TRANSBOUNDARY DISASTER RISK ASSESSMENT AND SCENARIO PLANNING FOR TROPICAL CYCLONES AND DROUGHTS IN THE ASEAN REGION

Transbоundary Disaster Risk Assessment and Scenario Planning for Tropical Cyclones and Droughts in the ASEAN Region

The ASEAN Secretariat
Jakarta

The Association of Southeast Asian Nations (ASEAN) was established on 8 August 1967. The Member States are Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand and Viet Nam. The ASEAN Secretariat is based in Jakarta, Indonesia.

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Cover photo: Typhoon Rammasun (Glenda) passed through Laguna province in the Philippines with winds over 120 kph in the early morning of 16 July 2014.

Photo: Asian Development Bank.

FOREWORD

ASEAN is facing an increasingly complex disaster risk landscape, and climate change particularly poses serious threats as it increases the frequency and intensity of disasters. The ASEAN region has also been increasingly devastated by transboundary disasters such as droughts, floods, tsunamis and tropical cyclones.

Studies on transboundary disasters in the ASEAN region are crucial to offer common understandings and approaches that are needed to tackle regional and transboundary issues as well as to support capacity building and strength cooperation in disaster management.

As the Chair of the ASEAN Committee on Disaster Management, it is my honour to introduce the study on **Transboundary Disaster Risk Assessment and Scenario Planning for Tropical Cyclones and Droughts in the ASEAN Region**. The study provides an in-depth assessment on the impacts of transboundary disasters based on various transboundary disaster risk scenarios which focused on three ASEAN Member States namely Cambodia, the Philippines and Viet Nam, while considering tropical cyclones and droughts for the transboundary risk scenarios.

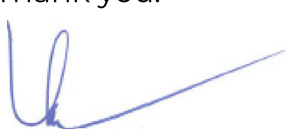
The study underlines the potential impacts of tropical cyclones and drought in the ASEAN region as well as highlights recommendations for the ASEAN Member States to enhance disaster risk management actions in line with the ASEAN Agreement on Disaster Management and Emergency Response (AADMER) Work Programme 2021-2025.

The study showcases the need for collaboration on transboundary disaster risk management in the ASEAN region. The overall coordination in the planning and development for the study of the ASEAN Secretariat is appreciated. The Asian Development Bank's support and collaboration in this study are critical to advance the learning of transboundary risk issues.

It is our hope and expectation that this study will provide more rigorous resources for professionals and policymakers to accelerate ASEAN's effort in building a resilient ASEAN Community in the years to come.

Together, we can build a more resilient ASEAN Community and better prepare to face the challenges of the future.

Thank you.



Mr. Pham Duc Luan
Director-General, Viet Nam Disaster and
Dike Management Authority,
Ministry of Agriculture and Rural Development, Viet Nam,
Chair of ASEAN Committee on Disaster Management

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ACRONYMS

AADMER	ASEAN Agreement on Disaster Management and Emergency Response
ACDM	ASEAN Committee on Disaster Management
ACE	AHA Centre Executive Programme
ADB	Asian Development Bank
ADPC	Asian Disaster Preparedness Center
AHA CENTRE	ASEAN Centre for the Coordination of Humanitarian Assistance
AMS	ASEAN Member States
ASEAN	Association of Southeast Asian Nations
BNPB	*Badan Nasional Penanggulangan Bencana* (National Disaster Management Organization)
GCM	Global Climate Model
CEEP	Central and Eastern Equatorial Pacific
CMIP	Coupled Model Intercomparison Project
CRF	Cambodia Rice Federation
DDPM	Department of Disaster Prevention and Mitigation
DMC	Disaster Management Center
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
ENSO	El Niño-Southern Oscillation
EOS	Earth Observatory of Singapore
ASEAN-ERAT	ASEAN Emergency Response and Assessment Team
ESA	European Space Agency
EWS	Early warning systems
FAO	Food and Agriculture Organization of the United Nations
GAR	Global Assessment Report
GCM	Global Climate Models
GDDP	Global Daily Downscaled Projections
GESI	Gender and social inclusion
HFA	The Hyogo Framework for Action
IPCC	Intergovernmental Panel on Climate Change

LGU	Local Government Unit
LULC	Land Use Land Cover
MAPDRR	The Myanmar Action Plan on Disaster Risk Reduction
MRC	Mekong River Commission
NDP	National Drought Plans
NEX	NASA's Earth Exchange
NDRRMC	National Disaster Risk Reduction and Management Council
PAGASA	Philippine Atmospheric, Geophysical and Astronomical Services Administration
PDNA	Post-Disaster Needs Assessment
PGI	Protection, Gender and Inclusion
PSA	Philippine Statistics Authority
PWD	Persons with Disabilities
SADDD	Sex, Age and Disability Disaggregated Data
SFDRR	Sendai Framework for Disaster Risk Reduction
SSP	Shared Socioeconomic Pathways
SST	Sea Surface Temperatures
SRTM	NASA's Shuttle Radar Topography Mission
TA	Technical Assistance
UNCCD	United Nations Convention to Combat Desertification
UNCT	United Nations Country Team
UNDRR	United Nations Office for Disaster Risk Reduction
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
UNFCCC	The United Nations Framework Convention on Climate Change
UNOCHA	United Nations Office for the Coordination of Humanitarian Affairs

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Photo: Country side near Hồ Chí Minh, North Viet Nam, by DaiLuo is licensed under CC BY 2.0

EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

The study on *Transboundary Disaster Risk Assessment and Scenario Planning for Tropical Cyclone and Droughts in the ASEAN Region* demonstrates the potential impacts of tropical cyclones and drought in the ASEAN region under various climate change scenarios and to make recommendations for the ASEAN Member States to enhance disaster risk management actions, in line with the ASEAN Agreement on Disaster Management and Emergency (AADMER) Work Programme 2021-2025.

The Intergovernmental Panel on Climate Change concluded in its Sixth Assessment Report[1] that compound heatwaves and droughts were projected to become more frequent, including concurrent events across multiple locations, while tropical cyclones were also projected to intensify in the future. The study has developed climate change projection scenarios for the ASEAN region and integrated them into transboundary disaster risk scenarios. The study focused on **three** ASEAN Member States - Cambodia, the Philippines and Viet Nam, while considering tropical cyclones and droughts for the transboundary risk scenarios.

The study found that **transboundary tropical cyclones in Southeast Asia could damage many more residential houses in the future**. As many as 182,000 residential houses in Cambodia, the Philippines, and Viet Nam could be damaged by tropical cyclones in 2050. That is a sixty-percent increase from the estimated 114,000 houses currently being damaged each year by tropical cyclones. **The increased risk comes particularly from increasing wind speeds from future transboundary tropical cyclones, although the impacts are uneven across the region**. While the Philippines is affected the most by tropical cyclones, Cambodia and Viet Nam are expected to experience the largest risk increase, when future climate scenarios are considered. The coastal provinces in the north and center of Viet Nam will experience especially large increases in expected annual losses. **The risk of tropical cyclones is projected**

1. Intergovernmental Panel on Climate Change - IPCC, 2023: Summary for Policymakers. In: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_SPM.pdf

THE STUDY, WHICH FOCUSED ON CAMBODIA, THE PHILIPPINES AND VIET NAM, CONSIDERED TROPICAL CYCLONES AND DROUGHTS FOR THE TRANSBOUNDARY RISK SCENARIOS. IT HAS DEVELOPED CLIMATE CHANGE PROJECTION SCENARIOS FOR THE ASEAN REGION AND INTEGRATED THEM INTO TRANSBOUNDARY DISASTER RISK SCENARIOS.

to increase across the region, affecting key sectors such as agriculture. The agriculture sector can also suffer from extreme winds. Particular crops such as corn and rice are prone to strong winds and flooding caused by tropical cyclones.

