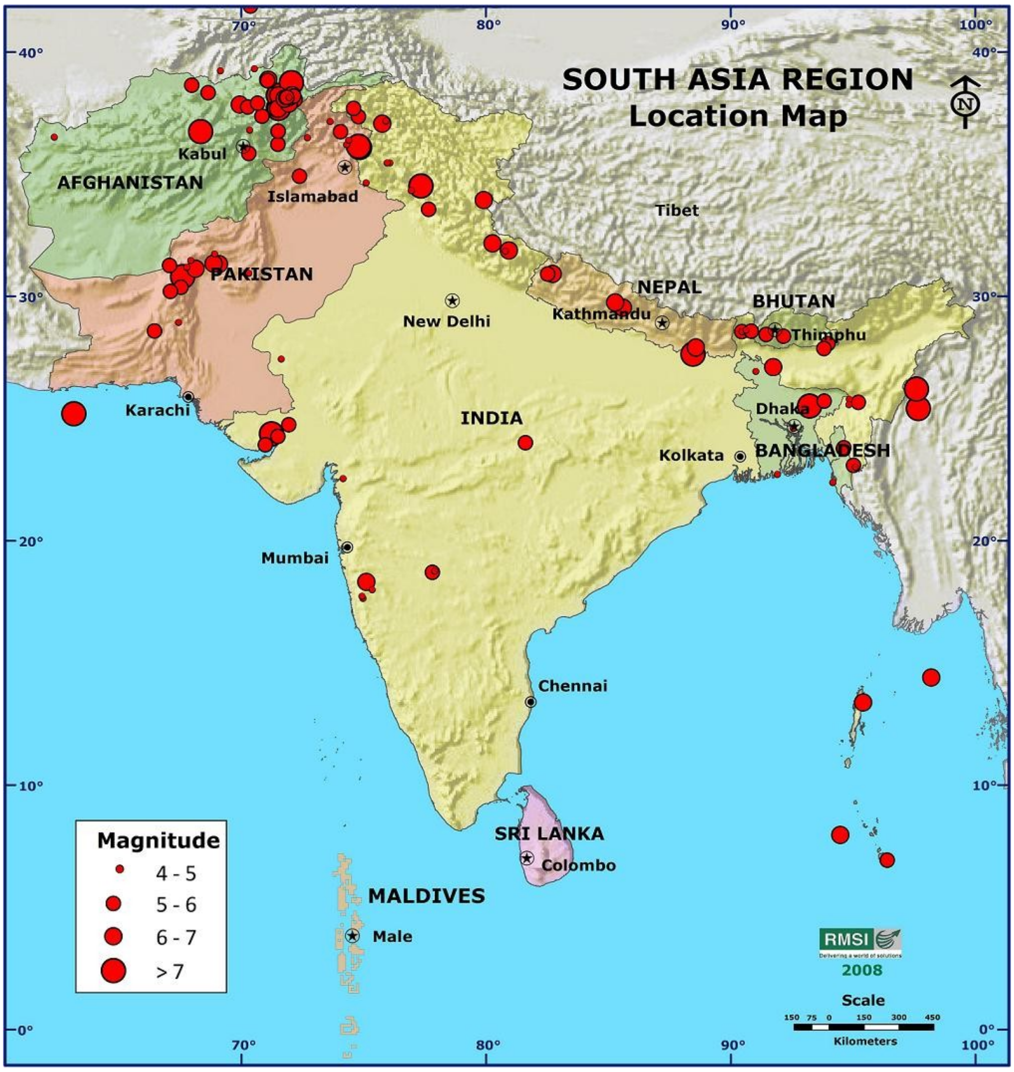


Figure 11 Distribution of major damaging earthquakes reported in SAR (1900 to 2006)

Source: Data compiled from NGDC, ADRC, OCHA, SAARC, CRED

The 1934 Nepal-Bihar earthquake of magnitude 8.1 caused serious damage to 60 percent of the buildings in Kathmandu valley (JICA, 2002). The 1934 and the recent 1988 Nepal–Bihar earthquake together created heavy loss of life and property both in Nepal and India. Almost whole of Nepal is under the high and very high earthquake intensity zones while 60 percent of Bhutan is under the same zone categories. Afghanistan and Bangladesh have close to half of their territory within the high and very high seismic zones. India has 16 percent of its land within the high and very high seismic zones. South and central India are under the low seismic zones. The entire Sri Lanka and Maldives are under the low seismic zones. In the past, earthquake events occurred offshore of both of these islands, however, there is no record of any catastrophic earthquake event in the close vicinity.

Figure 12 presents the earthquake risk map of SAR in terms of a mortality risk index (ISDR, 2009). This map has been generated using past Modified Mercalli Intensity (MMI) (Wald et. al., 1999, 2005; Wald and Allen 2007), as it makes it easier to relate the recorded ground motions to the expected felt and damage distribution.

From the figure, it is evident that the entire Himalayan range running through Afghanistan, Pakistan, India, Nepal, and Bhutan falls under very high earthquake mortality risk. Apart from this a large part of mid-western Pakistan, some parts of western India and isolated pockets in central India, and the Chittagong Hill Tract (CHT) district of Bangladesh also fall under very high earthquake mortality risk.

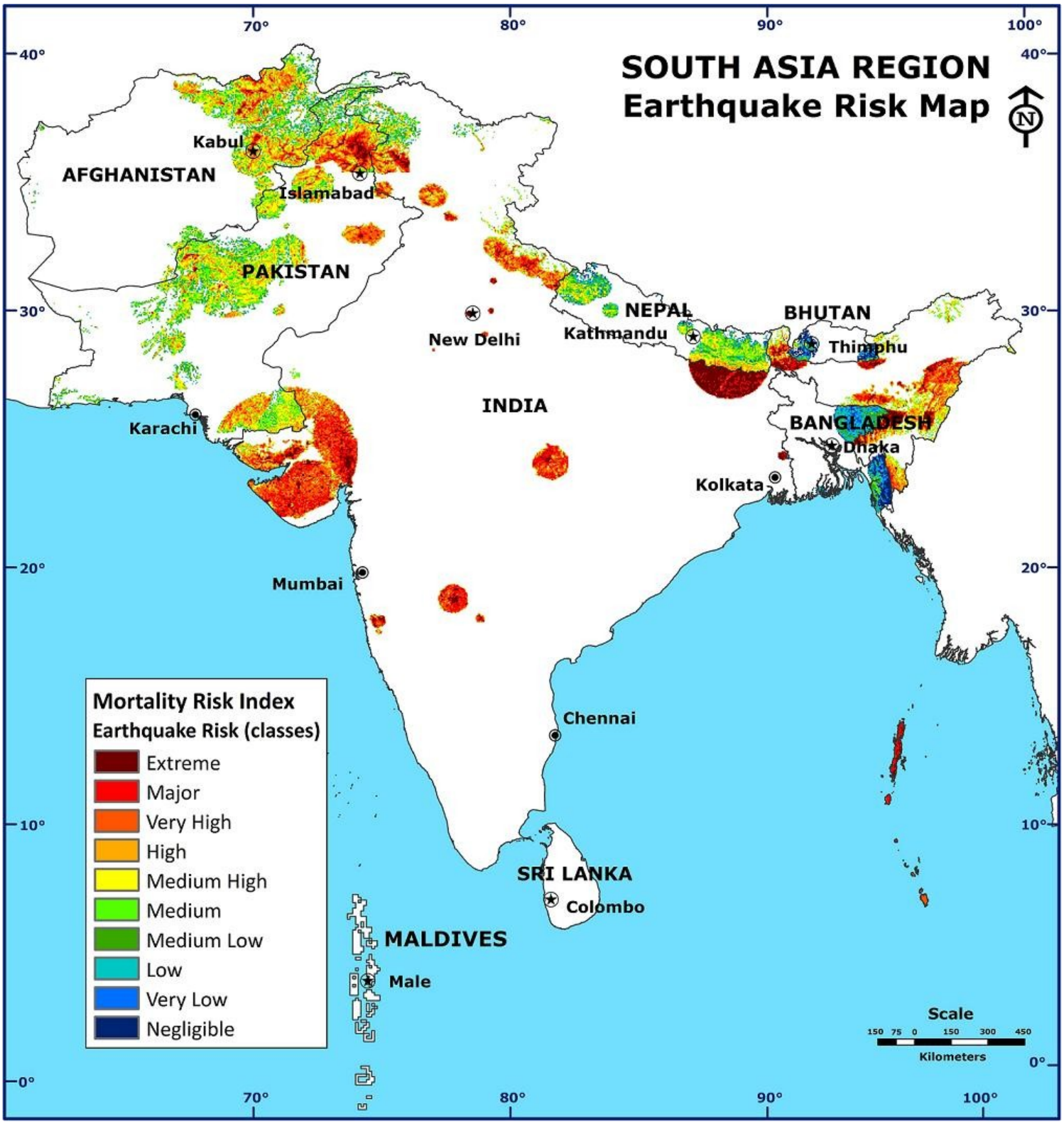


Figure 12 Earthquake mortality risk map of SAR

Source: Extracted from GAR preview data platform
http://preview.grid.unep.ch/index.php?preview=data&events=earthquakes&lang=eng

Table 4 presents the percentage area and population in four mortality risk categories (low, moderate, high and extreme) for each SAR country. From this table, it is clear that, in terms of extreme risk percentage area of the country, India ranks first followed by Pakistan and Afghanistan. While, in terms of extreme risk as a percentage of the population of the country, Afghanistan ranks first followed by Pakistan and India.

Table 4 Percentage area and population in each earthquake mortality risk category

Country	% of total country geographic area					% of total country population				
	Low	Moderate	High	Extreme	total	Low	Moderate	High	Extreme	total
Afghanistan	1.38	11.49	6.12	1.02	20.01	0.24	6.52	19.03	28.65	54.44
Bangladesh	21.53	5.41	0.41	0.26	27.61	10.41	9.33	0.19	0.12	20.05
Bhutan	22.5	4.9	0.77	0.39	28.56	13.12	18.25	1.7	5.47	38.54
India	0.14	2.2	4.45	4.35	11.14	0.01	0.17	1.23	8.23	9.64
Nepal	8.18	27.51	4.62	0.4	40.71	0.84	25.93	17.98	2.23	46.98
Pakistan	1.57	19.98	8.52	1.94	32.01	0.07	3.57	10.59	12.22	26.45
Sri Lanka	0	0	0	0	0	0	0	0	0	0

Source: Area and population computed from the earthquake mortality risk map of GAR platform (http://preview.grid.unep.ch/index.php?preview=data&events=earthquakes&lang=eng)

The reader should kept in mind limitation of the above analysis presented as these has been taken from a global analysis, wherein mortality risk maps have been prepared depending upon availability of data for each country (ISDR, 2009).

1.15.2 Flood

SAR is highly influenced by monsoonal climate. The major rivers of the region are fed both by rainfall and the Himalayan glaciers. The floods in the region are mostly due to the amount of excess rainfall compared to the drainage capacity. At present, there is no systematic detection of flood events in SAR as there is for cyclones and earthquakes.

Floods are triggered by various phenomena and there are different types of floods. For example one can often differentiates among flash floods, river floods, and urban floods, all of which are caused by a combination of heavy precipitation and poor drainage. The severity of these flood types depends on rainfall intensity, spatial distribution of rainfall, topography and surface conditions (ISDR, 2009).

Coastal areas in SAR are more vulnerable to flash floods due to a combination of heavy rainfall and high tide or storm surges. The flood risk is expected to increase significantly in the future with further increases in population density in these areas. As predicted by various climate change models, rising sea-levels and more frequent extreme rainfall events are further expected to increase the flood risk.

Many of the urban areas in the region have recently experienced flash floods caused by rainfall due to unplanned urban growth and change in land use.

Figure 13 presents the flood risk map of SAR in terms of a mortality risk index (ISDR, 2009). The map has been generated mostly using riverine floods. Peak-flow magnitude estimates for ungauged sites have been computed, based on records from a set of gauging stations, following the directions of the Bulletin 17B from United States Water Resources Council's Hydrology Subcommittee (Sando, 1998). This is a four-step process:

- Estimation of peak-flow values for a hundred-year recurrence interval for gauging stations, based on log-Pearson type III modeling of the records; constitution of groups of gauging stations taking into account basin and climatic characteristics;
- Elaboration of a regression formula for each group, which predicts peak-flow values from basin and climatic characteristics;
- Attribution of a reference group for each ungauged site;

- Estimation of its peak-flow by the corresponding regression formula. In order to solve the problem of data homogeneity in some climatic regions, a global approach is adopted for the whole statistical analysis (ISDR, 2009).

Flooded areas corresponding to exceptional events of a 100-year recurrence interval are generated by calculating the river stage. This is achieved using peak-flow estimates and the Manning equation through complex and automated processes based on GIS (ISDR, 2009).

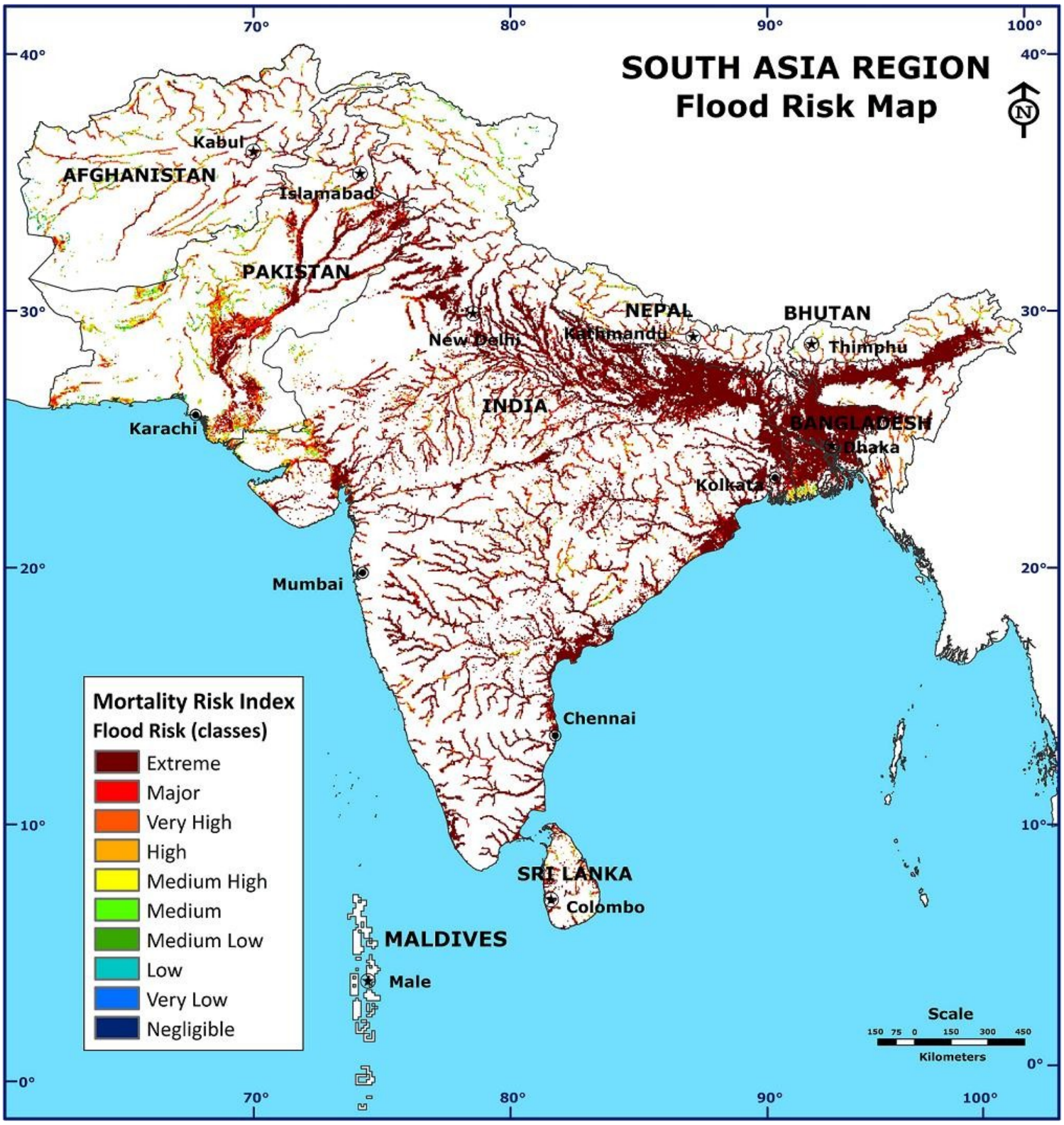


Figure 13 Flood mortality risk map reported in SAR
Source: Extracted from GAR preview data platform
(http://preview.grid.unep.ch/index.php?preview=data&events=floods&lang=eng)

Table 5 presents the percentage area for each SAR countries in four flood mortality risk categories (low, moderate, high and extreme) of the total geographic area of each country.

Table 5 Percentage area and population in each flood mortality risk category

Country	Percentage of country area					Percentage of country population				
	Low	Moderate	High	Extreme	total	Low	Moderate	High	Extreme	total
Afghanistan	0.27	2.27	3.78	4.30	10.63	0.04	1.19	3.93	26.22	31.38
Bangladesh	0.06	1.47	2.65	69.95	74.12	0.00	0.11	0.97	76.82	77.91
Bhutan	0.05	2.26	4.42	6.01	12.74	0.00	1.02	3.56	24.88	29.45
India	0.01	0.80	3.44	20.09	24.34	0.00	0.08	1.63	33.49	35.20
Nepal	0.13	2.11	4.54	12.94	19.72	0.06	0.71	2.07	32.96	35.80
Pakistan	0.21	3.51	6.25	10.63	20.60	0.03	0.59	4.05	22.37	27.04
Sri Lanka	0.06	2.05	5.92	14.18	22.21	0.00	0.70	3.47	23.26	27.43

Source: Area computed from the flood mortality risk map of the GAR preview data platform ***(http://preview.grid.unep.ch/index.php?preview=data&events=floods&lang=eng)***

From Figure 13 and Table 5, it is clear that about 70 percent area of Bangladesh falls in the extreme flood mortality risk category. The Himalayas, its foot hills and coastal cities are also highly prone to flood and almost 20 percent area of India falls in the extreme flood mortality risk category. Thus, in terms of percentage of the geographical area of the country in the extreme flood zone, Bangladesh ranks first followed by India, Sri Lanka, Nepal, Pakistan, Bhutan, and Afghanistan. In terms of population under extreme flood mortality, Bangladesh ranks first followed by India, Nepal, Afghanistan, Bhutan, Sri Lanka, and Pakistan. The sparsely/uninhabited areas of Pakistan and Afghanistan, the central and northern portions of India and central portion of Sri Lanka are the only areas spared from endemic flooding. Regarding the flood mortality risk in Bangladesh and India, the CRED EM-DAT database also supports the above conclusions. Out of 400 flood events that occurred in SAR during the period 1967 – 2006, 163 events were located in India and 70 in Bangladesh. . It may be noted, that the geographical extent of India is very large when compared to that of Bangladesh.

The reader should keep in mind the limitations of the above analyses as these have been extracted from a global analysis, wherein mortality risk maps have been prepared depending upon availability of data for each country.

Drought

Almost the entire SAR is under the threat of drought of varying intensities. They affect a greater number of people than any other natural hazard. Drought refers to a condition of an insufficient supply of water necessary to meet demand, both being highly location-specific. For example, a few months of deficient rainfall can adversely affect rain-fed agricultural systems while several months to a year (or more) of drought may be necessary to impact a water supply system with substantial storage capacity. Given the varying impacts of drought several drought indicators are in use around the world (ISDR, 2009).

Among natural hazards, drought risk is especially difficult to quantify. First, unlike earthquakes, floods or tsunamis that occur along generally well-defined fault lines, river valleys or coastlines, drought can occur anywhere (with the exception of deserts where it doesn't have meaning). Defining what constitutes a drought across the wide range of regional climates around the globe is challenging in its own right, identifying what drought characteristic (its intensity, duration, spatial extent) is most relevant to a specific drought sensitive sector (agriculture, water management, etc.) poses another layer of complexity. Drought does not destroy infrastructure or directly lead to human mortality. Famines may be triggered by drought but increased human mortality during famine is ultimately linked to a broader set of issues surrounding food security (ISDR, 2009).

Figure 14 presents the drought map of SAR in terms of a drought frequency Standardized Precipitation Index (SPI) map (ISDR, 2009). SPI captures the drought intensity and frequency and compares an accumulated precipitation amount for a given time interval (in the present study the past 3, 6 and 12 months over the period (1951-2004) with historical values for the same month. The difference between the observed and historical value is then expressed in terms of a standardized normal distribution having a mean of zero (indicating no difference from the historical average). Increasingly negative values of SPI indicate increasingly drier-than-average conditions, with values less than -1 generally considered as indicating drought (Figure-15). The approach is widely used in the analysis of hydro meteorological time series and drought frequency analysis (Dracup et al. 1980; Clausen and Pearson 1995; Fernández and Salas 1999; Keyantash and Dracup 2002; Sirdaş and Şen 2004; among many others).

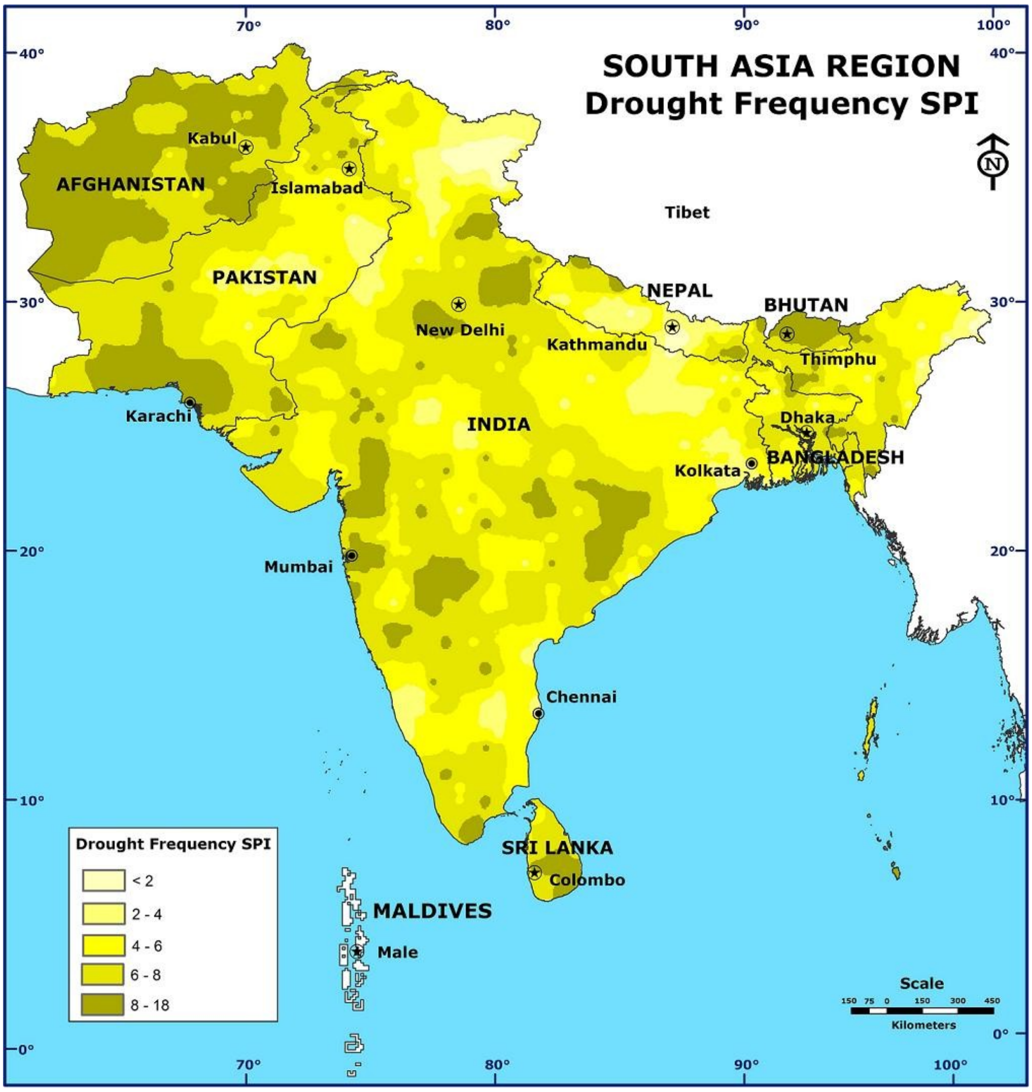


Figure 14 Drought Frequency SPI map reported in SAR

Source: Extracted from the GAR preview data platform (http://preview.grid.unep.ch/index.php?preview=data&events=droughts&lang=eng)

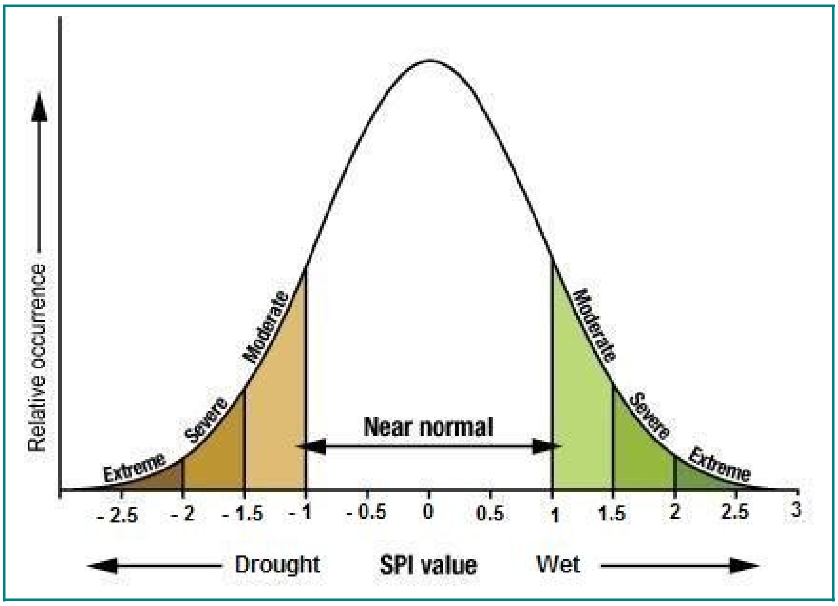


Figure 15 The relative occurrence versus value of the SPI (Index < -1 for drought)

(http://preview.grid.unep.ch/index.php?preview=data&events=droughts&lang=eng)

The predominant activity in SAR countries is agriculture and drought can affect agriculture thereby the livelihood of large numbers of people. Incidentally, many of the high drought prone areas are also prone to floods, accentuating the harsh conditions of the population living in the region.

Table 6 presents the percentage area and population of each country under different drought SPI-frequency categories.

Table 6 Percentage area and population in each drought SPI-frequency category

Country	% of total country geographic area						% of total country population					
	Very Low	Low	Mod.	High	Very High	total	Very Low	Low	Mod.	High	Very High	total
Afghanistan	0.00	0.00	1.17	35.14	63.69	100	0.00	0.00	1.00	47.82	51.18	100
Bangladesh	0.22	1.81	40.89	54.12	2.96	100	0.00	1.14	34.20	62.12	2.54	100
Bhutan	0.00	0.00	1.54	29.38	69.08	100	0.00	0.00	3.71	54.88	41.41	100
India	1.34	9.17	36.74	42.73	10.02	100	0.17	11.07	37.30	41.59	9.87	100
Nepal	5.37	36.33	33.31	18.13	6.86	100	9.72	42.10	29.18	13.29	5.71	100
Pakistan	0.08	8.26	29.84	44.13	17.69	100	0.16	18.25	40.31	28.92	12.36	100
Sri Lanka	0.00	0.00	7.48	55.38	37.14	100	0.00	0.00	3.33	66.91	29.76	100

Source: Area computed from the drought SPI-frequency map of the GAR preview data platform
(http://preview.grid.unep.ch/index.php?preview=data&events=droughts&lang=eng)

The drought frequency SPI map presented in Figure 14 has some important limitations as the map has been derived from a global scale analysis (UNISDR, 2009). First, variations in regional climate which are associated with small scale topographic features, such as rain shadows, will likely not be well captured in the drought analysis. More generally, the issue of data quality in regions with sparse precipitation observing stations needs to be kept in mind. Using the calendar year as the period in which drought events are identified may disguise the occurrence of events that develop near the start, or end, of a given year.

1.15.3 Landslide

The Himalayan Mountain ranges are prone to landslides and avalanches. Portions of Western Ghats region (Konkan and southern part of Western Ghats) of India are also prone to landslides affecting life, agriculture and assets. The mountain slopes of these regions have been altered by intense human activities that increase landslide events. The term landslide refers to slides with rapid mass movement, like rockslides, debris flows, induced by both rainfall and earthquake; which pose a threat to human life. Slow moving slides have significant economic consequences for constructions and infrastructure, but rarely cause any fatalities. Rapid mass movement also includes snow avalanche, which is not taken into consideration, as well as rock avalanches and submarine slides (ISDR, 2009).

