



United Nations
Educational, Scientific and
Cultural Organization

UNESCO Bangkok

Asia and Pacific Regional Bureau for Education

CLIMATE CHANGE VULNERABILITY MAPPING FOR GREATER MEKONG SUB-REGION

OCTOBER 2015



Water Resources & Environment Institute
Faculty of Engineering
Khon Kaen University

CLIMATE CHANGE VULNERABILITY MAPPING FOR GREATER MEKONG SUB-REGION

OCTOBER 2015

Asst.Prof.Dr.Kittiwet Kuntiyawichai

Asst.Prof.Dr.Vichian Plermkamon

Dr. Ramasamy Jayakumar

Mr. Quan Van Dau



UNESCO Bangkok
Asia and Pacific Regional Bureau for Education

WREI



Water Resources & Environment Institute
Faculty of Engineering
Khon Kaen University

Published in 2015 by the UNESCO Bangkok Office and WREI, Khon Kaen University, Thailand

© UNESCO 2015



This publication is available in Open Access under the Attribution-ShareAlike 3.0 IGO (CC-BY-SA 3.0 IGO) license (<http://creativecommons.org/licenses/by-sa/3.0/igo/>). By using the content of this publication, the users accept to be bound by the terms of use of the UNESCO Open Access Repository (<http://www.unesco.org/open-access/terms-use-ccbysa-en>).

The designations employed and the presentation of material throughout this publication do not imply the expression of any opinion whatsoever on the part of UNESCO concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

The ideas and opinions expressed in this publication are those of the authors; they are not necessarily those of UNESCO and do not commit the Organization.

Coordinator: Ramasamy Jayakumar and Kittiwet Kuntiyawichai

Design/Layout: Quan Van Dau

• UNESCO Bangkok Office

UNESCO Bangkok is the Asia-Pacific Regional Bureau for Education and the Cluster Office for the six Mekong countries (Cambodia, Lao PDR, Myanmar, Singapore, Thailand and Vietnam). Recently the Natural Science sector was created at UNESCO Bangkok in response to increased demands for regional cooperation. The Natural Science Sector of Bangkok Office will serve in areas including: Water Sciences; Ecological and Earth Sciences; Science Policy for Sustainable Development; cross-cutting issues climate change and disaster risk reduction.

• WREI Khon Kaen University

Water Resources and Environment Institute (WREI), Faculty of Engineering, Khon Kaen University, was officially established on June 14, 1979, as a training center for water professionals in the fields of water resources management and development, providing technical services for public agencies and private sector companies in the Northeast of Thailand, as well as conducting water-related research.

Acknowledgements

The authors would like to thank all organizations and persons for their review comments. The authors would also like to extend our thanks to Dr. Milorad Kovacevic, Chief Statistician Human Development Report Office of the UNDP for his technical assistance in determining the Human Development Index (HDI).

In addition, the authors wish to acknowledge the assistance of experts from Cambodia, Lao PDR, Myanmar, Thailand, and Vietnam for their valuable insights and recommendations. The authors gratefully acknowledge the valuable comments and insightful suggestions of the reviewers, which have improved the quality of this study. Finally, the authors would like to express our appreciation to UNESCO Bangkok: Asia and Pacific Regional Bureau for Education for generous financial support, which made it possible to conduct the study of climate change vulnerability mapping for greater Mekong sub-region.

Executive summary

It is well recognized that the impacts of climate change pose a serious threat to socio-economic, environment, and people's livelihoods, particularly those in developing countries where severe natural disasters like tropical cyclones, floods, droughts, landslides, and rising sea levels are common. In this context, there is no debate that adaptation strategies and mitigation responses, particularly for the region's most vulnerable people, are needed. Limitations to enhancing adaptive capacity to climate change can restrict the provision of quantitative insights into vulnerability to the phenomenon. This is why addressing the vulnerability to and possible impacts of climate change at the sub-regional level is a major concern of this study.

The key objective of this study is to identify the areas in Mekong countries that are most vulnerable to climate change and climate-induced water problems. These findings will be useful for better targeting of and priority setting for climate change adaptation initiatives. The study was undertaken in five Mekong countries, i.e. Cambodia, Lao PDR, Myanmar, Thailand, and Vietnam. Based on work by the Intergovernmental Panel on Climate Change (IPCC) (2001), a framework for vulnerability assessment conceptualizes vulnerability to climate change by looking at exposure and sensitivity of a system to a climate hazard, and the ability of the system to cope with, adapt to or recover from the effects of hazardous conditions.

This study finds that Mekong countries are adversely affected by major natural hazards, such as tropical cyclones, floods and droughts. Additionally, the study also mapped adaptive capacity and areas that are vulnerable to the impacts of climate change, which can be a useful tool for determining degrees of adaptation and mitigation responses at the provincial level. The mappings showed that Thailand has a high adaptive capacity to climate change among Mekong countries, whereas the western coastline of Myanmar and the Cambodian Mekong lowland region were identified as the most vulnerable areas in the sub-region. The findings of this study will be valuable for the five Mekong countries in ensuring sustainable adaptation to climate change.

TABLE OF CONTENTS

Acknowledgements	i
Executive Summary	ii
Acronyms and Abbreviations	v
1. Introduction	1
1.1 Key terms for climate change impact assessment	1
1.2 Objective	2
2. Methodology	3
2.1 Data collection	3
2.2 Vulnerability assessment	4
2.2.1 Exposure	4
2.2.2 Sensitivity	6
2.2.3 Adaptive capacity	6
2.3 Data analysis	10
3. Results and discussions	10
3.1 Natural disaster country profile	10
3.2 Climate-related hazard maps for Mekong countries	17
3.3 Human and ecological sensitivity maps	23
3.4 Adaptive capacity mapping	27
3.5 Climate change vulnerability mapping for greater Mekong sub-region.....	27
3.6 Determining areas vulnerable to climate change impacts in the Mekong countries	32
3.7 Preliminary verification results of climate change vulnerability assessment for the Mekong countries	35
4. Conclusion and recommendations	39
References	42
Appendix	44
Appendix 1 List of the vulnerable areas in the Mekong Countries	45
List of Tables	
Table 1 The goalposts considered for calculating the HDI	7

Table 2 Natural disaster profile of Cambodia from 1980 – 2014	11
Table 3 Natural disaster profile of Lao PDR from 1980 – 2014	13
Table 4 Natural disaster profile of Myanmar from 1980 – 2014	14
Table 5 Natural disaster profile of Thailand from 1980 – 2014	15
Table 6 Natural disaster profile of Vietnam from 1980 – 2014	16
Table 7 Protected areas in the Mekong countries in 2014	25
Table 8 Additional elements for vulnerability assessment for the countries in the Mekong region	35
Table A1 List of the vulnerable areas in the Mekong countries	45

List of Figures

Figure 1 The method used in deriving the climate change vulnerability index	5
Figure 2 Tropical cyclone frequency from 1980 to 2014	18
Figure 3 Flood frequency from 1980 to 2014	19
Figure 4 Drought frequency from 1980 to 2014	20
Figure 5 Landslide frequency from 1980 to 2014	21
Figure 6 Sea level rise at 5-meter	22
Figure 7 Demographic estimates and projections from 1960 to 2050	23
Figure 8 Population density of the Mekong countries in 2013	24
Figure 9 Protected areas in 2014	26
Figure 10 Human Development Index in the Mekong countries	29
Figure 11 Provincial-level mapping of adaptive capacity in the Mekong countries .	30
Figure 12 Vulnerability index in the Mekong countries	31
Figure 13 Distribution of vulnerability index for the Mekong Countries	32
Figure 14 Map of the most vulnerable areas in the Mekong countries at risk from climate change	34
Figure 15 Spatial comparison of the Mekong Adaptive Capacity Indices between the results of (a) WREI (2015) and (b) Yusuf and Francisco (2009)	37
Figure 16 Spatial mapping of vulnerability to climate change in the Mekong countries based on the results of (a) WREI (2015) and (b) Yusuf and Francisco (2009)	38
Figure 17 Spatial mapping of vulnerable areas to climate change in the Mekong countries based on the results of (a) WREI (2015) and (b) Yusuf and Francisco (2009)	39

ACRONYMS AND ABBREVIATIONS

IPCC	Intergovernmental Panel on Climate Change
TAR	Third Assessment Report
PDR	People's Democratic Republic
EM-DAT	Emergency Events Database
CRED	Centre for Research into the Epidemiology of Disaster
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
ADRC	Asian Disaster Reduction Center
UNISDR	United Nations International Strategy for Disaster Reduction
SLR	Sea Level Rise
CReSIS	Centers for the Remote Sensing of Ice Sheets
GDP	Gross Domestic Product
PPP US\$	Purchasing Power Parity in US dollar
WDPA	World Database on Protected Area
FAO	Food and Agriculture Organization of the United Nations
AQUASTAT	FAO's global water information system
GHGs	Greenhouse Gases
HDI	Human Development Index
UNESCO	United Nations Educational, Scientific and Cultural Organization
IQ	Intelligence Quotient
O-net	Ordinary National Educational Test
Gini	A measure of statistical dispersion intended to represent the income
NCDM	National Committee for Disaster Management
NDMO	National Disaster Management Office
DDPM	Department of Disaster Prevention and Mitigation
NOAA	National Oceanic and Atmospheric Administration
GLOBE	Global Land One-kilometer Base Elevation
NGDC	National Geophysical Data Center
GIS	Geographic Information System

DEM	Digital Elevation Model
WGS	World Geodetic System
ACI	Adaptive Capacity Index
WWF	World Wildlife Fund
WREI	Water Resources and Environment Institute



Drought in the Wyangala Dam © by Michael Hall, 2007

1. Introduction

Climate change poses a vital threat to development, especially in developing countries where poverty is dominant and infrastructure is inadequate for current needs (Schweikert et al., 2014). According to the Intergovernmental Panel on Climate Change (IPCC) in 2001, developing countries will be more vulnerable to climate change than developed nations. In fact, most developing countries in Asia do not have the capacity to adapt to climate change and they need external support for adaptation (Francisco, 2008). According to the United Nations (2014), the Asia-Pacific region is the world's most natural disaster-prone region and over the past decade has seen a more than three-fold increase in the number of deaths due to disasters, with more than 41.2 percent of people living in poor conditions in 2013. Therefore, there is an urgent need to address the impacts of climate change and vulnerability at the regional level in order to prepare adaptation strategies for minimizing/avoiding current and future damage.

In recent years, the impacts of climate change in the Mekong countries have had a significant influence on human lives, economic activities, physical assets and the environment. These impacts include the increasing frequency and intensity of tropical cyclones, floods, droughts, landslides and rising sea levels. Because of this an updated study on climate change vulnerability and climate resilience for the Mekong countries during the period from 1980 to 2014 was carried out for this report.

Based on the Third Assessment Report (TAR) of the IPCC, the degree to which a system is susceptible to or unable to cope with the adverse effects of climate change, including climate variability and extremes, was defined as “vulnerability”. It is also linked to the function of the character, magnitude, and rate of climate variation to which the system is exposed, its sensitivity, and its adaptive capacity” (IPCC, 2001). Therefore, in developing the framework for this study, vulnerability is considered to be the function of exposure, sensitivity, and adaptive capacity.

1.1 Key terms for climate change impact assessment

In adapting to and learning how to live with the consequences of climate change, assessing vulnerability plays a significant role in determining the severity of

future impacts. Based on the IPCC report, vulnerability to climate change can be determined by looking at three areas.

- *Exposure* is defined as the degree that natural and manmade systems are exposed to significant climatic variations. Two major factors are involved: the variables affected by climate change (e.g. population, property), and the change in climate itself (e.g. rise in sea levels, changes in temperature);
- *Sensitivity* refers to the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli. In this study, the population density and protected areas are considered the primary indicators for sensitivity assessment;
- *Adaptive capacity* is the ability of a system to adjust to climate change (e.g. in practices, processes, structures, etc.) to moderate the potential damage from projected or actual changes in the climate, to take advantage of its opportunities, or to cope with its consequences. It is influenced by the level of socioeconomic development, technology, institutions, and infrastructure.

1.2 Objective

The overall objective of this study is to identify which areas in Mekong countries are the most vulnerable to climate change. These findings will be useful for policy makers in the region as well as external donors in better targeting and setting priority areas for their support towards climate change adaptation initiatives. The specific objectives are:

1. To identify which sub-national areas/units (regions, provinces, depending on the availability of the data) of Mekong Countries (Cambodia, Lao PDR, Myanmar, Thailand and Vietnam) are the most vulnerable to climate change.
2. To show these vulnerable areas in a map for ease of reference.

2. Methodology

An assessment of current climate change vulnerability of different geographical areas of the Mekong region was conducted based on historical and most recently available information from public sources and climate change experts in the region. The study also covers the likely changes in climatic conditions, climate variability and extreme climatic events (in the form of exposure to climate change) and sensitivity to changes. More important insights for the methodology of this study are discussed below.

2.1 Data collection

Climatic data (such as the frequency of tropical cyclones, floods, droughts, and landslides) were obtained from the Emergency Events Database (EM-DAT) by the Centre for Research into the Epidemiology of Disaster (CRED) for the period of 1980 to 2014. In EM-DAT, an event was considered to be a disaster if at least one of the following criteria is met: 10 or more people reported killed, 100 or more people reported affected, state of emergency declared or an appeal for international assistance issued. Datasets were used for comparison from various sources, such as the United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP), the Asian Disaster Reduction Center (ADRC), the United Nations International Strategy for Disaster Reduction (UNISDR), and the national statistical offices in the Mekong countries studied.

Some key considerations must be addressed when carrying out a climate change vulnerability assessment in response to increasing scientific evidence which demonstrates that climate change and global warming may ultimately cause sea levels to rise. Therefore a mapping from the taken from the Centers for the Remote Sensing of Ice Sheets (CReSIS) showing the inundation zones of a five-meter sea level rise (SLR) was used as one of the variables reflecting climate change vulnerability. Life expectancy at birth, mean years of schooling, school life expectancy and related information were obtained from UNDP country reports of the five Mekong countries. Information about standards of living, gross domestic product (GDP) per capita, and Purchasing Power Parity in US dollar (PPP US\$) were taken from various sources, such as UNDP country reports and the websites of national statistical offices. Information on protected areas in 2014 was

provided by the World Database on Protected Areas (WDPA, 2014), and population density in 2013 was derived from national statistical offices. Which areas are equipped for irrigation was determined from the FAO's global water information system, AQUASTAT, which is the most quoted source on global water statistics. In addition, poverty incidences, income inequality, technology, institution and infrastructure were also retrieved from UNDP country reports and available online sources.

2.2 Vulnerability assessment

A clear conceptual framework is an essential first step in identifying the most vulnerable areas in Mekong countries. This is key in understanding and defining key concepts of the vulnerability assessment and their analytical relationships towards a broader mapping exercise, and is depicted in Figure 1. In this assessment, an overall climate change vulnerability index for each sub-national administrative area in five Mekong countries –Cambodia (24 provinces), Lao PDR (18 provinces), Myanmar (7 states and 7 divisions), Thailand (77 provinces), and Vietnam (63 provinces) –was derived by taking into account areas and socio-economic sectors most at risk. Accordingly, as outlined in the Third Assessment Report of the IPCC, vulnerability was defined as the function of exposure (the multiple climate hazards), sensitivity (human activity and ecological sensitivity), and adaptive capacity (some measures of adaptation under a scenario-based approach).

2.2.1 Exposure

Exposure is a component of vulnerability which is not only the extent to which the system is subjected to significant climatic variations, but also the degree and duration of these variations (Adger, 2006). Climatic data from 1980 to 2014 were used to delineate a multiple-risk mapping that provides underlying exposure to climate risks. Firstly, an inundation risk mapping for each major disaster was carried out using the historical records obtained from the EM-DAT database.

An assessment of exposure was made by taking climate-related hazards from historical exposure as representative of future climate risks. Five climate-related hazard maps for five climate-related risks were obtained pertaining to: tropical cyclones, floods, drought, landslides and 5-meter SLR. Subsequently, the

spatial interaction between the vulnerability of a particular element at risk and the hazard posed to that element was depicted by overlaying all 5 hazard maps in a GIS environment and presenting this as a multiple hazard map (Yusuf & Francisco, 2009) (Note: equal assigned weights for each hazard map were assumed to possess the same degree of vulnerability for this assessment as the degree of importance of each hazard is unknown).