The study also found that **drought events are likely to occur more frequently and more severely in the ASEAN region due to the variability of rainfall influenced by climate change**. This is particularly true among the 3 focus countries (Cambodia, the Philippines, and Viet Nam), where the probability of drought is projected to increase by 60-80% in the future. However, this increasing trend is also prominent in other countries such as Indonesia, Lao PDR, Myanmar and Thailand. **Increased drought risk could impact crop production in Cambodia, the Philippines and Viet Nam**. Among the three focus countries, it appears that Cambodia is most likely to be hit hardest by future drought and in a worst-case scenario, will see a 46% increased probability of drought in the dry season by 2080. The northern and central parts of Cambodia may experience a higher number of drought events compared to other parts of the country. The study shows that croplands and rice plantation areas are likely to face severe and extreme drought in the future. Under a moderate climate change scenario, 89% of Cambodia's croplands could potentially face extreme drought, while in Viet Nam, 63% of the country's rice paddy field area is likely to be affected by severe drought. For the Philippines, most of the cropland areas are likely to endure extreme drought in the future. The results also show that drought will affect a large area spanning multiple countries in the ASEAN region, extending from Cambodia to southern Viet Nam and covering the Mekong Delta. As a result, drought is more likely to create a transboundary effect among these countries that share common water resources from the Mekong River. This increased risk of drought is likely due to the variability of rainfall which is influenced by climate change. **The vulnerabilities of people within**

the region have not been sufficiently accounted for in risk assessment and scenario planning. While it is well-known that the fatality and injury rates from disasters tend to be higher for vulnerable populations, their vulnerabilities are often not explicitly accounted for in the disaster risk assessment and scenario planning process. Particularly, Sex, Age and Disability Disaggregated (SADD) data has not be widely utilized in the analysis of risk exposure and vulnerability.

ABOUT 182,000

RESIDENTIAL HOUSES IN CAMBODIA, THE PHILIPPINES, AND VIET NAM COULD BE DAMAGED BY TROPICAL CYCLONES IN 2050.

BASED ON THESE FINDINGS, THE STUDY HAS MADE RECOMMENDATIONS, ALIGNING WITH THE AADMER WORK PROGRAMME 2021-2025, FOR THE ASEAN MEMBER STATES TO CONSIDER.

ON PREVENTION AND MITIGATION

CONSIDER THE IMPLICATION OF MORE INTENSE TROPICAL CYCLONES AND INCREASING WIND SPEEDS INTO EXISTING BUILDING REGULATIONS AND BUILDING CODES.

Cambodia, the Philippines, and Viet Nam should reconsider the wind zone maps in the building codes, improve the enforcement of building codes, and invest in strengthening buildings that are not in compliance with to the building codes.

CONSIDER INCREASING DROUGHT RISKS IN CROP INSURANCE PROGRAMMES, PARTICULARLY IN COMPENSATION SCHEMES TO PREVENT LOW-INCOME PEOPLE FROM FALLING INTO EXTREME POVERTY.

The ASEAN Member States should develop specific compensation schemes according to the increased risk, in alignment with the national crop insurance programme guideline of the ASEAN Climate Resilience Network.

DISAGGREGATE DATA ON THE VULNERABLE POPULATION, TAKING INTO CONSIDERATION DEMOGRAPHIC CATEGORIES WHEN CONDUCTING RISK ASSESSMENTS, WHICH CAN BE GATHERED BY PREPARING DETAILED DEMOGRAPHIC PROFILES OF THE COMMUNITIES RESIDING IN THE MOST HIGH-RISK AREAS.

The ASEAN Member States should integrate Sex, Age and Disability Disaggregated (SADD) data in the process for quantifying the impact of tropical cyclones and droughts and should prioritize developing community risk profiles in the most hazard-prone areas.

ON PREPAREDNESS, RESPONSE AND RECOVERY

CONSIDER TRANSBOUNDARY RISK SCENARIOS INTO EXISTING ASEAN RESPONSE PREPAREDNESS MECHANISMS.

ASEAN response procedures and plans such as the Standard Operating Procedure for Regional Standby Arrangements and Coordination of Joint Disaster Relief and Emergency Response Operations (SASOP), the ASEAN Joint Disaster Response Plan (AJDRP) and the ASEAN Regional Disaster Emergency Response Simulation Exercise (ARDEX) should consider using the transboundary drought and tropical cyclones from this study as case studies and scenarios for drills and simulation exercises.

CONSIDER THE TROPICAL CYCLONE AND DROUGHT HAZARD INTENSITY PARAMETERS SUGGESTED BY THIS STUDY AS A TRIGGER MECHANISM FOR PRE-DISASTER ANTICIPATORY ACTIONS.

The ASEAN Member States as well as their technical partners should consider the drought and tropical cyclone hazard intensity parameters from this study as anticipatory action triggers.

CONSIDER INTEGRATING TRANSBOUNDARY HAZARD SCENARIOS INTO RECOVERY STRATEGIES, INCLUDING POST-DISASTER NEEDS ASSESSMENTS AND RESOURCE ALLOCATIONS AND SHARING FOR RECOVERY ASSISTANCE.

The ASEAN Secretariat and the ACDM Working Group on Preparedness, Response, and Recovery (ACDM WG PRR) should introduce transboundary hazard scenarios, that can affect multiple ASEAN Member States at the same time or successively, into regional strategies for post-disaster needs assessment (PDNA) and recovery assistance planning.

THIS REPORT IS DIVIDED INTO TWO PARTS.

PART A:

THE POLICY BRIEF IS A SUMMARY OF THE STUDY INTENDED FOR POLICY MAKERS.

PART B:

THE TECHNICAL REPORT PROVIDES ALL THE TECHNICAL DETAILS OF THE ANALYSES AND RESULTS OF THE STUDY.

Photo: The Umbrella Girl by Shubert Ciencia is licensed under CC BY 2.0

PART A: POLICY BRIEF

1. INTRODUCTION

The Association of Southeast Asian Nations (ASEAN), home to over 680 million people, is one of the most disaster-prone regions in the world. Between 2004 and 2014, the ASEAN region suffered more than 50 percent of the total global disaster fatalities, or 354,000 of the 700,000 deaths in disasters worldwide. The total economic loss during this period was US$91 billion.[2] Across the region, over 152 million people (approximately one in four of the population) are living within areas experiencing floods and over 60% of the population is living within areas that experience droughts.[3] Climate change could exacerbate the impact of hydro-climatic hazards even further in the future.

50 PER CENT

OF GLOBAL DISASTER FATALITIES BETWEEN 2004 AND 2014 WERE FROM THE ASEAN REGION, WITH TOTAL ECONOMIC LOSS AMOUNTING TO

US$91 BILLION.

