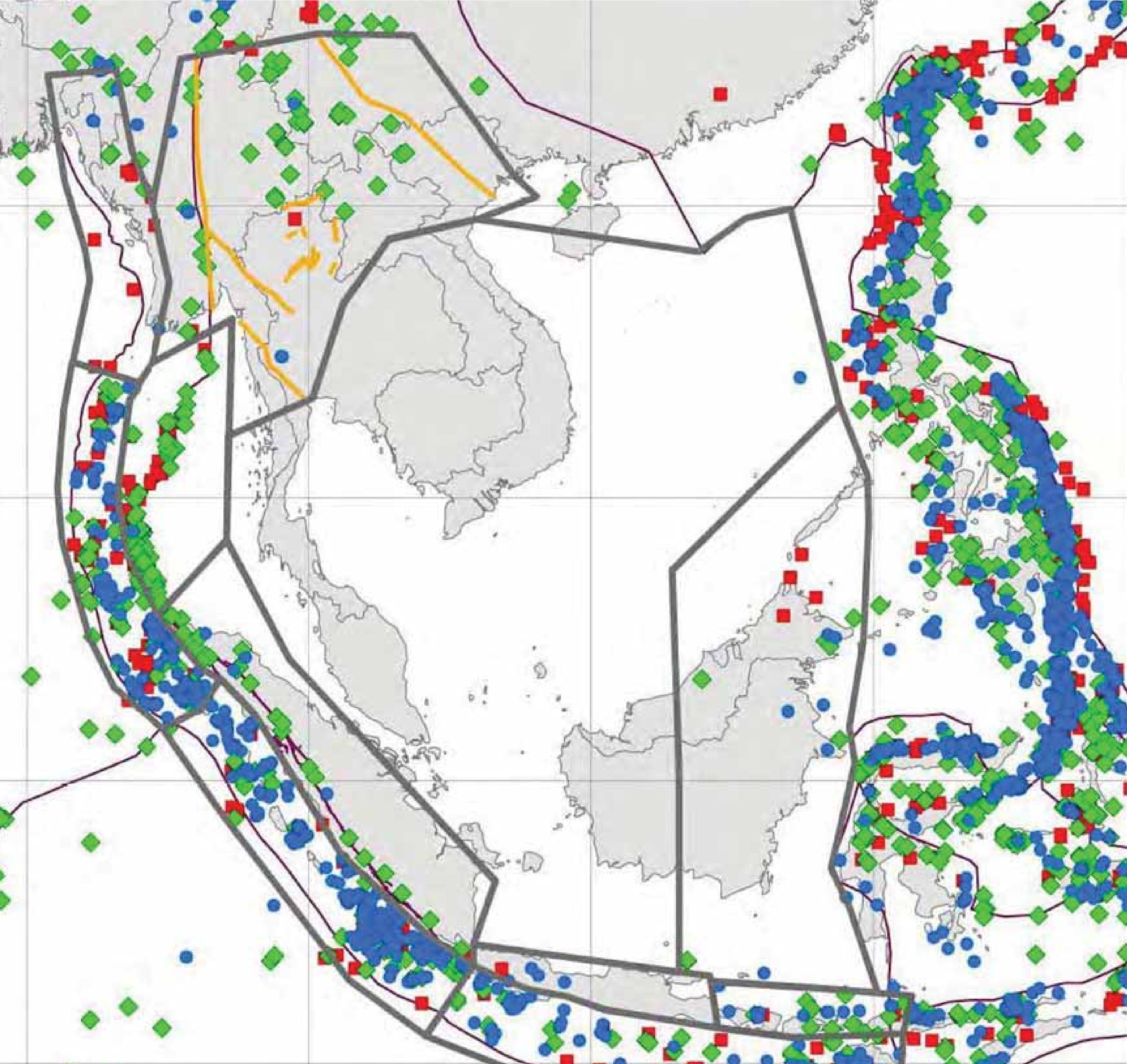

Synthesis Report on Ten ASEAN Countries Disaster Risks Assessment

ASEAN Disaster Risk Management Initiative

December 2010

Preface

The countries of the Association of Southeast Asian Nations (ASEAN), which comprises Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam, is geographically located in one of the most disaster prone regions of the world. The ASEAN region sits between several tectonic plates causing earthquakes, volcanic eruptions and tsunamis. The region is also located in between two great oceans namely the Pacific and the Indian oceans causing seasonal typhoons and in some areas, tsunamis. The countries of the region have a history of devastating disasters that have caused economic and human losses across the region. Almost all types of natural hazards are present, including typhoons (strong tropical cyclones), floods, earthquakes, tsunamis, volcanic eruptions, landslides, forest-fires, and epidemics that threaten life and property, and droughts that leave serious lingering effects.

Typhoons are the most prevalent hazard in the region, causing destruction to human life, buildings, agriculture and infrastructure alike, while causing flooding and landslides/mudslides. The region provides compelling evidence of the destructive power of such disasters. For example, the recent tropical cyclone Nargis of May 2008 in Myanmar killed over 133 thousand people, affected over 2.4 million people and caused an estimated economic loss of over $ 4 billion. Over 600 thousand hectares of agriculture land was flooded, killing about 50 per cent of the draught animals. In the same year, on June 21, 2008, Typhoon Fenghsen in the Philippines killed 573 and affected at least 4 million people in just four hours. In October 2009, cyclone Pepang (Parma) in the Philippines killed 539 people, affected 4.5 million and caused an estimated economic loss of $592 million.

Some of the major disasters of recent times in the region are: the December 26, 2004 Indian Ocean tsunami, September 16, 1990 Luzon earthquake (Philippines), May 26, 2006 Yogyakarta earthquake (Indonesia), June 1991 volcanic eruption of Mount Pinatubo (Philippines), 2005 (Thailand), and 1997 (Vietnam) droughts, September 2009 cyclone Ketsana (known as Ondoy in the Philippines), catastrophic flood of October 2008, and January 2007 flood (Vietnam), September 1997 forest-fire (Indonesia) and many others. Climate change is expected to exacerbate disasters associated with hydro-meteorological hazards.

Often these disasters transcend national borders and overwhelm the capacities of individual countries to manage them. Most countries in the region have limited financial resources and physical resilience. Furthermore, the level of preparedness and prevention varies from country to country and regional cooperation does not exist to the extent necessary. Because of this high vulnerability and the relatively small size of most of the ASEAN countries, it will be more efficient and economically prudent for the countries to cooperate in the areas of civil protection, and disaster preparedness and prevention.

With the aim of reducing ASEAN's vulnerability to the risk of disasters, the World Bank, United Nations International Strategy for Disaster Reduction (UNISDR), through the Global Facility for Disaster Risk Reduction (GFDRR), and in collaboration with other international partners have started support for implementing the ASEAN Agreement for Disaster Management Emergency Response (AADMER) to promote sustainable development in ASEAN region. The AADMER is a regional legally binding agreement that binds ASEAN Member States together to promote regional cooperation and collaboration in reducing disaster losses and intensifying joint emergency response to disasters in the ASEAN region. AADMER is also ASEAN's affirmation of its commitment to the Hyogo Framework for Action 2005-2015 (HFA). The HFA, endorsed by 168 countries, is coordinated by UNISDR to provide nations and communities the roadmap to disaster-proof the significant development gains.

To support ASEAN, the World Bank, UNISDR and ASEAN secretariat signed a tripartite Memorandum of Cooperation (MoC) on disaster risk reduction (DRR) in 2009. The MoC lays a framework for technical support from the World Bank and UNISDR to help the ASEAN secretariat formulate and implement strategies and action plans for disaster risk reduction and management. The objectives of this program include (i) building ASEAN's capacity in the areas of disaster risk reduction and climate change adaptation; (ii) mobilizing resources for the implementation of DRR initiatives in ASEAN; and (iii) helping ASEAN policy-makers gain knowledge of effective and practical ways to reduce disaster risks.

As part of the work of the tripartite MoC, the objective of this assignment is to develop a synthesis report on ASEAN member states' disaster risks by carrying out a desk review of already available reports, studies, maps, analyses and assessments regarding disaster risks at the country and regional levels. This 'desk review' also analyses trans-boundary disaster risks and their effects; projected losses in the absence of mitigation measures (Average Annual Loss, AAL and economic losses for different probabilities of exceedance), climate change assessment, population growth, economic development, and urban expansion. Disaster Risk assessments for all the countries and the region have been prepared and the review concludes with recommendations on the way forward for ASEAN disaster risk reduction.

Acknowledgments

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Special thanks for the guidance and expertise provided are also extended to: UNISDR and The World Team

This study has been possible thanks to the contributions of several national and regional interlocutors.

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Abbreviations, Acronyms and Symbols

AADMER	ASEAN Agreement on Disaster Management and Emergency
AAL	Average Annual Loss
ACDM	ASEAN Committee on Disaster Management
ADB	Asian Development Bank
ADPC	Asian Disaster Preparedness Center
ADRC	Asian Disaster Reduction Center
ARPDM	ASEAN Regional Programme on Disaster Management
ASC	Asian Seismological Commission
ASEAN	Association of Southeast Asian Nations
BAU	Business-As-Usual
CRED	Centre for Research on the Epidemiology of Disasters
DLNA	Damage, Loss and Needs Assessment
DMP	Disaster Management Plan
DRI	Disaster Risk Index
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
EM-DAT	Emergency Events Database, developed by the Office of US Foreign Disaster Assistance and the Centre for Research on the Epidemiology of Disasters
ENSO	El Niño Southern Oscillation
ERAT	ASEAN Emergency Rapid Assessment Team
ESCAP	Economic and Social Commission for Asia and the Pacific
EU	European Union
EV	Economic Vulnerability
GCM	Global Circulation Model
GDP	Gross Domestic Product
GEF	Global Environment Facility
GFDRR	Global Facility for Disaster Reduction and Recovery
GHG	Greenhouse Gases
GIS	Geographic Information System
GLOF	Glacial Lake Outburst
GNI	Gross National Income
GNP	Gross National Product
GSHAP	Global Seismic Hazard Program
HDA	Human Development Index
HFA	Hyogo Framework for Action 2005-2015
IFRC	International Federation of Red Cross and Red Crescent Societies
IIEES	International Institute of Earthquake Engineering and Seismology
INCEDE	International Center for Disaster-Mitigation Engineering
IMF	International Monetary Fund
ITCZ	Inter-Tropical Convergence Zone
JICA	Japan International Cooperation Agency
MDG	Millennium Development Goals
MDRD	Mainstreaming Disaster Risk Reduction into Development
MoC	Memorandum of Cooperation
MRC	Mekong River Commission
MRI	Meteorological Research Institute
MSL	Mean Sea Level

NGDC	National Geophysical Data Centre
NGI	Norwegian Geotechnical Institute
OFDA	Office of the US Foreign Disaster Assistance
PDNA	Post-Disaster Needs Assessment
PDR	People's Democratic Republic
PGA	Peak Ground Acceleration
PRECIS	Providing Regional Climates for Impact Studies
RCM	Regional Circulation Model
RSV	Relative Social Vulnerability
SDC	Swiss Agency for Development and Cooperation
SIC	Scientific Information Center
SIDA	Swedish International Development Cooperation Agency
SV	Social Vulnerability
TDRM	Total Disaster Risk Management
UN	United Nations
UNDAC	United Nations Disaster Assessment and Coordination
UN DESA	United Nations Department of Economic and Social Affairs
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNEP	United Nations Environmental Programme
UNICEF	United Nations Children's Fund
UNISDR	United Nations International Strategy for Disaster Reduction
UNOCHA	United Nations Office for the Coordination of Humanitarian Affairs
USAID	United States Agency for International Development
WB	World Bank
WMO	World Meteorological Organization
WSSI	World Seismic Safety Initiative

$	US dollar
%	per cent
°C	degree Celsius
cc	cubic centimetre
cm	centimetre
cu m	cubic meter
ha	hectares
kg	kilogram
kg/ha	kilogram per hectare
km	kilometre
km/h	kilometre per hour
m	meter
MW	megawatt
ppm	parts per million
sq km	square kilometre

Executive Summary

1

This synthesis report on ASEAN disaster risks has been prepared by carrying out a desk review of already available reports, studies, maps, analyses and assessments regarding disaster risks at the country and regional levels within the scope of the tripartite Memorandum of Cooperation (MoC) on Disaster Risk Reduction (DRR), between ASEAN Secretariat, the UNISDR and the World Bank. The MoC on DRR is a part of ASEAN Agreement for Disaster Management Emergency Response (AADMER), which is in line with the Hyogo Framework for Action 2005 – 2015 (HFA). The objective of this synthesis report is to carry a simplified quantitative risk assessment to determine the social and economic loss potentials and the likelihood of occurrence of different hazards at country and regional levels.

The review analyses and assesses disaster risk at country and regional levels, focusing on natural hazards such as earthquakes, tropical cyclonic storms (typhoons), floods, landslides, tsunamis, droughts, and forest fires. It analyses transboundary disaster risks (common risks) and their effects, and projected losses in the absence of mitigation measures (Average Annual Loss, AAL and economic losses for different probabilities of exceedance). The review also analyses climate change assessment, economic developments, and urban expansion and rural development in ASEAN countries.

ASEAN consists of the ten following countries - Brunei, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam. It covers a total land area of 4.48 million sq km and has a population of 593 million (2009). The People's Republic of China borders the region to the north, the Pacific Ocean and Papua New Guinea to the east, Australia to the southeast, the Indian Ocean to the south, Bay of Bengal and Andaman-Nicobar Islands (India) to the west and India and Bangladesh to the northwest.

The ASEAN region is geographically diverse and includes high hills and rugged mountains, elevated plateaus, highlands, floodplains, coastal plains and deltas. It is home to large river systems such as the Mekong and Ayeyarwady, and major water bodies such as the Tonle Sap and Lake Toba, the latter being the largest volcanic lake in ASEAN region. Most part of ASEAN has hot and humid tropical climate, an exception being the mountainous areas in the Indochina Peninsula that experience a milder temperature and drier landscape.

A major part of the population in the region lives in riverine plains, delta and coastal plains. Hence, the most populous areas are subjected to periodic and extensive hazards such as flood, tsunami, and cyclone. Moreover, the unique geographic and climatic conditions make ASEAN one of the world's most vulnerable regions to disasters caused by natural hazards as well as climate change impact. Almost every year, powerful typhoons that cause flooding and landslides batter the region. In addition, the region faces risk from earthquakes, volcanic eruptions, tsunamis, and forest fires that threaten life and property, and drought that leaves serious lingering effects.

A review of the existing hazard, vulnerability and economic loss data at country level was performed. The main data sources consulted include the CRED EM-DAT, ADRC, NGDC, GSHAP, MRC, WAMIS, DWR, Munich Re, World Bank, UNISDR, GAR, InTerragate, IFNet, and CCFSC, DESINVENTAR, country specific reports and research papers were also reviewed.

The socio-economic data was 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 (GAR, 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, drought, cyclonic storm, and multi-hazards. The hazard risk data were analyzed along with grid based population data to assess the population exposed to various hazard risks.

To analyze risk profiles at country and regional levels, reported economic disaster data (1970-2009) have been used. However, for earthquake and tsunami (1900-2009), a longer duration of disaster data have been used. Analyses of projected losses in the absence of mitigation measures expressed in the form of average annual loss (AAL) and economic loss potential for selected probabilities of exceedance have been carried out.

1.1 Key findings

Disasters

The disasters risk assessment analyses show that in terms of human casualties, cyclonic storms are the dominant disaster risk in ASEAN followed by earthquakes, tsunamis, floods, epidemics, landslides, droughts, volcanic eruptions and forest-fires. During the last 40 years (1970-2009), 1,211 reported disasters have caused over 414,900 deaths. Out of the reported disasters, 36 per cent were floods, 32 per cent were cyclonic storms, 9 per cent were earthquakes, 8 per cent were epidemics, and 7 per cent were landslides. Cyclones (storms) caused the maximum number of deaths: over 184,000, followed by earthquakes (114,000) and tsunamis (83,600).

Vulnerability

The social vulnerability (SV) ranking of each country was estimated based on the average number of people killed per year per million (relative social vulnerability). The analysis of disaster data for the period 1970-2009 shows that the average number of people killed per year per million for ASEAN region is 17.5. In Myanmar, the relative SV is more than 3.5 times that of Indonesia (the second highest). In terms of relative SV ranking, Myanmar has the highest ranking followed by Indonesia, Philippines, Thailand, Vietnam, Lao PDR, Cambodia, and Malaysia. Due to paucity of disaster loss data, the SV ranking could not be carried out for Brunei and Singapore. The quantitative risk assessment performed in this study confirms the following risk patterns for the ASEAN countries:

- Cambodia: floods represent the dominant risk followed by droughts
- Indonesia: forest (wild) fires, earthquakes and tsunamis, and floods represent the dominant risks followed by volcanoes, droughts, and landslides
- Lao PDR: cyclonic storms, and floods are the dominant risks followed by droughts
- Malaysia: floods are the dominant risks followed by forest fires, tsunamis, and cy clonic storms
- Myanmar: cyclonic storms are the dominant risk followed by tsunamis, floods and forest-fires
- Philippines: typhoons (cyclonic storms) are the dominant risk followed by floods, earthquakes; volcanoes, droughts, and landslides
- Thailand: floods are the dominant risk followed by tsunamis, cyclonic storms, and droughts
- Vietnam: cyclonic storms, and floods are the dominant risk followed by droughts, and landslides
- Brunei and Singapore: no disaster data is available

Disasters can have enormous economic consequences. The quantitative risk assessment performed in this study confirms that a catastrophic event with a 200-year return period (0.5 per cent annual probability of exceedance) would have a major impact on ASEAN countries' economies, some of which are already fragile. To gauge the potential economic impact, the economic vulnerability (EV) ranking of each country has been estimated in terms of likely economic losses that an event with a 200-year return period would cause as a percentage of that country's Gross Domestic Product (GDP PPP) (Figure A). According to this categorization, Myanmar has the highest EV ranking in the region, followed in descending order by Laos, Indonesia, Cambodia, Vietnam, Philippines, Thailand, and Malaysia.

Due to paucity of economic loss disaster data, the Average Annual Loss (AAL) and economic loss analysis for different probabilities of exceedance could not be carried out for Brunei and Singapore.

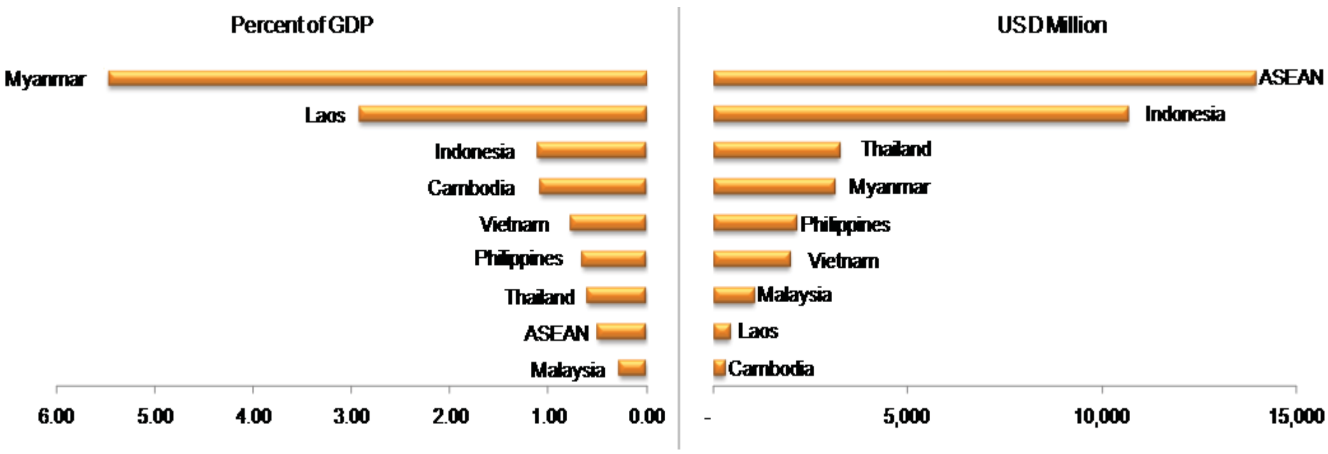
Urban areas are especially vulnerable to the adverse impact of disasters. Capital cities: Manila, Jakarta, Bangkok, Ha Noi, and Singapore are amongst the most populated cities in the ASEAN region and all are undergoing intense economic transformation. In terms of earthquake risk, Manila is at highest risk followed by Jakarta and Bangkok. In terms of flood risk, Manila is also at highest risk followed by Jakarta, Bangkok, and Ha Noi. In terms of tropical cyclonic risk, Manila is also at highest risk followed by Ha Noi, and Jakarta. In terms of overall risks from these hazards, Manila is at highest risk, followed by Jakarta, Bangkok, Ha Noi, Singapore, Kuala Lumpur, Naypyidaw, Phnom Penh, Vientiane, and Bandar Seri Begawan.

Climate change impact

Climate change is considered as one of the most significant developmental challenges confronting ASEAN nations in the 21st century. According to the Intergovernmental Panel on Climate Change (IPCC, 2007) reports, the mean surface air temperature in Southeast Asia increased at the rate of 0.1 – 0.3°C per decade between 1951 and 2000. Following the global trend, the mean sea level is projected to rise by 40 cm on average by 2100 in comparison to 1990. Moreover, the region experiences decreasing rainfall and increasing sea levels (1–3 mm per year). The frequencies of extreme weather events like heat waves, heavy precipitation, and tropical cyclones have been increasing considerably. These climatic changes have brought massive flooding, landslides, and droughts in different regions and have caused extensive damage to property, assets, and human life. High concentration of population and intense economic activities in coastal areas, and a high dependence on agriculture and forestry in many countries of the region are making the situation more complex and may hinder the regions sustainable development.

Global Circulation Models addressing climate change do not present a uniform view of the impact of climate change on ASEAN as they have limited capabilities 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 0C over the next 80 years.

Figure A Economic Loss Potential for annual probability of exceedance of 0.5 per cent



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 ASEAN could be as high as a 6-7 per cent loss in GDP by 2100 compared to what could have been achieved in a world without climate change.

1.2 Way forward

Based on the analyses, the review makes the following recommendations to reduce disaster risk in ASEAN:

Additional analyses

Three levels of analyses are envisioned to refine the results presented in this report. These analyses should emphasize more on floods, typhoons (tropical cyclonic storms), and earthquakes and tsunamis, 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 (for example a 100-km grid) should be considered. Risk aggregation by hazard type and area would provide, at low cost, a much more refined picture of the risk than is offered by the present analysis.

Level 2: On a second level, using the same methodology, worst-case scenarios should be considered for the highly populated cities. This analysis would provide a reasonable quantification of loss, given the occurrence of a particular disaster scenario. The uncertainty around the risk could then be bracketed by scientifically estimating the range of probability of occurrence of such scenarios. Such worst-case scenario studies can be used in preparation of city specific Disaster Management Plans (DMP).

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

Drought hazard should be addressed in the context of climate change and long-term adaptation strategies should be considered. Climate risk assessments study should merge traditional risk assessments with climate change assessments.

Use of Open Source Risk Models is recommended, in which probabilistic techniques are applied to the analysis of various natural hazards. At this level of analysis, hazard information is combined with exposure and vulnerability data allowing the user to determine the risk simultaneously on an inter-related multi-hazard basis. In recent years, several open source GIS-based multi-hazard risk platform has/are being developed. HAZUS-MH is a powerful risk assessment platform for analyzing potential losses from earthquakes, floods, and winds. CAPRA- Central American Probabilistic Risk Assessment is another GIS-based platform for risk analysis of earthquakes, tsunamis, tropical cyclones, floods, landslides, forest-fires, and volcanoes. HazSana'a and HazYemen are other two such open source GIS-based multi-hazard risk platform being developed for Sana'a city and Yemen country, respectively. These open source platform should build upon existing initiatives, with the objective of consolidating methodologies for hazard, exposure, and risk assessment, and raising risk management awareness in the region.

1.3 Limitations of the Study

This report is a quick assessment study of the region, carried out in a short time of 4 months. Risk is commonly quantified as the product of hazard, exposure, and vulnerability. However, in this study, the approach for risk assessment is much simpler than the standard probabilistic methods and estimation of average annual economic losses (AAL) and losses for different annual probability of exceedance (AEP) are carried out directly based on recorded historical losses. Thus, the approach is dependent on availability of historical loss data.

The other limitations may be due to the use of historical data. Often damage estimates of large, catastrophic events tend to be overestimated, while those of more frequent, less severe events are often underestimated. Socio-economic losses from typhoons (strong tropical cyclones) occur more in the form of flooding caused by typhoons. However, losses are often reported as caused by the typhoons only, since separating the reported losses caused by typhoon and flood induced typhoon is a difficult proposition. Economic losses caused due to forest-fires in the past in Indonesia are very high. Risk assessment carried out in this study, shows AAL for forest fires is highest in Indonesia, which is contrary to popular belief in the country. The economic loss probability estimates presented in this report are not intended for designing catastrophe insurance schemes, which require a much more detailed approach that models hazard, exposure and vulnerability of buildings and infrastructure.

1.4 Report structure

The report is organized as follows:

- Chapter 1 is the Executive Summary
- Chapter 2 provides an overview of disaster risk assessment, taking into account the shift in disaster management practices towards an integrated DRR approach.
- Chapter 3 briefly examines the geography and demographic characteristics of the ASEAN region.
- Chapter 4 outlines the methodology adopted to carry out the risk assessments used in this study.
- Chapter 5 provides country profiles and analyses of disaster risk assessment at country level. This includes an examination of the socio-economic and biophysical context of individual countries, as well as specifics such as disaster risk statistics. Information is presented in a concise format for easy and quick reference.
- Chapter 6 provides a regional profile and analyses disaster risk assessment at regional level. The chapter also includes risk maps tailored to ASEAN countries using Global Risk Assessment (GAR) PREVIEW Global Risk Data Platform.
- Chapter 7 examines trans-boundary disaster risk and its effects, including a look at major trans-boundary disasters in the ASEAN region.
- Chapter 8 provides a summary of economic highlights of each country.
- Chapter 9 provides a summary of climate change assessments, identifies the vulnerabilities of individual countries, and examines the potential impact of such changes across the region.
- Chapter 10 examines the hazard risk management framework, assessing the levels of individual countries' emergency preparedness, institutional capacity building, risk mitigation investments and catastrophe risk financing.
- Chapter 11 identifies priority areas requiring detailed risk assessment based on the data gathered for this report.
- Chapter 12 includes conclusions and summary recommendations.
- Annexes include risk assessment methodology, references, list of organizations and institutions, and relevant Internet sites.

Risk Assessment: An Overview

2

"Building a culture of prevention is not easy. While the costs of prevention have to be paid in the present, its benefits lie in a distant future. Moreover, the benefits are not tangible; they are the disasters that did NOT happen."
(Kofi Annan, 1999)

The frequency and impact of disasters triggered by natural hazards have grown dramatically since the early twentieth century, rising by more than 800 per cent worldwide over the last 40 years alone (Munich Re, 2005; CRED EM-DAT, 2005). Moreover, the global trend is set to worsen now that climate change has become a threat, prompting an anticipated increase in the frequency and severity of weather-related disasters.

Disasters due to natural hazards can have catastrophic impacts on nations and regions. These events can disrupt the social, economic and environmental status of societies at a number of different levels. The social impact of disasters includes loss of livelihoods, assets and infrastructure, as well as harm to emotional and physical well-being. Disasters can cause social unrest, which can lead to the discontinuation of development programmes. Environmental losses are often significant.

Disasters tend to hit the poorest most as they have little or no financial or physical resilience. The poor tend to depend most on a well-functioning environment for their livelihoods and struggle most to rebuild their lives and assets in the aftermath of a disaster.

The extent of damage caused by disasters depends on the vulnerability of the affected area as well as the severity of the hazard. Consequently, efforts aimed at reducing vulnerabilities through such measures as prior hazard forecasting or enhancing resilience can help to greatly reduce the impact of disasters.

Until the 1990s, disaster risk assessments were given lower priority than disaster response (rescue and relief). Since then, there has been a strategic shift in disaster management practices towards an integrated DRR approach, which includes incorporating DRR planning in the development process of countries and regions. There are several international initiatives, particularly those of the UNDP (2004), UNISDR (2004), UNISDR Global Assessment Report (GAR, 2009) and the World Bank (Dilley et al., 2005), that encourage nations to integrate disaster preparedness and mitigation into their development plans. This has brought a new dimension and perspective to the efforts to manage disasters.

In the ASEAN countries, priorities on the issues of monitoring, forecasting and early warning of disasters caused by natural hazards are gaining importance, and there is a shift from the traditional response-oriented approach to a mitigation-oriented approach. In addition, there is a gradual shift towards incorporating disaster risk management into development plans. It is significant that all the ten countries participated in the second World Conference for DRR, held in Hyogo in January 2005, and committed to adopt the Priorities for Action outlined in the HFA.

The recognition of the greater need for protective strategies to safeguard societies and economies from the adverse effects of disasters has focused attention on vulnerabilities and risk factors, and the beneficial role of disaster risk management. Appreciating the need for DRR and implementing the concept requires a proper understanding of factors including the nature and severity of the impact of disasters, knowledge of previous occurrences, an identification of any trends and an understanding of the vulnerability of populations and property.

To facilitate the implementation of DRR, UNISDR and UNDP are currently revising a core set of indicators and a methodology developed in 2004 (UNDP, 2004) to guide and monitor progress towards the reduction of risk from natural hazards.

Other measures include the several initiatives to develop global databases on hazards. EM-DAT, developed by the Office of US Foreign Disaster Assistance (OFDA) and the Centre for Research on the Epidemiology of Disasters (CRED), is one such effort and is widely used for macro-level risk assessment.

Disaster events can vary in magnitude or intensity, frequency, duration, area of extent, speed of onset, spatial dispersion and temporal spacing. Disasters from drought, being slow-onset hazard events, have lingering impacts on society and it may be difficult to define the exact dates of such events. Generally, disaster statistics tend to be more precise on a smaller scale where the evaluation of damage is undertaken in a more systematic manner, based on agreed methodologies (UNISDR, 2004).

Academics and emergency managers are continuously working to develop appropriate methodologies for assessing disaster risks, and several methods are in the process of being finalized or have recently been published (Inter-American Development Bank, 2005; UNDP, 2004). There is a great deal of effort taking place in benchmarking and vulnerability/risk indexing (ProVention Consortium, 2006). UNDP, for example, published a global report entitled 'Reducing Disaster Risk: a Challenge for Development' (UNDP, 2004), and has developed the Disaster Risk Index (DRI) and a relative vulnerability assessment using various indicators. Vulnerability and DRI are usually challenging. It is always a difficult matter to weigh the catastrophic severity of a disaster that might occur at 200-year intervals against the annual flood that will most certainly occurs

For relative vulnerability assessments, various economic and social variables have been used. However, in most of these methodologies there are several common variables, such as the number of events, the number of deaths, the number of deaths per year per million people, the size of the affected population per year or the amount of economic loss.

The Study Area

3

The Association of Southeast Asian Nations (ASEAN) region (Figure 1) covers an area of 4.48 million sq km, and has a total population (2009) of 593 million (Table 1). ASEAN, consisting of 10 independent countries, namely, Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar (Burma), Philippines, Singapore, Thailand, and Vietnam is a region of Southeast Asia extending from the south of China, east of India and north of Australia. Cambodia, Laos, peninsular Malaysia, Myanmar (Burma), Thailand, and Vietnam are part of mainland Southeast Asia (Indochina) while Brunei, East Malaysia, Indonesia, the Philippines, and Singapore are part of maritime Southeast Asia.

Geographically, ASEAN is an extremely large region with varied geography, and includes high hills and rugged mountains, elevated plateaus, highlands, floodplains, coastal plains and deltas. It is home to large river systems such as the Mekong and Ayeyarwady, and major water bodies such Tonle Sap and Lake Toba, the later being the largest volcanic lake in ASEAN. Most part of ASEAN has a hot and humid tropical climate, an exception being the mountainous areas in the Indochina Peninsula that experience milder temperature and drier landscape.

A major part of the population in the region lives in riverine plains, delta and coastal plains. Thus, most populous areas are subjected to periodic and extensive hazards like flood, tsunami, and cyclone. Moreover, the unique geographic and climatic conditions make ASEAN one of the world's most vulnerable regions to natural hazards as well as climate change impact. Almost every year, powerful typhoons with flooding and landslides, and earthquakes affect some countries in the ASEAN region with similar frequency.

Figure 1

Location map of ASEAN countries

Table 1

Table 1: Overview of countries in ASEAN region (2009 statistics) #

Country	Area sq km	% of ASEAN Region	Population	% of ASEAN Region	Pop. density (per sq km)	Annual pop. growth (%)	Urban Pop. % (2008)	GDP - per capita (PPP) USD	GDP (PPP) USD Billion	GDP (official exchange rate) USD	GDP growth rate %	HDI 2007*
Brunei	5,765	0.1	388,190	0.1	67	1.759	75	50,100	19.44	14.70	-1.9	0.920
Cambodia	181,035	4.0	14,494,293	2.4	80	1.765	22	1,900	27.92	10.90	-1.5	0.593
Indonesia	1,904,569	42.5	240,271,522	40.5	126	1.136	52	4,000	968.50	514.90	6.1	0.734
Laos	236,800	5.3	6,834,345	1.2	29	2.320	31	2,100	14.61	5.72	3.0	0.619
Malaysia	329,847	7.4	25,715,819	4.3	78	1.723	70	14,700	378.90	207.40	-2.8	0.829
Myanmar	676,578	15.1	48,137,741	8.1	71	0.783	33	1,200	56.49	26.52	1.0	0.586
Philippines	300,000	6.7	97,976,603	16.5	327	1.957	65	3,300	327.20	158.70	1.6	0.751
Singapore	697	0.0	4,657,542	0.8	6,682	0.998	100	50,300	234.50	163.10	-2.6	0.944
Thailand	513,120	11.5	65,998,436	11.1	129	0.626	33	8,100	535.80	266.40	-3.5	0.783
Vietnam	331,210	7.4	88,576,758	14.9	267	1.137	28	2,900	256.00	91.76	4.4	0.725

Source: https://www.cia.gov/library/publications/the-world-factbook/index.html
*: http://hdr.undp.org/en/statistics/

#: All indicators given in table are of 2009 except otherwise mentioned

Methodology

4

A simple and straightforward approach to estimating risk is to base calculations solely on the data provided by historical records. If the data sets are relatively complete, and cover a period sufficiently long enough to include several return periods of the events under consideration, then reliable risk estimates can be derived. Approaches that are more robust model the physics of event generation and introduce physical parameters to supplement the incompleteness of the historical records. It consists of hazard (scenario and ground motion) module, exposure (inventory) module, vulnerability module, damage module and loss module. The sketch below presents a generalised earthquake-modeling framework.

However, the development and implementation of such models require significant time and resources, way beyond the scope of the present study.

This synthesis report on the Ten ASEAN Countries is based on a desk review of existing studies by academia, governments and international governmental and non-governmental organizations. The following sections describe the methodology being adopted in carrying out the hazard, vulnerability and risk assessments.

4.1 Data review

A survey of literature on economic loss data due to disasters shows that for most ASEAN countries, disaster economic loss data for all hazards except earthquakes and tsunamis are available from the late 1960s. Thus, the report will present analyses and estimates of the hazard, vulnerability and risk based on the historical events that have affected the countries and the region over the last 40 years (1970 to 2009).

Because most hazards have short return periods, of less than 40 years, this window will provide a reliable picture of the characteristics of the phenomena. Nevertheless, significant disaster events at country and regional levels that predate the late 1960s have also been reviewed. Earthquakes and tsunamis that have long to very long return periods required special treatment. Consequently, in terms of economic losses, a longer duration of earthquakes and tsunamis data covering about 100 years has been reviewed, analyzed and simulated based on the damage description and the number of people killed and affected. However, to provide consistency with the other hazards, disaster risk statistics for all the hazards will be provided for a 40-year time period.

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

Data sources

Since 1970, 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 available in print and on the Internet. This section describes the most relevant data sources that have been identified for this study.

- The Centre for Research on the Epidemiology of Disasters (CRED) maintains the EM-DAT global emergency events database on disasters (natural and technological hazards), which is one of the most exhaustive sources of data available in the public domain. While EM-DAT data date back to the 1900s, data on economic losses caused by disasters in most ASEAN countries have become generally available since the 1980s. As per EM-DAT, for an emergency event to be classified as a disaster must meet at least one of the following criteria:
    - 10 or more people reported killed
    - 100 people reported affected
    - Declaration of a state emergency
    - Call for international assistance
- The Asian Disaster Reduction Centre (ADRC) has compiled data from various sources, including: UNOCHA, DesInventar, the Government of the United States, the Government of Japan, OFDA, IFRC, WMO, and the reinsurance industry and private agencies. The data in the form of country reports are available for all of the ASEAN countries except Brunei.
- The Department of Water Resources (DWR), Thailand (www.dwr.go.th) has provided socio-economic loss analyses (for the period 2000-2008) for flood and drought in the Lower Mekong Basin (LMB) covering Cambodia, Laos, Thailand, and Vietnam.
- Asian Disaster Preparedness Centre (ADPC) has compiled data from various sources. The data are available for most of the ASEAN countries, in the form of country and regional reports.
- The Mekong River Commission (MRC) with secretariat at Lao PDR was established in 1995 by an agreement between the governments of Cambodia, Lao PDR, Thailand and Viet Nam. MRC also provides flood and drought disaster data in the form of reports.
- The International Flood Network (IFNet) was created in March 2003. IFNet is a network aiming to promote activities that will contribute to reduce the negative impacts of floods all over the world. It provides flood disaster data in the form of reports.
- The World Agro Meteorological Information Service (WAMIS) main objective of WAMIS is to provide a dedicated web server for disseminating agro-meteorological products available to the global agricultural community on a near real-time basis issued by WMO Members. It also provides flood and drought disaster data in the form of reports.
- The World Bank's East Asia and Pacific (EAP) unit has prepared brief country disaster risk profiles for Cambodia, Indonesia, and Viet Nam.
- The Global Assessment Report (GAR) preview platform (ISDR, 2009; http://preview.grid.unep.ch) has created spatial data for the entire world using simplified modeling techniques and has provided mortality risk data for tropical cyclone (typhoon), earthquake, flood, landslide, and multiple hazards for the ASEAN region.
- The National Geophysical Data Centre (NGDC) database is an exhaustive database on earthquake events since 1900 for most countries in the world. The database has an approximate economic loss range for events, where exact economic loss estimates are not available.
- The Dartmouth Observatory has compiled flood data across the world for major events since 1980. The site has documented the

flood extents for different periods using satellite data. Dartmouth data has recorded a Glide number for each event, which is a unique identifier and a standard practice many international organizations are now following. The site is exclusively for flood data, though economic losses are sparsely documented.

In addition, there are various hazard-specific studies analyzing particular events at the country level. However, these reports fall short in providing detailed country-level risk information.

Apart from the above-mentioned sources, specific reports and data on countries and the ASEAN region are being reviewed and analyzed, especially those on climate change assessment, population growth, economic and urban expansion, and identification of priority areas (Mega cities) for detailed risk assessment. Several key institutions and organizations in the region were contacted while compiling this report.

Data issues

In spite of the efforts of data gathering organizations, historical data on disasters have many 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:

- Lack of a single organization performing data collection and compilation, which can lead to lack of standardization in data collection methodologies and definitions.
- Biased data can occur because of differences in the rationale behind data gathering.
- Prolonged disaster events (like famine over many years) may be recorded as multiple events.
- Regional events which spread across different political boundaries, such as floods or earthquakes, can be recorded in all the affected countries and may be counted as different events.
- Changes in national boundaries can also cause ambiguities and difficulties in comparing historical data.
- 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 database managers gather data from a variety of public sources, such as newspapers, insurance reports, or through aid agencies. The original information is not gathered specifically for analytical purposes, so even if the compiling organization applies strict definitions, there can still be inherent shortcomings in the data.

There are other issues in disaster data gathering that concern the impact diffusion of events. Hazards such as droughts do not have clear-cut start and end dates as the occurrences start slowly and their impacts linger long after the official end of the events. Furthermore, the impact can extend far beyond the visible physical damage and can often affect livelihoods.

All the datasets obtained from the identified sources are being examined with these issues in mind. The steps required to resolve at least some of them are presented in the next section.

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 process is to identify the most reliable sources, cross check them with other sources, and identify and resolve inconsistencies in order to create a best-estimate database for use in the study. Table-2 presents the data sources used for each hazard listed. The rest of this section presents some of the steps followed to assure that the most reliable data have been

Table 2 Details on data sources used and period covered for each hazard in the study

Hazard	Period	Sources		Comments
		Primary	Secondary	
Earthquake	1900 - 2009	CRED EM-DAT, ADRC, Munich Re, NGDC, GSHAP	ADPC, WB, UNISDR, GAR, InTerragate, DESINVENTAR, Research Publications	Data are compared and cleaned using different sources including individual research papers. For regional analysis, damaging earthquakes and tsunamis from 1900 to 2009 are considered. For some countries there is not enough disasters economic loss data to compute hazard-specific AAL.
Cyclonic Storm (Typhoon)	1970 - 2009	CRED EM-DAT, ADRC, Munich Re,	ADPC, WB, GAR, CCFSC, InTerragate, DESINVENTAR, Research Publications	
Flood	1970 - 2009	CRED EM-DAT, ADRC, DWR, WAMIS, MRC, IFNet, Munich Re	Dartmouth Observatory, WB, GAR, ADPC, CCFSC InTerragate, DESINVENTAR, Research Publications	
Drought	1970 - 2009	CRED EM-DAT, ADRC, DWR, WAMIS, MRC, IFNet	MRC, CRED EM-DAT, ADRC, WB, ADPC, InTerragate, DESINVENTAR, Research Publications	
Landslide/ mudslide	1970 - 2009	CRED EM-DAT, ADRC, Munich Re, NGI (2004)	WB, GAR, InTerragate, DESINVENTAR, Research Publications	
Volcano	1970 - 2009	CRED EM-DAT, ADRC	ADPC, InTerragate, International Association of Volcanology and Chemistry of the Earth's Interior, Global Volcanism Program, Smithsonian Institution, Research Publications	
Tsunami	1900 - 2009	CRED EM-DAT, ADRC, Munich Re,	ADPC, InTerragate, Research Publications	
Forest-Fire	1970 - 2009	CRED EM-DAT, ADRC	ADPC, InTerragate, Research Publications	

gathered and used.

Another specific problem faced in the study of smaller countries concerns the problem of disasters spreading across national boundaries. Many events, including tropical cyclones (typhoons), floods, earthquakes, and droughts, transcend borders and are recorded in more than one country, resulting in duplication of event and impact values, when data are used for analysis at a regional level. To avoid this issue, data sources like Dartmouth have documented data by event rather than by country. In such cases, the format adopted in the CRED EM-DAT database is used to identify, correlate and record data for individual country losses.

To deal with these anomalies, data from different sources are compared on an event-by-event basis. The event was ignored if it was not reported in any of the above-mentioned sources. If an event was only recorded in one data source, it was crosschecked using published reports, papers and media news reports, particularly if there were major variations in the reported number of deaths, the size of affected population, and economic losses.

4.2 Hazard risk and vulnerability estimates

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

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 (GAR, 2009; http://preview.grid.unep.ch) along with country specific disaster data.

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) PPP and population density were also considered to describe the social and economic vulnerability.

The country-level socio-economic indicators are being taken from the World Fact Book (CIA, 2010; http://www.cia.gov); UNDP (http://esa.un.org/unup/; http://hdr.undp.org/en/statistics/); IMF (http://www.imf.org) and disaster risk statistics are prepared based on reported disaster data. Where a socio-economic indicator is not available for the year 2009, the corresponding value available for the latest year is used. For the ASEAN region, socio-economic indicators are derived from country-level socio-economic indicators.

4.3 Risk assessment

Risk is commonly quantified as the product of hazard and exposure. In this study, the intent is to quantify the risk directly based on recorded historical losses. This approach is much simpler than the standard probabilistic methods, but it provides reliable estimates as long as records cover a sufficient period, as explained earlier in this chapter. In the case of this study, data covering a 40-year period (1970-2009) are considered for all hazards except earthquakes and tsunamis (1900-2009). As outlined in section

4.1, data for earthquakes and tsunamis are used which cover a longer period because damaging earthquakes and tsunamis generally have longer return periods than those for other hazards.

In addition to the general data issues identified in Section 4.1, it is important to consider the following additional issues:

- The use of historical data for loss computation may have some shortcomings. Often damage estimates of large, catastrophic events tend 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 are available the one with the more conservative estimate is considered.
- The severity of reported damage often depends on the economy of the affected area, even though the intensity of the hazard may be similar. For example, floods in developed countries tend to cause higher economic losses per unit area flooded than floods in countries such as Myanmar.
- Socio-economic losses from typhoons (strong tropical cyclones) occur more in the form of flooding caused by typhoons. However, losses are often reported as caused by the typhoons only, since separating the reported losses caused by typhoon and flood induced typhoon is a difficult proposition.

The methodology for loss analysis was adopted from The World Bank and UNISDR publication "ISDR (2009). Central Asia and Caucasus Disaster Risk Management Initiative (CAC DRMI): Risk Assessment for Central Asia and Caucasus, Desk Study Review' and is presented in Annex 1.

Statistical methods were applied to determine the probability and frequency of a hazard's occurrence and the level of economic losses it could cause. Number of deaths, deaths per year, deaths per million population, and affected population were also estimated. Economic loss potential for different probabilities of exceedance and AAL was calculated for each country and regional level.

4.4 Presentation of results

The results are presented at country, and regional levels. Data are presented to capture the composition of disasters by hazard type within a country, and the relation between the events and their impacts is examined along with estimations of socio-economic losses.

There is a strong link between natural hazards and their biophysical settings, while vulnerability depends largely on socio-economic conditions. Consequently, a brief overview of each country is provided as background information prior to the disaster risk assessment. The report presents analyses of disaster events and their impact at the country, and regional levels in the context of biophysical and socio-economic settings.

Country Risk Profiles

5

This section deals with the preliminary assessment of disaster risks in Ten ASEAN countries. The assessment is conducted from both hazard-specific and country-level perspectives. Reported disaster data for various hazards at country level are used for hazard-specific and country-level risk assessment. The approach adopted for economic loss analysis is presented in Annex 1.

An event with a 0.5 per cent annual probability of exceedance (AEP) in one year occurs on average every 200 years and generally corresponds to a catastrophic event. An event with a 5 per cent and 20 per cent annual probability of exceedance occurs on average every 20 years and 5 years, respectively.

As a preamble to the country-level risk assessments, the physical and social settings of each country are provided in brief. This is important as disaster frequency and intensity have a direct relationship with the biophysical and socio-economic setting of the country.

The country-level socio-economic indicators have been taken from the World Fact Book (CIA, 2010; http://www.cia.gov); the World Bank (2010; http://web.worldbank.org); Asian Development Bank (ADB, 2010; http://www.adb.org); UNDP (http://esa.un.org/unup/; http://hdr.undp.org/en/statistics/); and IMF (http://www.imf.org) and disaster risk statistics have been prepared based on reported disaster data. Where a socio-economic indicator is not available for the year 2009, the corresponding value available for the latest year is used. For the ASEAN region, socio-economic indicators have been estimated from country-level socio-economic indicators.