As shown in Figure 16, the north and north eastern part of the India and almost 80 percent of Nepal is prone to landslides. Landslides in these regions can also trigger flood. Almost the entire Bhutan is prone to landslides. Even though Sri Lanka is not categorized as a landslide affected country as per the hazard map, the country has recorded 3 events during the period 1967 – 2006. Maldives is the only country in the region not prone to landslide due its topographic characteristics. CRED database has recorded 77 landslide events in this period in SAR of which the majority are reported in India, Nepal and Pakistan.

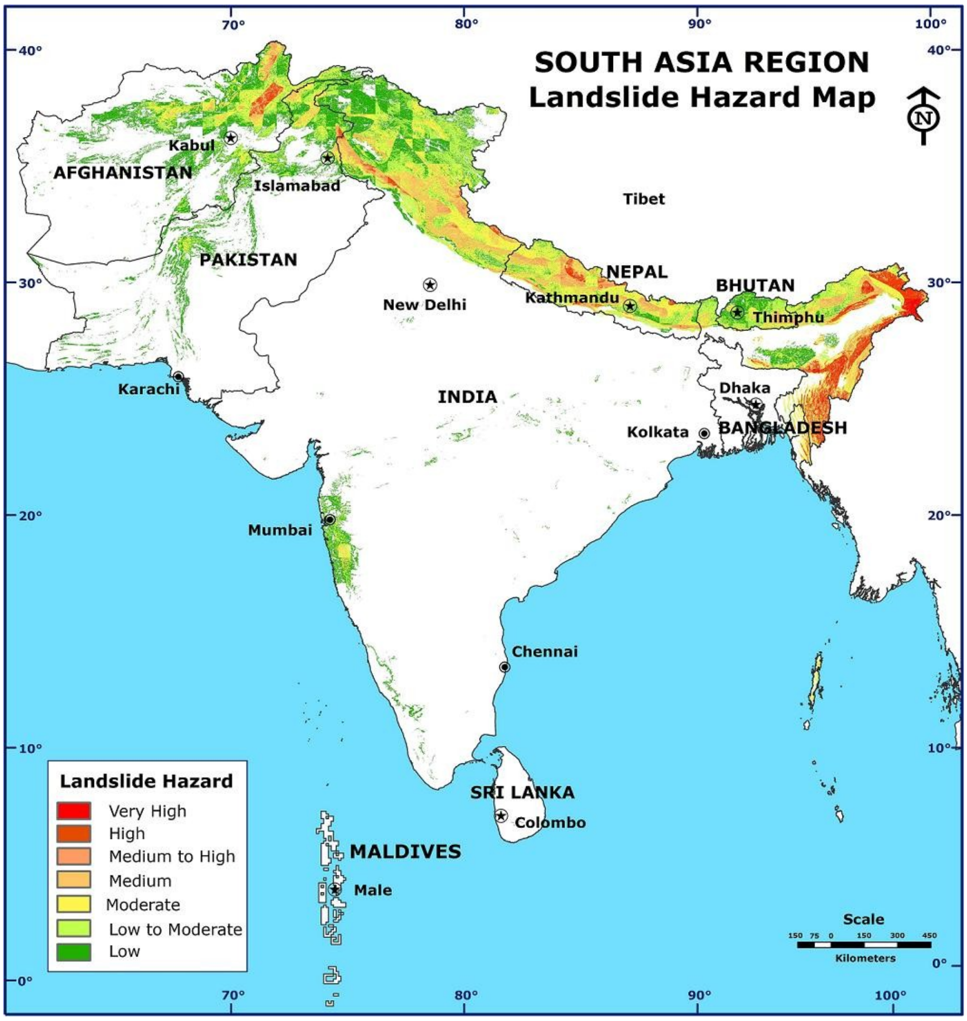


Figure 16 Landslide hazard map of SAR

Source: NGI, 2008 (NGI 2004 landslide hazard data received through personal communication with NGI).

Note: The categorization is based on NGI data. NGI has classified hazard values ranging 0 – 1,750 and has grouped into low, low to moderate, moderate, medium, medium to high, high and very high classes. To understand in simple term this class was related to average annual incidence on landslide hazard events based on the reported disaster and it can be derived that low zones have an average annual incidence less than 0.1, moderate: 0.11 – 0.3, high: 0.31 – 0.8 and very high: greater than 0.8.

The landslide risk map in terms of mortality risk index is presented in Figure 17.

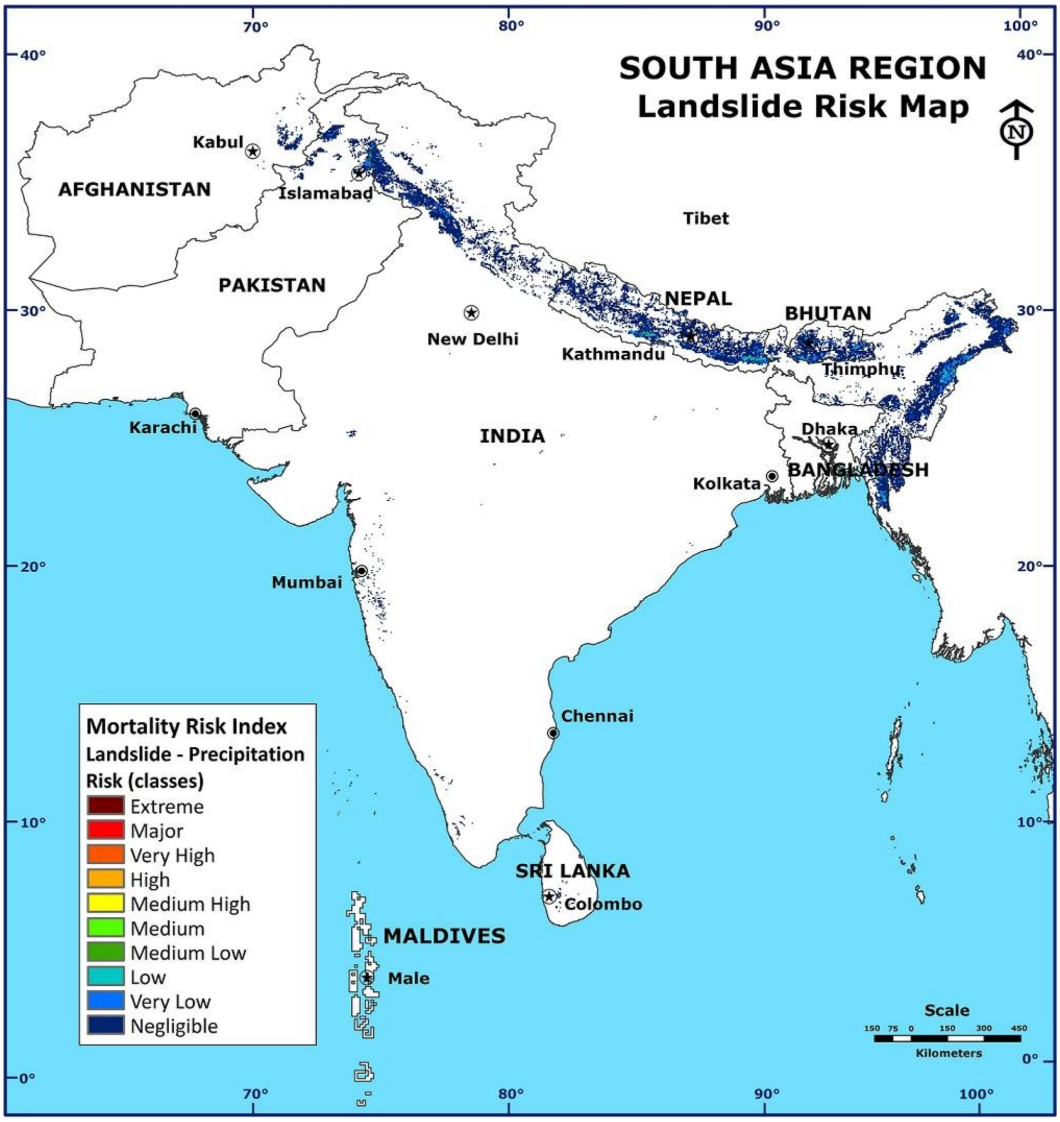


Figure 17 Landslide mortality risk map of SAR

Source: GAR preview data platform
(http://preview.grid.unep.ch/index.php?preview=data&events=landslides&lang=eng)

The landslide hazard, defined as the annual probability of occurrence of a potentially destructive landslide event, depends on the combination of trigger and susceptibility (Figure 18). In the analyses performed in this study, a landslide hazard index was defined using six parameters: slope factor, lithological (or geological) conditions, soil moisture condition, vegetation cover, precipitation, and seismic conditions. For each factor, an index of influence was determined and a relative landslide hazard indicator was obtained by multiplying and summing the indices (ISDR, 2009).

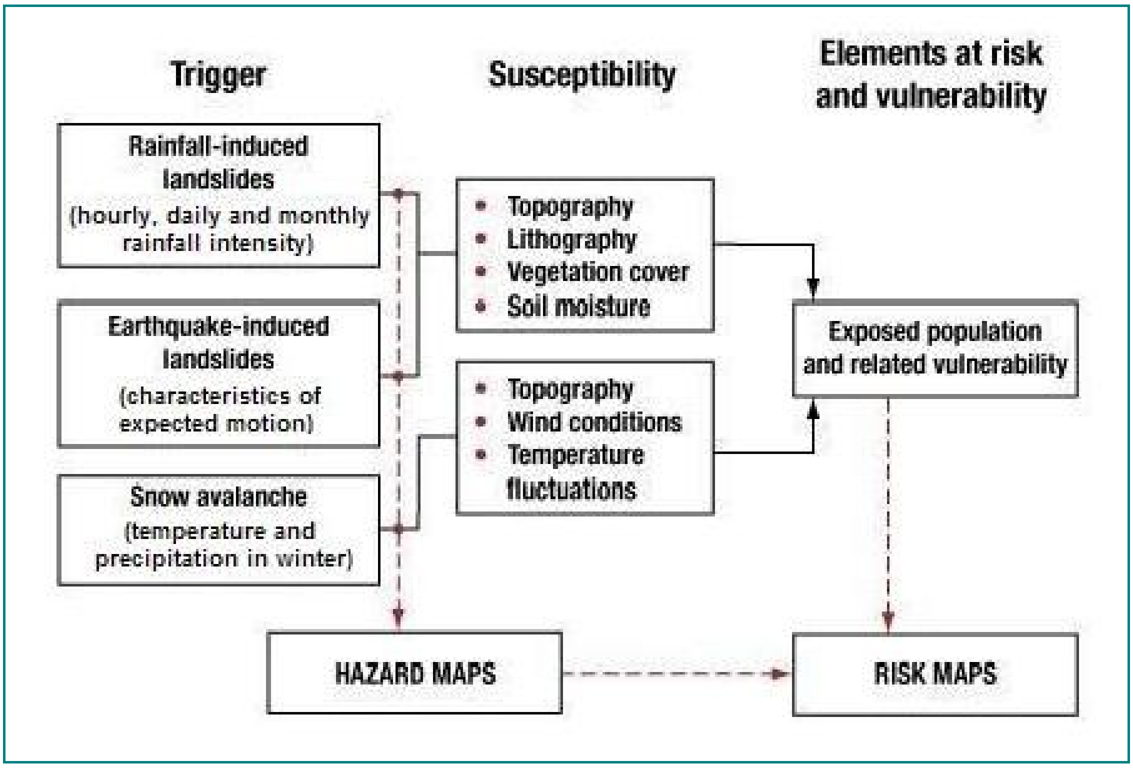


Figure 18 Schematic approach for landslide hazard and risk evaluation (ISDR, 2009)

Table 7 presents the percentage area and percentage population at risk for each SAR countries in four landslide mortality risk categories (low, moderate, high and extreme) of the total geographic area and total population of each country.

Table 7 Percentage area and population in each landslide mortality risk category

Country	% of total country geographic area					% of total country population				
	Low	Moderate	High	Extreme	total	Low	Moderate	High	Extreme	total
Afghanistan	0.68	0.00	0.00	0.00	0.68	1.08	0.00	0.00	0.00	1.08
Bangladesh	8.28	0.07	0.00	0.00	8.35	1.49	0.04	0.00	0.00	1.53
Bhutan	56.49	0.19	0.00	0.00	56.68	82.84	2.29	0.00	0.00	85.13
India	4.12	0.01	0.00	0.00	4.14	1.89	0.03	0.01	0.00	1.92
Nepal	44.47	0.27	0.00	0.00	44.74	35.97	1.18	0.00	0.00	37.15
Pakistan	1.52	0.01	0.00	0.00	1.53	1.31	0.01	0.00	0.00	1.32
Sri Lanka	1.38	0.00	0.00	0.00	1.38	1.08	0.00	0.00	0.00	1.08

Source: Area computed from the landslide mortality risk map of the GAR preview data platform (http://preview.grid.unep.ch/index.php?preview=data&events=landslides&lang=eng)

The reader should keep in mind the limitations of the above analyses. Human impact is a very important triggering factor for landslides, which is ignored in the model. On a global scale analysis, one could introduce an index that is related to population density and/or infrastructure density. The lithology factor has been used with the aid of a coarse resolution geological map of the world.

1.15.4 Cyclone

The presence of warm oceans, the tropical climatic conditions and the wind patterns in the region make SAR prone to cyclone risk. Tropical cyclones are powerful hydro-meteorological hazards that are unevenly spread in SAR as their development depends on specific climatic and oceanic conditions. A tropical cyclone has multiple impacts on the affected areas, including:

- Damage caused by extremely powerful winds
- Torrential rains leading to floods and/or landslides
- High waves and damaging storm surge, leading to extensive coastal flooding

The complexity of the multiple forms of impact triggered by tropical cyclones would call for integrated modeling of wind, rain, storm surge and landslides. However, in this analysis, priority was given to modeling the winds and storm surge.

The proposed global model of tropical cyclones wind hazard is based on the observations of 2821 historical cyclone events through an estimation of the radial wind speed profile using a parametric model. The model is based on an initial equation from Holland (1980), which was further modified to take into consideration the movement of cyclones over time. It is an update of the original data set (Herold et al., 2003) developed by UNEP/GRID-Europe between 2001-2003 (Nordbeck, Mouton and Peduzzi, 2005 for the detailed methodology). The dataset was made available by the United Nations Environment Programme (UNEP) under the name PREVIEW Global Cyclones Asymmetric Wind speed profiles (Global Risk Data Platform) and other derived products (wind sum, frequency and physical exposure) were used (Peduzzi et al., 2002; Dao and Peduzzi, 2004) to compute the Disaster Risk Index (DRI) published by the United Nations Development Programme (UNDP 2004).

The previous model covered 1980–2004 but had only 8 years in North Indian Ocean. This version was further improved by extending the time coverage from 1975 to 2007. It is spatially globally complete, except over South India Ocean where two years are missing (1975 and 1976). This is the reason why the study period of 30 years starts in 1977. Otherwise it is very complete, even the information on the 2004 Catarina cyclones that affected Brazil (south Atlantic) was also modeled (data courtesy of Anteon Corp./Roger Edson 2004; http://cimss.ssec.wisc.edu/tropic/brazil/brazil.html).

India is one among the countries in the world having a high mortality risk due to cyclone. Table 8 presents, by country, the percentage area under different cyclone zones. In terms of percentage area covered under the cyclone influence, Bangladesh comes first in the list in SAR followed by Sri Lanka, India and Pakistan. Even though in India, the area under cyclone influence is only 12 percent of the total area there has been more than 100 events reported during the 1967–2006 period some of which having caused substantial damage.

The cyclone risk map in terms of a mortality risk index is presented in Figure 19.

Table 8 presents the percentage areas for each SAR country in four cyclone mortality risk categories (low, moderate, high and extreme) of the total geographic area of each country.

The cyclone surge physical exposure map is presented in Figure 19.

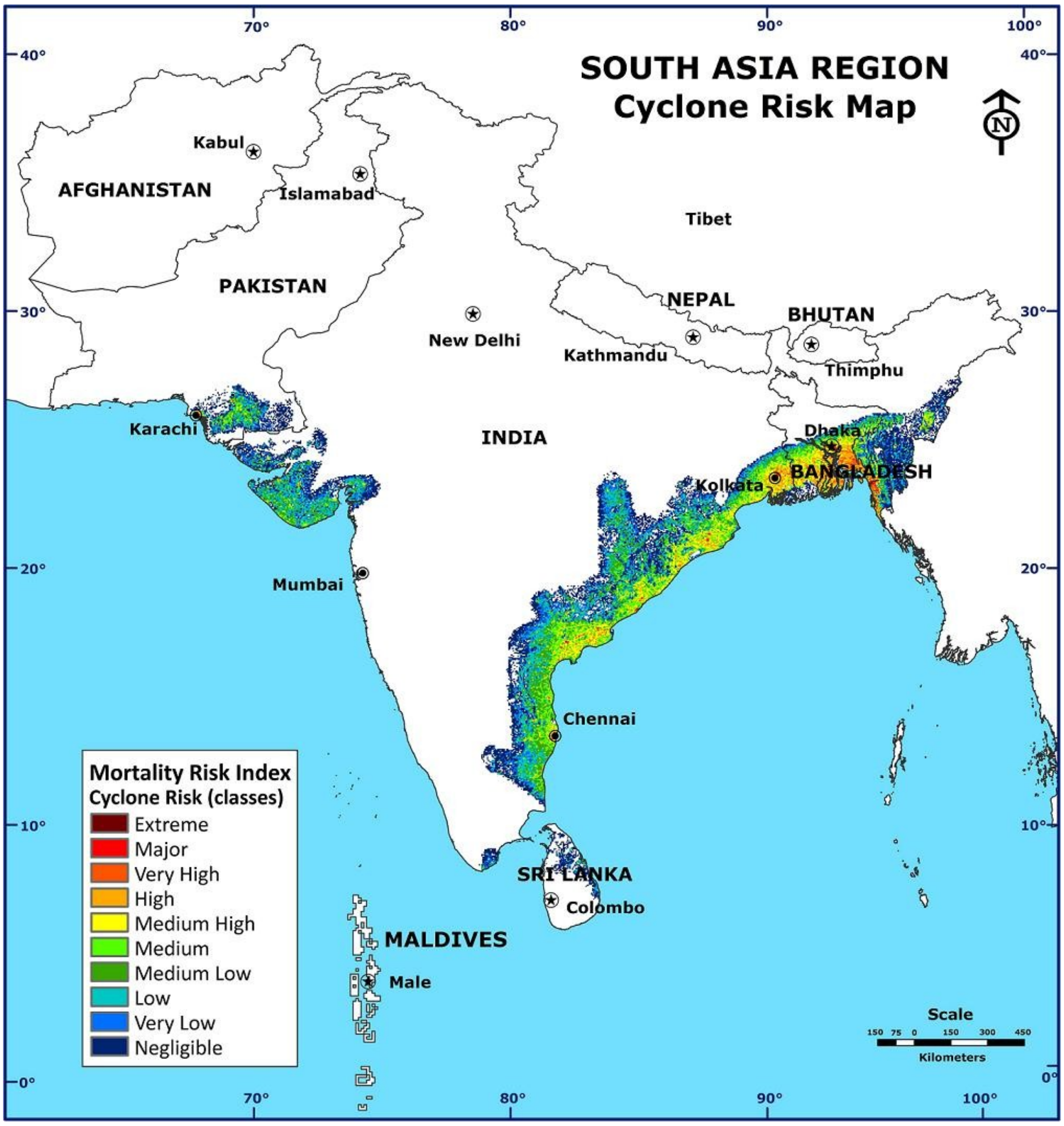


Figure 19 Cyclone mortality risk map of SAR

Source: Area computed from the cyclone mortality risk map of the GAR preview data platform (http://preview.grid.unep.ch/index.php?preview=data&events=cyclones&lang=eng)

Table 8 Percentage area and population in each cyclone mortality risk category

Country	% of total country geographic area					% of total country population				
	Low	Moderate	High	Extreme	total	Low	Moderate	High	Extreme	total
Afghanistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bangladesh	14.96	23.56	16.80	0.83	56.15	5.57	20.05	26.85	8.30	60.77
Bhutan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
India	9.51	5.58	0.54	0.03	15.66	5.14	8.42	3.34	1.54	18.44
Nepal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pakistan	3.36	1.00	0.07	0.01	4.44	2.15	3.08	4.32	3.45	13.00
Sri Lanka	19.23	0.67	0.00	0.00	19.90	12.25	1.66	0.00	0.00	13.91

Source: Area computed from the cyclone mortality risk map of the GAR preview data platform (http://preview.grid.unep.ch/index.php?preview=data&events=cyclones&lang=eng).

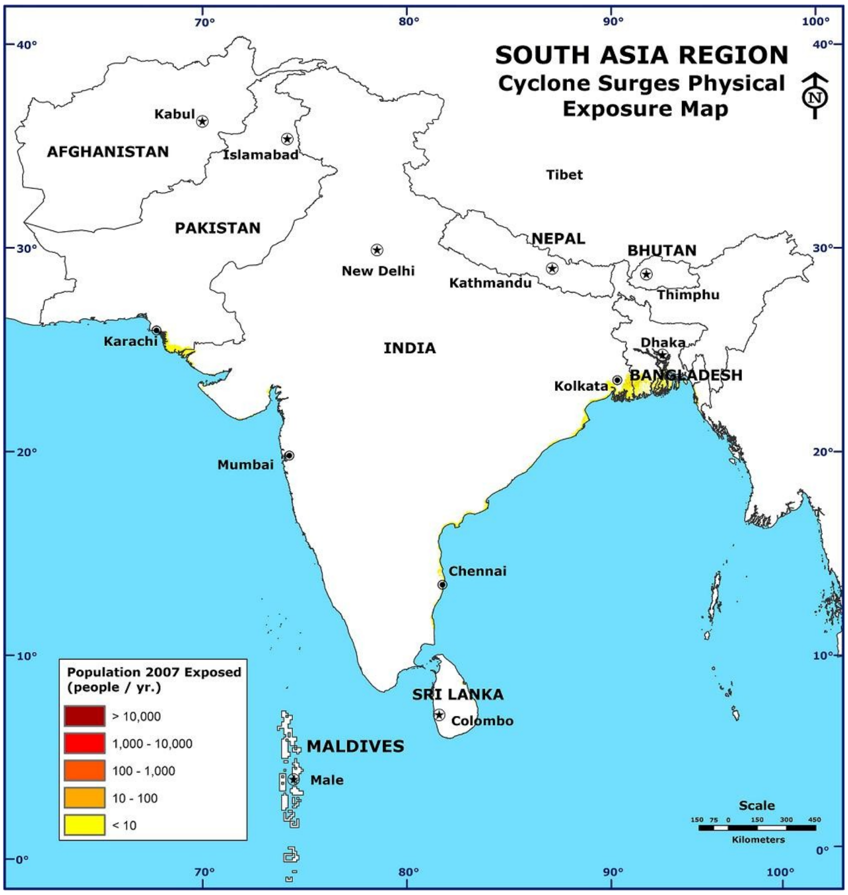


Figure 20 Cyclone surge physical exposure map of SAR

Source: Extracted from the GAR preview data platform ***(http://preview.grid.unep.ch/index.php?preview=data&events=surges&evcat=3&lang=eng)***

Table 8 presents the percentage areas for each SAR countries in four cyclone surge physical exposure categories (low, moderate, high and extreme) of the total geographic area of each country.

Table 9 Percentage area and population in each cyclone surge physical exposure category

Country	% of total country geographic area					% of total country population				
	Low	Moderate	High	Extreme	total	Low	Moderate	High	Extreme	total
Afghanistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bangladesh	8.13	0.11	0.00	0.00	8.24	6.28	0.81	0.00	0.00	7.09
Bhutan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
India	0.59	0.00	0.00	0.00	0.60	0.87	0.14	0.01	0.00	1.03
Nepal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pakistan	0.57	0.00	0.00	0.00	0.57	0.16	0.00	0.00	0.00	0.16
Sri Lanka	0.51	0.00	0.00	0.00	0.51	0.63	0.00	0.00	0.00	0.63

Source: Area computed from the cyclone surge physical exposure map of the GAR preview data platform ***(http://preview.grid.unep.ch/index.php?preview=data&events=surges&evcat=3&lang=eng)***

1.15.5 Volcano

Disasters related to volcanic activities are not reported in SAR countries. There are three active volcanoes in the region which have erupted recently. Two of them are located in India, in Andaman Nicobar islands (erupted in 2005, 2006) and one in Bangladesh (erupted in 2008). According to the Smithsonian Institute, there was a submarine eruption reported near Pondicherry (off the eastern coast of India) in 1757 in which an ephemeral island was formed. However, the Geological Survey of India reported no knowledge of any volcanic activities in this region (Padang 1963). In Afghanistan there are two volcanoes: the Dacht-i-Navar volcanic field is a group of 15 trachyandesitic lava domes located in west-central Afghanistan, southwest of Kabul. The age of these volcanoes is not known precisely, they were tentatively considered to be of Pleistocene age (Lapparent et al., 1965). The Vakak Group (also spelled Wakak) consists of 18 dacitic and trachytic volcanoes located WSW of Kabul (Table 10).

Table 10 Volcanoes in SAR

Country	Location	Last eruption
Afghanistan	Dacht-i-Navar Group (southwest of Kabul)	Holocene
	Vakak Group (WSW of Kabul)	Holocene
India	Barren Island(Andaman sea)	2006
	Baratang ((Andaman island)	2005
	Narcondam (Andaman sea)	Holocene
Bangladesh	Nagar gri Arakan island	2008
Pakistan	Neza e Sultan	No information available
	Malan Island	
	Jebel e Ghurab	
	Chandragup	
	Hingol	

Source: http://www.volcano.si.edu/

As there is no volcano reported disaster during 1967 – 2006 in SAR, volcano hazard is not considered for risk analysis.

1.16 Potential impact of Climate Change

Climate change is a long term issue. It is expected to be a major factor to contribute to extreme temperature, floods, droughts, intensity of tropical cyclones, and higher sea levels. Based on recent studies, climate change is expected to manifest itself in terms of:

- Rising in temperature (studies show that global average temperatures are likely to rise by between 0.5ºC and 1.7ºC by the 2050s).
- Variation in precipitation (largest changes are anticipated in equatorial regions and Southeast Asia).
- Extreme weather events, such as tropical cyclones (these are likely to become increasingly frequent and intense, involving heavy rainfall, high winds and storm surges).
- Rising in sea levels (these are expected to rise, with severe implications for coastal areas and low-lying islands in particular).

These climatic changes are likely to influence people's vulnerability adversely affecting livelihood and in turn contribute to poverty. Vulnerability to these hazards is also increasing, due to continuing poverty and social vulnerability, poorly planned urbanization, environmental degradation, and population growth. Climatic variability has both a short term and long term impact: it can increase the vulnerability of society causing sudden loss of income and assets, sometimes on a periodic basis or otherwise in the long term, in a gradual basis.

Many international summits calling attention to these issues are taking place at international, regional and national levels (Bali conference, 2007; Osla Policy forum meeting, 2008). The 'mainstreaming' of climate risk management and disaster risk reduction into development policy and planning is a key priority for the international community. Adaptation strategies need to ensure that they are environmentally sensitive in order to address the potential impact of climate change both in the short and long terms.

1.16.1 Climate Change Trends from Climate Models

This analysis details a set of key indicators to describe the impact of climate change on SAR countries.

A number of climatic models have been developed in the last few years to estimate the amount of climate change to be expected under the present conditions. These models can be broadly classified into three categories:

- Global Circulation Models (GCM). These models consider the whole earth circulation at a resolution level of about 350 km grid cells. Twenty-one of these models have been recognized as robust and their results summarized under the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC). One of these global models is the HadCM3 developed by the Hadley Center.
- Regional Circulation Models (RCM). These models consider a region at a higher level of resolution and use results of the GCMs to model the boundary conditions of the region of interest. PRECIS, also called HadRM3, is such a model with a horizontal resolution of 50 km. It is driven by the atmospheric winds, temperature and humidity output of HadCM3.
- High resolution models. These models operate at even higher resolution. The Meteorological Research Institute model (MRI) generates data at 20 km horizontal resolution.

All these models use a baseline simulation (1961-1990) generated by the model as a reference point and generate future estimates (2020s, 2050s and 2080s). The future estimates are based on two general carbon emission levels the A1B and A2 scenarios (IPCC, 2001). The baseline simulation can be used at the regional level to determine how well the models were able to estimate past climatic conditions.