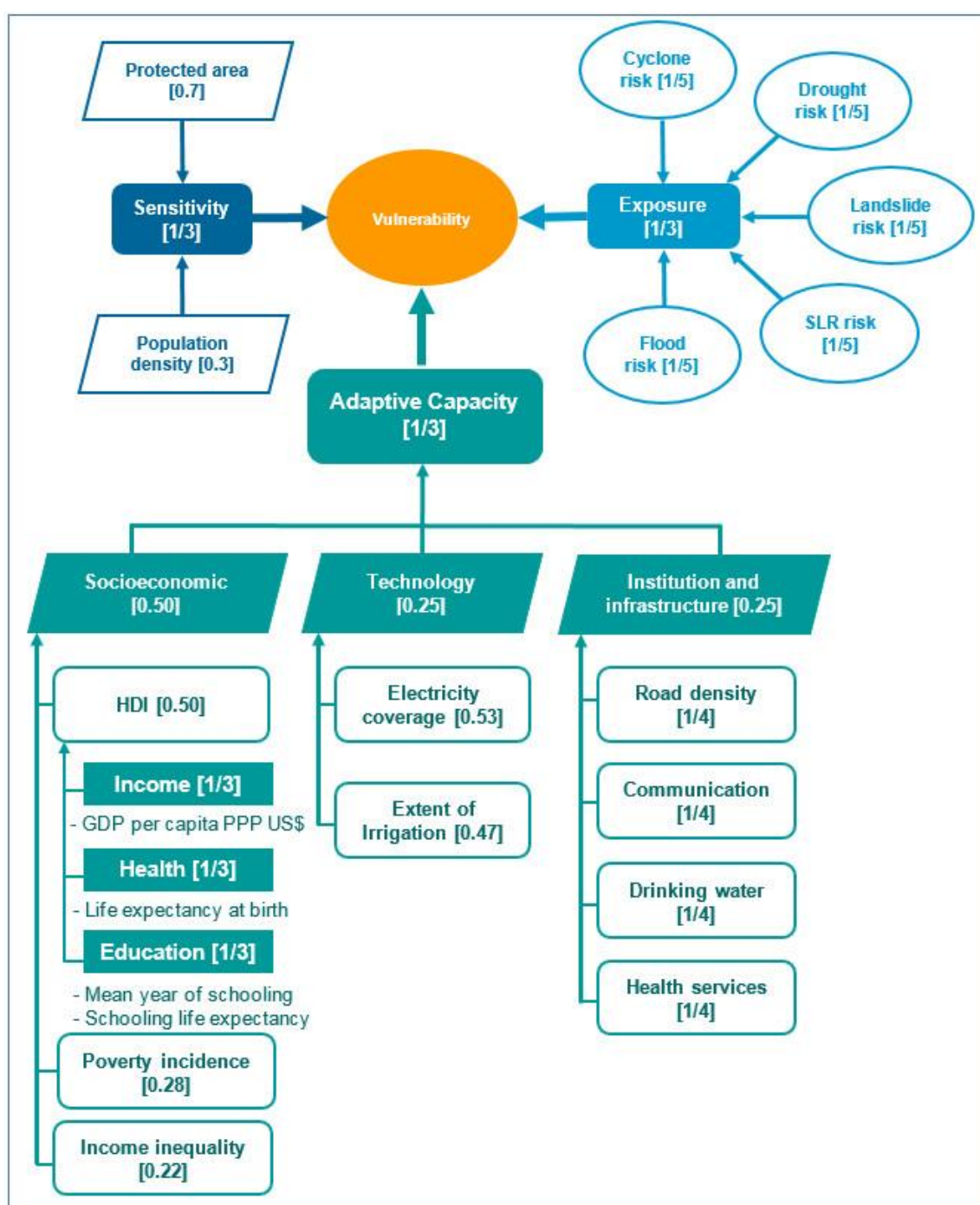


Figure 1 The method used in deriving the climate change vulnerability index (Yusuf & Francisco, 2009)

2.2.2 Sensitivity

Human intervention and changes in the way land is used are affecting the atmosphere, playing a key role in global warming. In fact, the impacts of human activities are significantly increasing the amount of greenhouse gases (GHGs), aerosols, and cloudiness. There are two primary indicators in assessing sensitivity in the context of climate change: population density and protected areas. Population density – the number of people per square meter at the provincial level – was used in assessing human sensitivity to climate-hazard exposure, whereas the extent of protected areas was linked to the ecological sensitivity of the region. Regions with a higher population density will be more vulnerable than lesser populated areas with the same degree of exposure to climate change. It was also found that the regions with more protected areas are likelier to have more effective biodiversity conservation efforts in the future. (Note: A biodiversity region was calculated by the percentage of protected areas divided by the total area of the province). As specified by Yusuf and Francisco (2009), the sensitivity risk index can be defined as the weighted averages of each standardized value such as 0.70 for population density and 0.30 for protected areas. In this assessment, the latest available population density data in 2013 and the protected areas in 2014 were used to assess quantitative sensitivity.

2.2.3 Adaptive Capacity

Understanding vulnerability and climate resilience is fundamental to developing sustainable adaptation strategies. Therefore, within the context of vulnerability to climate change, the determinants of adaptive capacity must be addressed in order to examine the potential responses of a system to climate variability and change (Harley et al., 2008). As defined in the Fourth Assessment Report of the IPCC (2007), adaptive capacity is the ability or potential of a system to respond successfully to climate variability and change, and includes adjustments in both behavior and in resources and technologies. By developing a theoretical framework for this assessment, the approach of Yusuf and Francisco (2009) was adopted and modified to map climate change vulnerability in the Mekong region. In examining the relationship of vulnerability and resilience, adaptive capacity was determined as a function of socio-economics, technology, institutions and infrastructures.

Socio-economics

The Human Development Index (HDI), poverty incidence, and income inequality were considered to be critical indices among determinants of adaptive capacity because of their impact on human resources and nation development. The HDI receives greater weight (0.50) than poverty incidence (0.28) and income inequality (0.22), because it emphasizes the people and their capabilities. The HDI is a summary measure of average achievement in key dimensions of human development, such as having a long and healthy life, being knowledgeable, and having a decent standard of living (UNDP, 2014). Consequently, GDP per capita (PPP US\$) was used to measure the standard of living at the provincial level. Life expectancy at birth was used to determine longevity, whereas mean year of schooling and school life expectancy were used to assess education. According to the UNESCO Institute for Statistics (UNESCO, 2014), the mean year of schooling was defined as the average level of education among adults (age 25 years and older), and school life expectancy was calculated as the sum of the age-specific enrolment rates for the levels of education specified. Before calculating the HDI, an index needs to be developed for each of the three key dimensions of human development. To calculate the aforementioned indices –life expectancy, education, and GDP per capita – minimum and maximum values (goalposts) were chosen for each underlying indicator as shown in Table 1.

Table 1 The goalposts considered for calculating the HDI

Indicator	Minimum value	Maximum value
Life expectancy at birth (years)	20	85
Adult literacy rate (%)	0	100
Combined gross enrolment ration (%)	0	100
GDP per capita (PPP US\$)	100	40,000

Source: UNDP, 2011b

Despite data limitations, measurements for the HDI can still be obtained in several ways. For instance, UNDP (2014) reported that, in Thailand, the education index can be calculated by average secondary enrollment rate, average number of years in school, average intelligence quotient (IQ) of children between six

and 15 years of age, and the average O-Net score of upper secondary students. The health index was calculated based on average number of underweight births, mental health score, and the percentage of the population with various characteristics, including: physical illness; disability; unhealthy behavior (smoking or alcohol consumption); exercise, and the number of physicians relative to the population. The income index was based on household income, poverty incidence, households with consumer debt, and income disparity measured by the Gini coefficient. The HDI could then be determined by average weights of education, health, and income indices.

In Lao PDR, the education index was built based on the adult literacy rate and the combined gross enrolment ratio for primary, secondary, and tertiary schools (UNDP, 2006). The income index was calculated using adjusted GDP per capita (PPP US\$) with the minimum and maximum values of US\$100 and US\$40,000, respectively. Income was adjusted because achieving a respectable level of human development does not require unlimited income. The health index was calculated based on life expectancy at birth (using a minimum value of 25 years and a maximum value of 85). However, in Vietnam, the HDI comprised four components: life expectancy at birth – minimum 25 years and maximum 85 – percentage of adult literacy rate, combined gross enrollment ratio (with minimum and maximum values of 0 and 100, respectively), and GDP per capita (PPP US\$) with a minimum value of US\$100 and US\$40,000 for a maximum value as presented in Table 1 (UNDP, 2011b).

Such information on Myanmar and Cambodia is quite limited at present. For Cambodia, the education index was calculated by literacy rate by age group along with the school attendance rates of children ages 6 – 14 years. Child survival rate of beyond the age of 5 was used to determine the health index, and consumption expenditures from small area estimations expressed in Riel per day were used for the income index (UNDP, 2011a). In Myanmar, the education index was determined by the average net enrollment rate in primary education and literacy rates for people between the ages of 15 and 24. The proportion of births attended by skilled health personnel was used for the health index. Normalized household consumption expenditures, including and excluding health expenditures per adult equivalent were used for the income index. Gini values were unavailable in Myanmar

(UNDP, 2013). Inequality incidence was calculated based on the consumption share of the bottom at 20 percent and the consumption gap between the richest and poorest at 20 percent.

Technology

Technology can play an important role in climate change adaptation (IPCC, 2007). Technology is used to directly or indirectly manage climate change and its effects in areas such as flood control measures, early warning systems, etc. Regions with greater technological capacity are better able to adapt (IPCC, 2001). In this study, electricity coverage and the extent of irrigation were used as primary indicators of adaptive capability related to climate resilience. Electricity coverage was defined as the percentage of households with access to electricity, and the extent of irrigation was determined by the percentage of an area equipped for irrigation. Following Yusuf and Francisco's (2009) guidelines, the electricity coverage was weighted as 0.53 and the area equipped for irrigation was weighted as 0.47 in assessing the potential of adaptive strategies.

Institution and infrastructure

Institution and infrastructure are important in estimating communities' resilience or vulnerability to climate change (Agrawal, 2002). Regions with well-developed institutions and infrastructure were considered to have greater adaptive capacity. The capacity of institutions and infrastructure to adapt to climate change at the regional level was considered based on secure access to transport facilities and infrastructure (i.e. road density); reasonable access to communication and information for learning exchange (i.e. communication); strategic areas that secure a sufficient and accessible water supply (i.e. drinking water); and access to and availability of support services (i.e. health services). Road density was defined as the length of road per square kilometer, while communication was defined as the number of fixed phone lines per person. Drinking water was defined as the percentage of households with access to clean water, and health services were defined as the percentage of inhabited accessed health services and health facilities.

2.2.4 Data analysis

The primary purpose of this assessment was to identify the climate change vulnerability index with relatively higher or lower adaptive capacity assessed based on the determinant values or scores of each indicator. It is important to note that each indicator contains different types of value units, which results in the individual indicators for each determinant being aggregated. Therefore, a normalization analysis for each indicator was carried out to normalize values of disparate units. One of the most notable approaches reported by UNDP is presented in Equation 1.

$$\text{Normalized}_{[where\ higher\ is\ better]} = \frac{(\text{Actual} - \text{Minimum})}{(\text{Maximum} - \text{Minimum})} \quad (1)$$

It seems that Equation 1 can only be applied if the actual value is expressed as “where higher is better” such as income capacity, education, health, etc. However, there are some indicators “where lower is better”, such as poverty incidence, income inequality, etc. As such, the normalization value data can be calculated using Equation 2.

$$\text{Normalized}_{[where\ lower\ is\ better]} = \frac{1 - (\text{Actual} - \text{Minimum})}{(\text{Maximum} - \text{Minimum})} \quad (2)$$

3. Results and discussions

3.1 Natural disaster country profile

Cambodia

Cambodia is located in the south of Southeast Asia and bordered by Lao PDR, Thailand, and Vietnam. The country covers an area of 181,035 square kilometers (km²) and the population was last recorded at 15.4 million in 2014, with 80% of the population living in rural areas. Fifty-two percent of the population lives in the central plains, 30% live in areas surrounding the Tonle Sap Lake, 11% live in the highlands and mountains, and only 7% live along the coast (World Bank, 2015a). The economy relies primarily on agriculture, industry, and services, with a total GDP in 2014 of about US\$ 16.7 billion. Cambodia is vulnerable to flooding and droughts, and is mostly reliant on agriculture and fisheries.

Situated at the downstream of the Mekong River, Cambodia is susceptible to numerous ongoing hazards and it is considered to be one of the most disaster-prone countries in Southeast Asia. Every year, floods of varying intensity affect socio-economic conditions and the livelihoods of Cambodians in two major watersheds, the Mekong River and the Tonle Sap Lake. The most catastrophic flood ever to hit Cambodia was in September 1996, impacting approximately 1.3 million people, damaging more than 600,000 hectares of crops and 50,000 houses (ADRC, 2015b). Additionally, during the period of 1998 to 2002, flooding accounted for almost about 70% of rice production losses, with drought responsible for an additional 20% (World Bank, 2011). In later years, drought has also been a problem affecting welfare and food security in Cambodia. It usually occurs during a period of abnormally dry weather and prolonged dry spells as a result of poor seasonal rainfall characterized by a late start to and early end of the rainy season. For example, the last major drought in 2002 was considered Cambodia's worst, which affected 420 communes in 10 provinces of the Mekong lowland and northeastern region (i.e. Prey Veng, Kandal, Kampong Speu, Takeo, Svay Rieng, Kampong Thom, Kampong Cham, Kratie, Odor Meanchey, and Banteay Meanchey). Based on the figures from the National Committee for Disaster Management (NCDM), the drought affected about 2,047,340 people, resulting in damages of US\$21.5 million. EM-DAT data showed that during the period of 1980 to 2014, there were an average of 0.51 floods per year, 0.09 tropical cyclones, 0.14 occurrences of drought, and 0.06 landslides (see Table 2).

Table 2 Natural disaster profile of Cambodia from 1980 - 2014

Exposure	Event (event/year)	Total death (person)	Total affected (person)	Damage (US\$ 1,000)
Flood	0.51	1,641	13,275,587	1,419,100
Tropical cyclone	0.09	44	178,091	10
Drought	0.14	0	6,550,000	138,000
Landslide	0.06	N/A	N/A	N/A

Source: EM-DAT, 2015

Lao PDR

Lao PDR is located in Southeast Asia and surrounded by Myanmar and China to the northwest, Vietnam to the east, Cambodia to the south, and Thailand to the west. The country has a total land area of approximately 236,800 km², 80% of which comprises mountainous areas. In 2014, the population was approximately 6.8 million people and the country had a total GDP of about US\$11.77 billion (World Bank, 2015a). According to the World Bank, Lao PDR is ranked as one of the poorest or least developed countries in the region and in the world, with 26% of its population living below the poverty line in 2010. In addition, the country has faced widespread food insecurity, with over a third of the population experiencing rice shortfalls for two to six months of the year.

Lao PDR is prone to regular flooding due to the effects of overflow from major rivers such as the Mekong and Sekong. Insufficient dyke systems along the river mean that the effects of deforestation, and land degradation intensify runoff and flooding in the region. Most of the people in Lao PDR live in rural areas where they depend on agriculture and are vulnerable to periodic droughts. It is estimated that 46% of the rural population live in lowland areas where food insecurity due to the impacts of natural disasters is a concern (World Bank, 2015a).

Lao PDR is vulnerable to extreme events, including floods and droughts. Floods are usually triggered by strong cyclones, such as tropical cyclones Xangsane in 2006 and Lekima in 2007, which affected over 600 villages and damaged 160,000 hectares of paddy field. Recently, Lao PDR was also hit by typhoon Ketsana in September 2009, which caused serious flooding in the country's southern and central regions. The National Disaster Management Office (NDMO) reported that at least 26 people were killed and more than 180,000 people were impacted. During the period of 1980 to 2014, the average annual rates for disasters in Lao PDR as reported by CRED were: 0.51 flood events, 0.14 tropical cyclones, and 0.11 occurrences of drought (no data was available for landslides) (see Table 3).

Table 3 Natural disaster profile of Lao PDR from 1980 – 2014

Exposure	Event (event/year)	Total death (person)	Total affected (person)	Damage (US\$ 1,000)
Flood	0.51	158	3,834,743	143,828
Tropical cyclone	0.14	72	1,436,199	405,951
Drought	0.11	0	750,000	1,000
Landslide	0.00	N/A	N/A	N/A

Source: EM-DAT, 2015

Myanmar

Myanmar is located in the northwest of Southeast Asia, bordered by Bangladesh and India to the northwest, China to the north, Lao PDR and Thailand to the east and the Bay of Bengal and Andaman Sea to the south. It is divided administratively into 7 States and 7 Divisions. Myanmar has a total land area of about 676,578 km² with a population of more than 51 million people and a total GDP of about US\$64.3 billion in 2014 (World Bank, 2015b).

Myanmar has a tropical climate with three seasons: the rainy season (May to October); winter (October to February); and summer (February to May). Average annual rainfall ranges between 4,000 to 5,600 mm in coastal areas to 600 to 1,400 mm in central dry zones (Myanmar, 2009). Most of the country lies between the Tropic of Cancer and the Equator which results in it being affected by a number of extreme climatic events, such as tropical cyclones, floods, droughts, earthquakes, and landslides. One such event, Cyclone Nargis, made landfall in Myanmar in May 2008, crossing the southern part of the country over two days and devastating the whole Ayeyarwady delta region. According to official figures, the cyclone resulted in 84,500 deaths, with 53,800 missing and a total of about 2.4 million people affected (Zöckler et al., 2013). Myanmar is also earthquake prone as it lies on one of the two main earthquake belts of the world, the Alpine-Himalayan orogenic belt that starts from the northern Mediterranean in the west and extends eastwards through Turkey, Iran, Afghanistan, the Himalayas, Myanmar and Indonesia (Myanmar, 2009). In 2011, Myanmar experienced a strong, magnitude 6.9 on the Richter scale earthquake, with its epicenter east of Shan State that killed at least 75 people.

Flooding usually occurs in June, August, and from late September to October with risk highest in August (during the peak of the monsoon period). Landslides in Myanmar are mostly triggered by heavy rainfall and earthquakes. Geomorphologically, the Western Ranges and Eastern Highlands are inherently unstable regions with steep mountain slopes and unstable geologic conditions, which are considered as the vulnerable to landslide hazards. Annual averages for disasters from 1980-2014 were: 0.5 floods, 0.17 tropical cyclones, 0.11 occurrences of drought, and 0.11 landslides (see Table 4).

Table 4 Natural disaster profile of Myanmar from 1980 – 2014

Exposure	Event (event/year)	Total death (person)	Total affected (person)	Damage (US\$ 1,000)
Flood	0.50	431	1,048,412	136,655
Tropical cyclone	0.17	138,709	2,866,125	4,067,688
Drought	0.11	N/A	N/A	N/A
Landslide	0.11	125	146,367	N/A

Source: EM-DAT, 2015

Thailand

Thailand is situated at the center of the Indochina peninsula on mainland Southeast Asia. It is bordered by Myanmar to the north and west, Lao PDR to the north and northeast, Cambodia and the Gulf of Thailand to the east, and Malaysia to the south. The country covers an area of about 513,115 km² with a population of approximately 67 million people in 2014. Thailand experienced rapid economic growth between 1985 and 1996, with a GDP of about US\$373.8 billion in 2014, and is becoming a newly industrialized country and a major exporter, compared to other countries in the region (World Bank, 2015b).