For an emergency event to be classified as a disaster it must meet at least one of the following criteria:

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

5.1 Brunei Darussalam

Overview

Country-level Information (2009)	
Geographic area (km²)	5,765
Population	388,190
Population density (per sq.km)	67
Population growth (annual %)	1.759
Urban population (% of total)	75 (2008)
Poverty headcount ratio, $2 a day (PPP) (% of population)	NA
Current GDP ($ billion)	14.7
GDP growth (annual %)	-1.9
GDP - per capita (PPP)($)	50,100
Agricultural GDP (%)	0.7 (2005)
Industry GDP (%)	75.0 (2005)
Service GDP (%)	24.3 (2005)
Human Development Index (HDI)	0.920 (2007)

Figure 2 Percentage distribution of reported disasters in Brunei

Disaster Risk Statistics (1970-2009)				
Disaster type	*No. of disasters/ year*	*Total no. of deaths*	*Deaths/ year*	*Relative vulnerability (deaths/year/ million)*
Flood	0.05	1	0.03	0.06
Landslide	0.05	1	0.03	0.06
Wind Storm	0.03	-	0.00	0.00
Epidemic	0.03	1	0.03	0.06

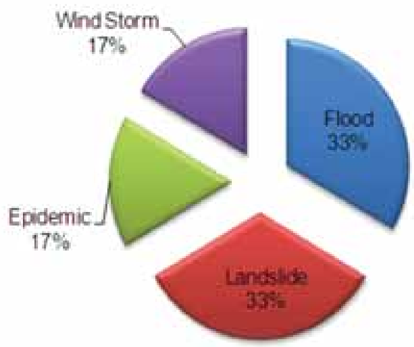


Figure 2: Percentage distribution of reported disasters in Brunei

Figure 3 Average annual economic loss ($ million) of Brunei

Economic Loss Potential		
Annual exceedance probability	*Economic loss ($ million)*	*Percentage to GDP PPP (2009)*

Figure 3 : Average annual economic loss ($ million) of Brunei

No Disaster data is available

Regional setting

Brunei Darussalam is situated on the northwestern coast of the island of Boreno between east longitudes 114°04′ and 115°23′ and north latitudes of 4°00′ and 5°05′. The country is surrounded on three sides by the eastern Malaysian state of Sarawak and to the north by the South China Sea. It is divided into two parts by Sarawak. It has a land area of 5,765 sq km, a coastline of about 161 km along the South China Sea, and a population of 388,190 with Bandar Seri Begawan as the main population centre. The western part of Brunei is predominantly hilly lowland whereas the eastern part consists of mostly rugged mountain terrain. The summit ridge of Bukit Pagon, in the western part, contains the highest point of the country with an elevation of 1,850m above sea level and lowest point is South China Sea (0m). The coast has a wide, tidal and swampy plain. Brunei has an equatorial climate characterized by uniformly high temperature, high humidity and heavy rainfall. Temperatures range from 23 - 32 degree Celsius, while annual rainfall varies from 2,500 mm on the coast to 7,500 mm in the interior.

Hazard profile

Historically, Brunei is one of the least vulnerable countries to natural hazards. The country is vulnerable to low-level hazards from earthquakes, cyclonic storms, floods, landslides, and seasonal smoke/haze resulting from forest fires in Indonesia (Figure 2). However, in the recent years it has faced a few disasters (http://news.brunei.fm/2009/08/06/country-experiencing-worst-disaster-year/).In 2009, Brunei faced floods, landslides, a pandemic, serious fire outbreak, and the haze. In 2008, Brunei experienced landslides, floods, and strong winds, while in 2007, the country experienced floods, and strong winds.

The region is reputedly a region of high seismic hazard. However, Brunei is fortunate not to be located in an earthquake hazard prone area and is in a low seismic hazard region (GSHAP, 1998). Its capital city, however, has experienced small earthquakes (in the range of 4-5 magnitude), which caused swaying of some high-rise buildings (5-6 stories) in 1992 (Waifong, 1993) and 2005. Due to low seismic hazard, there was a general feeling of complacency as mentioned by Waifong in 1993, in a conference on Seismic risk management for countries of the Asia Pacific region, Bangkok. However, in 2006, the country established a National Disaster Management Centre (NDMC) to take on Disaster Risk Reduction (DRR) initiatives.

Risk profile

As per reported historical disaster data (http://www.preventionweb.net, EM DAT), Brunei suffered from one forest fire disaster in 1998, which caused an economic loss of $ 2 million with no reported casualties. However, in recent years, the country has faced a few disasters as reported in Brunei news. In 2009, Brunei faced floods, landslides, a pandemic, serious fire outbreak and the haze. In 2008, Brunei experienced landslides, floods, and strong winds, while in 2007, the country experienced floods, and strong winds (http://news.brunei.fm/2009/08/06/country-experiencing-worst-disaster-year/).

Thus, the country is at risk from natural hazards such as earthquakes, landslides, floods, forest-fires, storms (winds), and haze. The risk from earthquakes and haze is low from within the country and moderate to large from transboundary events.

Due to non-availability of disaster data (except one forest-fire event), the disaster risk analysis-economic loss potential (AAL and economic losses for different probabilities of exceedance) has not been carried out.

5.2 Cambodia

Overview

Country-level Information (2009)	
Geographic area (km^2)	181,035
Population	14,494,293
Population density (per sq.km)	80
Population growth (annual %)	1.765
Urban population (% of total)	22
Poverty headcount ratio, $2 a day (PPP) (% of population)	35% (2004)
Current GDP ($ billion)	10.90
GDP growth (annual %)	-1.5
GNI per capita, PPP ($)	1,900
Agricultural GDP (%)	29 (2007)
Industry GDP (%)	30 (2007)
Service GDP (%)	41 (2007)
Human Development Index (HDI)	0.593 (2007)

Figure 4 Percentage distribution of reported disasters in Cambodia

Disaster Risk Statistics (1970-2009)				
Disaster type	*No. of disasters /year*	*Total no. of deaths*	*Deaths/ year*	*Relative vulnerability (deaths/ year/ million)*
Flood	0.35	1,245	31.13	2.15
Drought	0.10	-	-	-
Storm	0.08	30	0.75	0.05
Epidemic	0.23	788	19.70	1.36

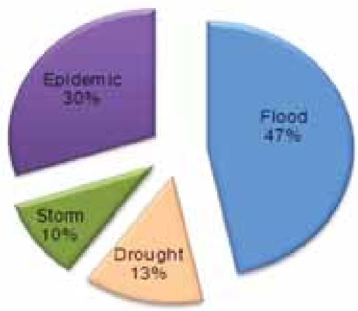


Figure 4: Percentage distribution of reported disasters in Cambodia

Figure 5 Average annual economic loss ($ million) of Cambodia

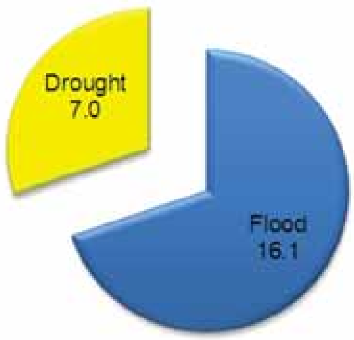


Figure 5: Average annual economic loss ($ million) of Cambodia

Loss data not sufficient for other hazards

Economic Loss Potential		
Annual exceedance probability	*Economic loss ($ million)*	*Percentage to GDP PPP (2009)*
0.5%	298.98	1.07
5.0%	112.15	0.40
20.0%	38.35	0.14

Regional setting

The Kingdom of Cambodia is located in Southeast Asia, bordering Thailand to the north and west, Laos to the northeast, Vietnam to the east and southeast and the Gulf of Thailand in the south. The country covers an area of 181,035 sq km with a population of 14.49 million (2009). The total length of land boundary is 2,572 km and coastline of 443 km. About 75 per cent of the country lies at elevations of less than 100 m above mean sea level mostly comprising low-lying alluvial plain. The highest and lowest elevations in Cambodia are 1,813 m (Phnom Aural) and 0 m (Gulf of Thailand), with respect to mean sea level. The climate in Cambodia is tropical monsoon with the rainy season extending from May to October. The country has an average annual rainfall of 1,400 mm on the central plain and about 3,800 mm in the mountains and along the coast. The average annual temperature is 27°C. The heaviest precipitation occurs in September-October, whereas January-February remains the driest period. The Mekong River flows in a north-south direction through the country. The Tonle Sap (Great Lake) of Cambodia is the largest in ASEAN region. The lake covers an area of 2,700 sq km in the dry season and reaches more than 10,000 sq km during the monsoon season.

Hazard profile

Cambodia is vulnerable to disasters caused by natural hazards, including floods, droughts, cyclonic storms, epidemics, landslides, and earthquakes. Figure 4 shows the hazard-specific distribution of various disasters that occurred during the period 1970-2009.

Cambodia is susceptible to heavy monsoon flash and riverine flooding, mainly because of deforestation, erosion of riverbanks causing the river to become shallower. On an average, the Mekong River and its tributaries and local downpours flood 25 per cent of the plains annually. Rainfall-runoff is often blocked by the high water level in the Mekong River and Tonle Sap Great Lake. The country is rarely hit by coastal floods. Analysis of disaster data show that floods have affected a large number of people and caused significant economic losses. For example, the July-August 2000 flood killed 347 people, affected 3.45 million people and caused an economic loss of $160 million. The other significant flood events occurred in 1991, 1994, 1996, 1999, 2001, 2002, 2004, 2005, 2006, and 2007.

The imbalance in the distribution of monsoon rainfall results in drought conditions in some parts of Cambodia. During the rainy season from May to November, a dry spell of 10-20 days can give rise to extensive drought and damage paddy crop. Prolonged drought in some part of the country may result in significant losses. For example, the 2002 drought affected 650,000 people and caused an economic loss of $38 million; another severe drought in 1994–1996 affected 5 million people and caused an economic loss of $100 million.

Some provinces of Cambodia also experienced cyclonic storms. In November 1997, Linda Typhoon hit Pou lo wei island wreckaging 81 fishing boats and leaving hundreds of victims (1998 Country Report, ADRC). The September 29 to October 05, 2009, typhoon Ketsana killed 43 persons and affected 49,000 families (Cambodia PDNA report, 2010).

Cambodia lies in a region of low seismic hazard (GSHAP, 1998) and there has been no reported disaster event due to earthquakes in the past three decades.

The country is also affected by landslides triggered by floods. In 1997, the flow of the Mekong River caused landslides in Kandal and Kampong Chain Prey Veng provinces, and in Phnom Penh city. Almost every year people living near the riverbanks face destruction by landslide (1998 Country Report, ADRC). However, no disaster events have been reported in various disaster databases due to landslides.

Risk profile

Vulnerability indicators such as the number of disaster events, deaths, affected population and economic losses have been plotted against hazard types as well as for 5-year intervals covering the 40-year period 1970-2009. Figure 6 (a, b, c) shows the plots of the total number of deaths, affected population and economic losses against each hazard type, while Figure 7 (a, b, c) presents the same variables plotted against 5-year periods.

Figure 6 shows that among natural hazards, floods caused the largest number of deaths (1,245), affected the largest population (9.66 million) and caused the highest economic loss ($532 million).

The period 1995-1999 (Figure 7) was the worst in terms of number of deaths (750), while 2000-2004 was the worst in terms of number of people affected (7.537 million) and economic loss ($302.5 million), caused mainly by the floods of 2000, 2001, and 2004.

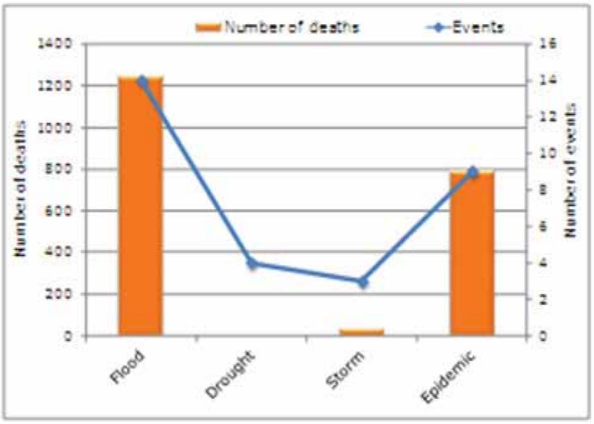
Floods have the highest frequency (0.35) and death rate (31.13). The relative vulnerability was also highest for floods (2.15), followed by epidemics (1.36) and storms (tropical cyclones 0.05).

Floods are the dominant risk in Cambodia, with an economic AAL of $16.1 million, followed by droughts ($7 million) (Figure 5).

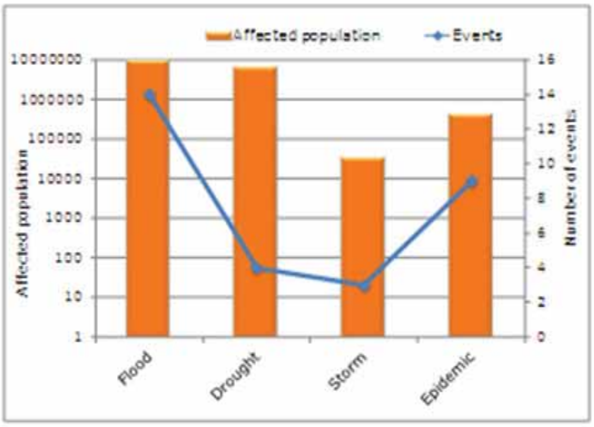
The 20-year return period (an event with 5 per cent probability of exceedance) loss for all natural hazards is $112 million (0.4 per cent of GDP PPP); while the 200-year return period (an event with 0.5 per cent probability of exceedance, generally corresponds to a catastrophic event) loss is $299 million (1.07 per cent of GDP PPP).

Figure 6 Cambodia: Disaster events and socio-economic impact by hazard type (1970-2009)

6a Disaster events and number of deaths



6b Disaster events and affected population



6c Disaster events and economic loss

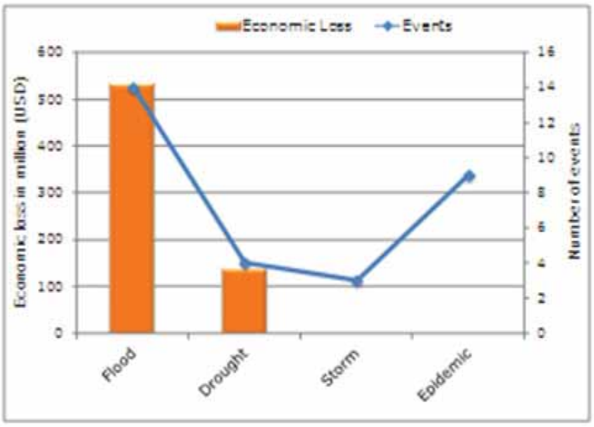
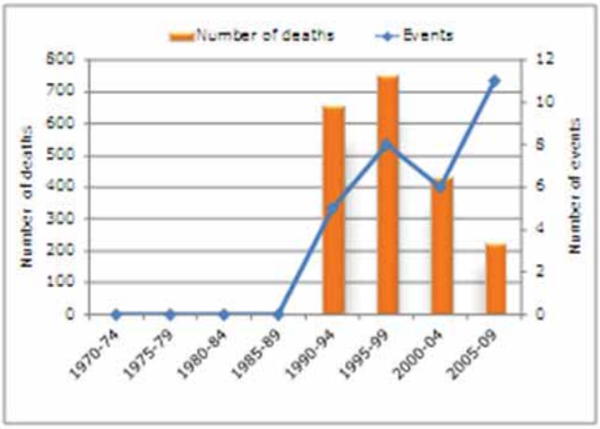
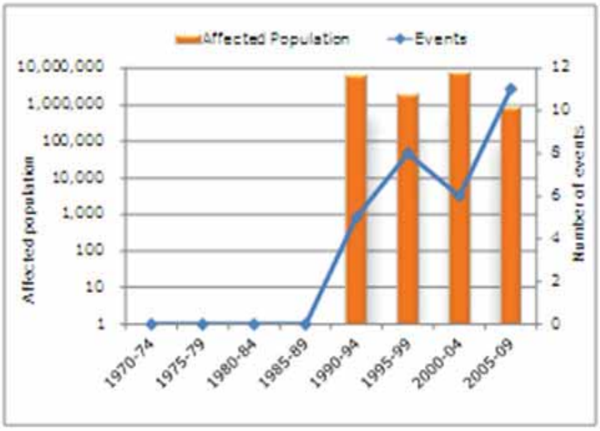


Figure 7 Cambodia: Disaster events and socio-economic impact by 5-year periods (1970-2009)

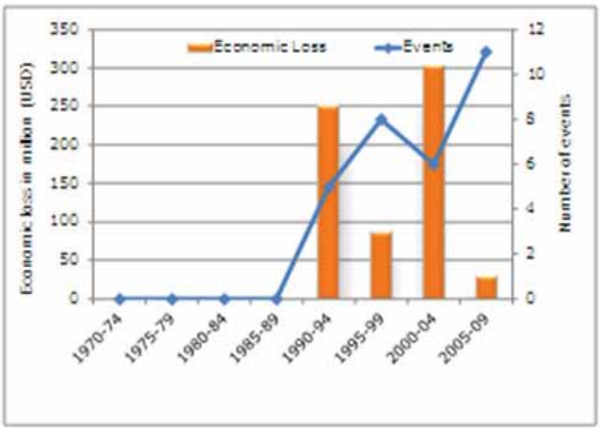
7a Disaster events and number of deaths



7b Disaster events and affected population



7c Disaster events and economic loss



5.3 Indonesia

Overview

Country-level Information (2009)	
Geographic area (km^2)	1,904,569
Population	240, 271,522
Population density (per sq.km)	126
Population growth (annual %)	1.136
Urban population (% of total)	52
Poverty headcount ratio, $2 a day (PPP) (% of population	17.8 (2006)
Current GDP ($ billion)	514.90
GDP growth (annual %)	6.1
GDP - per capita (PPP)($)	4,000
Agricultural GDP (%)	14.4
Industry GDP (%)	47.1
Service GDP (%)	38.5
Human Development Index (HDI)	0.734 (2007)

Figure 8 Percentage distribution of reported disasters in Indonesia

Disaster Risk Statistics (1970-2009)				
Disaster type	*No. of disasters / year*	*Total no. of deaths*	*Deaths / year*	*Relative vulnerability (deaths/year/ million)*
Flood	3.20	5,420	135.50	0.56
Drought	0.20	1,329	33.23	0.14
Storm	0.23	1,692	42.30	0.18
Epidemic	0.83	3,886	97.15	0.40
Tsunami	0.08	83,525	2088.13	8.69
Earthquake	2.10	97,166	2429.15	10.11
Landslide	1.03	1,845	46.13	0.19
Volcano	0.93	661	16.53	0.07
Wildfire	0.23	300	7.50	0.03

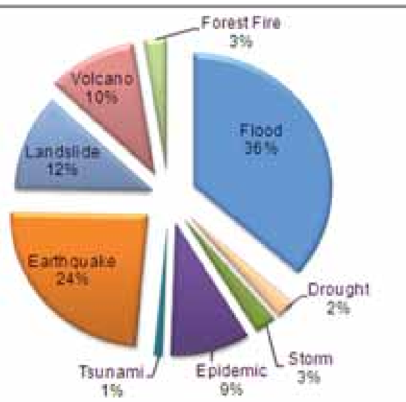


Figure 8: Percentage distribution of reported disasters in Indonesia

Figure 9 Average annual economic loss ($ million) of Indonesia

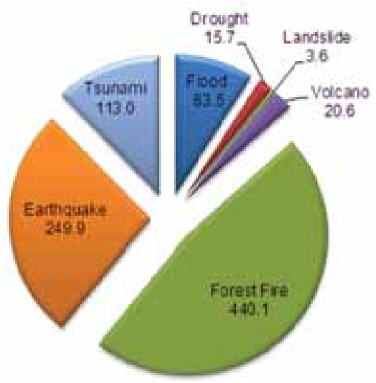


Figure 9: Average annual economic loss ($ million) of Indonesia

Loss data not sufficient for other disasters

Economic Loss Potential		
Annual exceedance probability	*Economic loss ($ million)*	*Percentage to GDP PPP (2009)*
0.5%	10,639.52	1.10
5.0%	3,623.14	0.37
20.0%	1,314.69	0.14

Regional setting

The Republic of Indonesia is one of the largest archipelagos in the world and is world's 16th largest country in terms of land area. According to the Indonesian Naval Hydro-Oceanographic office, it consists of 17,508 islands (5 major islands and about 30 smaller groups). Sumatra is the largest island covering an area of 473,606 sq km. The other important islands are Java/Madura, Kalimantan, Sulawesi and Papua. The country bridges two continents, Asia and Australia, forming an archipelago between the Indian Ocean and the Pacific Ocean. Indonesia has a total area of 1.905 million sq km and a population of over 240 million (2009). It is predominantly mountainous, with about 400 volcanoes, 100 of which are active. Puncak Jaya in Papua is the highest point of Indonesia with an elevation of 5,030 m and the lowest point is Indian Ocean (0 m) from mean sea level. Several important rivers flow through the country like Musi, Batanghari (Sumatra), Barito, Mahakam (Kalimantan), Memberamo, Digul (Papua) and Bengawan Solo, Citarum (Java). Lake Toba, located in Indonesia, is the largest volcanic lake in the world. Owing to its location along the equator, Indonesia has a tropical climate. The average annual rainfall ranges from 1,780 mm in the lowlands to 3,175 mm in the mountainous region. The average temperature in Indonesia is 27.7° C and the average temperature range is 1.5° C.

Hazard profile

Amongst all the ASEAN countries, Indonesia is one of the most vulnerable countries to natural hazards including forest (wild) fires, earthquakes and tsunamis, floods, volcanoes, droughts, landslides, typhoons (storms), and epidemics. Figure 8 shows the hazard-specific distribution of various disasters that occurred in the country for the period 1970-2009.

As a tropical country with forestland, forest fire events are frequent in Indonesia. Forest fires not only cause environmental damage but also cause haze, thereby influencing lives of people in and around the country. The major fire event of September 1997 in the Forest of Sumatra Island killed 240 people, affected 32,070 people and caused an estimated loss of $8.0 billion.
The country is located in the Ring of Fire where three earthquake belts run through the country, subjecting the areas of Sumatra, Java, Bali, East Nusa Tenggara, Maluku, Sulawesi and Irian Jaya to

seismic activities. The December 26, 2004 (Boxing day) earthquake (magnitude 9.1) and tsunami events killed 165,708 people, affected more than 0.5 million people and caused an economic loss of $4.45 billion in Indonesia. Indonesia lies in a region with low to very high seismic hazard (GSHAP, 1998).
The uncontrolled population growth, improper development and management of rivers causes floods during the rainy season and droughts during the dry season almost every year in some parts of Indonesia. The recent flood event of January 2007 in the Jakarta region killed 68 people, affected 217,087 people and caused an estimated damage of about $ 971 million.

Droughts also cause significant socio-economic losses in the country. A major drought in the year 1997 killed 672 people, affected 1.07 million people and caused an estimated damage of $ 88 million.

Risk profile

Vulnerability indicators such as the number of disaster events, deaths, affected population and economic losses have been plotted against hazard types as well as for 5-year intervals covering the 40-year period 1970-2009. Figure 10 (a, b, c) shows the plots of the total number of deaths, affected population and economic losses against each hazard type, while Figure 11 (a, b, c) presents the same variables plotted against 5-year periods.

Figure 10 shows that among all hazards, earthquakes and tsunamis combined together caused the largest number of deaths (180,691) followed by floods (5,420), landslides (1,845), typhoons/storms (1,692), droughts (1,329), volcanoes (661) and wildfires (300). Floods affected the largest number of people (7.581 million), followed by earthquakes and tsunamis combined together (7.477 million) and droughts (4.600 million). Earthquakes and tsunamis combined, also caused the highest economic loss ($9.412 billion); followed by wildfires (9.329 billion), volcanoes ($344 million), droughts ($160 million and landslides ($122 million).

The period 2000-2004 (Figure 11) was the worst in terms of number of deaths (168,588); 2005-2009 was the worst in terms of the number of people affected (7.203 million); while economic losses were worst in the period 1995-1999 ($10.213 billion), mainly due to the 1997-98 wildfires, 1996 floods, 1998 earthquake and 1997 drought.

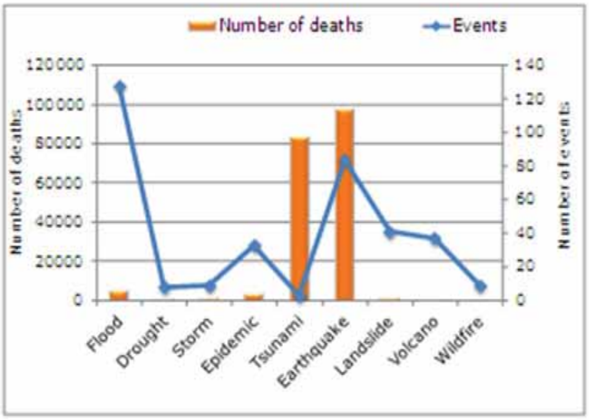
Floods had the highest frequency (3.20), followed by earthquakes (2.10), landslides (1.03) and volcanoes (0.93). The relative vulnerability was highest for earthquakes (10.11), followed by tsunamis (8.69) and floods (0.56).

Forest fires, earthquakes and tsunamis combined, and floods are the dominant risks in Indonesia, with an economic AAL of $440 million, $363 million, and $84 million respectively (Figure 9). It may be noted that AAL for forest fires is highest, which is contrary to popular belief in the country.

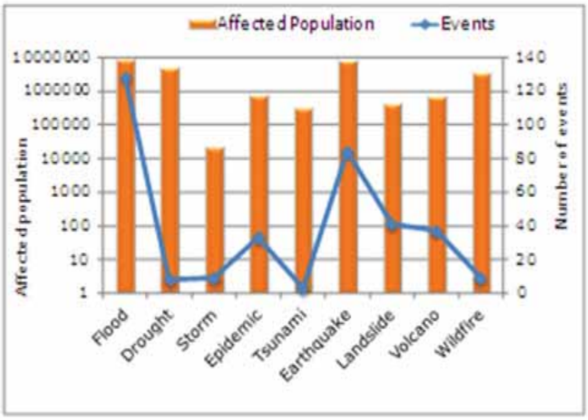
The 20-year return period (an event with 5 per cent probability of exceedance) loss for all natural hazards is $3.623 billion (0.37 per cent of GDP PPP); while the 200-year return period (an event with 0.5 per cent probability of exceedance, generally corresponds to a catastrophic event) loss is $10.64 billion (1.10 per cent of GDP PPP).

Figure 10 Indonesia: Disaster events and socio-economic impact by hazard type (1970-2009)

10a Disaster events and number of deaths



10b Disaster events and affected population



10c Disaster events and economic loss

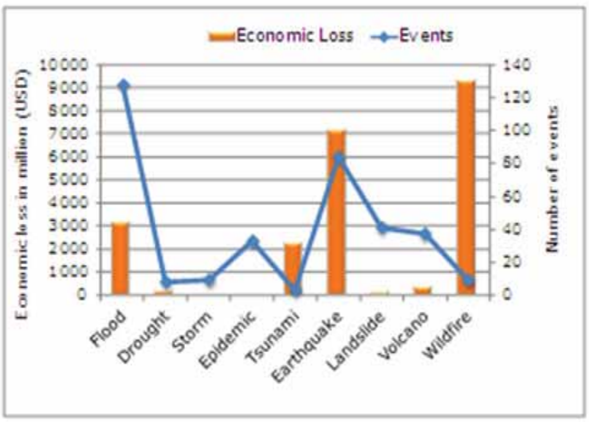
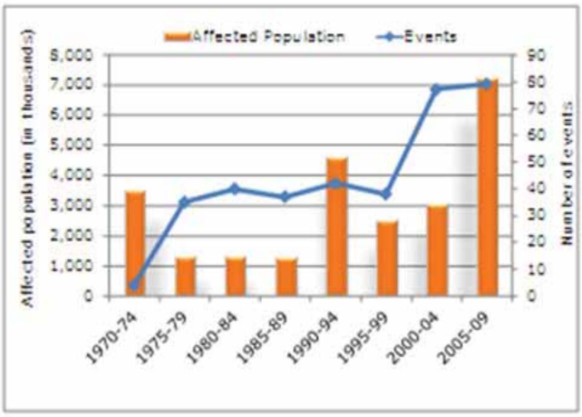


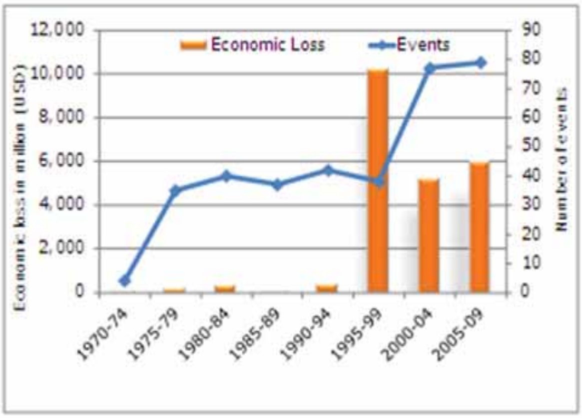
Figure 11 Indonesia: Disaster events and socio-economic impact by 5-year periods (1970-2009)

11a Disaster events and number of deaths

11b Disaster events and affected population



11c Disaster events and economic loss



5.4 Lao PDR

Overview

Country-level Information (2009)	
Geographic area (km^2)	236,800
Population	6,834,345
Population density (per sq.km)	29
Population growth (annual %)	2.32
Urban population (% of total)	31
Poverty headcount ratio, $2 a day (PPP) (% of population)	26 (2005)
Current GDP ($ billion)	5.72
GDP growth (annual %)	3.0
GDP - per capita (PPP)($)	2,100
Agricultural GDP (%)	39.2
Industry GDP (%)	33.9
Service GDP (%)	26.9
Human Development Index (HDI)	0.619 (2007)

Figure 12 Percentage distribution of reported disasters in Laos

Disaster Risk Statistics (1970-2009)				
Disaster type	*No. of disasters /year*	*Total no. of deaths*	*Deaths /year*	*Relative vulnerability (deaths/year/ million)*
Flood	0.68	146	3.65	0.53
Drought	0.18	-	0.00	0.00
Storm	0.15	223	5.58	0.82
Epidemic	0.20	786	19.65	2.88

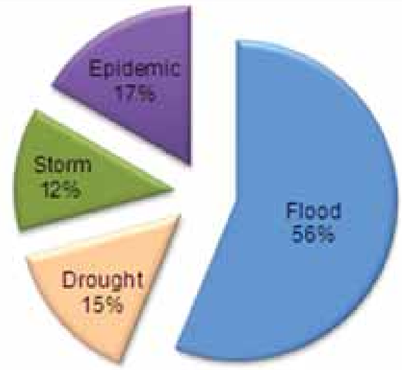


Figure 12: Percentage distribution of reported disasters in Laos

Figure 13 Average annual economic loss ($ million) of Lao PDR

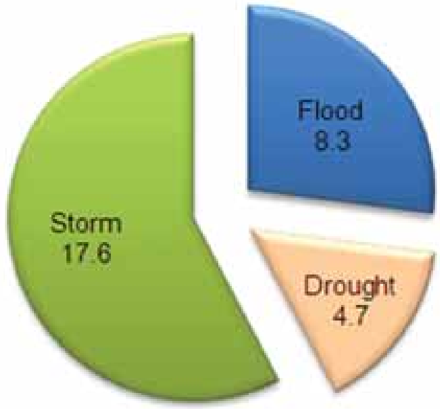


Figure 13: Average annual economic loss ($ million) of Lao PDR

Loss data not sufficient for other disasters

Economic Loss Potential		
Annual exceedance probability	*Economic loss ($ million)*	*Percentage to GDP PPP (2009)*
0.5%	425.77	2.91
5.0%	132.91	0.91
20.0%	44.29	0.30

Regional setting

The Lao People's Democratic Republic (PDR) also referred to as Lao PDR or Laos is a landlocked country, located in the heart of the Indochina peninsula in the Southeast Asia. The country is bordered by Myanmar and the People's Republic of China to the northwest, Vietnam to the east, Cambodia to the south and Thailand to the west. It covers a total area of 236,800 sq km and has a population of 6.834 million (CIA, 2009). The landscape of country mostly consists of rugged mountains (75 per cent) with some plains and plateaus. Phou (means mountain) Bia is the highest mountain in Xiengkhuang province with an elevation of 2,817 m above sea level and the lowest point is in the Mekong River (70 m). Laos is criss-crossed by many rivers and streams, of which the Mekong is the largest, flowing through 1,898 km of the country from north to south with 22 main tributaries. Its climate is characterised as warm, tropical climate dominated by two monsoons:

- The South-West monsoon: mid May-mid October, heavy and frequent rainfall and high humidity, wind, warm and wet
- The North-East monsoon: November-mid March, the atmospheric pressure is high, low temperature and humidity, cool dry air

The dry season spans during December-April. However, the weather remains semi-tropical in the northern mountains as well as in the high range of the Annamite Chain bordering Vietnam to the east. The annual rainfall varies from 1,000 mm – 3,000 mm with an average rainfall of 1,714 mm and the temperature varies from 15°C to 40°C.

Hazard profile

Lao PDR is vulnerable to natural hazards including typhoons (storms), floods, droughts, landslides, earthquakes, volcanoes and epidemics. Figure 12 shows the hazard-specific distribution of various disasters that occurred in the country from 1970 to 2009.

Flood is the major cause of disasters in Lao PDR - both in terms of frequency as well as in terms of consequences. There are floods along the Mekong River every year in the central and southern parts of the country and flash floods in northern part of the country. In 2002, floods affected over 0.25 million people and in 2005 this number was over 48 million people. During period 1970-2009, about 30 floods have been recorded in the country, including large floods that occurred in 1971, 1978, 1995, 1996, 2000, 2001, 2002, 2005, 2008 and 2009. The direct and indirect losses experienced by Lao PDR in 2008 were further compounded by the biggest flood ever in the history of the country in August 2008. The Mekong River exceeded historical levels and reached its highest peak in 100 years (personal communication, 2010).

Typhoons are a major cause of flooding in Lao PDR. The peak typhoon months are September and October and maximum they affect the country above 15 °N. The October 2009, typhoon Ketsana killed 16 persons, affected more than 0.12 million, and caused a reported economic loss of $100 million. Another major tropical storm Lewis in the year 1993 killed 8 people, and caused an estimated damage of about $ 302 million.

Droughts have also caused socio-economic damages in Lao PDR. They occur over the whole country, with the central and southern provinces being the most affected. A major drought event of 1988 affected 730,000 people, and caused a reported economic loss of $ 40 million.

Lao PDR lies in a region with low to high seismic hazard (GSHAP, 1998). There are a few low magnitude earthquakes reported in the northern part of the country, such as the November 1996 earthquake in Houay Xay district of Bokeo province (1998 Country Report, ADRC) and May 16, 2007 earthquake with magnitude of 6.3 located at a western border area of LAO PDR's with Thailand, Myanmar, and China (NGDC). However, no disaster caused by earthquakes in the country has been reported.

Landslides also pose a hazard and are triggered most often due to heavy rainfall causing damage to roads, especially in northern part of the country, where terrain is hilly (2005 Country Report, ADRC).

Risk profile

Vulnerability indicators such as the number of disaster events, deaths, affected population and economic losses have been plotted against hazard types as well as for 5-year intervals covering the 40-year period 1970-2009. Figure 14 (a, b, c) shows the plots of the total number of deaths, affected population and economic losses against each hazard type, while Figure 15 (a, b, c) presents the same variables plotted against 5-year periods.

Figure 14 shows that among all hazards, epidemics caused the largest number of deaths (786), followed by typhoons (223) and floods (143). Droughts affected the largest number of people (4.25 million) followed by floods (4.155 million) and typhoons (1.591 million); while typhoons caused the largest economic loss ($406 million) followed by floods and droughts.

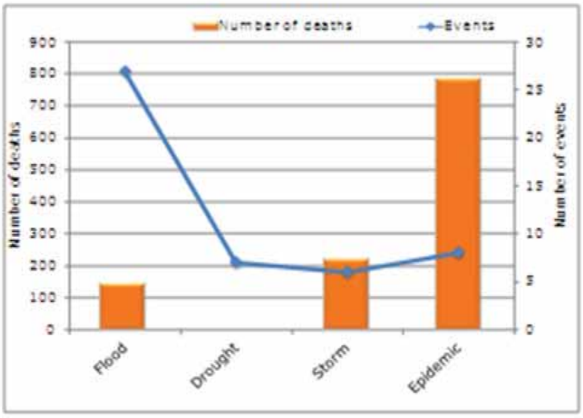
The period 1990-1994 (Figure 15) was the worst in terms of number of deaths (683) and economic losses; while 1975-1979 was worst in terms of number of people affected (3.959 million). The 1990-1994 economic losses ($353.68 million) were caused mainly by the 1993 typhoon Lewis. Floods disasters have the highest frequency (0.68); while epidemics have the highest death rate (19.65), followed by typhoons (5.58) and floods (3.65). The relative vulnerability was highest for epidemics (2.88), followed by typhoons (0.82), and floods (0.53).

Typhoons (Cyclonic storms) and floods are the dominant risk in Lao PDR with an economic AAL of $17.6 million and $8.3 million, respectively followed by droughts ($4.7 million) (Figure 13).

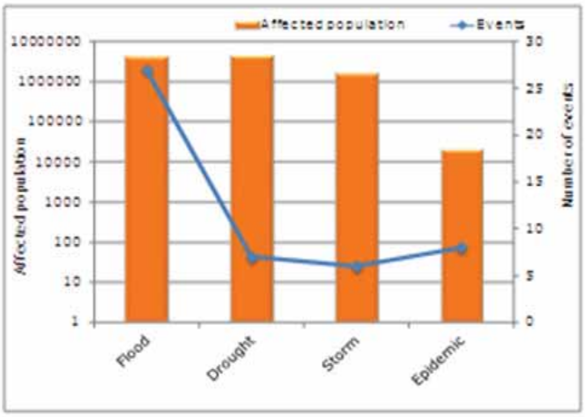
The 20-year return period (an event with 5 per cent probability of exceedance) loss for all natural hazards is $133 million (0.91 per cent of GDP PPP), while the 200-year return period (an event with 0.5 per cent probability of exceedance, generally corresponds to a catastrophic event) loss is $426 million (2.91 per cent of GDP PPP).

Figure 14 Lao PDR: Disaster events and socio-economic impact by hazard type (1970-2009)

14a Disaster events and number of deaths



14b Disaster events and affected population



14c Disaster events and economic loss

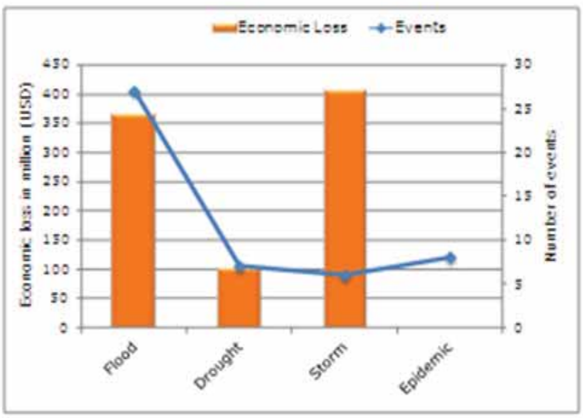
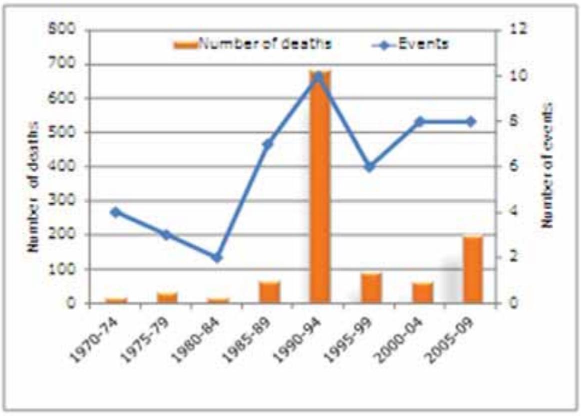
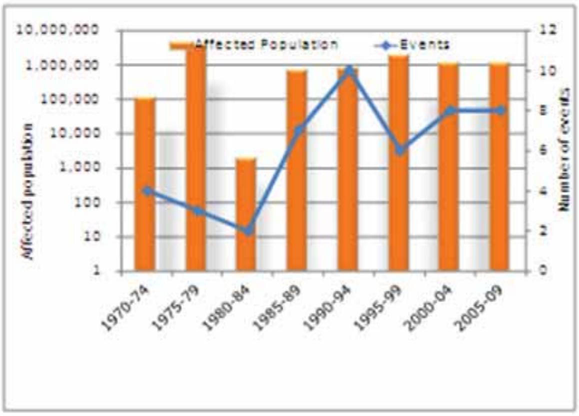


Figure 15 Lao PDR: Disaster events and socio-economic impact by 5-year periods (1970-2009)

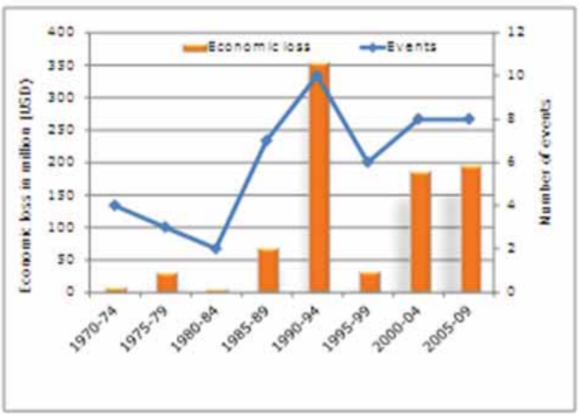
15a Disaster events and number of deaths



15b Disaster events and affected population



15c Disaster events and economic loss



5.5 Malaysia

Overview

Country-level Information (2009)	
Geographic area (km²)	329,847
Population	25,715,819
Population density (per sq.km)	78
Population growth (annual %)	1.723
Urban population (% of total)	70
Poverty headcount ratio, $2 a day (PPP) (% of population)	5.1 (2002)
Current GDP ($ billion)	207.4
GDP growth (annual %)	-2.8
GDP - per capita (PPP)($)	14,700
Agricultural GDP (%)	10.1
Industry GDP (%)	42.3
Service GDP (%)	47.6
Human Development Index (HDI)	0.829 (2007)

Figure 16 Percentage distribution of reported disasters in Malaysia

Disaster Risk Statistics (1970-2009)				
Disaster type	*No. of disasters /year*	*Total no. of deaths*	*Deaths/ year*	*Relative vulnerability (deaths/year/ million)*
Flood	0.83	255	6.38	0.25
Drought	0.03	0	0.00	0.00
Storm	0.15	275	6.88	0.27
Epidemic	0.30	538	13.45	0.52
Tsunami	0.03	80	2.00	0.08
Landslide	0.10	152	3.80	0.15
Forest Fire	0.10	0	0.00	0.00

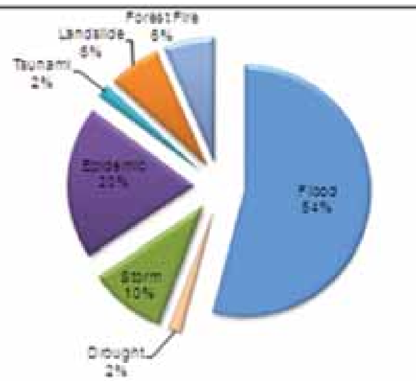


Figure 16: Percentage distribution of reported disasters in Malaysia

Figure 17 Average annual economic loss ($ million) of Malaysia

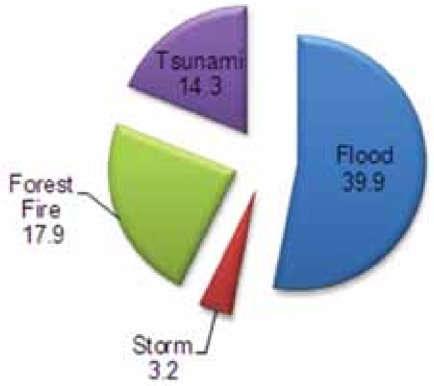


Figure 17: Average annual economic loss ($ million) of Malaysia

Loss data not sufficient for other disasters

Economic Loss Potential		
Annual exceedance probability	*Economic loss ($ million)*	*Percentage to GDP PPP (2009)*
0.5%	1031.76	0.27
5.0%	326.52	0.09
20.0%	85.34	0.02

Regional setting

Malaysia, located just north of the equator, is a Southeast Asian country consisting of 13 states and three Federal Territories. The country is separated into Peninsular Malaysia and Malaysian Borneo (East Malaysia) by the South China Sea. The Peninsular region is bordered by Thailand and Singapore whereas Malaysian Borneo shares borders with Indonesia and Brunei. Malaysia has an area of 329,847 sq km, with a population of 25.72 million (2009). The country has a coastline of 4,675 km (Peninsular Malaysia 2,068 km; Malaysian Borneo 2,607 km). Both Peninsular and East Malaysia consist of coastal plains rising to rugged forested mountainous interiors. The highest and lowest elevations of Malaysia are Gunung Kinabalu (4,100 m above mean sea level) in East Malaysia and Indian Ocean (0 m mean sea level). Malaysia has a hot and humid tropical climate. The country experiences both the southwest (April to October) and northeast (October to February) monsoons. The average temperature in Malaysia is 27.5°C. The highest monthly average temperature is 33°C whereas the lowest monthly average is 22°C. It receives an average rainfall of 2,409 mm.

Hazard profile

Malaysia is vulnerable to natural hazards including floods, forest fires, tsunami, cyclonic storms, landslides, earthquakes, epidemics, and haze. Figure 16 shows the hazard-specific distribution of various disasters that occurred in the period 1970-2009.

Floods have caused significant damages in the country. The recent flood event of January 2007, in the Johor-Pahang region killed 17 people, affected 137,533 people and caused the economic loss of about $ 605 million.

Forest fires have caused significant socio-economic losses in the country. The major event of August 1997 caused economic losses of about $ 300 million.

The Boxing Day (26th December) Tsunami event of 2004 caused a major disaster in the country by killing 80 people, affected 5,063 people and caused economic loss of $ 500 million.

The Storm events are also on the rise in the country, the major events of 1996, 1997 and the recent event of 2004 have altogether killed 273 people, affected a population of about 46,291 and caused an economic loss of $ 53 million.

Malaysia lies in a region with high to very high seismic hazard (GSHAP, 1998). However, no disaster caused by earthquakes in the country has been reported.

Landslide hazards are also significant in the country. However, no disaster caused by landslides in the country has been reported.

Risk profile

Vulnerability indicators such as the number of disaster events, deaths, affected population and economic losses have been plotted against hazard types as well as for 5-year intervals covering the 40-year period 1970-2009. Figure 18 (a, b, c) shows the plots of the total number of deaths, affected population and economic losses against each hazard type, while Figure 19 (a, b, c) presents the same variables plotted against 5-year periods.