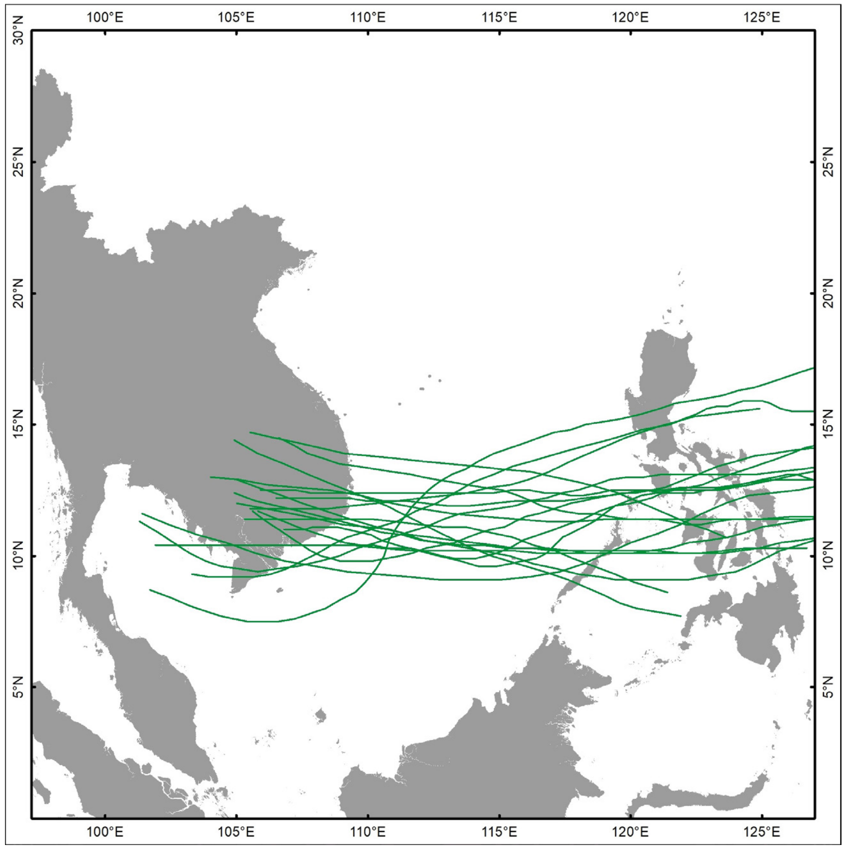
The northern parts of the ASEAN region are prone to tropical cyclones. Cambodia, Lao PDR, the Philippines, Thailand and Viet Nam face risk from the Western Pacific and Myanmar faces tropical cyclone risk from the Indian Ocean. The Philippines is a global tropical cyclone hotspot and has a long history of intense super storms. In Cambodia and Viet Nam, tropical cyclones are typically milder and usually only receive the 'tropical storm' classification. All of these tropical cyclones can cause extensive damage to homes and infrastructures due to strong winds, storm surges and corresponding coastal flooding, pluvial flooding and rainfall-triggered landslides.

Tropical cyclones (also known as typhoons) are formed and gain strength over warm sea waters, although they tend to slow down once they make landfall. Many of the storms that affect the Philippines are formed over the Pacific Ocean, while those that affect Cambodia and Viet Nam are often formed over the water body to the east of Viet Nam. However, typhoons that form in the Pacific Ocean can also regularly travel beyond the Philippines and may gain extra strength before making landfall in Viet Nam and affecting neighboring countries such as Cambodia. These transboundary tropical cyclones pose a significant threat to the region. The following figure illustrates

2. ASEAN Vision 2025 on Disaster Management, https://asean.org/wp-content/uploads/2021/01/fa-220416_DM2025_email.pdf

3. United Nations, Economic and Social Commission for Asia and the Pacific (ESCAP) (2020). The Disaster Riskscape across South-East Asia: Key Takeaways for Stakeholders. ST/ESCAP/2885.

Figure 1
Eighteen tropical cyclone tracks that can cause the destruction of more than 1,000 houses in three different ASEAN countries (Cambodia, the Philippines, and Viet Nam).



the paths of recent transboundary tropical cyclones in the ASEAN region.

All of the countries in the ASEAN region are under threat from droughts.[4] These droughts mainly occur due to regional and global phenomena such as El Niño and the Indian Ocean Dipole (IOD).[5] Much of the region lies within the tropical climatic zone, with temperatures above 25 degrees Celsius throughout the year. The region is strongly influenced by the Asian monsoons, which bring significant amounts of rainfall to parts of Southeast Asia. The severity of droughts also depends on the severity of such phenomena, the ocean–atmospheric processes, and climate change. However, drought severity at the local level may still vary due to land use/land cover practices.

There is evidence from observations gathered since 1950 of change in some climate extremes. Combining this with the knowledge from model projections, it is

4. Association of Southeast Asian Nations (ASEAN) and United Nations, Economic and Social Commission for Asia and the Pacific (ESCAP), 2021. Ready for the Dry Years, second edition.

5. The Australian Government's Bureau of Meteorology, The Indian Ocean Dipole (IOD), http://www.bom.gov.au/climate/enso/history/ln-2010-12/IOD-what.shtml

more likely than not that the frequency of the most intense tropical cyclones will increase substantially in some ocean basins. There is also medium confidence that since the 1950s some regions of the world have experienced trends toward more intense and longer droughts.[6] Accordingly, disaster scenario planning must consider the effects of climate change in shaping hazards and disaster risks foreseen to affect the ASEAN region in the future.

2. CONCEPTUAL BACKGROUND

An assessment of transboundary risk scenarios for tropical cyclones and droughts in the ASEAN region was carried out, focusing primarily on Cambodia, the Philippines, and Viet Nam. The main objectives of the study were to demonstrate the potential impacts of tropical cyclones and droughts in these countries under various climate change scenarios and to make recommendations for the ASEAN Member States to enhance the current outputs and works under the ASEAN Agreement on Disaster Management and Emergency (AADMER) Work Programme 2021-2025.[7] This study directly contributes to the implementation of Priorities 1 and 2 of the AADMER Work Programme. Priority Programme 1, on Risk Assessment and Monitoring, benefits directly from the transboundary risk assessment methodology used in this study. At the same time, Priority Programme 2, on Prevention and Mitigation, can utilize the resulting hazard, vulnerability, and risk information for disaster risk reduction and climate change adaptation planning, as well as planning for long-term resilient development.

This study also contributes to the implementation of one of the nine groups of actions under the ASEAN Regional Plan of Actions for Adaptation to Drought 2021-2025 (ARPA-AD) and specifically the group focused on a "risk, impact, and vulnerability assessment." These risk-based scenarios also fit closely with the ARPA-AD, in terms of Action 2: "early warning, preparedness, and

6. Intergovernmental Panel on Climate Change (IPCC), 2012. Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change, https://www.ipcc.ch/site/assets/uploads/2018/03/SREX_Full_Report-1.pdf

7. AADMER Work Programme 2021-2025, https://asean.org/wp-content/uploads/2021/08/AADMER-Work-Programme-2021-2025.pdf

planning", in particular the sub-action to develop and implement regional drought monitoring, forecasting and early warning systems with ground monitoring stations, and/or to enhance these systems at a national level. The research presented here also contributes to the implementation of the ARPA-AD and specifically objective a) "to guide national and regional strategic actions and a time-bound action plan for drought awareness, early warning and preparedness, planning and management, and emergency response in ASEAN."

THE FINDINGS OF THIS STUDY CONFIRM THE EXPECTATION THAT CLIMATE CHANGE WILL EXACERBATE DISASTER RISKS, AND WILL CONTINUE TO DO SO, INTENSIFYING BOTH DROUGHTS AND TROPICAL CYCLONES ACROSS THE ASEAN REGION, WITH TRANSBOUNDARY IMPACTS.

The future climate for ASEAN countries is not precisely known. Scientists have established several different plausible climate change scenarios in order to foresee the likely future climate and estimate its impacts. These scenarios are based on different possible levels of greenhouse emissions and are called Shared Socioeconomic Pathways (SSPs). This study followed the most updated approach of the IPCC's Sixth Assessment Report[8] and generated scientific data by running four climate models, resulting in the mapping of projected tropical cyclones and droughts in the ASEAN region for various time horizons, through to the 2080s. Descriptions of the climate change models are included in the **Part B - Technical Report** of this study.

The results from the four different climate models indicate that the frequency and intensity of tropical cyclones and droughts in Southeast Asia are expected to increase significantly in the future. The findings of this study confirm the expectation that climate change will exacerbate disaster risks, and will continue to do so, intensifying both droughts and tropical cyclones across the ASEAN region, with transboundary impacts. The scenarios considered in this report predict substantial impacts from tropical cyclones in all three countries on residential houses, infrastructure, increased poverty, and related damages and losses totaling billions of US dollars. Drought is also expected to cause heavy impacts on key economic sectors, such as agriculture and rice farming in particular, for the three countries.

8. IPCC Sixth Assessment Report (AR6), https://www.ipcc.ch/assessment-report/ar6/

3. KEY FINDINGS

3.1
TRANSBOUNDARY TROPICAL CYCLONES IN SOUTHEAST ASIA COULD DAMAGE MANY MORE RESIDENTIAL HOUSES IN THE FUTURE.

Results of the study show that tropical cyclones can unleash extensive damage due to strong winds, storm surge waves and corresponding coastal flooding, inland flooding due to excessive rain and overflowing rivers, and rainfall-triggered landslides. These have direct impacts on the buildings and houses located in the path of the storms. The study finds that each year, as many as 182,000 residential houses in Cambodia, the Philippines, and Viet Nam could be damaged by tropical cyclones by 2050. That is a sixty-percent increase from the estimated 114,000 houses currently being damaged each year by tropical cyclones.