Climate science suggests that the influence of climate change be measured with respect to the baseline and be expressed in the form of change in temperature and rainfall. These changes lead to weather and climate hazards in the form of accentuated drought and floods events in the region.

(a) Global Circulation Models IPCC AR4 climate trends

Global Circulation Models IPCC AR4 climate trends shows the projections for temperature and precipitation changes based on the results of the 21 global models summarized in AR4 (Figure 21). There is great uncertainty over how the frequency and severity of rainfall will change in SAR with anthropogenic warming. The GCMs give a divergent picture of how precipitation will change in the northwestern part of the region this century.

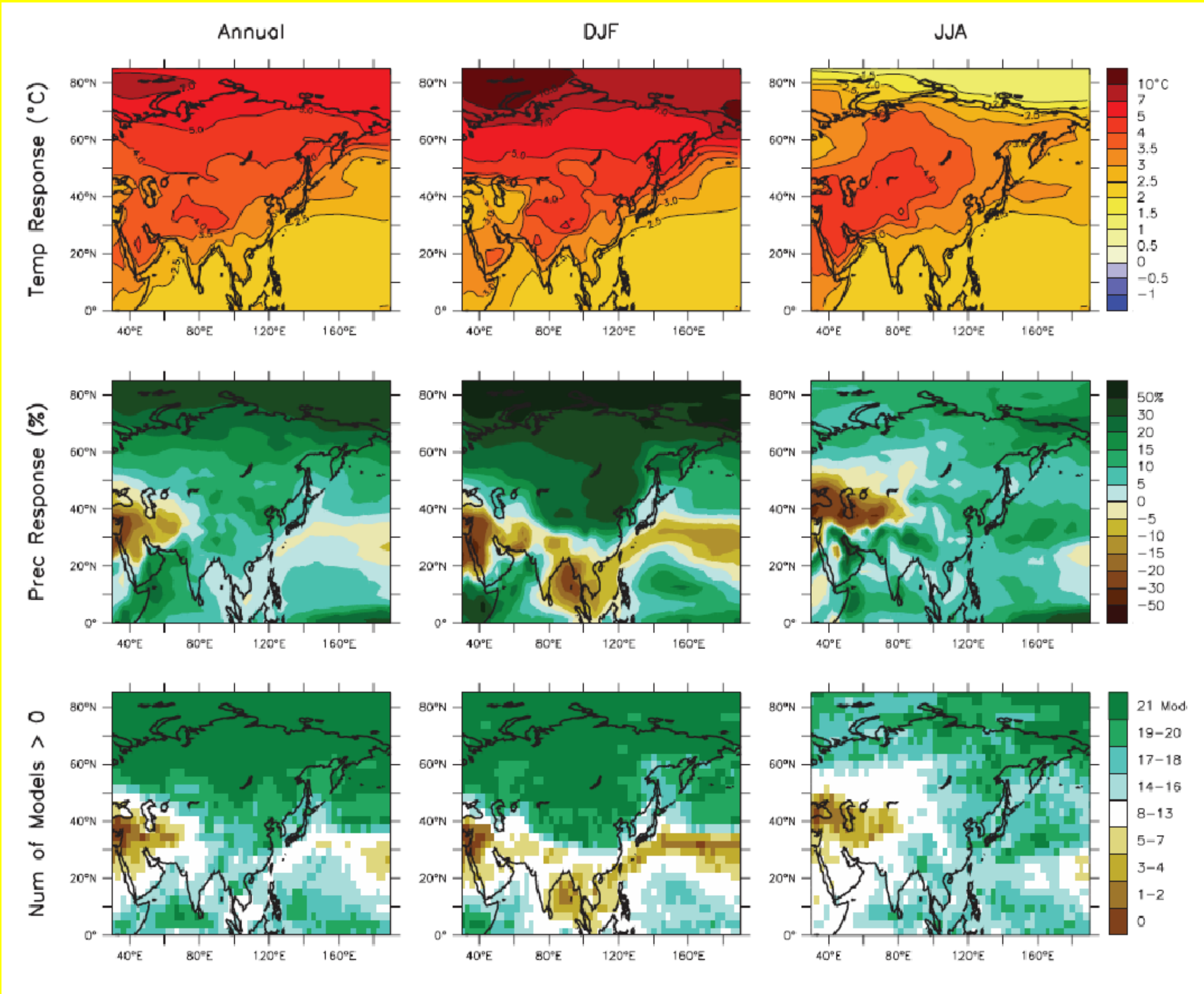


Figure 21 Temperature and precipitation changes over Asia from the IPCC AR4 multi-model ensemble simulations for emissions scenario A1B

Source: Reproduced from Chapter 11 of IPCC AR4 pg. 883.

Note: Top: Annual mean, Dec-Jan-Feb (DJF) and June-July-Aug (JJA) temperature change between 1990s and 2090s. Middle: as above, but fractional change in precipitation. Bottom: number of models, out of 21, that project an increase in precipitation.

On the average, the ensemble suggests little change in the winter months amount of precipitation (DJF – Dec., Jan., and Feb.) and an increase in the intensity of the summer monsoon, (JJA – June, July, and August). The third row of the figure indicates that slightly more than half of the models are in agreement with the rainfall increase presented in the second row of the figure. The amount of uncertainty shown in Figure 21 can be understood when one considers that the GCMs are unable to accurately represent the present day rainfall over India, mainly because their resolution is inadequate to properly represent the detailed topography of South Asia and the cloud microphysics involved in the tropical convective processes. Only the HadCM3 and CSIRO models (using higher resolution) are able to realistically represent the present-day observed maximum rainfall during the monsoon season (Rupa Kumar et al. 2006).

(b) PRECIS climate trends

PRECIS (HadRM3) carries over the large-scale characteristics of HadCM3, and therefore, benefits from the better representation of the monsoon in the model. The spatial patterns of present-day seasonal rainfall and extremes (1-day and 5-day maximum rainfall) are well represented (Rupa Kumar et al, 2006). Based on PRECIS model projections for scenario A2, the change in the annual maximum, annual minimum temperature and annual rainfall with respect to the baseline (1961-1990) have been computed for India. The Figure 22 shows (a) change in the annual rainfall (b) change in maximum temperature and (c) change in the minimum temperature.

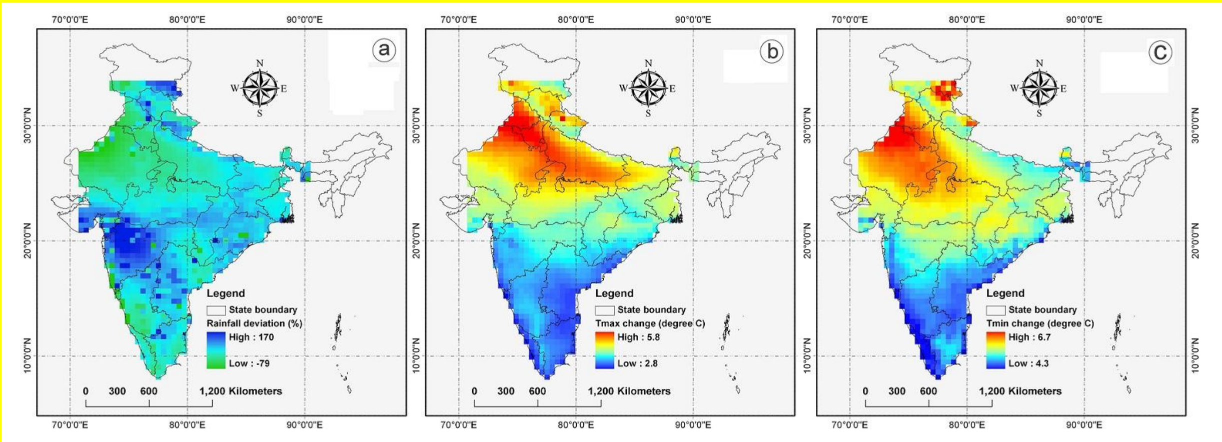


Figure 22 (a) change in the annual rainfall (b) change in maximum temperature and (c) change in the minimum temperature

(c) MRI climate trends

The Meteorological Research Institute (MRI) with a 20 km horizontal resolution has provided improved estimates of over SAR. Some of the key outputs of change projections are discussed below.

Surface air temperature shows increasing trends in future mean surface temperatures. On an average, the temperatures are projected to increase by as much as 3 to 4 ºC towards the end of 21st century which seems to be quite consistent with other GCMs projections for the region. The warming is spread across the region, however it is less pronounced towards the northern part of the regions as shown in Figure 23.

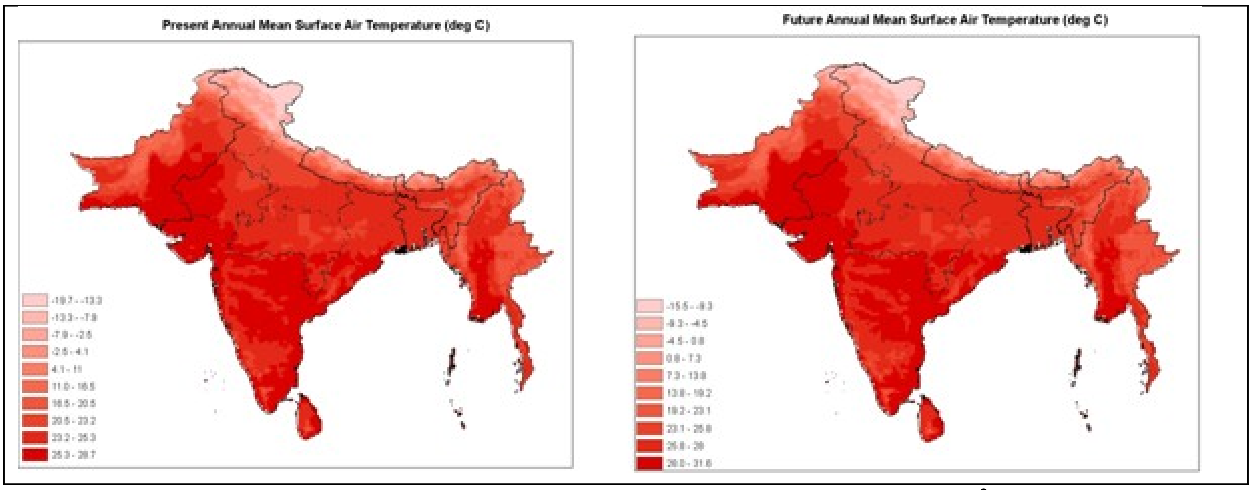


Figure 23 Spatial patterns of a) annual mean surface temperature (^{0}C) for the period 1961-1990 and b) annual future mean surface temperature for the period 2081-2100.

The change in rainfall under present and future climatic scenarios is clearly evident by amount and intensity of rainfall per day (Figure 24). This also leads to spatial differences in the projected rain for the region as compared to other GCMs.

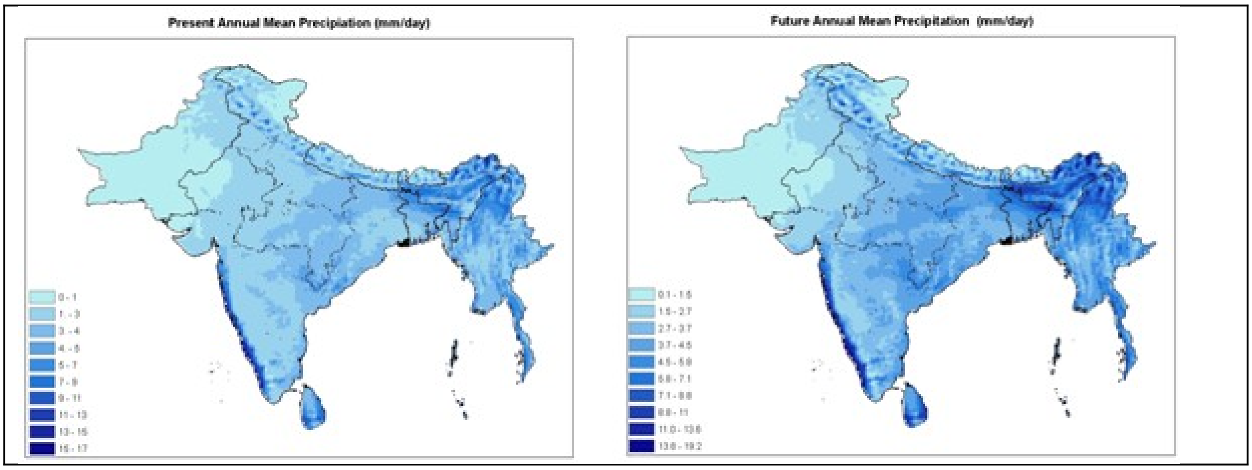


Figure 24 Spatial patterns of a) annual mean precipitation (mm/day) for the period 1961-1990 and b) annual future mean precipitation (mm/day) for the period 2081 -2100.

1.16.2 Asian-Pacific Network climate change estimates

While the above gave an analysis using dynamic high resolution GCM outputs, in order to report first estimate analysis on other South Asian countries, the Asia-Pacific Network (APN) for Global Change Research report on Bangladesh, India, Sri Lanka, Nepal and Pakistan was used to present the following findings (APN, 2005). These findings are based on the trends observed from reported data on some important climate indices. List of these indices include: 1) monthly maximum value of daily maximum temperature, 2) monthly minimum value of daily minimum temperature, 3) consecutive dry days, 4) monthly maximum one day maximum precipitation, 5) monthly maximum consecutive five day precipitation and 6) annual total precipitation in wet days. A summary for each of these five countries are given below.

Bangladesh: Based on the long term data for the period of 1961-2000 from nine stations the analyses showed a positive trend in monthly maximum value of daily maximum temperature all over the country. However, there is no significant trend in monthly minimum value of daily minimum temperature. It also reports that consecutive dry days have decreased in many stations. The annual total precipitation in wet days is on the rise at all stations with an exception in central coastal station.

India: The temperature extreme analyses are reported using 121 stations data from 1970 to 2003 while the extreme rainfall analyses use 149 stations from 1951-2003. The study reports that there is an increasing trend in monthly maximum value of daily maximum temperature at 91 out of the 121 stations. The monthly minimum value of daily minimum temperature also shows a similar trend in 76 stations. Monthly maximum one day maximum precipitation shows an increasing trend at 91 out of 149 stations. In case of monthly maximum consecutive five day precipitation, positive trend is detected at 87 out of 149 stations. Consecutive dry days show a decreasing trend at 88 stations indicating a negative trend. Annual total precipitation in wet days also shows a positive trend at 80 stations.

Nepal: Nepal lying in the southern flank of the Himalaya is affected profoundly by the monsoonal circulation of South Asia. Temperature based analysis has been carried out using data from six stations; whereas precipitation based indices have been carried out using data from 27 stations. The monthly maximum value of daily maximum temperature is rising in 5 out of 6 stations. The monthly minimum value of daily minimum temperature also shows a similar trend. Monthly maximum one day maximum precipitation does not show a significant positive trend whereas it is quite significant in the case of monthly maximum consecutive five day precipitation where it shows positive trend in 18 out of 27 stations. Consecutive dry days have significantly decreased as 24 stations indicate a negative trend. Over all, the precipitation indices indicate that there is an increasing tendency of precipitation in Nepal.

Pakistan: Daily data from 17 meteorological stations have been used for the study of temperature and precipitation indices. Analysis shows monthly maximum value of daily maximum temperature has increased except in the monsoon dominated region, while monthly minimum value of daily minimum temperature has decreased at more than 75 percent of the stations. Consecutive dry days are decreasing in most of stations. The monthly maximum one day maximum precipitation and monthly maximum consecutive five day precipitation show an increasing trend. Annual total precipitation in wet day has shown an increasing trend at 13 stations out of 17 stations.

Sri Lanka: In Sri Lanka, data from seven stations for the period of 1971-2000 has been used for study of temperature based indices. In case of rainfall based indices, data from 11 stations for the period of 1961-2000 have been used.

Trend analysis shows an increasing trend in monthly maximum value of daily maximum temperature at 5 out of 7 all the stations. The monthly minimum value of daily minimum temperature shows increasing trend at all the stations. There is a decreasing trend in annual total precipitation in wet days especially in the dry zone and intermediate zone. A decreasing trend in the monthly maximum one day maximum precipitation and the monthly maximum consecutive five day precipitation are seen in many places. Consecutive dry days have increased in many stations.

All the temperature indices have increased across the South Asia region. The monthly maximum value of daily maximum temperature has increased in Sri Lanka and India whereas it has decreased in Bangladesh and Nepal and remained unchanged in Nepal. Annual total precipitation in wet day has increased across the region except in Sri Lanka where it has decreased.

Brief summary of climate change vulnerability and impacts in South Asian countries is provided in Table 11.

Table 11 Summary of climate change vulnerability and impacts in South Asian countries

Country	Vulnerability to Climate Change
Afghanistan	**Water Resources** Water resources management is likely to be severely impacted by changes in the climate (DFID CNTR, 2008).
	Agriculture Agriculture is likely to be severely impacted by changes in climate. The vulnerability of the agricultural sector to increased temperatures and changes in rainfall patterns and high snow melt. Increased soil evaporation, reduced river flow from earlier snow melt, and less frequent rain during peak cultivation seasons will impact upon agricultural productivity and crop choice availability. Crop failure levels due to water shortages and the amount of potentially productive land left uncultivated will likely increase. More water intensive staple crops will become less attractive to farmers, with a likely increase in the attractiveness of those that are more drought hardy, including opium poppy. By 2060, large parts of the agricultural economy are likely to have become marginal without significant investment in water management and irrigation (DFID CNTR, 2008).
Bangladesh	**Water Resources** Water related impacts of climate change likely to be most critical– largely

	related to coastal and riverine flooding, but also enhanced possibility of winter (dry season) drought in certain areas. Both *coastal* flooding (from sea and river water), and inland flooding (river/rain water) are expected to increase.
	Coastal zones Acute impacts on coastal zones due to the combined effects of climate change, sea level rise, subsidence and changes of upstream discharge, cyclones and coastal embankments. Four key types of primary physical effects i.e. saline water intrusion, drainage congestion, extreme events, changes in coastal morphology identified as key vulnerabilities in the coastal areas.
	Agriculture The estimated impacts on rice yield are likely to vary between -6% to +14% depending on different climate change scenarios. Agricultural areas in tropical Asia and Bangladesh in particular, are vulnerable to many environmental extremes such as floods, cyclones, and storm surges. For example, on an average during the period 1962-1988, Bangladesh lost about 0.5 million tons of rice annually as a result of floods that accounts for nearly 30% of the country's average annual food grain imports.
Bhutan	**Water Resources** The availability of water in Bhutan is heavily dependent on heavy rainfall, snow, land use practices, and user demand. A reduction in the average flow of snow-fed rivers, combined with an increase in peak flows and sediment yield, might have major impacts on hydropower generation, urban water supply, and agriculture. An increase in rainfall intensity may increase run-off, enhance soil erosion, and accelerate sedimentation in the existing water supplies or reservoirs.
	Agriculture In Bhutan upland crop production, practiced close to the margins of viable production, can be highly sensitive to variations in climate. A temperature increase of 2 ºC might shift the cultivating zone further into higher elevation. Climate change is expected to increase the severity and frequency of monsoonal storms and flooding in the Himalayas, which might aggravate the occurrence of landslides. In addition to the danger to life and property, some of the generated sediments may be deposited in the agricultural lands or in irrigation canals and streams, which will contribute to deterioration in crop production and in the quality of agricultural lands.
	Extreme events In Bhutan, the entire northern upper land has snow-fed lakes in the mountain tops. Increased temperature and greater seasonal variability in precipitation may lead to accelerated recession of glaciers and result in increase in the volume of these lakes.
India	**Agriculture** Among the cereals, wheat production potential in the sub-tropics is expected likely to be affected the most, with significant declines anticipated in several regions including South Asia. For example wheat yields in central India may drop by 2% in a pessimistic climate change scenario. Districts in western Rajasthan, southern Gujarat, Madhya Pradesh, Maharashtra, northern Karnataka, northern Andhra Pradesh, and southern Bihar are highly vulnerable to climate change in the context of economic globalization. Numerous physical (e.g. cropping patterns, crop diversification, and shifts to drought-/salt-resistant varieties) and socio-economic (e.g. ownership of assets, access to services, and infrastructural support) factors come into play in enhancing or constraining the current capacity of farmers to cope with adverse changes. Temperature rise of 1.5 ºC and 2 mm increase in precipitation might result in a decline in rice yields by 3 to 15 %. Sorghum yields would be affected and yields are predicted

	to vary from +18 to -22 % depending on a rise of 2 to 4 ºC in temperatures and increase by 20 to 40 % of precipitation.
	Water resources Increased glacial melt due to warming is predicted to affect river flows. Increased warming might result in increased flows initially with reduced flows later due to decrease in glacier in future climate. Available records suggest that Gangotri glacier is retreating by about 30 m per year (NASA, 2001). A warming is likely to increase melting far more rapidly than accumulation. As reported in IPCC (1998), glacial melt is expected to increase under changed climate conditions, which would lead to increased summer flows in glacier fed river systems for a few decades, followed by a reduction in flow as the glaciers disappear. Climate change could impact the Indus River basin. The total annual run-off from the upper basin is likely to increase by 11% to 16%. It estimated that although increased run-off could be advantageous for water supply and hydropower production it could aggravate problems of flooding, water logging, and salinity in the upper basin. Also, even with an overall water surplus, shortages might occur in local areas of the highly productive Punjab rice–wheat zone and in the unglaciated valleys of the upper basin. According to United Nations projections, India is estimated to experience water stress by 2025, and is likely to cross the 'water scarce' benchmark by the year 2050 under the high growth scenario. Water stress and scarcity are defined as situations where per capita annual water availability is less than 1700 m^3 and 1000 m^3 respectively.
	Human Health Changes in climate may alter the distribution of important vector species (for example, mosquitoes) and may increase the spread of disease to new areas that lack a strong public health infrastructure. High altitude populations that fall outside areas of stable endemic malaria transmission may be particularly vulnerable to increases in malaria, due to climate warming. The seasonal transmission and distribution of many other diseases transmitted by mosquitoes (dengue, yellow fever) and by ticks (Lyme disease, tick-borne encephalitis), may also be affected by climate change.
Maldives	**Water Resources** The population of Maldives mainly depends on groundwater and rainwater as a source of freshwater. Both of these sources of water are vulnerable to changes in the climate and sea level rise. With the islands of the Maldives being low-lying, the rise in sea levels is likely to force saltwater into the freshwater lens. The groundwater is recharged through rainfall. Although the amount of rainfall is predicted to increase under an enhanced climatic regime, the spatial and temporal distribution in rainfall pattern is not clear.
	Ecosystem and Biodiversity Studies show that the corals are very sensitive to changes in sea surface temperature. Unusually high sea surface temperatures in 1998 had caused mass bleaching on coral reefs in the central regions of the Maldives. If the observed global temperature trend continues, there would be a threat to the survival of the coral reefs in the Maldives.
	Extreme Events Over 80% of the land area in the Maldives is less than 1 m above mean sea level. Being so low-lying, the islands of the Maldives are very vulnerable to inundation and beach erosion. Presently, 50% of all inhabited islands and 45% of tourist resorts face varying degrees of beach erosion. Coastal infrastructure is also highly vulnerable to the impacts of sea level rise and extreme events. Given the geophysical characteristics of the islands and the population pressure, all human settlements, industry and vital infrastructure lie close to the

	shoreline.
	Human Health Although malaria has been eradicated from the Maldives, climate change is likely to induce a threat of malaria outbreaks. Poor sanitation in the islands of Maldives along with conducive environment for the spread of diseases might lead to the outbreak of water related and waterborne diseases such as diarrhea.
Nepal	**Water Resources** Studies reported in Nepal's initial national communication indicate no major changes in the hydrological behavior due to rise in temperatures. However, changes in precipitation are expected to have major impacts. Nepal are categorized as dangerous due to threat to glacier lake outburst floods (GLOFs). As highlighted by IPCC (2001), glacial melt is expected to increase under changed climate conditions, which would lead to increased summer flows in some river systems for a few decades, followed by a reduction in flow as the glaciers disappear.
	Agriculture Soil loss is a major cause of decline in agriculture production in Nepal and the negative effects of climate change may further aggravate this situation. The impact of rise in temperatures on wheat and maize are expected to be negative.
	Extreme Events In Nepal, DHM (2004) found that almost 20% of the present glaciated area above 5000 m altitude is likely to be snow and glacier free with an increase of air temperature by 1° C. Similarly, a rise in 3° C to 4° C temperatures would result in the loss of 58 to 70% of snow and glaciated areas with threat of GLOFs.
	Human Health Studies carried out in Nepal indicate the risk of malaria, kalaazar and Japanese encephalitis under different climate change scenarios. The subtropical and warm temperate regions are predicted to be particularly vulnerable to malaria and kalaazar.
Pakistan	**Agriculture** In the hot climate of Pakistan, cereal crops are already at the margin of stress. An increase of 2.5°C in average temperature would translate into much higher ambient temperatures in the wheat planting and growing stages. Higher temperatures are likely to result in decline in yields, mainly due to the shortening of the crop life cycle especially the grain filling period. The National Communication highlighted that crops like wheat, cotton, mango, and sugarcane would be more sensitive to increase in temperatures compared to rice. The flow of Indus river basin is also likely to effect the cotton production in Pakistan, which might be detrimental to the economy as it is the main cash crop of the country.
	Extreme Events Pakistan comparatively is less vulnerable to changes in sea level but for the port city of Karachi. Karachi's greatest vulnerability to climate change may come from increased monsoonal and tidal activity, resulting in periodic flooding.
Sri Lanka	**Water Resources** Studies indicate that much of the water from heavy rainfall events in Sri Lanka would be lost as run-off to the sea.
	Agriculture Extreme events of rise in temperature and changes in rainfall patterns will have adverse impacts on agricultural production in Sri Lanka. Most cropping

	activities for e.g., coarse grain, legumes, vegetables, and potato are likely to be affected adversely due to the impacts of climate change. The highest negative impact is estimated for coarse grains and coconut production. An increase in the frequency of droughts and extreme rainfall events could result in a decline in tea yield, which would be the greatest in regions below 600 m. With the tea industry in Sri Lanka being a major source of foreign exchange and a significant source of income for laborers, the impacts are likely to be grave.
	Human Health In Sri Lanka, expansion and shift in malarial transmission zones is expected. Areas bordering the non-endemic wet zone of the country are likely to become highly vulnerable to malaria.
	Extreme Events Significant erosion is already evident on many of Sri Lanka's beaches. This is likely to increase significantly with accelerated sea level rise. A rise in sea level would tend to cause a shoreline recession except where this trend is balanced by the influx of sediment. In a 30 cm sea level rise scenario, the study projects a possible shoreline recession of about 30 m and for a 100 cm scenario, the shoreline retreat is expected to be about 100 m. A one meter rise in sea level could drown most of the coastal wetlands in Sri Lanka.

Source: UNDP (2007/2008), South Asian Regional Study on Climate change Impacts and Adaptation: Implications for Human Development, occasional paper, Human Development Report Office, UNDP.

1.17 Social and Economic Vulnerability Analysis

Social vulnerability (SV) is a complex set of characteristics that include a person's initial well-being, livelihood and resilience, self-protection, social protection, social and political networks and institutions (Cannon et al., 2004). The number of people killed in disaster is one of the major indicators of SV in a country. In this study, SV of a country was estimated based on average number of people killed per year and SV ranking was estimated based on average number people killed per year per million (relative social vulnerability). **Table 12** presents the SV and relative SV at country level from different hazards such as earthquake, flood, cyclone, landslide and drought. It can be seen that average number of people killed per year in Bangladesh are 2.4 times that of India, however, the average number of people killed per year per million in Bangladesh are more than 17 times that of India. Thus, from relative SV point of view, Bangladesh ranks first followed by Pakistan, Afghanistan, Nepal, India and Sri Lanka. Due to paucity of data, relative SV of Bhutan and Maldives could not be assessed.

Table 12 Comparative analysis of social vulnerability for SAR countries

Country	Population	Total Killed (1967-2006)	Combined Disaster Risk from earthquake, flood, cyclone, landslide and drought	
			Killed/year	(killed/year)/million
Afghanistan	31,889,923	13,403	335.1	10.5
Bangladesh	155,463,091	509,936	12,748.4	82.0
Bhutan	663,964			
India	1,109,811,147	212,433	5,310.8	4.8
Maldives	300,292			
Nepal	27,641,362	8,174	204.4	7.4
Pakistan	159,002,039	88,543	2,213.6	13.9
Sri Lanka	19,886,000	1,952	48.8	2.5

Economic vulnerability (EV) of a country can be measured in terms of likelihood of the economic losses resulting from the various disasters. In order to rank SAR countries on the basis of relative EV, economic loss potential for 0.5 percent probability of exceedance (corresponds to 200 year return period) has been estimated using economic losses of past 40 years (1967-2006) disaster data for earthquake, flood, cyclone, landslide and drought hazards (**Table-13**). Due to paucity of economic loss disaster data, the analysis could not be carried out for Bhutan and Maldives.