Figure 18 shows that among natural hazards, epidemics caused the largest number of deaths (538), followed by storms (275), floods (255), landslides (152) and Tsunami (80). Floods affected the largest number of people (792,058) and caused the highest economic loss ($1.116 billion), followed by tsunami ($500 million), forest-fire ($302 million) and storms ($53 million).

The highest number of deaths from disasters caused by natural hazards was in the period 1995 - 1999 (Figure 19), when 556 people died. The period 2005-2009 was the worst in terms of number of people affected (322,526) and economic loss ($1.056 billion), mainly caused by the devastating floods of 2007.

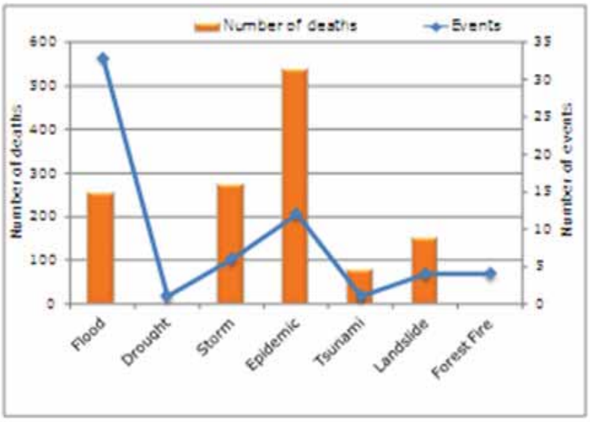
The disasters caused by floods has the highest frequency (0.83 per year), followed by epidemics, storms, landslides and forest fires. The death rate was highest for epidemics (13.45), followed by storms (6.88), floods (6.38), landslides (3.8) and tsunami (2.0). The relative vulnerability was highest for epidemics (0.52), followed by storms (0.27) and floods (0.25).

Floods are the dominant risk in Malaysia with an economic AAL of $ 39.9 million, followed by forest fires ($17.9 million), tsunami ($14.3 million) and storms ($3.2 million) (Figure 17).

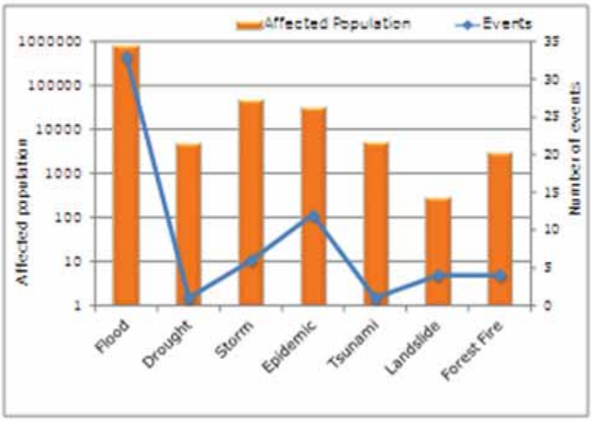
The 20-year return period (an event with 5 per cent probability of exceedance) loss for all natural hazards is $327 million (0.09 per cent of GDP PPP), while the 200-year return period (an event with 0.5 per cent probability of exceedance, generally corresponds to a catastrophic event) loss is $1.032 billion (0.27 per cent of GDP PPP).

Figure 18 Malaysia: Disaster events and socio-economic impact by hazard type (1970-2009)

18a Disaster events and number of deaths



18b Disaster events and affected population



18c Disaster events and economic loss

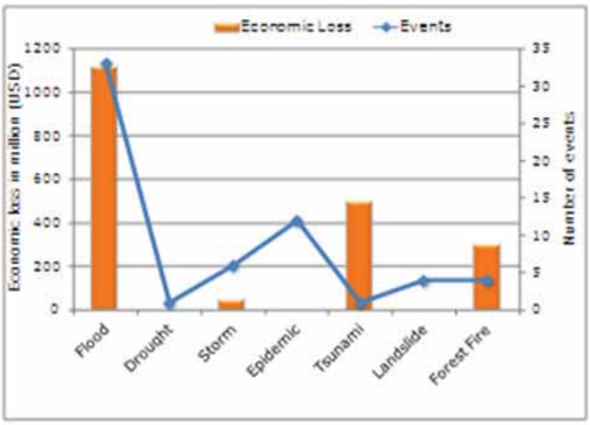
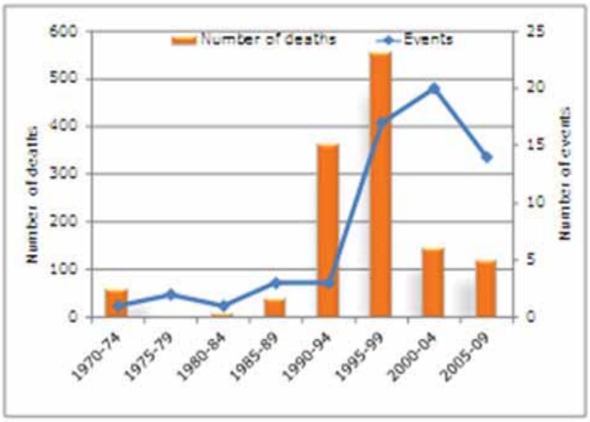
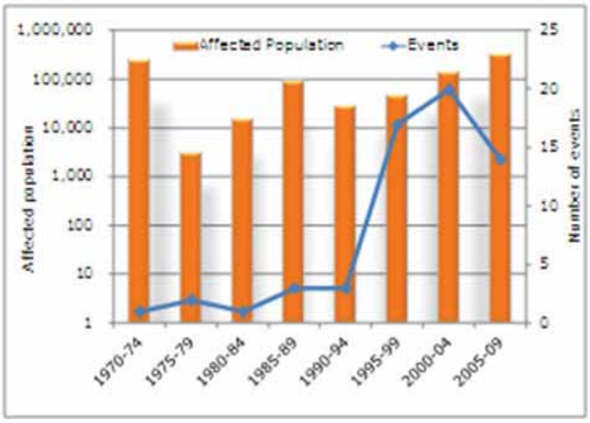


Figure 19 Malaysia: Disaster events and socio-economic impact by 5-year periods (1970-2009)

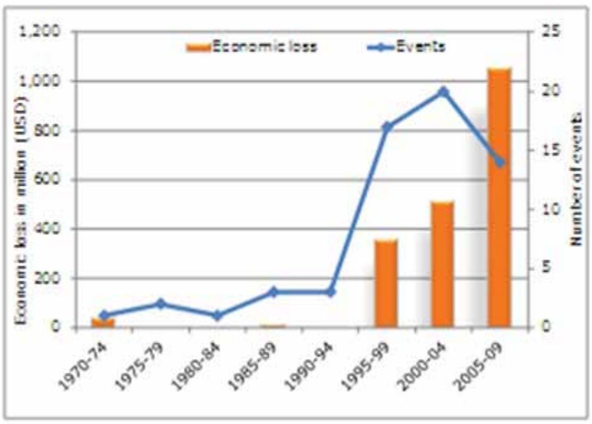
19a Disaster events and number of deaths



19b Disaster events and affected population



19c Disaster events and economic loss



5.6 Myanmar

Overview

Country-level Information (2009)	
Geographic area (km²)	676,578
Population	48,137,741
Population density (per sq.km)	71
Population growth (annual %)	0.783
Urban population (% of total)	33
Poverty headcount ratio, $2 a day (PPP) (% of population)	32.7 (2007)
Current GDP ($ billion)	26.52
GDP growth (annual %)	1.0
GDP - per capita (PPP)($)	1,200
Agricultural GDP (%)	42.9
Industry GDP (%)	19.8
Service GDP (%)	37.3
Human Development Index (HDI)	0.586 (2007)

Figure 20 Percentage distribution of reported disasters in Myanmar

Disaster Risk Statistics (1970-2009)				
Disaster type	*No. of disasters / year*	*Total no. of deaths*	*Deaths/ year*	*Relative vulnerability (deaths/year/ million)*
Flood	0.43	364	9.10	0.19
Storm	0.18	138,864	3471.60	72.12
Epidemic	0.05	40	1.00	0.02
Landslide	0.05	41	1.03	0.02
Forest Fire	0.05	8	0.20	0.00
Earthquake	0.05	-	0.00	0.00
Tsunami	0.03	71	1.78	0.04

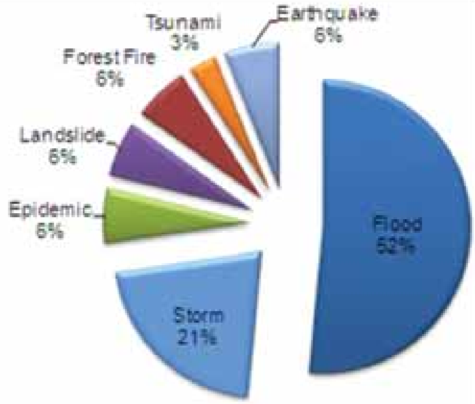


Figure 20: Percentage distribution of reported disasters in Myanmar

Figure 21 Average annual economic loss ($ million) of Myanmar

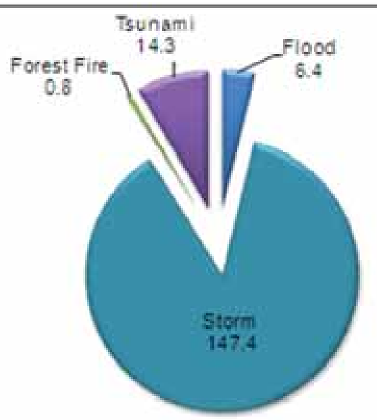


Figure 21: Average annual economic loss ($ million) of Myanmar

Loss data not sufficient for other disasters

Economic Loss Potential		
Annual exceedance probability	*Economic loss ($ million)*	*Percentage to GDP PPP (2009)*
0.5%	3093.22	5.48
5.0%	872.75	1.54
20.0%	226.68	0.40

Regional setting

Myanmar lies between 9°32′ N and 28°31′ N latitude and between 92°10′ E and 101°11′ E longitude. The country is bordered by China on the northeast, Laos on the east, Thailand on the southeast, Bangladesh on the west, India on the northwest and the Andaman Sea/Bay of Bengal on the south and southwest. Myanmar has a total population of 48.138 million (2009) with a total land area of 676,578 sq km. The country has a land boundary of 5,876 km and coastline of 1,930 km. The topography is characterized by central lowlands, which are ringed by steep, rugged highlands. Based on topographic condition, Myanmar is divided into three parts – the western ranges (Himalayan ranges that divide India and Myanmar), the central plains (Ayeyarwadi delta and other river basins) and the eastern hilly regions (Shan Plateau). Hkakabo Razi is the highest point of Myanmar with an elevation of 5,881 m above mean sea level and the Andaman Sea is the lowest point (0 m). Ayeyarwadi is country's longest river and the major part of Myanmar's population lives in this river valley.

Myanmar has a tropical monsoon climate. However, due to diverse topographic conditions the climate varies widely within the country. The country has a cloudy, rainy, hot, humid summer during the southwest monsoon (June to September) and a less cloudy, scanty rainfall, lower humidity, mild temperature during the northeast monsoon (December to April). The average temperature in Myanmar is 27°C. The highest and lowest monthly average temperature ranges from 38°C in April to 13°C in January. The country receives an average rainfall of 776 mm per year.

Hazard profile

Myanmar is one of the most vulnerable countries to natural hazards, including cyclonic storms, floods, earthquakes, tsunamis, forest fires, landslides, and epidemics. Figure 20 shows the hazard-specific distribution of various disasters that occurred in the country for the period 1970-2009.

Having a long coastline along the western part of the country, the Bay of Bay of Bengal is regarded as a cyclone vulnerable area. Being a heavy rainfall country, Myanmar suffers from floods in the mid-monsoon period of August to October (2005

Country Report, ADRC). The complex topography of this mountainous country, its high rainfall levels, and the large number of glaciers mean that Myanmar is highly exposed to the flood hazard.

Analysis of disaster data shows that the country is severely affected by cyclonic storms. The recent tropical cyclone Nargis of May 2008 killed 138,366 people, affected about 2.42 million people, and caused an estimated economic loss of $ 4.0 billion.

The single major Tsunami event of 26th December 2004 caused a major disaster in the country by killing 71 people, affecting 15,700 people and causing an economic loss of $ 500 million.

Flood events are also very frequent in the country. There were 17 flood events in the past three decades. The flood events of 1991 and 1992 together killed 28 people, affected 364,601 people and caused an economic loss of $ 135 million.

Landslide hazard is also significant in Myanmar.

Myanmar lies in a region with moderate to very high seismic hazard (GSHAP, 1998). The seismic hazard in the northern part of the country in the Kachin state is very high in comparison to southern part of the country. There are three regions of earthquake epicentres concentration in Myanmar. The first one lies along the eastern foothills of Rakhine Yoma, Chin Hills and Naga Hills. The second zone is located along the Sagaing facet, the third zone is situated along the northern edge of Shan plateau south of Mogok. These belts are closely related to the tectonics of Myanmar. Large earthquakes occurred in Bago in 1930, in Yangon in 1970, and in Pagan in 1975 (2003 Country Report, ADRC).

Risk profile

Vulnerability indicators such as the number of disaster events, deaths, affected population and economic losses have been plotted against hazard types as well as for 5-year intervals covering the 40-year period 1970-2009. Figure 22 (a, b, c) shows the plots of the total number of deaths, affected population and economic losses against each hazard type, while Figure 23 (a, b, c) presents the same variables plotted against 5-year periods.

Figure 22 shows that among natural hazards, cyclones (storms) caused the largest number of deaths (138,864), followed by floods (364), tsunami (71), landslides (41), epidemics (40), and forest fire (8). Cyclones affected the largest population (2.738 million) and caused the highest economic loss ($4.011 billion).

The period 2005-2009 (Figure 23) was the worst in terms of number of deaths (138,501), number of affected people (2.658 million), and in terms of economic loss ($4 billion), mainly caused by the 2008 cyclone Nargis on May 02-03, 2008.

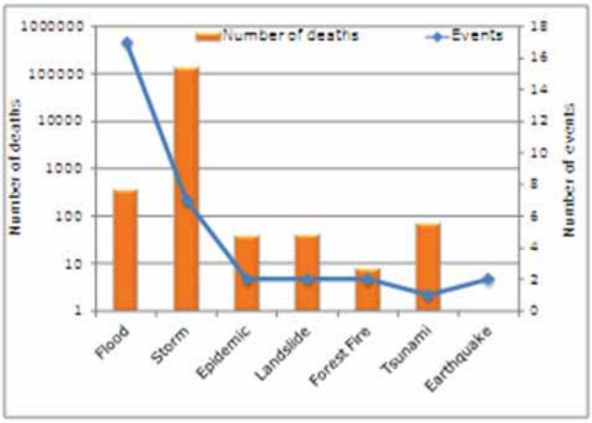
Floods had the highest frequency (0.43), followed by cyclones (0.18), earthquakes, landslides, forest fires, and epidemics with the same frequency (0.05). The death rate was highest for cyclones (3,472), followed by floods (9). The relative vulnerability was also highest for cyclones (72.12), followed by floods (0.19) and landslides (0.02).

Cyclones are the dominant risks in Myanmar (Figure 21), with an economic AAL ($147.4 million), followed by tsunami ($14.3 million), floods ($6.4 million), and forest fires ($0.8 million).

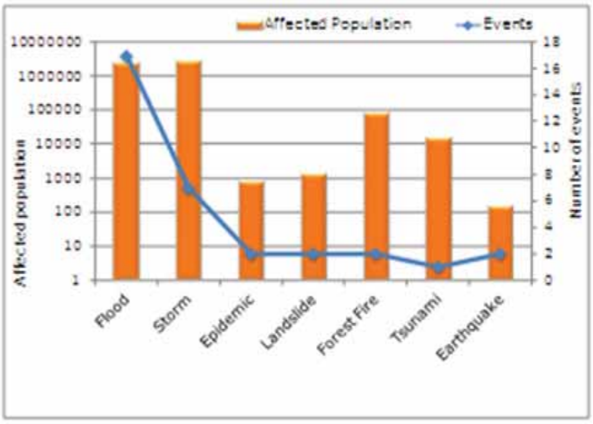
The 20-year return period (an event with 5 per cent probability of exceedance) loss for all natural hazards is $873 million (1.54 per cent of GDP PPP), while the 200-year return period (an event with 0.5 per cent probability of exceedance, generally corresponds to a catastrophic event) loss is $3.093 billion (5.48 per cent of GDP).

Figure 22 Myanmar: Disaster events and socio-economic impact by hazard type (1970-2009)

22a Disaster events and number of deaths



22b Disaster events and affected population



22c Disaster events and economic loss

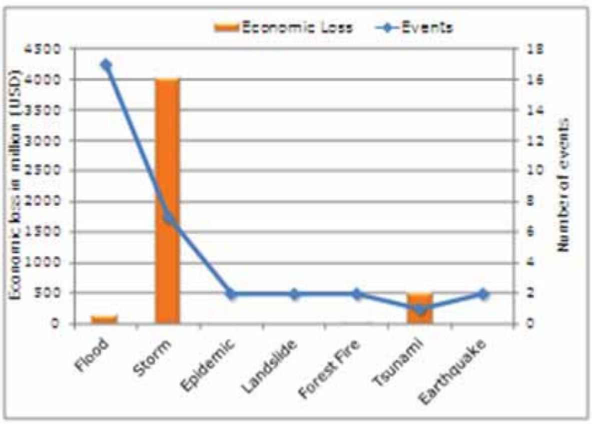
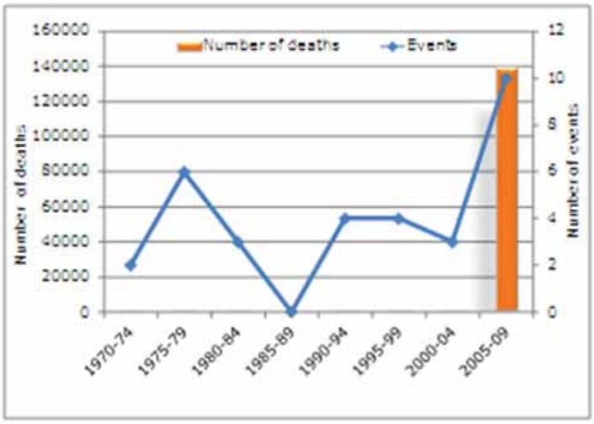
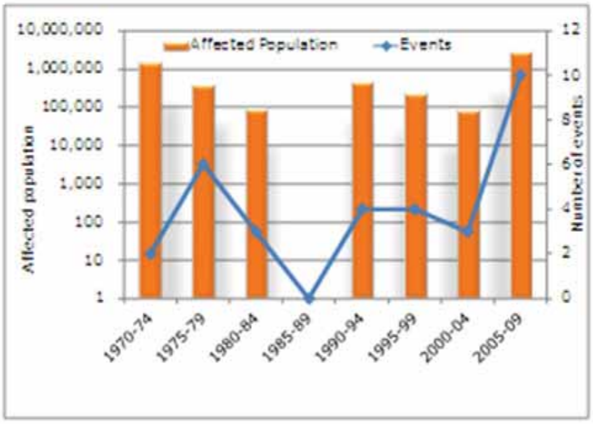


Figure 23 Myanmar: Disaster events and socio-economic impact by 5-year periods (1970-2009)

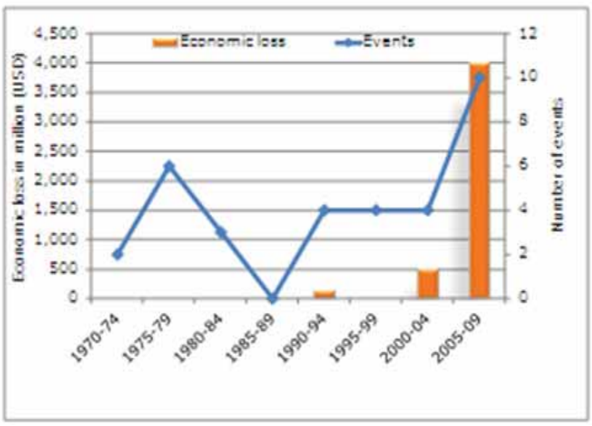
23a Disaster events and number of deaths



23b Disaster events and affected population



23c Disaster events and economic loss



5.7 Philippines

Overview

Country-level Information (2009)	
Geographic area (km²)	300,000
Population	97,976,603
Population density (per sq.km)	327
Population growth (annual %)	1.957
Urban population (% of total)	65
Poverty headcount ratio, $2 a day (PPP) (% of population)	30 (2003)
Current GDP ($ billion)	158.7
GDP growth (annual %)	1.6
GDP - per capita (PPP)($)	3,300
Agricultural GDP (%)	14.9
Industry GDP (%)	30.9
Service GDP (%)	54.2
Human Development Index (HDI)	0.751 (2007)

Figure 24 Percentage distribution of reported disasters in Philippines

Disaster Risk Statistics (1970-2009)				
Disaster type	*No. of disasters /year*	*Total no. of deaths*	*Deaths/ year*	*Relative vulnerability (deaths/year/ million)*
Flood	2.45	2,974	74.35	0.76
Storm	6.18	31,373	784.33	8.01
Epidemic	0.33	460	11.50	0.12
Landslide	0.68	2,656	66.40	0.68
Forest Fire	0.03	2	0.05	0.00
Earthquake	0.40	8,569	214.23	2.19
Drought	0.20	8	0.20	0.00
Volcano	0.40	719	17.98	0.18

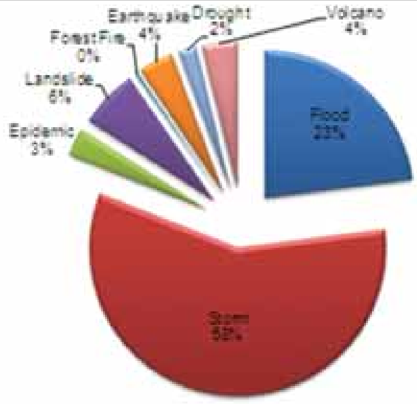


Figure 24: Percentage distribution of reported disasters in Philippines

Figure 25 Average annual economic loss ($ million) of Philippines

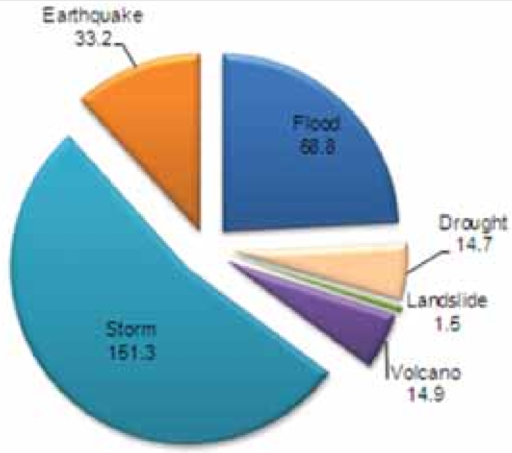


Figure 25: Average annual economic loss ($ million) of Philippines

Loss data not sufficient for other disasters

Economic Loss Potential		
Annual exceedance probability	*Economic loss ($ million)*	*Percentage to GDP PPP (2009)*
0.5%	2,144.02	0.66
5.0%	1,208.46	0.37
20.0%	686.08	0.21

Regional setting

The Republic of Philippines, comprising of more than 7,100 islands in Southeast Asia, is an archipelago between the Philippine and South China Seas. The country is bounded by South China Sea in the west, Pacific Ocean in the east, Sulu and Celebes Sea in the south and the Bashi Channel in the north. It covers a total area of 300,000 sq km and has a population of 97.977 million (2009). It has three major island groups- Luzon in the north, Visayas in the middle and Mindanao in the South. The topography of Philippines is mostly mountainous with narrow to extensive coastal lowlands. Most of the mountainous islands are covered by tropical rainforests and are volcanic in origin. Mount Apo, located in the Mindanao island is the highest point of the country with an elevation of 2,954 m above sea level. The lowest elevation is marked by the Philippine Sea (0 m). The Cagayan River and Laguna de bay are respectively the longest river and largest lake in the Philippines. Philippines experiences tropical marine climate through the northeast monsoon (November to April) and the southwest monsoon (May to October). The country has an average temperature of 27.7 °C and average rainfall of 2,061 mm per year. The monthly average temperature varies from 34 °C in May to 22 °C in January and February.

Hazard profile

Philippines is one of the most vulnerable country to natural hazards, including cyclonic storms, floods, earthquakes, volcanoes, droughts, forest fires, landslides, and epidemics. The reported disaster data for the past 40 years (Figure 24) shows the hazard-specific distribution of various disasters that occurred in the country for the period 1970-2009.

The Philippines, located near the western edge of the Pacific Ocean, is in the direct path of seasonal typhoons and monsoon rains, which bring floods, storms, and their attendant landslides and other forms of devastation. The country is also located in the “ring of fire”, where the continental plates collide and cause periodic earthquakes and volcanic eruptions.

The analysis of disaster data shows that Philippines is frequented by storms. The country witnessed 243 storms in the last three decades.

The recent tropical cyclone Pepeng in October 2009, killed 539 people, affected a population of 4.5 million and caused an economic loss of $ 592 million. Moreover, in the past three decades storms have caused total economic loss of $ 6.2 billion.

Floods are also very frequent in the country with 98 events in the last three decades. The major flood event of September 1995 in the South Cotabato region, killed 416 people, affected more than 24,000 people and caused an estimated economic loss of $ 700 million.

The country is also prone to earthquakes and Philippines lies in a region with low to very high seismic hazard (GSHAP, 1998). The September 16th 1990 Luzon earthquake of magnitude 7.7, with its epicentre near Rizal city killed more than 2,412 people, affected more than 1.5 million and caused an economic loss of $ 370 million. The earthquake caused secondary hazards such as liquefaction and landslides affecting infrastructure of the region badly (Rantucci, 1994).

Philippines is also prone to disasters caused by drought. There were about 8 events of drought during 1970-2009, these events altogether affected more than 6.5 million people and caused an economic loss of $ 353 million.

There are also a significant number of volcanic eruptions in the country. As per available disaster data, the country has been affected by 16 events of volcanic eruption in the past three decades. The major volcanic eruption of Mount Pinatubo in June 1991, killed 640 people, affected more than 1.0 million people and caused an economic loss of $ 211 million.

Twenty-seven events of landslides occurred during the years 1970-2009. These events altogether killed about 2,600 people, affected 315,000 people and caused an economic loss of $ 33 million.

Risk profile

Vulnerability indicators such as the number of disaster events, deaths, affected population and economic losses have been plotted against hazard types as well as for 5-year intervals covering the 40-year period 1970-2009. Figure 26 (a, b, c) shows the plots of the total number of deaths, affected population and economic losses against each hazard type, while Figure 27 (a, b, c) presents the same variables plotted against 5-year periods.

Figure 26 shows that among natural hazards, typhoons (storms) caused the largest number of deaths (31,373), affected the largest population (111.93 million), and caused the highest economic loss ($6.72 billion).

The period 1990-1994 (Figure 27) was the worst in terms of number of deaths (11,483), while 2005-2009 was the worst in terms of affected population (40.795 million) and economic losses ($2.294 billion), caused mainly by September–October 2009 typhoon Pepeng (Parma) and storm Ondoy (Ketsana).

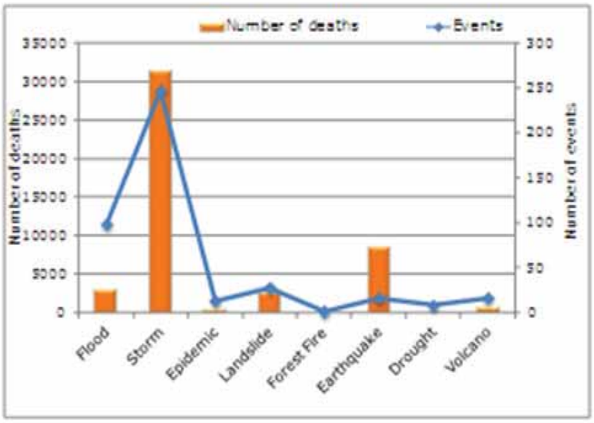
Storms has the highest frequency (6.18), followed by floods (2.45), landslides (0.68), earthquakes and volcano with the same frequency (0.40). The death rate was highest for storms (784), followed by earthquakes (214), and floods (74). The relative vulnerability was also highest for storms (8.01), followed by earthquakes (2.19), and floods (0.76).

Storms are the dominant risk in Philippines with an economic AAL of $151.3 million, followed by floods ($68.8 million), earthquakes ($33.2 million), volcanoes ($14.9 million), droughts ($14.7 million), and landslides (1.5 million) (Figure 25).

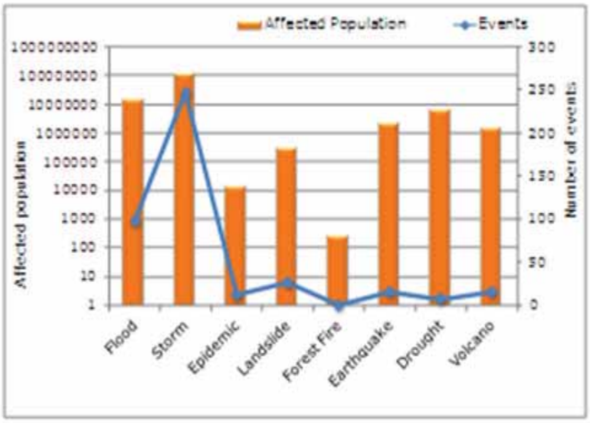
The 20-year return period (an event with 5 per cent probability of exceedance) loss for all natural hazards is $1.208 billion (0.37 per cent of GDP PPP), while the 200-year return period (an event with 0.5 per cent probability of exceedance, generally corresponds to a catastrophic event) loss is $2.14 billion (0.66 per cent of GDP PPP).

Figure 26	Philippines: Disaster events and socio-economic impact by hazard type (1970-2009)

26a Disaster events and number of deaths



26b Disaster events and affected population



26c Disaster events and economic loss

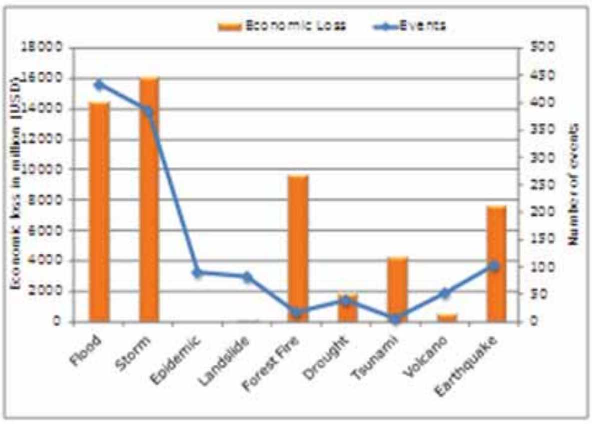
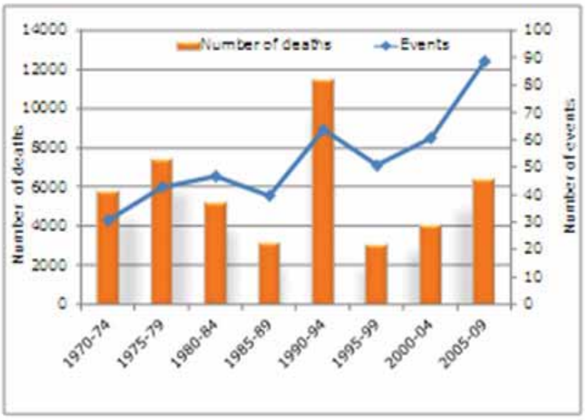
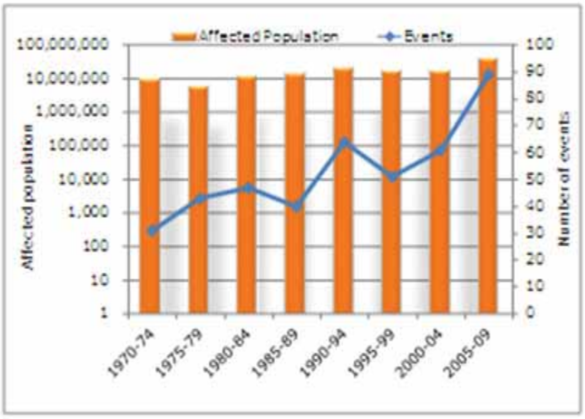


Figure 27	Philippines: Disaster events and socio-economic impact by 5-year periods (1970-2009)

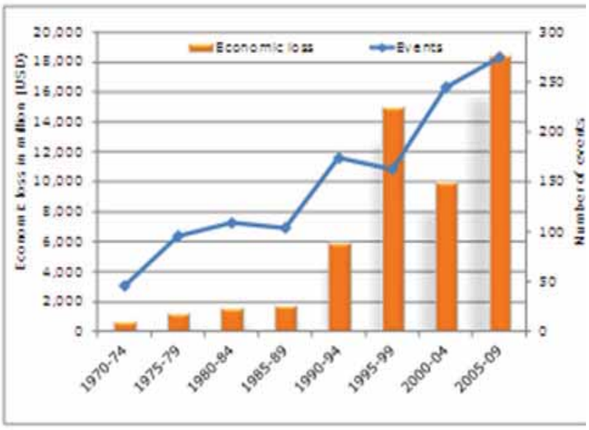
27a Disaster events and number of deaths



27b Disaster events and affected population



27c Disaster events and economic loss



5.8 Singapore

Overview

Country-level Information (2009)	
Geographic area (km²)	697
Population	4,657,542
Population density (per sq.km)	6,682
Population growth (annual %)	0.998
Urban population (% of total)	100
Poverty headcount ratio, $2 a day (PPP) (% of population)	NA
Current GDP ($ billion)	163.1
GDP growth (annual %)	-2.6
GDP - per capita (PPP)($)	50,300
Agricultural GDP (%)	-
Industry GDP (%)	26.8
Service GDP (%)	73.2
Human Development Index (HDI)	0.944 (2007)

Figure 28 Percentage distribution of reported disasters in Singapore

Disaster Risk Statistics (1970-2009)				
Disaster type	*No. of disasters / year*	*Total no. of deaths*	*Deaths/ year*	*Relative vulnerability (deaths/year/ million)*
Epidemic	0.08	36.00	0.90	0.19

Figure 28: Percentage distribution of reported disasters in Singapore

Figure 29 Average annual economic loss ($ million) of Singapore

Figure 29: Average annual economic loss ($ million) of Singapore	Economic Loss Potential		
No disaster data available	Annual exceedance probability	Economic loss ($ million)	Percentage to GDP PPP (2009)
	0.5%		
	5.0%		
	20.0%		

Regional setting

The Republic of Singapore is an island city-state off the southern tip of the Malay Peninsula between Malaysia and Indonesia. It is the smallest nation of ASEAN. Singapore consists of 56 islands including the mainland Singapore. Most of the territory of Singapore is occupied by lowlands, including a gently undulating central plateau containing a water catchment area and nature preserve. The country has a total area of 697 sq km and a population of 4.6 million making it the most densely populated country in ASEAN. The highest and lowest elevations are 166 metres (Bukit Timah Hill) and 0 m (Singapore Strait) above mean sea level, respectively. The country has a coastline of 193 km. Singapore has a hot and humid tropical climate characterized by two distinct main monsoon seasons, the northeastern monsoon (December-March) and the southeastern monsoon (June-September). Separating these two monsoon seasons are two relatively short inter-monsoon periods (April–May and October–November), marked by frequent afternoon and early evening thunderstorms. Singapore has abundant rainfall throughout the year with an annual average rainfall of 2,282 mm. The average highest and lowest monthly mean temperature is 32°C and 24°C respectively. The diurnal temperature variation is small and is observed to reach highs of 31°C to 33°C during the day and lows of 23°C to 25°C during night (http://app.nea.gov.sg).

Hazard profile

Historically, Singapore is one of the least natural hazard-prone countries in the ASEAN region. The country is vulnerable to low levels of hazards from earthquakes, cyclonic storms, floods, and seasonal trans-boundary events of smoke/haze. Although Singapore is spared from disasters caused by natural hazards, the challenges for the emergency services are in preventing and mitigating manmade disasters in a highly urbanised environment with many high-rise buildings and Hazardous Material (HazMat) industries. About 80 percent of country's population resides in high-rise buildings (2005 Country Report, ADRC).

The ASEAN region is reputedly a region of high seismic hazard. Although Singapore is located in the region with low seismic hazard (GSHAP, 1998), however due to its location, the high rise buildings on a soft-soil in Singapore are vulnerable to large to great far-field earthquakes from the surrounding regions such as Sumataran subduction zone and Sumatran strike slip fault. The Sumataran subduction zone has generated four great earthquakes in the last 300 years. Two occurred in 1800s: moment magnitude (Mw) of 8.75 in 1883 Mw 8.4 in 1861 (Newcomb and McCann, 1987). Two other earthquakes occurred recently: Mw 9.3 Banda Aceh on December 26, 2004, which generated the great tsunami and Mw 8.7 Nias island earthquake on March 28, 2005. The Sumatran strike slip fault is a fragmented fault and runs through the entire length of Sumatra of about

1,900 km. Historically, the largest earthquakes that occurred in this fault are Mw 7.7 in 1892 and Mw 7.6 in 1943. The recent tremors from the September 2009 Sumatra offshore earthquake were experienced in 234 buildings, located mainly in the central, northern and western parts of Singapore (http://www.khaleejtimes.com).

Although there are no major flood events in the country, heavy rain for few hours can cause local flooding in some parts of the country. The continuous drainage improvement works by the local authorities have significantly reduced the flood-prone areas in Singapore (http://www.getforme.com/previous2006/071206_floodproneareasinsingaporereducedby15footballfields.htm).

The country is also prone to frequent smoke/haze from the forest fires of Indonesia. These haze events severely affect the visibility as well as cause health problems (http://www.siiaonline.org/?q=events/ singapores-efforts-transboundary-haze-prevention)

Moreover, country is also affected by various epidemics. The recent epidemic Severe Acute Respiratory Syndrome (SARS) in 2003 killed 33 people and affected 205 people.

Risk profile

As per the reported historical disaster data (http://www.preventionweb.net, EM DAT), Singapore has suffered only three disaster event caused by epidemics. However, the country is at risk from far-field large to great magnitude earthquakes. Singapore is at a distance (nearest) of 600 km from Sumataran subduction zone and 400 km away from Sumatra fault, which have the potential of generating large to great magnitude earthquakes, respectively. The seismic waves from such earthquakes will be rich in low frequency and may produce a resonance like situation to high-rise buildings on soft-soil.

The country does not suffer from flood disasters due to the continuous drainage improvement works by the local authorities, and only has a risk of local flooding in some low-lying parts of the country.

Due to non-availability of disaster data, the disaster risk analysis - statistical and economic loss potential (AAL and economic losses for different probabilities of exceedance) has not been carried out.

5.9 Thailand

Overview

Country-level Information (2009)	
Geographic area (km^2)	513,120
Population	65,998,436
Population density (per sq.km)	129
Population growth (annual %)	0.626
Urban population (% of total)	33
Poverty headcount ratio, $2 a day (PPP) (% of population)	10 (2004)
Current GDP ($ billion)	266.4
GDP growth (annual %)	-3.5
GDP - per capita (PPP)($)	8,100
Agricultural GDP (%)	12.3
Industry GDP (%)	44.0
Service GDP (%)	43.7
Human Development Index (HDI)	0.783 (2007)

Figure 30 Percentage distribution of reported disasters in Thailand

Disaster Risk Statistics (1970-2009)				
Disaster type	*No. of disasters /year*	*Total no. of deaths*	*Deaths/ year*	*Relative vulnerability (deaths/year/ million)*
Flood	1.48	2,684	67.10	1.02
Storm	0.75	927	23.18	0.35
Epidemic	0.13	212	5.30	0.08
Landslide	0.08	47	1.18	0.02
Forest Fire	0.03	-	-	-
Tsunami	0.03	8,345	208.63	3.16
Earthquake	0.03	-	-	-
Drought	0.15	-	-	-

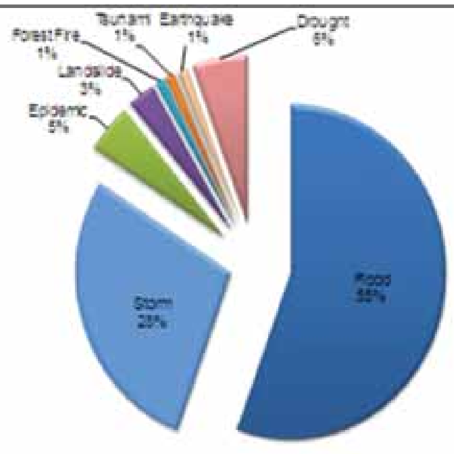


Figure 30: Percentage distribution of reported disasters in Thailand

Figure 31 Average annual economic loss ($ million) of Thailand

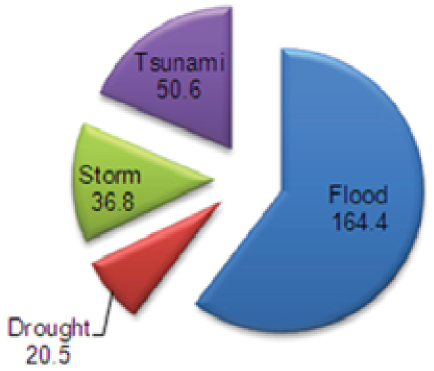


Figure 31: Average annual economic loss ($ million) of Thailand

Loss data not sufficient for other disasters

Economic Loss Potential		
Annual exceedance probability	*Economic loss ($ million)*	*Percentage to GDP PPP (2009)*
0.5%	3219.65	0.60
5.0%	1215.71	0.23
20.0%	421.62	0.08

Regional setting

Thailand is located in the centre of the Southeast Asian Peninsula, covering an area of 513,120 sq km. The country has a population of more than 65.998 million (2009). Myanmar and Laos in the north, Laos and Cambodia in the east, the Gulf of Thailand and Malaysia in the south and the Andaman Sea and southern extremity of Myanmar in the west, border the country. It has a coastline of 3,219 km. The northern part of Thailand is mountainous covered by dense forest and the eastern part consists of the Khorat Plateau. The central part of the country is covered predominantly by the flat Chao Phraya river valley, which runs into the Gulf of Thailand. The narrow southern isthmus (Kra Isthmus) joins the landmass with the Malay Peninsula. The highest and lowest elevations are 2,576 m (Doi Inthanon) and 0 m (Gulf of Thailand) above mean sea level respectively. Chao Phraya and Mekong are among the most important rivers of Thailand. The climate of Thailand is mostly tropical. The whole country can be divided into two climatic zones. The north, northeast, southeast and central parts of the country (including Bangkok) experience three distinct seasons: rainy (June to October), cool (November to February) and hot and sunny weather (March to May). The southern part, on the other hand, has a tropical rainforest climate. The southern isthmus remains hot and humid throughout the year. The average temperature and rainfall of Thailand is 27.7°C and 1,492 mm, respectively.

Hazard profile

Thailand is vulnerable to natural hazards, including floods, tsunamis, storms, droughts, landslides, forest fire, earthquakes, and epidemics. Figure 30 shows the hazard-specific distribution of various disasters that occurred in the country for the period 1970-2009.

Thailand is most frequently affected by floods. There have been about 59 flood events during 1970-2009. Various flood events in the year 1993 alone killed 41 people, affected 890,000 people, and caused total economic losses of $ 2 billion.

Cyclonic storms have also caused significant disasters in the country. There have been around 30 storm events in the past three decades, which killed 1,696 people, affected more than 3.2 million people, and caused a total economic loss of $ 911 million.

The major Tsunami event of 26th December

2004 caused a major disaster in the country by killing 8,345 people, affecting 67,007 people, and causing an economic loss of $ 1 billion.

Droughts have also been a significant hazard in the country. The recent major drought event of year 2005 caused an economic loss of $ 420 million.

Thailand lies in a region with low to high seismic hazard (GSHAP, 1998). The May 16, 2007 earthquake with magnitude of 6.3 located at a western border area of LAO PDR's with Thailand, Myanmar, and China (NGDC) rocked Northern provinces, including Chiang Rai, Chiang Mai and Nan causing people fleeing out of their houses in panic (http://thailand.prd.go.th). As per report, one of the damaged structures was the main Pagoda of Wat Phra That Chom Kitti in Chiang Rai, where cracks were reported with a broken top part; however, there have been no reported disaster events due to earthquakes in the past three decades in Thailand.

Risk profile

Vulnerability indicators such as the number of disaster events, deaths, affected population and economic losses have been plotted against hazard types as well as for 5-year intervals covering the 40-year period 1970-2009. Figure 32 (a, b, c) shows the plots of the total number of deaths, affected population and economic losses against each hazard type, while Figure 33 (a, b, c) presents the same variables plotted against 5-year periods.

Figure 32 shows that among natural hazards, tsunami caused the largest number of deaths (8,345); while floods affected the largest population (32.26 million and caused the highest economic loss ($5.179 billion).

The period 2000-2004 (Figure 33) was the worst in terms of number of deaths (9,008); 1995-1999 was the worst in terms of affected population (15.96 million), while 1990-1994 was worst in terms of economic losses ($2.462 billion), which was mainly caused by the floods during this period.

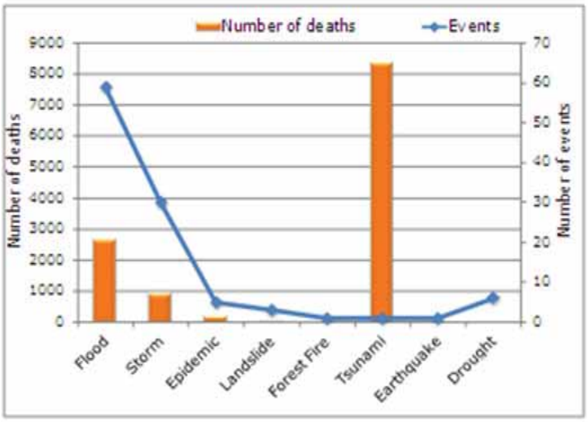
Floods has the highest frequency (1.48), followed by storms (0.75), and droughts (0.15). The death rate was highest for tsunami (209), followed by floods (67), and storms (23). The relative vulnerability was also highest for tsunami (3.16), followed by floods (1.02), and storms (0.35).

Floods are the dominant risk in Thailand with an economic AAL of $164.4 million, followed by tsunami ($50.6 million), storms ($36.8 million) and droughts ($20.5 million) (Figure 31).

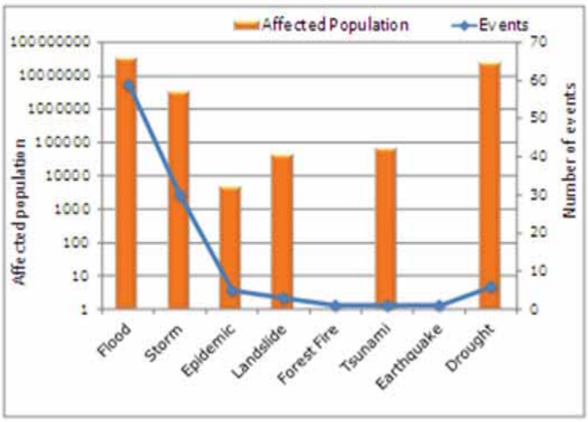
The 20-year return period (an event with 5 per cent probability of exceedance) loss for all natural hazards is $1.216 billion (0.23 per cent of GDP PPP), while the 200-year return period (an event with 0.5 per cent probability of exceedance, generally corresponds to a catastrophic event) loss is $3.22 billion (0.6 per cent of GDP PPP).