24% OF HOUSES DESTROYED IN CAMBODIA, THE PHILIPPINES, AND VIET NAM BY PAST TROPICAL CYCLONES RESULTED FROM TRANSBOUNDARY EVENTS AND WILL POTENTIALLY EXPAND TO 31-37% DUE TO CLIMATE CHANGE.

The damage to houses will be increasingly caused by transboundary tropical cyclones. Under historical climate conditions, about 24% of the residential houses in Cambodia, the Philippines, and Viet Nam damaged by tropical cyclones were a result of transboundary events. The same figure potentially increases to 31-37% in the future, when climate change scenarios are considered.

All types of buildings can be vulnerable to extreme winds, but small differences in the design, construction quality and strength of materials can significantly influence the extent of damage sustained during a storm. As a result, lower-quality houses outside urban areas may be particularly susceptible to wind damage.

3.2
THE INCREASED RISK IS PARTICULARLY FROM INCREASING WIND SPEEDS FROM FUTURE TRANSBOUNDARY TROPICAL CYCLONES BUT THE IMPACTS ARE UNEVEN ACROSS THE REGION.

All the models in this study indicated that wind speeds would intensify in the future, when climate scenarios were considered. The Philippines will still be significantly more vulnerable to extreme wind speeds resulting from tropical cyclones compared to the other ASEAN countries. However, large areas of Viet Nam will experience wind speeds that are considered in the typhoon category. Cambodia and Lao PDR will also

THE FINDING INDICATES THAT WIND MAPS IN THE BUILDING CODES BASED ON HISTORICAL DATA WILL BE INSUFFICIENT FOR THE BUILDINGS TO WITHSTAND INTENSIFIED WIND IN THE FUTURE.

encounter more extreme wind speeds. Even Bangkok, Thailand, may face tropical storm conditions that can cause substantial damage.

The figure below shows the projected intensification of wind speeds in the ASEAN region, up to the year 2050. This finding indicates that the wind maps in the building codes that were based on historical data, will not be sufficient for the buildings to withstand intensified wind in the future.

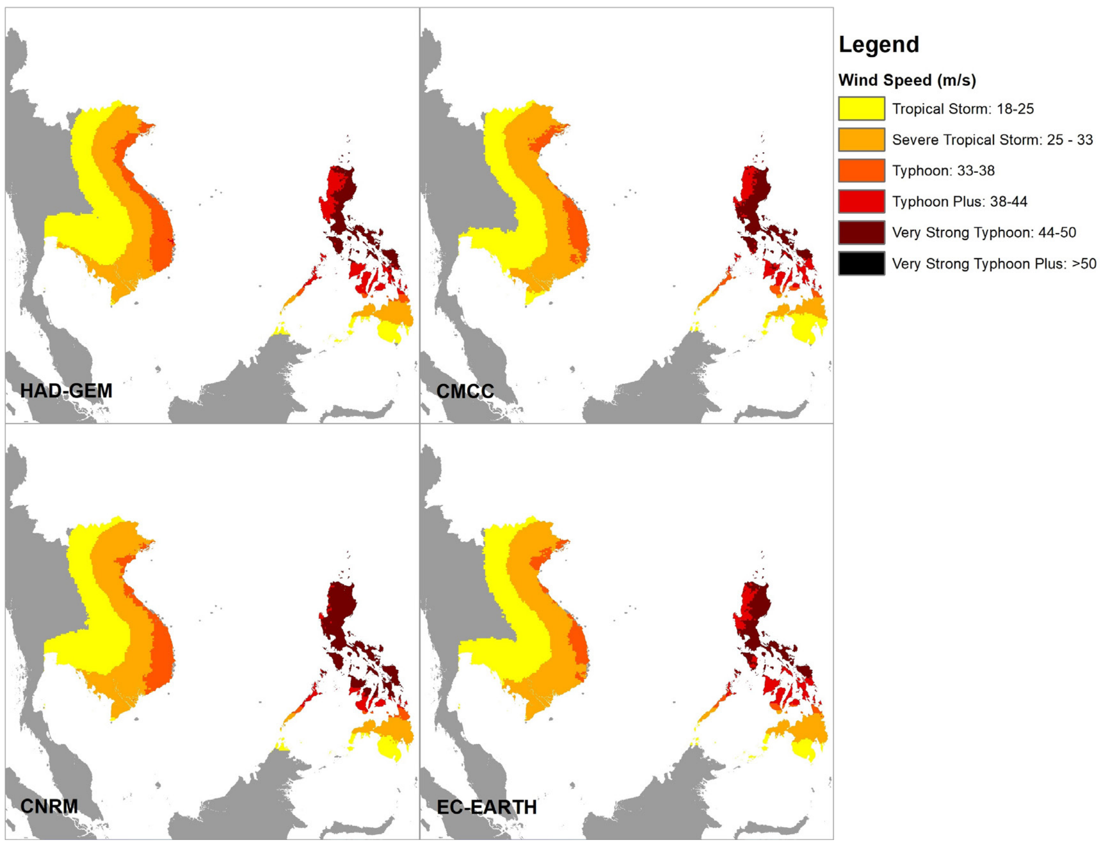


Figure 2
Wind speeds with a 50 year return period in Southeast Asia given 2015-2050 climate conditions for four different climate models.

Of the three countries covered by this report, the Philippines is the country most affected by tropical cyclones in terms of the number of houses destroyed, monetary damage, and welfare loss. The country already loses approximately 0.5% of its GDP annually due to tropical cyclone damage. On the other hand, Cambodia and Viet Nam experience an annual loss of 0.05% and 0.1% of their respective GDPs.

THE CURRENT ANNUAL LOSS OF GDP DUE TO TROPICAL CYCLONES

THE PHILIPPINES
0.5%
CAMBODIA
0.05%
VIET NAM
0.1%

KEY METRICS REVEAL CAMBODIA AND VIET NAM ARE AT RISK OF EXPERIENCING SIGNIFICANT INCREASES IN LOSS DUE TO TROPICAL CYCLONES.

Cambodia and Viet Nam are expected to experience the largest increases in risk of tropical cyclones as revealed by all metrics. Although the Philippines will still experience a higher risk compared to these countries, the risk in Cambodia and Viet Nam is predicted to grow relatively faster.

Extreme events in Viet Nam in particular, may become much more severe, with a 1-in-200-year event potentially causing up to USD 4-5 billion in damages in the future, compared to less than USD 2 billion under the historical climate conditions. The coastal provinces in the north and center of Viet Nam will experience especially large increases in expected annual losses. Thus, it is recommended to investigate whether the policies that are currently in place are appropriate to manage future cyclone risk, especially in these areas in Cambodia and inland Viet Nam. The Philippines, having experienced many severe tropical cyclones in the past, should focus more on optimizing and enforcing existing policies.

The majority of expected annual monetary losses are concentrated in major cities such as Manila, Hanoi, Ho Chi Minh City, and Phnom Penh. When a household experiences catastrophic damage and loses a large portion of its assets, it can lead to a severe decline in living standards. Households that spend most of their income on necessities have limited resources to recover from the damage, making them particularly vulnerable to the effects of tropical cyclones. This information can also be used to compare different compensation schemes and evaluate which schemes are the most beneficial for society. This can help to prioritize investments in compensation schemes, ensuring that limited resources are used in the most effective way to reduce the impact of tropical cyclones on the most vulnerable persons.