Table 13 Comparison of economic losses for different probability exceedance in SAR Countries

Country	Economic Loss ($ Millions)			Percent of GDP		
	Annual exceedance probability			Annual exceedance probability		
	0.5%	5%	20%	0.5%	5%	20%
Afghanistan	280	80	25	3.30	0.95	0.30
Bangladesh	3,976	1,958	912	6.42	3.16	1.47
Bhutan	-	-	-	-	-	-
India	10,987	4,913	2,035	1.20	0.50	0.20
Maldives	-	-	-	-	-	-
Nepal	807	321	119	9.00	3.39	1.33
Pakistan	4,024	1,258	382	3.17	0.99	0.30
Sri Lanka	275	107	39	1.02	0.40	0.14

It is clear that India, Pakistan and Bangladesh exhibit the largest losses. This can be explained by the large exposure at risk and the high level of hazard. When expressing the economic loss potential (0.5 per cent probability of exceedance) as a function of the GDP, Nepal stands out followed by Bangladesh, Afghanistan, Pakistan, India and Sri Lanka.

1.17.1 Socio-Economic Impact of Climate Change

Developing countries are especially vulnerable to climate change because of their geographic exposure, low incomes, and greater reliance on climate sensitive sectors such as agriculture. The cost of climate change in India and South East Asia could be as high as a 9-13% loss in GDP by 2100 compared with what could have been achieved in a world without climate change. Up to an additional 145-220 million people could be living on less than $2 a day and there could be an additional 165,000 to 250,000 child deaths per year in South Asia and sub-Saharan Africa by 2100, due to income loss alone. (Stern Review, 2007).

Water Management

Irrigation and effective water management will be very important in helping to reduce and manage the effects of climate change on agriculture. Many developing countries do not have enough water storage to manage annual water demand based on the current average seasonal rainfall cycle. This will become an even greater bind with a future, less predictable cycle. As an example, countries like India, Bangladesh and Nepal have sufficient rainfall to satisfy their needs as long as they can save water from the wet season for the dry season. The percentage of the water to be transferred from wet to dry season mainly through storage is respectively 21, 41 and 47 percent for these countries, but their storage capacity is only a fraction of the requirements with India at 76 percent, Bangladesh at 33 percent and Nepal at 3% (Brown and Lall, 2006) since it relies on snow and ice as storage. Unless major investments are made to negate the increase impact of climate variation by developing large storage facilities, cycles of significant water shortage can be expected.

Impact on the region as a whole

As discussed in Table 11, many sectors in SAR, including water resources, agriculture and food security, ecosystems and biodiversity, human health and coastal zones will get impacted by Climate change (2071-2100). In addition, many environmental and developmental problems in SAR will be exacerbated by climate change. Under climate change, predicted rainfall increases over most of SAR, particularly during the summer monsoon. The amount of rainfall would increase while the number rainy days would decrease. Floods would become more severe and frequent. Temperature would increase for all months making the chances of drought just as likely as present in spite of the increase rainfall.

The increase in rainfall intensity combined with higher frequency of critical temperature exceedance could have a significant impact on crop yield. It is estimated that crop yields might fall by up to 30%, creating a very high risk of hunger (food security) in several countries (UNFCC, 2007). The Stern Review suggests that mean yields for some crops in northern India could be reduced by up to 70% by 2100. This is set against a background of a rapidly rising population that will need an additional 5 million tons of food production per year just to keep pace with the predicted increase in population to about 1.5 billion by 2030 (Roy, 2006).

The permanent melt down and retreat of the Himalayan glaciers is estimated to reduce by 30 percent over the next 50 years their contribution of the water supply to the rivers of the Northern Indian plains. This will have a major impact on water management and crop irrigation, this supply having to be replaced by storage of another form (Roy, 2006).

Some specifics by countries

Afghanistan

The worsening climatic conditions in Afghanistan will continue to impact the socio-economic development of the country, creating stresses for specific vulnerable groups (DFID CNTR, 2008).

Bangladesh

Karim et al (1996) projects a net negative effect on the yields of rice, the staple food of the most population in Bangladesh. On an average, during the period 1962-1988, Bangladesh lost about 0.5 million tons of rice annually as a result of floods that accounts for nearly 30% of the country's average annual food grain imports (Paul and Rashid, 1993).

Bhutan

Upland crop production, practiced close to the margins of viable production, can be highly sensitive to variations in climate. Climate change will cause the cultivating zone to shift upwards to unsuitable steep slopes. It is also expected to increase the severity and frequency of monsoonal storms and flooding in the Himalayas, which could aggravate the occurrence of landslides. In addition to the danger to life and property, some of the generated sediments may be deposited in the agricultural lands or in irrigation canals and streams, which will contribute to deterioration in crop production and in the quality of agricultural lands (NEC, 2000).

India

Wheat yields in central India may drop by 2% in a pessimistic climate change scenario (GoI, 2004). Kumar and Parikh (2001) show that even after accounting for farm level adaptation, a 2°C rise in mean temperature and a 7% increase in mean precipitation will reduce net revenues by 8.4%.

Maldives

The population of Maldives mainly depends on groundwater and rainwater as a source of freshwater. Both of these sources of water are vulnerable to changes in the climate and sea level rise. With the islands of the Maldives being low-lying, the rise in sea levels is likely to force saltwater into the freshwater lens. (MoEC, 2005).

Nepal
IPCC (2001) highlighted that glacial melt is expected to increase under changed climate conditions, which would lead to increased summer flows in some river systems for a few decades, followed by a reduction in flow due to decrease in glacier volume. Soil loss is a major cause of decline in agriculture production in Nepal and the negative effects of climate change may further aggravate this situation. The impact of rise in temperatures on wheat and maize are expected to be negative.

Pakistan
In the hot climate of Pakistan, cereal crops are already at the margin of stress. An increase in average temperature would translate into much higher ambient temperatures in the wheat planting and growing stages. Higher temperatures are likely to result in decline in yields, mainly due to the shortening of the crop life cycle especially the grain filling period. Wheat yields are predicted to decline by 6-9% in sub-humid, semiarid, and arid areas with 1°C increase in temperature (Sultana and Ali, 2006), while even a 0.3°C decadal rise could have a severe impact on important cash crops like cotton, mango, and sugarcane (MoE, 2003).

Sri Lanka
Half a degree temperature rise is predicted to reduce rice output by 6%, and increased dryness will adversely affect yields of key products like tea, rubber, and coconut (MENR, 2000). In warm, semi-arid regions, deficiency of moisture would be a major constraint. Most cropping activities for e.g., coarse grain, legumes, vegetables, and potato are likely to be affected adversely due to the impacts of climate change. The highest negative impact is estimated for coarse grains and coconut production. An increase in the frequency of droughts and extreme rainfall events could result in a decline in tea yield, which would be the greatest in regions below 600 m. With the tea industry in Sri Lanka being a major source of foreign exchange and a significant source of income for laborers the impacts are likely to be grave.

Country Risk Profile

This section dealt with preliminary assessment of disaster risks in SAR countries. Reported disaster data at country level were used for country level risk assessment. The approach adopted for economic loss analysis is presented in Annexure 1.

An event with a 0.5 percent of probability of occurrence in one year occurs on an average every two hundred year and generally corresponds to catastrophic event. An event with a 5 percent and 20 percent probability of occurrence occurs on an average every 20 years and five years, respectively.

As a preamble to the country level risk assessment the physical and social setting of each country is provided in brief. This is important as disaster frequency and intensity have a direct relationship with bio physical and socio economic setting of the region.

The country level general information was taken from the World Bank statistics 2006 and disaster risk statistics were prepared based on reported disaster data. The information related to agriculture and forest land is of 2005. The GDP presented corresponds to total GDP of the country or region.

1.18 Afghanistan

1.18.1 Overview

Figure 25 Location map of Afghanistan

Country level information (2006)	
Geographic Area	652,090 sq km
Population	31,889,923
Population Density	49
Urban population (% to total population)	28
Agriculture land (% to total area)	58.3
Forest land (% to total area)	1.3
Human Development Index	0.345
GDP	$ 8.4 billion
Agricultural GDP (%)	38.8
Industry GDP (%)	26.6
Service GDP (%)	34.6

Disaster risk statistics (1967-2006)

Disaster type	Number of disasters/yr	Casualties/ yr	Average total affected population /yr
Earthquake	0.68	232	15,357
Flood	1.18	78	26,002
Drought	0.08	1	113,200
Landslide	0.15	15	7,529
Cyclone	0.10	9	566

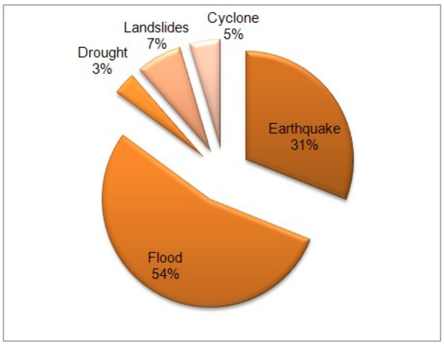


Figure 26 Percentage distribution of reported disaster Afghanistan (1967-2006)

Average Annual economic Loss, AAL

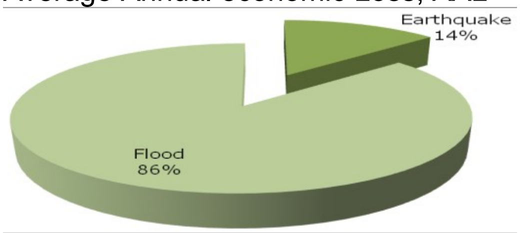


Figure 27 Average Annual economic Loss of Afghanistan

Economic loss data not sufficient for other hazards

Economic loss potential (1967-2006)

Annual exceedance probability	Economic loss ($ millions)	Percentage to GDP
0.5%	280	3.3%
5%	80	0.95%
20%	25	0.30%

1.18.2 Regional Setting

Afghanistan is in the northern part of SAR. It is a landlocked and mountainous country with plains in the north and southwest. The country has an area of 652,090 sq km with population of 31,889,923. The population density of the country is 49 persons per sq km. Due to its geographic characteristics large parts of the country have arid to semiarid climate with hot summers and cold winters.

Afghanistan has ethnically and linguistically mixed demographics. Islam is the main religion followed in the country with about 99 percent of the population being Muslim. Excluding about 28 percent urban population, most Afghans are of tribes or kingship-based groups and follow traditional customs and religious practices. Kabul is the only city in Afghanistan with over one million residents. The country has 28 percent of urban population. Till recently the country was experiencing political problems and due to that there is a lack of systematic socio economic data collected at the country level including census data.

Only 12.13 percent of the total geographic area of the country is under arable land. Afghanistan is rich in mineral resources. The south eastern part has large quantity of gold, silver, copper, zinc and iron ore deposit. North east part of the country is rich in precious and semi-precious stones such as lapis, emerald and azure. There are potentially significant petroleum and natural gas reserves in the north. The country also has uranium, coal, chromite, talc, barites, sulfur, lead, and salt. These mineral resources are yet to be tapped due to political and civil unrest existed in the country until recently.

1.18.3 Hazard Profile

Afghanistan is prone to a number of natural hazards such as earthquakes, floods, droughts, and landslides. As per GSHAP (1998), Afghanistan lies in a region with moderate to high seismic hazard. The history of destructive earthquakes in Afghanistan spans more than four thousand years. In Afghanistan, earthquakes are relatively frequent, being more frequent in the north and northeast of Hindukush mountain areas, and often trigger landslides. Due to earthquakes, more than 7,000 people were killed in the last 10 years, including the magnitude 6.5 Nahrin earthquake on May 30, 1998, in which about 4,000 deaths were reported (USGS, 2007). Another earthquake in the same region occurred on March 25, 2002 that killed about 1,000 people and affected more than 90,000. On February 4, 1988, an earthquake of magnitude 5.9 occurred in mountains about 300 km north of Kabul and killed 2,300 people and left 8,000 homeless. The shaking from this earthquake triggered many destructive landslides. In Afghanistan, relatively small earthquakes have caused fatalities due to largely inadequate construction practices in the region. Northern Afghanistan is one of the rare continental regions on Earth where destructive earthquakes occur at a depth 200 km or more (USGS, 2007). Keeping in view the damage caused by Kashmir (POK) 2005 earthquake, the earthquake hazard potential in Afghanistan could be very high in terms of magnitude, damage to structures and landslides.

In terms of number of disasters, flood is more a recurring hazard. As some of the major rivers of Afghanistan are fed by the glaciers in Himalayas, floods are common in spring when snow begins to melt and rainfall is heavy. Over the period 1967 – 2006 flood constitutes about 54 percent of the total disasters while earthquake accounts for about 31 percent.

1.18.4 Risk Profile

Vulnerability indicators – number of disasters, deaths, affected population and economic loss have been plotted against time period (1967 – 2006) in Figure 28, Figure 29 and Figure 30 respectively. Vulnerability analysis over time indicates that a large number of deaths have been recorded during the period (1997 - 2001) even though the number of events is quite low.

In contrast, during the last 5 years (2002 – 2006), even though the number of events is drastically high, the deaths recorded are much lower. This skew in the behavior could be attributed to the two earthquakes of 1998 (about 4700 and 2323 deaths respectively). The earthquake of 2002 has killed about 1000 people.

A quick analysis of Figure 29 indicates that over the last one decade, there has been a drastic increase in the population affected by natural hazards. Some of the recent major events are responsible for this increase. The drought of 2006 and 2000 affected 2.5 million and 1.9 million people respectively. The floods of 1998, 1991, 1978 and 1972 have also impacted a large section of the population. The earthquake of 1998 has alone affected 0.11 million people.

In terms of annual occurrence, flood is highest (1.18 per year), in terms of total affected population, drought seems to be most severe and in terms of vulnerability (assessed based on deaths per million) earthquakes are most devastating (232 deaths per year on an average) in Afghanistan during the last 40 years. Other hazards: flood, landslides and cyclone are also showing significant numbers of deaths. Drought is having a lower numbers indicating that the number of deaths is less and total population affected is large leading to relatively low vulnerability.

The vulnerability of Afghanistan to natural hazards has been further accentuated by decades of war and civil conflict, as well as environmental degradation. Several humanitarian agencies have assessed significant shortcomings in the areas of water, sanitation, health, security and natural resource management. On top of this, the high level of poverty, lack of livelihood and income generating opportunities, chronic health problems, and poor state of the infrastructure all add to the burden of natural hazards on the people of Afghanistan.

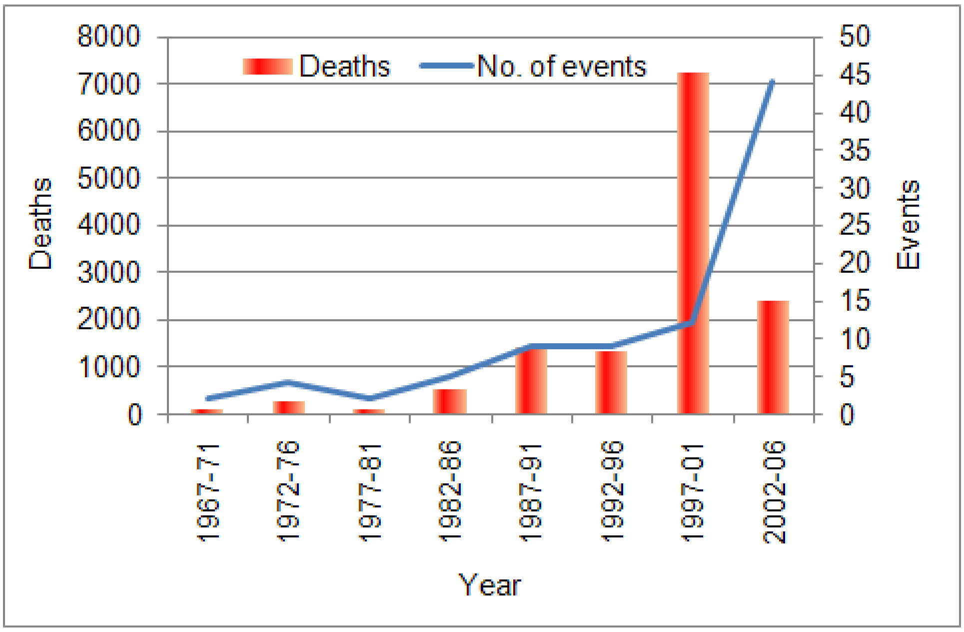


Figure 28 Reported disasters and deaths in Afghanistan during 1967 - 2006

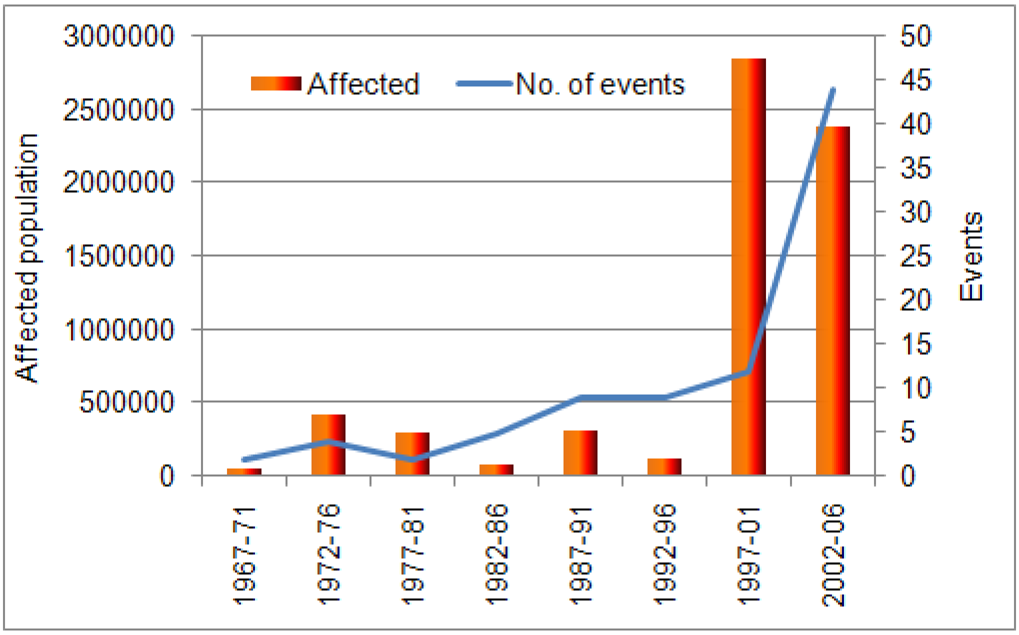


Figure 29 Reported disasters and affected population in Afghanistan during 1967 - 2006

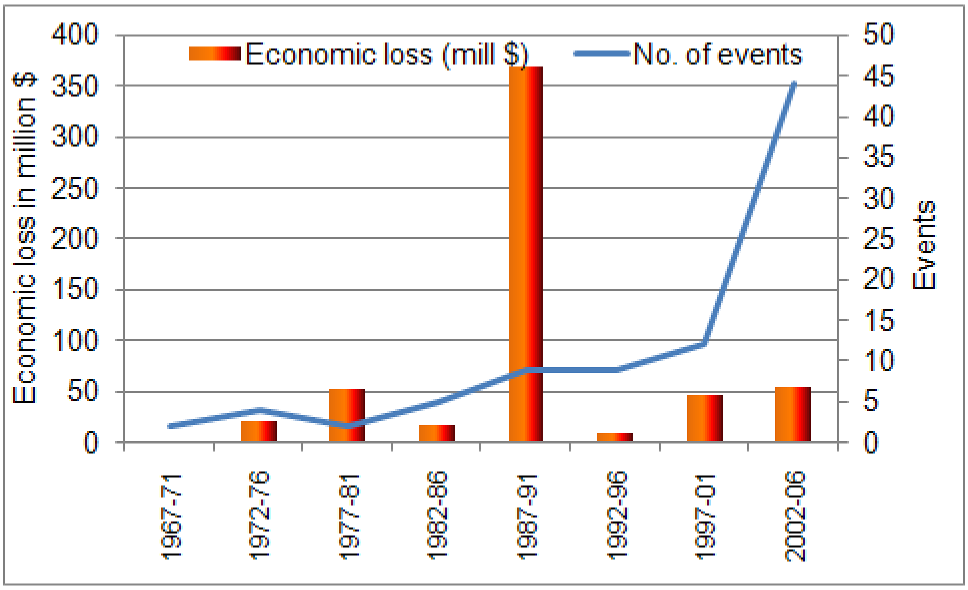


Figure 30 Reported disasters and economic loss in Afghanistan during 1967 - 2006

The average annual loss due to floods is much higher as compared to earthquakes (Figure 27). The 1988 flood has caused a loss of $ 260 million and the 1991 flood caused a loss of $ 0.60 million. In 1998 two earthquakes occurred in Afghanistan and caused a total economic loss of $ 0.02 million.

The probability of economic losses exceeding $ 280 million in one year is about 0.5 percent. This is about 3 percent of the country's GDP. The probability of annual losses exceeding $ 80 million is about 5 percent.

1.19 Bangladesh

1.19.1 Overview

Figure 31 Location map of Bangladesh

Country level information (2006)	
Geographic Area	1,44,000 sq km
Population	155,463,091
Population Density (person per sq km)	1080
Urban population (% to total population)	23.9
Agriculture land (% to total area)	69.2
Forest land (% to total area)	6.0
Human Development Index	0.547
GDP	$ 61.9 billion
Agricultural GDP (%)	19.6
Industry GDP (%)	27.9
Service GDP (%)	52.5

Disaster risk statistics (1967-2006)			
Disaster type	Number of disasters/yr	Casualties/ yr	Average total affected population /yr
Earthquake	0.20	1	33
Flood	1.80	1,018	7,339,990
Drought	0.10	0.5	625,050
Landslide	0.00	0	0
Cyclone	2.50	11,729	1,101,669

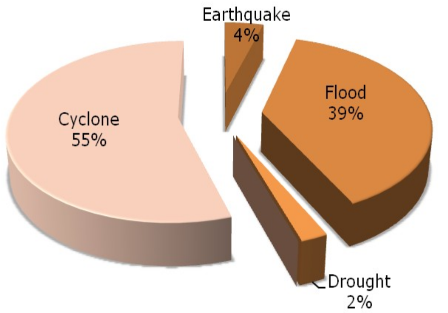


Figure 32 Percentage distribution of reported disaster in Bangladesh (1967-2006)

Average Annual economic Loss, AAL

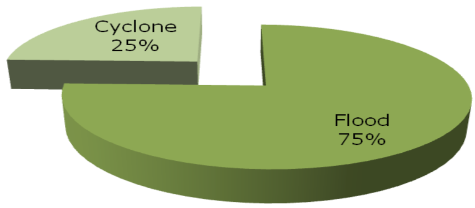


Figure 33 Average Annual economic Loss of Bangladesh

Economic loss data not sufficient for other hazards

Economic loss potential (1967-2006)		
Annual exceedance probability	Economic loss ($ millions)	Percentage to GDP
0.5%	3,976	6.42%
5%	1,958	3.16%
20%	912	1.47%

1.19.2 Regional Setting

Bangladesh is located in one of the world's largest river delta. The rivers Ganges, Brahmaputra and the Meghna and its tributaries drain into this delta. The deltaic region of Bangladesh is having the largest stretch of mangrove vegetation in the world and is called the '*Sunderbans*'. The country is bounded by the Himalayas in the north and the funnel shaped low coastal area is boarded by Bay of Bengal in the south. Majority of east and west boarder of the country are shared by India. The river systems and the deltaic formation heavily influence the socio-economic activities of the country. Out of the total area of 144,000 sq km of Bangladesh about 10,000 sq km is covered with water. The geographic characteristics of bordering the Bay of Bengal also influence the climatic conditions and the prevalence of natural hazards in the country. Bangladesh has a tropical monsoon climate characterized by heavy seasonal rainfall, high temperatures, and high humidity. About 80 percent of Bangladesh's rain occurs during the monsoon season with an annual rainfall of about 1,600 mm. Several parts of the country receive at least 2,300 mm of rainfall per year.

The country has a population of 155,463,091 with a population density of 1080 person per sq km. Dhaka, the capital, has a population of 6.7 million and is one of the most densely populated mega-cities in Asia and the world. Bangladesh is an agricultural country with about three-fifths of the population engaged in agriculture. Jute and tea are principal sources of foreign exchange.

1.19.3 Hazard Profile

Bangladesh is vulnerable to natural hazards, such as cyclone, floods, drought and tidal surge which affect almost the entire country every year. The country is also exposed to occasional earthquakes. On an average Bangladesh is struck by major cyclones 16 times a decade. The cyclone which crossed the Bangladesh coast on April 29, 1991, often described as '*Super Cyclone',* killed nearly 140,000 people and injured more than 139,849 (Choudhury, 1992). The cyclone '*Sidr*' struck the south western coast on November 15, 2007 affecting not only the coastal districts of the administrative division of Khulna but also about half of the tropical Sundarbans forest. In May 1985, a severe cyclonic storm hit the coast of Bangladesh with a wind speed of 154 km/hr generating waves of 4 m height. This resulted in killing more than 11,000 persons, damaging more than 94,000 houses, killing about 135,000 head of livestock.

Bangladesh experiences floods almost every year causing loss of human life, damage to property and communication systems. Often the flood also leads to shortage of potable drinking water causing a wide spread of water borne diseases. For example, in 1988 two-thirds of Bangladesh's 64 districts experienced unusually heavy rainfall that resulted in extensive floods that left millions homeless and without potable water. Half of the Dhaka was flooded. The runways at the Zia International Airport, an important transit point for disaster relief supplies, were also flooded rendered relief work even more challenging. About 2 million tons of crops were reportedly destroyed. Though monsoon rains are the major cause of flooding, other important factors like rapid run-off, the effect of confluences of major rivers, the flat topography of the delta and surges in the Bay of Bengal also contribute to flooding (Karim, 1995). Four types of natural floods (flash flood, river flood, rain water flood and storm surge flood) are all seen in the country between April and October almost every year (Brammer and Khan, 1991).

Bangladesh has experienced many droughts before and after independence. The 1973 drought, one of the most severe droughts of the century, has severely affected the northern Bangladesh. In 1975, drought affected 47 percent of the country and more than half of the total population. The 1978-79 drought is one of the most severe droughts in recent times with widespread damage to crops reducing rice production by about 2 million tons, directly affecting about 42 percent of the cultivated land and 44 percent of the population. Similarly, the 1982 drought caused loss of rice production by about 53,000 tonnes (Ramamasy and Baas, 2007). The drought of 1989 added a new dimension, it dried up most of the rivers in Northwest Bangladesh with dust storms ravaging in several districts, including Naogaon, Nawabganj, Nilpahamari and Thakurgaon. The drought of 1989 has been longest in the last 46 years (Karim, 1995). The 1994-95 droughts is the most persistent drought in recent times, which caused immense crop damage, especially to rice and jute, the main crops of Northwest Bangladesh and to bamboo clumps, a main cash crop in the region (Ramamasy and Baas, 2007). However, no loss of life was reported in 1994-95 droughts (Paul, 1995).

Unlike other natural hazards, earthquakes do not occur frequently in Bangladesh. However, that does not mean the region has low seismic hazard potential. Bangladesh occupies the most active tectonic boundary zone between Indian Plate and Myanmar Plate that stretches up to Sumatra via Andaman-Nicobar zone of severe seismicity. Historically, significant damaging earthquakes (four earthquakes of magnitude greater than 8 during 1897, 1905, 1934 and 1950) have occurred around Bangladesh. Thus, the country's positional adjacency to the very active Himalayan ranges and ongoing deformation in nearby parts of south-east Asia expose it to strong shaking from a variety of earthquake sources capable of producing tremors of magnitude 8 or greater, that can impact most of the country. In addition, historical seismicity within Bangladesh indicates that there is potential for damaging moderate to strong earthquakes. The June 12, 1989 earthquake of magnitude 5.7 killed 1 person and injured 100 persons in the Banaripara area of Bangladesh. The earthquake was felt in much of eastern Bangladesh including at Chittagong and Rangpur. Another earthquake of magnitude 5.1 occurred in northern Bangladesh on June 20, 2002, causing several injuries in the Rajshahi division. More recently, on November 28, 2005, a small earthquake of magnitude 4.7 occurred in the Gangas Canyon in the northern Bay of Bengal, and was felt in southern parts of West Bengal (ASC website).

1.19.4 Risk Profile

Bangladesh has a history of large numbers of deaths due to natural hazards. This includes the drought of 1943 (killing 1.9 million), cyclones of 1942, 1963, 1965, 1970, 1985, and 1991. Vulnerability indicators – number of disasters, deaths, affected population and economic loss have been plotted against time period (1967 – 2006) in Figure 34, Figure 35 and Figure 36 respectively for Bangladesh. During the last five year the number of deaths is showing a decreasing trend even though the number of events is increasing. 1967-71 is the period which has recorded large number of deaths which is mainly because of the 1970 cyclone which killed 300,000 people.