Figure 32 Thailand: Disaster events and socio-economic impact by hazard type (1970-2009)

32a Disaster events and number of deaths



32b Disaster events and affected population



32c Disaster events and economic loss

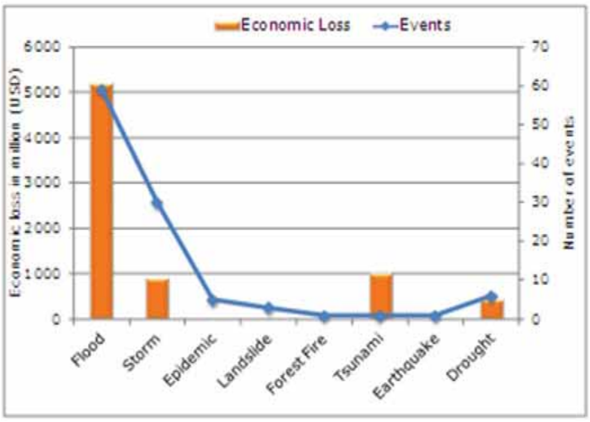
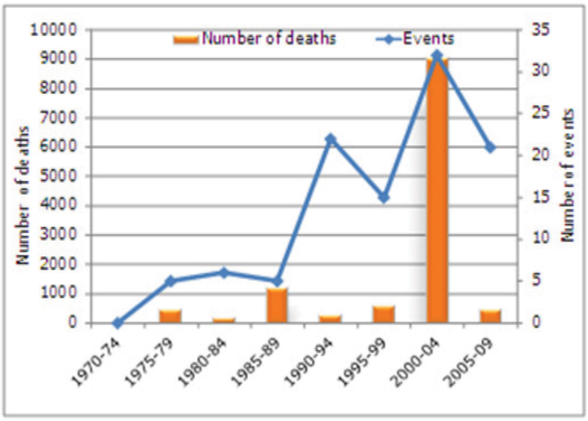
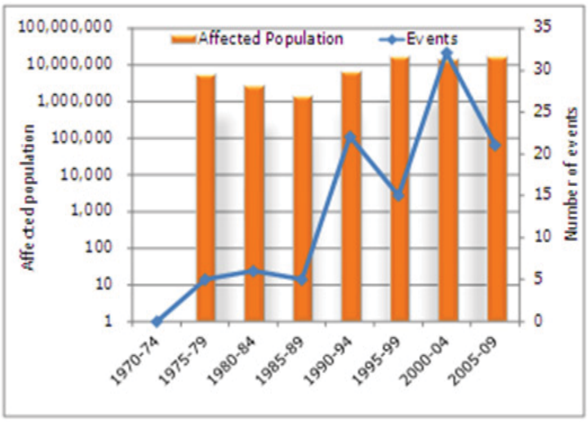


Figure 33 Thailand: Disaster events and socio-economic impact by 5-year periods (1970-2009)

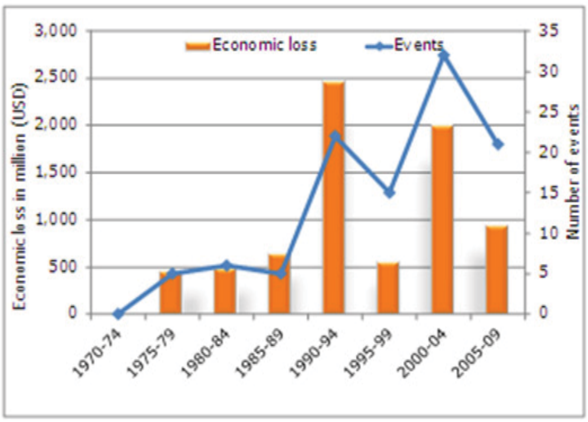
33a Disaster events and number of deaths



33b Disaster events and affected population



33c Disaster events and economic loss



5.10 Vietnam

Overview

Country-level Information (2009)	
Geographic area (km²)	331,210
Population	88,576,758
Population density (per sq.km)	267
Population growth (annual %)	1.137
Urban population (% of total)	28
Poverty headcount ratio, $2 a day (PPP) (% of population)	14.8 (2007)
Current GDP ($ billion)	91.76
GDP growth (annual %)	4.4
GDP - per capita (PPP)($)	2,900
Agricultural GDP (%)	21.4
Industry GDP (%)	39.9
Service GDP (%)	38.7
Human Development Index (HDI)	0.725 (2007)

Figure 34 Percentage distribution of reported disasters in Vietnam

Disaster Risk Statistics (1970-2009)				
Disaster type	*No. of disasters /year*	*Total no. of deaths*	*Deaths/ year*	*Relative vulnerability (deaths/year/ million)*
Flood	1.45	4,712	117.80	1.33
Storm	1.95	10,679	266.98	3.01
Epidemic	0.23	584	14.60	0.16
Landslide	0.13	317	7.93	0.09
Forest Fire	0.03	-	0.00	0.00
Drought	0.13	-	0.00	0.00

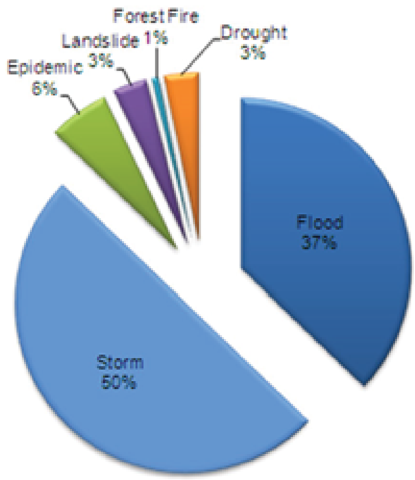


Figure 34: Percentage distribution of reported disasters in Vietnam

Figure 35 Average annual economic loss ($ million) of Vietnam

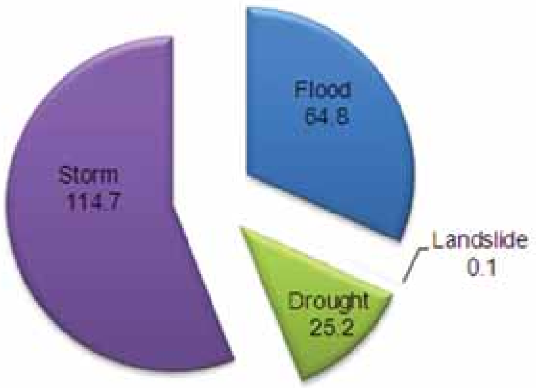


Figure 35: Average annual economic loss ($ million) of Vietnam

Economic Loss data not sufficient for other disasters

Economic Loss Potential		
Annual exceedance probability	*Economic loss ($ million)*	*Percentage to GDP PPP (2009)*
0.5%	1,971.15	0.77
5.0%	906.76	0.35
20.0%	412.69	0.16

Regional setting

Vietnam occupies the eastern and southern part of the Indochina Peninsula in Southeast Asia. It is bordered by China to the north, Laos and Cambodia to the west, the South China Sea along the entire coast (south and east). The country has a total area of 331,210 sq km and a total population of 88.577 million (2009). The topography consists of hills and densely forested mountains in the far northern and north-western parts and low, flat deltas in the south and north. The central part of the country is mostly highlands. The highest and lowest points of Vietnam are 3,144 m (Fan Si Pan) and 0 m (South China Sea) above sea level. The Mekong and Red are two significant rivers of Vietnam and their deltas are densely populated. Owing to the geographical location and shape, the southern part of the country experiences tropical climate, whereas the northern part has monsoonal climate with a hot, rainy season (May to September) and the warm, dry season (October to March). The average temperature in Vietnam is 24.1 °C and the average rainfall is 1,680 mm.

Hazard profile

Vietnam is prone to a number of disasters due to natural hazards such as cyclonic storms, floods, droughts, landslides, forest fires and epidemics. Figure 34 shows the hazard-specific distribution of various disasters that occurred in the country for the period 1970-2009.

Cyclonic storms and floods are the most frequent catastrophic natural hazards in the country. On an average, about 30 cyclonic storms originate in the Western Pacific Ocean each year of which about 10 are generated in the South China Sea. Of these, an average of 4 to 6 hit Vietnam, the recent major cyclone 'Ondoy' in September 2009 killed 174 people, affected 629 people, and caused an economic loss of $ 785 million. Moreover, in the past three decades there have been 79 storm events in the country, which altogether killed 10,802 people, affected a population of about 41 million people, and caused a total economic loss of $ 4 billion.

Located in the tropical region, Vietnam is subjected to the Southeast Asian Monsoon, which causes intense and uneven rainfall in the country. This very intense and uneven distribution of rainfall is the main cause of floods, landslides, and mudflows in the mountains. The river network in Vietnam has a total length of about 25,000 km, concentrated into three rather clearly defined networks (1999 Country Report, ADRC). The catastrophic flood event in the October 2008, killed 99 people, affected 600,000 people, and caused an economic loss of $ 479 million. In the past three decades, there have been 58 flood events, which altogether killed 4,712 people, affected 26 million people, and caused the total economic loss of $ 2.75 billion.

Vietnam is also prone to disasters due to drought. The country has suffered significant socio-economic losses in the past decades due to drought. The major drought events in the years 1997 and 2002 affected about 3.0 and 1.3 million people, and caused the economic losses of $ 407 and 200 million respectively.

The country was also afflicted by five major landslide events, which altogether killed 317 people, affected more than 39,000 people, and caused a total economic loss of $ 2.3 million.

Vietnam lies in a region with low to high seismic hazard (GSHAP, 1998). However, there have been no reported disaster events due to earthquakes in the past three decades.

Risk profile

Vulnerability indicators such as the number of disaster events, deaths, affected population and economic losses have been plotted against hazard types as well as for 5-year intervals covering the 40-year period 1970-2009.Figure 36 (a, b, c) shows the plots of the total number of deaths, affected population and economic losses against each hazard type, while Figure 37(a, b, c) presents the same variables plotted against 5-year periods.

Figure 36 shows that among natural hazards, storms caused the largest number of deaths (10,679), affected the largest population (41.25 million) and caused the highest economic loss ($4.016 billion).

The period 1995-1999 (Figure 37) was the worst in terms of number of deaths (6,643), while 1980-84 was the worst in terms of affected population (19.452 million), and 2005-2009 economic loss ($3.885 billion) caused mainly by the storms in 2006 and 2009, and floods in 2007 and 2009.

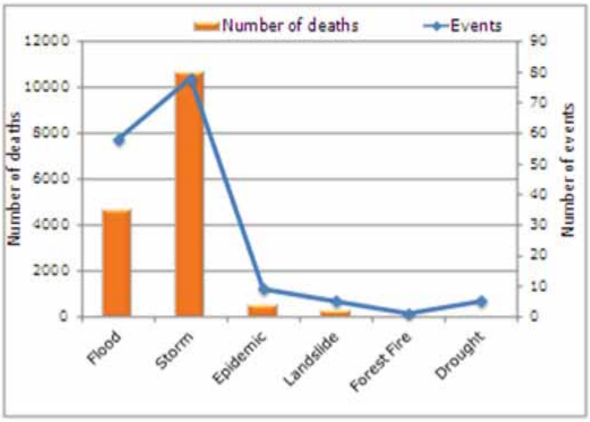
Cyclonic storms has the highest frequency (1.95), followed by floods (1.45). The death rate was highest for storms (267), followed by floods (118). The relative vulnerability was also highest for storms (3.01), followed by floods (1.33).

Cyclonic storms and floods are the dominant risk in Vietnam with an economic AAL of $114.7 million and $64.8 million, respectively followed by droughts ($25.2 million), and landslides ($0.1 million) (Figure 35).

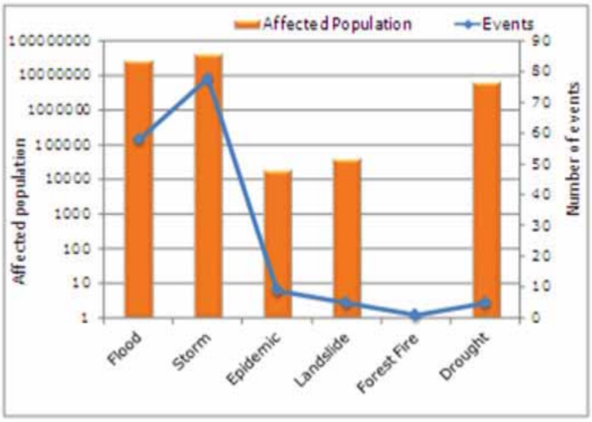
The 20-year return period (an event with 5 per cent probability of exceedance) loss for all natural hazards is $907 million (0.35 per cent of GDP PPP), while the 200-year return period (an event with 0.5 per cent probability of exceedance, generally corresponds to a catastrophic event) loss is $1.971 billion (0.77 per cent of GDP PPP).

Vietnam: Disaster events and socio-economic impact by hazard type (1970-2009)

36a Disaster events and number of deaths



36b Disaster events and affected population



36c Disaster events and economic loss

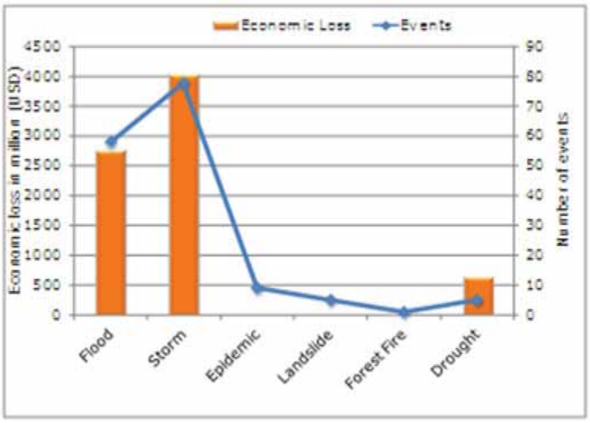
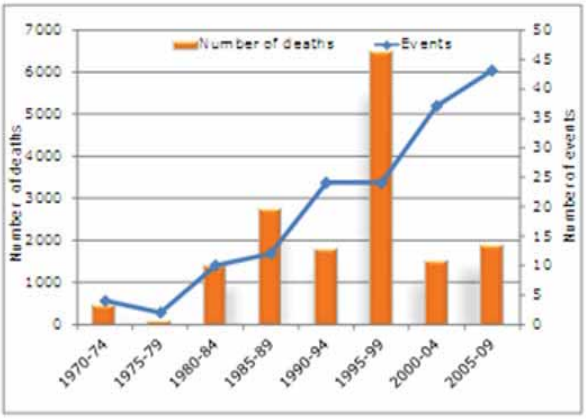


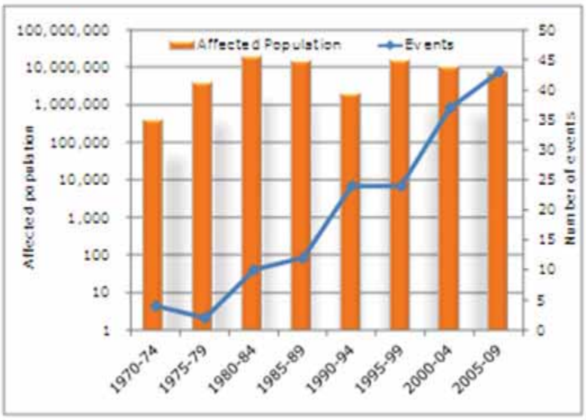
Figure 37

Vietnam: Disaster events and socio-economic impact by 5-year periods (1970-2009)

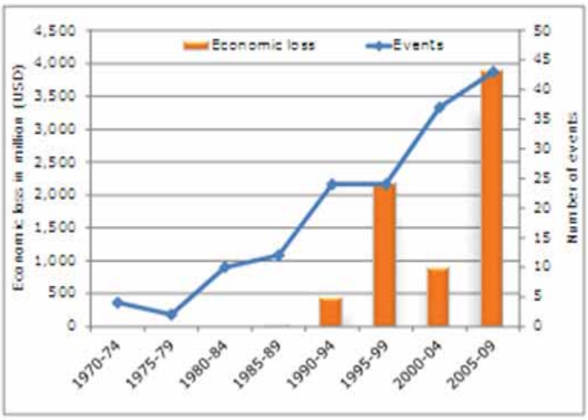
37a Disaster events and number of deaths



37b Disaster events and affected population



37c Disaster events and economic loss



ASEAN Regional Profile

6

6.1 Overview

ASEAN Regional-Level Information (2009)	
Geographic area (km²)	4,479,621
Population	593,051,249
Population density (per sq.km)	132
Population growth (annual %)	1.24
Urban population (% of total)	47.10
Poverty headcount ratio, $2 a day (PPP) (% of population)	-
Current GDP ($ billion)	1460.10
GDP growth (annual %)	1.43
GDP - per capita (PPP) ($)	4,734
Agricultural GDP (%)	-
Industry GDP (%)	-
Service GDP (%)	-
Human Development Index (HDI)	-

Figure 38 Percentage distribution of reported disasters in ASEAN

Disaster Risk Statistics (1970-2009)				
Disaster type	*No. of disasters / year*	*Total no. of deaths*	*Deaths / year*	*Relative vulnerability (deaths/year / million)*
Flood	10.85	17,800	445.0	0.75
Storm	9.65	184,063	4,601.6	7.76
Epidemic	2.28	7,294	182.4	0.31
Landslide	2.05	5,058	126.5	0.21
Forest Fire	0.45	310	7.8	0.01
Drought	0.98	1,337	33.4	0.06
Tsunami	0.15	92,021	2,300.5	3.88
Volcano	1.33	1,380	34.5	0.06
Earthquake	2.58	105,735	2,643.4	4.46

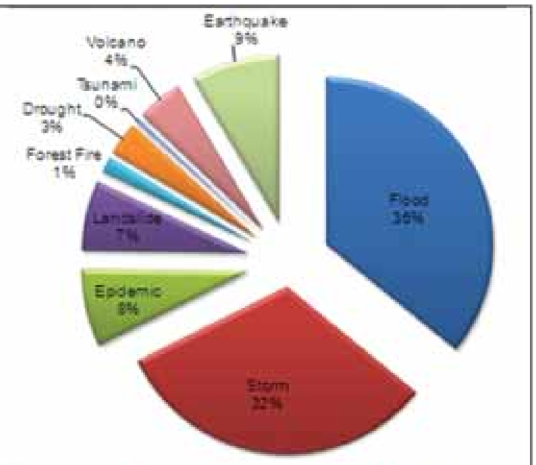


Figure 38: Percentage distribution of reported disasters in ASEAN

Figure 39 Average annual economic loss ($ million) of ASEAN

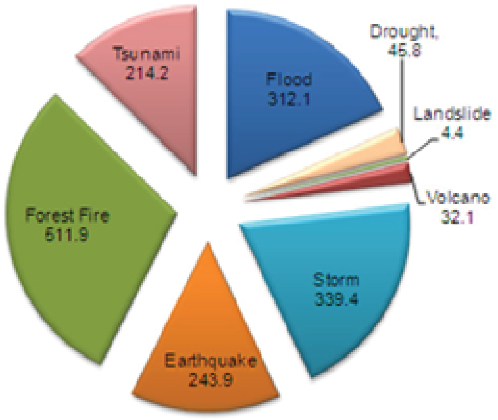


Figure 39 : Average annual economic loss ($ million) of ASEAN

Loss data insufficient for other disasters

Economic Loss Potential		
Annual exceedance probability	*Economic loss ($ million)*	*Percentage to GDP PPP (2009)*
0.5%	13,942.52	0.49
5.0%	6207.27	0.22
20.0%	2888.84	0.10

6.2 Regional setting

Southeast Asia, a sub-region of Asia, is geographically located south of China, east of India and north of Australia. It comprises of the 10 independent member countries of the Association of Southeast Asian Nations (ASEAN) and the newly formed state of Timor-Leste. The association was established on 8th August 1967 in Bangkok, Thailand by the ASEAN Declaration (Bangkok Declaration) and was signed by Indonesia, Malaysia, Philippines, Singapore and Thailand. The other member states joined this association later. Among the ASEAN countries, those located in the Asian mainland are Myanmar, Cambodia, Laos, Thailand, Vietnam and Malaysia (Peninsular part). The remaining countries of Brunei Darussalam, Malaysia (Eastern part), Indonesia, Philippines and Singapore are located in the island arcs and archipelagos to the east and southeast. This region covers a total land area of 4.48 million sq km and has a population of 593.05 million (2009). Indonesia is the only ASEAN country through which the equator passes. It is geographically the largest ASEAN country, covering 42.52 per cent of the total ASEAN area. Myanmar and Thailand are the second and third largest, accounting for 15.1 per cent and 11.5 per cent of the total area, respectively. Indonesia is the most populated country, accounting for more than 240 million populations (2009). Singapore, being an island city-state, has the highest population density of 6,682 persons per sq km, whereas Laos has the least population density (29 persons per sq km).

ASEAN covers a large area of varied geography, including high hills and rugged mountains such as Hengduan Shan, Annamite, extended Himalayan range, elevated plateaus such as Shan Plateau, Khorat Plateau, extensive highlands, flood plains, coastal plains, and deltas. Among numerous rivers and streams, the Mekong and Ayeyarwadi are the major rivers in the region. Tonle Sap or Great Lake in Cambodia is the largest freshwater lake in Southeast Asia, whereas Lake Toba of Indonesia is the largest volcanic lake in the world. ASEAN countries have generally a tropical hot and humid climate with the exception of the northwestern part that experiences a humid sub-tropical climate. The region receives plentiful rainfall and remains humid all round the year. Generally, the countries have a dry and wet season due to seasonal shifts in winds or, monsoon. However, the mountainous areas in the northern part have a milder and drier climate at high altitudes.

6.3 Socio-economic setting

Amongst all the ASEAN scenarios, Indonesia is the most populous country with a sub-regional share of 40.5 per cent of the total population, followed by Philippines, which accounts for 16.5 per cent (Table 1).

Singapore is the most densely populated country (6,682 people per sq km), while Laos is the most sparsely populated country (29 people per sq km). The average population density for the region is moderate, at just 132 people per sq km (Table 1).

All the ASEAN countries have a positive population growth rate, varying from 0.6 to 2.3 per cent. Myanmar is the poorest country in the region with GDP PPP per capita of $ 1,200 and HDI of 0.586 (2007). Cambodia stands second poorest with a GDP PPP per capita of $ 1,900 and HDI of 0.593 (2007) (Table 1).

6.4 Disasters overview

The region is vulnerable to natural hazards including forest-fires, cyclonic storms, floods, earthquakes, tsunamis, droughts, volcano, landslides, and epidemics. The percentage distribution of various disasters that occurred in ASEAN during 1970-2009 is shown in Figure 38. The disaster matrix by country is presented in Table 3.

Figure 40 Population density map (Source: Landscan)

Table 3 Disaster matrix by country (1970-2009)

Country	Hazards							
	Earthquake	Flood	Landslide	Drought	Storm (typhoon/ cyclones)	Volcano	Forest Fire	Tsunami
Brunei	X	X	X	X	X		X	
Cambodia	X	XXX	X	XX	X		X	
Indonesia	XXX	XXX	XXX	XX	XX	XXX	XX	XXX
Laos	X	XXX	XX	XX	XX	X	X	
Malaysia	X	XXX	XX	X	X		XX	X
Myanmar	XX	XXX	XX	XX	XXX		X	X
Philippines	XXX	XXX	XXX	XX	XXX	XX	X	X
Singapore	X	XX			X			
Thailand	X	XXX	XX	XX	XX		X	X
Vietnam	X	XXX	XX	XX	XXX		X	X
ASEAN	XX	XXX	XX	XX	XXX	XX	XX	XX

Scale: Disaster incidence ranges relative within the country/region from XXX 'high' to X 'low'.

6.5 Major natural hazards overview and vulnerability assessment

This section provides a high-level picture of the regional hazards and risk mortality maps (tailored to ASEAN countries using GAR PREVIEW Global Risk Data Platform) and tables charting the percentage of areas under the categories of low, moderate, high and very high mortality risk mortality categories.

In detailed risk analyses performed for economic loss estimations or emergency response planning, vulnerability is usually disaggregated into losses to buildings and infrastructure, business interruption, and social impact quantified in terms of the number of fatalities and casualties. In this analysis, a rapid assessment approach is followed where a simple proxy is used to quantify the vulnerability. The selected proxy is 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 ASEAN. The mortality risk maps are overlaid with gridded population data (Landscan) and analyzed using GIS to identify the percentage area and population at risk from various hazards.

Earthquakes

ASEAN is a region of varying seismic hazard, ranging from very high seismic hazard associated with the subduction process beneath the Indonesian and Philippine archipelagos to moderately low seismic hazard across a large stable region that contains the Malaysian peninsula. The sliding of the India and Australia tectonic plates beneath the Sunda and Burma tectonic plates resulted in wide-spread volcanic and earthquake activity (Figure 41 and (Figure 42)) in the Indonesian island chain, which is part of the 'Ring of Fire'. This region is marked by reverse, thurst, strike-slip and normal focal mechanism. The Sunda subduction zone produces thrust-fault earthquakes, whereas intraplate normal-fault and reverse-fault earthquakes occur within the shallow Indian and Australian plates. Earthquakes that take place within the subducted zones of the Indian and Australian plates extend down to depths of hundreds of km (Petersen et. al., 2007). The December 26th, 2004, the devastating megathrust earthquake (magnitude 9.1) occurred as thrust-faulting on the interface of the Indian plate and the Burmese plate. The resulting tsunami caused significant socio-economic losses in several countries such as Indonesia, Thailand, Malaysia, India, Myanmar, Sri Lanka, and Maldives. Table 4 represents earthquake events with 1,000 or more deaths in the region.

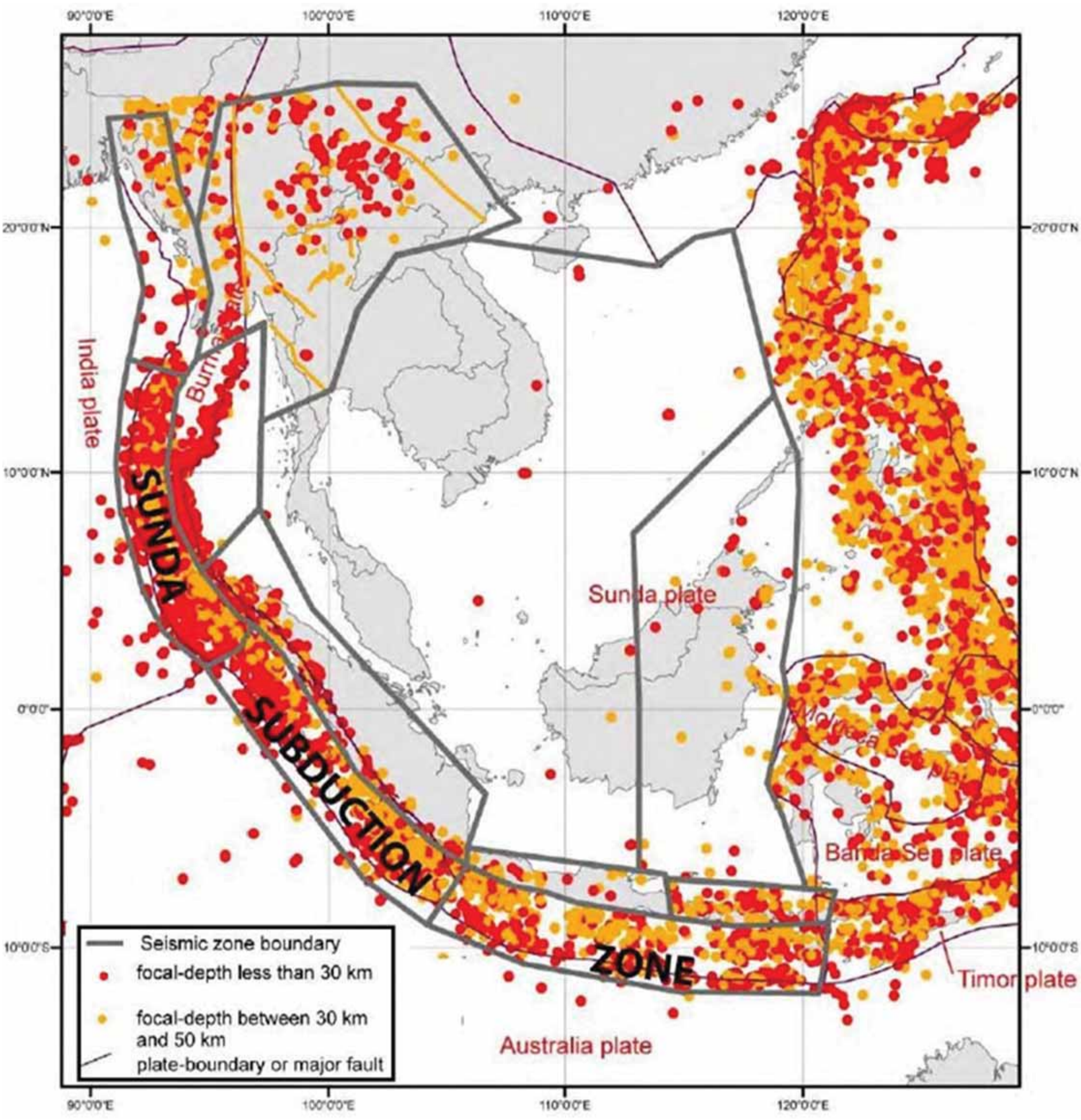
Table 3 Earthquakes with 1,000 or more deaths in ASEAN region (since 1900)

Sl. No.	Date UTC	Location	Location	Magnitude	Deaths
1	20/01/1917	Bali, Indonesia	9.0S, 115.8E	-	1,500
2	16/08/1976	Mindanao, Philippine	6.3N, 124.0E	7.9	8,000
3	16/07/1990	Luzon, Philippine	15.7N, 121.2E	7.7	1,621
4	12/12/1992	Flores Region, Indonesia	8.5S, 121.9E	7.5	2,500
5	26/12/2004	Sumatra	3.30N, 95.87E	9.1	*2,27,898
6	23/08/2005	Northern Sumatra, Indonesia	2.07N, 97.01E	8.6	1,313
7	26/05/2006	Indonesia	7.961S, 110.446E	6.3	5,749
8	30/09/2009	Southern Sumatra, Indonesia	0.720S, 99.867E	7.5	1,117

*: includes deaths from resulting tsunami

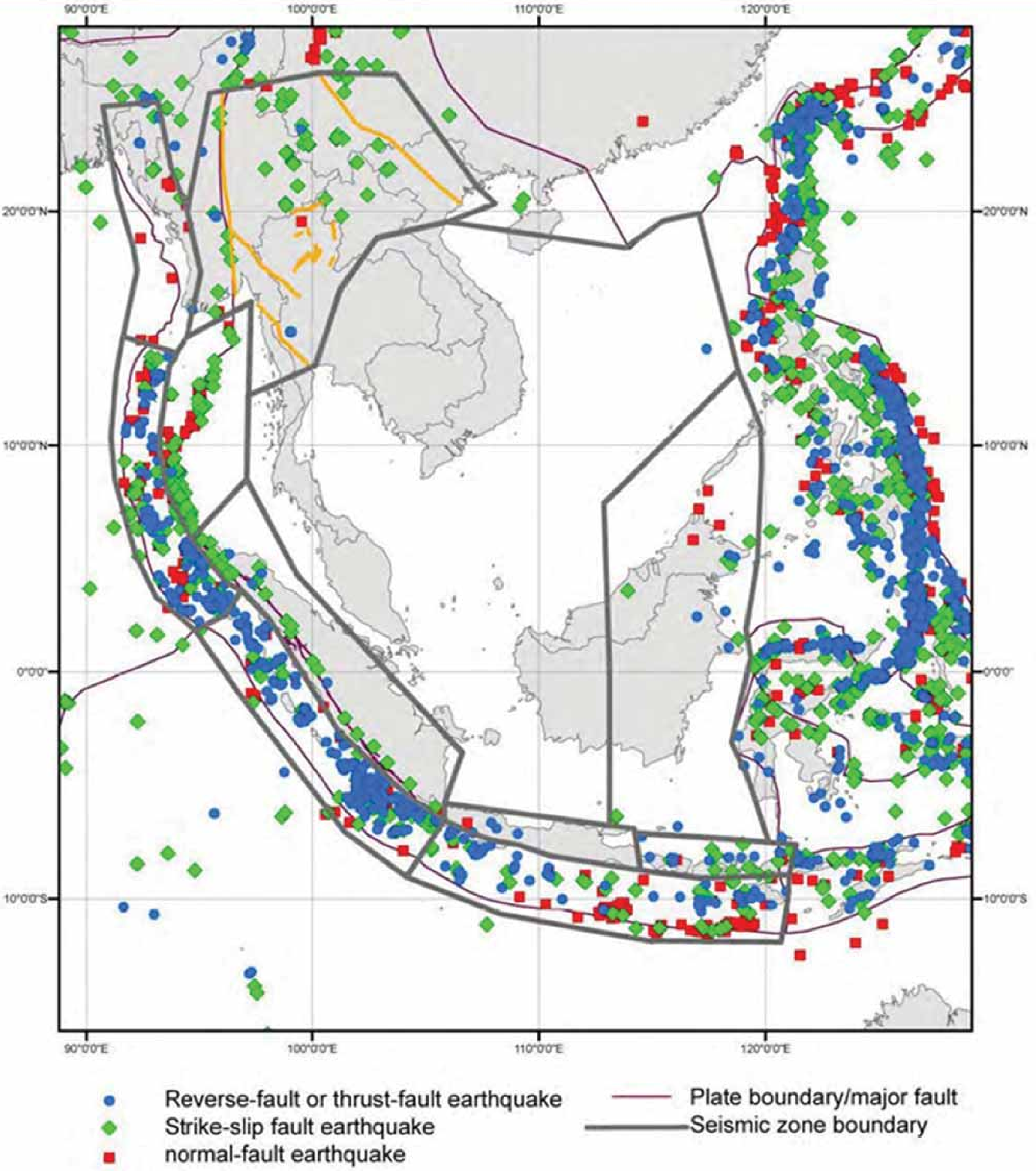
Source: USGS (http://earthquake.usgs.gov/earthquakes/world/world_deaths.php)

Figure 41 Shallow depth earthquake with focal depth <50km



Source: Petersen et. al. (2007), Documentation for the Southeast Asia Seismic Hazard Maps

Figure 42 Shallow depth (< 50 km) earthquake source zones for which Harvard Centroid Moment Tensor (CMT) solutions are available

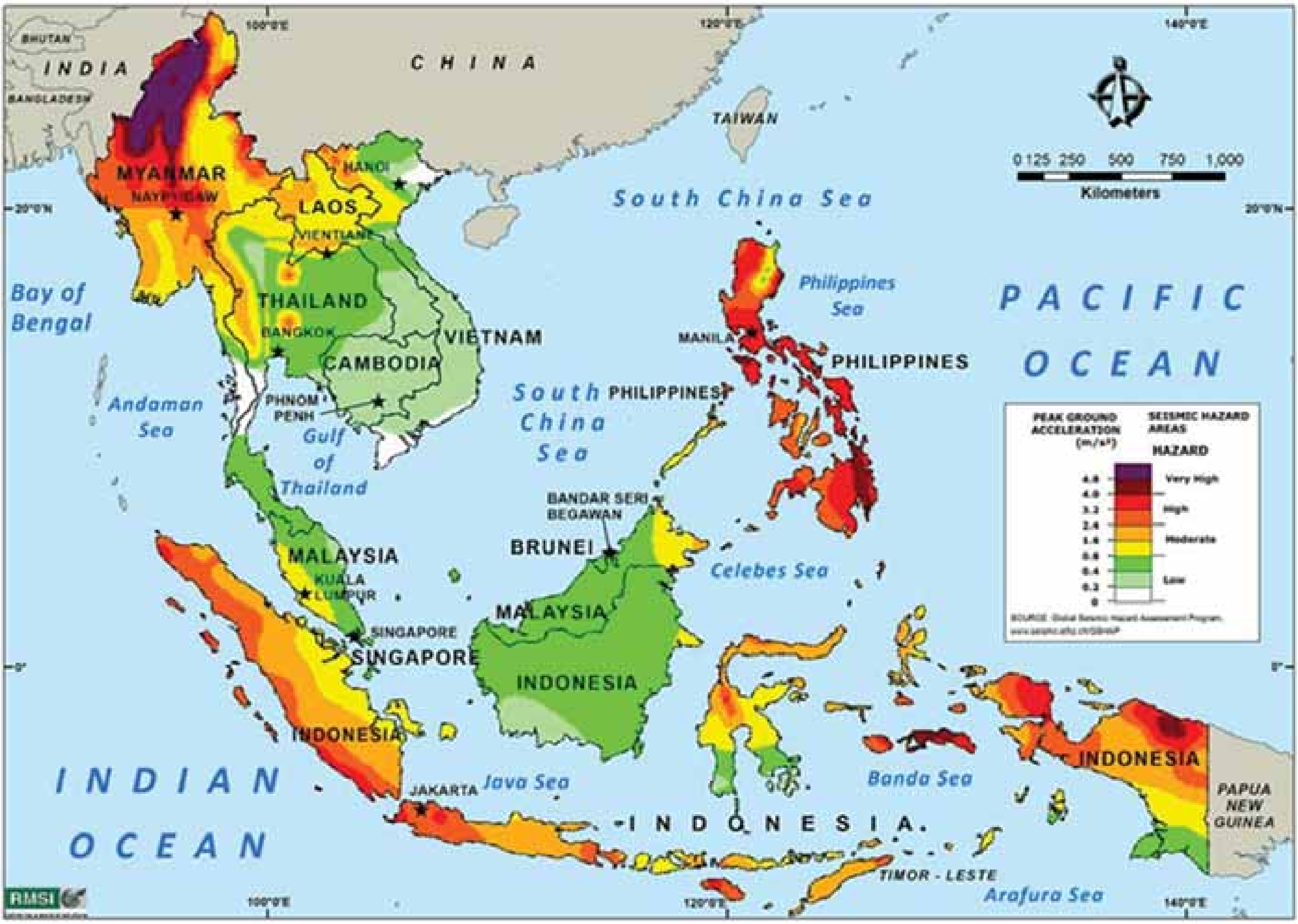


Source: Petersen et. al. (2007), Documentation for the Southeast Asia Seismic Hazard Maps

GSHAP has categorized ASEAN into four earthquake zones – low, moderate, high, and very high hazard – based on the expected 475-year return period peak ground acceleration (PGA). As discussed in the country and region profiles, the earthquake hazard in ASEAN is low to very high (Figure 43). Almost the entire area of Indonesia, Philippines and Myanmar fall in the very high hazard zone (Figure 43).These countries either have experienced some of the most severe catastrophic earthquakes of the world or are located in regions with a potential for large magnitude earthquakes. Long-term slip rates and estimates of earthquake size define the rate of large-magnitude earthquakes on crustal faults in hazard analysis. The length of the mapped fault and down dip width estimates from seismicity are used to calculate maximum magnitudes of earthquakes expected to occur on these faults (Wells and Coppersmith, 1994). The analysis shows that in the ASEAN region, the earthquake hazard is highest over the Sunda subduction zone, the Sumatran fault, the Sagaing fault (in Myanmar), and the Red River fault (in northern Vietnam) (Petersen et al 2007).

The risk to populations due to the earthquake

Figure 43 Earthquake hazard map of ASEAN (Source: GSHAP, 1998)



Note: Map based on peak ground acceleration for 10 per cent probability of exceedance in 50-year (corresponds to 475-year return period) hazard zones 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).

hazard in the ASEAN countries is very high. The 2004 Indian Ocean Tsunami in Southeast Asia and surrounding region, for instance, caused significant socio-economic losses and triggered a huge migration of people from the meizoseismal zone. Given the extent of the risk, it is safe to conclude that a large section of the ASEAN population is vulnerable to earthquake hazard.

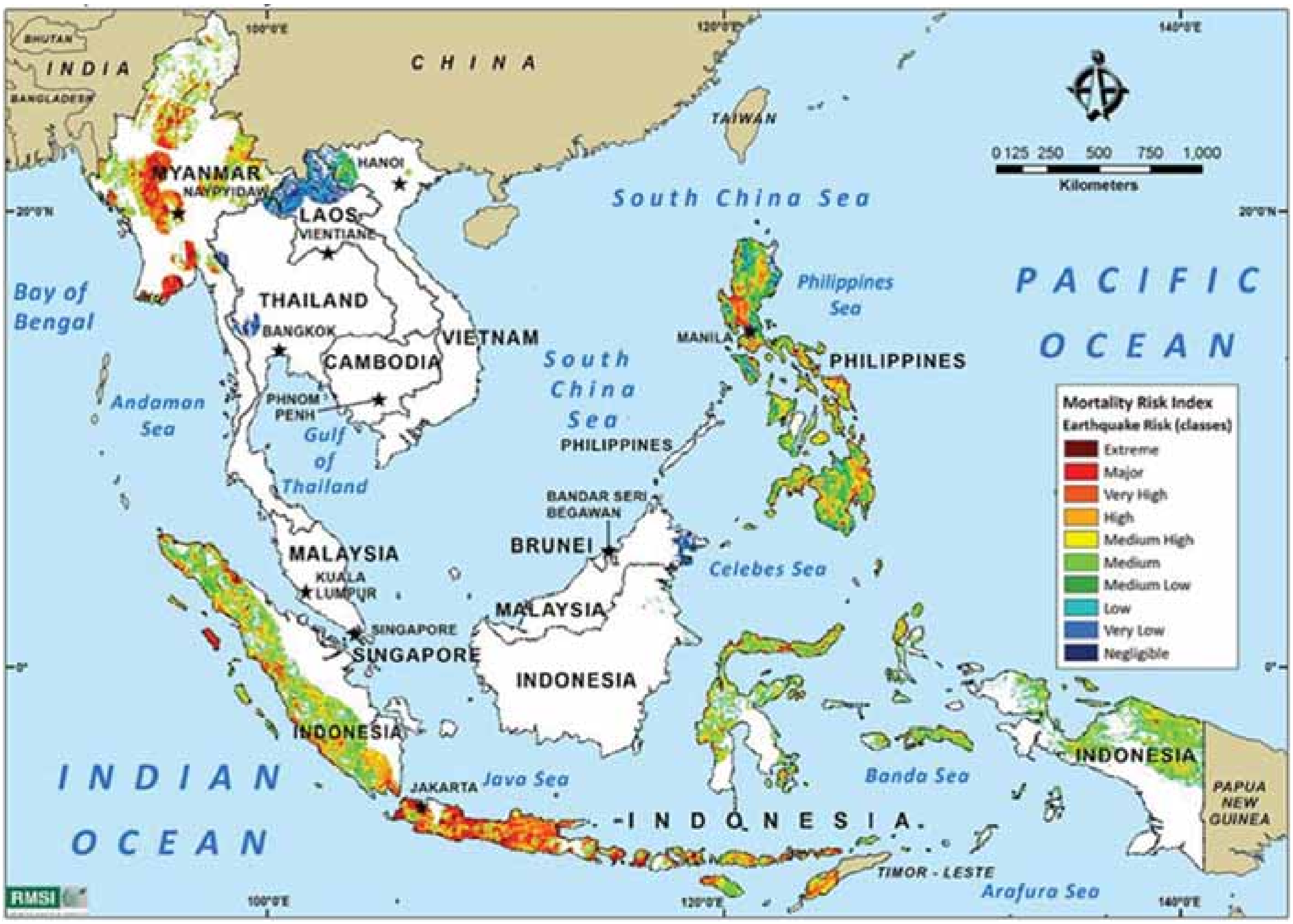
Figure 44 presents the earthquake risk map of ASEAN in terms of a mortality risk index (GAR, 2009). This map has been generated using past Modified Mercalli Intensity (MMI) (Wald et. al., 1999, 2005; Wald and Allen 2007) maps, also referred to as meizoseismal maps, as it makes it easier to relate the recorded ground motions to the expected felt area and damage distribution.

From Figure 44, it is evident that earthquake mortality risk is considerably high in the island states of Philippines and Indonesia, and the Indochina Peninsular state of Myanmar.

Table 5 presents the percentage area and population in four mortality risk categories (low, moderate, high and extreme) for each ASEAN country.

Table 5 indicates that more than 80 per cent of the

Figure 44 Earthquake mortality risk map of ASEAN (Source: ISDR, 2009)



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

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

Country	% of total country geographic area						% of total country population					
	Low	Mod.	High	Extreme	No data	Total	Low	Mod.	High	Extreme	No	Total
Brunei	-	-	-	-	100.00	100	-	-	-	-	100.00	100
Cambodia	-	-	-	-	100.00	100	-	-	-	-	100.00	100
Indonesia	3.38	20.38	11.36	3.11	61.77	100	0.11	3.50	25.98	43.87	26.54	100
Laos	15.97	0.95	0.02	-	83.06	100	8.96	4.51	0.06	-	86.47	100
Malaysia	2.43	0.08	-	-	97.49	100	1.15	0.37	-	-	98.48	100
Myanmar	0.03	13.38	12.13	4.96	69.50	100	0.00	2.00	12.54	34.71	50.75	100
Philippines	11.21	49.19	26.64	3.09	9.87	100	0.40	13.70	41.55	40.60	3.75	100
Singapore	-	-	-	-	100.00	100	-	-	-	-	100.00	100
Thailand	2.41	0.12	0.00	-	97.47	100	0.74	0.46	0.00	-	98.80	100
Vietnam	2.84	2.34	0.13	-	94.69	100	0.20	1.04	0.45	-	98.31	100

Source: Area and population computed from the earthquake mortality risk map of GAR platform and potential population computed from Landscan data

population in Philippines lives in high to extreme earthquake mortality risk zone, whereas in Indonesia and Myanmar, people living in high to extreme mortality risk zones constitute about 69 and 47 per cent of the country population, respectively. On the other hand, Brunei, Singapore and Cambodia have least earthquake mortality risk.

Floods

Floods (Figure 45) are one of the most significant natural hazards in ASEAN. Due to its mountainous terrain, several rivers and their tributaries criss-cross the region. Floods are triggered by various phenomena and there are different types of floods. For example one can often differentiates among flash floods, riverine 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 (GAR, 2009).

In ASEAN, majority of population live in riverine plains, low-lying coastal plains, and deltas. Hence, the flood mortality risk is much higher in those areas. Among major rivers, the Mekong and Ayeyarwadi cause periodic flood disasters in Vietnam, Cambodia, Thailand and Myanmar causing huge socio-economic losses. The flood risk is expected to increase significantly in the future with further increases in population density in the low lying areas which are prone to floods. As predicted by various climate change models, rising sea-levels and more frequent extreme rainfall events are further expected to increase the flood risk.