Thailand's climate is influenced by monsoon winds of seasonal character – the southwest and northeast monsoons. The southwest monsoon, which starts in May, brings a stream of warm moist air from the Indian Ocean towards Thailand, resulting in abundant rainfall. The northeast monsoon, which starts in October, brings cold and dry air from the anticyclone in mainland China over major parts of Thailand. In the past, Thailand has been affected by several major natural disasters

such as Typhoon Gay in 1989, which hit southern Thailand, causing more than 800 fatalities in and around the Gulf of Thailand and resulting in damages of more than US\$497 million. The Department of Disaster Prevention and Mitigation (DDPM) reported that from 2002 to 2010 floods have resulted in more than 1,000 deaths and economic damage of more than US\$1.1 million. In 2011, Thailand experienced one of the worst floods in the country's history which was triggered by the Nock-ten tropical cyclone. The flood spread over 65 of 77 provinces in the country's northern, northeastern and central regions. About 815 people died as a result of the floods, while more than 13.6 million were affected, 20,000 km² of farmland was confirmed to have been destroyed, contributing to an estimated US\$ 45.7 billion in damage and economic losses, as estimated by the World Bank. Thailand's rice growing region of about 9.2 million hectares is one of the areas most vulnerable regions to major droughts. The DDPM estimated that an average of 59 provinces and 14.9 million people were affected by major droughts from 2007 to 2013, with damages of more than US\$ 23.30 million. From 1980 to 2014, the average annual occurrences of disasters was: 1.94 floods, 0.89 events tropical cyclones, 0.26 occurrences of drought, and 0.09 landslides (see Table 5).

Table 5 Natural disasters profile of Thailand from 1980 – 2014

Exposure	Event (event/year)	Total death (person)	Total affected (person)	Damage (US\$ 1,000)
Flood	1.94	3,606	50,308,778	44,944,408
Tropical cyclone	0.89	895	42,37,503	892,039
Drought	0.26	0	29,982,602	424,300
Landslide	0.09	47	43,110	N/A

Source: EM-DAT, 2015

Vietnam

Vietnam is located in the eastern region of Southeast Asia. The country is bordered by China to the north, Lao PDR to the northwest, Cambodia to the southwest, and Malaysia across the South China Sea to the southeast. Vietnam has a total land area of approximately 332,698 km² with a population of 90.6 million people in 2014 (World Bank, 2015b). According to the World Bank, Vietnam has

been one of the best performing economies in the world over the past decade. In recent years, relative contributions from agriculture, forestry, and fishing have declined due to the rapid growth of the industrial and service sectors, with a total GDP of about US\$ 186.2 billion (in 2014).

The country is situated along coastline areas in the tropical monsoon belt and has a diverse topography and climate. It is also considered a highly hazard-prone area, where with regular major natural disasters, such as tropical cyclones, floods, droughts, and landslides. The UNDP reported that an average of six to eight cyclones affected Vietnam every year. Most tropical cyclones bring strong winds and heavy rains that can cause secondary hazards such as floods and lead to significant socio-economic consequences. In addition, intense rainfall associated with tropical cyclones usually causes flooding in Vietnam. Flooding is considered the primary threat in terms of its threat to human life as well as its impact on the economy, society and agricultural production. In 1999, Vietnam experienced some of its most severe flooding when heavy storms resulted in significant downpours in the central region. It was reported that the flood affected six coastal provinces (from Quang Binh to Binh Dinh), resulted in more than 600 people either dead or missing and cost nearly US\$ 300 million in property losses (FAO, 2003). Annual averages for disasters in Vietnam for the period 1980-2014 were: two floods, 2.57 tropical cyclones, 0.14 drought-related events, and 0.17 landslides (see Table 6).

Table 6 Natural disaster profile of Vietnam from 1980 – 2014

Exposure	Event (event/year)	Total death (person)	Total affected (person)	Damage (US\$ 1,000)
Flood	2.00	4,884	26,895,560	3,746,227
Tropical cyclone	2.57	10,805	42,032,951	6,167,835
Drought	0.14	N/A	6,110,000	649,120
Landslide	0.17	330	39,074	2,300

Source: EM-DAT, 2015

3.2 Climate-related hazard maps for Mekong countries

As described in the methodology section, the climate-related hazard maps for Mekong countries were delineated for five climate related risks: tropical cyclone frequency, flood frequency, drought frequency, landslide frequency, and 5-meter SLR.

Tropical cyclone

According to the National Oceanic and Atmospheric Administration (NOAA), a tropical cyclone is a rotating, organized system of clouds and thunderstorms that originates over tropical or subtropical waters and has a closed low-level circulation. Based on EM-DAT data, Figure 2 indicates tropical cyclone frequency (per event per year) from 1980 to 2014. Vietnam is clearly the most vulnerable country, especially along its eastern coastline. Tropical cyclones are also an annual threat in Myanmar, particularly the coastal area close to the Bay of Bengal. Cyclones usually occur along the western coastal areas and the fertile plain of Myanmar during the pre-monsoon period – April to May and October to December. Thailand and Lao PDR are also vulnerable to cyclones, while the risk is lower in Cambodia.

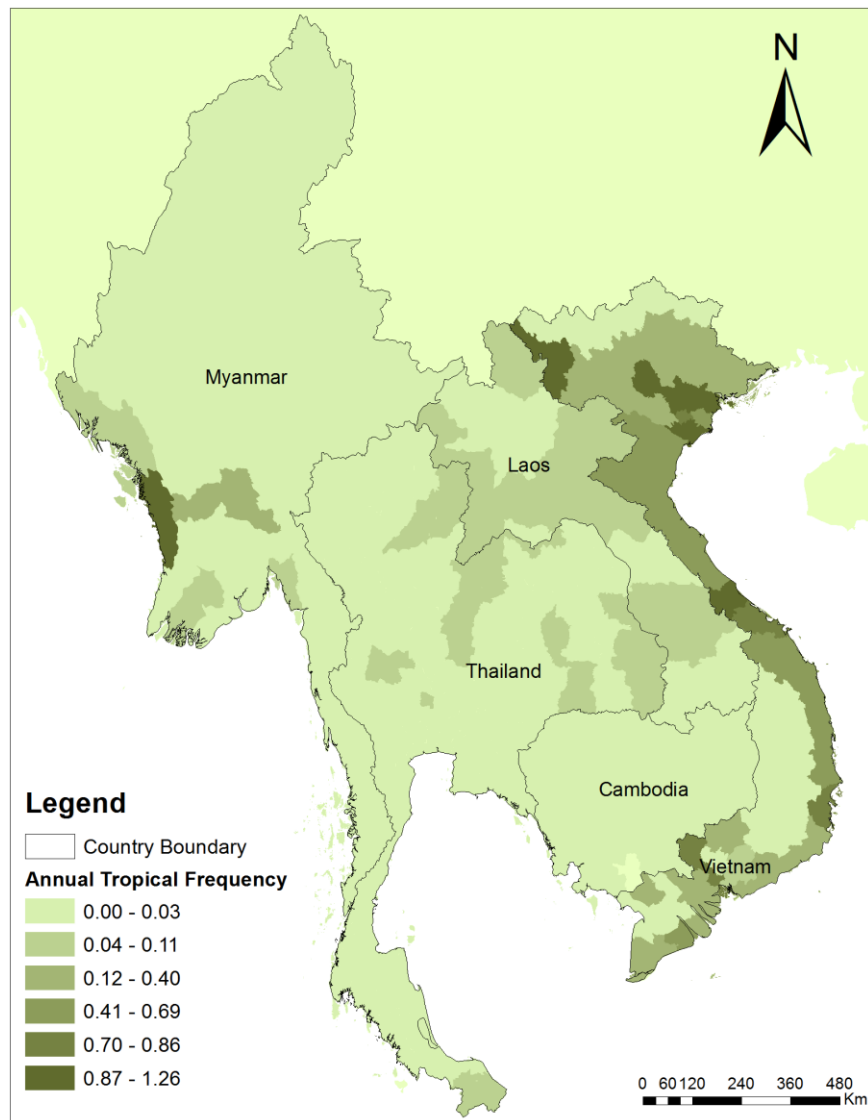


Figure 2 Tropical cyclone frequency from 1980 to 2014 (EM-DAT, 2015)

Flood frequency

The downstream Mekong region was the most vulnerable in terms of flooding during this period. Generally, floods occurred in the Cambodian Mekong lowland region towards the Mekong delta in southern Vietnam. Additionally, flood also take place in the Red River Basin in the central and northeastern regions of Vietnam. In Myanmar, a number of flood events occurred along the western coastline and central region, in areas including Ayeyarwady Division, Yangon Division, Mandalay Division, and Rakhine State). In Thailand, the Chao Phraya River Basin located in the central region and the Chi River Basin located in the northeastern region were the areas most vulnerable to floods. Floods have become more frequent in the south and central regions of Lao PDR, in areas such as along

the Mekong River Basin and the Sekong River Basin. Figure 3 shows annual flood frequency in Mekong countries (per event per year) from 1980-2014.

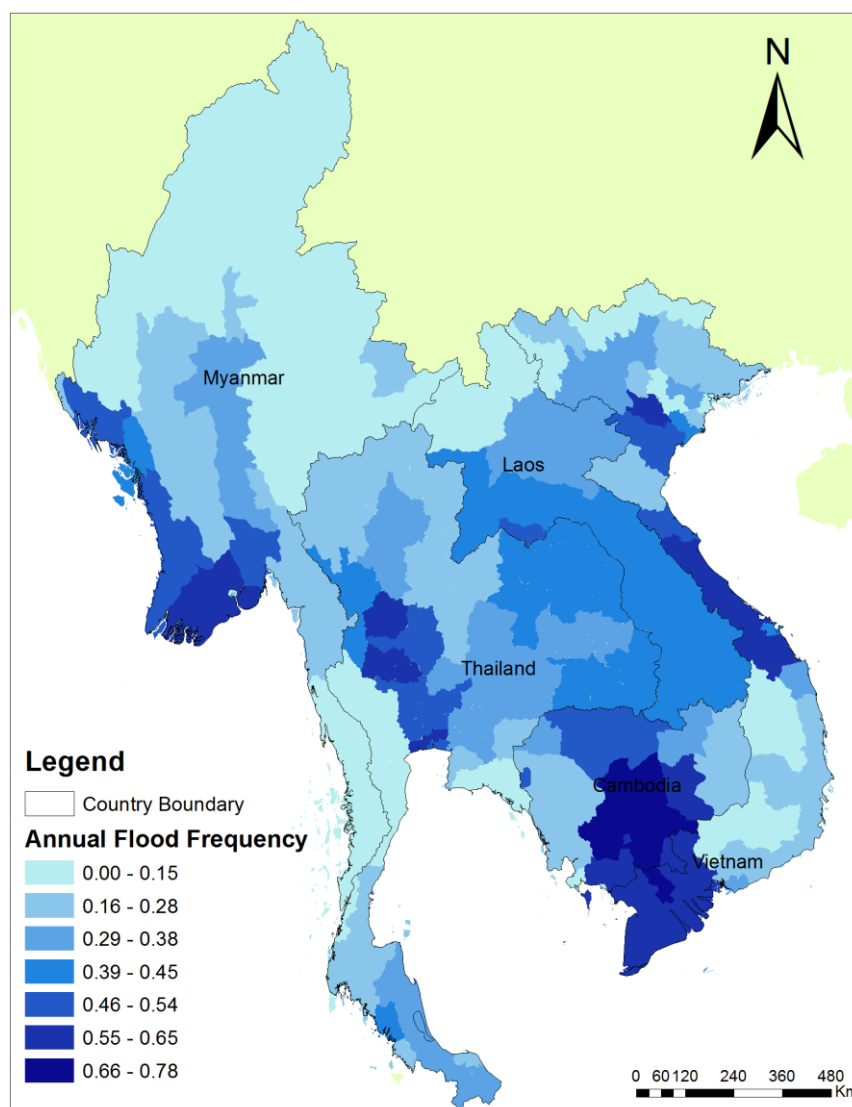


Figure 3 Flood frequency from 1980 to 2014 (EM-DAT, 2015)

Drought frequency

Drought is the most serious constraint to environmental services and socio-economic conditions. It is usually caused by a lack of rainfall, a decline in soil moisture, a failure of water management systems, etc. As illustrated in Figure 4, in Thailand the northeast region of is the area most vulnerable to drought. In Myanmar, the dry zone extends along the central part of the Inner-Burman Tertiary Basin and Indo-Burman Ranges, and some parts of Sagaing, Magwe, and Mandalay Divisions.

Droughts also occur in the north and central highlands of Vietnam, including the Cambodian Mekong lowland region and the central region of Lao PDR.

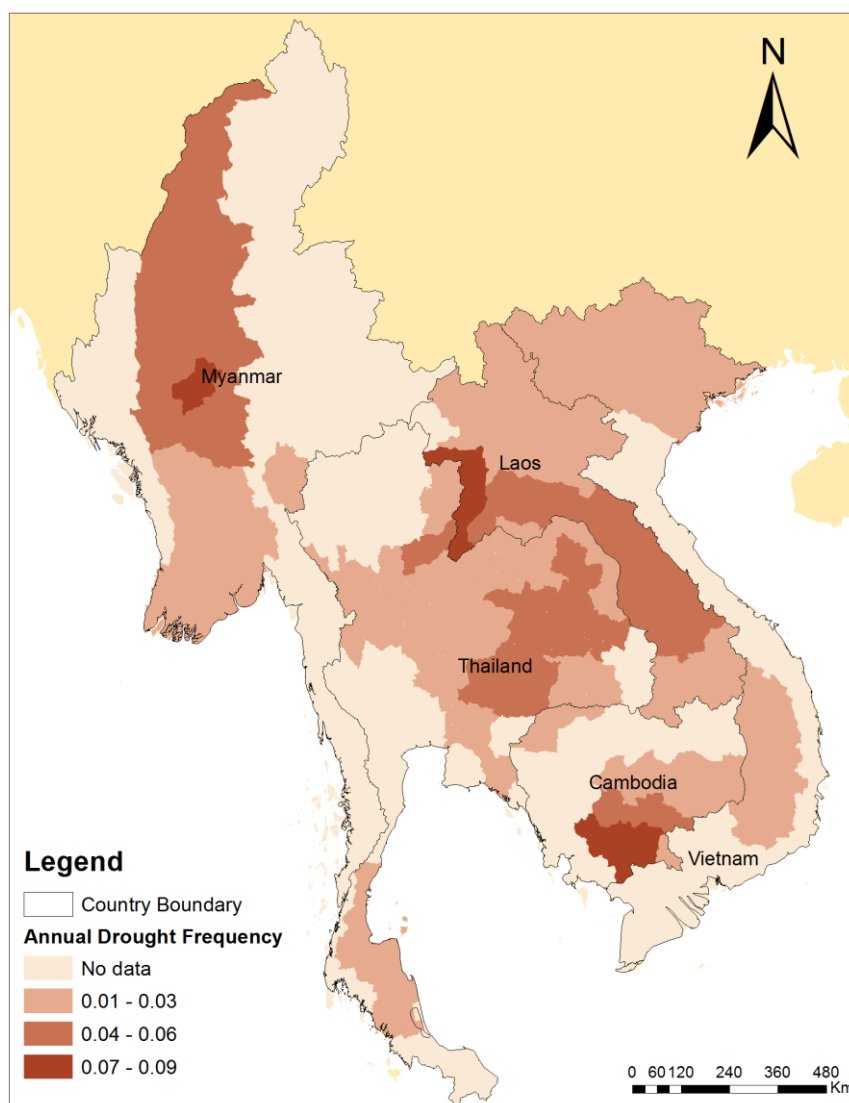


Figure 4 Drought frequency from 1980 to 2014 (EM-DAT, 2015)

Landslide frequency

A landslide occurs when a mass of earth or rock moves down a slope and can be triggered by heavy rainfalls or earthquakes. From 1980-2014 in Vietnam, landslides mostly occurred in the north and central highland regions. These regions are 35% of the country's areas that are highly vulnerable to landslides. Heavy rainfall and flash floods were the main factors causing landslides in the northern region of Thailand, where the intensity and frequency of the disaster tended to increase. As Figure 5 shows, the areas in Myanmar most vulnerable to landslides are in the

western ranges and eastern highlands. Information on landslides in Cambodia and Lao PDR is limited; however, it was noted that there were several events in the Cambodian Mekong lowland region during this period. The UNDP reported that approximately 5.24% of the total area of Lao PDR were at high to very high levels of vulnerability to landslides, which mostly occurred in the southeast and central regions.