There was significant number of deaths as well as population affected during the period 1987-91. The floods of 1988, 1989 and the cyclone of 1991 have affected large number of people in Bangladesh. More than 80 percent of the population of Bangladesh is potentially exposed to earthquakes, floods and droughts while more than 70 percent are exposed to cyclones. The economic loss data also shows the harshness of natural hazards in the country apart from large number of deaths and population affected.

The average annual incidence of various hazards shows high incidence of hydro metrological hazards than geological. The cyclones and floods have recorded an annual average incidence of 2.5 and 1.8 respectively. Vulnerability in terms of average annual death and physical exposure is also high for these two hazards.

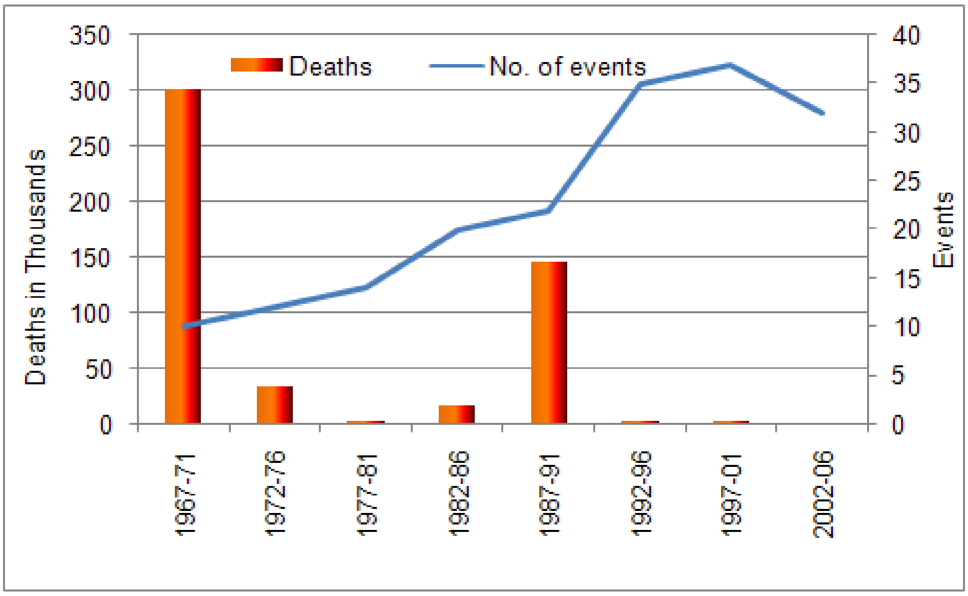


Figure 34 Reported disasters and deaths in Bangladesh during 1967 - 2006

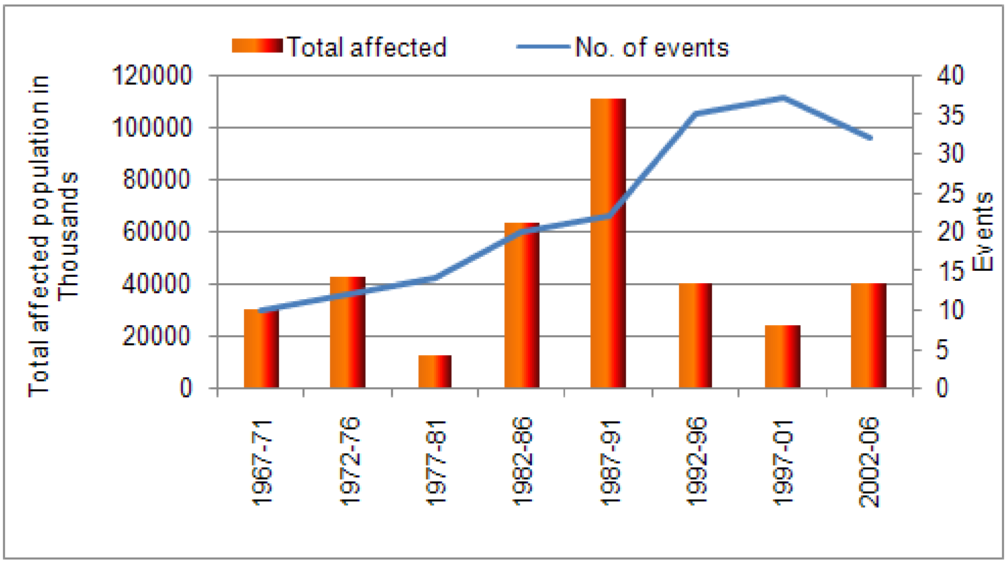


Figure 35 Reported disasters events and total affected population in Bangladesh during 1967 - 2006

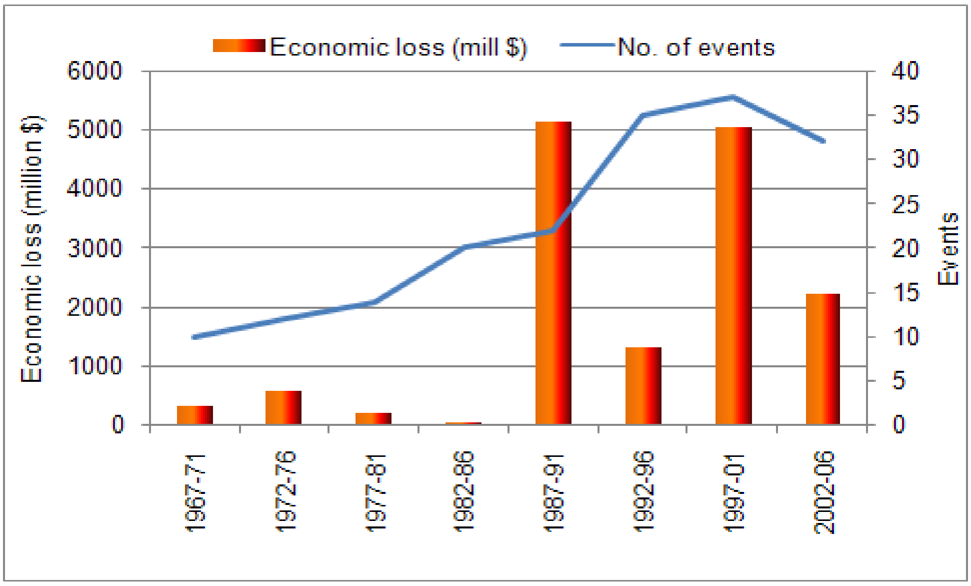


Figure 36 Reported disasters and economic loss in Bangladesh during 1967 – 2006

The economic loss data also shows the severity of natural hazards in the country apart from a large number of deaths and affected population. The probability of economic losses exceeding $ 4 billion in one year is about 0.5 percent. This is about 6.42 percent of the country's GDP. The probability of annual losses exceeding $ 1.9 billion is about 5 percent.

1.20 Bhutan

1.20.1 Overview

Figure 37 Location map of Bhutan

Country level information (2006)	
Geographic Area	47,000 sq km
Population	663,964
Population Density (persons per sq km)	14
Urban population (% to total population)	8.2
Agriculture land (% to total area)	12.6
Forest land (% to total area)	68.1
Human Development Index	0.579
GDP	$ 0.942 billion
Agricultural GDP (%)	22.8
Industry GDP (%)	38.5
Service GDP (%)	38.6

Disaster risk statistics (1967-2006)			
Disaster type	Number of disasters/yr	Casualties/ yr	Average total affected population /yr

No loss data

Average Annual Economic Loss, AAL

No loss data

Economic loss potential (1967-2006)		
Annual exceedance probability	Economic loss ($ millions)	Percentage to GDP

1.20.2 Regional Setting

Bhutan often called the Kingdom of Bhutan is a mountain nation in the Himalayan mountain range located between China and India. There are mountain peaks exceeding 7000 m above mean sea level (MSL). The highest peak in Bhutan is the Kula Kangri, 7,553 m high above MSL. Bhutan has a varied climate with some influence of monsoons. Monsoons bring between 60 to 90 percent of the region's rainfall with Western Bhutan receiving bulk of it. The southern plains and foothills have a subtropical climate, the inner Himalayan valleys of the southern and central regions are temperate, and the northern part is cold, with year-round snow. The rainfall varies with a total annual rainfall of nearly 650 mm and most of the rivers are fed by the snow on the mountain peaks. The rivers are trans-boundary in nature and flows into India and Bangladesh. Winters are cold, summers are hot; the rainy season is characterized with frequent landslides.

The country has a geographic area of 47,000 sq km with a population of 663,964. The highlands are the most populous part of the nation - Thimphu, the capital of Bhutan lies in the western region of this highland. The region is characterized by its many rivers (flowing into India's Brahmaputra), and the expansive forests that cover 70 percent of the nation.

Bhutan is a low income country according to the World Bank’s Classification of Economies by region and income, FY 2005. The annual percentage of population growth is estimated at 2.5 in the year 2004 as compared to 2.6 in the previous year. Bhutan's economy is based mainly on agriculture, and forestry which provide the main livelihood for 80 percent of the population and account for about 40 percent of the GDP. The economy is closely aligned with India's through strong trade and monetary links. The Gross Domestic Product in the country was $ 0.942 billion in the year 2006 with an annual growth rate of 4.9 percent.

1.20.3 Hazard Profile

Bhutan with its mountainous terrain is prone to multiple natural hazards such as flood, landslides and earthquakes. Glacial melt added to monsoon-swollen rivers contributes to flooding and the influence sometimes crosses the border into the neighboring countries. Sometimes glacial movement temporarily blocks river flows and later bursts open threatening downstream areas with unexpected floods also known as Jokulhlaups, or Glacial Lake Outburst Flood (GLOF). The phenomenon GLOFs, has become the most serious natural hazard in the country as the Himalayan glaciers retreat rapidly due to the climate change (MoHCA, 2006). As per reports, there are 2,674 glacial lakes, out of which 24 glacial lakes are ‘*potentially dangerous’* posing threats of GLOFs at any time. Flash floods and landslides pose an annual threat to human lives and livelihood, especially in the southern and eastern parts of the country.

Landslide events are closely linked with flooding events and also recurrent phenomenon in Bhutan. In the rainy season, those slopes are highly susceptible to landslides where terrain is steep and rocks underlying the soil cover are highly fractured, allowing easy seepage of water. Landslides also get triggered due to earthquakes. The country has experienced landslides triggered in the aftermath of the 1980, 1988 and 2003 earthquakes (MoHCA, 2006).

Geophysically, Bhutan is located in one of the most seismically active zone in the world. Due to its proximity to NE part of India, which is seismic zone V (highest severity as per seismic zoning map of India, IS: 1893, 2002), Bhutan has high earthquake hazard. The country falls in seismic zone IV and V as per IS: 1893 (2002). In the last 100 years, the country has experienced 3 big earthquakes of magnitude exceeding 8 during 1905, 1934 and 1950 and another 10 earthquakes exceeding magnitude 7.5 occurred in the Himalayan belt. In recent years, Thimpu, Parpo and Phuentsholing have witnessed 3 significant earthquakes. The 1980 Sikkim earthquake of magnitude 6.1 had caused several cracks in the buildings in Thimpu, Phuentsholing, Gelephu, Samdrup Jongkhar and Trashigang. Damages are reported to houses in the villages due to this earthquake. As discussed above, the earthquake triggered landslides and Phuentsholing – Thimpu national highway was blocked. The 1988 and 2003 Nepal-Bihar earthquake also caused similar damages to human settlements, institutional buildings and highways (MoHCA, 2006).

1.20.4 Risk Profile

There is a dearth of reported disaster loss data for Bhutan. As a result quantitative risk assessment of Bhutan could not be undertaken. To analyze the potential risk to the country, the regional hazard maps were referred. The analysis of hazard and population maps shows that 19 percent of the population are highly vulnerable to earthquake, 16 to flood and 43 percent are to moderate drought.

1.21 India

1.21.1 Overview

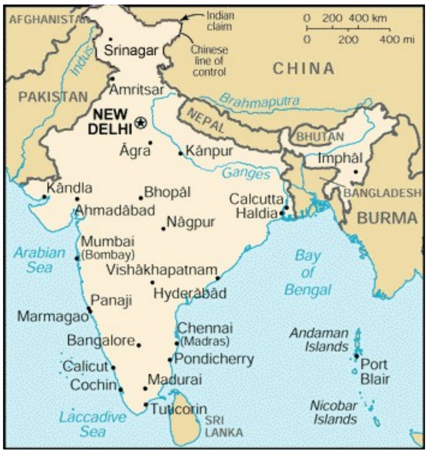


Figure 38 Location map of India

Country level information (2006)	
Geographic Area	3,287,260 sq km
Population	1,109,811,147
Population Density (person per sq km)	338
Urban population (% to total population)	28
Agriculture land (% to total area)	60.6
Forest land (% to total area)	20.6
Human Development Index	0.619
GDP	$ 911 billion
Agricultural GDP (%)	18.2
Industry GDP (%)	29.5
Service GDP (%)	52.3

Disaster risk statistics (1967-2006)			
Disaster type	Number of disasters/yr	Casualties/ yr	Average total affected population /yr
Earthquake	0.88	2,672	180,112
Flood	4.05	1,308	18,243,862
Drought	0.20	8	24,029,375
Landslide	0.88	104	95,978
Cyclone	1.83	1,219	2,047,990

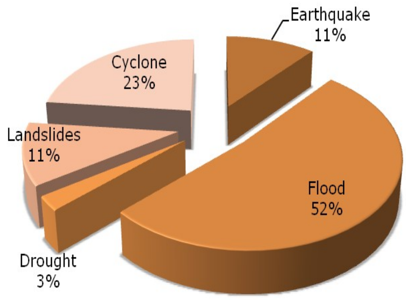


Figure 39 Percentage distribution of reported disaster India (1967-2006)

Average Annual Economic Loss, AAL

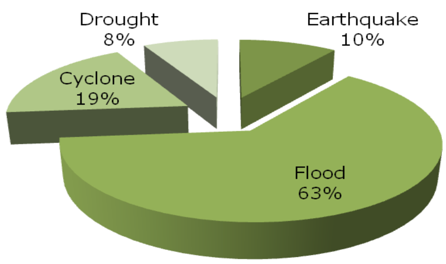


Figure 40 Average Annual Economic Loss of India

Economic loss data not sufficient for landslide

Economic loss potential (1967-2006)		
Annual exceedance probability	Economic loss ($ millions)	Percentage to GDP
0.5%	10,987	1.2%
5%	4,913	0.5%
20%	2,035	0.2%

1.21.2 Regional Setting

India is the largest country both in terms of size and population in SAR. Due to this vast size there is high diversity in terms of physiography, climate, socio economic and culture in the country. These diversity factors and the vast size of the country also make the country rank high in terms of reported number of disasters and risk to natural hazards.

India is located to the north of the equator between latitude 8°4' and 37°6' north and longitude 68°7' and 97°25' east. In southwest India is bound by the Arabian Sea, Bay of Bengal in the southeast, and Indian Ocean in the south. Himalayas are in the north, northeast, and northwest. The climate of India is diverse ranging from arid desert in the west, alpine tundra and glaciers in the north, and humid tropical regions in the southwest supporting rainforests and the island territories. The rain fall distribution also varies across the country and some of the major rivers are being fed by glaciers in the Himalayan ranges. About 56 percent of the country's land area is arable along with rich mineral resources spread in different parts.

India is the seventh-largest country in the world with a total land area of 3,287,260 sq km and population of 1.11 billion; the world's second most populous country. Almost 72 percent of country's population lives in rural areas. In recent years migration to larger cities has led to a dramatic increase in the country's urban population. India's largest cities are Mumbai, Delhi, Kolkata, Chennai, Bangalore, Hyderabad and Ahmadabad.

India is one among the top developing countries that is experiencing fast urbanization and economic growth. The period after the 1990s witnessed around 4.5 to 5 percent rise of India's GDP output. The Indian GDP growth rate registered an impressive growth of 8.5 percent during 2004 and has reached to 9 percent in 2006. In relation to disasters, this fast growth increases the vulnerability and risk to hazards both natural and man-made due to immigration of large population, unplanned construction and encroachment into environmentally fragile areas and lack of adherence to mitigation standards.

1.21.3 Hazard Profile

Due to the vast size of the country, the number of disaster events and as well as the losses (death, total affected, and economic loss) are high for India when compared to other SAR countries. India is highly vulnerable to natural hazards, particularly earthquake, flood, drought, cyclone and landslides. The country also experienced massive losses due to extreme temperatures and epidemics as well. The geologic formation of the region along with the human activities accentuated the impact of natural hazards like earthquake and landslides. The lower Himalayan region experiences landslides due to loose debris, heavy rainfall, and human interventions like deforestation and cultivation on steep slopes, while in the Western Ghats region, intense intervention of human activities along with rainfall triggers landslides.

Since the Himalayan mountain ranges are considered to be the world's youngest fold mountain ranges, the subterranean Himalayas are geologically very active. The Himalayan frontal arc, bordered by the Arakan Yoma fold belt in the east and the Chaman fault in the west forms one of the most seismically active regions in the world. The country has experienced three great earthquakes (magnitude greater than 8) since 1900. These are the Kangra earthquake of 1905, great Assam earthquakes of 1950, and the Bihar-Nepal earthquake of 1934. The other recent large damaging Himalayan earthquakes are: 1991 Uttrakashi earthquake of magnitude 6.5, 1988 Nepal–Bihar earthquake of magnitude 6.8, 1999 Chamoli earthquake of magnitude 6.8, and recent 2005 Kashmir (POK) earthquake of magnitude 7.7. These are a few of the earthquakes, which have caused colossal loss of life and property.

The peninsular part of the country comprises of continental crust regions, which were considered stable as they are far away from the tectonic activity of the boundaries. These regions were considered seismically less active, however, 1967 Koyna earthquake of magnitude 6.5, 1993 Latur earthquake of magnitude 6.3, 1997 Jabalpur earthquake of magnitude 6.0 and 2001 Bhuj earthquake of magnitude 7.7 are the few recent earthquakes in this region, which have caused considerable loss of life and property.

Thus, the entire country is prone to earthquakes of varying intensities. Based on the observed past damage and fault patterns (SEISAT, 2000), the country has been divided into four seismic zones (IS: 1893, 2002), seismic zone II (least seismic zone) to Zone V (most severe seismic zone). As per Vulnerability Atlas of India (BMTPC, 2006), 10.9 percent and 17.3 percent of the area of the country falls in very high and high damage risk zones respectively.

Flood is considered as a common natural hazard that recurs almost every year in many parts of India and more than once in certain parts of the country. The heavy southwest monsoon rains cause flooding in north, north eastern and southern parts of India. The heavy rain also causes flash floods in many of the urban cities impacting life and causing heavy economic loss.

Almost entire India is flood-prone. Flash floods resulting from extreme precipitation have become increasingly common in central India over the past several decades, coinciding with rising temperatures. Recently, on July 26, 2005 Mumbai has experienced a major flood, in which a record rainfall of 1011 mm occurred at the Vihar Lake area. This has exceeded the record of one day rainfall of 985 mm at Chirrapunjee. On the other hand, the variation of rainfall distribution also causes drought conditions in many parts of the country, particularly Gujarat, Rajasthan, southern and eastern Maharashtra, northern Karnataka, Andhra Pradesh, and Orissa. In the past, droughts have led to regular famines in India, including the Bengal famine of 1770, in which up to one third of the affected population died; the 1876–1877 famine, which led to the death of about five million people; the 1899 famine, with over 4.5 million fatalities; and the Bengal famine of 1943, with over five million starvation death and famine-related illnesses.

The oscillatory movement of Inter Tropical Convergence Zone and the pressure differences development in peninsular India, Bay of Bengal and Arabian Sea lead to cyclonic situations. Cyclones bring with them strong winds, heavy rains and storm surges that often affect life, livelihood and assets in the coastal areas. On an average, a major (Category 3 or higher) cyclone develops every other year. The Cyclone 05B, a 'Super Cyclone' that struck Orissa on 29 October 1999, was the worst in terms of damage and loss of life in the last 25 years.

The tsunami resulted from the 2004 Indian Ocean earthquake struck the Andaman and Nicobar Islands and east coast of India causing an estimated 10,000 deaths. Until then it was believed that India has negligible threat from tsunamis, though there are historical anecdotal evidences of tsunami occurrence in the past.

India has two active volcanoes: the Barren Island volcano which last erupted in May 2005 and the Baratang in Andaman Sea in 2005. The Narcondam volcano in Andaman Sea is considered as dormant volcano. No deaths or economic losses are reported due to volcanoes in India.

1.21.4 Risk Profile

Average annual incidence of flood is of the order of 5 per year in India while the death rate shows higher rate due to earthquakes (2,672 per year) compared to floods (1,308 per year). Flood affect large number of people and impact agriculture while earthquakes damage buildings and infrastructure resulting in large number of deaths. Population affected by cyclones is also significant with an average annual death rate of 1,219.

The hazard incidence data shows a steady increasing trend during the period 1967-2006 (Figure 41). Number of deaths has shown lower values during 1972-76 but after 1982, it is steadily increasing with disaster events. The period 2002-06 has recorded the highest number of deaths as well as number of disasters. Number of total affected population was highest in 2002-06 and 1987-91 (Figure 42). The 1987 drought affected 300 million people and the 2002 flood affected 42 million people.

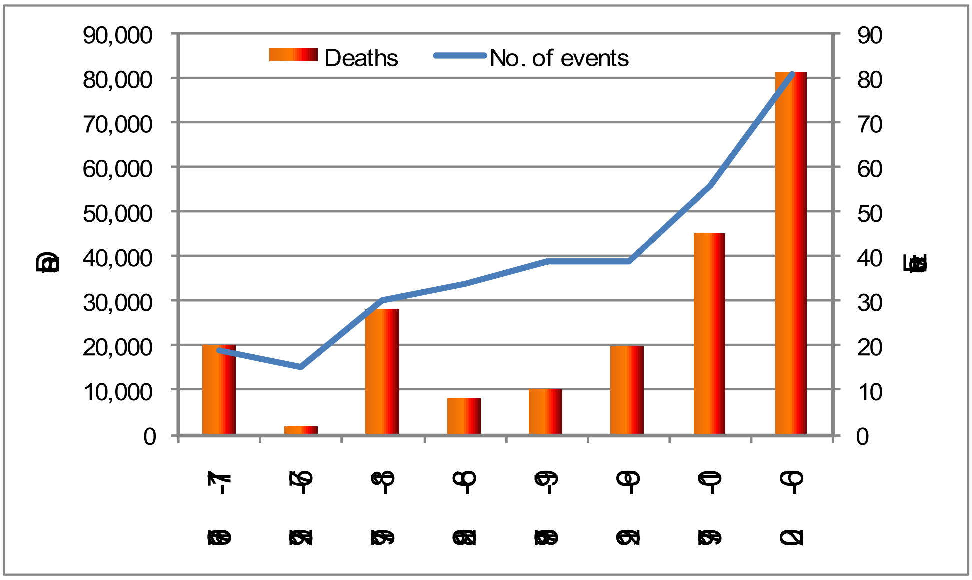


Figure 41 Reported disasters and deaths in India during 1967 - 2006

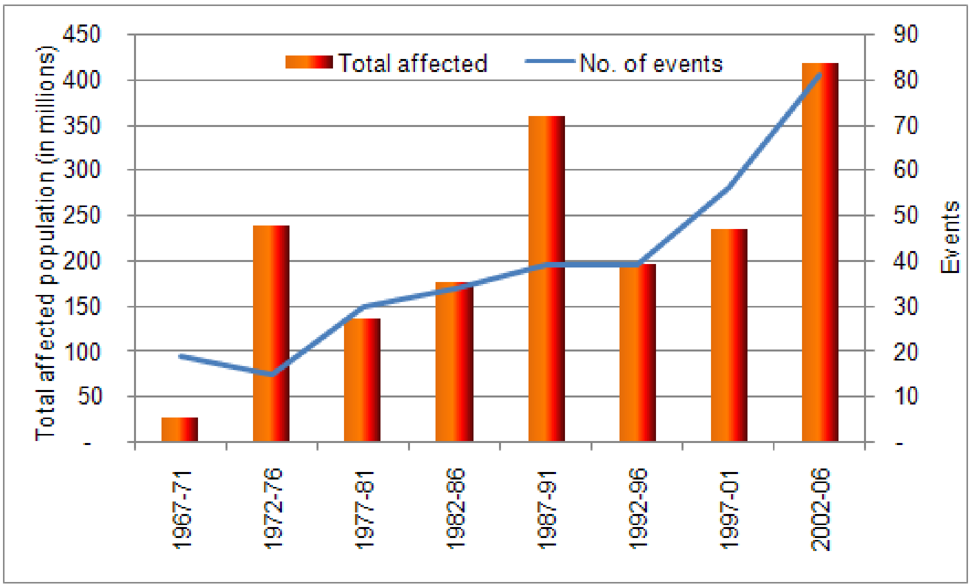


Figure 42 Reported disasters and total population affected in India during 1967 - 2006

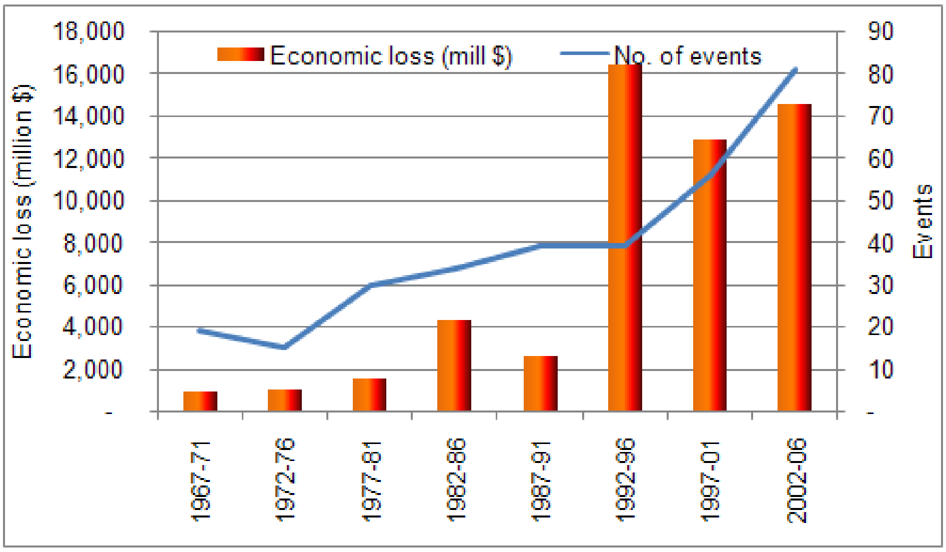


Figure 43 Reported disasters and economic loss in India during 1967 – 2006

In terms of economic loss hydro metrological hazards (floods and cyclones) cause the majority of loss in the country. India has experienced huge economic losses during the period 1992 -2006 (Figure 43). The 2004 Tsunami caused a loss of $ 1,022 million. In addition to 2004 Tsunami, floods during this year also have caused huge economic loss ($ 2,500 million) in the country. The floods of 2005 and 2006 have caused loss in the tune of $ 3,390 million and $ 5,830 million respectively. Cyclones along Indian coast also contribute to heavy losses as coastal areas of India are centers of high economic activity and high population density.

The probability of economic losses exceeding $ 11 billion in one year is about 0.5 percent. This is about 1.2 percent of the country's GDP. The probability of annual losses exceeding $ 5 billion is about 5 percent.

1.22 Maldives

1.22.1 Overview

Figure 44 Location map of Maldives

Country level information (2006)	
Geographic Area	300 sq km
Population	300,292
Population Density (person per sq km)	1,001
Urban population (% to total population)	19.9
Agriculture land (% to total area)	46.7
Forest land (% to total area)	-
Human Development Index	0.741
GDP	$ 0.927 billion
Agricultural GDP (%)	-
Industry GDP (%)	-
Service GDP (%)	-

Disaster risk statistics (1967-2006)			
Disaster type	Number of disasters/yr	Casualties/yr	Average total affected population /yr

No data

No loss data

Economic loss potential (1967-2006)		
Annual exceedance probability	Economic loss ($ millions)	Percentage to GDP

1.22.2 Regional Setting

Maldives is an Island country with a total land area of 300 sq km. It is an archipelagic group comprising of about 1196 coral islands in the Indian Ocean spreading over 90,000 sq km. The atolls are situated at the top of submarine ridge of 960 km long that rises abruptly from the depths of the Indian Ocean and runs from north to south are composed of live coral reefs and sand bars. Out of the chain of islands, only 200 islands are inhabited and 992 are uninhabited and most of the islands lie between 1 and 1.5 m above mean sea level. Islands are too small to have rivers, but small lakes and marshes can be found in some islands. Maldives has a predominantly maritime climate with dominance of monsoon phenomena. The annual rainfall averages 2,540 mm on the north and 3,810 mm in the south. The presence of Indian landmass has a high influence in the climate of this island country.