3.3
THE RISK OF TROPICAL CYCLONES IS PROJECTED TO INCREASE ACROSS THE REGION, AFFECTING KEY SECTORS SUCH AS AGRICULTURE.

EXTENSIVE DAMAGE TO STAPLE CROPS LIKE RICE DUE TO TROPICAL CYCLONES MAY CONTRIBUTE TO LOCAL FOOD SHORTAGES, DISPROPORTIONATELY AFFECTING THE POOR AND INCREASING FOOD COSTS ACROSS THE ASEAN REGION.

Geographically, the most significant changes in tropical cyclone risk will occur in northeastern and central eastern Viet Nam including the metropolitan area of Hanoi, one of the global manufacturing hubs. Home to approximately 20 million people, Hanoi also serves as the political and economic center of Viet Nam. The other economic hub, Ho Chi Minh City, is also at considerable risk. This could damage production capabilities or could disrupt the workforce and cause downtime days. In the Philippines, northeastern Luzon may experience heightened tropical cyclone risks, while the southern region (Mindanao) is expected to remain a relatively low-risk area. Coastal regions and flat delta areas are especially at risk because tropical cyclones typically slow down over land and become stronger in coastal areas. Furthermore, tropical cyclones can cause storm surges at sea that can cause coastal flooding in these coastal areas. Sea level rise (not included in this study) can further exacerbate the impact of tropical cyclones on the coastal areas.

The agriculture sector can also suffer from extreme winds. Large crops with relatively small root systems such as corn, are especially vulnerable. Rice, a critical crop in Southeast Asia, is prone to strong winds and flooding caused by tropical cyclones during its later growth stages. Extensive damage to locally consumed crops like rice may contribute to local food shortages, necessitating increased food imports, which can be costly in years of already high global food prices. This, in turn, could lead to increased food costs that disproportionately affect the poor, who allocate a substantial portion of their income to food. Strategic food reserves, maintained either on a national or ASEAN level, could be a potential solution to this issue. Another option is transitioning to crops less sensitive to tropical cyclones, such as root crops or low-growing leafy greens.

The results presented in this report confirm the expectation that climate change is intensifying tropical cyclone risk unevenly across the ASEAN region, but with transboundary impacts.

3.4
DROUGHT EVENTS ARE LIKELY TO OCCUR MORE FREQUENTLY AND MORE SEVERELY IN THE ASEAN REGION DUE TO THE VARIABILITY OF RAINFALL INFLUENCED BY CLIMATE CHANGE.

WHEN APPLYING THE FUTURE CLIMATE SCENARIOS, THE FREQUENCY OF DROUGHT SIGNIFICANTLY INCREASES. CAMBODIA APPEARS TO BE HIT HARDEST BY FUTURE DROUGHT, WITH A 46% INCREASED PROBABILITY OF DROUGHT IN THE DRY SEASON BY THE 2080S.

Droughts in the ASEAN region have been influenced by regional climatic conditions such as El Niño, affecting the amount and pattern of rainfalls over the region. When adding climate change scenarios into the simulation, this study reveals an increasing trend of both the occurrence probability and intensity of droughts between now and the 2080s, if no action to mitigate the impact of climate change is taken. This trend is particularly true in the three focus countries (Cambodia, the Philippines, and Viet Nam), where the probability of experiencing drought is projected to increase by 60-80%. However, this increasing trend is also prominent in other countries such as Indonesia, Lao PDR, Myanmar, and Thailand.

The results of the study indicate that the increase in drought occurrence probabilities is most concerning in Cambodia and Viet Nam. Based on the historical climate conditions, the northwestern, western and southwestern regions of Cambodia are expected to experience the highest likelihood of drought, with 35-45% probability during a dry season. In Viet Nam, the south-central region and the Mekong Delta area showed the highest probability of drought occurrences, with 35-45% during the dry season. Finally, the northern and southern regions of the Philippines are expected to experience drought with a 30-40% probability during the dry season.

When applying the future climate scenarios, the frequency of drought significantly increases. It appears that Cambodia will most likely be hit hardest by future drought, and given a worst-case scenario, a 46% increased probability of drought in the dry season by the 2080s. It is very likely that the areas with infrequent drought conditions in the past, could experience more recurring drought conditions in the future. **[Ref: Part B – Technical Report, Section 3.4]**

The northern and central parts of Cambodia may experience a higher number of drought events

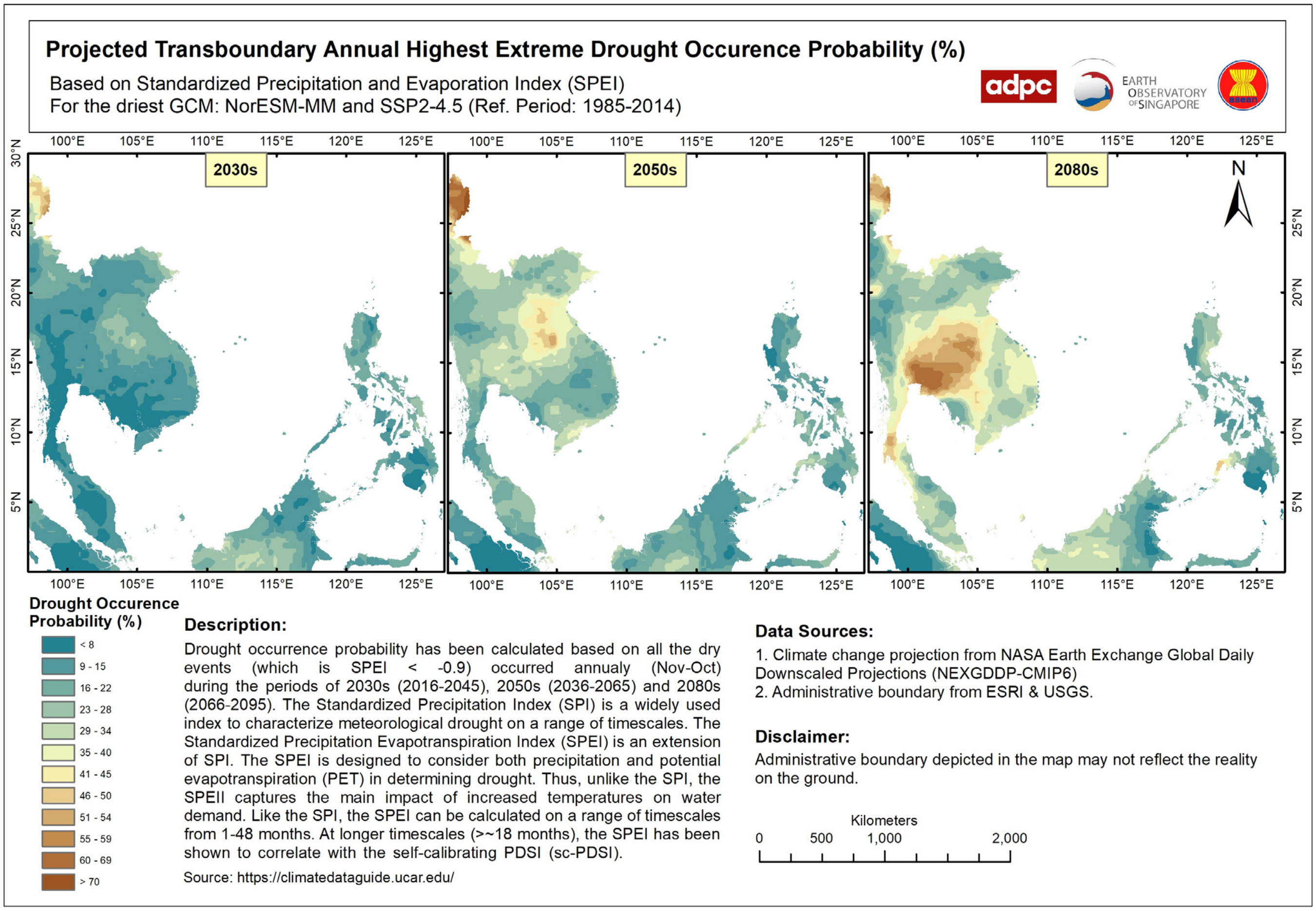


Figure 3
Projected drought occurrence probability (%) during dry season.