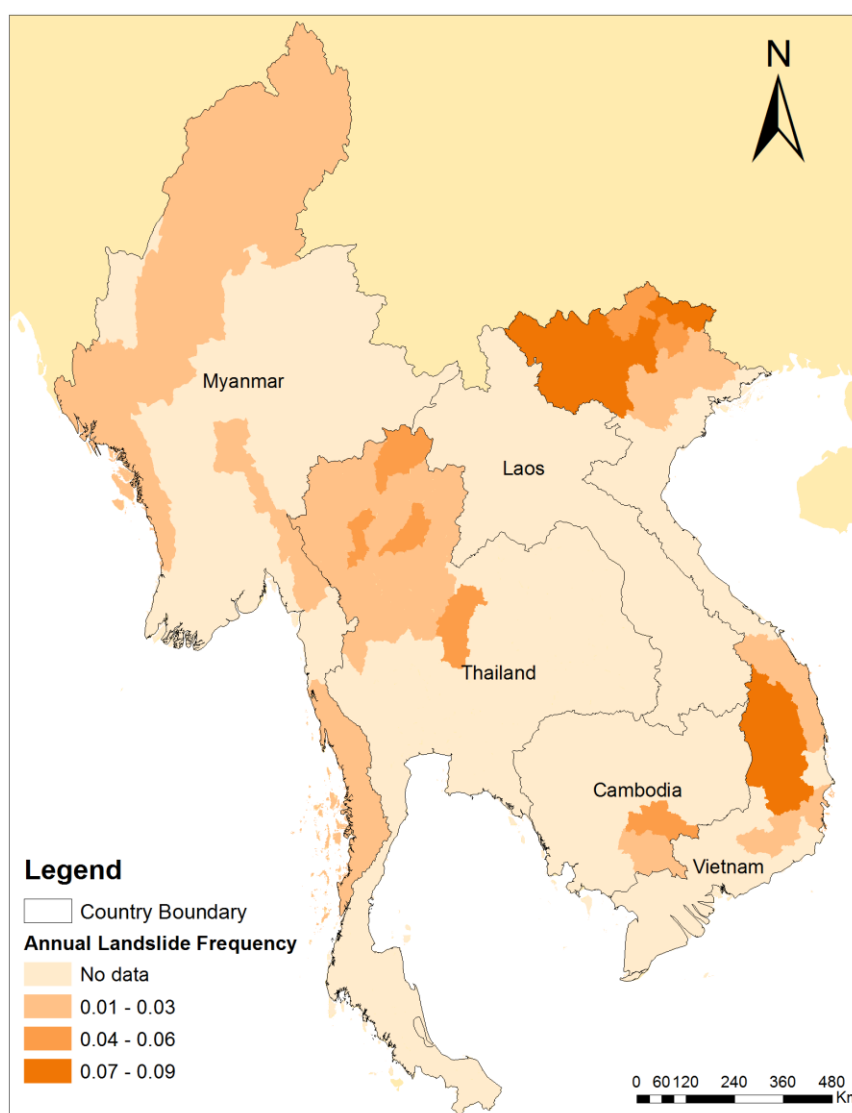


Figure 5 Landslide frequency from 1980 to 2014 (EM-DAT, 2015)

Sea level rise 5m

The 5-meter Sea Level Rise (SLR) was calculated from the Global Land One-kilometer Base Elevation (GLOBE) on a regular latitude/longitude grid with a spatial resolution of 1 km. As described by the CReSIS, the inundation zones were

derived from the ETOPO2 raster elevation dataset developed by the National Geophysical Data Center (NGDC). The inundated areas were computed based on elevation and proximity to the current ocean shoreline. To define the population at risk, data were separated from LandScan data in 2004 and a global population dataset developed by the Oak Ridge National Laboratory Global Population Project. A Geographic Information System (GIS) was involved in developing the 5-meter SLR map. The delineation was carried out in two steps: (1) the algorithm flags all raster cells in the Digital Elevation Model (DEM) that lie adjacent to the contiguous ocean; (2) the cells within that group of flagged cells whose elevation value (less than or equal to the desired SLR increment) were selected and reassigned as ocean cells (CReSIS, 2015). Areas that could potentially be inundated are outlined in Figure 6.

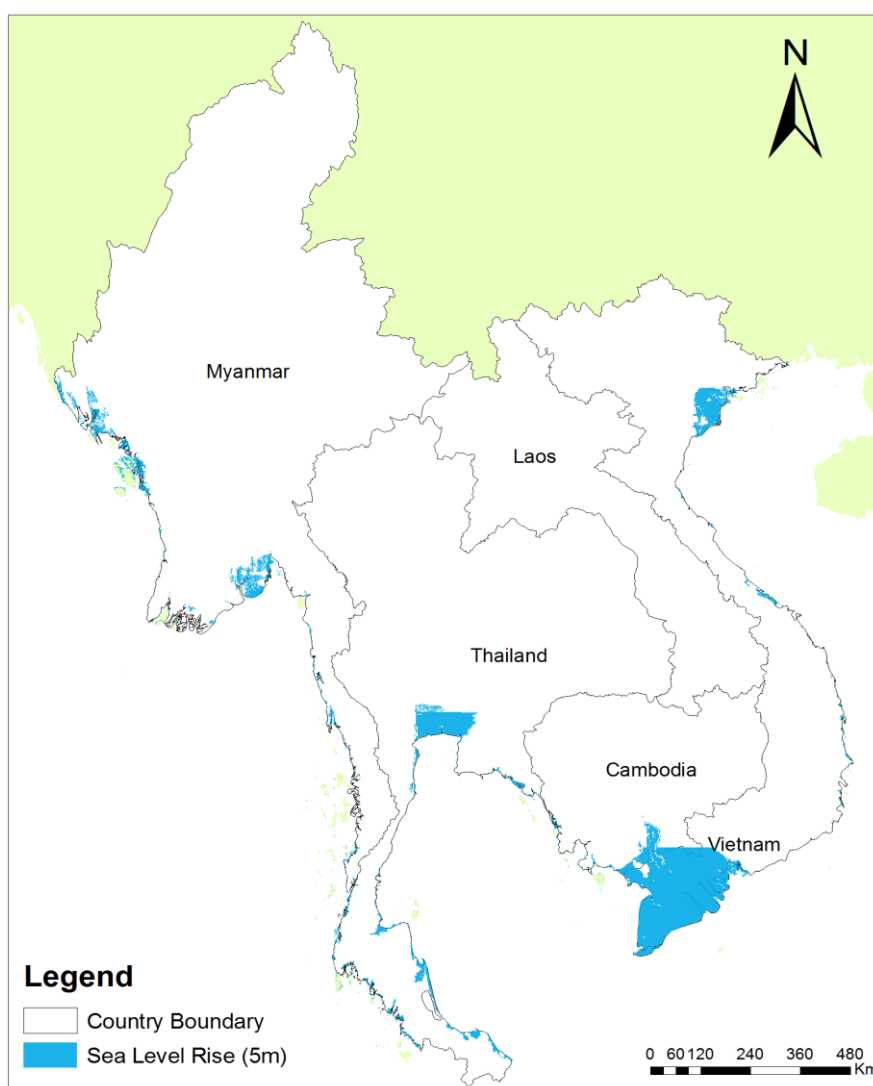


Figure 6 Sea level rise at 5-meter (CReSIS, 2015)

3.3 Human and ecological sensitivity maps

Sensitivity was assessed by evaluating the impacts of human activities and ecological sensitivity of the region. According to demographic data from 2013, the population of Vietnam, the most populous country in the Mekong region, was generally dispersed in urban areas such as Ha Noi (with a population density of 2,000 inhabitants per km²) and Ho Chi Minh City (population density of 4,000 per km²). However, Thailand's capital city, Bangkok, has a higher population density – 5,400 inhabitants per km² as of 2013. The population in Vietnam is projected to increase to more than 100 million people by 2050 (Figure 7), according to World Bank estimates, which means greater susceptibility to natural hazards. Thailand's population was projected to decrease in the future to the point where it will be equal to that of Myanmar, which is projected to have a significant population increase by 2050 (Figure 7). Meanwhile, Lao PDR and Cambodia are expected to have slight population increases by 2050.

Figure 8 provides an overview of population density in Mekong countries as of 2013.

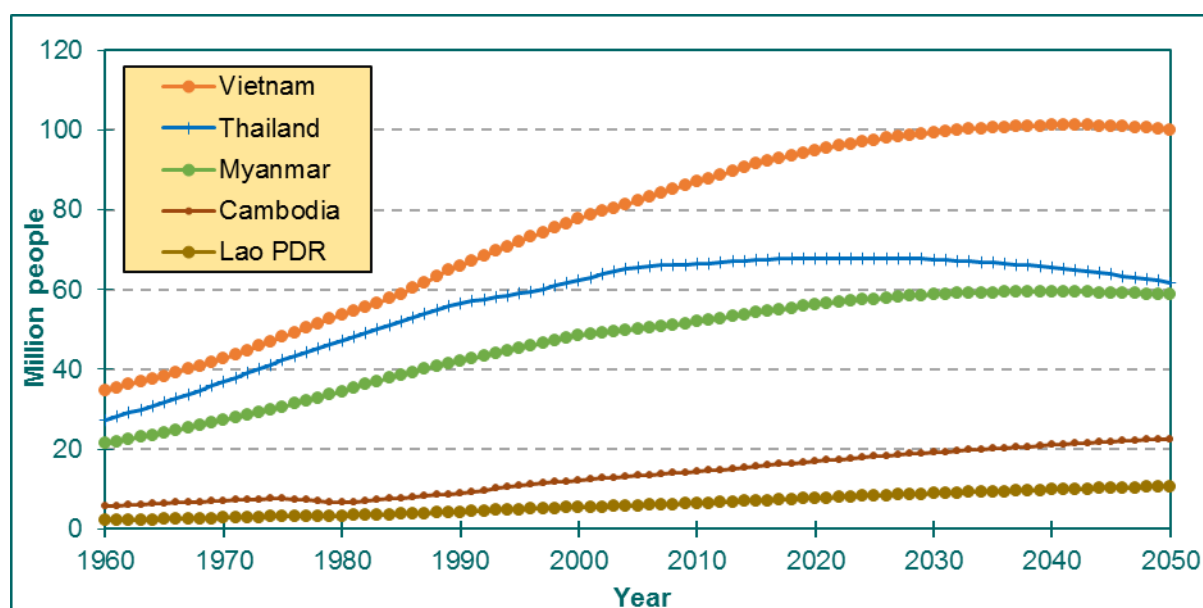


Figure 7 Demographic estimates and projections from 1960 to 2050
(World Bank, 2015)

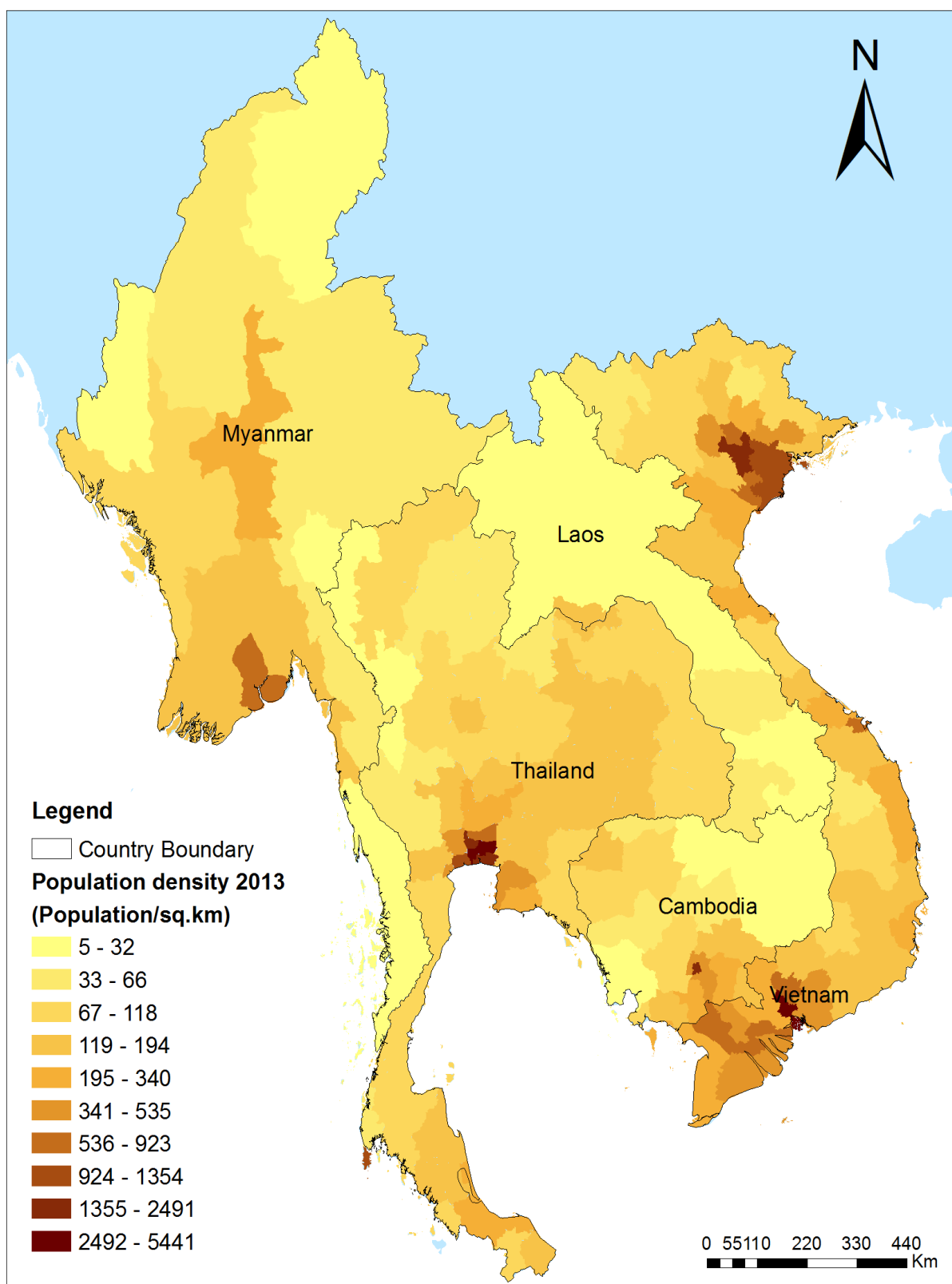


Figure 8 Population density of the Mekong countries in 2013
(National Statistical Offices, 2013)

In terms of conserving biodiversity, Figure 9 illustrates protected areas in the Mekong countries as of 2014 provided by WDPA. Based on the Geographic Coordinate System with World Geodetic System of 1984 (WGS 1984) horizontal datum, each protected area is represented either as a polygon boundary or a point location. The Mollweide projection was used to calculate protected land area and protected marine area in the WDPA attribute table. Cambodia, Thailand, and Lao PDR were shown to have more protected areas than Vietnam and Myanmar, as illustrated in Table 7. Cambodia has 44 protected areas, occupying 47,466 km², or approximately 26% of the country's total land area. Thailand has 237 protected areas recorded in the WDPA database, covering 102,818 km², or roughly 21% of the total land area. Lao PDR had 33 protected areas, covering 38,542 km² or approximately 17% of total land area. Myanmar had 57 protected areas covering 48,592 km², approximately 7% of the country's total land area. The 223 protected areas in Vietnam cover about 25,153 km² or about 7% of total land area.

Table 7 Protected areas in the Mekong countries in 2014

	Cambodia	Thailand	Lao PDR	Myanmar	Vietnam
Land area (km²)	182,511	517,784	231,276	673,073	329,873
Protected area (km ²)	47,377	97,133	38,542	48,268	21,467
Marine area (km²)	47,786	305,550	0	520,268	660,496
Protected area (km ²)	89	5,685	0	324	3,686
Total protected areas (km²)	47,466	102,818	38,542	48,592	25,153
Number of protected area	44	237	33	57	223
Percentage (%)	26	21	17	7	7

Source: WDPA, 2014

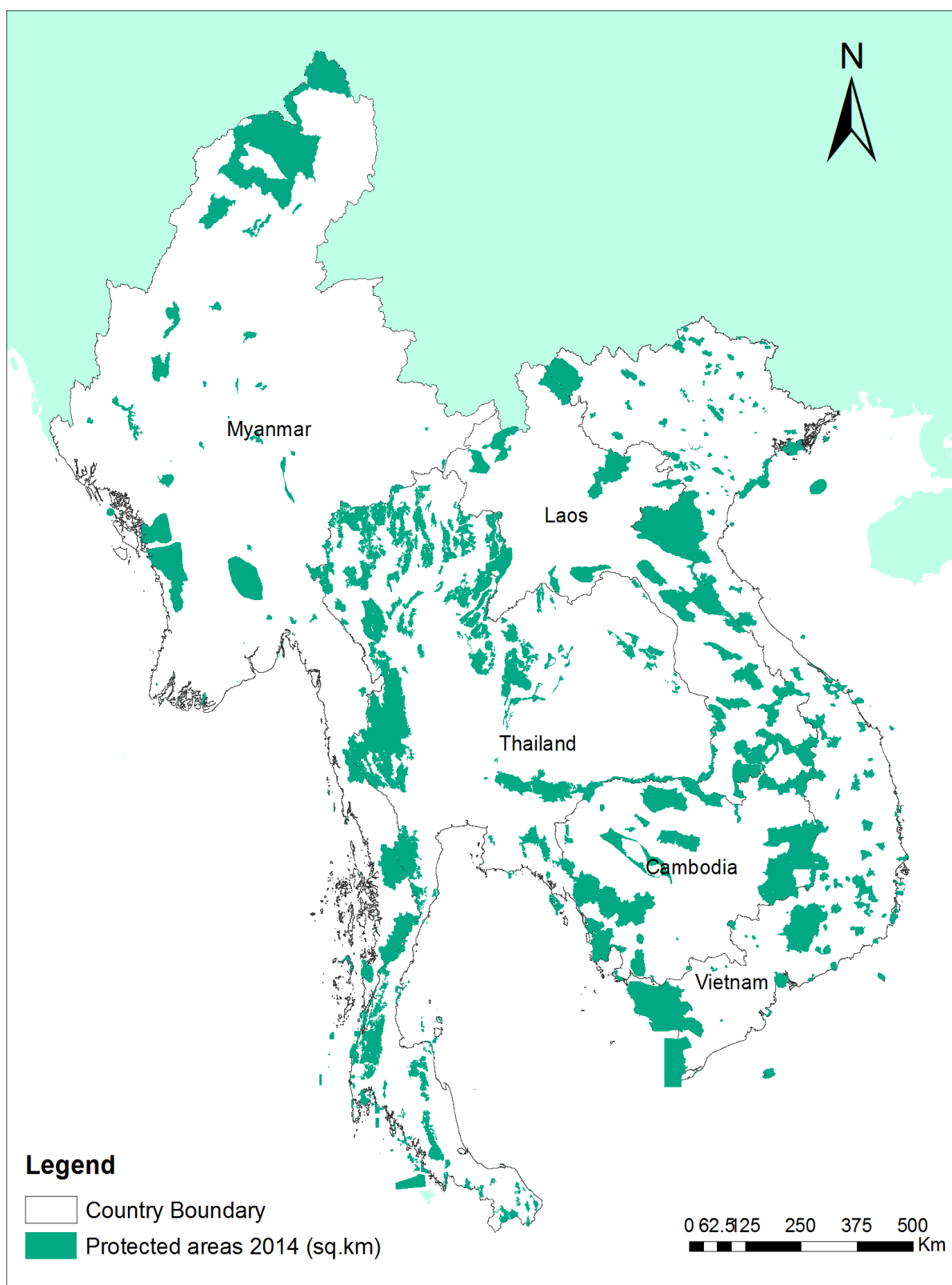


Figure 9 Protected areas in 2014 (WDPA, 2014)

3.4 Adaptive capacity mapping

Adaptive capacity is an essential factor in determining vulnerability to climate change and in conducting a comprehensive assessment of how a system can adapt and cope with its impacts. In this study, Adaptive Capacity Index (ACI) scores for the Mekong countries were determined to empirically assess the adaptive capacity of each (as illustrated in Figure 10). The higher the score on the ACI index, the less vulnerable the country is to climate change, while lower scores reflect greater vulnerability.