Maldives has a total population of 300,292. Estimation of the population density is difficult because many of Maldives' approximately 1,200 islands are uninhabited. Of the approximately 200 inhabited islands in 1988, twenty-eight had fewer than 200 inhabitants, 107 had populations ranging from 200 to 500, and eight had populations between 500 and 1,000. A government study in the mid 1980s listed 25 places with a population of more than 1,000. The 1990 census recorded an average population density for the Maldives as 706 persons per sq km. The country has constrained resources but is experiencing high population growth which is estimated to reach 400,000 by 2020. The economy of the country mainly thrives on tourism and fisheries. With economic reforms towards a liberalized economy, the GDP has experienced a growth averaged over 7.5 percent per year during the last one decade. The tsunami of December 26, 2004 resulted in a fall in the GDP.

1.22.3 Hazard Profile

The location and the low level of the country makes Maldives vulnerable to hazards related to wave surge, wind storm and flash floods. For the same reason the country is vulnerable to seal level rise too. In May 1991, tidal waves were created as a result of violent monsoon winds resulting in damage of thousands of houses and piers. It has flooded arable land with seawater, and uprooted thousands of fruit trees. The damage caused was estimated at $ 30 million. The December 26, 2004 tsunami has severely affected the Maldives and killed more than 100 people, displaced about 12,000, and caused a property damage that exceeds $ 300 million. Due to the tsunami, 39 islands were significantly damaged and nearly a third of Maldives' population was severely affected. About 29,580 residents were displaced and around 12,000 remained homeless. World Bank-ADB-UN System estimated total damage of $ 470 million, which is equal to 62 percent of Maldives' GDP of 2004. Tourism, which is one the main source of income of the country suffered badly due to this event. Nineteen out of 87 tourist resorts were closed after the tsunami impact. Severe damages were caused to habitats, health facilities, transportation, and communication facilities also.

The dependence of the country on fisheries and the tourism sector increases the social and economic vulnerability to hazards of the sea. The northern atolls are at greater risk to hazards from storms and storm surge than the southern atolls. The population growth in some of the islands is alarming due to the increase in density and constrains size of the land.

1.22.4 Risk Profile

RMSI has carried out a detailed disaster risk profile of Maldives in 2006 for UNDP (UNDP, 2006). As there was dearth of reported disaster data available the risk profile presented here is an extract from this study. The study assessed the risk of prevailing natural hazards in Maldives using simulation modeling. The hazards included are tsunami, earthquake, cyclone (storm), waves surge due to storms and sea level rise. Multi-hazard risk index was calculated.

Physical and social vulnerability of the inhabited islands were assessed. The summary of the key findings of the study is provided here.

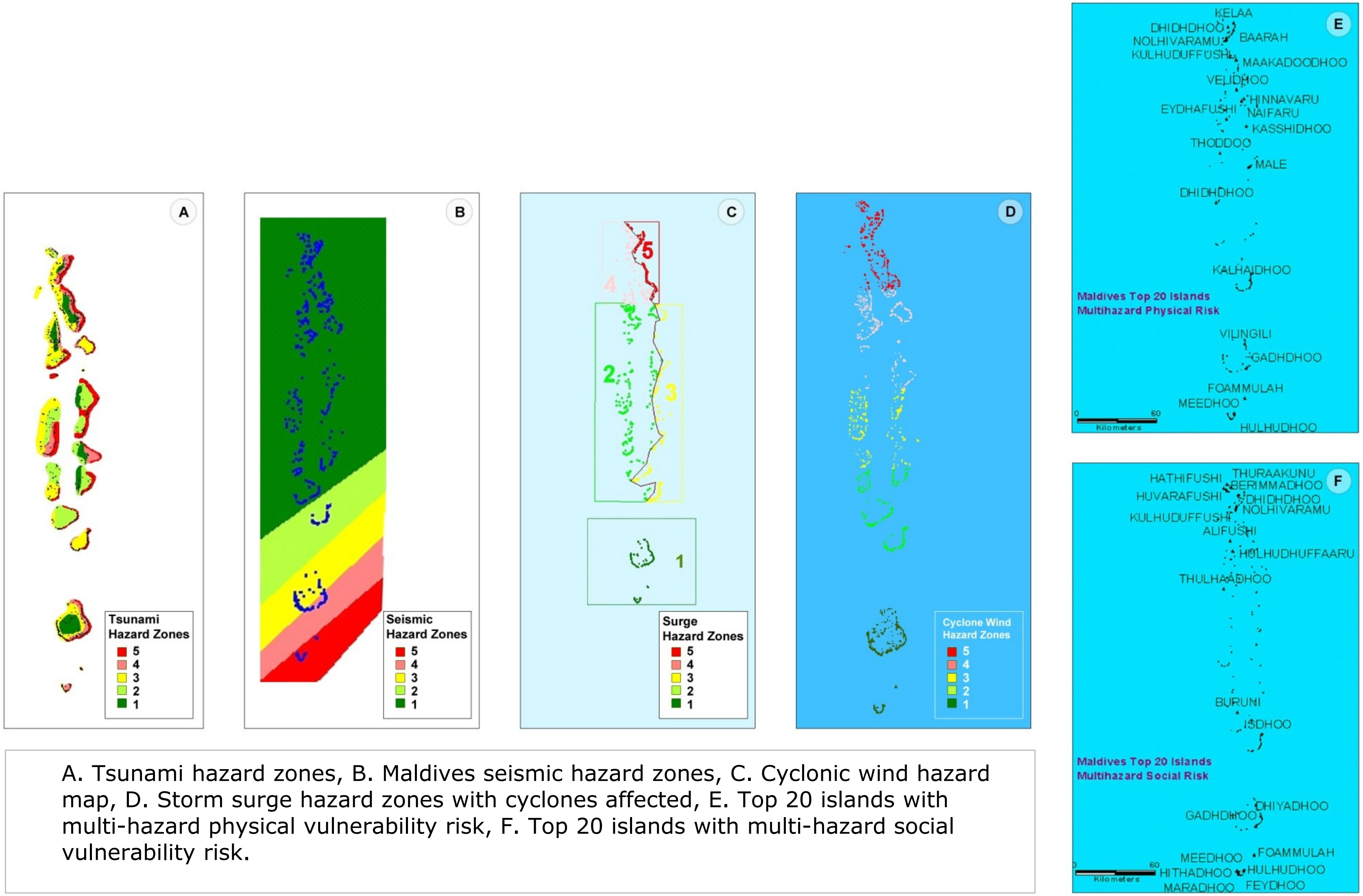
The disaster risk scenario for Maldives can be described as moderate in general. Despite this, Maldives is among the most severely affected countries hit by the Asian Tsunami on December 26, 2004. The Maldives experienced moderate risk conditions owing to a low probability of hazard occurrence and high vulnerability from exposure due to geographical, topographical and socio-economic factors. It is crucial to address this context of Maldives' high level of vulnerability in order to avoid the present scale of losses and damage in the future. Such an address requires a detailed risk assessment which will map out *where* the risks from multiple hazards are concentrated in Maldives and also, *who* is affected and *how*.

Maldives has tsunami hazard largely from the east though relatively low hazard is from the north and south also. So, islands along the eastern fringe of eastern atolls are at greater hazard. Islands along the western fringe of western islands have relatively low tsunami hazard. Historically, Maldives has been affected by three earthquake sources in the Indian Ocean. Of the total 85 tsunamis generated since 1816, 67 originated from the Sumatra subduction zone in east and the remaining 13 from the Makran coast zone in north and Carlsburg Transform fault zone in south. The probable maximum tsunami wave height is estimated at 4.5 m in zone 5. The return period of December 26, 2004 tsunami is found to be 219 years (one of numerous probable events).

The northern atolls are at greater hazard from cyclonic winds and storm surge. This reduces gradually to very low hazard in southern atolls. The maximum probable wind speed in zone 5 is 96.8 knots (180 kmph) and the cyclonic storm category is a lower CAT-3 on Suffir-Simpson scale. At this speed, high damage is expected from wind, rain and storm surge hazards.

Except for Seenu, Gnaviyani and Gaafu atolls, the earthquake hazard is low across the country. The probable maximum MMI is estimated at 7-8 in zone 5. This level of MMI can cause moderate to high damage.

Sea level rise due to climate change has uniform hazard throughout the country. The IPCC (IPCC, 2001) estimates a projected sea level rise of 0.09 m to 0.88 m for 1990 to 2100. The impact on Maldives is directly proportional to the elevation of islands. Since about three-quarters of the land area of Maldives is less than a meter above mean sea level, the slightest rise in sea level will prove extremely threatening. Male is estimated to be inundated by 15 percent by 2025 and 50 percent by 2100 under conservative scenarios of climate change. Due to non-availability of high resolution topographic data impacts other islands could not be undertaken.



A. Tsunami hazard zones, B. Maldives seismic hazard zones, C. Cyclonic wind hazard map, D. Storm surge hazard zones with cyclones affected, E. Top 20 islands with multi-hazard physical vulnerability risk, F. Top 20 islands with multi-hazard social vulnerability risk.

Figure 45 Hazard zone and vulnerability map of Maldives

Overall, Maldives has moderate hazard levels except for the low probability and high consequential tsunami hazard in the near future, and high probability and high consequential Sea level rise hazard in the distant future.

Risk from physical vulnerability is more a function of exposure concentration. As such, Male tops the list with highest risk. The islands with risk index 5 (very high) and risk index 1 (very low) are given in the tables below. Risk index 1 means "safe island" in relative terms.

S. No.	ISLAND	ATOLL	MULTI HAZARD PHYSICAL RISK INDEX
1	MALE	KAAFU	5
2	FOAMMULAH	GNAVIYANI	5
3	KULHUDUFFUSHI	HAA DHAALU	5
4	HULHUDHOO	SEENU	5
5	DHIDHDHOO	HAA ALIFU	5
6	DHIDHDHOO	ALIFU DHAALU	5
7	KELAA	HAA ALIFU	5
8	NOLHIVARAMU	HAA DHAALU	5
9	GADHDHOO	GAAFU DHAALU	5
10	NAIFARU	LHAVIYANI	5
11	THODDOO	ALIFU ALIFU	5
12	EYDHAFUSHI	BAA	5
13	KALHAIDHOO	LAAMU	5

S.NO.	ISLAND	ATOLL	MULTI HAZARD PHYSICAL RISK INDEX
1	BODUFOLHUDHOO	ALIFU ALIFU	1
2	HIMENDHOO	ALIFU ALIFU	1
3	MAALHOSS	ALIFU ALIFU	1
4	MATHIVERI	ALIFU ALIFU	1
5	UKULHAS	ALIFU ALIFU	1
6	MANDHOO	ALIFU DHAALU	1
7	DHONFANU	BAA	1
8	KIHAADHOO	BAA	1
9	KUDARIKILU	BAA	1
10	HULHUDHELI	DHAALU	1
11	MEEDHOO	DHAALU	1
12	RIBUDHOO	DHAALU	1
13	DHARANBOODHOO	FAAFU	1
14	MAGOODHOO	FAAFU	1
15	THINADHOO	GAAFU DHAALU	1
16	FODHDHOO	NOONU	1
17	KANDOODHOO	THAA	1
18	OMADHOO	THAA	1
19	VANDHOO	THAA	1
20	RAKEEDHOO	VAAVU	1

Risk from social vulnerability has no definite trend except Male being in low risk. The risks are randomly spread across the country as several factors drive the vulnerability. The tables below give islands with risk index 5 (very high) and risk index 1 (very low). Risk index 1 means "safe island" in relative terms.

S.NO.	ISLAND	ATOLL	MULTI HAZARD SOCIAL RISK INDEX
1	THURAAKUNU	HAA ALIFU	5
2	BERINMADHOO	HAA ALIFU	5
3	HATHIFUSHI	HAA ALIFU	5
4	NOLHIVARAMU	HAA DHAALU	5
5	ALIFUSHI	RAA	5
6	HULHUDHUFFAARU	RAA	5
7	BURUNI	THAA	5
8	DHIYADHOO	GAAFU ALIFU	5
9	GADHDHOO	GAAFU DHAALU	5
10	MEEDHOO	SEENU	5
11	HITHADHOO	SEENU	5
12	FEYDHOO	SEENU	5

S.NO.	ISLAND	ATOLL	MULTI HAZARD SOCIAL RISK INDEX
1	BODUFOLHUDHOO	ALIFU ALIFU	1
2	FERIDHOO	ALIFU ALIFU	1
3	HIMENDHOO	ALIFU ALIFU	1
4	MAALHOSS	ALIFU ALIFU	1
5	MATHIVERI	ALIFU ALIFU	1
6	RASDHOO	ALIFU ALIFU	1
7	THODDOO	ALIFU ALIFU	1
8	MANDHOO	ALIFU DHAALU	1
9	KAMADHOO	BAA	1
10	KUDARIKILU	BAA	1
11	DHARANBOODHOO	FAAFU	1
12	FIEEALEE	FAAFU	1
13	MAGOODHOO	FAAFU	1
14	NILANDHOO	FAAFU	1
15	MADUVVARI	RAA	1
16	MEEDHOO	RAA	1
17	KANDOODHOO	THAA	1
18	OMADHOO	THAA	1
19	VANDHOO	THAA	1
20	RAKEEDHOO	VAAVU	1

1.23 Nepal

1.23.1 Overview

Figure 46 Location map of Nepal

Country level information (2006)	
Geographic Area	147,180 sq km
Population	27,641,362
Population Density (person per sq km)	188
Urban population (% to total population)	21.1
Agriculture land (% to total area)	29.5
Forest land (% to total area)	24.7
Human Development Index	0.534
GDP	$ 8.94 billion
Agricultural GDP (%)	34.6
Industry GDP (%)	17.2
Service GDP (%)	48.2

Disaster risk statistics (1967-2006)			
Disaster type	Number of disasters/yr	Casualties/ yr	Average total affected population /yr
Earthquake	0.05	31	0
Flood	0.70	136	60,575
Drought	0.10	0	115,000
Landslide	0.35	37	11,065
Cyclone	0.10	1	5

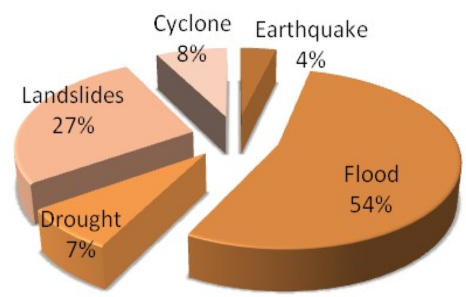


Figure 47 Percentage distribution of reported disaster Nepal (1967-2006)

Average Annual Economic Loss, AAL

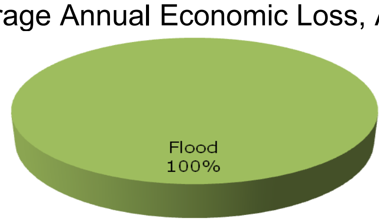


Figure 48 Average Annual economic Loss (AAL) of Nepal

Economic loss data not sufficient for other hazards

Economic loss Potential (1967-2006)		
Annual exceedance probability	Economic loss ($ millions)	Percentage to GDP
0.5%	807	9.00%
5%	321	3.59%
20%	119	1.33%

1.23.2 Regional Setting

Nepal is a landlocked mountain nation in the Himalayan ranges with the world highest peak and is located between India and China. The country has a geographic area of 147,180 sq km with a population of 27,641,362. Even though Nepal is such a small country, it has wide diversity in terrain from Tarai plains in the southern part to rugged mountain in the north. With this maze of mountains, hills, ridges, and low valleys, altitudinal variation has resulted in ecological diversity. The Mountain Region, the Hill Region, and the Tarai Region form the three distinct physiographic divisions of Nepal. All the three terrain formations runs parallel to each other, as continuous ecological belts from east to west, occasionally bisected by the country's river systems.

The climate of the country varies from tropical to subtropical and has a good influence of monsoon activities in the Indian subcontinent. The Himalayan mountain ranges also play a prominent role in the prevailing climatic conditions of the nation. The economic and livelihood activities of the region are also dependant on the climate and terrain conditions. The rivers mostly originate from China, drain the nation and finally forming the tributaries of the River Ganges and flow into India. Along with rain, the glaciers also feed these river systems which sometimes cause floods both in Nepal and parts of India.

Due to the terrain characteristics of the nation, the human settlements are disparate and badly connected. The rivers flowing through the rugged terrain system cannot be used for navigation. Nepal is one of the poorest nations with a per capita GNI of $1,010. The economic underdevelopment could be attributed to terrain, lack of resource, landlocked position, lack of modern institutions, weak infrastructure, and a lack of policies conducive to development. Due to the terrain nature and political issues existing in neighboring countries, the trade route of Nepal is only through India. In 1980s, the real economic growth of Nepal averaged at 4 percent annually, but the 1989 trade and transit dispute with India adversely affected economic progress, and economic growth declined to only 1.5 percent. The economic growth did not keep pace with population growth. Largely dependent on agriculture, economic growth also was undermined by poor harvests.

Agriculture dominates the country’s economy. In the late 1980s, it constituted the livelihood of more than 90 percent of the population although only approximately 20 percent of the total land area was cultivable. This accounted for, on an average, about 60 percent of the GDP and approximately 75 percent of exports. Tourism is another sector that provides substantial revenue to the nation mostly in the form of foreign exchange.

1.23.3 Hazard Profile

The country is highly vulnerable to flood landslide, drought, earthquake and wind storms. Landslide events often associated with earthquakes and floods. Among the major hazards, flood and landslides are most recurrent and have claimed more than 200 lives annually over the past 10 years (MoWR, 2004; MoHA, 2005). Landslides threaten the safety of many hill communities and disrupt economic activities by blocking roads. Heavy monsoon rains at the end of August 2006 led to extensive flooding and landslides. More than 80,000 people were directly affected and in remote areas, the adverse weather and difficult terrain greatly impeded initial relief work. Frequent flood and drought undermine the agricultural productivities of hundreds of thousands of poor farmers. In most monsoon seasons, dozens of people lose their lives, hundreds are displaced and thousands lose their livelihood due to landslides and floods across the western part of country while at the same time, farmers in the east of the country might be suffering from drought (UNCTN, 2007).

Seismically, Nepal lies in one of highly active seismic belt of the world that extends from Java, Myanmar, the Himalayas, Iran to Turkey. Historically, Nepal has long history of destructive earthquakes. The 1934 Nepal - Bihar earthquake produced strong shaking in Kathmandu valley and caused serious damage of 60 percent of the buildings in the Kathmandu valley (JICA, 2002). Three earthquakes of similar size occurred in the Kathmandu valley in the 19th century: in 1810, 1833 and 1866 AD. The seismic record of the region, which extends back to 1255 AD, suggests that earthquakes of this size occur approximately every 75 year, indicating that a devastating earthquake is inevitable in the long term and likely in the near future (NSET, 1999).

1.23.4 Risk Profile

Nepal is ranked the 11th most at risk country to earthquakes, the 13th to floods and one of the twenty most multi-hazard prone countries (BCPR, 2004; World Bank (2005b); UNCTN, 2007). Almost whole of the Nepal is in high seismic risk zone and a strong earthquake in the Kathmandu valley would cause an estimated deaths of 40,000 people and injury to 90,000 or more (UNCTN, 2007). It has been estimated that on average one disaster event leading to two deaths occurred everyday in Nepal between 1971 and 2003 (NSET, 2005).

Natural hazards tend to lead to more deaths in Nepal than in most South Asian countries. It is reported that 0.4 percent of total people affected by natural hazards in Nepal die; a figure four times higher than the average for South Asia (IFRC, 2004; UNCTN, 2007).

The number of deaths due to natural hazards has been relatively low during the last decade. However, there is a significant loss of life in Nepal during 1967 – 1996. The annual average incidence of flood disaster is highest (0.7 events per year) and landslides stands next (0.35 events per year). Average annual incidence of death is highest for flood compared to other hazards while physical exposure is high for drought. The 1991 flood killed 1,334 people and the earthquake of 1988 killed 708 people. The landslides and debris flows during 1993 had taken the lives of 1259 people affecting 44 districts and damaging many bridges and dams as well bringing a total economic loss of more than 47194 million Rupees, i.e., about $ 936 million (Chitrakar et al, 2007). These are two events that recently killed significant number of people in Nepal. The incidence trend of disaster shows a dip during 1997-01, otherwise in general shown an increasing trend over time. Number of events recorded during 1982-86 is highest even though death is not that high (Figure 49).

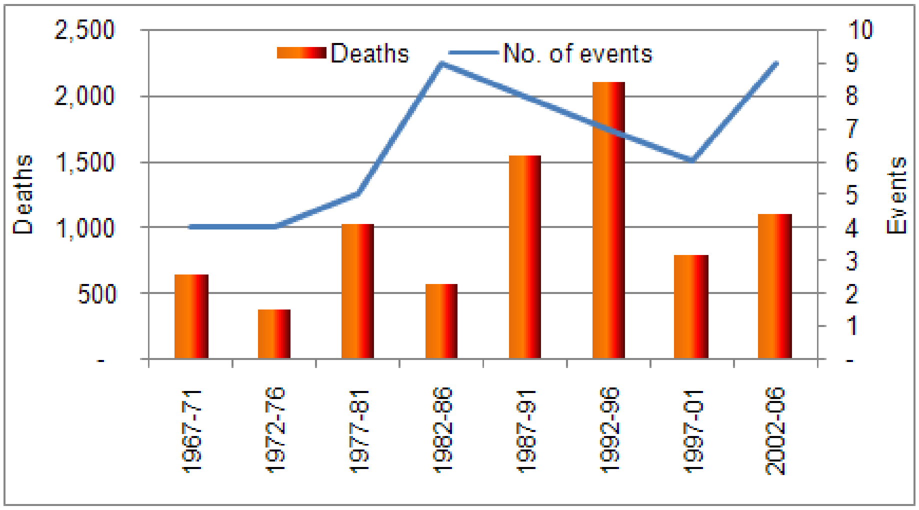


Figure 49 Reported disasters and deaths in Nepal during 1967 - 2006

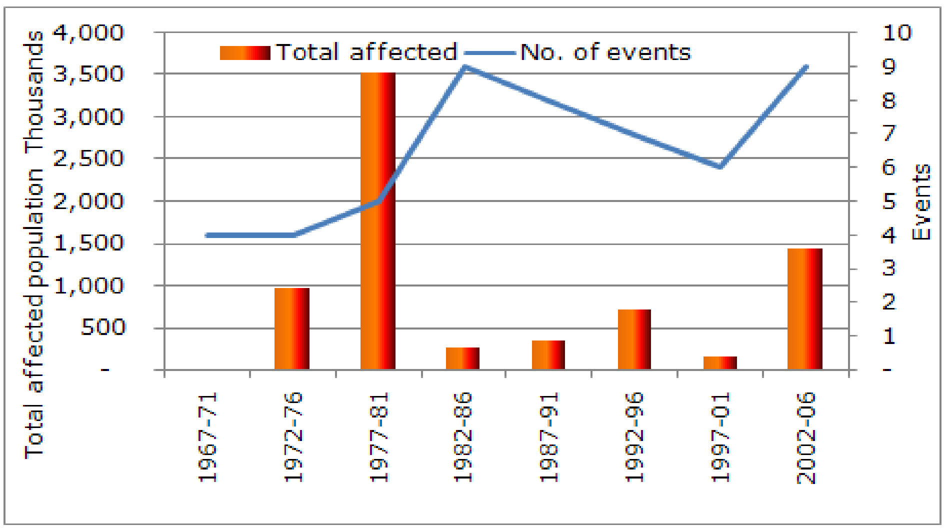


Figure 50 Reported disasters and total population affected in Nepal during 1967 – 2006

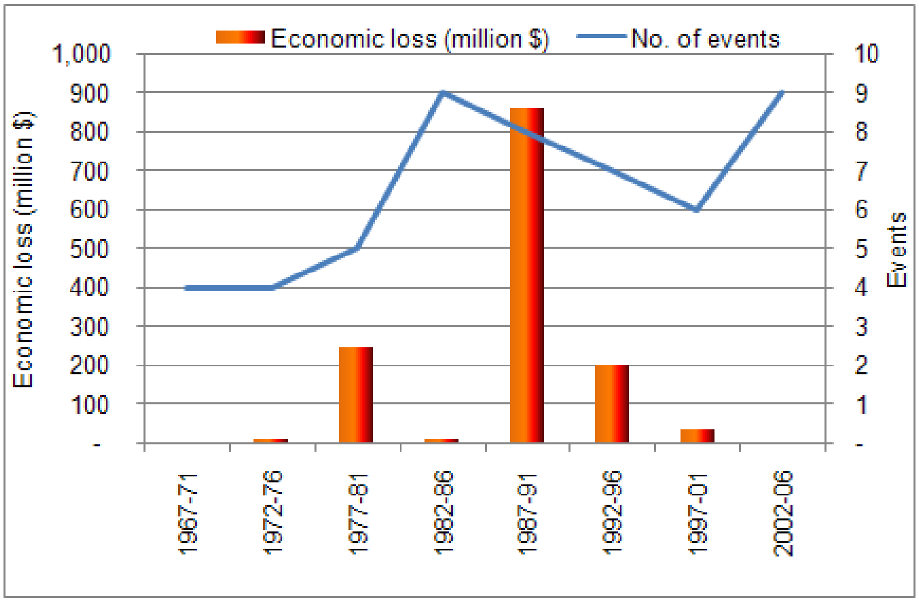


Figure 51 Reported disasters and economic loss in Nepal during 1967 – 2006

In terms of affected population, the period from 1977-81 has recorded the highest number (Figure 50). The drought of 1979 affected 3.5 million people, about 13 percent of Nepal population. The 1980 earthquake affected 240,600 people (0.9 percent of the national population). The 2002 landslide also affected significant number of people (265,865 people). The economic loss is highest during 1992-96. All the disaster during this period caused significant deaths (Figure 51). The 1987 flood incurred the highest economic loss ($ 727 million) during the last 40 years. The 1980 earthquake caused an economic loss of $ 245 million.

The probability of economic losses exceeding $800 million in one year is about 0.5 percent. This is about 9 percent of the country's GDP. The probability of annual losses exceeding $300 million is about 5 percent.

1.24 Pakistan

1.24.1 Overview

Figure 52 Location map of Pakistan

Country level information (2006)	
Geographic Area	796,100 sq km
Population	159,002,039
Population Density (person per sq km)	200
Urban population (% to total population)	33.7
Agriculture land (% to total area)	35.1
Forest land (% to total area)	2.4
Human Development Index	0.551
GDP	$ 126.84 billion
Agricultural GDP (%)	20.4
Industry GDP (%)	26.9
Service GDP (%)	52.7

Disaster risk statistics (1967-2006)			
Disaster type	Number of disasters/yr	Casualties/ yr	Average total affected population /yr
Earthquake	0.67	1970	161,998
Flood	1.20	209	1,046,158
Drought	0.02	4	55,000
Landslide	0.15	3	75
Cyclone	0.30	29	13,495

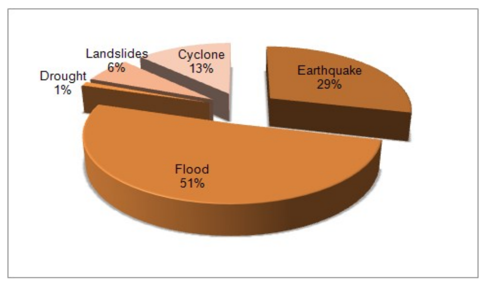


Figure 53 Percentage distribution of reported disaster Pakistan (1967-2006)

Average Annual Economic Loss, AAL

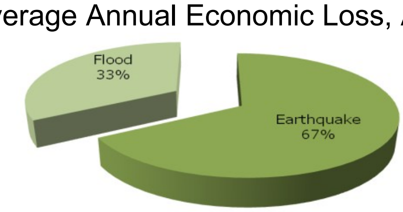


Figure 54 Average Annual Economic Loss of Pakistan

Economic loss data not sufficient for other hazards

Economic loss Potential (1967-2006)		
Annual exceedance probability	Economic loss ($ millions)	Percentage to GDP
0.5%	4,024	3.17%
5%	1,258	0.99%
20%	382	0.30%

1.24.2 Regional setting

Pakistan is bordered by Afghanistan to the north-west and Iran to the west. People's Republic of China borders in the north and India to the east. Pakistan was part of India till 1947. There are three distinct physiographic regions in the country: the northern highlands; the Indus River plain; and the Balochistan Plateau. Pakistan has a temperate climate which is mostly arid to semi arid with sparse rainfall. A distinct climatic variation prevails across the nation from warm humid maritime climate along the coast to temperate alpine climate in the Karakoram ranges. The Indus River originates in the mountain ranges of the Himalayas and drains into the Arabian Sea forming one of the biggest deltaic system. Karachi, the capital city of Pakistan is located in this deltaic region.