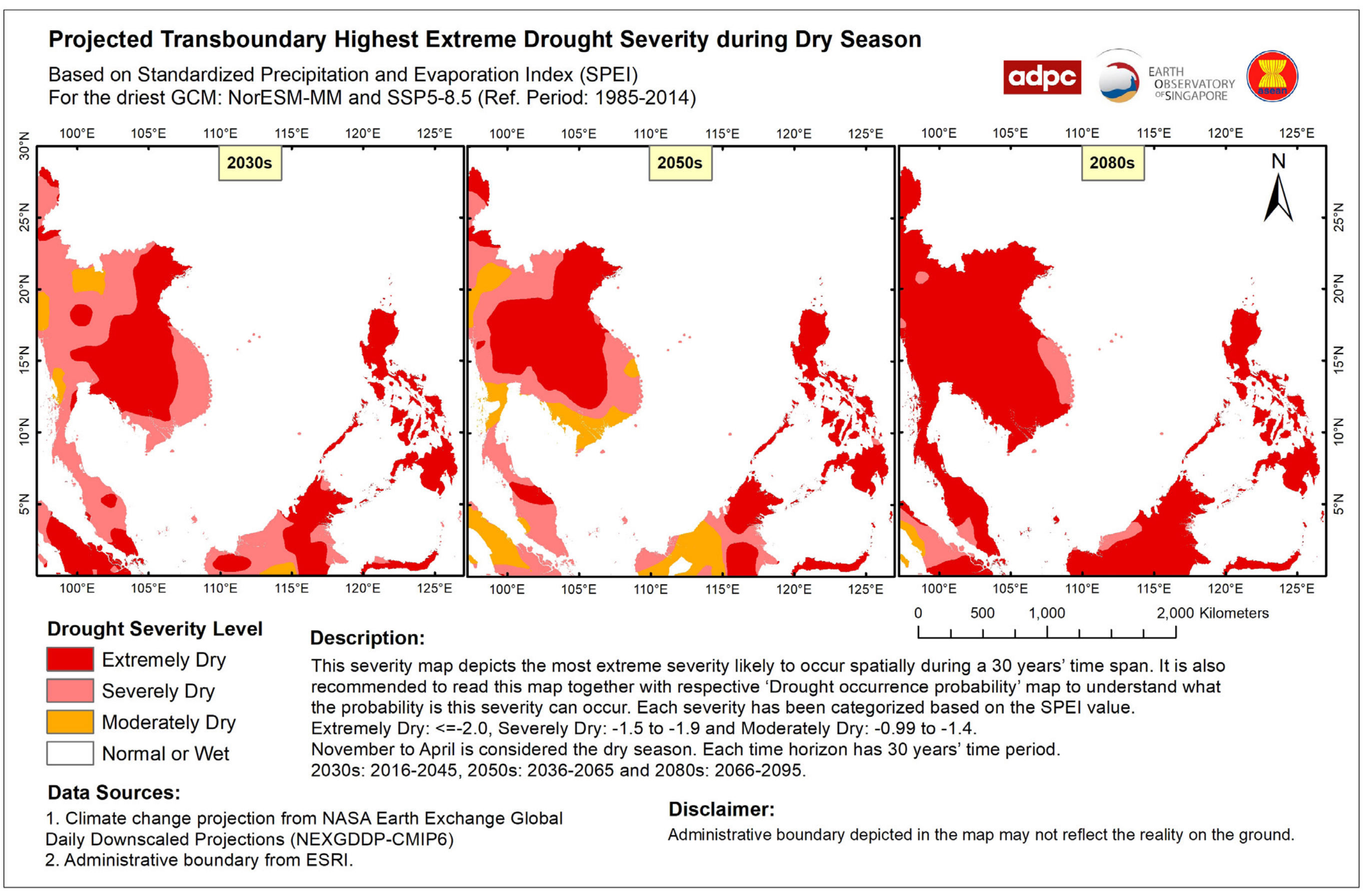
compared to other parts of the country and to the region overall. The results also show that the spatial extent of drought-hit areas cover multiple countries, extending from Cambodia to southern Viet Nam and the Mekong Delta. As a result, drought is more likely to create a transboundary effect among these countries that share common water resources from the Mekong River.

When countries share water resources, a major drought over the region can lead to transboundary water shortage issues. For example, if a drought lowers the water level of a river shared by two countries, the downstream country will likely suffer more from a water shortage, especially if the upstream country mismanages the river. Lower water levels in rivers and dam reservoirs can also reduce a region's ability to generate electricity.

For example, the Nam Ngum Hydropower station built on the Nam Ngum River provides an important opportunity for Lao PDR to export surplus power to Thailand. During the drought of 2007, the station's power generation dropped significantly, causing a 40% decline in the power plant's utilization rate, impacting electricity exports to Thailand.

When considering the intensity of drought, a similar observation can be made. Drought is expected to be more intense in the 2080s, when compared to the historical climate condition. Considering extreme climate change scenarios, the entire area of Cambodia and the Philippines could be under threat from an extreme drought during the dry season by the 2080s, while Viet Nam is expected to face extreme and severe drought. The figure below depicts an example of the increasing trend of projected drought severity during the dry season for 2030, 2050, and 2080.

Figure 4: Projected drought severity during the dry season.



3.5
INCREASED DROUGHT RISK COULD IMPACT CROP PRODUCTION IN CAMBODIA, THE PHILIPPINES AND VIET NAM.

THE STUDY BRINGS TO THE FOREFRONT THE ASEAN REGION'S INTERCONNECTEDNESS AND THE IMPORTANCE OF COLLECTIVELY ADDRESSING THE TRANSBOUNDARY IMPACTS OF HAZARDS DUE TO CLIMATE CHANGE. ADVERSE EFFECTS IN ONE ASEAN COUNTRY CAN OFTEN SPILL ACROSS BOUNDARIES.

The study shows that the area of croplands and rice exposed to severe and extreme drought are likely to increase in the future, when considering climate change scenarios. Under a moderate scenario (SSP2-4.5), 89% of Cambodia's croplands could potentially be exposed to extreme drought in the future. Similarly, 88% of the rice paddy field area is expected to be exposed to drought. Under the same moderate scenario, 63% of Viet Nam's rice paddy field area is likely to be exposed to severe drought, while 33% could face extreme drought in the future. The result for the Philippines shows that most of the cropland areas are likely to be exposed to extreme drought in the future.

This spatial variability in the future occurrence of drought events calls for the development and implementation of local, national, and also transboundary or regional strategies to address the challenges collectively, as drought impacts in one ASEAN country can often spill across boundaries, affecting countries beyond the original location of the drought. For example, drought conditions in Viet Nam are likely to impact food prices and food security across and beyond the region as Viet Nam is one of ASEAN's top rice exporters. The ASEAN Member States could consider regional strategies to alleviate this potential impact by conducting joint research on drought-resilient crops and or crop variety that may help to buffer productivity.

The findings of the study presented here show that the transboundary impacts of drought and tropical cyclones can be complex and highlight the interconnectedness of the region and the importance of cooperation and collaboration among ASEAN countries in addressing transboundary impacts of these hazards.

3.6
THE VULNERABILITIES OF PEOPLE WITHIN THE REGION HAVE NOT BEEN SUFFICIENTLY ACCOUNTED FOR IN RISK ASSESSMENT AND SCENARIO PLANNING.

The study shows that for Cambodia, the Philippines and Viet Nam combined, more than 220,000 women and 10,000 persons with disability could be injured each year as their houses are damaged by tropical cyclones. While it is well-known that the fatality and injury rates from disasters tend to be higher for these vulnerable populations, their vulnerabilities were often not explicitly accounted for in the transboundary disaster risk assessment and scenario planning process.

In the ASEAN region, Sex, Age and Disability Disaggregated (SADD) data has not been widely utilized in the analysis of risk exposure and vulnerability. The particular challenges in the region directly relevant to this study are described below.