Thailand ranks first among the Mekong countries and 89th in the world, on the Human Development Index, with an HDI score of 0.722 as of 2013. Vietnam's HDI score was 0.638 for 2013, 121th in the world and second in the Mekong region; Cambodia's HDI score was 0.584, 136th in the world and third in the region; Lao PDR's score was 0.569, 139th in the world and fourth in the region; while Myanmar's score was 0.524, 150th in the world, and fifth in the Mekong region).

Bangkok has the highest adaptive capacity in the Mekong region with an ACI score of 0.82. Myanmar has the lowest adaptive capacity as reflected by low ACI scores – 0.18 for Chin State and 0.22 for Rakhine State. This reflects its low HDI score, low level of technological development, high poverty incidence, and income inequality. For easy visualization, adaptive capacity in the Mekong countries was mapped at the provincial level based on socio-economic, technological, institutional and infrastructure indicators (Figure 11). Adaptive capacity is generally inversely proportional with vulnerability –the regions with higher adaptive capacity will be less vulnerable and better able to adapt to the impacts of climate change. However, even these regions are still heavily affected by other factors, such as exposure and sensitivity. Adaptive capacity remains an effective criterion for the mitigation of vulnerability towards climate change.

3.5 Climate change vulnerability mapping for greater Mekong sub-region

Vulnerability assessments are crucial to identifying areas that are unsustainable and their capacity to respond to climate change. Using the IPCC (2001) framework for this study, the climate change vulnerability of the Mekong

countries was mapped to identify the region's vulnerable areas (Figure 12). (Note: Vulnerability is considered a function of exposure, sensitivity, and adaptive capacity). The Mekong lowlands, the eastern region of Cambodia, the western coastline and the central region of Myanmar were identified as areas most vulnerable to climate change. Thailand, with the exception of Bangkok, is considered to be less vulnerable to climate change than other except Bangkok. In Vietnam, the vulnerable areas to climate change are located in the Mekong River Delta and Red River Delta.

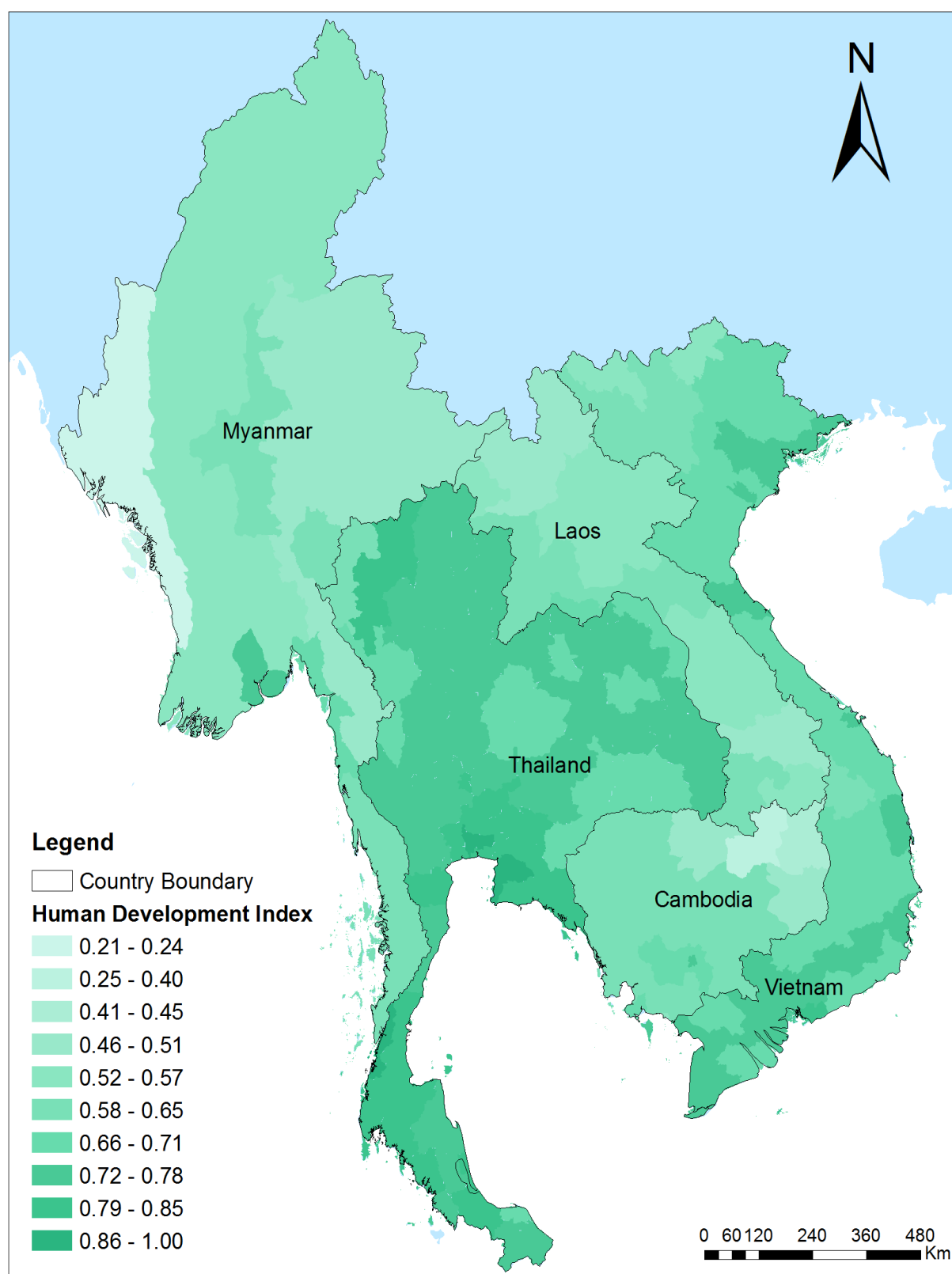


Figure 10 Human Development Index in the Mekong countries

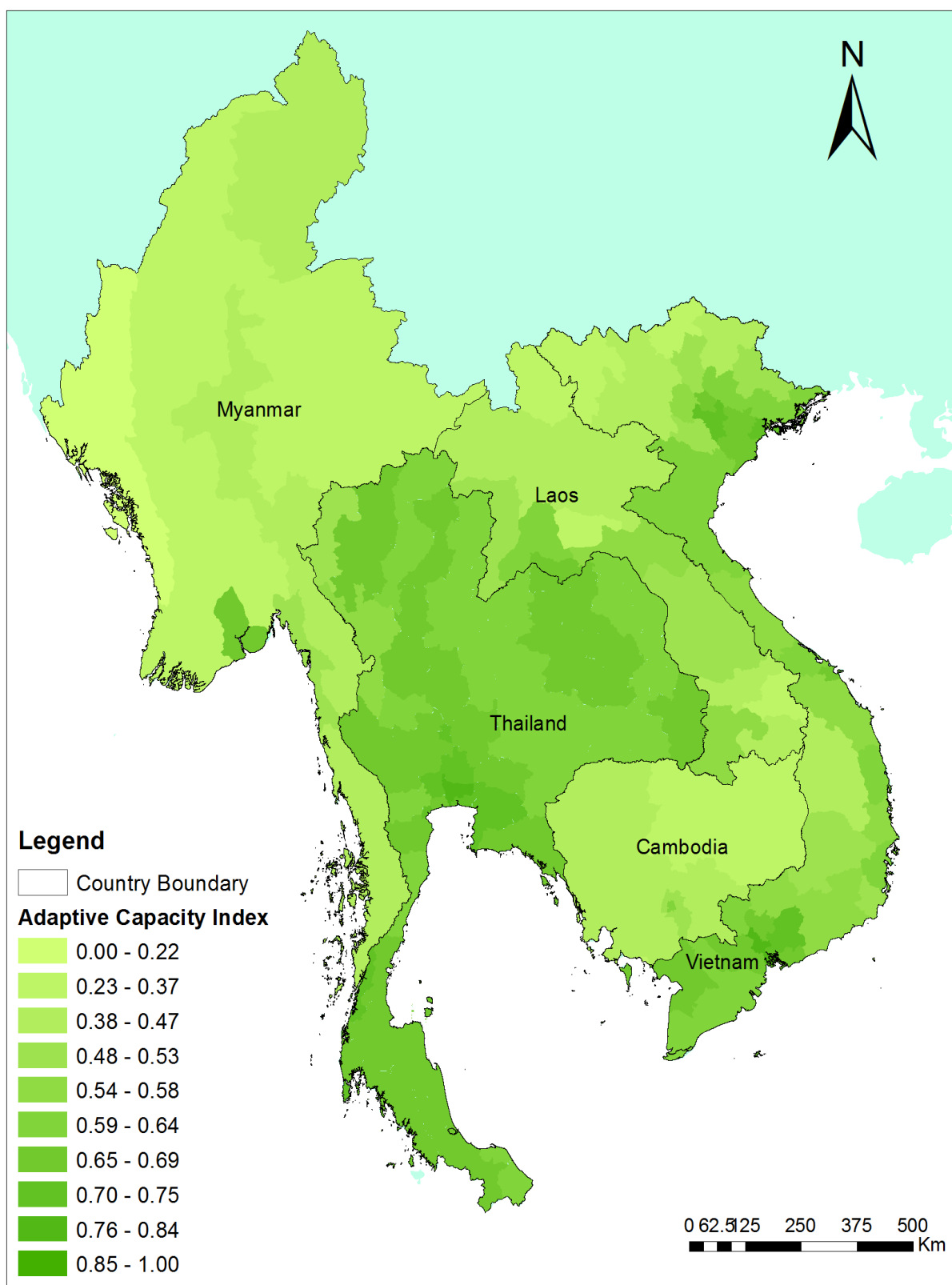


Figure 11 Provincial-level mapping of adaptive capacity in the Mekong countries

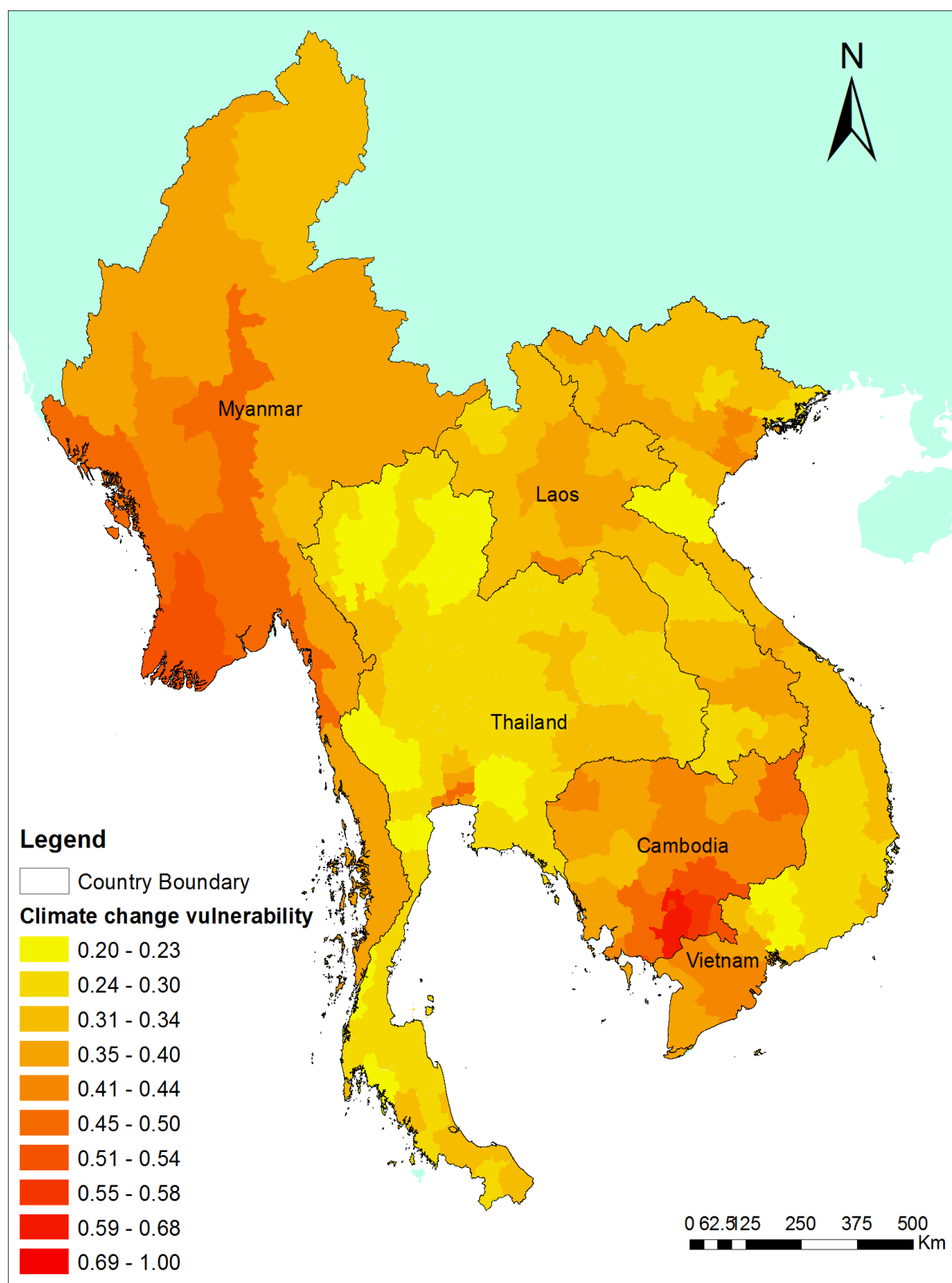


Figure 12 Vulnerability index in the Mekong countries

3.6 Determining areas vulnerable to climate change impacts in the Mekong countries

Determining which areas are vulnerable to the impacts of climate change impacts can serve as a basis to guide vulnerability assessments and adaptation actions to diminish future risks for vulnerable countries in the Mekong region. The steps to achieve this can be described as follows.

The distribution of vulnerability indices was first determined using the Whisker-plots for each country (Figure 13). The regions that fell in the fourth quartile of the maximum values were considered to be the most vulnerable. Correspondingly, the vulnerability indices with values higher than 0.51 were chosen as the vulnerability index in this assessment. Thereafter, ArcGIS software was used to group the aforementioned indices into three classes: mildly vulnerable, moderately vulnerable, and highly vulnerable. (Note: High vulnerability indicates the likelihood that climate-induced changes will have the maximum adverse impacts on people's health, safety and livelihoods).

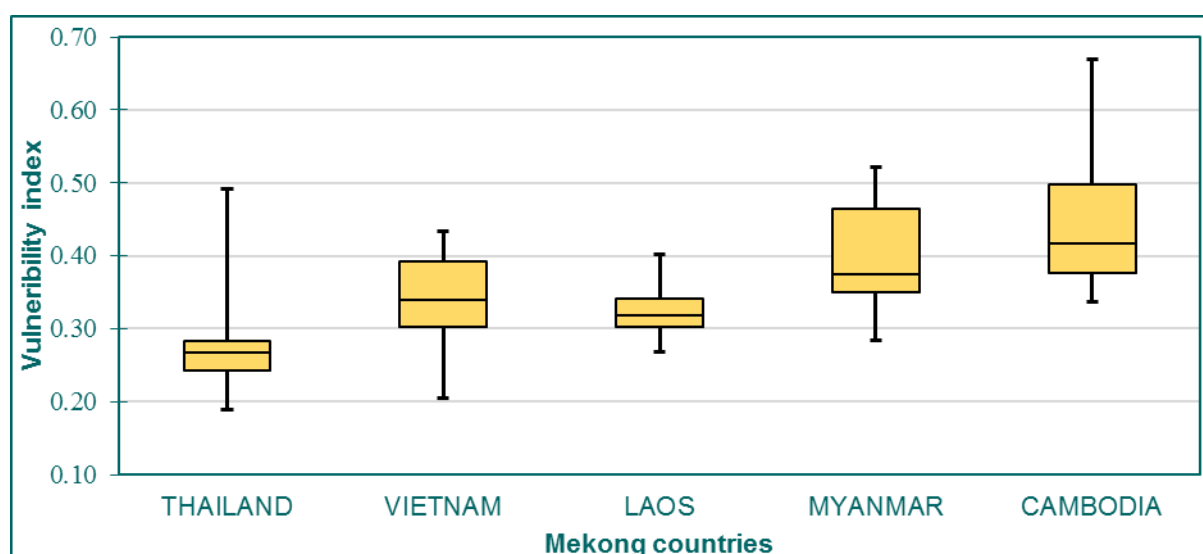


Figure 13 Distribution of vulnerability index for the Mekong countries

Cambodia and Myanmar were identified as being the most vulnerable to climate change in the Mekong region (Figure 14). Looking at the period of 1980-2000, Yusuf and Francisco (2009) had previously identified Cambodia's Mondulkiri and Ratanak Kiri Provinces as that country's most vulnerable areas as they were both exposed to climate variability and had limited adaptive capacity.