Pakistan has a varied landscape with plains, deserts, forests, hills and plateaus ranging from Karakoram mountain ranges in the north to the coastal areas of the Arabian Sea in the south. Pakistan geologically overlaps both the Indian and the Eurasian tectonic plates. The north-western corner of the Indian plate lies in Sind and Punjab province. Most of the North-West Frontier Province and Balochistan lies within the Eurasian plate which mainly comprises the Iranian plateau, some parts of the Middle East and central Asia. Along the edge of the Indian plate lie the northern areas and Pakistani-administered Azad Kashmir (POK) and hence are prone to severe earthquakes where the two tectonic plates collide.

The country has an area of 796,100 sq km and a population of 159,002,039 with a population density of 200 persons per sq km. The annual population growth of the country is more or less steady at 2.1 percent. The population is mostly concentrated in the lower plains with Karachi having a population density of 3,957 persons per sq km. Initially, the economy of the country was rooted in agriculture but the industrial sector gathered its momentum and is now in prominence. The country has registered about 6 percent economic growth with its foreign direct investment. Country is one among the growing economies of the World.

The GDP of the country was $ 126.84 billion in the year 2006 with an annual growth rate of 7 percent in the same year with an average annual growth rate of 6.5 percent for the period of 2005-09.

1.24.3 Hazard Profile

Pakistan is vulnerable to earthquake, flood, cyclone and drought and landslides. Pakistan lies in a region of moderate to high seismic hazard (Zhang et al, 1998); the greatest hazard is in parts of the North West Frontier Province (NWFP), in the vicinity of Quetta and along the border with Iran. Historically, earthquakes in the magnitude range of 7.0 have been experienced in Balochistan and along the border with Afghanistan and India. As far as flood is concerned, both the upper and lower reaches of Indus and its tributaries gets flooded most of the year. The cyclones and windstorms cause wave surges and flooding in the coastal stretches. Even though flood is one of the major natural hazards, the country has significant drought risk. The mountain ranges of Himalayas extending to the northern part of the country are prone to landslides.

1.24.4 Risk Profile

Analysis of the disaster data for the last 40 years shows that the incidence of natural hazards is increasing over the time (Figure 55). This has peaked during the 2002-06 period killing significant number of people (74,899 people). Flood has higher annual average incidence, 1.2 events per year and earthquake 0.68 events per year. Annual average incidence of death is highest for earthquake (1970 deaths per year), even though physical exposure is highest for flood, 1,046,158 persons per year.

A large number of people were affected during the period 1972-76, 1992-96 and 2002-06 periods (Figure 56). The 2005 POK earthquake has taken 73,378 lives, affected 5,128,000 people and incurred an economic loss of $ 5,200 million (Figure 57). The floods are recurring phenomenon in this region also affecting large number of people. Some of major floods in the recent past affected large population and incurred big economic losses included the floods of 1973, 1976, 1978, 1992, 1996 and 2005. Some of the years have recorded more than one flood. The economic loss in the last one and half decades recorded huge economic losses particularly the 2002-06 periods. The 1999 drought has lead to an economic loss of $ 247 million. The drought of 2001 has reduced the economic growth rate of the country by 2.6 percent as compared to an average growth rate of over 6 percent. It is not a coincidence that areas which experience disasters frequently, are amongst the poorest regions in the country; e.g. Balochistan, Tharparker, Cholistan and Northern areas. In order to ensure continuity of current economic growth in the medium to longer terms, the country must address risks posed by natural hazards (Yousaf, 2007).

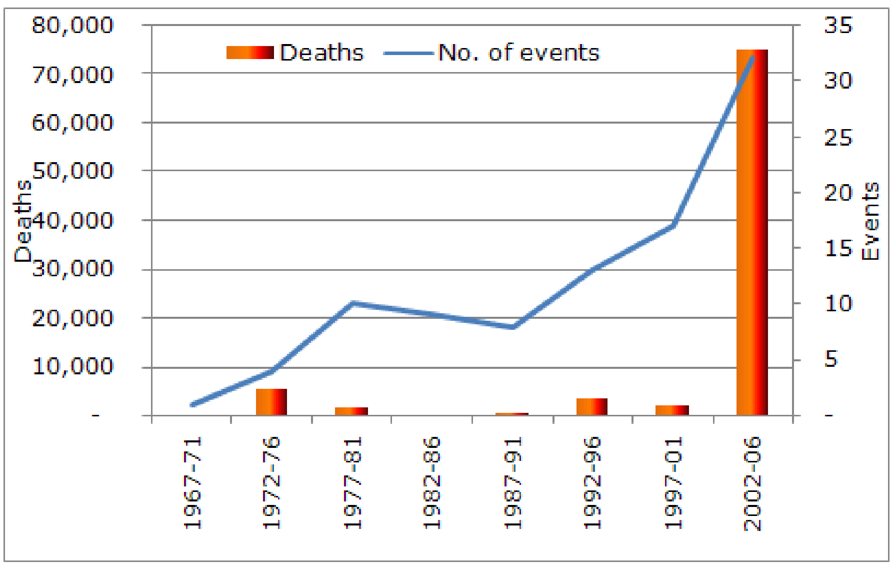


Figure 55 Reported disasters and deaths in Pakistan during 1967 - 2006

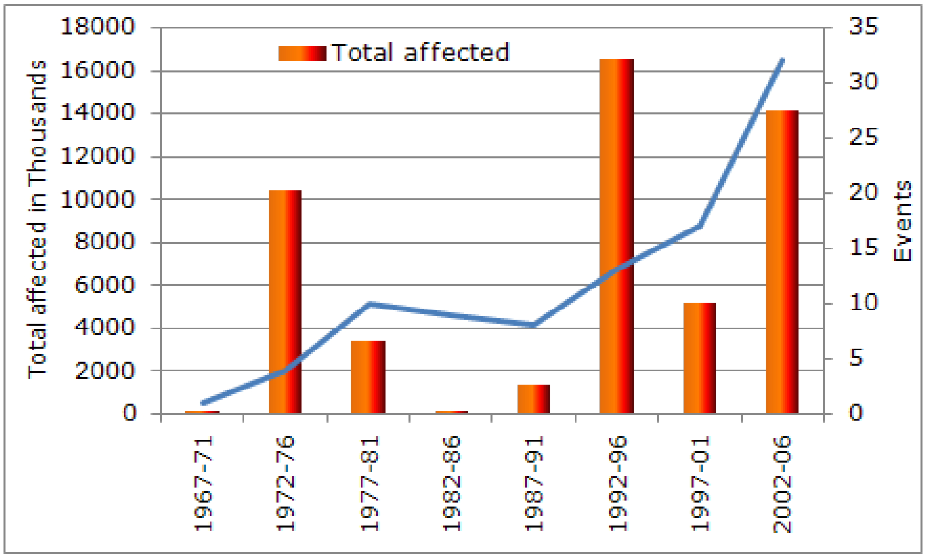


Figure 56 Reported disasters and total affected in Pakistan during 1967 - 2006

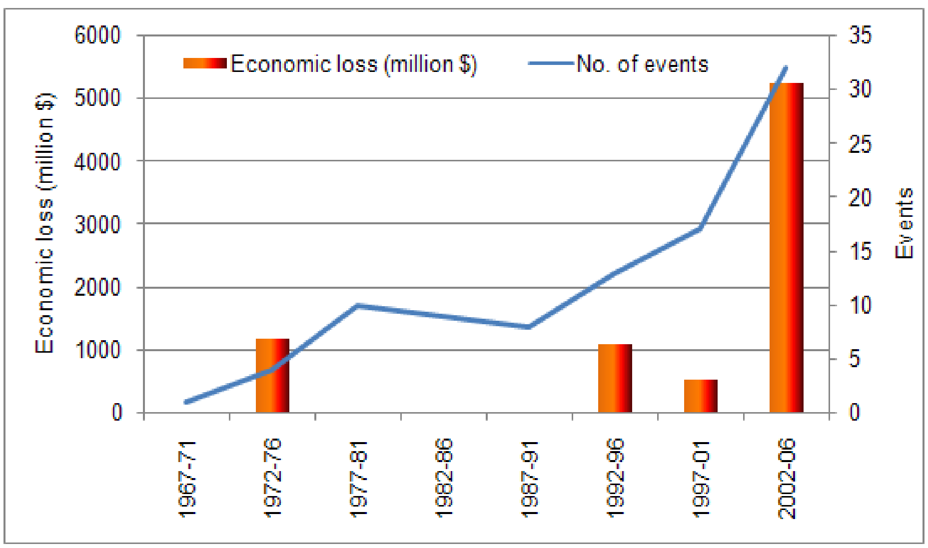


Figure 57 Reported disasters and economic loss in Pakistan during 1967 - 2006

The probability of economic losses exceeding $ 4 billion in one year is about 0.5 percent. This is about 3.2 percent of the country's GDP. The probability of annual losses exceeding $ 1.2 billion is about 5 percent.

1.25 Sri Lanka

1.25.1 Overview

Figure 58 Location map of Sri Lanka

Country level information (2006)	
Geographic Area	65,610 sq km
Population	19,886,000
Population Density (person per sq km)	303
Urban population (% to total population)	30.9
Agriculture land (% to total area)	36.5
Forest land (% to total area)	29.4
Human Development Index	0.743
GDP	$ 26.964 billion
Agricultural GDP (%)	11.3
Industry GDP (%)	30.6
Service GDP (%)	58.1

Disaster Risk Statistics (1967-2006)			
Disaster type	Number of disasters/yr	Casualties/ yr	Average total affected population /yr
Earthquake	0.00	0	0
Flood	0.95	27	241,947
Drought	0.23	0	206,400
Landslide	0.08	3	3
Cyclone	0.08	19	34,700

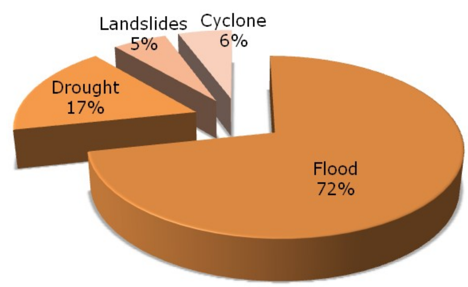


Figure 59 Percentage distribution of reported disaster Sri Lanka (1967-2006)

Average Annual Economic Loss, AAL

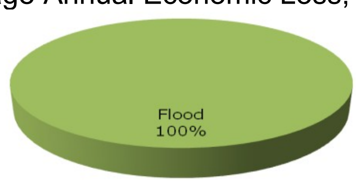


Figure 60 Average Annual Economic Loss of Sri Lanka

Economic loss data not sufficient
For other hazards

Economic loss Potential (1967-2006)		
Annual exceedance probability	Economic loss ($ millions)	Percentage to GDP
0.5%	275	1.02%
5%	107	0.40%
20%	39	0.14%

1.25.2 Regional Setting

Sri Lanka is an island country located in the Indian Ocean in the southern part of SAR. It has a total area of 65,610 sq km of which 870 sq km is occupied by water. Due to its location surrounded by sea and being in the equatorial zone, the country experiences hot humid climate with dominant influence of monsoons. Three distinguishable topographic zones can be observed in the country: the central highlands, the plains, and the coastal belt. The country has a population of 19,886,000 and a population density of 303 persons per sq km with a densely populated coastal stretch. Due to the size of the country, the river systems are relatively small and the longest river is Mahavali River (335 km long). Most of the prominent rivers originate from the central highlands. Sri Lanka is known for its high levels of biodiversity but according to U.N. figures, the country is experiencing heavy deforestation and the primary forests today cover only 2.6 percent of the country.

The country has been experiencing ethnic conflict for the last three decades. This internal civil war has also slowed down the economic growth. With an economy of $ 27 billion, and a per capita GNI (PPP) of about $ 3,840, Sri Lanka has been experiencing positive growth rates in recent years. The main economic sectors of the country are tourism, tea export, apparel, textile, rice and other agricultural products. In addition to these economic sectors overseas employment contributes highly in foreign exchange, most of them from middle-east. The service sector contributes about 58 percent of the GDP of the country.

1.25.3 Hazard Profile

Sri Lanka is vulnerable to floods, cyclones, droughts and landslides. These disasters have caused loss of life, and enormous damage and destruction to property. Floods are more common in Sri Lanka than any the other natural hazard. Among the major rivers of the country, Kalani, Gin, Nilwala and Mahaweli are vulnerable to floods. These areas have seen a considerable increase in population as more people live and work here. The Southwest monsoons cause flooding in the districts of Kegalle, Ratnapura, Kalutara, Colombo, Gampaha and Gall, while Northeast rains impact Ampara, Trincomalee, Badulla, Polonnaniwa, Batticaloa, Matale and Monaragala (Fernando, 1999).

As far as Cyclonic hazard is concerned, Sri Lanka has been affected mostly by cyclones developing in the Bay of Bengal. The Eastern, Northern and North Central regions of the country are prone to cyclone and have suffered severe damages. The 1978 cyclone alone affected more than one million people, with about a thousand fatalities, partially and completely damaged nearly 250,000 houses, destroyed 90 percent of the coconut plantation in the Batticaloa district and resulted in Rs. 600 million (local currency) in immediate relief operations (Fernando, 1999).

Droughts are also prominent in Sri Lanka. The drought in 1996 affected 181,095 families in 17 districts and resulted in even interruption to power supply. Droughts with small impact are annual phenomena. Droughts of regional significance do occur once in every 3 to 4 years with severe droughts happening over 10 year period. After the severe drought of 1935-1937, the other significant droughts occurred during the periods 1947-1949, 1953-1956, 1965, 1974-1977, 1981-1983, 1985 and in 1995-1996. Out of all these major droughts, those occurred during the periods 1953-1956, 1974-1977, 1981-1983 and 1995-1996 had caused major setbacks to the economy. Although droughts cannot be classified as sudden disasters, they cause hardship and economic loss mostly to farmers (Fernando, 1999).

During the last two decades the severity of landslides has increased in the mountain slopes of the Central and South Western regions of the Island because of heavy rains, geological changes in the hill country and accentuated by the indiscriminate clearance of steep slopes in the mountainous areas. The landslides of January 1986 and again those of May and June 1989 surpassed all previous landslides in recent memory, on all counts of the extent of damage and personal tragedy (Fernando, 1999). The 1986 January landslide claimed 51 lives, rendered nearly 100 families homeless and affected all the seven landslide-prone districts of the country. The May and June 1989 landslide event claimed more than 300 lives and rendered a large number of families homeless. In October 1993, the landslide at Helauda in Ratnapura district resulted in the loss of 29 lives and destruction of many houses.

Sri Lanka lies in a region with low seismic hazard. Historically, mild earthquakes have been experienced in different parts of the country. Onshore hazard is low but earthquakes in the magnitude range 5 to 6 have occurred in the Gulf of Mannar. Magnitude 7+ events in the Sumatra-Andaman arc and magnitude range 6 earthquakes have originated in the north Indian Ocean (Zhang et al, 1998). Even though earthquake events are not recorded in the historic disaster data, the country is under the influence of the earthquake influenced tsunami. The 2004 Tsunami has severely impacted the country.

1.25.4 Risk Profile

The disaster data for the last 40 years show a decreasing trend in the frequency of disaster occurrence. The country has experienced high frequency of disasters during 1972-76, 1977-81, 1982-86, 1992-96 and 1997-01 (Figure 61). The number of people killed is highest during 1977-81. The total population affected recorded highest during 1982-86. The 2004 Tsunami killed 35,399 people, affected 1,019,306 and incurred a loss of $ 1,316 million (Figure 62). This is one of the major events that impacted Sri Lanka in the recent history. Cyclone events like the one in 1978 have killed large number of people. From the analysis of the total population affected it is seen that drought played a major role leading to vagaries of life of the Sri Lankans. Flood and cyclones are recurring hazards in the country causing significant economic losses (Figure 63).

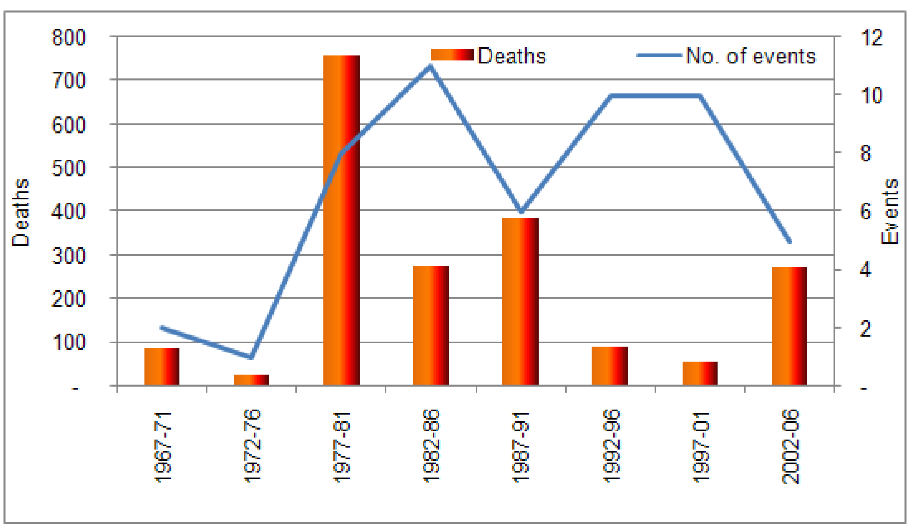


Figure 61 Reported disasters and deaths in Sri Lanka during 1967 - 2006

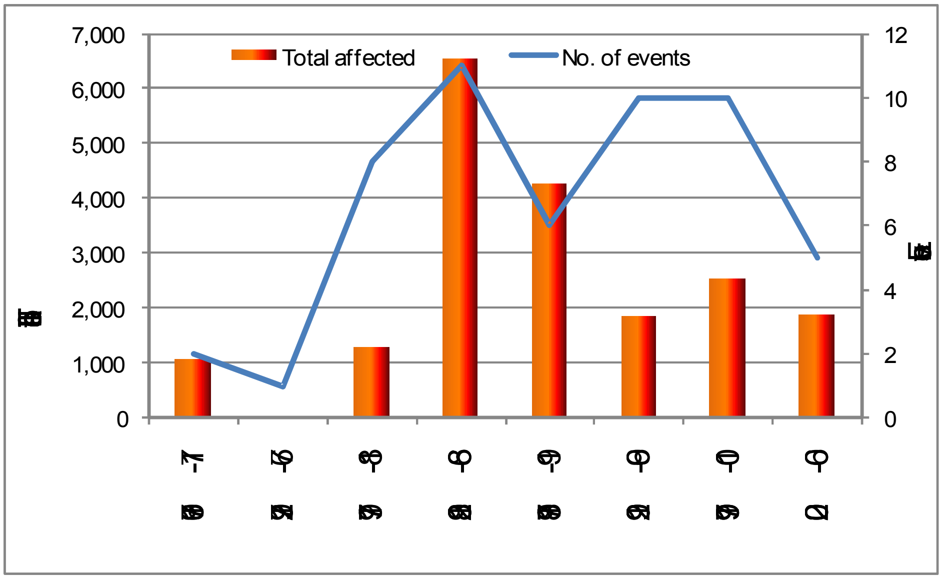


Figure 62 Reported disasters and total affected population in Sri Lanka during 1967 - 2006

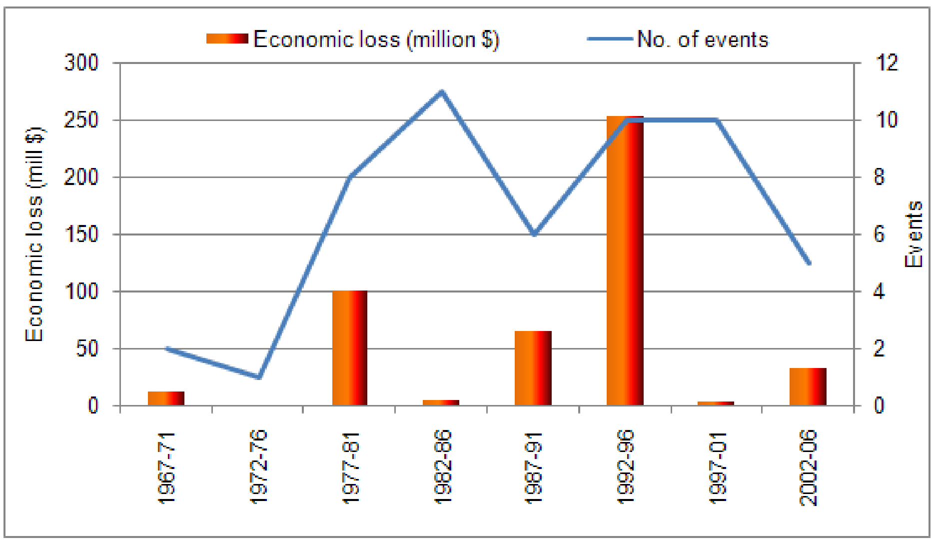


Figure 63 Reported disasters and economic loss in Sri Lanka during 1967 - 2006

Annual average incidence of flood disasters is highest (0.95 events per year) while in terms of number of deaths, floods have killed more number of people (27 persons per year) than cyclones (19 persons per year). The physical exposure is high for flood, drought and cyclone.

The probability of economic losses exceeding $ 275 million in one year is about 0.5 percent. This is about 1 percent of the country's GDP. The probability of annual losses exceeding $ 100 million is about 5 percent.

Priority Areas for Detailed Risk Assessments

Risk mitigation and management activities should be focused on areas where hazard frequency, exposure and vulnerability are high in order to optimize resources to decrease economic losses and casualties. Probabilistic risk analyses provide the necessary tools to make this type of decision. The expected economic loss is quantified in terms of probability of exceedance and AAL, quantities commonly used in the financial and political arena to guide decisions. The usefulness of mitigation plans can be tested in these analyses in terms of economic loss reduction and provide the input for cost-benefit analyses. Advanced probabilistic analyses go beyond economic loss and address the social impact of the hazard. The social impact can be measured in terms of number of deaths, injured and total affected and even emergency response requirements. In possession of economic and social impact estimates, decision makers have the proper tools to identify optimum solutions.

Short of having this type of information, this analysis attempts to identify priority areas for investigation based on the data gathered.

1.26 Selection of Indicators to Define Priority Areas

World Bank Natural Disaster Hotspot Study used multi-hazard index to identify disaster hotspots (Dilley et al., 2005). The study considered hazard frequency, economic loss and mortality to identify natural disaster hotspots. The analysis was performed at the grid level for the whole world resulting in each grid being assigned a risk index. The approach followed in this report is less quantitative as the data event and loss data was gathered at the country level and not discretized within a country.

In detailed risk analyses, the vulnerability is usually disaggregated into loss to buildings and infrastructure, business interruption loss and social impact quantified in terms of number of deaths and total affected. In this analysis, a rapid assessment approach was followed where a simple proxy is used to quantify the vulnerability. The selected proxy was the population at risk. This assumption is robust first because most of the buildings and the infrastructure are concentrated in populated areas and second because the population itself is quite vulnerable to the hazard. It could be argued that an increase in population is not directly correlated to an increase in vulnerability because the resilience of the population can be increased through awareness and better planning process. However, in general it is observed that fast development growth in most of the developing countries increases population growth, intensifies economic activities and increases vulnerability to natural hazards. This holds true for SAR countries.

The hazards considered are earthquakes, flood, drought, landslide, cyclone and volcano. For a disaster to be considered as critical, it must be relatively frequent, impact a large area and be potentially extremely destructive. In SAR, this eliminates landslide, volcano and the wind component of cyclone. The data gathered confirm that the losses from these events have been minimal over the last 40 years. Landslides have a limited geographical impact even though quite deadly, volcanic eruptions could have extreme consequences but do not appear probable and the wind component of cyclones generate little damage as compared their water component. Drought is a slow onset disaster, even though its consequences may be severe and impact millions of people, the setting of the event provides sufficient time to respond to the disaster and limit its impact. Flood, either generated by monsoon rain or typhoon rain, do give some warning of their imminent approach, except maybe for some types of flash floods. Unfortunately, in SAR the warnings are not taken seriously, not disseminated at times sufficient enough to respond or the affected people do not have the means or capability to evacuate quickly to minimize the number of fatalities. Flood is thus considered as a rapid onset hazard even though less sudden than earthquake. Flood and earthquake are therefore the two remaining hazards considered for further investigation. Losses recorded for the last 40 years indicate also that these two hazards are the most devastating in SAR.

The earthquake hazard is clearly identified in Figure 10. The most active region is located along the Himalayas arc from northern Bangladesh to beyond Kabul (Afghanistan) and additional regions of high seismicity in Afghanistan and Pakistan. Northern India is in a region of moderate to high seismicity that included New Delhi (India).

The flood prone areas are well defined (Figure 13 and Table 5). The analysis shows that about 70 percent area of Bangladesh falls in the extreme flood mortality risk category. The Himalayas, its foot hills and coastal cities are also highly prone to flood and almost 20 percent area of India falls in the extreme flood mortality risk category. Thus, in terms of percentage of the geographical area of the country in the extreme flood zone, Bangladesh ranks first followed by India, Sri Lanka, Nepal, Pakistan, Bhutan, and Afghanistan. In terms of population under extreme flood mortality, Bangladesh ranks first followed by India, Nepal, Afghanistan, Bhutan, Sri Lanka, and Pakistan. The sparsely/uninhabited areas of Pakistan and Afghanistan, the central and northern portions of India and central portion of Sri Lanka are the only areas spared from endemic flooding. Regarding the flood mortality risk in Bangladesh and India, the CRED EM-DAT database also supports the above conclusions. Out of 400 flood events that occurred in SAR during the period 1967 – 2006, 163 events were located in India and 70 in Bangladesh. It may be noted, that the geographical extent of India is very large when compared to that of Bangladesh.

The reader should keep in mind the limitations of the above analyses as these have been extracted from a global analysis, wherein mortality risk maps have been prepared depending upon availability of data for each country.

The areas highly vulnerable to rainfall floods are the flood plains of the three major rivers, the Indus, the Ganges and the Brahmaputra. The areas highly vulnerable to cyclone-generated rains are the low-lying area along the eastern India and Bangladesh. For cyclone prone area, a good measure of the hazard is the area of land with an elevation less than 10 m because these areas are vulnerable to storm surge as well as cyclone generated flood. Table 17 gives the population by country living in those areas.

1.27 Population at Risk

In the last few years, there has been a tendency to focus on risk to mega-cities, mega-cities being defined as cities having a population of 10 million or more. Such an approach takes the position of looking at worst-case scenarios. Clearly, the consequences of some of these scenarios would be catastrophic both in terms of human losses and devastation, economic losses and national impact. If the Kashmir (POK) 2005 earthquake has occurred right under Islamabad, the impact would have been much greater than observed, if the Orissa (India) 1999 "super cyclone" had made landfall right on Kolkata (India), the damage would have been much larger. Worst case events do happen: the shallow Kobe (Japan) 1995 earthquake occurred right under the city. However, in SAR, in the last 40 years, no mega-city has been directly impacted by a major disaster and still the total number of fatalities has reached 0.8 million and the economic loss $ 80 billion. If the losses from the last 20 years are extrapolated to 40 years, the number of fatalities remains about the same (0.8 million) but the economic loss increases to $ 140 billion (Figure 5).

In the next sections, a high-level comparison is made between the risk in the mega-cities and in the remainder of the population.

1.27.1 Mega-Cities

Mega-cities are not only a conglomeration of intense economic activities but also are areas of high population densities and ongoing constant migration of the working class in search of livelihood. The migration of working class population in mega-cities often lead to sprouting up of slums which are risk prone structures in ecologically fragile area. This has lead to a phenomenal growth of population in the mega-cities especially in the low-income countries. According to Brockerhoff (2000), just 25 years ago, less than 2 percent of the global population resided in "mega-cities" of 10 million or more inhabitants. Today the proportion exceeds 4 percent, and by 2015 it will cross 5 percent, when mega-cities will likely house 400 million people (Sherbinin et al, 2008). As it happens, these locations place global cities at greater risk from current and projected climate hazards and natural hazards such as cyclones, flooding, coastal erosion and deposition, and sea-level rise. The Centre for Research on the Epidemiology of Disasters (CRED) has observed that the climate related disasters are increasing well above all geological hazards (CRED, 2005). As per the CRED (2005) report, severity and periodicity of hazards events have increased. The problem is accentuated due to the drastic growth in population in the risk prone areas as well as increased severity and periodicity of hazard. This combination of increased hazards and exposure will result in greater number of disasters that claim lives and cause major economic losses. Five mega-cities are located in SAR. Table 14 shows the population growth in mega-cities in SAR countries. The trends in growth are well captured in Figure 64.