Figure 45 presents the flood risk map of ASEAN in terms of a mortality risk index (GAR, 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 the 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;

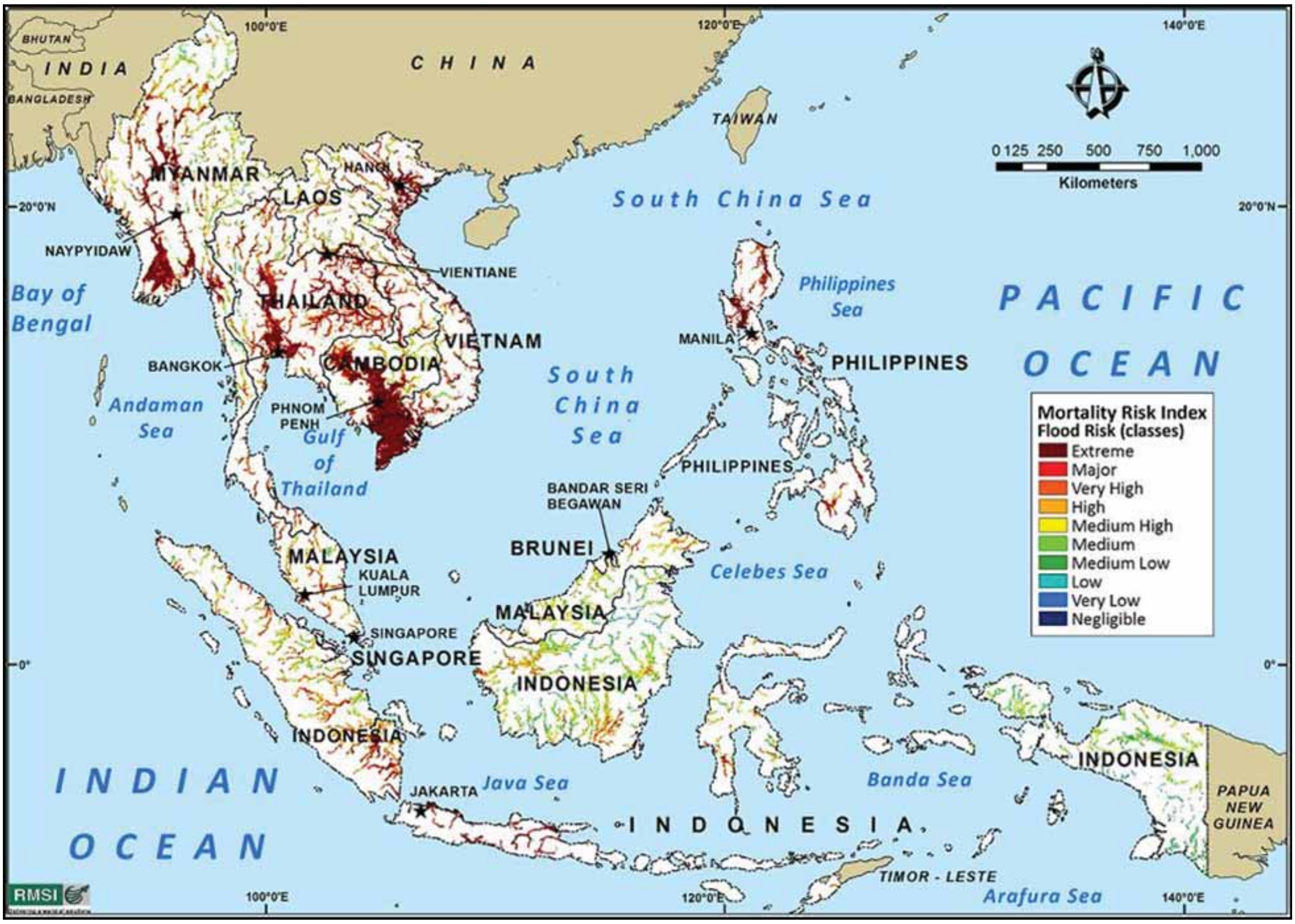
- Attribution of a reference group for each ungauged site;
- Estimation of its peak-flow by the corresponding regression formula. In order to solve the problem of data homogeneity in some climatic regions, a global approach is adopted for the whole statistical analysis (GAR, 2009).

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 (GAR, 2009).

The flood mortality risk map (Figure 45) shows that, with the exception of Singapore (Table 6), all other member states of ASEAN fall under different flood mortality risk zones. However, it should be noted that the map has limitations since there is no data for a large percentage of the area.

The floods risk is compounded by the fact that since agriculture is the major sector in most of the ASEAN countries, populations tend to concen-

Figure 45 Flood mortality risk map of ASEAN (Source: GAR, 2009)



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

trate in areas with access to water. If one considers countries with higher flood mortality risk in terms of per cent of their total geographical area, Cambodia ranks first with 33 percent of its area under high flood risk zone, followed by Vietnam (28 per cent), and Thailand (22 per cent).

If one considers per cent of total country population at higher flood risk, the flood hazard risk for ASEAN increases several folds. In Cambodia alone, more than 84 per cent of its population lives in the high to extreme flood mortality risk zones, whereas Vietnam and Myanmar account for 64 per cent and 48 per cent of their population living in high to extreme risk zones, respectively. The other ASEAN countries with significantly high flood mortality risks are Thailand (44 per cent) and Laos (42 per cent).

Table 6 Percentage area and population in each flood hazard category

Country	% of total country geographic area						% of total country population					
	Low	Mod.	High	Extreme	No data	Total	Low	Mod.	High	Extreme	No Data	Total
Brunei	-	0.75	-	0.75	98.5	100	-	0.63	-	8.26	91.11	100
Cambodia	0.26	5.43	6.49	26.9	60.92	100	0.01	0.94	4.96	79.07	15.02	100
Indonesia	1.37	6.04	3.32	2.39	86.88	100	0.06	0.73	2.46	16.94	79.81	100
Laos	0.01	5.25	6.25	6.98	81.51	100	0	1.58	5.06	39.17	54.19	100
Malaysia	0.34	6.54	5.32	2.45	85.35	100	0.03	1.68	3.04	17.80	77.45	100
Myanmar	0.63	5.68	5.29	9.76	78.64	100	0.06	1.33	5.15	43.46	50.00	100
Philippines	0.03	0.95	2.43	7.82	88.77	100	0	0.35	1.85	26.05	71.75	100
Singapore	-	-	-	-	100.00	100	-	-	-	-	100.00	100
Thailand	0.27	2.84	6.95	15.68	74.26	100	0.01	1.33	7.22	36.63	54.81	100
Vietnam	0.24	2.84	5.06	22.95	68.91	100	0.01	0.34	2.99	61.64	35.02	100

Source: Area computed from the flood mortality risk map of the GAR preview data platform and potential population computed from Landscan

Landslides

Landslides is another prevalent natural hazard in ASEAN, with the larger events often triggered by earthquakes, tropical cyclones, or floods. The high prevalence of landslides is due to the presence of mountains and rugged plateaus. The landslide risk map in terms of the mortality risk index is presented in Figure 46.

The landslide hazard, defined as the annual probability of occurrence of a potentially destructive landslide event, depends on the combination of the presence of a trigger and the susceptibility (Figure 47). In the analyses performed in this study, a landslide hazard index was defined using six parameters: slope factor, lithological (or geological) conditions, soil moisture conditions, vegetation

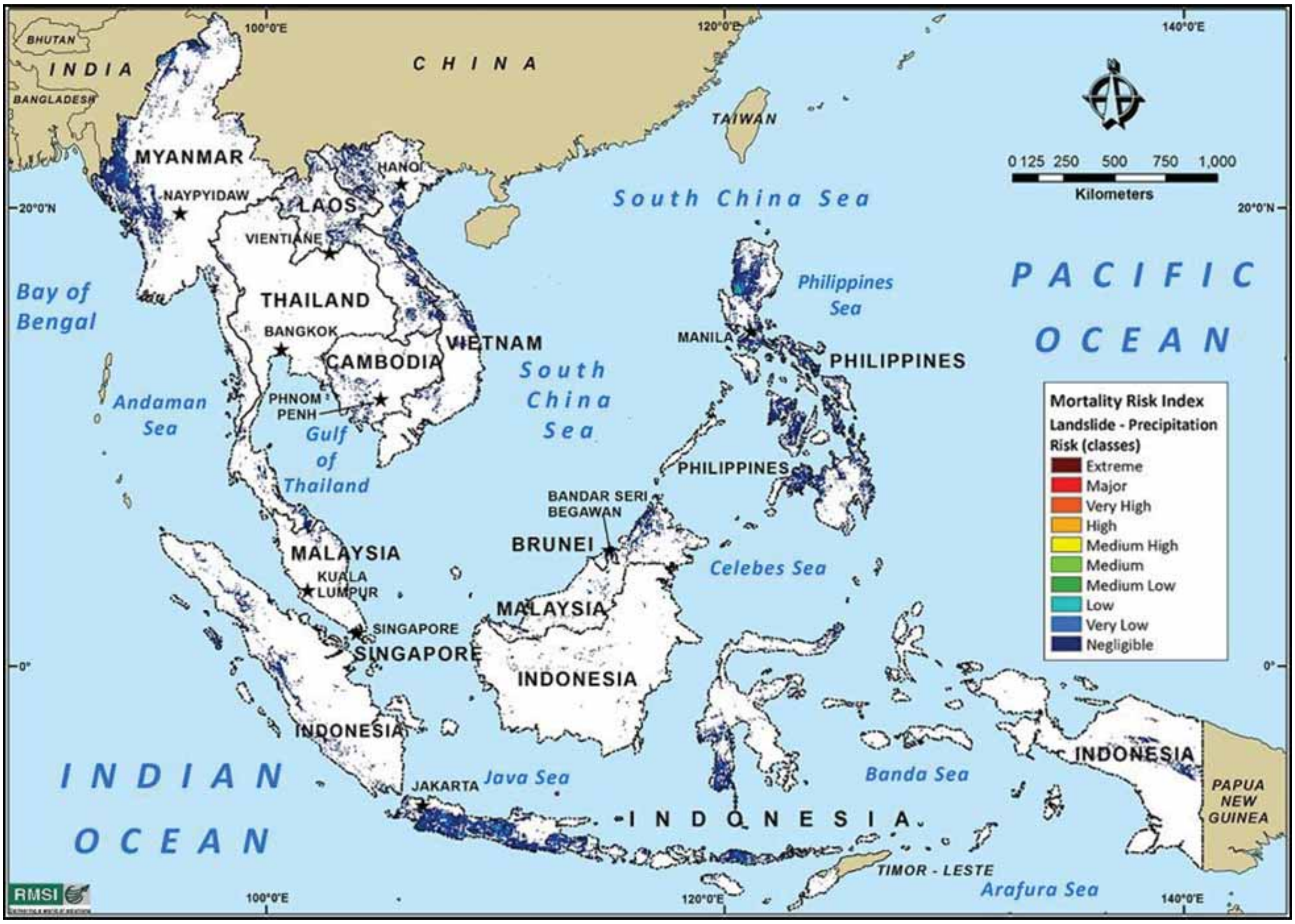


Figure 46 Landslide mortality risk map of ASEAN (Source: GAR, 2009)

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

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 (GAR, 2009).

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

It should be noted that people often move from highly dangerous landslide zones to the safer lower valleys and, consequently, the percentage of populations living in very high or high landslide hazard zones is very low (Table 7).

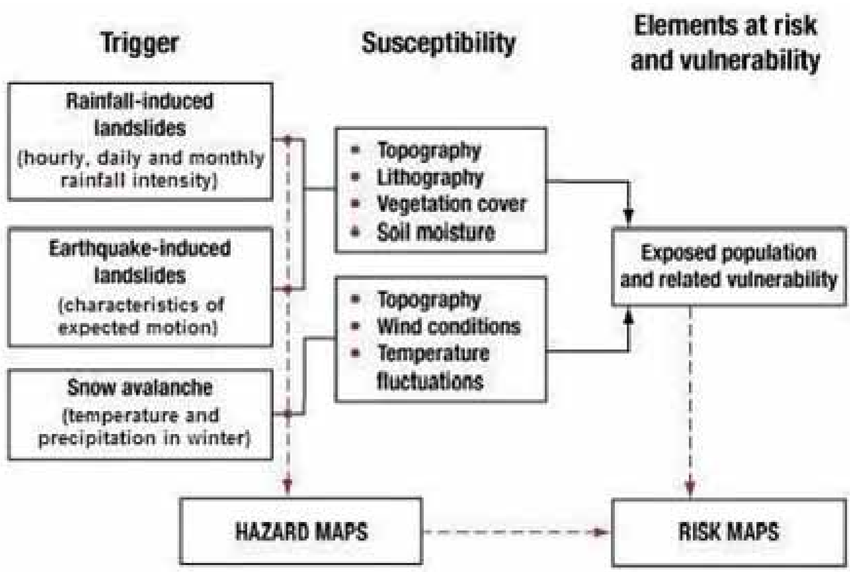


Figure 47 Schematic approach for landslide hazard and risk evaluation (GAR, 2009)

Table 7 Percentage area and population in each landslide hazard category

Country	% of total country geographic area						% of total country population					
	Low	Mod.	High	Extreme	No	Total	Low	Mod.	High	Extreme	No	Total
Brunei	15.30	-	-	-	84.70	100	68.74	-	-	-	31.26	100
Cambodia	5.10	-	-	-	94.90	100	3.44	-	-	-	96.56	100
Indonesia	8.50	0.01	-	-	91.49	100	31.72	0.05	-	-	68.23	100
Laos	16.25	-	-	-	83.75	100	11.51	-	-	-	88.49	100
Malaysia	6.67	0.01	-	-	93.32	100	7.65	0.08	-	-	92.27	100
Myanmar	12.29	0.03	-	-	87.68	100	9.79	0.50	-	-	89.71	100
Philippines	37.23	0.10	-	-	62.67	100	34.53	0.61	-	-	64.86	100
Singapore	-	-	-	-	100.00	100	-	-	-	-	100.0	100
Thailand	2.32	0.00	-	-	97.68	100	1.64	0.01	-	-	98.35	100
Vietnam	14.97	-	-	-	85.03	100	10.98	-	-	-	89.02	100

Source: Area computed from the landslide mortality risk map of the GAR preview data platform and potential population computed from Landscan

From Table 7, it is clear that the ASEAN region has a low landslide mortality risk, with limited areas under moderate risk. In terms of percentage of total country geographic area, Philippines (37 per cent) has the largest areas under landslide mortality risk, followed by Laos, Brunei and Vietnam. In terms of per cent of total country population at landslide mortality risk, Brunei is highest with 68 per cent of its population at landslide risk, followed by Philippines (35 per cent) and Indonesia (31 per cent). Singapore being a very small island state does not show any threat of landslide mortality risk.

The reader should keep in mind the limitations of the above analyses. Human impact is a very important triggering factor for landslides, which has been kept out of 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.

Droughts

Large areas of the ASEAN region come 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

Figure 48 Drought frequency SPI map of ASEAN (Source: GAR, 2009)

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

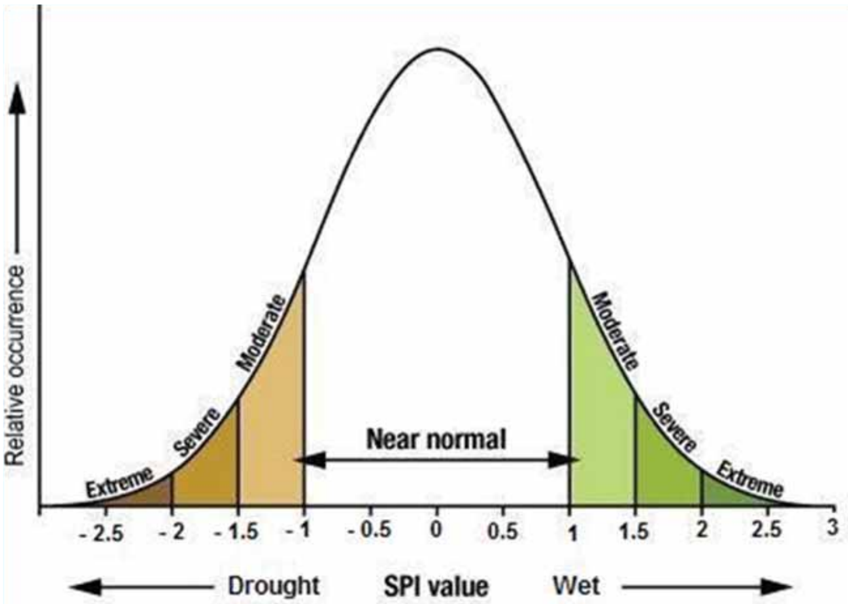


Figure 49 The relative occurrence versus value of the SPI (Index < -1 for drought)

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

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 (GAR, 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 (GAR, 2009).

Figure 48 presents the drought map of ASEAN in terms of a drought frequency Standardized Precipitation Index (SPI) map (GAR, 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 49). 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; among many others).

The predominant activity in ASEAN countries is agriculture. Since drought can affect agriculture, it also threatens the livelihood of a large number of people. Incidentally, many of the high drought prone areas are also prone to floods, accentuating the harsh living conditions of the population in the region.

The 2004-2005 drought in the Indochina Peninsula affected about 0.6 million people in Cambodia and 0.4 million people in Vietnam. The event caused very high economic losses of about $420 million and $42 million in Thailand and Vietnam, respectively.

Table 8 presents the percentage area and population of each country under different drought SPI-frequency categories. A majority of countries fall under high to extreme drought frequency SPI categories (except Brunei) both in terms of per cent of total country geographic area and per cent of total country population.

It should be noted that the percentages in the table do not reflect the complete picture of the hazard since there is no data for large areas of the region.

The drought frequency SPI map presented in Figure 48 has some important limitations as the map has been derived from a global scale analysis (GAR, 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.

Volcanoes

Indonesia and Philippines, located in the Pacific 'Ring of Fire', have a large number of world's active and dormant volcanoes (Figure 50). Although Indonesia leads the world in both the number and the global proportion of eruptions in each of the last four eruptive characteristics (fatalities, destruction of land, mudflows, and tsunamis), the Philippines shows substantially higher figures when each characteristic is considered as a percentage of that same region's total number of eruptions.

Table 8 Percentage area and population in each drought SPI-frequency category

Country	% of total country geographic area						% of total country population					
	Low	Mod.	High	Extreme	No data	Total	Low	Mod.	High	Extreme	No Data	Total
Brunei	-	-	4.62	15.38	80.00	100	-	-	0.04	1.61	98.35	100
Cambodia	-	0.09	5.72	37.90	56.29	100	-	0.01	0.54	48.60	50.85	100
Indonesia	-	3.52	24.59	39.81	32.08	100	1.28	10.91	41.12	46.69	-	100
Laos	0.81	24.34	45.34	25.43	4.08	100	0.48	29.52	35.32	30.74	3.94	100
Malaysia	-	2.35	13.62	40.73	43.30	100	1.30	11.64	40.69	46.37	-	100
Myanmar	13.20	16.88	17.92	28.30	23.70	100	3.76	11.95	21.77	41.42	21.10	100
Philippines	-	-	12.32	40.92	46.76	100	-	-	9.04	56.49	34.47	100
Singapore	-	-	100.00	-	-	100	-	-	100.00	-	-	100
Thailand	-	4.66	14.28	34.01	47.05	100	-	4.47	12.61	21.60	61.32	100
Vietnam	3.39	12.60	51.42	27.27	5.31	100	0.48	13.16	48.46	33.27	4.63	100

Source: Area computed from the drought SPI-frequency map of the GAR preview data platform and potential population computed from Landscan

Figure 50 Volcanoes of the ASEAN region

Source: Smithsonian Institution Volcanoes of the world, http://www.volcano.si.edu/world/globallists.cfm?listpage=googleearth

Indonesia is considered to be one of the high volcanic risk regions in the world in terms of population and the number of active volcanoes (Hincks, 2007). Located in the interaction and collision zone of several continental plates, Indonesia has 129 active volcanoes and 271 eruption points (Abidin et al., 2004). The country has witnessed the highest number of eruptions that produced fatalities (104), damage to arable land (186), mudflows (84), tsunamis (13), domes (76), and pyroclastic flows (96). The disastrous Krakatau eruption in 1883 was followed by several devastating eruptions in other parts of the country. The Sunda Arc, a subduction zone of the Indian Ocean crust beneath the Asian plate, includes 76 percent of the region's volcanoes. According to Katili and Siswowidjojo (1994), around 10 per cent of Indonesians live in the area endangered by volcanic eruptions and about 3 million of them live in the danger zones (Abidin et. al, 2004).

The volcanoes of Philippines are lined along the eastern margin of the Philippines archipelago and are associated with the Philippine Trench where the Philippine Sea Plate is being subducted towards the west (Castillo and Newhall, 2004). In

Philippines, 13 per cent of volcanic eruptions have resulted in fatalities and 22 per cent are responsible for damages to property and assets. The Taal and Mayon volcanoes have particularly high human impact compared to others. The higher rainfall in the country has resulted in redistribution of the tephra to the surrounding low lands. Secondary mudflows following the 1991 Pinatubo eruption were especially devastating. The volcanic series in Philippines has resulted from the subduction of the oceanic Philippine plate under the Asian plate.

Myanmar and Vietnam are the other countries in the ASEAN region, marked by Holocene volcanism. Popa, Singu Plateau and Lower Chindwin are the significant volcanoes of Myanmar. The volcanism in Vietnam is known for the recent unrest. Cu-Lao-Re Group, Toroeng Prong, Haut Dong Nai, Bas Dong Nai, Ile Des Cendres are some of the volcanoes in Vietnam with probable Holocene eruptions (http://www.volcano.si.edu/world/region.cfm?rnum=07&rpage=list).

Cyclonic Storms

ASEAN countries have generally a tropical hot and humid climate with the exception of the northwestern part that experiences a humid subtropical climate. The presence of warm oceans, the tropical climatic conditions and the wind patterns in the region make ASEAN prone to cyclonic storms risk. Tropical cyclones are powerful hydrometeorological hazards that are unevenly spread in the region 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 surges 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 winds and storm surge.

The proposed global model of tropical cyclones wind hazard is based on the observations of 2,821 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 developed by UNEP/GRID-Europe between 2001-2003 (GAR, 2009). 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 from 1977. Otherwise it is very complete. Even the information on the 2004 Catarina cyclones that affected Brazil (south Atlantic) was modeled (data courtesy of Anteon Corp./Roger Edson 2004; http://cimss.ssec.wisc.edu/tropic/brazil/brazil.html).

The cyclone risk map in terms of a mortality risk index is presented in Figure 51. From the figure, it is clear that Philippines has the highest cyclone mortality risk in the ASEAN region, followed by Vietnam and Myanmar. The region is periodically affected by great cyclonic storms such as Nargis, Ketsana, Morakot, Fengshen, Durian, Parma.

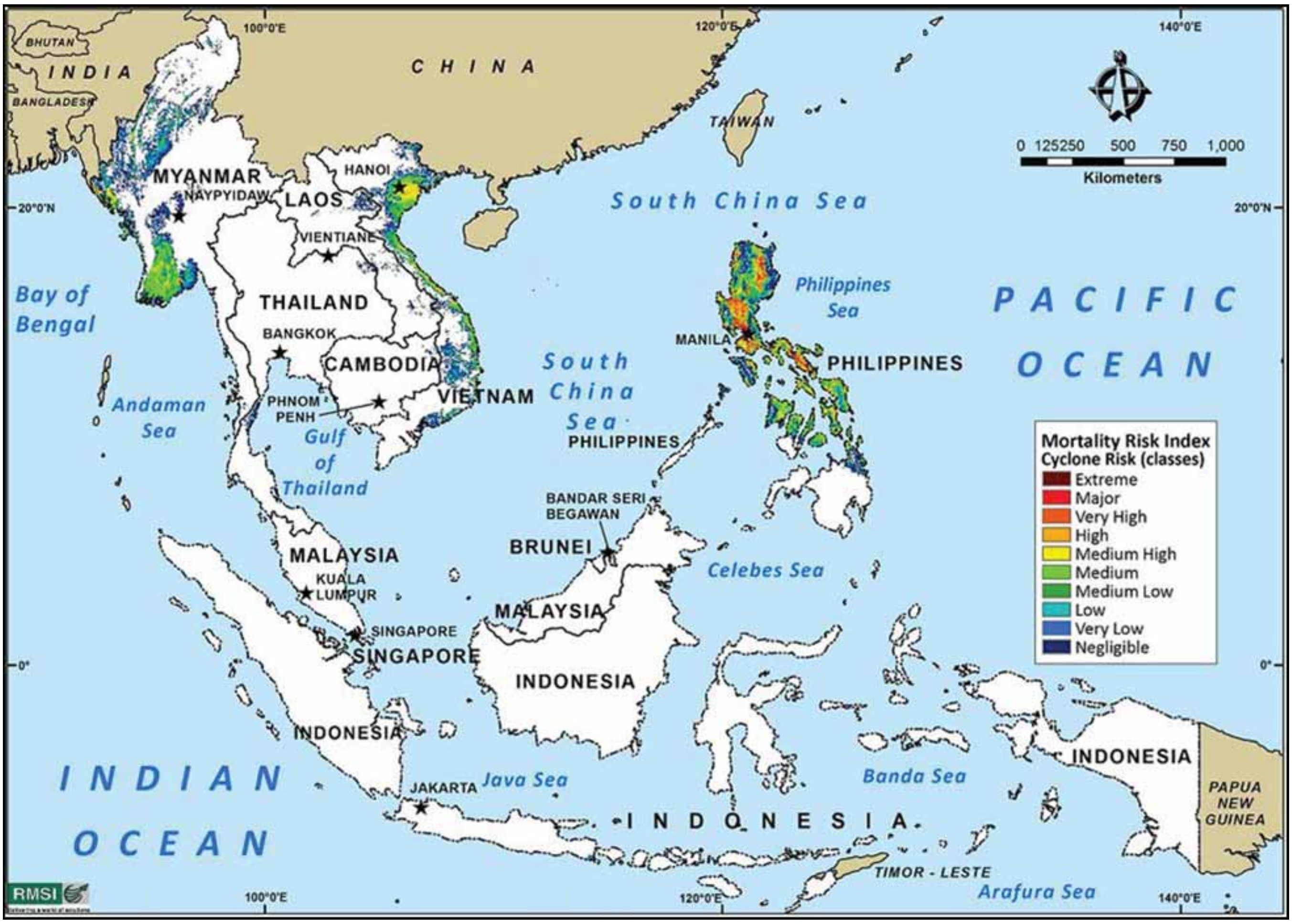


Figure 51 Cyclone mortality risk map of ASEAN (Source: GAR, 2009)

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 9 presents, by country, the percentage area under different cyclone zones. In terms of percentage area covered under the cyclone influence, Philippines comes first in the list in ASEAN followed by Vietnam and Myanmar. In Philippines, 25 percent of the area falls under the moderate cyclone mortality risk whereas, high to extreme mortality risk areas covers about 14 percent of the country. Due to a higher concentration of populations along its coasts, in Philippines, 58 per cent people live under high to extreme cyclone mortality zone. In Vietnam, more than 12 per cent of country's total area falls under the moderate to extreme cyclone mortality risk zone where 44 per cent of the country population lives. About 6 per cent of land area of Myanmar comes under the moderate to extreme cyclone mortality risk zones, accounting for 38 per cent of country's total population. In rest of the countries of ASEAN region, the cyclone mortality risk is very low.

Table 9 Percentage area and population in each cyclone mortality risk category

Country	% of total country geographic area						% of total country population					
	Low	Mod.	High	Extreme	No data	Total	Low	Mod.	High	Extreme	No Data	Total
Brunei	-	-	-	-	100.00	100	-	-	-	-	100.0	100
Cambodia	0.43	-	-	-	99.57	100	0.38	-	-	-	99.62	100
Indonesia	0.03	0.01	-	-	99.96	100	0.31	0.16	-	-	99.53	100
Laos	4.01	0.01	-	-	95.98	100	11.25	0.15	-	-	88.60	100
Malaysia	-	-	-	-	100.00	100	-	-	-	-	100.0	100
Myanmar	16.09	6.38	0.42	0.02	77.09	100	17.11	25.25	8.27	5.31	44.06	100
Philippine	23.23	24.97	11.72	2.39	37.69	100	3.02	15.07	23.56	34.79	23.56	100
Singapore	-	-	-	-	100.00	100	-	-	-	-	100.00	100
Thailand	0.91	0.03	-	-	99.06	100	1.18	0.27	-	-	98.55	100
Vietnam	19.72	11.10	0.83	0.01	68.34	100	13.87	35.86	8.13	0.74	41.40	100

Source: Area computed from the cyclone mortality risk map of the GAR preview data platform and potential population computed from Landscan

Multi-Hazard Mortality Risk

The multiple risks include an estimate of the risk induced by multiple hazards. To compute the multi hazard risk, spatial distribution of mortality risk is accumulated for tropical cyclones, floods, earthquakes and landslides for different countries. To calculate the multiple mortality risk index, first the risk absolute (average killed per year) and risk relative (killed per million per year) are calculated for each hazard type for each country (GAR, 2009). The mortality risk index is the average of risk absolute and risk relative and the unit in the estimated multi-hazard risk index ranges from 1 (negligible) to 10 (extreme). Figure 52 shows the multi-hazard mortality risk for the ASEAN region.

From Figure 52 and Table 10, it is evident that the multi-hazard mortality risk is higher for Philippines, Vietnam, Myanmar and Indonesia. In Philippines, in terms of country's total geographical area, 7 per cent of area comes under extreme multi-hazard risk category, followed by Vietnam (6 per cent) and Myanmar (5 per cent). Moreover, about 27 per cent of the area in Philippines falls under high multi-hazard risk, which clearly shows the country being exposed to different kinds of hazards.

About 52 per cent and 32 per cent of the total population of Philippines live under extreme and high multi-hazard mortality risk zones, respectively. This may be because of the high concentration of population in the coastal areas. Apart from Philippines, Indonesia (45 per cent), Myanmar (38 per cent) and Cambodia (33 per cent) are the other ASEAN countries with high population percentages living under extreme multi-hazard mortality risk.

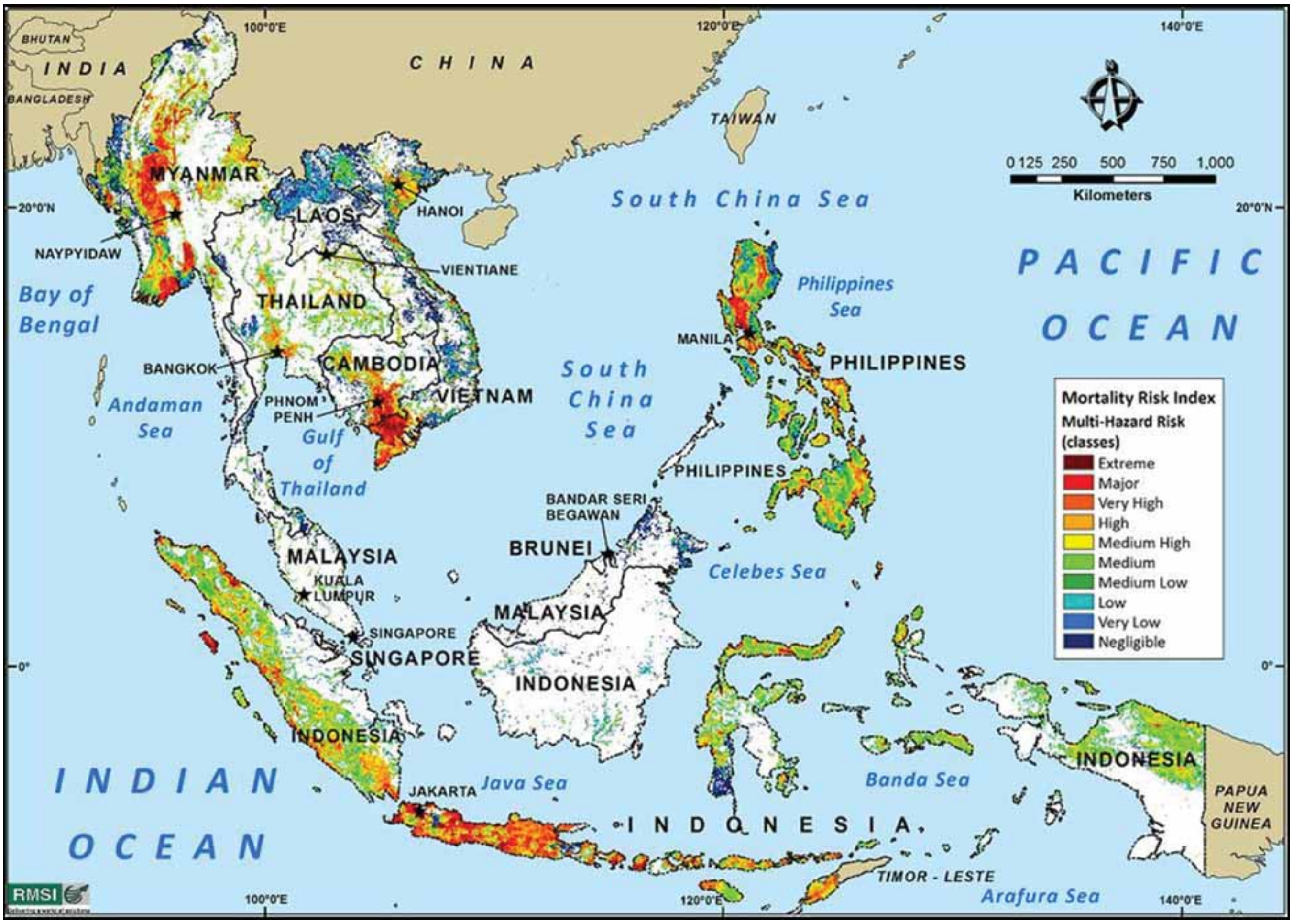


Figure 52 Multi-Hazard mortality risk map of ASEAN (Source: GAR, 2009)

6.6 Disaster risk profile

Vulnerability indicators such as the number of disaster events, deaths, affected population and economic losses have been plotted against hazard types as well as for 5-year intervals covering the 40-year period 1970-2009. Figure 54 (a, b, c) plots the total number of deaths, affected population and economic losses against each hazard type, while Figure 55 (a, b, c) presents the same variables plotted against 5-year periods.

Figure 54 shows that among natural hazards, typhoons (cyclonic storms) caused the largest number of deaths (184,063), followed by earthquakes (105,735) and tsunamis (92,021). Storms caused the highest economic loss ($16.098 billion), followed by floods ($14.475 billion), earthquakes ($7.673 billion), tsunamis ($4.253 billion), droughts ($1.828 billion), volcanoes ($561 million) and landslides ($157 million).

The period 2000-2004 (Figure 55) was the worst in terms of number of deaths (184,215) mainly because of 26 December 2004 tsunami. While, the period 2005-2009 was worst in terms of affected population (75.73 billion) and economic losses ($18.399 billion).

Floods have the highest frequency (10.85 per year), followed by storms (9.65), and earthquakes

Table 10 Percentage area and population in each multi-hazard category

Country	% of total country geographic area						% of total country population					
	Low	Mod.	High	Extreme	No data	Total	Low	Mod.	High	Extreme	No Data	Total
Brunei	14.55	0.37	0.37	-	84.71	100	60.48	2.45	5.81	-	31.26	100
Cambodia	7.40	11.57	12.28	4.82	63.93	100	3.84	16.04	31.74	33.72	14.66	100
Indonesia	6.18	21.48	11.49	3.26	57.59	100	4.29	5.72	27.05	45.85	17.09	100
Laos	29.76	7.19	1.71	0.19	61.15	100	18.94	18.91	14.64	9.82	37.69	100
Malaysia	9.31	3.02	0.33	0.01	87.33	100	8.46	10.05	7.25	0.34	73.90	100
Myanmar	9.56	18.77	14.10	5.32	52.25	100	6.05	17.14	24.95	38.63	13.23	100
Philippine	13.36	47.05	27.17	7.03	5.39	100	0.99	12.67	32.64	52.74	0.96	100
Singapore	-	-	-	-	100.00	100	-	-	-	-	100.00	100
Thailand	8.51	13.20	5.06	0.20	73.03	100	6.34	21.26	15.60	3.48	53.32	100
Vietnam	25.30	15.37	10.46	6.06	42.81	100	8.91	10.82	24.55	29.25	26.47	100

Source: Area computed from the Multi-Hazard mortality risk map of the GAR preview data platform and potential population computed from Landscan

(2.60). Storms have the highest death rate (4,602) followed by earthquakes (2,852), and tsunamis (2,090). The relative vulnerability is also highest for storms (7.76), followed by earthquakes (4.81) and tsunamis (3.52).

For ASEAN, economic AAL for different hazards is: Forest-fires ($512 million), storms ($339 million), floods ($312 million), earthquakes ($244 million), tsunamis ($214 million), droughts ($46 million), volcanoes ($32 million), and landslides ($4 million) (Figure 39).

The 20-year return period loss (an event with 5 per cent probability of exceedance) for all natural hazards is $6.207 billion (0.22 per cent of GDP PPP), while the 200-year return period (an event with 0.5 per cent probability of exceedance, generally corresponds to a catastrophic event) loss is $13.943 billion (0.49 per cent of GDP PPP).

6.7 Social and economic vulnerability analysis

Social vulnerability (SV) is a complex set of characteristics that include personal 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 a disaster is one of the major indicators of SV in a country. In this study, the SV of a country was estimated based on the average number of people killed per year, and the SV ranking was estimated based on the average number of people killed per year per million (relative social vulnerability).

The analysis of disaster data (Table 11) for the period 1970-2009 shows that the average number of people killed per year per million for the ASEAN region stood at 17.5. In Myanmar (highest), the relative SV is more than 3.5 times that of Indonesia (the second highest). In terms of relative SV ranking, Myanmar has the highest ranking followed by Indonesia, Philippines, Thailand, Vietnam, Laos, Cambodia, and Malaysia. Due to paucity of disaster loss data, the SV ranking could not be carried out for Brunei, and Singapore.

Table 11 Comparative analysis of social vulnerability for ASEAN countries

Country	Population (Millions)	Total Killed (1970-2009)	Combined Disaster Risk from Natural hazards	
			Killed per year	(Killed per year) per million
Brunei	0.38			
Cambodia	14.49	2,063	52	3.56
Indonesia	240.27	195,824	4,896	20.38
Laos	6.83	1,155	29	4.22
Malaysia	25.71	1,300	33	1.26
Myanmar	48.137	139,317	3,483	72.35
Philippines	97.97	46,761	1,169	11.93
Singapore	4.65			
Thailand	65.99	12,215	305	4.63
Vietnam	88.57	16,292	407	4.60
ASEAN	593.05	414,927	10,373	17.49

Source: Area computed from the Multi-Hazard mortality risk map of the GAR preview data platform and potential population computed from Landscan

The economic vulnerability (EV) of a country can be measured in terms of the likelihood of economic losses resulting from disasters. The relative EV of a country can be measured by the economic losses as a percentage of that country's GDP PPP. Average Annual Loss (Figure 53) and economic loss potential for different probabilities of exceedance have been estimated for all the natural hazards (Table 12). In order to rank ASEAN countries based on relative EV, the economic losses as a percentage of GDP PPP for 0.5 per cent of exceedance (200-year return period) have been taken as a benchmark. According to this categorization, Myanmar has the highest EV ranking in the region, followed in descending order by Laos, Indonesia, Cambodia, Vietnam, Philippines, Thailand and Malaysia. Due to paucity of economic loss disaster data, the Average Annual Loss (AAL) and economic loss analysis for different probability of exceedance could not be carried out for Brunei and Singapore.

Table 12 Comparison of economic losses in ASEAN countries and region

Country	Average Annual Loss (AAL) $ millions	Economic Loss ($ millions)			Per cent of GDP PPP		
		Annual exceedance probability			Annual exceedance probability		
		0.5%	5%	20%	0.5%	5%	20%
Brunei							
Cambodia	23	299	112	38	1.07	0.40	0.14
Indonesia	926	10,640	3,623	1,315	1.10	0.37	0.14
Laos	30	426	133	44	2.91	0.91	0.30
Malaysia	75	1,032	327	85	0.27	0.09	0.02
Myanmar	169	3,093	873	227	5.48	1.54	0.40
Philippines	284	2,144	1,208	686	0.66	0.37	0.21
Singapore							
Thailand	272	3,220	1,216	422	0.60	0.23	0.08
Vietnam	205	1,971	907	413	0.77	0.35	0.16
ASEAN	1,985	13,943	6,207	2,889	0.49	0.22	0.10

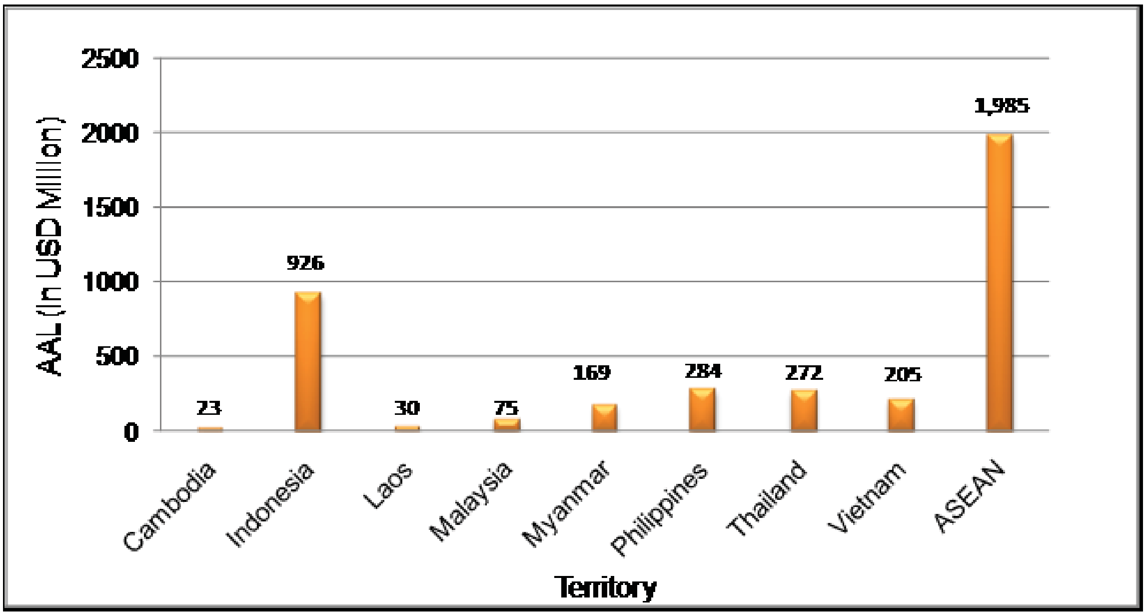
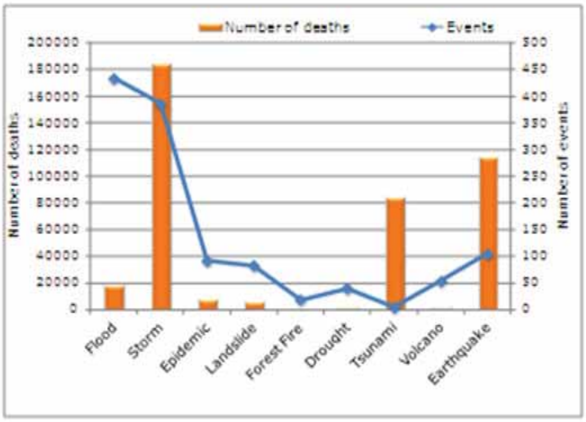


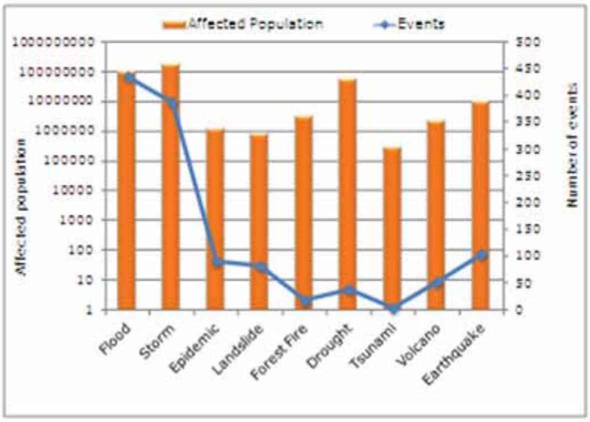
Figure 53 AAL for different countries and ASEAN region

Figure 54	ASEAN Disaster events and socio-economic impact by hazard type (1970-2009)

54a Disaster events and number of deaths



54b Disaster events and affected population



54c Disaster events and economic loss

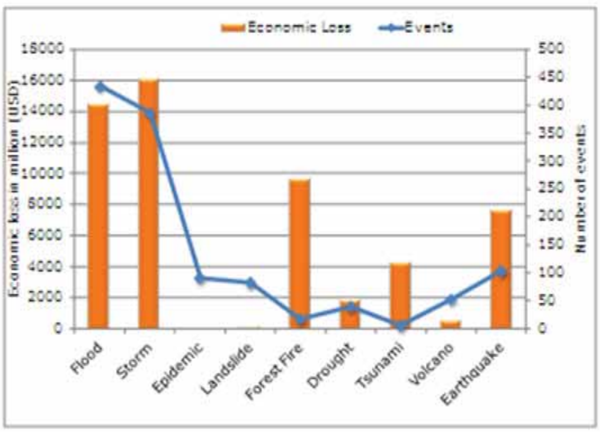
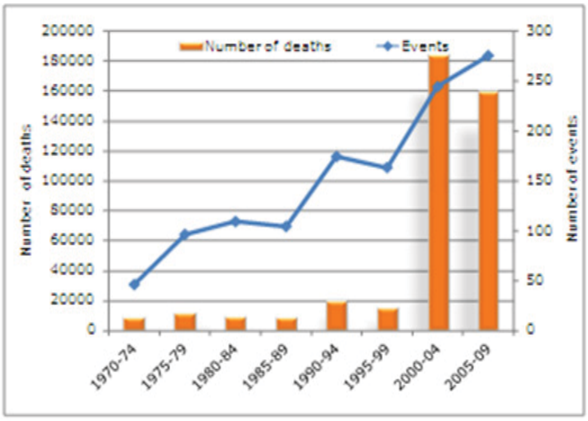
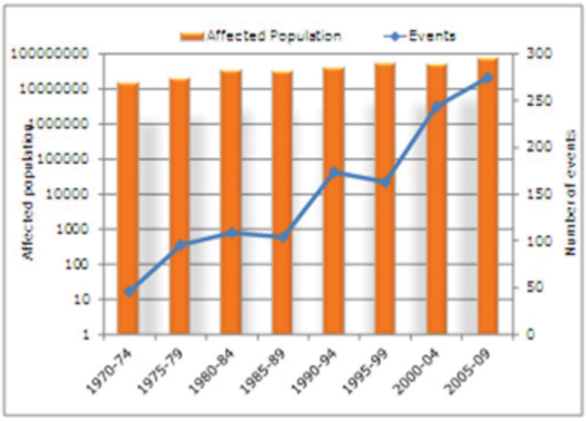


Figure 55	ASEAN Disaster events and socio-economic impact by 5-year periods (1970-2009)

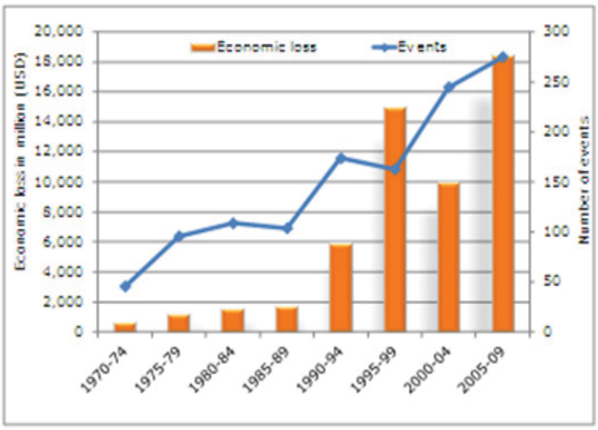
55a Disaster events and number of deaths



55b Disaster events and affected population



55c Disaster events and economic loss



Trans-boundary Disaster Risks and their Effects

7

There is a significant risk from trans-boundary hazards such as earthquakes and tsunamis, droughts, haze, typhoons, and floods in the ASEAN region. The effects of some of the most relevant past events are outlined below:

7.1 Indian Ocean Tsunami, 2004

The Indian Ocean tsunami that occurred on December 26, 2004 is the worst tsunami ever recorded, in terms of lives lost (USGS). This Tsunami was caused due to the magnitude (M) 9.3 Sumatra-Andaman earthquake that occurred along the Sunda Trench subduction zone plate boundary at the epicentre 3.31°N and 95.95°E, approximately 250 km south-southeast of Banda Aceh in northern Sumatra, Indonesia (Figure 56). The earthquake was widely felt all around the northern Indian Ocean (RMS, 2006). The earthquake-generated tsunami swept across the Indian Ocean within hours, affecting 14 countries. The hardest-hit and most severely affected countries included Indonesia, Sri Lanka, India, Thailand, Somalia, and Maldives. The other affected countries were Malaysia, Myanmar, Seychelles, Bangladesh, Tanzania, South Africa, Yemen, and Kenya. The event killed about 174,500 people in the 14 countries, caused an estimated economic loss of more than $10 billion, and insured losses of about $1.3 billion (RMS, 2006). It displaced hundreds and thousands of persons and over 3 million persons were affected (http://www.recoveryplatform.org).