Issues of sensitivity to and lack of adaptive capacity to cope with potential climate change impacts were taken into consideration. This study identified the Mekong lowlands in Cambodia, which includes the provinces of Kandal, Takeo, Prey Veng, and Svay Rieng, as the area most vulnerable to climate change from 1980 to 2014. There is significant evidence to support the identification of areas most vulnerable to climate change due to their locations in the disaster prone areas. Furthermore, a high population density and too few protected areas also contribute to making the Mekong lowlands in Cambodia the area of the country most vulnerable to natural disasters such as floods, droughts as well as rising sea levels.

Myanmar's vulnerability to climate change as well as low adaptive capacity puts it on the list of the most vulnerable countries. Ayeyarwady Division and west coast region of Rakhine State in particular are highly vulnerable. Ayeyarwady Division was designated as a vulnerable area because of its high population – 6.1 million people living in the area in 2013 – and low adaptive capacity, with an ACI score of 0.36. Moreover, the division itself is well known as a low-lying delta facing the Bay of Bengal, which is usually affected by major tropical cyclones (e.g. the devastating Nargis cyclone in May 2008), floods, and rising sea levels. Rakhine State was also identified as a vulnerable area because of its relatively low adaptive capacity (ACI score of 0.22). The state is mostly impacted by major tropical cyclones, such as Cyclone Mala in 2006 and Cyclone Giri in 2010, as well as landslide hazards, such as the devastating one that hit the area in 2010. Rakhine State is also affected by rising sea levels and coastal inundation due to it being situation along the western coastline of Myanmar.

The Mekong River and Red River deltas in Vietnam as well as Bangkok in Thailand are also among the Mekong's most vulnerable regions. As in other vulnerable areas, a well developed adaptive capacity is essential to climate change and adaption strategies. Only then can the destructive effects of climate variability be mitigated.

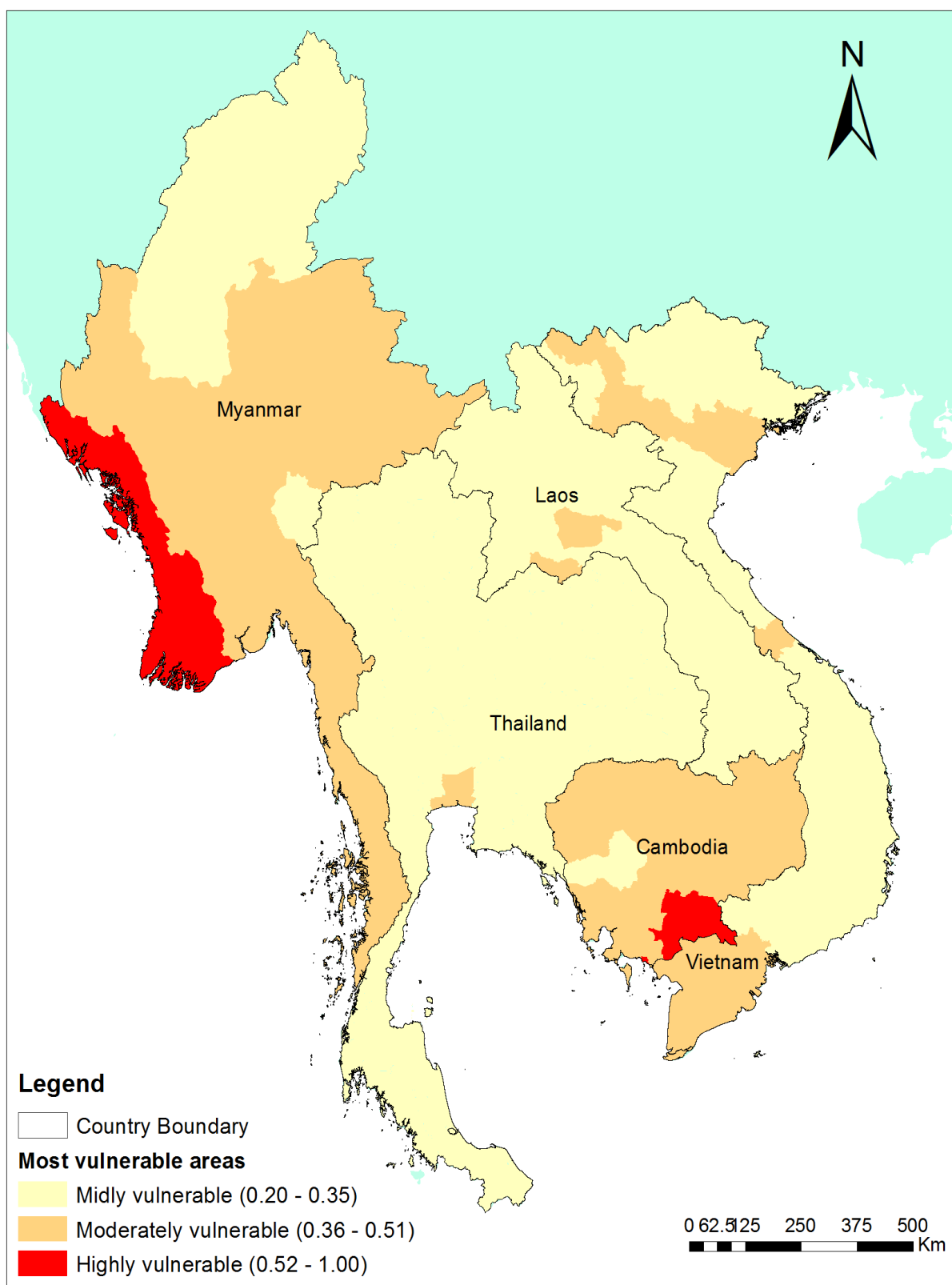


Figure 14 Map of the most vulnerable areas in the Mekong countries at risk from climate change

3.7 Preliminary verification results of climate change vulnerability assessment for the Mekong countries

To verify the results of this study, the main findings from Yusuf and Francisco (2009) were used to compare the outputs of this assessment through the mapping of adaptive capacity, vulnerability, and vulnerable areas within the Mekong region. It is important to note that the assessment in this study was based on the modification of the adaptation framework from the Yusuf and Francisco (2009) study. Some areas of focus were expanded on for this study, such as the number of countries, duration of assessment, adaptation indicators, and the variety of data sources, as shown in Table 8.

Table 8 Additional elements for vulnerability assessment for the countries in the Mekong region

Element	As considered in Yusuf and Francisco (2009)	As considered in WREI (2015)
<i>Country</i>	Thailand (72 provinces) Vietnam (53 provinces) Lao PDR (17 provinces) Cambodia (19 provinces)	Thailand (77 provinces) Vietnam (63 provinces) Lao PDR (18 provinces) Cambodia (24 provinces)
<i>Additional boundary</i>	Malaysia (14 provinces) Philippines (14 provinces) Indonesia (341 districts)	Myanmar (7 divisions and 7 states)
<i>Duration</i>	1980 – 2000	1980 – 2014
<i>Adaptive Capacity</i>	A function of socio-economic, technology, and infrastructure	A function of socio-economic, technology, institution, and infrastructure
<i>Exposure database</i>	UNEP, Norwegian Geotechnical Institute (NGI), CReSIS	EM-DAT, CReSIS, available online sources

Table 8 Additional elements for vulnerability assessment for the countries in the Mekong region (cont'd)

Element	As considered in Yusuf and Francisco (2009)	As considered in WREI (2015)
<i>Sensitivity database</i>	Center for International Earth Science Information Network (CIESIN), World Wildlife Fund (WWF)	National Statistical Offices, WDPA
<i>Adaptive capacity database</i>	UNDP country report, National Statistical Offices, available online sources	UNDP country report, National Statistical Offices, available online sources

Adaptation capacity

It is worth noting that there are strong correlations between the results of Yusuf and Francisco (2009) and WREI (2015) in terms of Adaptive Capacity Index (ACI) and specified ACI locations, as illustrated in Figure 15. All of Thailand and the areas along Vietnam's coastline have significantly higher ACI values, while these appear to be quite low in Lao PDR, Cambodia, and the northwestern region of Vietnam.

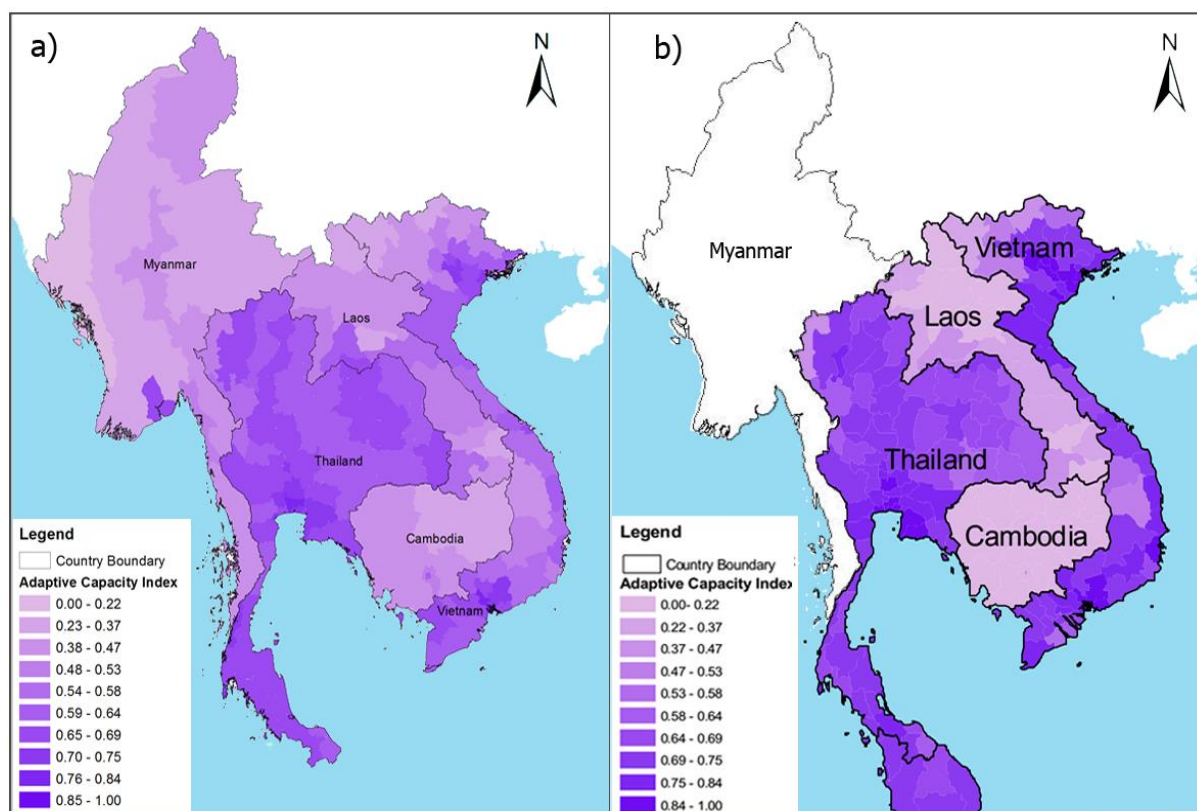


Figure 15 Spatial comparison of the Mekong Adaptive Capacity Indices between the results of (a) WREI (2015) and (b) Yusuf and Francisco (2009)

Climate change vulnerability

Figure 16 compares the assessment of vulnerability to climate change based on the findings from Yusuf and Francisco (2009) and WREI (2015). There are slight differences between the two – in Yusuf and Francisco (2009), the vulnerability indices range from 0.00 to 0.66, whereas they vary between 0.20 to 0.68 in WREI's assessment (2015). However, there is consistency when it comes to specified areas of vulnerability, with less vulnerable areas located in Thailand and more vulnerable ones in Cambodia, for example.

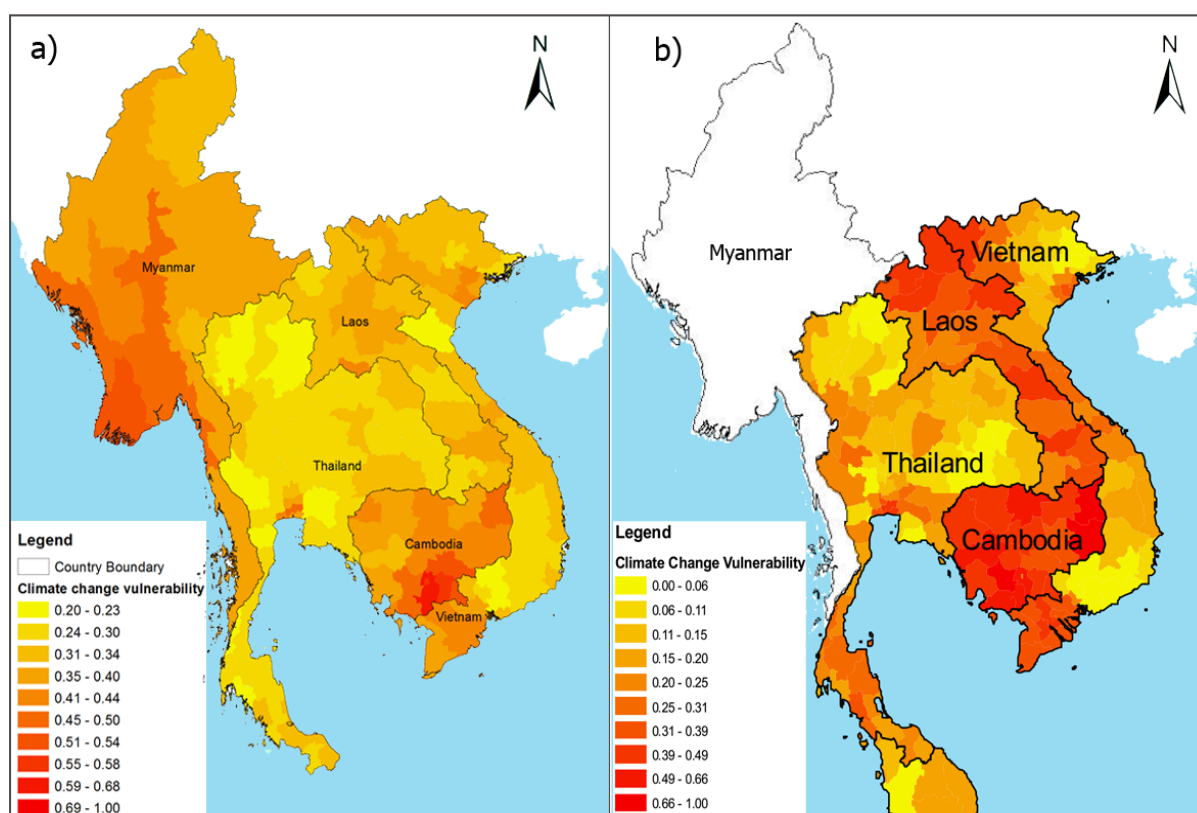


Figure 16 Spatial mapping of vulnerability to climate change in the Mekong countries based on the results of (a) WREI (2015) and (b) Yusuf and Francisco (2009)

Vulnerable areas to climate change impacts

Yusuf and Francisco (2009) found that the area most vulnerable to climate change from 1980 to 2000 was the western region of Cambodia. This study found that the Cambodian Mekong lowland region and the western coastline of Myanmar were the most vulnerable areas for the period of 1980 to 2014 (see Figure 17 for more details). High population density and a lack of protected areas make the Cambodia's Mekong lowland region particularly prone to natural disasters, such as floods, droughts as well as rising sea levels. Myanmar's western region, particularly Ayeyarwady Division and Rakhine State, were also categorized as among the areas most vulnerable to the impacts of climate change. Surprisingly, the eastern region of Cambodia was classified as only a moderately vulnerable area despite its low ACI values scores of between 0.29 and 0.32. This is due to the fact that the eastern region of Cambodia comprises mountainous areas that have a low population

density (5 to 15 persons per km²), with a higher number of protected areas (Figure 9).

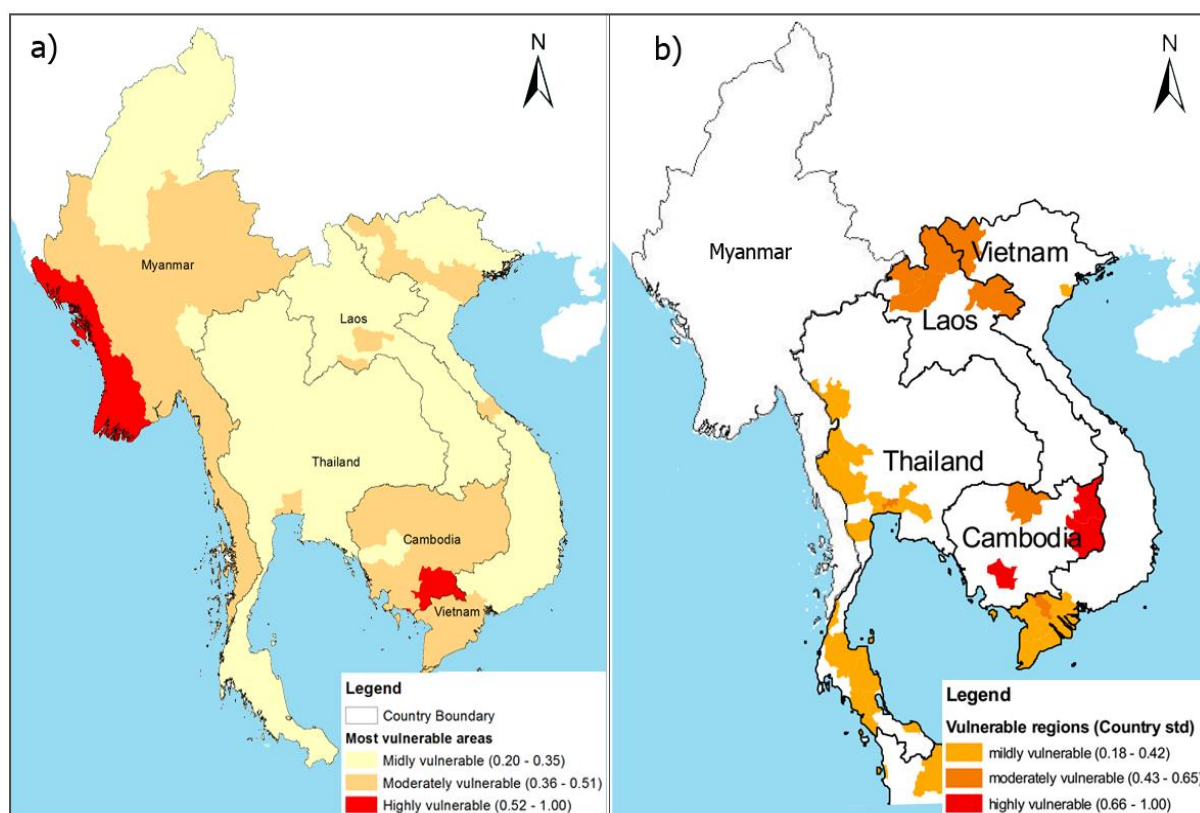


Figure 17 Spatial mapping of vulnerable areas to climate change in the Mekong countries based on the results of (a) WREI (2015) and (b) Yusuf and Francisco (2009)

4. Conclusion and recommendations

The IPCC's theoretical framework (2001) for assessing climate change vulnerability was adopted to identify vulnerable areas in the Mekong countries. In particular, vulnerability hotspots were identified for each sub-national administrative area in five Mekong countries – 24 provinces in Cambodia, 18 provinces in Lao PDR, 77 provinces in Thailand, 63 provinces in Vietnam, and 7 divisions and 7 states in Myanmar.