SEX, AGE AND DISABILITY DISAGGREGATED (SADD) DATA HAS NOT BEEN WIDELY UTILIZED IN THE ANALYSIS OF RISK EXPOSURE AND VULNERABILITY. AS A RESULT, IT RESTRICTS AN INCLUSIVE LENS IN DISASTER RISK ASSESSMENT AND ANALYSIS.

- Agencies responsible for carrying out disaster risk assessment do not have sufficient institutional capacities for applying an inclusive lens in the risk analysis. This is due to a lack of understanding of the unequal distribution of vulnerability and impacts.
- A unified and centralized platform for collecting and monitoring Sex, Age and Disability Disaggregated (SADD) data is lacking.
- The coordination between concerned stakeholders, in particular, relevant government agencies such as the disaster risk management offices, sectoral agencies, and gender organizations is not well defined.

Among the 3 pilot countries, Cambodia, the Philippines, and Viet Nam, an integration of GESI into transboundary disaster risk assessment and scenario planning varies from country to country. In Cambodia, although gender equality and social inclusion in disaster risk management and climate change has been incorporated in the National Action Plan for Disaster Risk Reduction (2019 – 2023) and the Cambodia Climate Change Strategy Plan (2014 – 2023), there is no clear reference to the SADD data integration in disaster risk assessment or management.

The Philippines is well-placed in terms of the SADD data inclusion utilizing a systematic and centralized data collection and monitoring platform, such as the Community-Based Monitoring System (CBMS). This effort, however, is still limited to only selected pilots within Local Government Units (LGUs) in the country.

In Viet Nam, statistical work on SADD data has improved over the past five years. The Ministry of Planning and Investment took the lead in issuing publications and conducting studies and surveys. However, when it comes to the implementation of GESI mainstreaming in Viet Nam, the main gaps in other AMSs mentioned above, are the lack of robust data and a centralized system for data collection and analysis. Insufficient institutional capacities and resources and the lack of coordination among the relevant agencies have also been identified.

4. KEY RECOMMENDATIONS

MANY OF THE EXISTING ASEAN PLANS FOR DISASTER RISK MANAGEMENT AND RISK MITIGATION DO NOT EXPLICITLY CONSIDER THE EFFECT OF CLIMATE CHANGE AND THE TRANSBOUNDARY RISK. IT IS IMPORTANT THAT THE ASEAN REGION RELOOKS AT THESE INCREASED RISKS AND TAKE ACTIONS TO ADDRESS THEM.

A risk-based scenario planning process serves the following objectives: to improve understanding of risks, support decision-making, explore emerging futures, assist resource allocation and facilitate communication to engage a broad range of stakeholders on disaster risk management (DRM) discussions. This study finds that the ASEAN region will face disasters, such as tropical cyclones and drought, that will be increasingly transboundary and more intense as a result of climate change. Many of the existing ASEAN agreements, frameworks, and mechanisms for disaster risk management and risk mitigation do not consider the effect of climate change and the transboundary risk explicitly. It is important that the ASEAN region relooks at these increased risks and take actions to address them.

This section outlines how the findings of this study on the transboundary disaster risk and scenario planning could contribute to enhancing current outputs and works in the ASEAN Agreement on Disaster Management and Emergency Response (AADMER) Work Programme 2021-2025, which the ACDM should consider. Moreover, some of the recommendations below may be outside the purview of ACDM and hence require coordination with other relevant ASEAN Sectoral bodies.

READERS SHOULD REFER TO PART B - TECHNICAL REPORT OF THIS STUDY FOR FURTHER DETAILS ON THE RECOMMENDATIONS THAT ARE STRUCTURED AND PROPOSED SPECIFICALLY BASED ON THE AADMER WORK PROGRAMME 2021-2024.

ON PREVENTION AND MITIGATION

01. Consider the implication of more intense tropical cyclones and increasing wind speeds into existing building regulations and building codes.

02. Consider increasing drought risks in crop insurance programmes, particularly in compensation schemes to prevent low-income people from falling into extreme poverty.

03. Disaggregate data on the vulnerable population, taking into consideration demographic categories when conducting risk assessments, which can be gathered by preparing detailed demographic profiles of the communities residing in the most high-risk areas.
[Ref Part B - Technical Report, Appendix B].

ON PREPAREDNESS, RESPONSE AND RECOVERY

04. Consider transboundary risk scenarios into existing ASEAN disaster preparedness mechanisms, including Standard Operating Procedures for Regional Standby Arrangements and Coordination of Joint Disaster Relief and Emergency Response Operations (SASOP) and the ASEAN Joint Disaster Response Plan (AJDRP), ASEAN Regional Disaster Emergency Response Simulation Exercise (ARDEX) to include transboundary risk scenarios.

05. Consider the tropical cyclone and drought hazard intensity parameters suggested by this study as a trigger mechanism of pre-disaster anticipatory actions **[Ref: Part B - Technical Report, sections 2.2 and 3.2].**

06. Consider integrating transboundary hazard scenarios into recovery strategies, including post-disaster needs assessments and resource allocations and sharing for recovery assistance.

PART B: TECHNICAL REPORT

1. Introduction
2. Transboundary Tropical Cyclone Risk Assessment
3. Transboundary Drought Risk Assessment
4. Transboundary Risk and Scenario Planning Recommendations for ASEAN

1. INTRODUCTION

1.1. OBJECTIVE

ADPC AND EOS HAVE USED THE LATEST CLIMATE CHANGE SCENARIOS AND THEIR UNDERLYING KNOWLEDGE TO DEMONSTRATE THE IMPACTS OF TROPICAL CYCLONES AND DROUGHTS UNDER HISTORICAL AND FUTURE CLIMATE CONDITIONS.

The main objective of the study is to demonstrate the possible impacts of tropical cyclones and drought in Cambodia, the Philippines, and Viet Nam, considering various climate scenarios. It aims to provide a regional perspective of the transboundary impacts of these hazards in order to foster transboundary cooperation in addressing such hazards in the future. The study contributes to the implementation of the ASEAN Agreement on Disaster Management and Emergency Response (AADMER) Work Programme[9] 2021-2025, particularly on Priority Programme 1: Risk Assessment and Monitoring and Priority Programme 2 : Prevention and Mitigation. These 2 Priority Programmes can benefit and make use of the resulting transboundary hazard, vulnerability, and risk information for disaster risk reduction and climate change adaptation planning, as well as long-term resilient development planning. ADPC and EOS have used the latest climate change scenarios and their underlying knowledge to demonstrate the impacts of tropical cyclones and droughts under historical and future climate conditions and to inform the ASEAN member states how to effectively address them.

9. AADMER Work Programme 2021-2025, https://asean.org/wp-content/uploads/2021/08/AADMER-Work-Programme-2021-2025.pdf

1.2. CONCEPTUAL BACKGROUND

Organizations in charge of national disaster management and other sectoral ministries in the Southeast Asia region have limited access to actionable risk information in support of their development planning processes. This is a critical challenge that needs to be addressed in order for the countries to achieve goals established under the Sustainable Development Goals (SDGs), the Sendai Framework for Disaster Risk Reduction (SFDRR), the Paris Agreement and other related commitments.

This study employs a holistic approach that supports regional cooperation through the ASEAN Secretariat, focusing on the applications of risk assessment for evidence-based policy making, while aiming for sustainability and ensuring that the regionally accepted methodology is replicable and scalable. Finally, gender and social inclusion are integrated throughout the approach.

What is risk assessment and why does it matter?

THE PRIMARY OBJECTIVE OF RISK ASSESSMENT IS TO HELP DECISION MAKERS UNDERSTAND THE DEGREE OF SEVERITY OF THE POTENTIAL IMPACT OF DISASTERS ON THE SECTORS OF INTEREST AND HELP IDENTIFY APPROPRIATE RISK MANAGEMENT STRATEGIES FOR THE PRIORITIZED RISKS.