This catastrophic event devastated the Banda Aceh Province and parts of the North Sumatra Province of Indonesia. The casualties were massive and accounted for 126,900 deaths in the country. The event also caused an estimated damage of $ 4.5 billion (RMS, 2006).

The tsunami also affected parts of the 400 km western coastline of Thailand. Phang-Nga and Krabi were the worst hit areas, whereas Ranong, Phuket, Trang and Satun were severely affected areas. As per RMS report (RMS, 2006), the death toll in Thailand was 5,400 people and economic losses touched $ 1 billion.

India experienced the devastating effects of the tsunami with tidal waves of 3 to 10 m high, which affected the eastern and southern coastal areas and Union Territory of Andaman & Nicobar Islands. The tsunami event killed 10,700 people (RMS, 2006). Tamil Nadu alone reported 7,983 deaths, followed by Pondicherry (591), Kerala (171), and Andhra Pradesh (105) (UNDP).

In Sri Lanka, the tsunami caused extensive damage killing over 31,000 persons and causing $ 1 billion damage (RMS, 2006). The Northeast region, including Kilinochi, Mullaitivu, Amparai, were the worst affected by the tsunami (UNDP).

From this huge catastrophe, it is clear that the death toll could have been drastically reduced if an early warning system had been in place to alert communities to evacuate the coastal areas and move inland. In addition to the extensive disaster relief and reconstruction during the post tsunami period, the international community took a series of steps including logistics, coordination, information systems, resource allocation and management at a regional level. Sincere efforts were made to install an Indian Ocean Tsunami Warning and Mitigation System (IOTWS) (http://apps.develebridge.net/usiotws/pageaahome.html, http://www.undp.org/cpr/disred/documents/tsunami/flashappeal_060105.pdf).

As per the Hyogo Framework of Action (HFA, 2005 – 2015), five priorities, namely, DRR as a political priority, risk assessment and early warning system, education and public awareness, mitigation and building codes, and preparedness for response have been initiated (UNISDR).

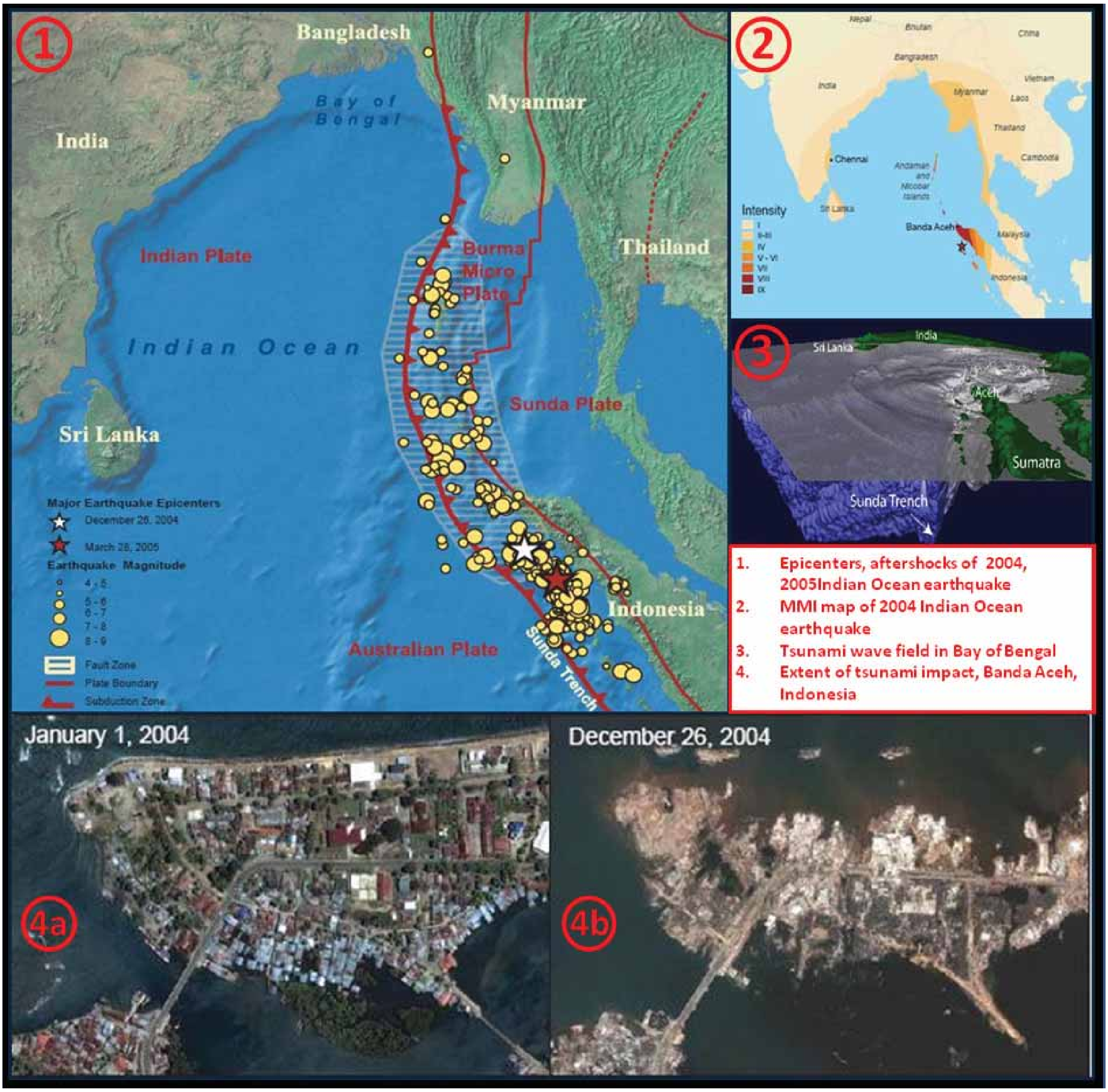


Figure 56 December 26, 2004 Indian Ocean Tsunami

Source: RMS and USGS

7.2 2004-05 Drought in Southeast Asia

Southeast Asia, particularly the Indochina peninsula (Myanmar, Cambodia, Laos, Thailand and Vietnam), suffered from extensive drought conditions. In 2004, the wet season ended about a month ahead of schedule, which triggered drought conditions to develop across the region. Figure 57 shows the satellite image of drought affected areas and precipitation anomalies (mm) in the Southeast Asia region in 2005.

The 2004-05 drought severely affected Thailand and the Thai government declared 70 out of its 76 province as drought-hit. It also affected more than 9.0 million farmers of Thailand and almost a million hectares of paddy field. As per UNESCAP (2007), the drought severely affected the production of rice, coffee, sugar and other crops and lowered the supply of water for drinking and irrigation According to EM-DAT, 0.6 million and 0.4 million people were affected in Cambodia and Vietnam, respectively. The event reportedly caused an economic loss of $ 420 million and $ 42 million in Thailand and Vietnam, respectively.

7.3 Mekong Flooding and Transboundary Water Dispute

The Mekong is the longest river of Southeast Asia with a drainage area of 795,000 sq km (Figure 58). It originates from the south-eastern Himalaya Mountains of China's Tibetan Plateau and flows towards the south and east on its way to the South China Sea. The length of the river is about 4,800 km and it flows through China, Myanmar, Laos, Thailand, Cambodia and Vietnam. The flows of Mekong and its tributaries are closely related to the rainfall pattern, particularly the monsoonal rainfall. Tonle Sap, a river-and-lake system in Cambodia, stores a portion of Mekong peak flow during the monsoonal period. The seasonal Mekong flood is chiefly attributed from the tributaries that join the mainstream along its lower course. The lower Mekong basin catchment area alone comprises more than 600,000 sq km. It covers almost all of Cambodia and Laos, one-third of Thailand and one-fifth of Vietnam. The Mekong River Basin is home to about 60 million people (The Mekong River Commission, MRC).

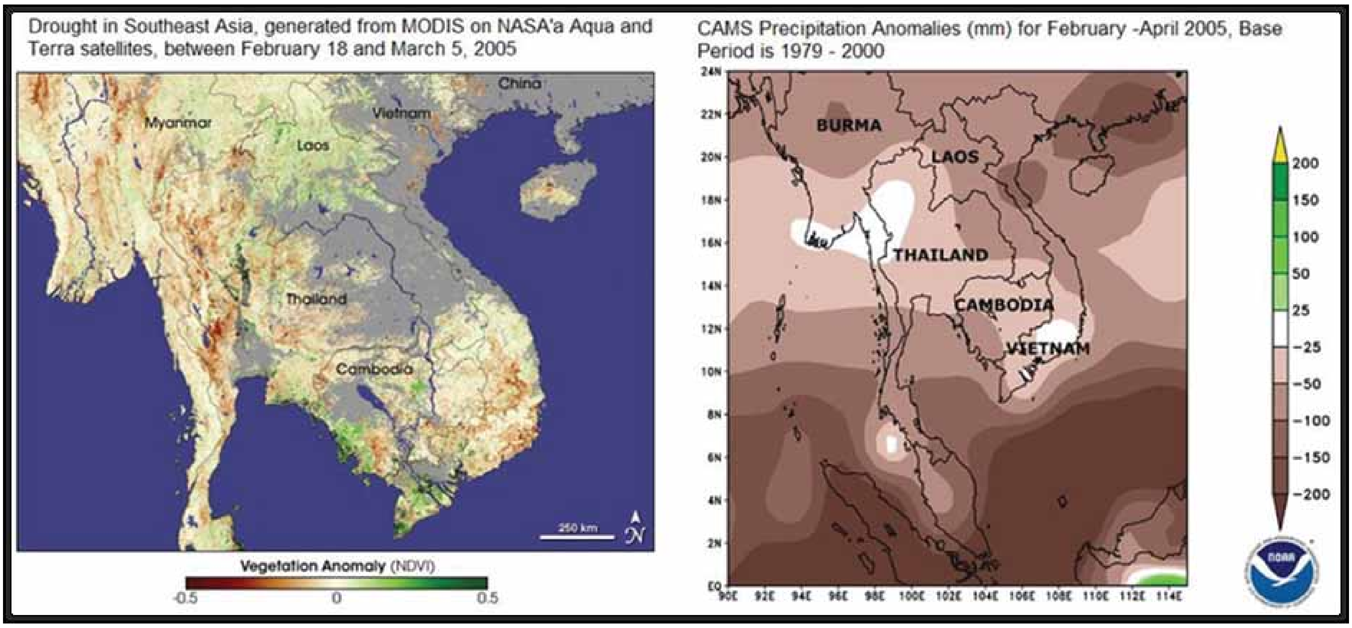


Figure 57 2004-05 drought in Southeast Asia

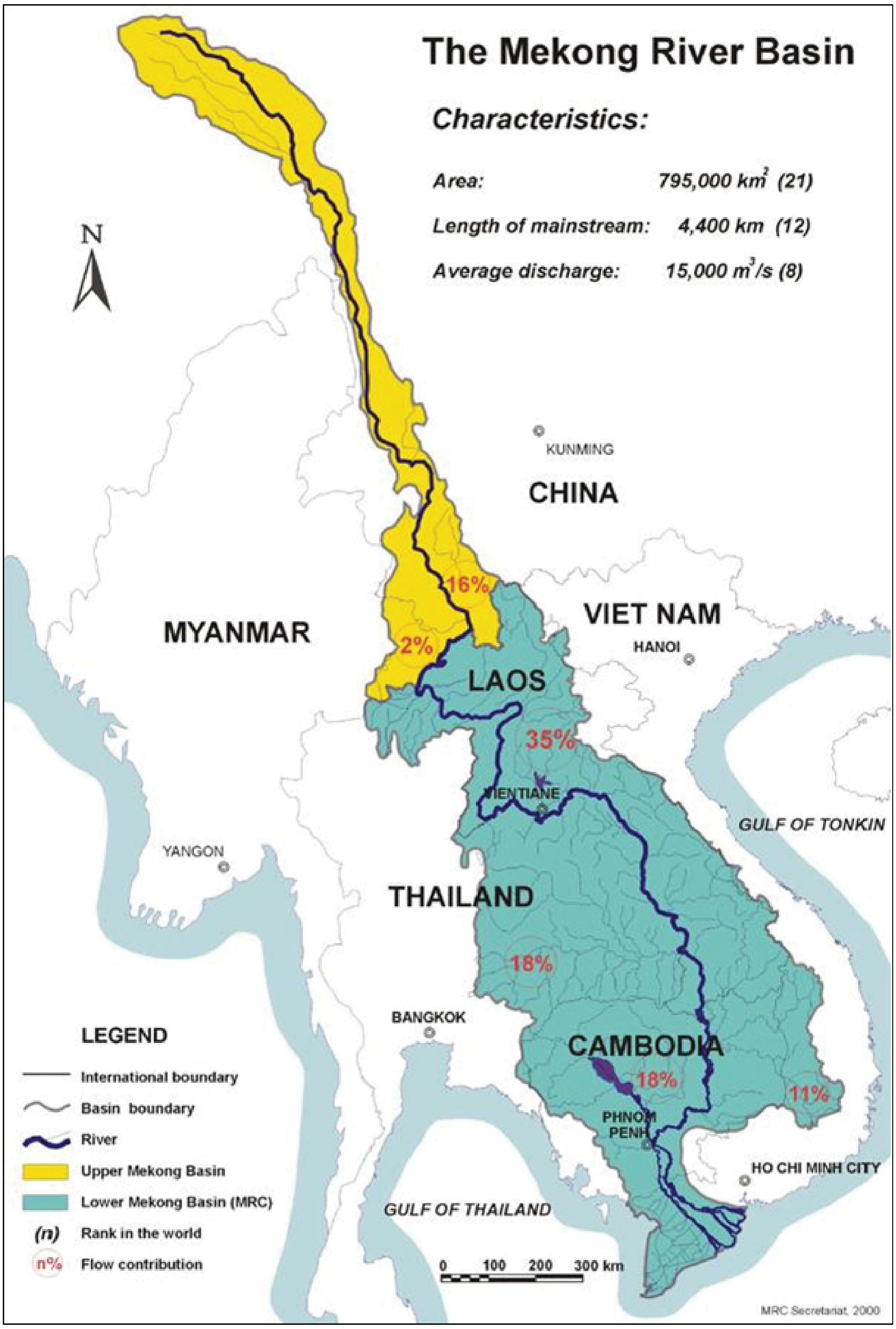


Figure 58 Mekong River Basin

The recurrent flood hazard in the Lower Mekong Basin (LMB) is a serious concern for the region. The high concentration of people living in the flood prone areas has increased the disaster risk to a significant extent. In 2000 (Aug-Nov), the Lower Mekong region observed a record-breaking flood in Cambodia and Vietnam, where over 300,000 people were evacuated from the flooded areas. The event caused 800 casualties with an economic loss of $ 400 million. During the 2001 flood event, more than 300 people died and caused an estimated economic damage of $ 100 million. In 2002, Cambodia, Vietnam, Thailand and Laos suffered heavy economic losses due to floods in the Mekong. The economic losses in Cambodia and Vietnam were $ 40 million and $ 24 million, respectively. Among the other flood events in the Mekong, the August 2008 event was the most significant, when the peak water level reached a record height of 13.7 m in Vientiane (Laos). Luang Prabang, Vientiane and Nong Khai along with other rural areas of Laos and Thailand were flooded by this event. It caused an economic loss of $ 66.5 million in Thailand (http://www.mekongnet.org).

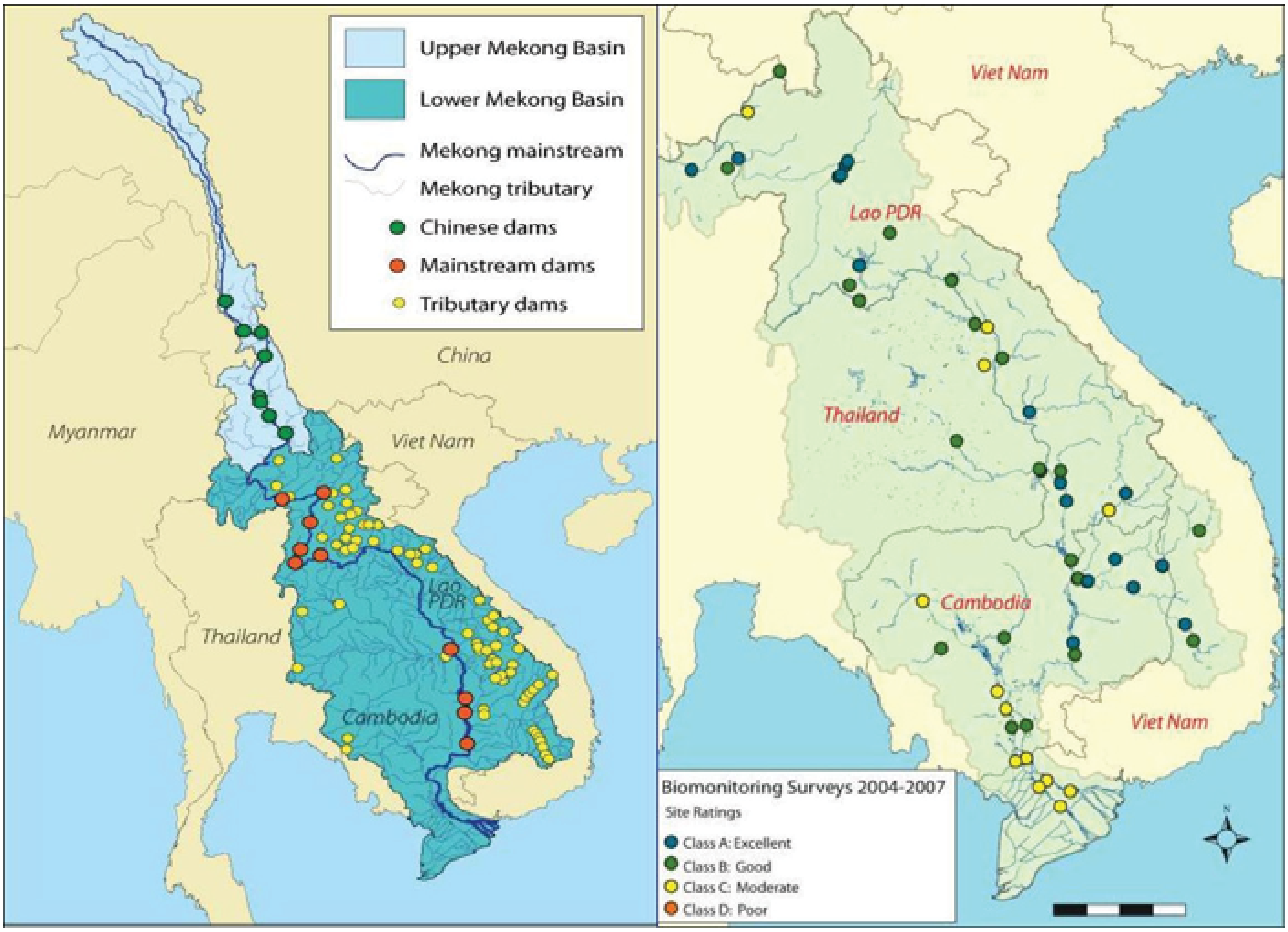


Figure 59 Dams in Mekong River Basin

Source: http://yaleglobal.yale.edu/sites/default/files/images/2009/07/damBIG.jpg & MRC

In addition to annual flood hazard, another emerging issue in ASEAN is the construction of dams on the upper Mekong River in China and increasing demands on water and environmental resources in the lower Mekong Basin (Figure 59). These transboundary issues may affect regional security (http://goliath.ecnext.com). China, located in the upstream position, engaged in an extensive program of environmentally detrimental 'Three Georges Dam' project. It has already completed the construction of two dams - Manwan (1993) and Dachaoshan (2003) and at least four others are under consideration. During the dam filling stage, the flow of the river reduces dramatically as experienced after the completion of the Manwan dam. The downstream countries fear that not only will the river volume decrease, but also the dams will prevent nutrient rich sediments from flowing to downstream countries. This may cause serious harm to agriculture and fishing activities in the downstream areas. Moreover, the Tonle Sap river-and-lake system in Cambodia would face the greatest danger of biodiversity degradation (http://www1.american.edu).

7.4 Typhoon Ketsana, September 2009

Typhoon Ketsana, one of the most destructive typhoons in recent years, caused severe damage in the Philippines, Vietnam, Cambodia, Laos, and Thailand (Figure 60). A low-pressure cell originated in the Western Pacific Ocean, intensified into a tropical depression on 24th Sept. 2009 and transformed into the tropical storm called Ketsana on the morning of the 26th Sept. The storm moved westward across Central Luzon Island of Philippines to the central part of the South China Sea and reached typhoon status by the afternoon of 28th Sept. It continued to move west and made landfall over Vietnam, before downgrading into a tropical storm by the evening of the 29th Sept. It downgraded again to a tropical depression while passing across the Lao P.D.R. to the north-eastern part of Thailand. After passing across Vietnam, Lao P.D.R. and entering the north-eastern part of Thailand, it produced widespread rain, especially in the lower part of the north-eastern Thailand. Flash floods were reported in several areas of the lower part of north-eastern and central Thailand. Typhoon Ketsana, which weakened to a tropical depression when it approached Thailand, affected

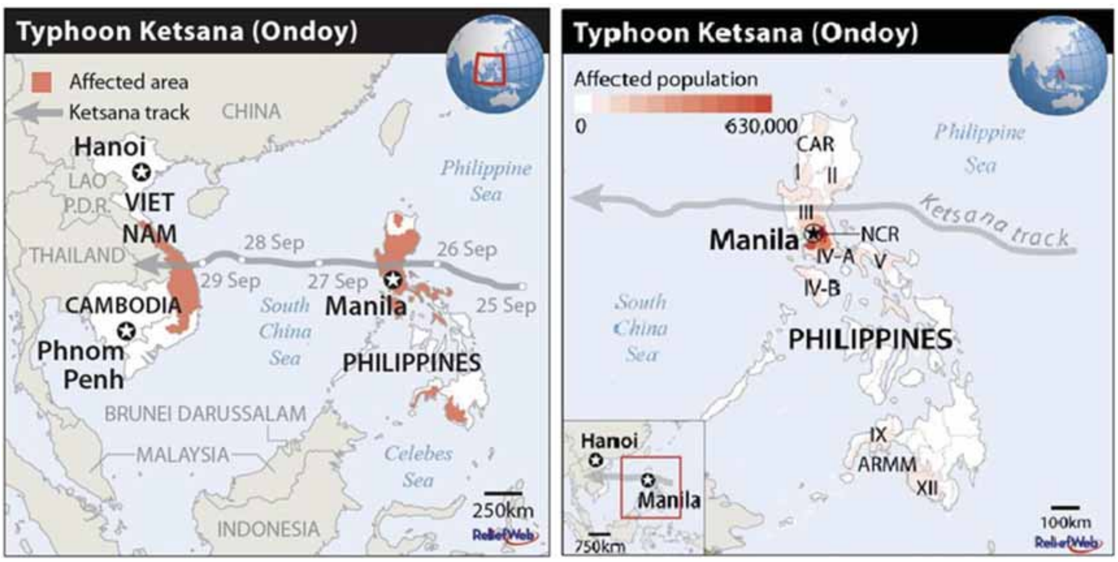


Figure 60 Track of Typhoon Ketsana

Source:http://www.reliefweb.int/rw/rwb.nsf/db900SID/LPAA-7WDH78?OpenDocument ,http://www.reliefweb.int/rw/fullmaps_sa.nsf/luFullMap/84454A7555668797C1257642004C03AF/$File/TC-2009-000205-PHL_0930.pdf?OpenElement approximately 40 provinces of north-eastern, northern and southern parts of Thailand. Two people were killed and 2.9 million people were affected. There were 44 houses destroyed, 4,683 houses partially damaged, and 821,300 acres of agricultural area were destroyed. The total damages were estimated at $ 20.3 million (http://typhooncommittee.org/).

7.5 1997-98 Southeast Asian Haze

The 1997-98, the Southeast Asian Haze (Figure 61), originated from widespread forest fires in the ASEAN countries, particularly Indonesia, causing significant transboundary air pollution. East Kalimantan of Indonesia was most severely affected, where more than 5.2 million hectares were under forest and land fire. The Sumatra Island of Indonesia also experienced regular forest and land fire during this period. The smoke originated from these forest fires that were set of indiscriminately to clear land mostly by slash-and-burn farmers and plantation companies (pulpwood and oil palm). These pumped enough smoke into the air to blanket the entire region by haze that extended as far as southern Thailand and Philippines in the north, with Malaysia and Singapore being worst affected. The life and health of more than 70 million people was jeopardized and natural habitat in the haze covered region were pushed closer to extinction. During 1997–98, the losses from regional haze in ASEAN in terms of its affect on agriculture, transport, tourism and other economic activities were estimated at $ 9 billion. (http://www.fire.uni-freiburg.de/se_asia/projects/asean.html, http://www.adb.org/Documents/Reports/SEA_WSSD/part_d4.pdf, http://www.idrc.ca/en/ev-9410-201-1-DO_TOPIC.html, http://www.adb.org/Documents/Reports/Fire_Smoke_Haze/intro.pdf).

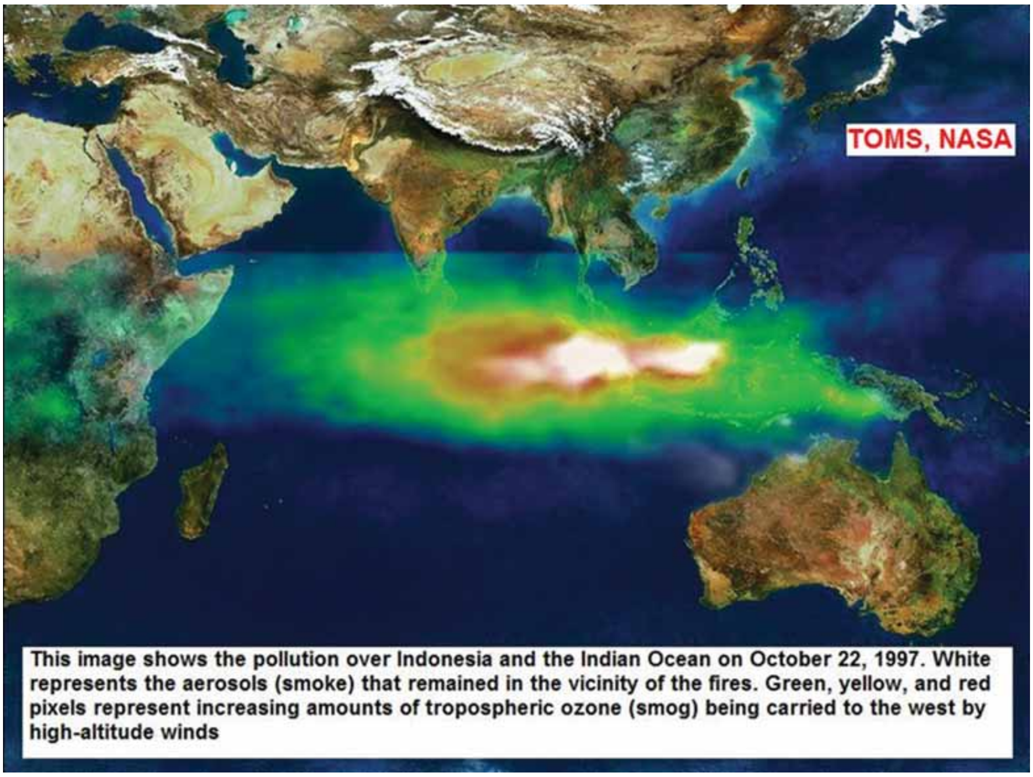


Figure 61 Southeast Asian Haze (1997-98)

Visible Earth, NASA (http://visibleearth.nasa.gov/view_rec.php?id=1651)

Population Growth and Economic Highlights

8

Most of the countries in ASEAN region are developing countries, with a substantial population and population growth rate. As the population and the economy of a country are two major, socio-economic parameters that are most affected due to the disasters caused by natural hazards. Thus, in the subsequent sections, the population and economic growth trends have been presented in brief.

8.1 Brunei

Brunei has a population of 0.39 million people growing with a rate of 1.76 per cent annually. The urban population accounts for 75 per cent of the total population of the country (CIA World Fact Book, 2009).

Economy

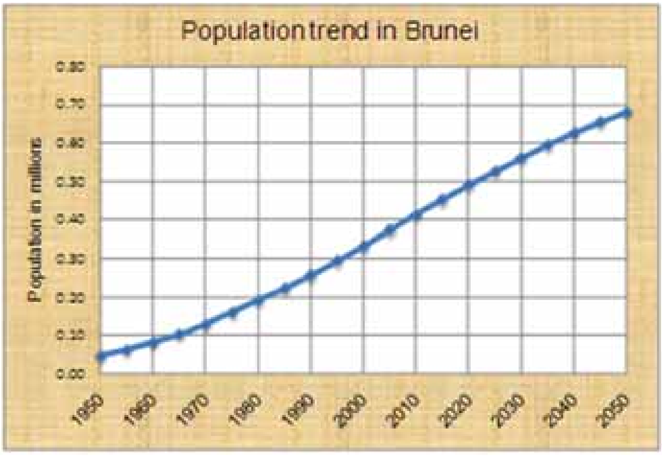
Brunei is a high-income country (WB, 2009) with a GDP PPP per capita of $50,100, GDP PPP of $ 19.44 billion and annual GDP growth rate of -1.90 per cent (CIA World Fact Book, 2009). The population and GDP growth trends for the country are shown in Figure 62.

The agricultural sector output (0.7 per cent of GDP) consists of a range of grains, fruits, vegetables and livestock.

The industrial/manufacturing sector output (75 per cent of GDP) mainly includes petroleum, petroleum refining, liquefied natural gas and construction.

The services sector (24.3 per cent of GDP) is concentrated in public administration and trades such as hotels, restaurants, wholesale and retail trade, transport, storage, and communications.

As a small well to do economy, Brunei depends critically on the crude oil and natural gas production, which accounts for more than 50 per cent of the GDP. The sustained GDP growth in the country saw a negative growth during period 2008-2009 due to the global melt down. However, as the global economy recovers the country is expected to grow positively at a constant rate (IMF).



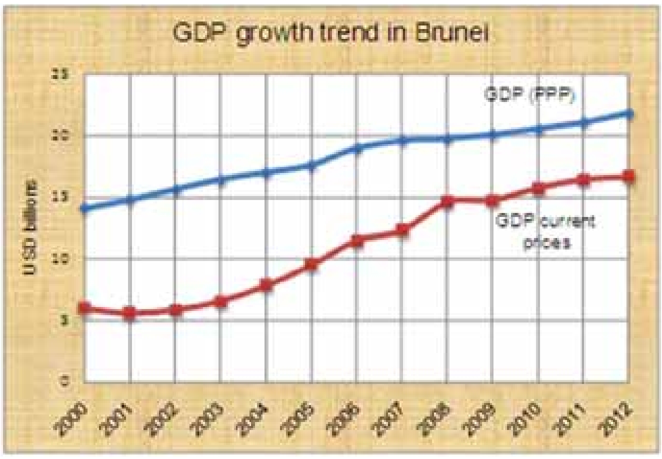


Figure 62 Population (1950-2050) and GDP (2000-2012) growth trends in Brunei

8.2 Cambodia

Cambodia has a population of 14.49 million, which is growing at the annual rate of 1.77 per cent. The urban population accounts for the 22 per cent of the total population (CIA World Fact Book, 2009).

Economy

Cambodia is a low-income country with the GDP PPP per capita of $ 1,900, GDP PPP of $27.92 billion and annual GDP growth rate of -1.5 per cent (CIA World Fact Book, 2009). The population and GDP growth trends for the country are shown in Figure 63.

The agricultural sector output (29 per cent of GDP) consists of a range of products such as rice, rubber, corn, vegetables, cashews, tapioca, and silk.

Tourism, garments, construction, rice milling, fishing, wood, dominate the industrial/manufacturing sector output (30 per cent of GDP) and wood products, rubber, cement, gem mining, and textiles.

The services sector (41 per cent of GDP) is concentrated in public administration and trades such as hotels, restaurants, wholesale and retail trade, transport, storage, and communications.

During the period 2004-2007, Cambodia's economy grew with an annual average rate of 10 per cent, which was mainly contributed by expansion in the garment, construction, agriculture, and tourism sectors. The tourism industry has continued to grow rapidly, with foreign arrivals exceeding 2 million per year in 2007-08. However, GDP growth declined to below 7 per cent in 2008 and saw a negative growth in the year 2009 because of the global economic slowdown (CIA World Fact Book, 2009). As the global economy recovers, the country's economy is expected to grow at a positive rate (IMF).

8.3 Indonesia

Indonesia has a population of 240.21 million with an annual growth rate of 1.14 per cent. The urban population in the country accounts for 52 per cent of the total population (CIA World Fact Book, 2009).

Economy

Indonesia is a low-middle income country (WB, 2009) with a GDP PPP per capita of $4,400, GDP PPP of $ 968.5 billion and annual GDP growth rate of 6.1 per cent (CIA World Fact Book, 2009). The population and GDP growth trends for the country are shown in Figure 64.

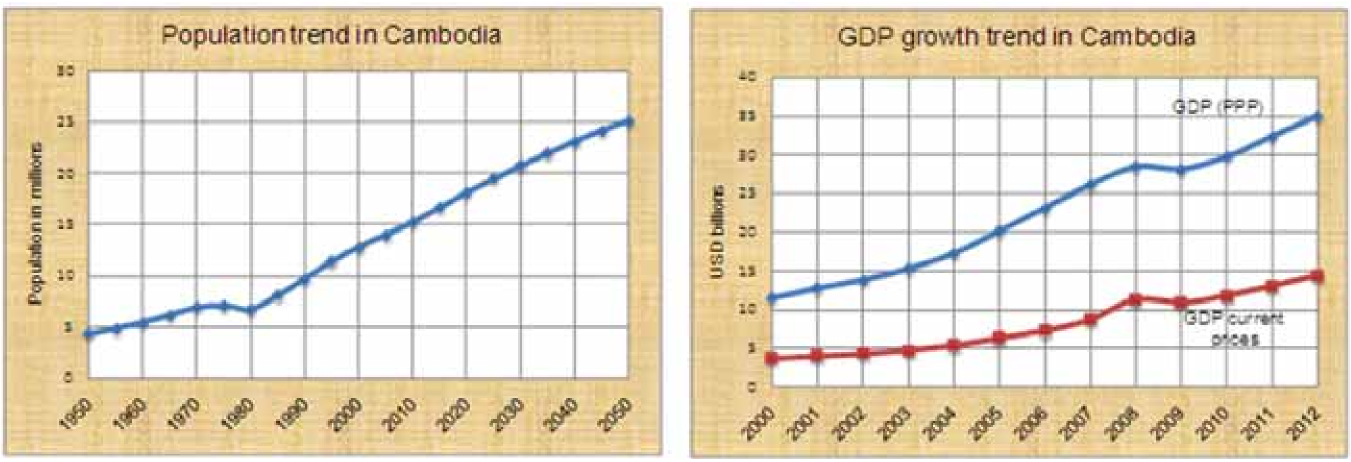


Figure 63 Population (1950-2050) and GDP (2000-2012) growth trends in Cambodia

Figure 64 Population (1950-2050) and GDP (2000-2012) growth trends in Indonesia

The agricultural sector output (14.4 per cent of GDP) consists of a range of products such as rice, cassava (tapioca), peanuts, rubber, cocoa, coffee, palm oil, copra; poultry, beef, pork, and eggs.

The industrial/manufacturing sector output (47.1 per cent of GDP) includes petroleum and natural gas, textiles, apparel, footwear, mining, cement, chemical fertilizers, plywood, rubber, food, and tourism.

The services sector (38.5 per cent of GDP) is concentrated in public administration and trades such as hotels, restaurants, wholesale and retail trade, transport, storage, and communications.

Indonesia's economy had a sustained GDP growth of 6.1 per cent. The country overcame the recent global economic slowdown with a positive growth rate, mainly due to its high reliance on the domestic consumption. The petroleum and natural gas production and exports along with wide range of industrial products contributed to the sustained economic growth in the country.

8.4 Laos

Laos has a population of 6.83 million growing at an annual rate of 1.15 per cent. The urban population in the country accounts 31 per cent of the total population of the country (CIA World Fact Book, 2009).

Economy

Laos is a low-income country (WB, 2009) with a GDP PPP per capita of $2,100, GDP PPP of $ 14.61 billion and an annual GDP growth rate of 3 per cent (CIA World Fact Book, 2009). The population and GDP growth trends for the country are shown in Figure 65.

The agricultural sector output (40 per cent of GDP) consists of variety of products such as sweet potatoes, vegetables, corn, coffee, sugarcane, tobacco, cotton, tea, peanuts, and rice. Animal husbandry in the form of rearing also contributes to this sectors output.

Copper, tin, gold, and gypsum mining dominate the industrial/manufacturing sector output (33.9 per cent of GDP); timber, electric power, agricultural processing, construction, garments, cement, and tourism.

The services sector (26.1 per cent of GDP) is concentrated in public administration and trades such as hotels, restaurants, wholesale and retail trade, transport, storage, and communications.

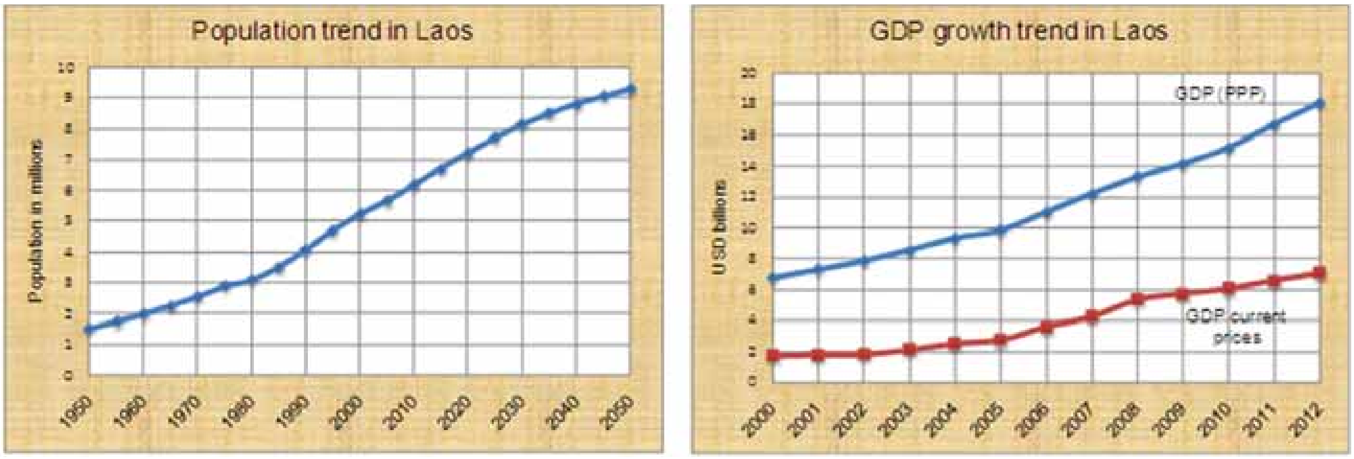


Figure 65 Population (1950-2050) and GDP (2000-2012) growth trends in Laos

Laos' economy is dominated by the agriculture sector. Rice cultivation accounts for about 40 per cent of GDP and provides more than 70 per cent of total employment in the country. The economy is also contributed from high foreign investment in hydropower, mining, and construction sector.

8.5 Malaysia

Malaysia has a population of 25.72 million growing at an annual rate of 1.72 per cent. The urban population in the country accounts for 70 per cent of the total population of the country (CIA World Fact Book, 2009).

Economy

Malaysia is an upper middle-income country (WB, 2009) with a GDP PPP per capita of $14,700, GDP PPP of $ 378.9 billion and an annual GDP growth rate of -2.8 per cent (CIA World Fact Book, 2009). The population and GDP growth trend for the country is shown in Figure 66.

Rubber, palm oil, cocoa, and rice production dominate the agricultural sector output (10.1 per cent of GDP).

The industrial/manufacturing sector output (42.3 per cent of GDP, 2006) includes rubber and oil palm processing and manufacturing, light manufacturing, electronics, tin mining and smelting, logging, timber processing, and petroleum production.

The services sector (47.6 per cent of GDP, 2006) is concentrated in goods and trades such as hotels, restaurants, wholesale and retail trade, transport, storage, and communications.

Malaysia has transformed itself since the 1970s from a producer of raw materials into an emerging multi-sector economy. The rising oil and gas exports from the country have given a boost to the economy. The country's economy has been growing steadily for the past one decade. However in 2009 the country reported negative growth in the economy.

8.6 Myanmar

Myanmar has a population of 48.14 million growing at an annual rate of 0.78 per cent. The urban population in the country accounts for 33 per cent of the total population of the country (CIA World Fact Book, 2009).

Economy

Myanmar is a low-income country (WB, 2009) with a GDP PPP per capita of $1,200, GDP PPP of $ 56.49 billion and an annual GDP growth rate of 1

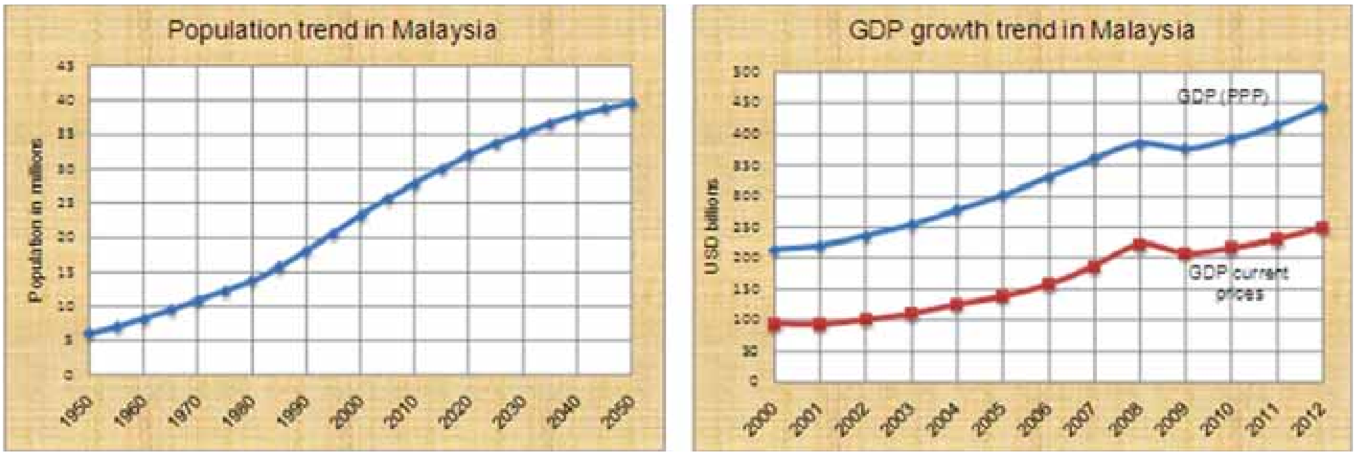


Figure 66 Population (1950-2050) and GDP (2000-2012) growth trends in Malaysia

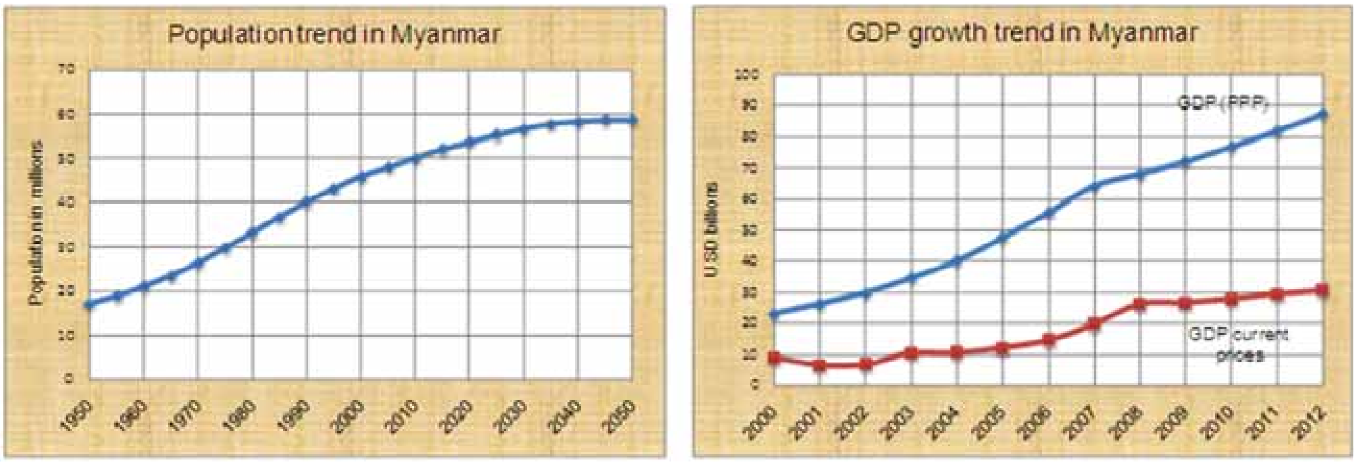


Figure 67 Population (1950-2050) and GDP (2000-2012) growth trends in Myanmar

per cent (CIA World Fact Book, 2009). The population and GDP growth trends for the country are shown in Figure 67.