The effects of climate change are particularly severe in the Mekong region, where there is a strong risk of natural disasters, including:

- *Tropical cyclones* along the coastline of Vietnam and the western coastline region of Myanmar;
- *Floods* in the Cambodian Mekong lowland region, Ayeyarwady River Basin of Myanmar, and the Mekong River Delta and Red River Delta of Vietnam;
- *Droughts* in the central region of Myanmar and the northeastern region of Thailand;
- *Landslides* in the northern region of Thailand, northern and central highland regions of Vietnam, and the western range and eastern highlands of Myanmar;
- *Rising sea levels* in the Mekong River Delta and Red River Delta of Vietnam, and in Bangkok, Thailand.

To assess the vulnerability of the Mekong countries to climate change, the Human Development Index (HDI) and Adaptive Capacity Index (ACI) of each country was determined and their vulnerable areas were mapped. This is of the utmost importance in terms of future planning to find solutions and to promote resilience. ACI results indicated that Thailand is among the countries with the highest adaptive capacity when it comes to climate change, whereas Myanmar appears to have the least adaptive capacity. Adaptive capacity plays an important role in mitigating climate change vulnerability in combination with HDI, both of which important factors in determining a country's social and economic well-being.

The study also highlighted the most vulnerable provinces in the Cambodian Mekong lowland region such as Kandal, Takeo, Prey Veng, and Svay Rieng, as well as Ayeyarwady Division and Rakhine State on the western coast of Myanmar.

One of the key findings of this study is that scientific information on the impacts of and vulnerability to climate change as well as the adaptive capacity of the five Mekong countries will assist decision-makers to more accurately address the gaps in and future threats to climate change resilience. This will also lead to the informed formulation of strategies, including the introduction of effective mitigation and adaptation actions at the regional level. These recommendations are drawn primarily from the key findings of this study and are aimed at enabling reliable, long-term planning.

- In this study, vulnerability assessments were carried out at the provincial level. It is recommended that future studies focus on the district or city level.
- Additional resources could improve the findings of the vulnerability assessment, particularly sensitivity indicators such as morbidity and mortality rates, food security, etc., as well as adaptive capacity indicators such as policy, employment, energy, tourism, research and development, etc.
- It is important to emphasize that the success of a climate change vulnerability assessment depends largely on the range and quality and availability of data, both of which were lacking in Cambodia and Myanmar, for example.
- The quantification of spatial errors in climate data is essential since this can be used to assess the robustness of key results in climate change vulnerability assessments for different geographic areas.
- It is crucial to carefully evaluate data sets as there are several data layers used in vulnerability mapping with entirely different scales and resolutions.
- A participatory process that involves all relevant stakeholders in most of the steps is important.
- Primary consideration should also be given to better integration of climate change information that responds to the needs of decision-makers and stakeholders in national planning processes. Development strategies and agricultural policies can be anticipated and planned by changing sector investments, a wide range of high-yield and climate-resilient crops, and management practices.
- The need for learning among stakeholders in climate change adaptation should also be emphasized through facilitation, training, and incentives for collaboration among researchers and participation of stakeholders.

References

- Adger, W. N. (2006). Vulnerability. *Global Environmental Change*, 16(3), 268-281. doi: <http://dx.doi.org/10.1016/j.gloenvcha.2006.02.006>
- ADRC. (2015a). Asian Disaster Reduction Center. *Disaster Information Archive*. August 2015, from http://www.adrc.asia/latest_disaster.php
- ADRC. (2015b). Asian Disaster Reduction Center. *Cambodia Country Report*. Retrieved September 13, 2015, from <http://www.adrc.asia/countryreport/KHM/KHMeng02/Cambodia3.htm>
- Agrawal. (2002). Common resources and institutional sustainability. E. Ostrom, T. Dietz, N. Dolsak, P. C. Stern, S. Stonich and E. U (Ed.), *Weber: National Academy Press*.
- CReSIS. (2015). The Center for Remote Sensing and Ice Sheets. Sea Level Rise Maps Retrieved August 2015, from www.cresis.ku.edu/content/research/maps
- EM-DAT. (2015). The International Disaster Database. Available from CRED/OFDA Disaster Profile Retrieved August, 2015, from <http://www.emdat.be/database>
- FAO. (2003). The role of local institutions in reducing vulnerability to recurrent natural disasters and in sustainable livelihoods development *CASE STUDY: Vietnam*. PO Box 4 Klong Luang, Pathumthani 12120, Thailand.
- Francisco, H. A. (2008). Adaptation to Climate Change: Needs and Opportunities in Southeast Asia. *ASEAN Economic Bulletin*, 25, 7-19. doi: 10.1355/ac25-1b
- Harley, M., Horrocks, L., Hodgson, N., & Minnen, J. V. (2008). Climate change vulnerability and adaptation indicators. *European Topic Centre on Air and Climate Change*.
- IPCC. (2001). Climate Change 2001: Impacts, Adaptation and Vulnerability. In O. F. C. James J. McCarthy, Neil A. Leary, David J. Dokken, Kasey S. White (Ed.), *Working Group II of the Intergovernmental Panel on Climate Change (IPCC)*. The Pitt Building, Trumpington Street, Cambridge, United Kingdom.
- IPCC. (2007). Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson ed.): Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
- Myanmar, U. (2009). Hazard Profile of Myanmar: Department for International Development (DFID), United Kingdom.
- Schweikert, A., Chinowsky, P., Espinet, X., & Tarbert, M. (2014). Climate Change and Infrastructure Impacts: Comparing the Impact on Roads in ten Countries through 2100. *Procedia Engineering*, 78, 306-316. doi: <http://dx.doi.org/10.1016/j.proeng.2014.07.072>
- UN. (2014). Statistical yearbook for Asia and the Pacific. United Nations Publications, PO Box 960, Herndon, Virginia 20172, United States of America.
- UNDP. (2006). International trade and human development *Lao PDR*. Ministry of Planning and Investment Department of Statistics, P.O. Box 60, Vientiane Lao P.D.R: United Nations Development Programme. Lane Xang Avenue, P.O. Box 345, Vientiane, Lao PDR.
- UNDP. (2011a). Building resilience: the future for rural livelihoods in the face of climate change. *Cambodia Human Development Report: The Ministry of Environment of Cambodia and UNDP Cambodia*.
- UNDP. (2011b). Social Services for human development. *Vietnam Human Development Report* (Juliette Elfik ed.). United Nations Development Programme. 25-29 Phan Boi Chau, Hanoi, Viet Nam.

- UNDP. (2014). Advancing human development through the Asean Community. *Thailand Human Development Report 22014*. United Nations Development Programme. 12th Floor, United Nations Building Rajdamnern Nok Avenue, Bangkok, Thailand.
- UNEP. (2013). The United Nations of Environment of Programme. Global Risk Data Platform Retrieved August 2015, from <http://preview.grid.unep.ch/index.php>
- UNESCO. (2014). Glossary. School life expectancy, from <http://www.uis.unesco.org/Pages/Glossary.aspx>
- UNISDR. (2015). The United Nations International Strategy for Disaster Reduction *Disaster Data and Statistics*. August 2015, from <http://www.preventionweb.net/english/professional/statistics/>
- WDPA. (2014). The World Database on Protected Area. Protected Areas, from <http://www.protectedplanet.net/>
- WorldBank. (2011). Vulnerability, Risk Reduction, and adaptation to climate change of Cambodia *Climate risk and adaptation country profile*.
- WorldBank. (2015a). Climate Change Knowledge Portal Retrieved September 15, 2015, from <http://sdwebx.worldbank.org/climateportal/>
- WorldBank. (2015b). The World Bank World Bank indicators database, from <http://data.worldbank.org/>
- Yusuf, A. A., & Francisco, H. A. (2009). Climate Change Vulnerability Mapping for Southeast Asia. *Economy and Environment Program for Southeast Asia (EEPSEA)*.
- Zöckler, C., Delany, S., & Barber, J. (2013). Sustainable Coastal Zone Management in Myanmar.

Appendix

Appendix 1

List of the vulnerable areas in the Mekong countries



UNESCO Bangkok
Asia and Pacific Regional Bureau for Education

Table A1 List of the vulnerable areas in the Mekong countries

Areas	VUL	ADA	MUL	SEN	POD	POP	POV	H_I	E_I	I_D	HDI	RANK
VIETNAM												
Can Tho	0.40	0.69	0.36	0.54	868	1222.4	11.7	0.84	0.79	0.62	0.75	38
Dong Thap	0.41	0.64	0.44	0.42	497	1680.3	15.6	0.80	0.78	0.50	0.69	32
Hau Giang	0.40	0.62	0.42	0.42	483	773.8	19.7	0.82	0.80	0.48	0.70	35
Kien Giang	0.38	0.65	0.49	0.29	274	1738.8	24.0	0.80	0.80	0.58	0.72	54
Long An	0.39	0.67	0.48	0.38	327	1469.9	11.0	0.83	0.82	0.55	0.73	43
Soc Trang	0.43	0.61	0.52	0.40	395	1308.3	27.3	0.79	0.74	0.52	0.68	15
Ha Tinh	0.30	0.60	0.32	0.18	207	1242.7	21.6	0.78	0.92	0.46	0.72	106
Nghe An	0.20	0.59	0.13	0.07	181	2978.7	26.7	0.78	0.85	0.47	0.70	193
Quang Binh	0.32	0.55	0.24	0.27	107	863.4	23.2	0.77	0.87	0.47	0.70	88
Quang Tri	0.38	0.55	0.36	0.33	129	612.5	29.6	0.68	0.88	0.50	0.69	50
Thanh Hoa	0.31	0.61	0.22	0.32	312	3476.6	26.5	0.79	0.86	0.46	0.70	99
Thua Thien - Hue	0.34	0.60	0.34	0.28	223	1123.8	19.4	0.75	0.84	0.49	0.69	77
Bac Giang	0.31	0.60	0.12	0.40	414	1593.2	23.8	0.79	0.85	0.43	0.69	101
Bac Kan	0.33	0.44	0.13	0.29	62	303.1	46.0	0.77	0.83	0.40	0.67	85
Cao Bang	0.32	0.42	0.09	0.29	77	517.9	53.1	0.72	0.82	0.43	0.66	91
Ha Giang	0.31	0.37	0.06	0.26	97	771.2	71.5	0.68	0.68	0.35	0.57	97
Lang Son	0.32	0.48	0.12	0.31	90	751.2	45.7	0.85	0.49	0.70	0.70	96
Lao Cai	0.32	0.41	0.09	0.30	103	656.9	56.8	0.69	0.74	0.50	0.64	87
Phu Tho	0.34	0.58	0.20	0.39	382	1351.0	23.6	0.78	0.84	0.45	0.69	79
Quang Ninh	0.29	0.63	0.18	0.32	194	1185.2	12.1	0.79	0.85	0.62	0.76	119
Thai Nguyen	0.28	0.59	0.12	0.31	327	1156.0	22.0	0.80	0.83	0.49	0.71	130
Tuyen Quang	0.33	0.49	0.18	0.30	127	746.7	40.0	0.77	0.83	0.45	0.68	81
Yen Bai	0.34	0.47	0.18	0.31	112	771.6	45.3	0.72	0.75	0.42	0.63	76
An Giang	0.40	0.66	0.40	0.46	609	2155.3	18.2	0.79	0.78	0.56	0.71	37
Bac Lieu	0.39	0.61	0.40	0.39	355	876.8	23.3	0.81	0.81	0.54	0.72	44
Ben Tre	0.41	0.62	0.43	0.43	535	1262.0	10.0	0.81	0.86	0.51	0.73	28
Ca Mau	0.38	0.59	0.46	0.28	230	1219.9	26.4	0.80	0.83	0.54	0.73	47
Tien Giang	0.41	0.66	0.39	0.48	679	1703.4	9.5	0.82	0.81	0.53	0.72	34
Tra Vinh	0.41	0.61	0.43	0.41	439	1027.5	22.3	0.79	0.76	0.46	0.67	30
Vinh Long	0.41	0.60	0.36	0.48	684	1040.5	11.8	0.82	0.84	0.53	0.73	26
Bac Ninh	0.41	0.68	0.24	0.67	1354	1114.0	10.2	0.81	0.86	0.57	0.75	29
Ha Nam	0.40	0.65	0.30	0.55	923	794.3	16.6	0.80	0.86	0.47	0.71	41
Ha Noi	0.37	0.74	0.24	0.60	2087	6936.9	4.9	0.83	0.85	0.63	0.77	58
Hai Duong	0.42	0.67	0.33	0.59	1055	1747.5	14.8	0.82	0.86	0.50	0.72	23
Hai Phong	0.35	0.73	0.31	0.48	1260	1925.2	7.9	0.82	0.83	0.58	0.74	63
Hung Yen	0.43	0.66	0.30	0.64	1244	1151.6	12.8	0.81	0.84	0.50	0.72	18
Nam Dinh	0.42	0.68	0.39	0.54	1113	1839.9	14.0	0.81	0.85	0.46	0.71	24
Ninh Binh	0.41	0.64	0.42	0.46	673	927.0	15.3	0.80	0.87	0.49	0.72	27
Thai Binh	0.39	0.67	0.42	0.43	1139	1788.4	19.0	0.82	0.88	0.46	0.72	45
Vinh Phuc	0.28	0.66	0.10	0.40	831	1029.4	12.0	0.82	0.84	0.57	0.74	135
Ba Ria-Vung Tau	0.34	0.69	0.30	0.42	529	1052.8	10.0	0.84	0.85	0.73	0.81	70
Binh Duong	0.27	0.67	0.00	0.47	669	1802.5	7.8	0.84	0.78	0.56	0.72	154
Binh Phuoc	0.23	0.57	0.03	0.24	134	921.8	17.2	0.78	0.83	0.50	0.70	179
Binh Thuan	0.27	0.57	0.11	0.29	154	1201.2	21.4	0.80	0.84	0.50	0.71	140
Dong Nai	0.23	0.70	0.08	0.29	469	2768.7	11.7	0.84	0.83	0.57	0.74	183

Table A1 List of the vulnerable areas in the Mekong countries (cont'd)