Table 14 Population growth in SAR mega-cities (1950 - 2015)

Country	City	Year (population in millions)			
		1950	1980	2000	2015
Bangladesh	Dhaka	0.417	3.257	10.159	17.907
India	Kolkata	4.446	9.03	13.058	16.798
	Delhi	1.39	5.558	12.441	20.946
	Mumbai	2.981	8.695	16.086	22.645
Pakistan	Karachi	1.028	5.048	10.032	16.155

Source: UN 2004

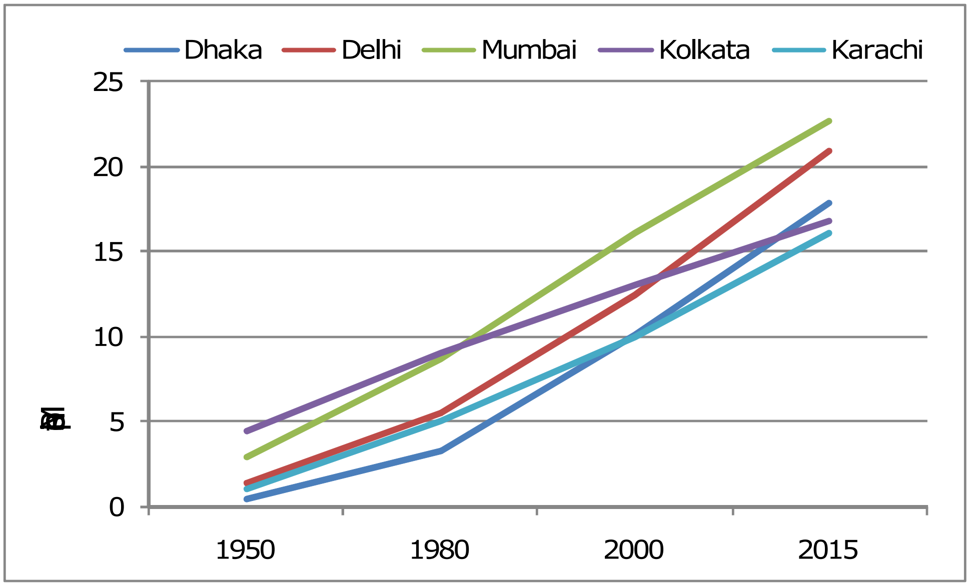


Figure 64 Population growth in SAR mega-cities (1950 - 2015)

All the mega-cities are vulnerable to earthquake and flood. Dhaka, Kolkata and Karachi are also vulnerable to cyclone. A high-level risk assessment attempt is made after giving a short description of the hazards the mega-cities are vulnerable to. The level of hazard in the cities is ranked based on the maps presented in the previous sections. Zone 3 corresponds to a high hazard, zone 2 to moderate hazard and zone 1 to low hazard.

Dhaka city lies in a seismic area and earthquakes of intensity of VIII of the Modified Mercalli Scale (MMI) are possible. As Dhaka city is located in the deltaic region, flood due to heavy rain, ice melt in the Himalayas as well as storm surge and flash flood due the cyclonic activities are frequent. As Dhaka is located somewhat in land, the impact of cyclones is expected to be lessened. Dhaka lies in earthquake zone 2, flood zone 3 and cyclone zone 2.

Kolkata city has a hazard profile similar to that of Dhaka city due to its proximity and other geographic characteristics. The floods in the city are due to heavy rainfall and tidal upsurge leading to flooding of low-lying areas of Garden Reach, Tollygunge and Khidderpore. However it is less prone to flooding than Dhaka. Being closer to the coast, it is more vulnerable to cyclone. Devastating cyclone history records are traced back to 1737, 1842, 1864, and 1867. Kolkata lies in earthquake zone 2, flood zone 2 and cyclone zone 3.

The Delhi region can be affected by moderate local earthquakes and large earthquakes occurring in the Himalaya belt. Due to Yamuna River (flows on the eastern part of city) and Najafgarh drains, Delhi experienced floods of moderate magnitudes. According to the Central Water Commission statistics, Yamuna River has crossed its danger level 25 times during the last 33 years. Some of the recent historic flood includes 1976, 1978, 1988 and 1995 flood. The location of city is too remote to be impacted by cyclones. New Delhi lies in earthquake zone 2, flood zone 1 and cyclone zone 0.

Mumbai, the second populous city of the world, is the commercial capital of India. The city has very high population density as well as intense economic activities. The demand for land pushed development activities into unfavorable areas prone to flood. The 2005 flood was one of the devastating one occurred in the recent past. Small to moderate earthquakes have occurred in the Mumbai area. The city lies in earthquake zone 2, flood zone 2 and cyclone zone 0.

Karachi located in the delta of the Indus is vulnerable to flood and cyclone. The floods are due to heavy rain as well as storm surge due to cyclonic activities off the coast of Karachi. The 2001 flood has caused heavy loss to the city. The city is also vulnerable to earthquake. Karachi lies in earthquake zone 2, flood zone 3 and cyclone zone 2.

Table 15 City level hazard matrix

City	Hazards Level			Population (million)	Impacted population weight	
	Earthquake	Flood	Cyclone	2008 (estimate)	Earthquake	Flood/Cyclone
Dhaka	2	3	2	14.0	1.0	0.5
Kolkata	2	2	3	14.9	1.1	0.5
Delhi	2	1		16.7	1.2	0.6
Mumbai	1	2		19.4	1.4	0.7
Karachi	2	3	2	13.1	0.9	0.5

The hazard levels for the five cities have been summarized in Table 15. This table also presents an impacted population weight. The weight is proportional to the city population normalized to the Dhaka population and is therefore a normalized measure of the exposure. To determine the risk, the population impacted by the hazard must then be estimated. In this simplified risk assessment, the assumption is made that the total population of the city could be affected by an earthquake while only half of it (as an upper limit) could be affected by a flood or flood generated cyclone. Variations in these high level estimates, do not affect the cities risk ranking within a single hazard, but can the impact the ranking of one hazard versus another. A risk index is derived by multiplying the hazard level by the impacted population weight for the hazard considered; the multi hazard risk index is obtained by adding the individual risk indices. The risk ranking for the five cities is given in Table 16.

For earthquake, New Delhi comes on top of the list followed by Kolkata and Dhaka; for flood and cyclone Kolkata ranks first followed by Dhaka and Karachi, for all hazards combined Kolkata ranks first followed by Dhaka and Karachi.

Table 16 City level risk ranking matrix

City		Risk Ranking	
	Earthquake	Flood/Cyclone	All hazards
Dhaka	2.0	2.5	4.5
Kolkata	2.1	2.7	4.8
Delhi	2.4	0.6	3.0
Mumbai	1.4	1.4	2.8
Karachi	1.9	2.3	4.2

1.27.2 Population outside mega-cities

The five mega-cities of SAR have a combined population of 80 million out of a total population of 1.5 billion for SAR. On a year-to-year basis, it is clearly the rest of the population that is being impacted by most of the hazards. A significant portion of the SAR population is exposed to hazards: more than 10 percent of the population is exposed to high earthquake hazard and close to half of the population is exposed to high flood hazard.

Coastal areas are the one of the most densely populated regions of the world. In a recent study (Gordon 2007), the land area with elevation less than 10 m from mean sea level covers 2 per cent of the world's land but contains 10 percent of the world's population and 13 percent of the world's urban population. This statistics hold true for SAR countries and some of the mega-cities of the world are located in the coastal areas in SAR; Mumbai, Kolkata, Dhaka and Karachi.

Table 17 Population within the Low Elevation Coastal Zone (lecz) in SAR countries

	Population within coastal zone of elevation < 10 m			
Country	Urban population	% urban population	Total population	% total population
Afghanistan	-	-	-	-
Bangladesh	15,428,668	41.38	62,524,048	40.08
Bhutan	-	-	-	-
India	31,515,286	10.11	63,188,208	5.69
Maldives	6,421	10.74	290,923	96.88
Nepal	-	-	-	-
Pakistan	2,227,119	4.16	4,157,046	2.61
Sri Lanka	961,977	15.66	2,231,097	11.22

Source: Center for International Earth Science Information Network (CIESIN), Columbia University. Low Elevation Coastal Zone (LECZ) Urban-Rural Estimates, Global Rural-Urban Mapping Project (GRUMP), Alpha Version. http://sedac.ciesin.columbia.edu/gpw/lecz.

Between 1990 and 2000, the population in the 0-10 m zones of Bangladesh has grown at more than twice the national population growth rate. presented below is extracted from the low elevation coastal zone data (lecz) created by the Center for International Earth Science Information Network (CIESIN), Columbia University and for SAR gives the percentage population and urban population lying within the 10 m lecz.

A very simple quantification of the risk is presented to assess the risk of the population living outside mega-cities. This is in line with the risk ranking of the mega-cities. The analysis has been performed for earthquake and flood and the results are presented in Table 18 and Table 19.

The hazard zones considered are high and very high for earthquakes and high for flood (flood only has three zones of hazard). From the hazard maps, the total population and total area at risk are estimated (**Table 18**, col. 2 and 3). Within these areas, the simplifying assumption is made that the hazard and the population are uniformly distributed. The population density is given in column 4. Column 5 assumes an area of impact for the hazard (30,000 sq km for a large earthquake) and the impacted population (col. 6). The results are independent of this assumption as it cancels out when column 7 is calculated. The chance for an event to occur at a specific location ("rate" col. 7) is the inverse of the total exposed area divided by the impacted area, for simplicity it is assumed that events cannot overlap. The expected population impacted in a mega-city is equal to "rate" time the mega-city population (col. 8). The expected population impacted outside a mega-city is equal to (1 -"rate") times the population impacted by the event (col. 9). Column 11 presents the ratios of expected affected populations. For earthquake, the expected population affected outside a mega-city is greater than inside the city by a factor of at least 1.4 and for flood by a factor of at least 3.5.

This simple analysis indicate that even though an event, particularly an earthquake, would be devastating if it were to occur within a mega-city, given the population distribution, the expected affected population outside a mega-city by similar events is still larger. In order to provide a more reliable picture of the risk, this analysis should be refined further using high-resolution grids rather than countrywide estimates to the hazard and affected population.

Table 18 Earthquake risk to population outside mega-cities in SAR

Earthquake zone high and very high											
1	2	3	4	5	6	7	8	9	10	11	12
Country	Exposed population	Exposed area (sq km)	Population density (sq km)	Area impacted by earthquake (200x150) sq km	Expected population affected by one occurrence	Chance for an earthquake to occur in any location ("rate")	Expected population affected outside a mega-city	Expected population affected witihin a mega-city	Mega-city population	Ratio of expected affected populations	Mega-city
Afghanistan	15,820,976	243,830	65	30,000	1,946,559	0.12	1,946,559				
Bangladesh	45,357,036	66,145	686	30,000	20,571,527	0.45	11,241,382	6,349,652	14,000,000	1.8	Dhaka
India	84,929,801	527,289	161	30,000	4,832,064	0.06	4,557,145	950,143	16,700,000	4.8	New Delhi
Nepal	24,818,944	136,459	182	30,000	5,456,371	0.22	5,456,371				
Pakistan	22,592,412	148,912	152	30,000	4,551,508	0.20	3,634,553	2,639,149	13,100,000	1.4	Karachi

Table 19 Flood risk to population outside mega-cities in SAR

Flood zone high											
1	2	3	4	5	6	7	8	9	10	11	12
Country	Exposed population	Exposed area (sq km	Population density (sq km)	Area impacted by flood (100x40) sq km	Expected population affected by one occurrence	Chance for an flood to occur in any location ("rate")	Expected population affected outside a mega city	Expected population affected witihin a mega-city	Mega-city population	Ratio of expected affected populations	Mega-city
Bangladesh	137,865,552	135,004	1,021	4,000	4,084,789	0.03	3,963,762	414,803	14,000,000	9.6	Dhaka
India	548,307,008	1,109,860	494	4,000	1,976,130	0.00	1,969,008	69,919	19,400,000	28.2	Mumbai
Pakistan	48,515,036	69,901	694	4,000	2,776,212	0.06	2,617,347	749,631	13,100,000	3.5	Karachi

Summary and Recommendations

1.28 Summary

South Asia Region is highly vulnerable to earthquake, flood, landslide, drought and cyclone. During the last 40 years (1967 – 2006), the reported 784 disasters have caused 0.80 million deaths. Out of the reported disasters, 50 percent were floods and 25 percent cyclones. Cyclones however were the cause of about 0.5 million deaths. Flood and drought affected the largest number of people (2 billion). The total economic loss was about $ 80 billion with flood alone causing about $ 49 billion loss. The number of deaths and economic losses due to earthquakes are also very significant in the region (196,400 deaths and $ 11.6 billion loss). About half of the population is exposed to high flood hazard and more than 10 percent of the population is exposed to high earthquake hazard. This indicates that, in addition of being severe, the hazards are geographically wide spread making any mitigation action unwieldy.

Afghanistan is highly vulnerable to flood and earthquake. The number of disasters related to flood are very high (47 out of 87; 54 percent) as compared to 27 (31 percent) for earthquake. Earthquake, however, caused more deaths (9,300) than flood (3,100). Flood contribute to the largest economic loss ($ 376 million) followed by earthquake ($ 183 million).

Bangladesh is highly prone to flood and cyclone. The number of disasters related to cyclone is very high (100 out of 182; 55 percent) as compared to flood (70; 38 percent). Cyclone caused more deaths (0.47 million) than flood (0.04 million). Flood affected the largest population and is the main contributor to loss (0.29 billion people and $ 12 billion respectively). Cyclone also contributes to significant economic losses of the order of $ 2.9 billion.

Bhutan is highly vulnerable from earthquake, flood and landslide. Insufficient data are available over the last 40 years to summarize deaths and economic losses.

India is highly vulnerable to flood, earthquake and cyclone. In terms of geographic area, India is larger than all the other SAR countries put together. For the same reason, the population affected as well as the occurrence of disasters and their impacts are high in the country. There were 162 floods (52 percent) and 73 cyclones (23 percent) out of 313 disaster events reported during the last 40 years. Earthquake caused the largest number of deaths (106,900) followed by flood (52,300). The economic loss due to flood was $ 33.3 billion followed by earthquake ($ 5.3 billion). Total number of population affected by drought is the largest (961 million) followed by flood (730 million).

Maldives is highly vulnerable to tsunami, cyclone, storm surge and sea level rise. The southern and eastern portions of the island are highly vulnerable compared to the rest of the country because of its low elevation. Due to the size and elevation of the country, Maldives would be highly vulnerable to the expected sea level rise due to climate change.

Nepal is highly vulnerable to flood, earthquake and landslide. Flood are most common (28; 54 percent) followed by landslides (14; 27 percent) out of the 52 reported disasters. Flood caused the highest number of deaths (5,400) and economic losses ($ 975 million) although drought affected more population (4.6 million). Damaging earthquakes have been reported in the past and the country is highly vulnerable to earthquake.

Pakistan is highly vulnerable to earthquake, flood, and cyclone. Flood are most common (48; 51 percent) followed by earthquake (27; 29 percent) out of 94 reported disaster events. Earthquake caused the larger number of deaths (78,800) and the largest economic loss ($ 5.3 billion). Flood affected the largest population (41.8 million).

Sri Lanka is highly vulnerable to flood, drought and cyclone. The total number of flood disaster events reported during the 40 years is 38 (72 percent) with 1,090 deaths. Flood affected the population most (9.7 million people) followed by drought and cyclone (8.2 million and 1.38 million respectively). Flood contributes most to the economic loss ($ 370 million).

Global Circulation Models addressing climate change do not present a uniform view of the impact of climate change on SAR as they have limited capability to forecast the present meteorological patterns. A high resolution climate change model of the region appears to be more stable and predicts a temperature increase of 3 to 4^{0}C over the next 80 years and a significant increase in rainfall in the eastern part of SAR.

Developing countries are especially vulnerable to climate change because of their geographic exposure, low incomes, and greater reliance on climate sensitive sectors such as agriculture. The cost of climate change in India and South East Asia could be as high as a 9-13% loss in GDP by 2100 compared with what could have been achieved in a world without climate change. Up to an additional 145-220 million people could be living on less than $2 a day and there could be an additional 165,000 to 250,000 child deaths per year in South Asia and sub-Saharan Africa by 2100, due to income loss alone. (Stern Review, 2007).

Social vulnerability was analyzed using mortality data from past disasters. The relative SV analysis shows that Bangladesh ranks first followed by Pakistan, Afghanistan, Nepal, India, and Sri Lanka. Due to paucity of data, relative SV of Bhutan and Maldives could not be assessed.

Economic vulnerability (EV) of a country can be measured in terms of likelihood of the economic losses resulting from the various disasters. When expressing the relative economic vulnerability in terms of economic loss corresponding to 0.5 percent probability of exceedance (corresponds to 200 year return period) as a function of the GDP, Nepal ranks first followed by Bangladesh, Afghanistan, Pakistan, India, and Sri Lanka. Due to paucity of economic loss disaster data, the analysis could not be carried out for Bhutan and Maldives.

Dhaka, Kolkata, Delhi, Mumbai, and Karachi are the five mega-cities in SAR with a total population of about 80 million. These cities are experiencing high population growth and intense economic activities. All the mega-cities are highly vulnerable to earthquake and flood. Dhaka, Kolkata and Karachi are also vulnerable to cyclone and storm surge. In a simple risk assessment taking into account the mega-city hazard zonation and population, Delhi ranks first for earthquake risk followed by Kolkata and Dhaka; for flood and cyclone Kolkata ranks first followed by Dhaka and Karachi, for all hazards combined Kolkata ranks first followed by Dhaka and Karachi. Besides mega-cities, highly populated low elevation coastal areas, highly vulnerable to floods and cyclone, present a significant risk.

1.29 Recommendations

Based on the analyses carried out in this study, the following recommendations are presented to reduce disaster risks in SAR.

1.29.1 Additional Analyses

Three levels of analyses are envisioned to refine the result presented in the report. These analyses should first focus on flood (either monsoon or cyclone generated) and earthquake as they are the most damaging quick-onset disasters.

Level 1: An analysis similar to this one based only on historical records should be repeated at a higher level of resolution. Instead of limiting the resolution of the analysis at the country level, a high resolution grid should be considered, 100 km grid for example. Risk aggregation by hazard type and area would provide, at low cost, a much more refined picture of the risk than the present analysis.

Level 2: As a second step, using the same methodology, worst case scenarios should be run for the mega-cities. This simple analysis would provide a reasonable quantification of the loss given the occurrence of a scenario. The uncertainty around the risk could then be bracketed by scientifically estimating the range of probability of occurrence of such scenarios.

Level 3: As a third step, fully probabilistic analyses containing all the elements of standard risk analysis should be performed for the hazards and regions identified as high risk in step 1 and 2.

Drought hazard should be addressed in the context of climate change. Being a slow onset hazard, response is readily available in the near term. Only long-term adaptation strategies should be considered.

1.29.1 Response to Disaster

Considering the trans-boundary nature of hazards in SAR, a coordinated approach among countries towards disaster response is required. The terrain characteristics of Himalayan Mountains, for example, demands that planned and coordinated response programs be in place for rescue and support operations. Nodal organizations such as SAARC can play a key role in coordination among SAR countries to reduce trans-boundary hazards.

1.29.2 Centralized Database

Any analysis or program gains from having access to high quality data. Data gathering particularly hydro-meteorological data should be centralized and coordinated not only within countries but also among countries. The presence of many trans-boundary rivers whose flow or dam management has direct impact on neighboring countries makes the coordination even more imperative.

Except for earthquake, all major hazards provide some warning time before they strike. Simple measures such as public education and warning could significantly reduce the number of deaths. Implementation of flood early warning systems not only within a country, but also across boundaries has the potential of reducing the social impact of the disaster.

1.29.3 Ensuring participation and Institutional strengthening

Regional cooperation and institutional strengthening are crucial for developing strategies towards hazards of trans-boundary nature. Institutional strengthening should be carried out in a coordinated approach under common framework and be implemented in a decentralized manner.

To ensure participation of all stakeholders, hazard management strategies must be judiciously selected considering the local and regional situational factors as well as the developmental needs of the region. Considering the terrain characteristics and size of the nations, different strategies need to be blended with the development planning process towards disaster risk reduction at country and regional levels.

1.29.4 Improvement in disaster risk assessment

Many of the SAR countries have district level disaster management plans in place. These plans should be refined as they often lack the details necessary to reflect ground realities.

They should be based on the level 2 or level 3 types of analyses recommended in section 6.2.1, reflecting realistic scenarios and associated responses. In addition, the disaster risk management plans should be integrated into local development plans. Such plans should further be assimilated within regional and national programs.

Disaster risk management activities should be carried out within a common framework that, if required, could be integrated at the national level or across boundaries.

1.29.5 Coordinated approach

Presently disaster response activities of most SAR countries are coordinated under institutions such as SAARC. ADRC is coordinating at a higher level with more countries party to it. The coordination, capacity and efficiency of these types of networks should be improved and their focus expanded to address disaster risk reduction. Human and financial resource augmentation, skill improvement and infrastructure development are required to achieve such goals. These efforts should be carried out with the participation of all the SAR countries to ensure future sustainable use of the networks.

1.29.6 Poverty alleviation and awareness generation

Poverty significantly exacerbates the impact of hazards both on the human and economic levels. Poverty usually implies that constructions are inadequate to resist earthquake resulting both in large numbers of casualties and devastating damages. Poverty is also associated with inadequate land use planning to avoid the impact of flood resulting in massive flood devastation. Finally poverty is connected to a lack of preemptive response to local hazards either because the authorities do not have the appropriate information to warn the population of the imminence of the hazard or because of the unwillingness or incapability of the locals to evacuate and leave behind their land and livelihood. Poverty reduction is indeed an issue with much broader ramifications than hazard response that is clearly outside the scope of this study, but increased awareness to the hazards can be handled at a local level with limited resources and direct results. The level of awareness to the danger of tsunami has increased significantly throughout the world after the December 26, 2004 tsunami. Continuous efforts should be made to increase the awareness of populations to less damaging but more frequent events to take some simple and effective steps to mitigate their impact. Storm surge can be handled well by using simple measures such as providing biological shield using mangrove plantation.

Annexure 1

1.30 Risk Assessment Methodology

An objective basis for decision making about risk management should include a quantitative assessment of the size and likelihood of the occurrence of different hazards present in the country, based on historical data. Such a basis help in planning risk mitigation strategy and convince stake holders of the need to invest in risk mitigation measures. The method of quantitative economic risk assessment used here is in accordance with the World Bank publication (Pusch, 2004) 'Preventable Losses: Saving Lives and Property through Hazard Risk Management, A Comprehensive Risk Management Framework for Europe and Central Asia, Working Paper series no. 9' and reveals the level of risk in each country and the probabilities of loss exceedance as a function of the level of economic loss.

1.30.1 Determining Risk

The method of quantitative risk assessment is presented in Figure 65. The objective of the risk assessment is to determine the probability that aggregate economic losses over one year period exceed a given amount. This probability is presented as a function of the level of loss and the curve generated is called the loss exceedance curve.

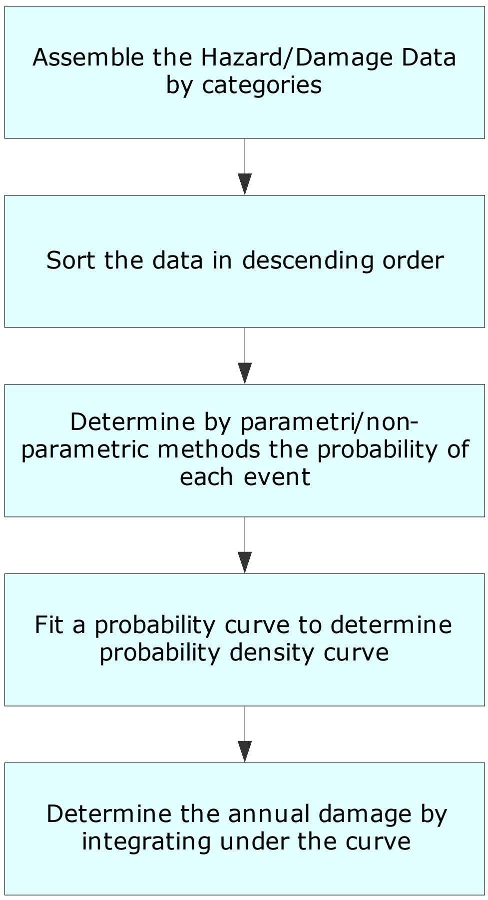


Figure 65 Quantitative risk assessment methodology (based on Pusch, 2004)

As explained in Pusch (2004), several methods can be used to generate the loss exceedance curve. The method that is used in this report is as follows.

The economic loss data is tabulated against its year of occurrence. In case of the reported event where no loss is given, a very small value of loss is considered. This is done in order to account for the missing loss data to some extent and maintain the occurrence of the events in the analysis. If each year is associated with a rank i (where i = 1 signifies the year of most severe losses, i = 2 the second most severe, and so on), then the year of lowest losses receives a rank i equal to the number of years over which there is a record, n. The Weibull's equation generally accepted to provide the best "fit" for disaster events caused by natural hazard was used to calculated the recurrence interval r (and its inverse, the probability of occurrence p) as a function of i:

$$r = (n+1)/i \text{ and}$$

$$p = i/(n+1).$$

Empirical distribution of economic losses is plotted against the recurrence interval. A typical distribution curve looks like the one presented in the Figure 66. Probability distributions are tested for their suitability for the estimation of losses for various return periods. Candidate distributions considered in this analysis are 2 Parameter Log Normal, 3 Parameter Log Normal, Gumbel and Pearson Type III. By looking at the best fit distribution and other three distributions fitted values, a weighted average has been calculated to arrive at the return period losses.

Return period losses for 0.5 percent, 5 percent and 20 percent of annual exceedance probability were calculated. An AAL is determined as the sum of loss of each event (L_i) multiplied by their rate of occurrence (p_i) (Grossi et al., 2005).

$$AAL=\sum p_i L_i$$

A best-fit relationship for these data points is obtained using standard analytical methods.

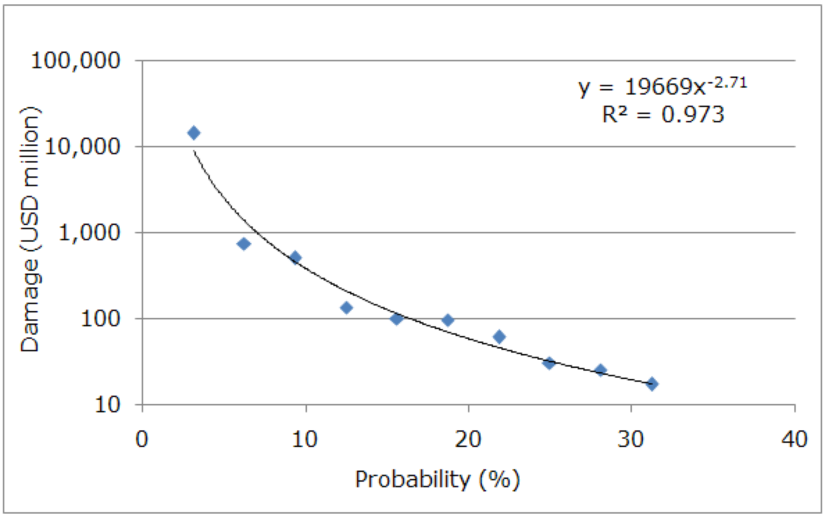


Figure 66 Sample distribution of the probability of damage levels: Earthquake damage versus probability of occurrence (based on Pusch, 2004)

1.30.2 Limitations of the Methodology

The simplified quantitative risk assessment conducted for this study is based on historical economic loss data reported in different data sources such as CRED EM-DAT, World Bank, UN, Dartmouth, DesInventar, NGDC, ADRC, ESCAP and National level data. They illustrate the magnitude of the problems and the broad strategic direction. The economic loss data used for the analysis for all hazards is limited to 40 years. This time span is considered taking into consideration of accuracy and completeness of the data for those years. The accuracy and completeness of the data issue are a particular challenge in SAR because of reporting issues of economic loss figures. Prior to 1970's, the economic loss data documented are often not complete and inferior in quality.

High priority areas for detailed risk modeling and assessment were identified based on identified indicators. For such detailed risk assessment, exposure data (building and infrastructure) need to be collected and analyzed. It also needs simulation modeling of historical events using present asset data to access risk from an event of a given intensity at a specific location (scenario analysis).

The economic loss probability estimates presented in this report are not intended for designing catastrophe insurance schemes, which require a more detailed approach- that model hazards, exposure and vulnerability of the buildings and infrastructure.

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http://www.undp.org/bcpr
http://www.gri-p.net/grip.php?ido=1000 (Global Risk Identification Program)
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