Rice, pulses, beans, sesame, groundnuts, sugarcane, hardwood, and fish farming and fish products dominate the agricultural sector output (42.9 per cent of GDP).

The industrial/manufacturing sector output (19.8 per cent of GDP) includes agricultural processing, wood and wood products, copper, tin, tungsten, iron, cement, construction materials, pharmaceuticals, fertilizer, oil and natural gas, garments, and jade and gems.

Public administration and trades such as hotels, restaurants, wholesale and retail trade, transport, storage, and communications dominate the services sector (37.3 per cent of GDP).

Immediately after its independence, Myanmar suffered from a five-year civil war (1992 to 1997) in which the country lost more than 60 per cent of its GDP (Figure 67). The country's economy began to recover in 1998, allowing the Government to focus on administration and implementing an economic and social development agenda.

8.7 Philippines

The Philippines has a population of 97.98 million growing at an annual rate of 1.96 per cent. The urban population in the country accounts for 65 per cent of the total population of the country (CIA World Fact Book, 2009).

Economy

Philippines is a low middle-income country (WB, 2009) with a GDP PPP per capita of $3,300, GDP PPP of $ 327.2 billion and an annual GDP growth rate of 1.6 per cent (CIA World Fact Book, 2009). The population and GDP growth trends for the country are shown in Figure 68.

The agricultural sector output (14.9 per cent of GDP) consists of cotton, which is cultivated in half of the country's irrigated land. It is a major contributor to the country's economic growth.

The oil and gas, food processing and cotton processing industries dominate the industrial/manufacturing sector output (30.9 per cent of GDP).

The services sector (54.2 per cent of GDP) is concentrated in public administration and trades such as hotels, restaurants, wholesale and retail trade, transport, storage, and communications.

As a middle-income country, the Philippines depends significantly on the service sector, which contributes more than 50 per cent to the country's economy. The countries economy has grown steadily in the past decade, until the global slowdown during 2008-2009, significantly affected the economic growth. However, as the global economy recovers the country is expected to grow at a steady rate in the future (IMF).

8.8 Singapore

Singapore has a population of 4.66 million growing at an annual rate of 1 per cent. The total population in the country is accounted as urban population (CIA World Fact Book, 2009).

Economy

Singapore is a high-income country (WB, 2009) with a GDP PPP per capita of $50,300, GDP PPP of $ 234.5 billion and an annual GDP growth rate of -2.6 per cent (CIA World Fact Book, 2009). The population and GDP growth trends for the country are shown in Figure 69.

Figure 68 Population (1950-2050) and GDP (2000-2012) growth trends in Philippines

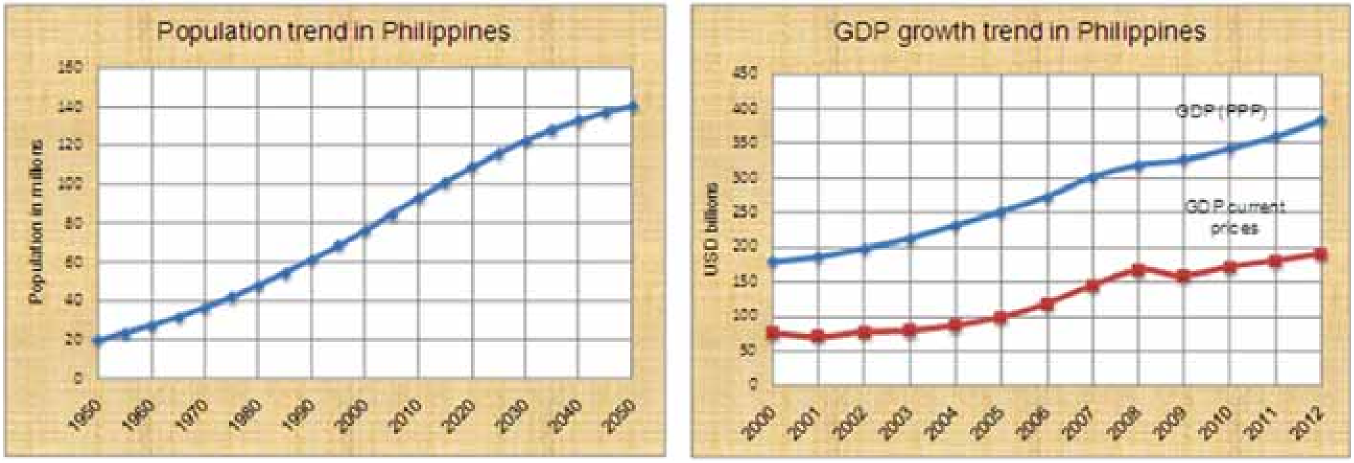


Figure 69 Population (1950-2050) and GDP (2000-2012) growth trends in Singapore

The agriculture sector is conspicuous by its absence.

The industrial/manufacturing sector output (26.8 per cent of GDP) includes electronics, chemicals, financial services, oil drilling equipment, petroleum refining, rubber processing and rubber products, processed food and beverages, ship repair, offshore platform construction, and life sciences.

The services sector (73.2 per cent of GDP) is concentrated in information technology, and trades such as hotels, restaurants, wholesale and retail trade, transport, storage, and communications.

As a high-income economy, Singapore depends heavily on exports, particularly in consumer electronics, information technology products, pharmaceuticals, and on a growing financial services sector. Since the year 2004, the economy has grown at a steady rate of 6.8 per cent until the global slowdown during 2008-2009, which significantly affected the economic growth. However, as the global economy recovers the country is expected to grow at a steady rate in the future (IMF).

8.9 Thailand

Thailand has a population of 66 million growing at an annual rate of 0.63 per cent. The urban population in the country accounts for 33 per cent of the total population of the country (CIA World Fact Book, 2009).

Economy

Thailand is a medium-income country with a GDP PPP per capita of $8,100, GDP PPP of $ 535.8 billion and an annual GDP growth rate of -3.5 per cent (CIA World Fact Book, 2009). The population and GDP growth trends for the country are shown in Figure 70.

Rice, cassava (tapioca), rubber, corn, sugarcane, coconuts, and soybeans dominate the agricultural sector output (12.3 per cent of GDP).

The industrial/manufacturing sector output (44 per cent of GDP) includes oil and natural gas, metals, machinery and equipment, textiles, and chemical products.

The services sector (43.7 per cent of GDP) is concentrated in public administration and trades such as hotels, restaurants, wholesale and retail trade, transport, storage, and communications.

As a middle-income country, Thailand depends mostly on the export of machinery, electronic components, agricultural products, and jewellery,

Figure 70 Population (1950-2050) and GDP (2000-2012) growth trends in Thailand

which contribute more than one third of the country's economy. Since 2000, country saw a steady annual economic growth of 4 per cent until the global slowdown during 2008-2009, which significantly affected the economic growth. However, as the global economy recovers the country is expected to grow at a steady rate in the future (IMF)

8.10 Vietnam

Vietnam has a population of 88.58 million growing at an annual rate of 1.14 per cent. The urban population in the country accounts for 28 per cent of the total population of the country (CIA World Fact Book, 2009).

Economy

Vietnam is a low-income country (WB, 2009) with a GDP PPP per capita of $2,900, GDP PPP of $ 256 billion and an annual GDP growth rate of 4.4 per cent (CIA World Fact Book, 2009). The population and GDP growth trends for the country are shown in Figure 71.

Paddy rice, coffee, rubber, cotton, tea, pepper, soybeans, cashews, sugar cane, peanuts, bananas, poultry, fish, and seafood dominate the agricultural sector output (21.4 per cent of GDP).

The industrial/manufacturing sector output (39.9 per cent of GDP) includes food-processing, garments, shoes, machine-building, mining, coal, steel, cement, chemical fertilizer, glass, tires, oil, and paper.

The services sector (38.7 per cent of GDP) is concentrated in public administration and trades such as hotels, restaurants, wholesale and retail trade, transport, storage, and communications.

As a low-income country, Vietnam's economy has been significantly contributed by the growing industrial and service sectors. The country's agricultural contribution has been declining significantly from 25 per cent in 2000 to about 21 per cent in 2009. For the past one decade, the country's economy has grown at an annual rate of 7 per cent until the global slowdown during 2008-2009, which significantly affected the economic growth. However, as the global economy recovers the country is expected to grow at a steady rate in the future (IMF)

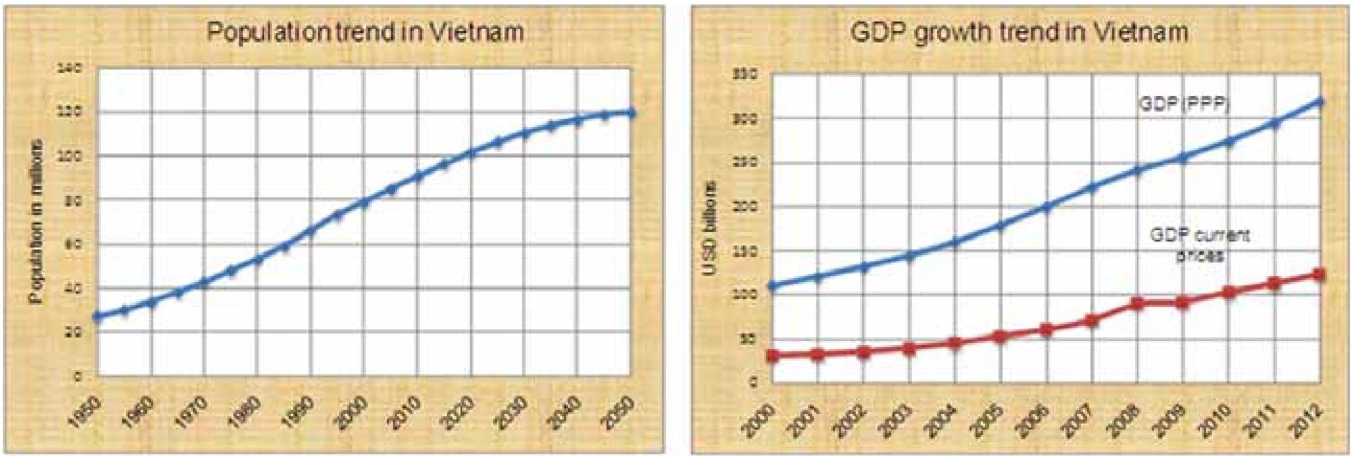


Figure 71 Population (1950-2050) and GDP (2000-2012) growth trends in Vietnam

Climate Change Assessment

9

ASEAN is one of the most vulnerable regions of the world to climate change. Climate change is likely to affect all aspects and sectors adversely, from national and economic security to human health, food production, infrastructure, water availability, and ecosystems and biodiversity. Several studies on ASEAN (Rataq, 2007; IPCC, 2007; Ho, 2008; Jesdapipat, 2008, Cuong, 2008) predict an increase in temperature from 1°C to 1.8°C per century. Precipitation patterns are also changing with a general decrease in mean annual rainfall and number of rainy days. The number of extreme weather events is increasing, and sea levels are rising at a rate of 1-3 mm per year (ADB, 2009). Climate change is expected to be a major contributor 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:

- Rise in temperature (studies show that global average temperatures are likely to rise by between 0.5°C and 1.7°C by the 2050s)
- Variation in precipitation (largest changes are anticipated in the 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)
- Rise 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 livelihoods 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, on a gradual basis.

Many international summits calling attention to these issues have been taking place at international, regional and national levels (Bali conference, 2007; Oslo Policy forum meeting, 2008, Copenhagen climate change conference, 2009). The 'mainstreaming' of climate risk management and DRR 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.

9.1 Climate change trends from climate models

This analysis details a set of key indicators to describe the impact of climate change on ASEAN 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 spatial 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 outputs 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 three general carbon emission levels, the A1B, B1, and A2 scenarios (IPCC, 2007). The baseline simulation can be used at the regional level to determine how well the models are 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 droughts, floods, and tropical cyclones in the region.

(a) Global circulation models IPCC AR4 climate trends
Global Circulation Models IPCC AR4 climate trends show the projections for temperature and precipitation changes based on the results of the 21 global models summarized in AR4 (Figure 72).

There is great uncertainty over how the frequency and severity of rainfall will change in ASEAN with anthropogenic warming. The GCMs give a divergent picture of how precipitation will change in the region by this century.

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 (Figure 72). 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) MRI climate trends
The Meteorological Research Institute (MRI) with a 20 km horizontal resolution has provided improved estimates of mean annual average temperature and precipitation over ASEAN. 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 °C towards the end of 21st century, which seems to be quite consistent with other GCM 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 73 and Figure 74.

The change in rainfall under present and future climatic scenarios is evident by amount and intensity of rainfall per day (Figure 75 and Figure 76). This also leads to spatial differences in the projected rainfall for the region as compared to other GCMs.

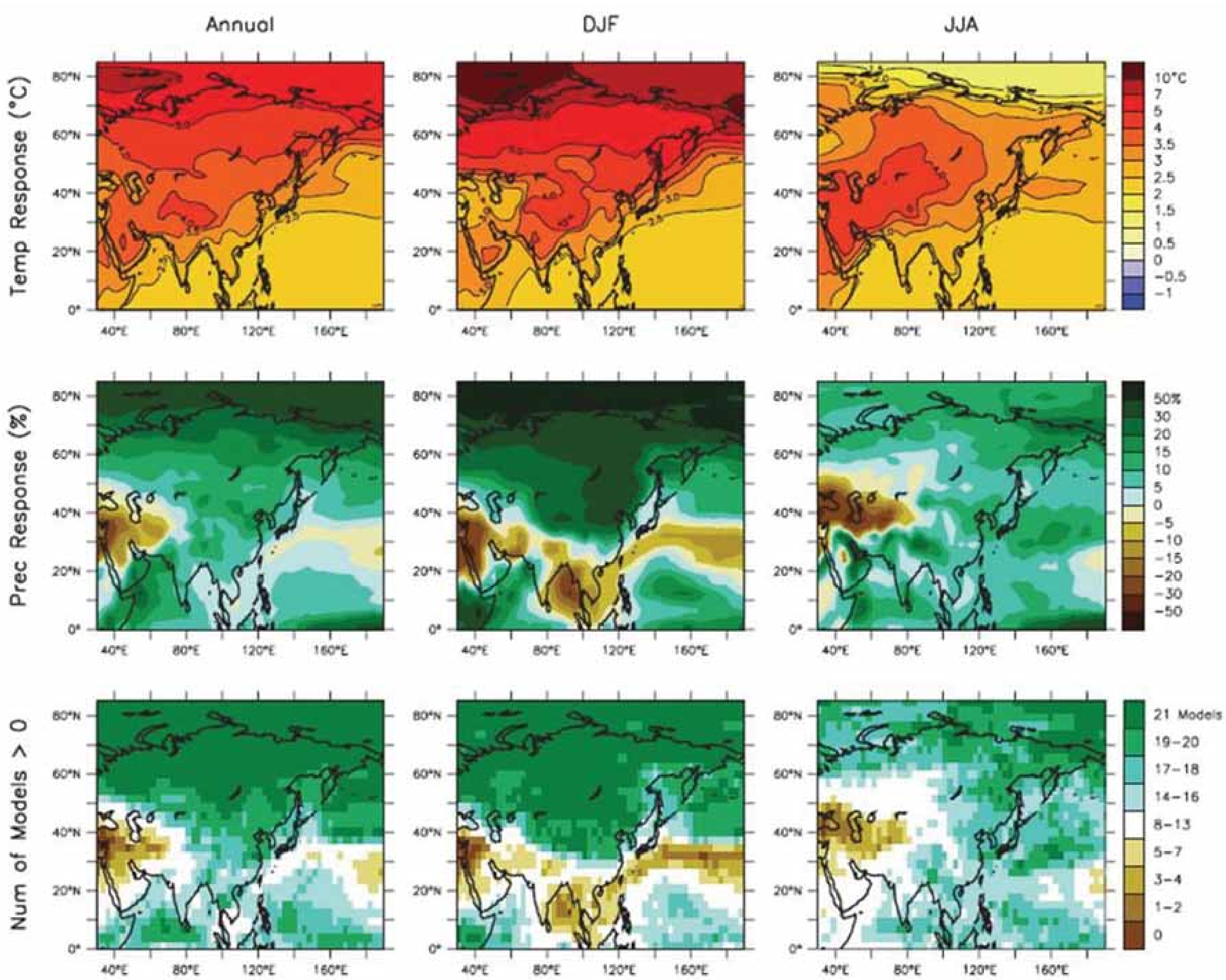


Figure 72 Temperature and precipitation changes in Southeast Asia (circled) from the IPCC AR4 multi-model ensemble simulations for emissions scenario A1B

(Source: Chapter 11 of IPCC AR4 pg. 883)

Note: Top row: 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.

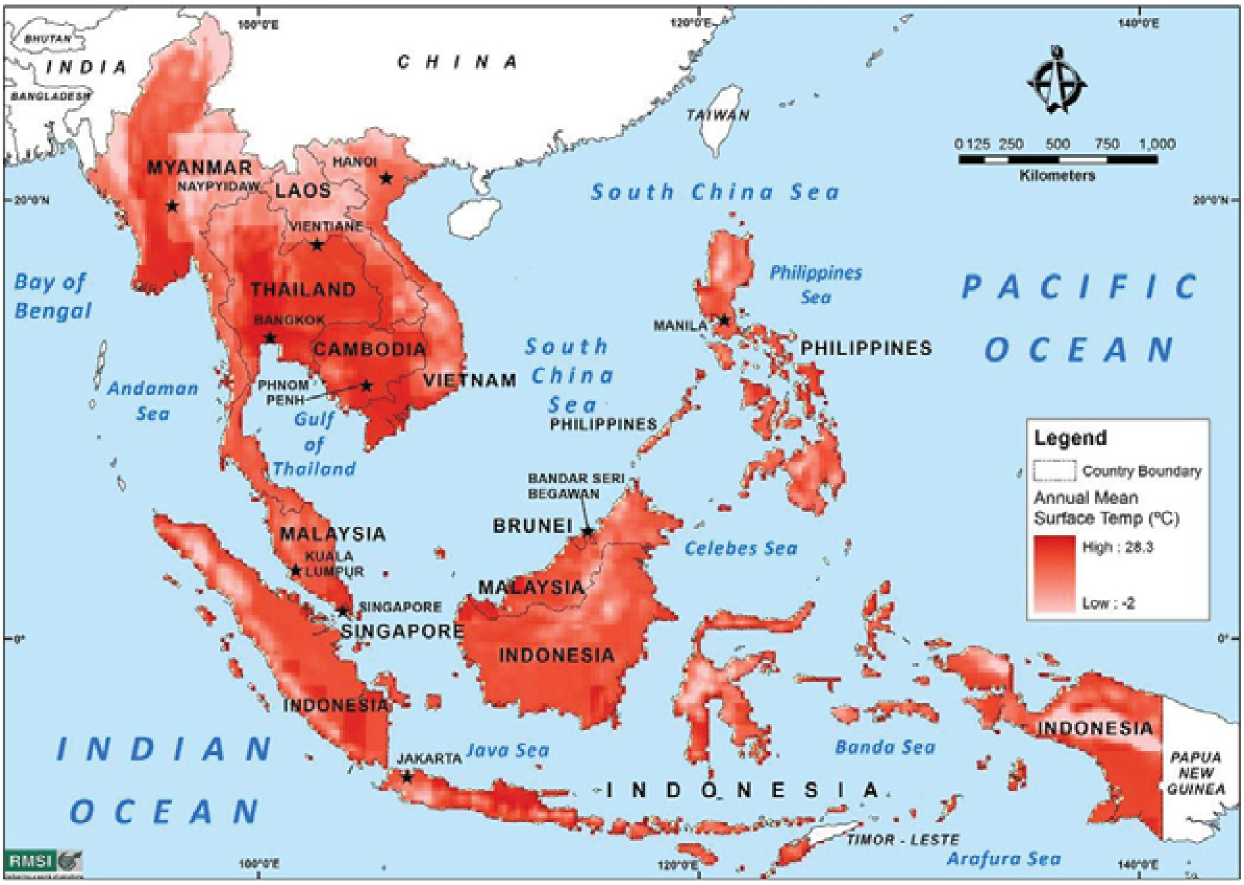


Figure 73 Spatial pattern of present annual mean surface temperature (ºC) for the period 1961-1990

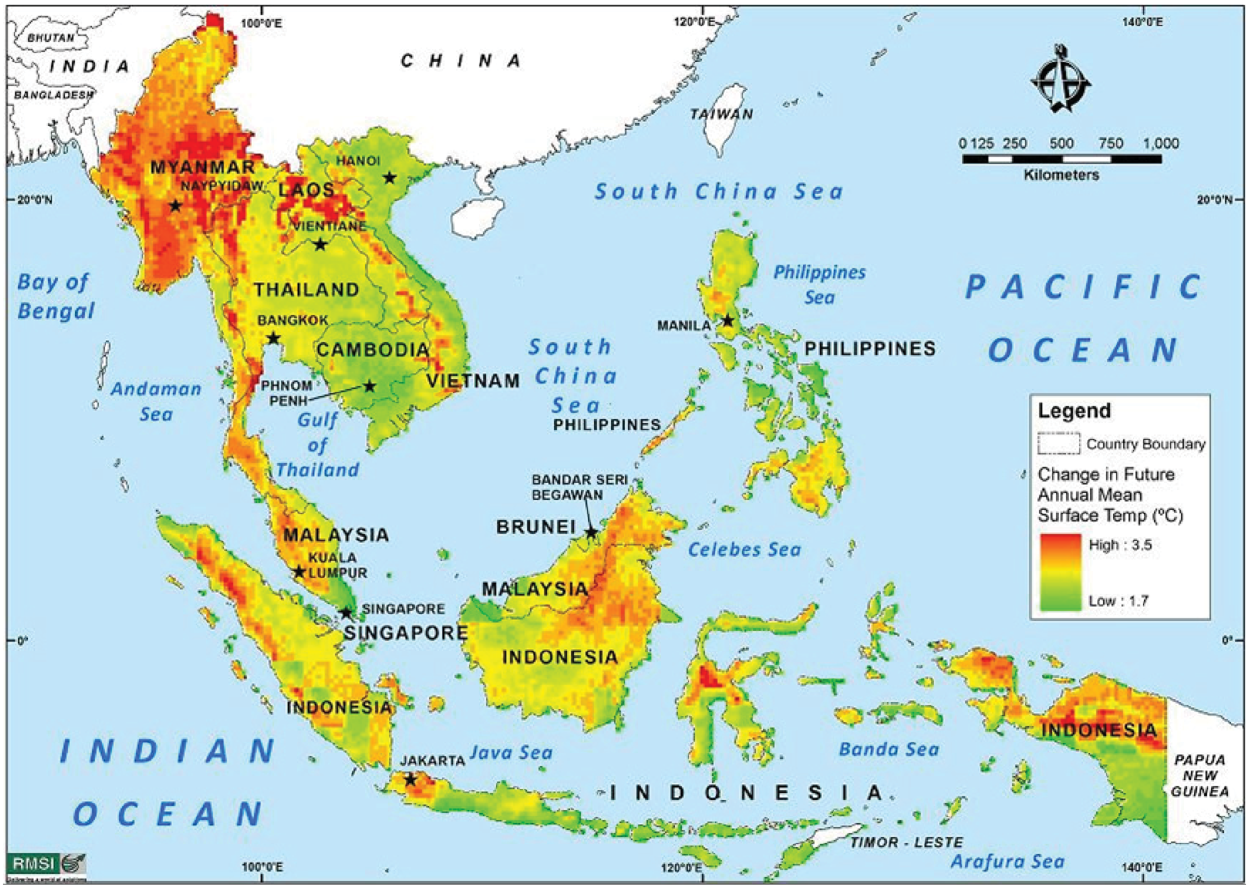


Figure 74 Spatial pattern of future annual mean surface temperature (ºC) for the period 2081-2200

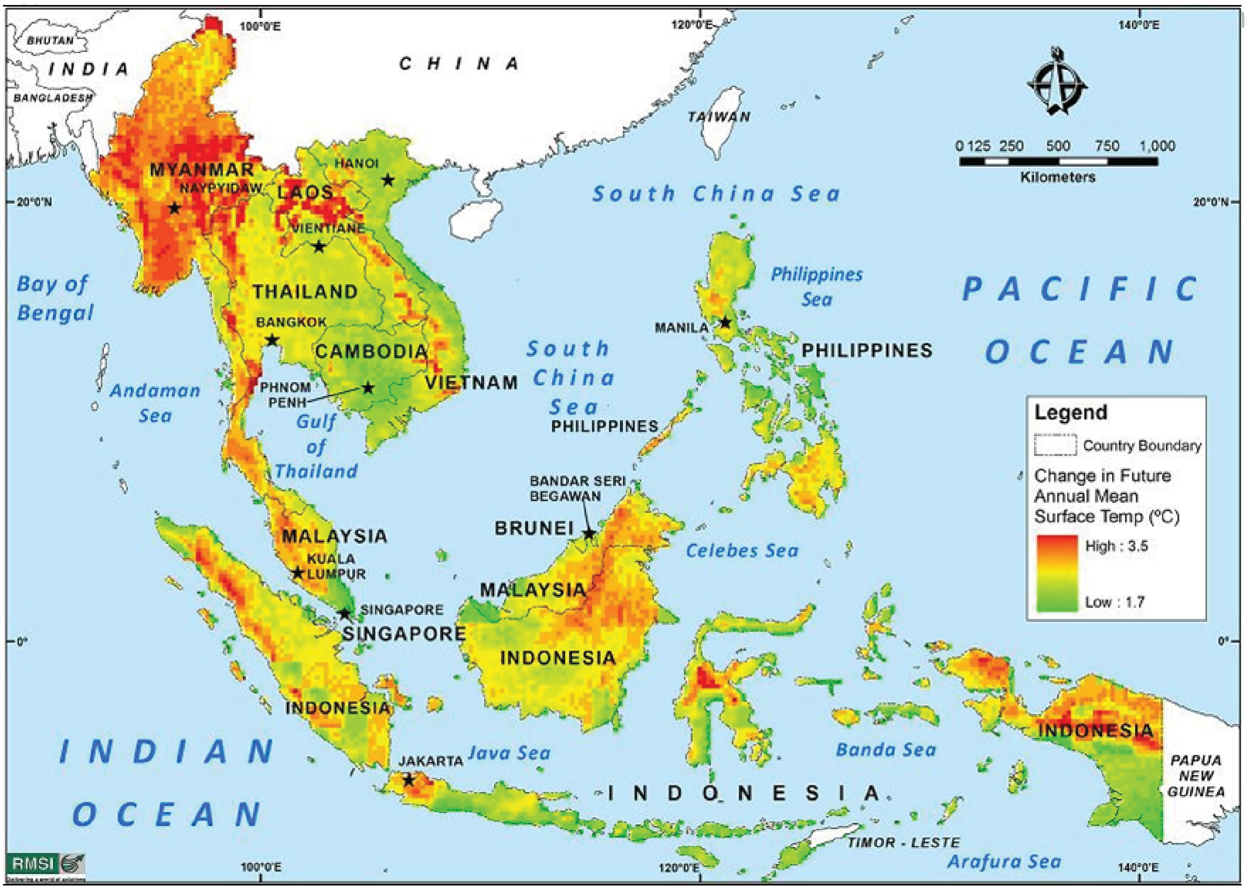


Figure 74a Spatial pattern of change in future annual mean surface temperature (ºC)

Figure 75 Spatial pattern of present annual mean precipitation (mm/day) for the period 1961-1990

Figure 76 Spatial pattern of future annual mean precipitation (mm/day) for the period 2081-2200

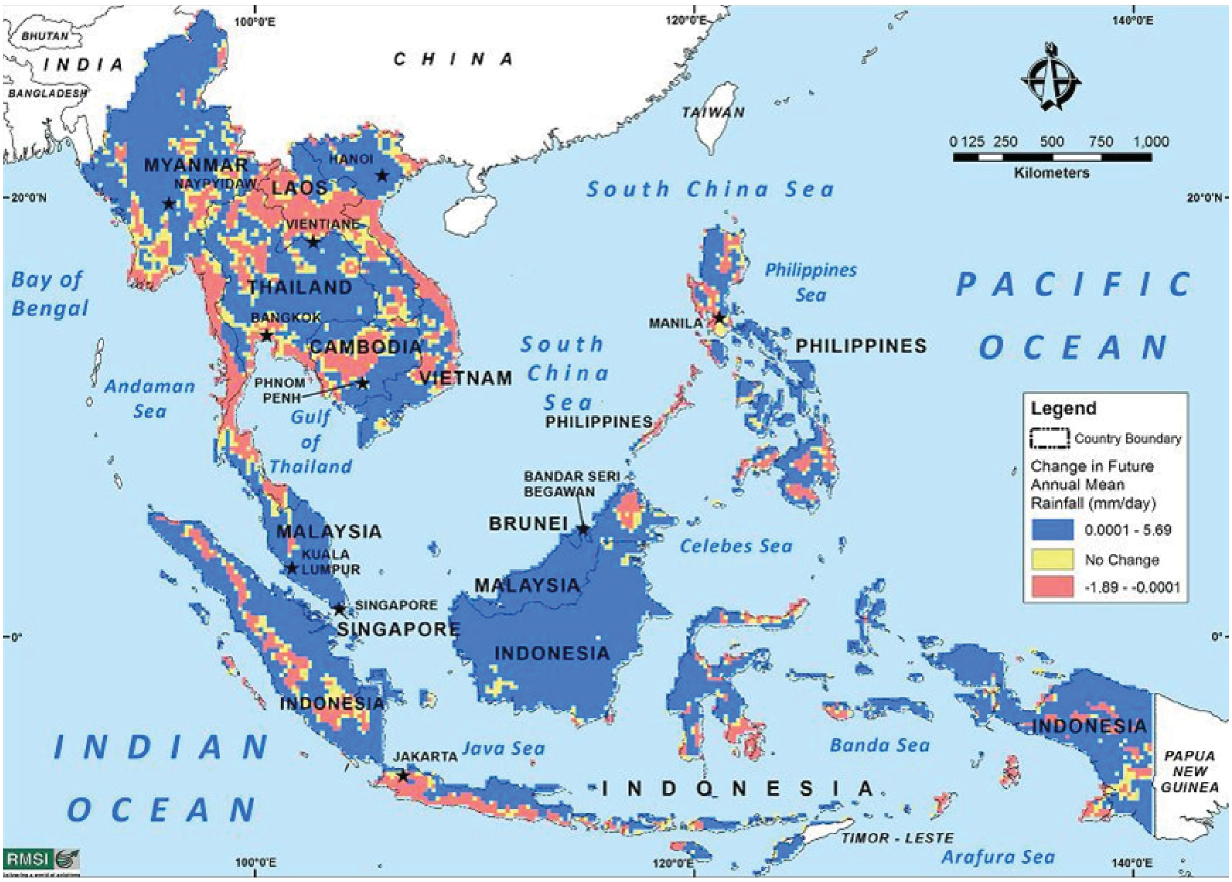


Figure 76a Spatial pattern of change in future annual mean precipitation (mm/day)

9.2 Observed and Projected climate change in ASEAN

Temperature Trend

Over the last 50 years, the ASEAN region has experienced an increase in average temperature at a rate of 0.1 – 0.3 °C per decade and sea level rise at a rate of 1 – 3 mm per year. As projected by IPCC (2007), the mean surface air temperature in Southeast Asia will increase by 0.8–0.9 °C by 2039, 1.3–2.0 °C by 2069, and 2.0–4.0 °C by 2100, depending on which business-as-usual (BAU) baseline scenario is assumed. The tendency for warming is likely to be stronger over mainland Southeast Asia and the larger landmasses of the archipelago (ADB, 2009).

Precipitation Trend

The precipitation pattern in the ASEAN region has changed inter-seasonally and inter-annually during last 50 years. Both the amount of rainfall and number of rainy days has been decreasing during this period. According to IPCC (2007), the ASEAN region shows an overall trend of decreasing precipitation until 2000 (Figure 77). It has been estimated that by 2050, Southeast Asia's precipitation will increase by 1 per cent under A1F1 and 2.25 per cent under B1 emission scenarios, with the strongest rise starting in December and ending in May. Moreover, due to varied topography and maritime influences, localized climatic change patterns are likely to show significant variation from the regional average. It is also predicted that the inter-tropical convergence zone (ITCZ) would receive more rainfall between December and May in some parts, whereas, precipitation will decrease away from the ITCZ (ADB, 2009).

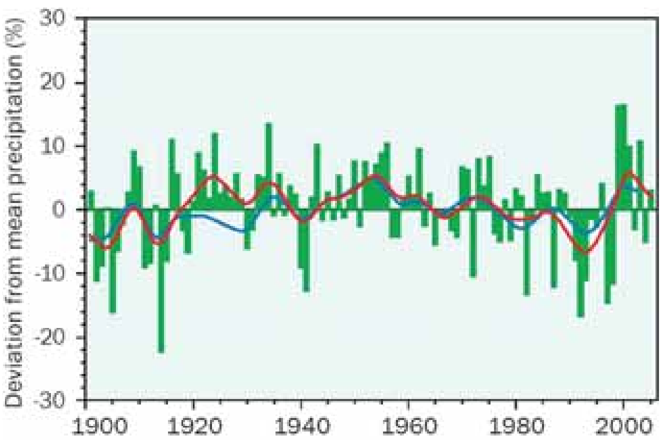


Figure 77 Annual precipitation in Southeast Asia

Note: Mean precipitation (2455 mm) is computed from 1961 to 1990. Green bars indicate annual variations in precipitation. Coloured lines highlight decadal variation. The blue line used Global Historical Climatology Network data from the National Climatic Data Center. The red line used data from the Climatic Research Unit.

Extreme Weather Events

Since 1950, IPCC (2007) has reported changes in temperature extremes such as heat waves, increasing the number of hot days and warm nights, and a decrease in the number of cold days and cold nights in ASEAN. The report also highlighted a significant increase in the number of heavy precipitation events in the region from 1900 to 2005 and an increased number of tropical cyclones. It has also been observed that the number of tropical cyclones increased markedly during the summer (July to August) and autumn (September to November) of strong El Niño Southern Oscillation (ENSO) years (ADB, 2009).

The climate changes in terms of extreme events in ASEAN are summarized in Table 13.

Sea Level Rise

The sea level in ASEAN has risen at the rate of 1–3 mm per year over the last few decades, marginally higher than the global average. IPCC (2007) predicts that by the end of the century, across all scenarios, the global mean sea level is projected to increase by 0.18–0.59 meters relative to the mean sea level in 1980-1999. For ASEAN, the most conservative scenario estimates that sea level will be about 40 cm higher than today by the end of the 21st century. As per ADB (2009), in some of the countries of the ASEAN region, sea level rise is already evident. Indonesia is experiencing mean sea level increase by 1–3 mm per year, in Vietnam, average sea level rise is about 2-3 mm per year (ADB, 2009). Though, Limited studies exist regarding projection of sea level in ASEAN, it has been

Table 13 Observed Changes in extreme events and severe climate anomalies in ASEAN

Extreme Events	Key Trends	Reference
Typhoons	On average, 20 cyclones cross the Philippines with about eight or nine making landfall each year; an average increase of 4.2 in the frequency of cyclones entering the Philippines during the period 1990—2003	PAGASA (2005)
Heat waves	Increase in hot days and warm nights and decrease in cold days and nights between 1961 and 1998	Manton et al. (2001), Cruz et al. (2006), Tran et al. (2005)
Intense rains and floods	Increased occurrence of extreme rains causing flash floods in Vietnam; landslides and floods in 1990 and 2004 in the Philippines, and floods in Cambodia in 2000	FAO/WFP (2000), FAO (2004a), Cruz et al. (2006), Tran et al. (2005)
Droughts	Droughts normally associated with El Niño years in Indonesia, Lao PDR, Myanmar, Philippines, and Vietnam; droughts in 1997 and 1998 causing massive crop failures and water shortages as well as forest fires in various parts of Indonesia, Lao PDR, and Philippines	Duong (2000), Kelly and Adger (2000), Glantz (2001), PAGASA (2001)

Source: Modified after ADB, April 2009

reported that as a result of climate change, Indonesia may lose a large number of small islands by 2030 due to a rise in sea level (Terra Daily, 2007).

Water Resources

ASEAN has extensive natural inland water systems, which play a vital role in the economic development of the member countries. The temperature increase may enhance the rate of evapotranspiration, which in turn affects the quantity and quality of water available for agricultural and industrial production as well as human consumption (ADB, 2009). ASEAN is already facing water stress and many areas in the region are depending upon limited groundwater and rainfall collection. Under this situation, climate change may worsen the water shortage due to extreme events like drought. Moreover, sea level rise may result in salt-water intrusions into available freshwater resources (UNCCD, 2009).

Projected maximum and minimum monthly flows in major river basins in ASEAN suggest increased flood risk during the wet season and increased water shortages during the dry season by the end of the century. It has been projected that areas under severe water stress in ASEAN may affect millions of people and influences the region's attainment of sustainable development (ADB, 2009). Hydropower, urban water supply and agriculture are among the sectors that may face serious impacts due to a reduction in flow of snow-fed rivers, coupled with increases in peak flows and sediment yields (UNCCD, 2009). It is estimated that water stress would be more evident on drier river basins with low seasonal flows.

Agriculture

Agriculture, a major economic sector throughout ASEAN, is expected to be affected by climate change in several ways. Temperature and rainfall are the primary key factors affecting agriculture in this region. Climate change through heat stress, water stress (drought), climate-associated pests and diseases, flooding, and typhoons, constitutes a significant challenge to ASEAN's status as a major producer of grain and industrial crops (such as rice, maize, soybean, rubber, oil palms, coconut).

The increased frequency and intensity of extreme events have already resulted in considerable economic damage to agricultural production in ASEAN. The region, in recent years, has experienced many strong tropical cyclones that have affected agricultural production significantly. Moreover, during the El Niño period, agricultural crops become vulnerable to pest attacks and diseases (ADB, 2009).

Several studies have predicted a possible decline in agricultural production potential in ASEAN due to climate change. In a study conducted by the International Rice Research Institute (Peng et al. 2004), it was found that rice production could decrease by 10 per cent for every 1°C increase in growing season minimum temperature. Another study, conducted by the Office of Natural Resources & Environmental Policy and Planning (ONEP 2008), shows that corn productivity may decrease by 5-44 per cent depending on the location of production in the ASEAN region. Cline (2007) predicts that crop yields in Asia could decline by about 7 per cent with CO2 fertilization and 19 per cent without CO2 fertilization towards the end of this century (ADB, 2009).

If these negative impacts on the region's agricultural production continue, with the increasing population of ASEAN, it is very likely that millions of people in the region will be unable to produce or purchase sufficient food (ADB, 2009).

Coastal and Marine Resources

The coastline of ASEAN region is highly vulnerable to the effects of climate change due to increased coastal hazards to large tidal variations or tropical cyclones (UNCCD, 2009). As the majority of population of the region lives in proximity to low-lying coastal areas, the effects of climate change on coastal areas and marine resources are of high importance.

Coral bleaching is the most commonly reported impact of climate change on marine resources. Wetland International estimates that the 1997–1998 El Niño damaged about 18 per cent of the coral ecosystems in the region (ADB, 2009).

Sea-level rise and increases in sea-surface temperature are the most probable major climate change-related stresses on coastal ecosystems (UNCCD, 2009). Rising sea level causes saltwater intrusions into both coastal freshwater and groundwater resources increasing the water shortage. Moreover, with many of the mangrove forests converted into aquaculture and other related activities, coastal areas are increasingly exposed to tidal waves and coastal erosion increasing their overall vulnerability.

According to Wassmann et al. (2004) and the Stern Report (Stern 2007), by 2100 rising sea levels are predicted to severely affect millions of people in ASEAN. Among these ASEAN Indonesia, Philippines, Thailand, and Vietnam are most vulnerable to the impact of sea level rise (ADB, 2009).

A brief summary of climate change vulnerability and impact in ASEAN countries is provided in Table 14.

Table 14 Summary of climate change vulnerability and impacts in ASEAN

Country	Vulnerability to Climate Change
Brunei	*Temperature and Rainfall* Brunei may get affected by decreasing precipitation and an increase in hot days and warm nights (heat stress) (WWF, 2007b). The extreme weather events associated with El- Niño were reported to be more frequent and intense in the past 20 years.
	Water Resources Water resources in marginal areas are likely to be vulnerable to climate change (WWF, 2007b).
	Sea Level Rise and Coastal Zones Projected sea-level rise is likely to result in significant losses of coastal ecosystems and people and the country will likely be at risk from coastal flooding (WWF, 2007b).
	Agriculture Possibility of substantial losses in rain-fed wheat (WWF, 2007b). Agricultural production may severely be affected by delayed rainy season and extreme climate events due to ENSO as well as increased soil salinity (ADB, 2009).
Cambodia	*Temperature and Rainfall* Cambodia's temperature may increase by up to 1.35 - 2.50 °C in 2100. Annual rainfall may increase between 3 to 35 per cent from current conditions. The lowland areas seem to be more likely to be affected by climate change than high land areas (Min. of Env. Cambodia, 2010).
	Sea Level Rise and Coastal Zones In Koh Kong province (1,160 sq km), if sea level rises by 1 m, about 0.4 per cent (4,444 ha) will be under water. The rainfall of 4 main river basins of Koh Kong may increase between 2 per cent to 15 per cent, resulting in increased water flow 2-10m3/s (Min. of Env. Cambodia, 2010).
	Agriculture Based on the past 5 years data (1996-2000), it has been observed that the rice production loss occurred mainly due to the occurrence of flood (>70 per cent), drought (~20 per cent) and other events such as pest & disease (~10 per cent). Flood and drought were not always associated with the ENSO events and flood mostly occurred due to the increase of water levels in the Mekong River and Tonle Sap Lake (Min. of Env. Cambodia, 2010).
Indonesia	*Temperature and Rainfall* Annual mean temperature in Indonesia has been increasing by around 0.3 °C since 1990 and has occurred in all seasons of the year, relatively consistent if not slightly lower than the expectation of the warming trend due to climate change. In 2020, it has been projected that mean temperature will increase somewhere between 0.36 to 0.47 °C compared to 2000, with the highest temperatures potentially occurring in the islands of Kalimantan and the southeastern part of the Moluccas (DFID, 2007). Increase in annual precipitation is predicted across the majority of the Indonesian islands, except in southern Indonesia where it is projected to decline by up to 15 per cent. There could be change in the seasonality of precipitation also; parts of Sumatra and Borneo may become 10 to 30 per cent wetter by the 2080's during December-February; Jakarta is projected to become 5 to 15 per cent drier during June-August. 30-day delay in the annual monsoon, 10 per cent increase in rainfall later in the crop year (April-June), and up to 75 per cent decrease in rainfall later in the dry season (July–September) (WWF, 2007c)

Country	Vulnerability to Climate Change
Indonesia (cont.)	*Water Resources* Decreased rainfall during critical times of the year may increase high drought risk, uncertain water availability, and consequently, uncertain ability to produce agricultural products, economic instability, and drastically more undernourished people, hindering progress against poverty and food insecurity (Wang et al., 2006). On the other hand, Increased rainfall during already wet times of the year may lead to high flood risk (WWF, 2007c)
	Extreme Events The country may experience prolonged droughts, increased flooding, and more frequent and severe storms as a consequence of climate change. Increased frequency and severity of El Niño events may in turn increase the fire hazards. The increasing ocean temperatures, sea-level rise, and increased number of storms may impact coastal systems (WWF, 2007c)
	Sea Level Rise and Coastal Zones Indonesia is currently experiencing sea level increase at 1-3 mm/year in coastal areas and this is projected to increase at a rate of about 5 mm per year over the next century (ADB, 2009). The mean sea level in the Jakarta Bay may increase by as much as 0.57 cm per year. Sea level rise would be likely to affect fish and prawn production as well as coastal agricultural production (DFID, 2007)
	Human Health Human health in Indonesia could be adversely affected by climate change and its associated effects both directly (e.g., deaths due to heat waves, floods, and storms) and indirectly (e.g., increases in infections and diseases and less available food). The cases of vector- borne infections (e.g., malaria and dengue), water-borne diseases (e.g. diarrhea, cholera), dengue fever and respiratory problems are likely to increase (WWF, 2007c)
	Agriculture Due to sea-level rise and declining dry-season precipitation, the aquaculture industry (e.g., fish and prawn industries) may be negatively impacted (Cruz et al., 2006). In rural districts such as Krawang and Subang, a 95 per cent reduction in local rice supply (down 300,000 tons) is estimated as a result of inundation of the coastal zone. In the same districts, maize output may be reduced by 10,000 tons and about half of this reduction may be due to inundation. The annual reduction of yield due to sea level rise would cost the rice and the maize (corn) farmers marginally (DFID, 2007)
Laos	*Temperature and Rainfall* Increases in annual mean temperatures may be around 0.1-0.3 °C per decade; annual dry season may get longer; the country may experience more intensive rainfall events; and more frequent and severe droughts and flooding events (GEF, 2009)
	Water resources The 4th IPCC report (2007) indicates that the Mekong basin may witness increasing maximum monthly flows of +35-41 per cent and decreasing minimum monthly flows of 17-24 per cent over the course of this century, which will substantially increase flooding risks in the wet season and water scarcity in the dry season
	Agriculture According to WFP, the country may face widespread food insecurity due to decrease in agricultural production because of climate change (GEF, 2009)
Malaysia	*Temperature and Rainfall* Malaysia may experience mean temperature rise of 0.6 to 3.4 °C in the next 60 years, whereas the precipitation may vary from -1 to +32 per cent during that time (MINC, 2000)
	Sea Level Rise and Coastal Zones The country may experience sea-level rise of 13 – 94 cm during the next 100 years period (MINC, 2000)

Country	Vulnerability to Climate Change
Malaysia (cont.)	*Agriculture* Crop yields and changes in productivity will vary considerably across Malaysia. Geographic limits and yields of different crops may be altered by changes in precipitation, temperature, cloud cover and soil moisture as well as increases in CO2 concentrations. High temperatures and diminished rainfall may reduce soil moisture, water available for irrigation, thus impairing crop growth in non-irrigated regions. Climate change may result – (i) Geographical shifts and yield changes in agriculture, (ii) Reduction in the quantity of water available for irrigation, and (iii) Loss of land through sea level rise and associated salinization. The risk of losses due to weeds, insects and diseases is also likely to increase (Siwar et. al.)
Myanmar	*Temperature and Rainfall* According to IPCC 2007, the probable temperature rise in Myanmar by 2100 could range between 1.8-4.0 °C, whereas possible temperature rise by 2100 is predicted to be 1.1-6.4 °C (World Vision A P, 2008)
	Sea Level Rise and Coastal Zones IPCC 2007 projected a probable sea level rise of 18-59 cm. Countries like Myanmar with a long coast-line and densely settled low-lying land are particularly vulnerable to rising sea levels. Even diminutive rises in sea level vertically can lead to enormous erosion horizontally in the country (World Vision A P, 2008). According to Alan Sharp of the Australian Government Bureau of Meteorology, “the flat nature of the delta region, cleared of mangroves for agriculture, offers no impedance to the force of the storm surge, allowing it to penetrate well inland”. Rising sea levels, stronger cyclones and ecosystem degradation mutually reinforce each other, exacerbating the fallout from seaward disasters (World Vision A P, 2008)
	Agriculture The World Bank has ranked Myanmar as the world’s eighth most vulnerable nation to sea level rise in terms of “agricultural land impacted”. According to the United Nations Food and Agriculture Organiza-tion (FAO), about 2,000 square km, or 16 percent of the delta’s agricultural land suffered severe salinity damage from the surge that swept salt water up to 35 km inland (World Vision A P, 2008)
Philippines	*Temperature and Rainfall* According to IPCC (2007), the mean, maximum, and minimum temperatures of Philippines have increased by 0.14°C per decade since 1971. The frequency of hot days and warm nights has also increased and the number of cold days and cool nights decreased. There has also been an increase in annual mean rainfall since 1980s and in the number of rainy days since the 1990s in Philippines (ADB 2009). As per ADB (2009), projected temperature increase of 1.2–3.9°C in Philippines by 2080, using all the IPCC emission scenarios is a distinct likelihood.
	Extreme Events On an average Philippines is hit by 20 cyclones with about 8-9 landfall each year (WWF, 2007a).
	Sea Level Rise and Coastal Zones Even under the most conservative scenario, sea level may be about 40 cm higher than today’s level by the end of 21st century (WWF, 2007a). With more number of people living in the coastal plain, the overall vulnerability may increase considerably.
	Agriculture The country may experience decrease in rice yield due to increases in temperature (WWF, 2007a).