Areas	VUL	ADA	MUL	SEN	POD	POP	POV	H_I	E_I	I_D	HDI	RANK
Ho Chi Minh City	0.38	0.77	0.25	0.66	3731	7818.2	2.9	0.85	0.83	0.65	0.77	49
Ninh Thuan	0.30	0.51	0.11	0.30	175	587.4	34.5	0.76	0.79	0.42	0.66	109
Tay Ninh	0.33	0.62	0.26	0.34	272	1095.6	11.8	0.81	0.80	0.56	0.72	82
Binh Dinh	0.31	0.61	0.19	0.34	250	1510.4	16.7	0.78	0.88	0.50	0.72	103
Da Nang	0.31	0.69	0.21	0.41	772	992.8	2.4	0.83	0.85	0.60	0.76	100
Khanh Hoa	0.29	0.63	0.17	0.34	229	1192.5	15.5	0.79	0.85	0.56	0.74	115
Phu Yen	0.31	0.56	0.18	0.31	175	883.2	22.1	0.77	0.84	0.48	0.69	98
Quang Nam	0.30	0.56	0.19	0.28	140	1461.0	23.5	0.77	0.86	0.51	0.71	105
Quang Ngai	0.33	0.55	0.18	0.35	240	1236.3	23.7	0.77	0.83	0.47	0.69	84
Dien Bien	0.34	0.34	0.15	0.22	55	527.3	71.1	0.67	0.70	0.43	0.60	74
Hoa Binh	0.35	0.50	0.24	0.31	175	808.2	40.0	0.77	0.83	0.44	0.68	67
Lai Chau	0.38	0.24	0.13	0.24	45	404.5	76.4	0.64	0.61	0.37	0.54	53
Son La	0.35	0.42	0.18	0.28	81	1149.3	63.6	0.73	0.75	0.44	0.64	66
Dak Lak	0.29	0.52	0.12	0.28	139	827.8	30.3	0.76	0.84	0.49	0.69	120
Dac Nong	0.26	0.49	0.04	0.22	85	553.2	32.5	0.73	0.82	0.50	0.68	162
Gia Lai	0.29	0.45	0.04	0.28	88	1359.9	43.3	0.74	0.80	0.46	0.67	121
Kon Tum	0.30	0.43	0.07	0.27	49	473.3	47.6	0.68	0.78	0.46	0.64	107
Lam Dong	0.24	0.56	0.07	0.22	128	1246.2	22.0	0.80	0.85	0.52	0.72	173
THAILAND												
Chiang Mai	0.21	0.65	0.10	0.19	86	1725.6	7.9	0.79	0.83	0.73	0.78	190
Chiang Rai	0.24	0.63	0.11	0.24	100	1162.2	17.8	0.77	0.76	0.65	0.72	176
Phetchaburi	0.20	0.67	0.12	0.16	76	475.4	8.4	0.83	0.79	0.74	0.79	195
Phetchabun	0.26	0.62	0.13	0.27	73	928.8	23.3	0.78	0.72	0.59	0.70	157
Loei	0.24	0.63	0.09	0.26	47	542.5	11.0	0.75	0.72	0.70	0.72	177
Phrae	0.21	0.65	0.14	0.12	65	426.4	13.1	0.71	0.81	0.68	0.73	192
Mae Hong Son	0.25	0.48	0.10	0.12	16	204.2	60.3	0.77	0.69	0.39	0.62	169
Krabi	0.22	0.69	0.08	0.27	78	368.1	5.3	0.85	0.72	0.82	0.80	188
Bangkok	0.49	0.82	0.36	0.93	5441	8515.2	7.8	0.86	0.95	0.91	0.90	10
Kanchanaburi	0.19	0.65	0.03	0.19	41	802.1	32.6	0.82	0.71	0.66	0.73	197
Kalasin	0.27	0.68	0.17	0.32	134	930.6	9.4	0.81	0.73	0.61	0.71	145
Kamphaeng Phet	0.27	0.67	0.21	0.26	91	786.8	14.0	0.74	0.69	0.72	0.72	153
Khon Kaen	0.28	0.65	0.17	0.31	160	1741.8	14.0	0.82	0.78	0.69	0.76	134
Chanthaburi	0.24	0.65	0.13	0.25	81	510.7	12.1	0.83	0.75	0.79	0.79	174
Chachoengsao	0.22	0.70	0.09	0.27	140	751.3	7.9	0.80	0.79	0.85	0.81	185
Chon Buri	0.26	0.70	0.08	0.39	369	1609.9	2.4	0.88	0.85	0.81	0.85	161
Chai Nat	0.28	0.68	0.19	0.33	126	310.2	10.0	0.77	0.74	0.73	0.75	131
Chaiyaphum	0.25	0.61	0.13	0.24	75	960.2	32.6	0.74	0.70	0.68	0.70	167
Chumphon	0.26	0.68	0.20	0.25	80	478.2	3.0	0.83	0.77	0.84	0.81	160
Trang	0.29	0.66	0.25	0.28	125	612.7	8.3	0.80	0.79	0.84	0.81	116
Trat	0.26	0.67	0.16	0.28	92	258.9	20.0	0.86	0.75	0.79	0.80	159
Tak	0.28	0.55	0.16	0.24	31	515.8	43.5	0.77	0.68	0.54	0.66	128
Nakhon Nayok	0.22	0.65	0.09	0.24	122	259.9	13.1	0.81	0.90	0.72	0.81	184
Nakhon Pathom	0.29	0.73	0.17	0.42	462	1001.1	6.7	0.84	0.82	0.79	0.82	124
Nakhon Phanom	0.33	0.63	0.30	0.31	104	575.8	24.2	0.76	0.73	0.58	0.69	86
Nakhon Ratchasima	0.26	0.64	0.14	0.29	122	2507.8	14.6	0.82	0.74	0.70	0.76	156
Nakhon Si Thammarat	0.30	0.69	0.29	0.29	150	1489.1	11.2	0.77	0.76	0.72	0.75	110
Nakhon Sawan	0.28	0.66	0.18	0.31	103	985.6	13.3	0.82	0.74	0.73	0.76	136

Table A1 List of the vulnerable areas in the Mekong countries (cont'd)

Areas	VUL	ADA	MUL	SEN	POD	POP	POV	H_I	E_I	I_D	HDI	RANK
Nonthaburi	0.38	0.77	0.33	0.57	2290	1424.4	1.2	0.86	0.85	0.88	0.86	51
Narathiwat	0.29	0.63	0.26	0.25	152	679.6	24.7	0.86	0.63	0.68	0.72	118
Nan	0.21	0.62	0.12	0.14	39	447.8	19.3	0.76	0.79	0.66	0.74	191
Buengkan	0.29	0.60	0.16	0.30	83	356.3	10.0	0.82	0.53	0.68	0.68	123
Buri Ram	0.28	0.60	0.14	0.30	122	1263.0	33.7	0.75	0.73	0.62	0.70	132
Pathum Thani	0.38	0.75	0.34	0.55	917	1399.3	3.6	0.87	0.77	0.80	0.81	48
Prachuap Khiri Khan	0.24	0.64	0.15	0.22	73	466.5	13.0	0.82	0.77	0.67	0.75	172
Prachin Buri	0.22	0.66	0.09	0.23	121	574.8	14.8	0.82	0.79	0.73	0.78	187
Pattani	0.32	0.62	0.19	0.38	319	618.0	33.5	0.83	0.69	0.60	0.71	89
Ayutthaya	0.30	0.74	0.24	0.39	340	870.2	6.9	0.83	0.79	0.76	0.80	112
Phayao	0.20	0.65	0.09	0.18	66	415.5	11.1	0.71	0.77	0.70	0.72	194
Phangnga	0.23	0.67	0.14	0.23	63	263.6	4.6	0.83	0.76	0.80	0.80	178
Phatthalung	0.27	0.68	0.23	0.26	144	494.7	8.4	0.78	0.77	0.76	0.77	148
Phichit	0.28	0.69	0.19	0.33	120	544.6	6.8	0.79	0.71	0.79	0.77	137
Phitsanulok	0.23	0.63	0.10	0.22	84	905.6	13.6	0.78	0.79	0.67	0.75	182
Phuket	0.32	0.72	0.13	0.54	978	531.1	5.8	0.82	0.82	0.84	0.83	94
Maha Sarakham	0.27	0.67	0.14	0.34	157	830.4	8.0	0.79	0.77	0.74	0.77	150
Mukdahan	0.26	0.60	0.17	0.22	81	352.1	32.3	0.79	0.73	0.69	0.74	158
Yasothon	0.27	0.64	0.14	0.32	89	281.0	23.8	0.76	0.73	0.68	0.72	143
Yala	0.25	0.65	0.12	0.29	97	439.6	13.4	0.85	0.69	0.75	0.77	165
Roi et	0.27	0.67	0.14	0.33	130	1079.2	12.9	0.75	0.74	0.77	0.75	155
Ranong	0.20	0.70	0.12	0.18	76	251.8	9.4	0.84	0.92	0.80	0.85	196
Rayong	0.23	0.68	0.03	0.36	241	855.8	3.6	0.84	0.75	0.76	0.78	180
Ratchaburi	0.25	0.60	0.05	0.28	154	800.7	30.1	0.83	0.78	0.62	0.74	171
Lop Buri	0.24	0.69	0.09	0.33	125	773.5	22.1	0.83	0.80	0.65	0.76	175
Lampang	0.23	0.63	0.13	0.19	59	741.8	12.4	0.75	0.82	0.67	0.75	181
Lamphun	0.22	0.66	0.10	0.22	91	409.5	9.6	0.72	0.80	0.72	0.75	186
Si Sa Ket	0.27	0.61	0.13	0.30	118	1047.3	35.9	0.72	0.74	0.60	0.68	142
Sakon Nakhon	0.28	0.61	0.17	0.28	85	818.9	28.6	0.79	0.73	0.64	0.72	133
Songkhla	0.29	0.66	0.22	0.33	204	1511.4	3.2	0.85	0.77	0.77	0.80	114
Satun	0.25	0.67	0.18	0.26	112	276.8	11.5	0.80	0.72	0.75	0.76	164
Samut Prakan	0.37	0.75	0.33	0.52	1934	1941.3	1.9	0.82	0.76	0.83	0.80	57
Samut Songkhram	0.29	0.71	0.16	0.42	450	187.7	6.8	0.82	0.79	0.65	0.75	122
Samut Sakhon	0.42	0.68	0.36	0.59	1057	921.4	3.4	0.90	0.71	0.80	0.80	19
Sa Kaeo	0.25	0.61	0.08	0.27	81	585.1	27.4	0.76	0.69	0.60	0.68	170
Saraburi	0.28	0.67	0.18	0.34	201	717.5	8.3	0.80	0.77	0.79	0.79	127
Sing buri	0.27	0.72	0.18	0.36	247	202.7	9.5	0.81	0.80	0.78	0.80	139
Sukhothai	0.25	0.65	0.14	0.28	95	624.5	13.4	0.74	0.74	0.72	0.73	163
Suphan Buri	0.27	0.67	0.17	0.32	159	854.0	26.8	0.85	0.74	0.69	0.76	141
Surat Thani	0.27	0.66	0.24	0.23	80	1029.2	4.1	0.84	0.74	0.85	0.81	149
Surin	0.28	0.63	0.16	0.32	138	1117.6	26.0	0.72	0.73	0.69	0.71	129
Nong Khai	0.27	0.69	0.17	0.33	150	453.5	14.2	0.79	0.75	0.70	0.74	152
Nong Bua Lam Phu	0.27	0.65	0.16	0.30	124	479.8	14.8	0.77	0.68	0.64	0.69	146
Ang Thong	0.29	0.68	0.17	0.37	266	257.1	14.4	0.79	0.77	0.74	0.77	125
Amnat Charoen	0.27	0.64	0.14	0.32	89	281.0	23.8	0.76	0.73	0.68	0.72	143
Udon Thani	0.27	0.66	0.16	0.31	109	1274.2	9.3	0.84	0.75	0.71	0.76	147
Uttaradit	0.21	0.64	0.11	0.18	56	436.9	18.3	0.76	0.76	0.69	0.74	189

Table A1 List of the vulnerable areas in the Mekong countries (cont'd)

Areas	VUL	ADA	MUL	SEN	POD	POP	POV	H_I	E_I	I_D	HDI	RANK
Uthai Thani	0.25	0.63	0.20	0.18	44	294.9	24.1	0.80	0.73	0.66	0.73	168
Ubon Ratchathani	0.25	0.66	0.12	0.29	110	1730.3	7.4	0.81	0.72	0.75	0.76	166
MYANMAR												
Ayeyarwaddy	0.52	0.36	0.34	0.59	172	6100.0	29.0	0.41	0.72	0.51	0.53	5
Bago	0.47	0.37	0.29	0.48	123	4900.0	33.0	0.60	0.65	0.48	0.57	14
Chin	0.37	0.18	0.01	0.29	13	465.0	73.0	0.09	0.60	0.22	0.23	55
Kachin	0.28	0.38	0.01	0.23	19	1689.6	44.0	0.44	0.69	0.43	0.51	126
Kayah	0.30	0.47	0.04	0.33	25	286.7	34.0	0.68	0.72	0.43	0.60	111
Kayin	0.35	0.41	0.09	0.37	52	1572.0	12.0	0.31	0.65	0.63	0.50	65
Magway	0.41	0.33	0.11	0.43	87	3912.7	42.0	0.61	0.68	0.39	0.54	33
Mandalay	0.43	0.44	0.10	0.65	206	6145.0	39.0	0.73	0.72	0.43	0.61	16
Mon	0.43	0.49	0.18	0.61	182	1914.0	22.0	0.85	0.68	0.54	0.68	17
Rakhine	0.52	0.22	0.43	0.35	87	3188.9	44.0	0.14	0.15	0.41	0.21	6
Sagaing	0.34	0.37	0.06	0.34	62	5320.3	27.0	0.45	0.73	0.50	0.55	75
Shan	0.35	0.36	0.08	0.35	37	5815.4	51.0	0.78	0.38	0.34	0.46	62
Tanintharyi	0.35	0.39	0.16	0.29	32	1406.4	34.0	0.66	0.65	0.53	0.61	64
Yangon	0.48	0.66	0.28	0.82	750	7355.0	15.0	0.79	0.72	0.80	0.77	11
LAO PDR												
Luangnamtha	0.27	0.46	0.04	0.23	16	172.0	30.5	0.58	0.47	0.45	0.50	151
Luangprabang	0.34	0.44	0.13	0.34	25	463.5	27.2	0.62	0.53	0.44	0.53	72
Oudomxay	0.32	0.42	0.04	0.33	18	314.3	33.7	0.60	0.50	0.37	0.48	95
Phongsaly	0.32	0.36	0.04	0.27	10	179.8	46.0	0.64	0.42	0.37	0.46	93
Salavanh	0.34	0.43	0.17	0.27	32	384.4	36.3	0.58	0.44	0.36	0.45	78
Savannakhet	0.33	0.51	0.16	0.33	39	937.9	28.5	0.64	0.57	0.41	0.53	83
Vientiane	0.30	0.59	0.18	0.33	20	506.9	28.0	0.72	0.69	0.46	0.61	104
Vientiane Capital	0.40	0.66	0.18	0.68	185	797.1	15.2	0.76	0.79	0.54	0.69	36
Xayabouly	0.32	0.52	0.18	0.30	22	389.1	15.7	0.68	0.66	0.45	0.59	92
Xaysomboun	0.39	0.31	0.17	0.31	9	0.0	30.6	0.64	0.58	0.43	0.54	46
Xekong	0.34	0.36	0.16	0.23	12	103.3	51.8	0.54	0.58	0.41	0.50	71
Xiengkhouang	0.34	0.41	0.12	0.32	15	282.8	42.0	0.64	0.66	0.40	0.55	73
Attapeu	0.31	0.45	0.15	0.22	11	133.5	24.6	0.56	0.62	0.43	0.53	102
Bokeo	0.30	0.42	0.03	0.30	25	174.0	32.6	0.68	0.56	0.41	0.54	108
Bolikhamxay	0.29	0.54	0.17	0.25	16	281.2	21.5	0.68	0.70	0.44	0.60	117
Champasak	0.28	0.54	0.16	0.20	41	670.1	10.0	0.64	0.71	0.45	0.59	138
Huaphanh	0.32	0.40	0.13	0.23	18	333.8	50.5	0.64	0.54	0.40	0.52	90
Khammuane	0.30	0.48	0.16	0.20	22	390.7	31.4	0.58	0.61	0.45	0.54	113
CAMBODIA												
Banteay Meanchey	0.41	0.39	0.13	0.49	126	776.1	25.5	0.72	0.71	0.48	0.64	31
Battambang	0.36	0.44	0.09	0.41	100	1170.7	24.8	0.71	0.71	0.50	0.64	61
Kampong Cham	0.49	0.44	0.30	0.62	184	1744.6	20.4	0.66	0.70	0.51	0.62	9
Kampong Chhnang	0.41	0.40	0.21	0.43	96	527.9	27.7	0.67	0.74	0.47	0.63	25
Kampong Speu	0.42	0.46	0.29	0.44	112	783.3	27.7	0.74	0.76	0.49	0.66	20
Kampong Thom	0.42	0.37	0.29	0.34	49	677.3	29.1	0.69	0.66	0.46	0.60	21
Kampot	0.47	0.45	0.43	0.42	127	618.5	20.4	0.71	0.71	0.51	0.64	13
Kandal	0.67	0.48	0.50	0.99	393	1402.9	14.6	0.76	0.76	0.58	0.70	1
Koh Kong	0.35	0.41	0.24	0.21	13	141.1	20.3	0.63	0.66	0.48	0.59	69
Kep	0.51	0.37	0.24	0.66	282	42.8	16.5	0.44	0.69	0.49	0.54	8

Table A1 List of the vulnerable areas in the Mekong countries (cont'd)

Areas	VUL	ADA	MUL	SEN	POD	POP	POV	H_I	E_I	I_D	HDI	RANK
Kratie	0.40	0.35	0.24	0.32	30	363.8	32.6	0.64	0.68	0.45	0.59	40
Pailin	0.35	0.46	0.21	0.28	85	97.4	23.9	0.63	0.66	0.53	0.61	68
Preah Sihanouk	0.42	0.45	0.28	0.42	101	260.1	15.6	0.65	0.77	0.55	0.65	22
Mondul Kiri	0.40	0.32	0.26	0.25	5	75.6	32.9	0.52	0.53	0.43	0.50	42
Oddar Meanchey	0.37	0.38	0.18	0.32	36	235.9	34.3	0.68	0.62	0.43	0.58	56
Phnom Penh	0.57	0.64	0.36	1.00	2491	1704.1	0.1	0.78	0.79	0.74	0.77	3
Pursat	0.34	0.39	0.18	0.22	34	436.2	27.8	0.68	0.68	0.47	0.61	80
Preah Vihear	0.40	0.35	0.35	0.20	14	191.1	37.0	0.35	0.60	0.40	0.45	39
Prey Veng	0.55	0.46	0.47	0.65	201	981.2	21.9	0.66	0.74	0.50	0.63	4
Ratanak Kiri	0.48	0.30	0.53	0.21	15	172.9	36.2	0.38	0.42	0.39	0.40	12
Siem Reap	0.38	0.42	0.17	0.38	99	1048.3	28.8	0.73	0.67	0.47	0.63	52
Stung Treng	0.36	0.32	0.13	0.28	11	127.7	36.8	0.13	0.59	0.41	0.38	60
Svay Rieng	0.51	0.45	0.38	0.59	169	501.4	17.4	0.61	0.75	0.53	0.63	7
Takeo	0.59	0.41	0.45	0.72	247	881.2	19.9	0.67	0.73	0.51	0.64	2

Where:

VUL: Climate change vulnerability index

ADA: Adaptive capacity index

MUL: Multiple climate hazard index

SEN: Sensitivity index

POD: Population density in 2013 (persons/km²)

POP: Population in 2013 (thousand people)

POV: Poverty incidence (%)

H_I: Health index

E_I: Education index

I_D: Income index

HDI: Human Development Index

RANK: Rank of climate change vulnerability index





United Nations
Educational, Scientific and
Cultural Organization

UNESCO Bangkok

Asia and Pacific Regional Bureau for Education

Mom Luang Pin Malakul Centenary Building
920 Sukhumvit Road, Prakanong, Klongtoey
Bangkok 10110, Thailand

Email: bangkok@unesco.org

Website: www.unesco.org/bangkok

Tel: +66-2-3910577 Fax: +66-2-3910866