Country	Vulnerability to Climate Change
Singapore	*Temperature and Rainfall* According to IPCC (2007), the projected temperature rise by the end of the century in Singapore is 2.5°C with a range of 1.7–4.4°C (ADB 2009). Changes in annual precipitation for Singapore may range from −2 per cent to +15 per cent with a median of about +7 per cent. As per ADB (2009), in Singapore, extreme rainfall and winds associated with tropical cyclones are likely to increase.
	Water Resources In Singapore, due to limited domestic availability of water resources, water is crucial when considering the effects of climate change. Half of the country's land area serves as a catchment to collect water for its reservoirs. Any significant reduction in rainfall will immediately bring considerable impact on water supplies (ADB, 2009).
	Sea Level Rise and Coastal Zones As per ADB (2009), sea level rise in Singapore is likely to be close to the global mean of 0.21–0.48 meters by the end of the century (ADB, 2009). Coastal land loss is also a major concern to Singapore. Increased coastal erosion has already affected some recreational areas along the coast such the East Coast Park (ADB, 2009).
	Human Health Cases of dengue fever are showing increasing trends and spreading to areas of Singapore where previously such cases were not found (ADB, 2009).
	Agriculture Singapore's agriculture sector contributes less than 1 per cent to the country's GDP. Given the low level of food production, the country relies mainly on imports to satisfy domestic demand. Therefore, any significant damage to crops in neighboring countries could affect food supplies (ADB, 2009).
Thailand	*Temperature and Rainfall* In Thailand, last 50 years observations show temperature increases ranging from 0.10–0.18°C per decade (ADB 2009). Based on the climate data generated by global circulation model, Thailand's temperature is projected to increase 2–4°C by the end of this century (TEI, 2000). In Thailand, there could be a shift in precipitation from the north to the south as predicted by impact studies conducted under the United States Country Studies (TEI, 1999) and Boonyawat and Chiwanno (2007).
	Water Resources Thailand has abundant water resources, but with the onset of climate change, the water balance has become a common annual problem in recent years. As per ADB 2009, changes in rainfall patterns and the frequency and intensity of rainfall have affected the quantity and quality of water resources from some watersheds (for example, Chaophraya Basin) down to rivers and estuaries (ADB, 2009).
	Sea Level Rise and Coastal Zones Thailand has reported increasing trends of mean sea levels in recent years. (ADB, 2009). Coral reefs in Thailand have been greatly affected by coral bleaching due to climate change. For example, severe coral bleaching was reported in the summer of 1991 in the Andaman Sea off Phuket, Phangnga, and Krabi. The El Niño year of 1998 also proved disastrous for coral reefs in Thailand
	Human Health The cases of dengue fever has shown increasing trends since 2000 and has become a greater concern in Thailand (ADB, 2009).
	Agriculture As per ADB (2009), Thailand's crop yield losses amounted to more than 50 billion baht (around $ 1.25 billion) between 1991 and 2000 from the agriculture sector due to floods, storms, and droughts.

Country	Vulnerability to Climate Change
Vietnam	*Temperature and Rainfall* Cuong (2008) predicted that most regions in Vietnam may experience an increase in temperature of 2–4°C by 2100. Vietnam's rainfall pattern may also be greatly affected by the Southwest Monsoon. As per ADB (2009), future rainfall in most of the areas of Vietnam may increase by 5–10 per cent towards the end of this century
	Water Resources Analysis of El Niño years shows that the increase in evapotranspiration due to increased temperature has reduced the availability of water for irrigation and other purposes in Vietnam. La Niña (associated with heavy rains) and tropical cyclones have caused massive flooding with considerable damage and loss in the Red River Delta, Mekong Delta, and Central Region (ADB 2009). There may be a decline in annual flow of the Red River by 13-19 per cent and Mekong River by 16-24 per cent in the Mekong River by the end of 21st century, which may contribute to the increasing water stress in Vietnam (WWF, 2007b).
	Extreme Events Typhoons, droughts, floods, and heat waves are among the significant extreme events in Vietnam. The peak month for typhoon landfalls in Vietnam has shifted from August to November over the last 50 years. The frequency of floods and droughts has also increased (ADB, 2009).
	Sea Level Rise and Coastal Zones In Vietnam, an upward trend in mean sea level has been observed, at an average increase of 2–3 mm per year. Based on A2 and B2 scenarios and using the Dynamic Interactive Vulnerability Assessment tool developed by the DINAS-COAST consortium (http://www.dinas-coast.net/), mean sea level for Vung Tau near the mouth of Sai Gon-Dong Nai River is expected to rise by 0.26 meters for A2 and 0.24 meters for B2 (relative to the 1995 baseline level) by 2050 (ADB 2009). Moreover, Vietnam has also suffered from severe saltwater intrusions into agricultural areas (ADB, 2009). As per ADB (2009), sea level rise, together with monsoons and storms will accelerate the speed of coastal erosion resulting in the destruction of many rich mangrove forests in Vietnam, particularly along the east coast of the Ca Mau cape (ADB, 2009)
	Human Health In Vietnam, dengue fever has become an annual epidemic in the plains and central coastal areas. It has been observed that the outbreaks are closely associated with the El Niño index (ADB, 2009)
	Agriculture The Dynamic-Ecological simulation model predicts a decrease in spring rice yield of 2.4 per cent by 2020 and of 11.6 per cent by 2070 under the A1B scenario in Vietnam. Summer rice could be less sensitive to the impact of climate change than spring rice, but the yield may decrease by 4.5 per cent by 2070. However, across the region, the projection is that maize grown in northern areas would experience increased yield while maize grown in central and southern areas would have reduced yields (ADB, 2009).

9.3 Climate change impacts on ASEAN

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 ASEAN could be as high as a 6-7 per cent loss in GDP by 2100 compared with what could have been achieved in a world without climate change (ADB, 2009). Up to an additional 145-220 million people could be living below poverty line (less than $2.0 a day) in South Asia and sub-Saharan Africa by 2100, due to income loss alone (Stern Review, 2007).

As per ADB (2009), the ASEAN region is highly vulnerable to climate change, as suggested by economic models such as the Stern Review (2007), PAGE2002. It has been projected that without further mitigation or adaptation, some the ASEAN countries may suffer a mean loss of 2.2 per cent of gross domestic product (GDP) by 2100, when the market impact on agriculture is considered. Due to relatively long coastlines, high population densities in coastal areas, high dependence on agriculture and natural resources, relatively low adaptive capacities, and mostly tropical climates, the mean impact of climate change on loss of GDP is much higher in these countries than the mean global average GDP loss (ADB, 2009). It is projected that if non-market impact (human health, ecosystem) and catastrophic risks are also considered, the loss due to climate change is about 6.7 per cent of GDP by 2100 in four ASEAN countries (Indonesia, Philippines, Thailand, and Vietnam) (ADB, 2009).

Over a longer period, the impact of climate change on non-market segments like ecosystems and human health may become more significant than the impacts on the market segments like agriculture and coastal resources. Therefore, to reduce the harmful effects of climate change, adaptive measures can play a significant role for the region. As per UNFCC (2007) estimates, by 2030, the combined cost of adaptation in both market and non-market segments could reach $ 44 billion to $ 166 billion for the whole world, and $28 billion to $ 67 billion for developing countries. Studies of adaptation costs and benefits for Southeast Asia are still limited. Adaptations such as sea walls and drought and heat-resistant crops can help the ASEAN countries to reduce the loss to GDP considerably (ADB, 2009). However, it should be noted that adaptation alone is not sufficient to reduce the harmful effects of climate change. Reductions in global green house gasses (GHG) will be needed to complement adaptation efforts.

Hazard Risk Management Framework – Status of ASEAN Countries

10

International organizations such as the World Bank and UNISDR are now promoting a proactive and strategic approach to DRR across the world. An important part of the approach is providing assistance to prepare for and recover from disasters caused by natural hazards that can result in great human and economic losses. It has been observed that developing countries suffer more when a disaster strikes. As per the World Bank, more than 95 per cent of all deaths caused by disasters occur in developing countries, and losses due to disasters caused by natural hazards are 20 times greater, as a percentage of GDP, in developing countries than in industrialized countries (World Bank, 2008).

The hazard risk management approach is based on the notion that disaster-prone countries should not be caught by surprise. Disasters happen, and technological, social, organizational and financial remedies exist. The fact is that poorly planned development can turn a recurring natural phenomenon into a human and economic disaster. The risk of disaster increases with faulty planning, such as allowing densely populated settlements on floodplains, permitting poor construction without following building codes in high earthquake hazard zones, or allowing the degradation of natural resources.

To reduce risks, targeted assistance needs to be provided before disasters strike such high-risk areas. To achieve this, hazard risk management in such areas needs to be mainstreamed into the national, regional, and local economic development process through gradually upgraded institutional, technical and financial capacity building for risk mitigation and emergency preparedness.

The following exercise is an attempt to assess the present hazard risk management framework of ASEAN countries. The parameters are based on the Hyogo Framework for Action 2005 – 2015 (HFA). The exercise has been prepared based on country-level information from various international entities and country progress reports (ACDR, 2010). Variables in the framework have been rated qualitatively into four categories: good, satisfactory, needs improvement or not available, and under construction. The framework includes all ASEAN countries (Figure 78) and is designed to provide a concise representation of the levels of preparedness of each country and to facilitate the planning of DRR activities in the region.

Figure 78 Hazard risk management framework – status of ASEAN countries

Emergency Preparedness

1. Emergency response planning
2. Exercises
3. Public awareness
4. Communication & information management systems
5. Technical emergency response capacity

Country	1	2	3	4	5
Brunei	N	N	N	N	N
Cambodia	N	N	N	N	N
Indonesia	N	N	N	N	N
Laos	N	N	N	S	N
Malaysia	S	N	S	N	N
Myanmar	N	N	S	S	S
Philippines	N	S	S	S	N
Singapore	G	G	G	S	G
Thailand	S	N	N	S	S
Vietnam	N	N	N	S	N

Institutional Capacity Building

1. Decentralized emergency management system
2. Community participation
3. Legislative framework
4. Training, education & knowledge sharing
5. International cooperation

Country	1	2	3	4	5
Brunei	N	N	N	N	G
Cambodia	N	N	N	N	G
Indonesia	N	N	S	N	G
Laos	N	N	U	S	G
Malaysia	N	S	S	N	G
Myanmar	N	N	N	N	G
Philippines	S	N	N	S	G
Singapore	G	G	G	G	G
Thailand	N	S	S	S	G
Vietnam	S	N	S	N	G

Risk Assessment

Risk Mitigation Investments

1. Warning and monitoring systems
2. Hazard mapping and land use planning
3. Code refinement and enforcement
4. Hazard specific risk mitigation

Country	1	2	3	4
Brunei	N	N	N	N
Cambodia	S	N	N	N
Indonesia	N	N	N	N
Laos	S	S	U	N
Malaysia	S	S	S	N
Myanmar	S	N	N	N
Philippines	S	S	N	N
Singapore	G	S	S	S
Thailand	S	N	N	N
Vietnam	S	N	N	N

Catastrophe Risk Financing

1. Ex-ante funding arrangements
2. Catastrophe insurance pool
3. Reserve funds
4. Contingent capital facility

Country	1	2	3	4
Brunei	N	N	N	N
Cambodia	N	N	N	N
Indonesia	S	N	S	S
Laos	U	N	N	S
Malaysia	S	N	S	S
Myanmar	S	S	N	S
Philippines	S	N	S	S
Singapore	S	N	S	S
Thailand	N	N	N	S
Vietnam	N	N	S	S

Key

G	Good
S	Satisfactory
N	Need improvement/not available
U	Under construction

Priority Areas for Detailed Risk Assessments

11

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 the types of decisions necessary for such activities. In these analyses, 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 assessment and address the social impacts of the hazards, which can be measured in terms of number of deaths, injured and total affected and even emergency response requirements. Decision makers in possession of economic and social impact estimates 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.

11.1 Selection of indicators to define priority areas

The GAR PREVIEW Global Risk Data Platform (GAR, 2009) used a mortality risk index to identify areas under 10 categories such as extreme, major, very high, high, medium, low. The study considered hazard frequency, magnitude, and mortality to identify areas under different risk mortality categories. The GAR approach provides a high-level picture of the mortality risk charting the per cent area under different risk mortality categories.

In detailed risk analyses, 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 number of people affected. In this analysis, a rapid-assessment approach was followed where a simple proxy was used to quantify vulnerability. The selected proxy was the population at risk. This assumption is robust, firstly because most of the buildings and the infrastructure are concentrated in populated areas, and secondly because the population itself is quite vulnerable to hazards.

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. However, in general it has been observed that rapid development in most developing countries increases population growth, intensifies economic activities, and increases vulnerability to natural hazards. This holds true for most of the ASEAN countries.

The major natural hazards considered are earthquake and tsunami, tropical cyclone, flood, drought, volcano, landslide, and forest-fire. For hazards to be considered critical, they must cause relatively frequent disasters, which affect large areas and are potentially extremely destructive from the socio-economic point of view. However, of the eight major hazards in ASEAN, only four cause rapid-onset disasters: earthquakes, cyclones, floods and landslides. The fifth, droughts, cause slow-onset disasters; even though their consequences may be severe and impact millions of people, there is time to respond to such disasters and limit their impacts. Although it is generally possible to predict floods, and warnings in ASEAN are sometimes properly disseminated, however, the response is often inadequate because the affected population lacks the means or capability to evacuate affected areas. Consequently, floods are considered here as rapid-onset hazards, even though they are less sudden than earthquakes.

It is these four rapid-onset disasters that are considered for further investigation. Historical socio-economic losses indicate that these hazards are the most devastating in ASEAN.

11.2 Population at risk

The increasing population (Table 15) and urbanisation of ASEAN is adding to the risks associated with disasters caused by natural hazards. Urban areas, having higher population densities and more concentrated infrastructure, are the key drivers of the overall economic development in the country (Table 16). The high population densities increase the vulnerability, because a single disaster event affects large number of people and their associated infrastructures. This is the case for all hazards, but is particularly true for earthquakes.

Figure 79 shows that, since the year 1990, there has been a general increase in the percentage of urban population of all the ASEAN countries except Singapore, where hundred per cent of population already live in the urban areas. This trend of increasing urbanization is expected to continue for the future decades. In the event of any disaster event occurring in these urban areas, the socio-economic damages are far greater when compared with the rural areas.

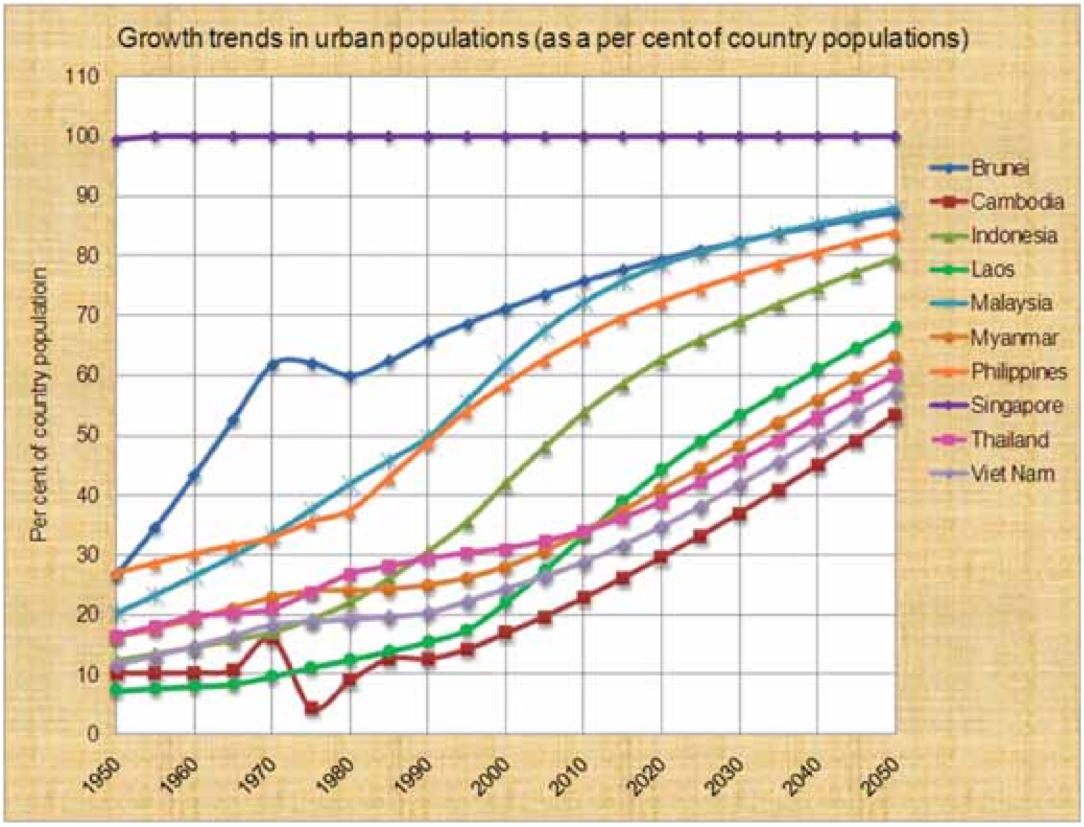


Figure 79 Growth trends in urban population as per cent of country population

Major cities

Major cities are not only conglomerations of intense economic activities but are also areas of very high population densities (Figure 80). This simple study addresses the scenario in the 10 capital cities of ASEAN, namely Bandar Seri Begawan, Phnom Penh, Jakarta, Vientiane, Kuala Lumpur, Naypyidaw, Manila, Singapore, Bangkok, and Ha Noi. All these cities are vulnerable to one or more natural hazards. A high-level risk assessment attempt is made here, based on population, risk mortality index maps (presented in section 6.5) and additional information gathered from literature. It should be noted that population is one of the key factors in determining the risk rankings for the cities.

The level of hazard is classified as very high, high, moderate and low with corresponding severity of 4, 3, 2, 1. The affected population in cities is assumed to be 100 per cent for earthquakes, 50 per cent for cyclones, 20 per cent for floods, and 1 per cent for landslides (Table 17).

The following are brief profiles of the 10 capital cities, including principal hazards faced by each. The reference photograph for each of the capital cities has been taken from Internet (http://en.wikipedia.org).

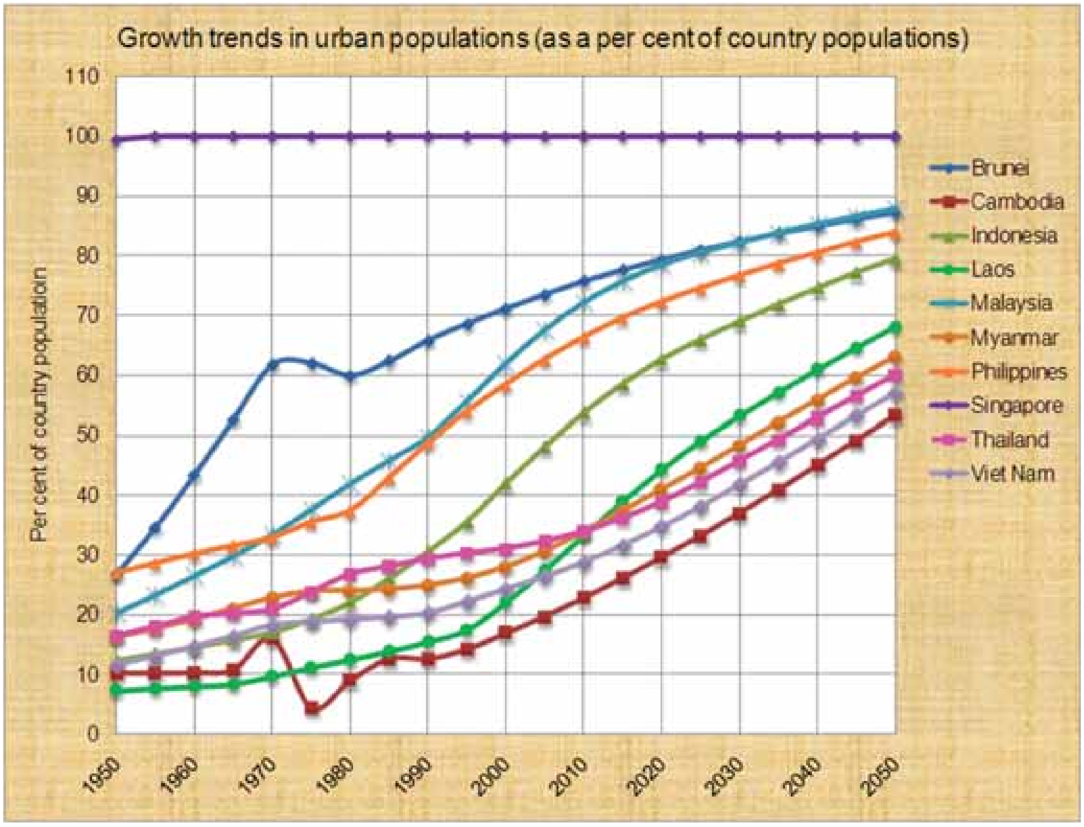


Figure 80 Population growth trends of major cities

Bandar Seri Begawan:

Located on the bank of the Brunei River, Bandar Seri Begawan is the capital and the largest city of Brunei. The city has a population 0.02 million (2009) and lies in the region with low, earthquake, flood, cyclone, and negligible landslide hazards. Bandar Seri Begawan is the least vulnerable to any natural hazards amongst all the major cities.

Phnom Penh:

Located on the banks of Tonle Sap, Mekong, and Bassac Rivers, Phnom Penh is the capital and largest city of Cambodia. Once known as the Pearl of Asia, the city is noted for its beautiful and historic architecture and attractions. The city is also the industrial, commercial, cultural, and tourist centre of the country. Phnom Penh is also the most populous city of the country with a population of 1.65 million (2009) and covering an area of about 375 sq km. Although Cambodia is a poor country, Phnom Penh has seen significant economic growth in recent years. Phnom Penh lies in a region of very high flood hazard, low earthquake and cyclone hazard, and negligible landslide hazard.

Jakarta:

Located on the northwest coast of Java, Jakarta is the capital and largest city of Indonesia. The city is the country's economic, cultural and political centre. It is also the most populous city of the country with a population of 9.70 million (2009). The city has a varying topography with the northern area just above the current sea level whereas the southern part of the city is hilly. The Ciliwung River creates a divide between east and west Jakarta. The city has been a key trading port in the region and continues to be economically important. However, the city has been facing problems because of extreme population growth. From a disaster point of view, Jakarta lies in a region with very high flood hazard, high earthquake hazard, low cyclone, and negligible landslide hazard.

Vientiane:

Vientiane is the capital and largest city of Laos. The city is also the most populous city of the country with a population of 0.83 million (2009). The city lies in a region of very high flood hazard, moderate earthquake hazard, low cyclone hazard, and negligible landslide hazard.

Kuala Lumpur:

Kuala Lumpur is the capital and largest city of Malaysia. The city covers an area of 244 sq km and has a population of 1.52 million (2009). The city has the fastest growing population and economy in the country. It is also the cultural and economic centre for finance, insurance, real estate, media and the arts. Kuala Lumpur is located at the confluence of the Klang and Gombak rivers. It lies within the Klang valley bordered by the Main Range mountains and the Strait of Malacca. Kuala Lumpur lies in a region of high flood hazard, moderate earthquake hazard, low cyclone hazard, and moderate landslide hazard.

Naypyidaw:

Naypyidaw has been made the capital of Myanmar, officially moving it from the former capital Yangon. The city is the third largest city of Myanmar with a population of 1.02 million (2009). The city lies in a region of very high flood hazard, high earthquake hazard, low cyclone hazard, and negligible landslide hazard.

Manila:

Located on the eastern coast of Manila Bay, Manila is the capital of Philippines and one of the most populous urban areas of the world with a population of 11.66 million (2009). The city covers an area of 636 sq km, and has a population density of more than 18,000 people per sq km. The city is also one of the major tourist destinations of the country and attracts more than 1 million visitors per year. Manila lies in a region of very high flood hazard, very high cyclone hazard, high earthquake hazard, and moderate landslide hazard.

Singapore:

Singapore is an island city-state on the southern tip of the Malay Peninsula. Singapore is a cosmopolitan city with a key role in international finance and trade. Tourism is one of the largest industries in Singapore. Covering an area of 697 sq km, the city has a population of 4.59 million (2009). Singapore is a culturally diverse city-state with a population of Chinese, Malay, Indian and other ethnicities. Singapore has a very high standard of living with a GDP PPP per capita of $50,300 (2009) and is one of the wealthiest countries in the world. Singapore lies in a region of low earthquake, flood, cyclone, and landslide hazard.

Bangkok:

Located on the banks of Chao Phraya River and close to the Gulf of Thailand, Bangkok is the capital and largest city of Thailand. The city is one of the largest cities in the world with an area of more than 1500 sq km and a population of 6.92 million (2009). Bangkok is one of Asia's major business, financial, and cultural centres. Tourism is one of the leading industries of Bangkok. It is estimated that more than 11 million foreign tourists visit the city every year. Bangkok lies in a region of very high flood hazard, low cyclone and earthquake hazards, and negligible landslide hazard.

Ha Noi:

Located on the banks of the Red River, Ha Noi is the capital city of Vietnam. Historically, Ha Noi has been the most important political centre of Vietnam. The city has a population of 4.72 million (2009). Ha Noi lies in a region of very high flood hazard, high cyclone hazard, low earthquake hazard, and negligible landslide hazard.

Table 17 shows that in terms of earthquake risk, Manila is at highest risk followed by Jakarta and Bangkok. In terms of flood risk, Manila is also at highest risk followed by Jakarta, Bangkok, and Ha Noi. In terms of tropical cyclonic risk, Manila is also at highest risk followed by Ha Noi and Jakarta. In terms of overall risks from these hazards, Manila is at highest risk, followed by Jakarta, Bangkok, Ha Noi, Singapore, Kuala Lumpur, Naypyidaw, Phnom Penh, Vientiane, and Bandar Seri Begawan.

Since many of the heavily populated cities in ASEAN are located on marginal or unstable land such as coastal areas, mountainous areas, and major river basins, they are even more vulnerable to the impacts of climate change (Citynet, 2009; WWF, 2009). From the impact of climate change and climate variability point of view, Manila and Jakarta are the most vulnerable cities, largely because of their size, degree of exposure (both experience frequent flooding), and have relatively low adaptive capacity. They are followed by Phnom Penh because of its low-level adaptive capacity. Bangkok is the next most vulnerable city because it has a high socio-economic sensitivity to impacts (large population and contribution in large proportion to country's GDP). Bangkok is followed by Kuala Lumpur, and Singapore, mostly because both have slightly more adaptive capacity than the other cities (WWF, 2009). The vulnerability to climate change for Ha Noi, Naypyidaw, Vientiane, and Bandar Seri Begawan is not available. However, these capital cities will also get affected by climate change phenomena such as temperature and precipitation changes and extreme weather events.

Table 15 Population (in millions) variation and percentage change between 2010, 2025 and 2050

	Brunei	Cambodia	Indonesia	Laos	Malaysia	Myanmar	Philippines	Singapore	Thailand	Vietnam
Population 2010	0.41	15.05	232.52	6.44	27.91	50.50	93.62	4.84	68.14	89.03
Population 2025	0.51	18.97	263.29	8.27	33.77	57.59	117.27	5.36	72.63	102.05
Population 2050	0.58	23.80	278.38	10.74	39.66	63.37	146.16	5.22	73.36	111.67
Change 2010-2025	26.04%	26.04%	13.23%	28.54%	20.98%	14.04%	25.27%	10.85%	6.59%	14.63%
Change 2010-2050	42.51%	58.07%	19.73%	66.94%	42.09%	25.50%	56.12%	7.94%	7.66%	25.43%

Table 16 Urban population (in millions) variation and percentage change between 2010, 2025 and 2050

	Brunei	Cambodia	Indonesia	Laos	Malaysia	Myanmar	Philippines	Singapore	Thailand	Vietnam
Population 2010	0.31	3.03	102.96	2.14	20.15	16.99	45.78	4.84	23.14	27.05
Population 2025	0.42	4.98	133.42	4.05	27.19	25.54	64.95	5.36	30.68	41.37
Population 2050	0.57	10.43	190.01	7.31	34.85	39.84	101.37	5.22	43.98	65.87
Change 20010-2025	34.74%	64.59%	29.58%	89.61%	34.95%	50.32%	41.87%	10.85%	32.57%	52.97%
Change 2010-2050	86.04%	244.57%	84.54%	242.23%	72.97%	134.50%	121.43%	7.94%	90.06%	143.54%

Table 17 Risk ranking for major cities* in ASEAN

City	Country	Earthquake	Flood	Cyclone	Landslide	Population (million) 2009	Earthquake Risk	Flood Risk	Tropical Cyclone Risk	Landslide Risk	Overall Risk	Risk Ranking
Manila	Philippines	3	4	4	2	11.66	34.99	9.33	23.32	0.23	67.87	1
Jakarta	Indonesia	3	4	1	0	9.7	29.11	7.76	4.85	0.1	41.72	2
Bangkok	Thailand	1	4	1	0	6.92	6.92	5.53	3.46	-	15.91	3
Ha Noi	Vietnam	1	4	3	0	4.72	4.72	3.78	7.08	0.05	15.59	4
Singapore	Singapore	1	1	1	1	4.59	4.59	0.92	2.3	0.05	7.85	5
Kuala Lumpur	Malaysia	2	3	1	2	1.52	3.04	0.91	0.76	0.03	4.74	6
Naypyidaw	Myanmar	3	4	1	0	1.02	3.07	0.82	0.51	-	4.4	7
Phnom Penh	Cambodia	1	4	1	0	1.65	1.65	1.32	0.83	-	3.8	8
Vientiane	Laos	2	4	1	0	0.83	1.66	0.66	0.42	0.01	2.74	9
Bandar Seri Begawan	Brunei	1	1	1	0	0.02	0.02	0	0.01	0	0.03	10

*: The cities considered in this analysis are Capital of each country

Conclusions and Recommendations

12

12.1 Conclusions

Disasters

The disaster risk assessment analyses show that that in terms of human casualties, cyclonic storms (typhoons) are the dominant disaster risk in ASEAN followed by earthquakes, tsunamis, floods, epidemics, landslides, droughts, volcanic eruptions and forest-fires. During the last 40 years (1970-2009), 1,211 reported disasters have caused 414,927 deaths. Out of the reported disasters, 36 per cent were floods, 32 per cent were cyclonic storms, 9 per cent were earthquakes and tsunami, 8 per cent were epidemics, 7 per cent were landslides, 4 per cent were volcanoes, 3 per cent were droughts, and 1 per cent was forest fires (Figure 38). Cyclones (storms) caused the maximum number of deaths: 184,063, followed by earthquakes (114,080) and tsunamis (83,605). The country level disaster matrix for the period 1970-2009 is shown in Table 3 (section 6.4).

Social vulnerability

The social vulnerability (SV) ranking of each country was estimated based on the average number of people killed per year per million (relative social vulnerability). The analysis of disaster data for the period 1970-2009 shows that the average number of people killed per year per million for ASEAN region is 17.5. In Myanmar, the relative SV is more than 3.5 times that of Indonesia (the second highest). In terms of relative SV ranking, Myanmar has the highest ranking followed by Indonesia, Philippines, Thailand, Vietnam, Lao PDR, Cambodia, and Malaysia. Due to paucity of disaster loss data, the SV ranking could not be carried out for Brunei and Singapore.

Economic vulnerability

The quantitative economic risk assessment performed in this study confirms that a catastrophic event with a 200-year return period (0.5 per cent annual probability of exceedance) would have a major impact on ASEAN countries' economies, which are already fragile. To gauge the potential economic impact, the economic vulnerability (EV) ranking of each country has been estimated in terms of likely economic losses that an event with a 200-year return period would cause as a percentage of that country's Gross Domestic Product (GDP PPP) (Figure 81). According to this categorization, Myanmar has the highest EV ranking in the region, followed in descending order by Lao PDR (Laos), Indonesia, Cambodia, Vietnam, Philippines, Thailand, and Malaysia. Due to paucity of economic loss disaster data, the Average Annual Loss (AAL) and economic loss analysis for different probabilities of exceedance could not be carried out for Brunei and Singapore.

The size of economic losses and the number of disasters are not well correlated. For example, although the number of earthquake and tsunami disasters combined together in ASEAN is much

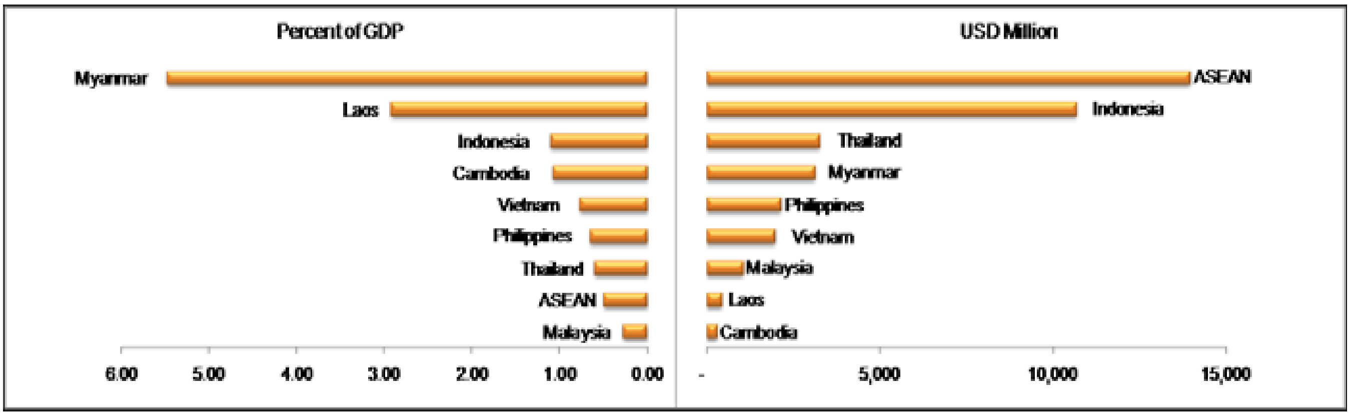


Figure 81 Economic Loss Potential for annual probability of exceedance of 0.5 per cent

lower than floods, the economic losses caused by those earthquakes and tsunamis combined together are much higher.

The quantitative risk assessment performed in this study confirms the following risk patterns for the ASEAN countries:

- Cambodia: floods represent the dominant risk followed by droughts
- Indonesia: forest (wild) fires, earthquakes and tsunamis, floods represent the dominant risks followed by volcanoes, droughts, and landslides
- Lao PDR: cyclonic storms and floods and are the dominant risks followed by droughts
- Malaysia: floods are the dominant risk followed by forest fires, tsunamis, and cyclonic storms
- Myanmar: cyclonic storms are the dominant risk followed by tsunamis, floods and forest-fires
- Philippines: typhoons (cyclonic storms) are the dominant risk followed by floods, earthquakes; volcanoes, droughts, and landslides
- Thailand: floods are the dominant risk followed by tsunamis, cyclonic storms, and droughts
- Vietnam: cyclonic storms and floods are the dominant risk followed by droughts, and landslides
- Brunei and Singapore: no disaster data is available

Urban areas are especially vulnerable to the adverse impact of disasters. Capital cities: Manila, Jakarta, Bangkok, Ha Noi, and Singapore are amongst the most populated cities in ASEAN region and all are undergoing intense economic transformation. In terms of earthquake risk, Manila is at highest risk followed by Jakarta and Bangkok. In terms of flood risk, Manila is also at highest risk followed by Jakarta, Bangkok, and Ha Noi. In terms of tropical cyclonic risk, Manila is also at highest risk followed by Ha Noi, and Jakarta. In terms of overall risks from these hazards, Manila is at highest risk, followed by Jakarta, Bangkok, Ha Noi, Singapore, Kuala Lumpur, Naypyidaw, Phnom Penh, Vientiane, and Bandar Seri Begawan.

Climate change impact

Climate change is considered as one of the most significant developmental challenges confronting ASEAN nations in the 21st century. According to the IPCC (2007) reports, the mean surface air temperature in Southeast Asia increased at the rate of 0.1 – 0.3°C per decade between 1951 and 2000. Following the global trend, the mean sea level is projected to rise by 40 cm on average by 2100 in comparison to 1990. Moreover, the region experiences decreasing rainfall and increasing sea levels (1–3 mm per year). The frequencies of extreme weather events like heat waves, heavy precipitation, and tropical cyclones have been increasing considerably. These climatic changes have brought massive flooding, landslides, and droughts in different regions and have caused extensive damage to property, assets, and human life. High concentration of population and intense economic activities in coastal areas, and a high dependence on agriculture and forestry in many countries of the region are making the situation more complex and may hinder the regions sustainable development.

Global Circulation Models (GCMs) addressing climate change do not present a uniform view of the impact of climate change on ASEAN as they have limited capabilities 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 0C over the next 80 years.

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 ASEAN could be as high as a 6-7 per cent loss in GDP by 2100 compared to what could have been achieved in a world without climate change.

12.2 Recommendations

Based on the analyses, the review makes the following recommendations to reduce disaster risk in ASEAN:

Additional analyses
Three levels of analyses are envisioned to refine the results presented in this report. These analyses should emphasize more on typhoons (tropical cyclonic storms), floods, and earthquakes and tsunamis, 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 (for example a 100-km grid) should be considered. Risk aggregation by hazard type and area would provide, at low cost, a much more refined picture of the risk than is offered by the present analyses.

Level 2: On a second level, using the same methodology, worst-case scenarios should be considered for the highly populated cities. This analysis would provide a reasonable quantification of loss, given the occurrence of a particular disaster scenario. The uncertainty around the risk could then be bracketed by scientifically estimating the range of probability of occurrence of such scenarios. Such worst-case scenario studies can be used in preparation of city specific disaster management plans (DMP).

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

Drought hazard should be addressed in the context of climate change and long-term adaptation strategies should be considered. Climate risk assessments study should merge traditional risk assessments with climate change assessments.

Use of Open Source Risk Models is recommended, in which probabilistic techniques are applied to the analysis of various natural hazards. At this level of analysis, hazard information is combined with exposure and vulnerability data allowing the user to determine the risk simultaneously on an inter-related multi-hazard basis. In recent years, several Open Source GIS-based multi-hazard risk platforms have/are being developed. These open source platform should build upon existing initiatives, with the objective of consolidating methodologies for hazard, exposure, and risk assessment, and raising risk management awareness in the region.

HAZUS-MH (FEMA, 2009) is a powerful multi-hazard (MH) risk assessment platform for estimating the effects of natural disasters (including earthquakes, riverine and coastal floods, and hurricane winds). In HAZUS-MH, GIS technology to produce estimates of hazard-related damage before, or after, a disaster occurs. It employs the Comprehensive Data Management System (CDMS) that facilitates the updating of state-wide datasets used in analysis.

CAPRA- Central American Probabilistic Risk Assessment is another GIS-based platform for risk analysis of earthquakes, tsunamis, tropical cyclones, floods, landslides, forest-fires, and volcanoes (http://gfdrr.org/docs/Snapshot_CAPRA.pdf). CAPRA was initiated in the January 2008 with a partnership between CEPREDENAC, the UNISDR, the World Bank and the Inter American Development Bank (IADB). The main objective of CAPRA includes raising awareness in the countries of Central America. The CAPRA aims at providing users with a set of tools that are capable of analyzing the magnitude, distribution, and probability of the potential losses due to various natural hazards. Thus CAPRA provides the user with a platform that helps in identifying, designing, and prioritizing the risk reductions measures.

HazSana'a and HazYemen are other two such open source GIS-based multi-hazard risk platform being developed for Sana'a city and Yemen country, respectively. (http://gfdrr.org/gfdrr/sites/gfdrr.org/files/publication/GFDRR_Probabilistic_Risk_Studies_Yemen.pdf). These probabilistic natural hazard risk assessment studies are being conducted in Yemen on initiatives of the World Bank, for flood and landslide risk assessment for Sana'a city; flood and landslide risk assessment in Hadramout and Al Mahra governorates; earthquake, flash flood, flood (coastal storm surge and tsunami), volcano, and landslide risk assessment for the whole country.

Annex 1: Risk Assessment Methodology

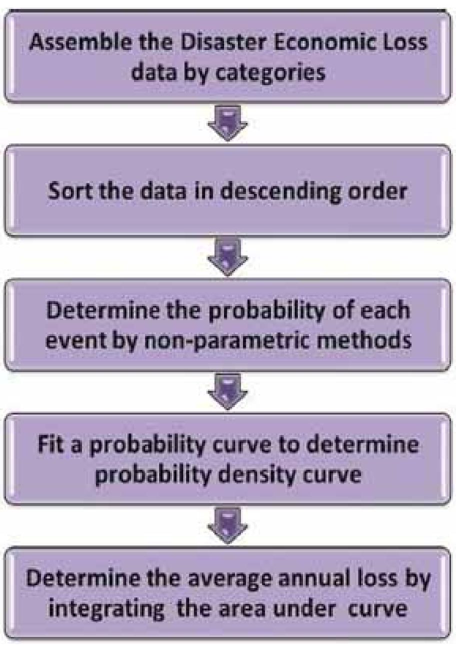
An objective basis for decision making on risk management should include a quantitative assessment of the size and likelihood of the occurrence of different hazards present in the country, based on historical data. Such a basis helps in planning a risk mitigation strategy and in convincing stakeholders 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 and UNISDR publication 'ISDR (2009). Central Asia and Caucasus Disaster Risk Management Initiative (CAC DRMI): Risk Assessment for Central Asia and Caucasus' and reveals the level of risk in each country and the probability of loss exceedance as a function of the level of economic loss.

Determining risk

The method of quantitative risk is presented in Figure 82. The objective of the risk assessment is to determine the probability that aggregate economic losses over a one-year period exceed a given amount. This is also referred as annual exceedance of probability. This probability is presented as a function of the level of loss and the curve generated is called the loss exceedance curve.

Figure 82

Quantitative risk assessment methodology (after Pusch, 2004)



Several methods can be used to generate the loss exceedance curve (Pusch, 2004). 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 a reported event where no economic loss is given, a very small value of economic 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. The economic loss values ($) that occurred in various disasters have been calibrated for the year 2009 ($) by using the factor for the corresponding year (http://www.measuringworth.com/ppowerus/). 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. Weibull's equation, generally accepted to provide the best 'fit' for natural hazard events, is used to calculate the recurrence interval r (and its inverse: the probability of occurrence p) as a function of i:

$r = (n+1)/i$ 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 83. Probability distributions are tested for their suitability for the estimation of economic losses for various return periods. Candidate distributions considered in this analysis are 2 Parameter Log Normal, 3 Parameter Log Normal, and Gumbel and Pearson Type III. By looking at the best-fit distribution and the other three distributions' fitted values, a weighted average has been calculated to arrive at the return period losses.

Return period economic losses for 0.5 per cent, 5 per cent and 20 per cent of annual exceedance probability were calculated. An Average Annual Loss (AAL) is determined as the sum of loss of each event (Li) multiplied by their rate of occurrence (pi) (Grossi et al., 2005).

AAL=∑ pi Li

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

Limitations of the Methodology

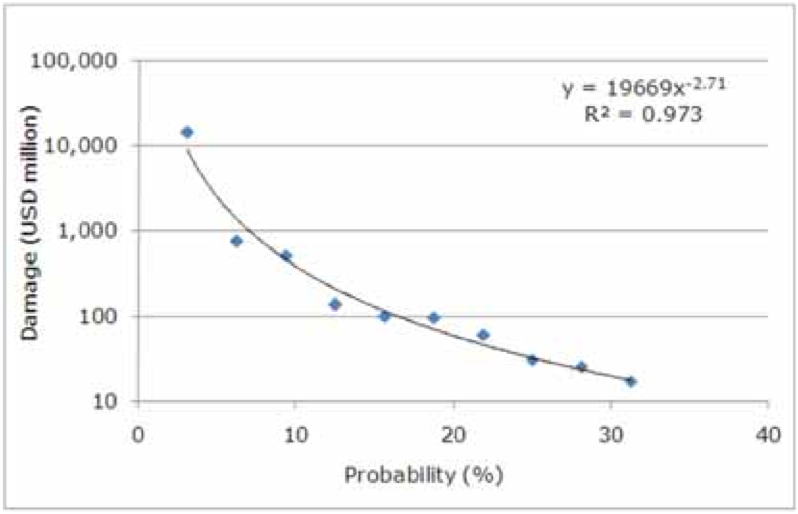
The simplified quantitative risk assessments conducted for this study are based on historical economic loss data reported in different data sources such as CRED EM DAT, The World Bank, UNISDR, GAR, DWR, WAMIS, IFNet, MRC, Dartmouth, NGDC, OCHA, NGI, ADRC, ADPC, InTerragate, Munich Re, Swiss Re national-level data. They illustrate the magnitude of the problems and the broad strategic direction. Except earthquakes and tsunamis, the economic loss data used for the analysis for all hazards are limited to 40 years; a longer duration of more than 100 years has been considered for earthquakes and tsunamis due to their large return periods. A 40-year time span is used due to the accuracy and completeness of the data it provides.

High-priority areas for detailed risk modelling and assessment are identified based on identified indicators. For such detailed risk assessment, exposure inventory data (building and infrastructure) need to be collected and analyzed. It also needs simulation modelling of historical events using present buildings and infrastructure data to assess risk from an event of a given hazard 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 much more detailed approach that models hazard, exposure and vulnerability of buildings and infrastructure.

Figure 83

Sample distribution of the probability of damage levels: earthquake damage versus probability of occurrence (after Pusch, 2004)



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