According to the terminology of the United Nations Office for Disaster Risk Reduction (UNDRR), disaster risk is defined as the potential loss of life, injury or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity. Risk assessment is defined as a qualitative or quantitative approach to determine the nature and extent of disaster risk by analyzing potential hazards and evaluating existing conditions of exposure and vulnerability that together could harm people, property, services, livelihoods and the environment on which they depend.[10]

In the technical sense, disaster risk is defined through the combination of three terms: hazard, exposure and vulnerability as illustrated in Figure 5.

A risk assessment identifies key areas prone to particular hazards—such as tropical cyclones and drought—key vulnerabilities and areas requiring priority attention in investment, capacity building, and policy/strategy reform.

10. UNDRR, Sendai Framework Terminology on Disaster Risk Reduction: disaster risk assessment, https://www.undrr.org/terminology/disaster-risk-assessment

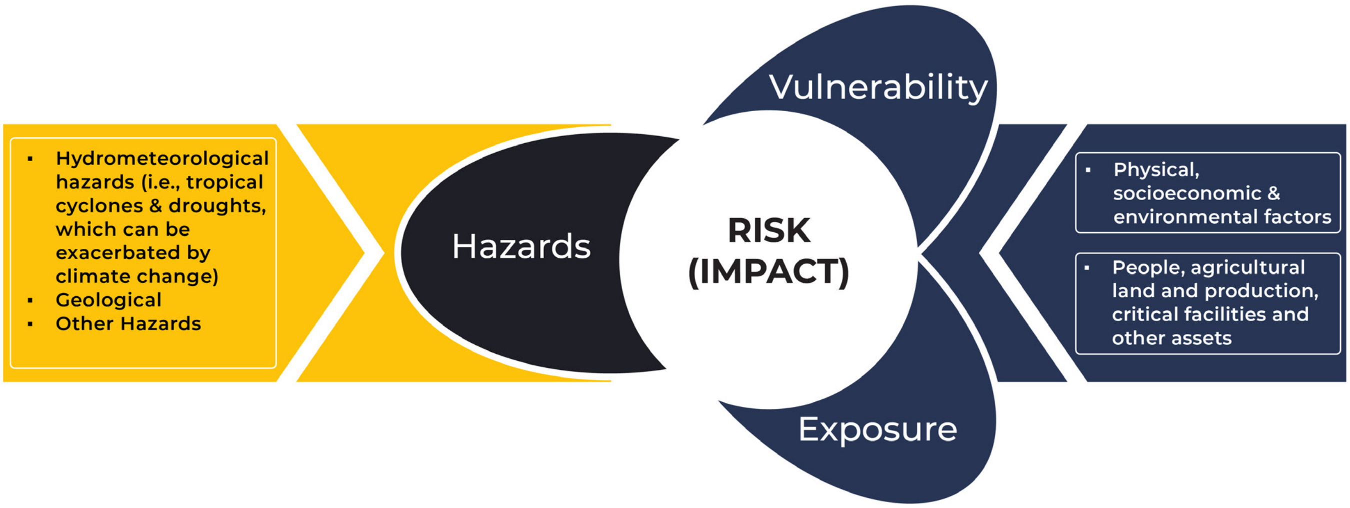


Figure 5
Components of risk (adapted from IPCC, 2012).

Climate change and its impacts on disaster risks

Disaster risk management and planning is affected by how climate change will alter future conditions. An assessment of possible future impacts of disasters should therefore take into consideration the anticipated climate change trends.

Climate change refers to the increasing changes in the measures of climatic phenomena, including precipitation, temperature and wind patterns, over a long period of time. This study shows that the possibility of more droughts and an increased intensity of cyclones is likely. As the global surface temperature increases, more water evaporates into the atmosphere. The increased ocean surface temperature, along with more vapor in the atmosphere, are ingredients which generate more powerful cyclones.[11] The likely increase in temperature will also probably result in more severe and more frequent droughts in Southeast Asia .

Examples of potential risk and impact caused by climate change (involving drought and tropical cyclones) are illustrated in Figure 6 and Figure 7 respectively.

11. U.S. Geological Survey, How can climate change affect natural disasters?, https://www.usgs.gov/faqs/how-can-climate-change-affect-natural-disasters

Figure 6
Illustration of potential impact of climate change on drought.

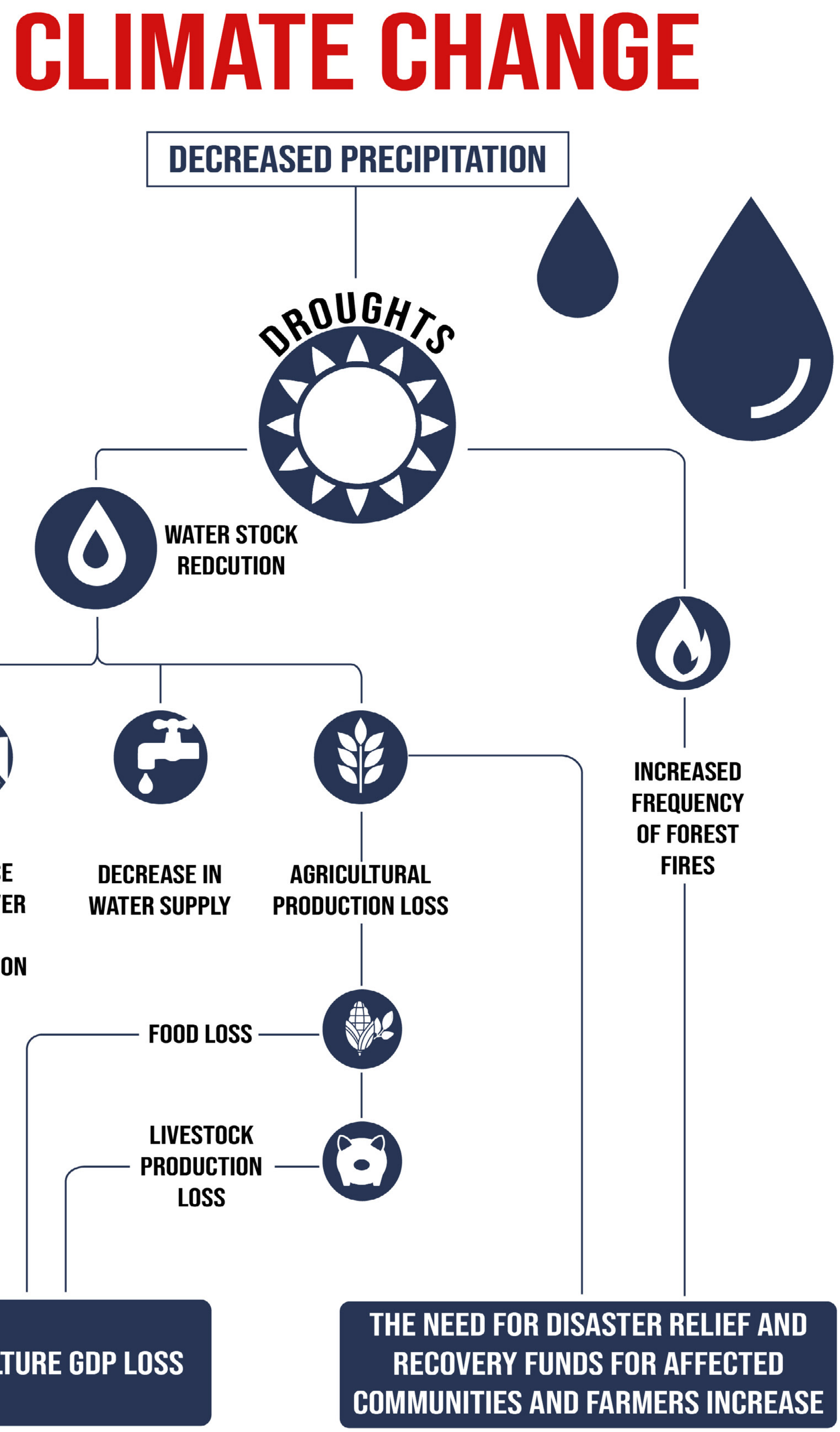
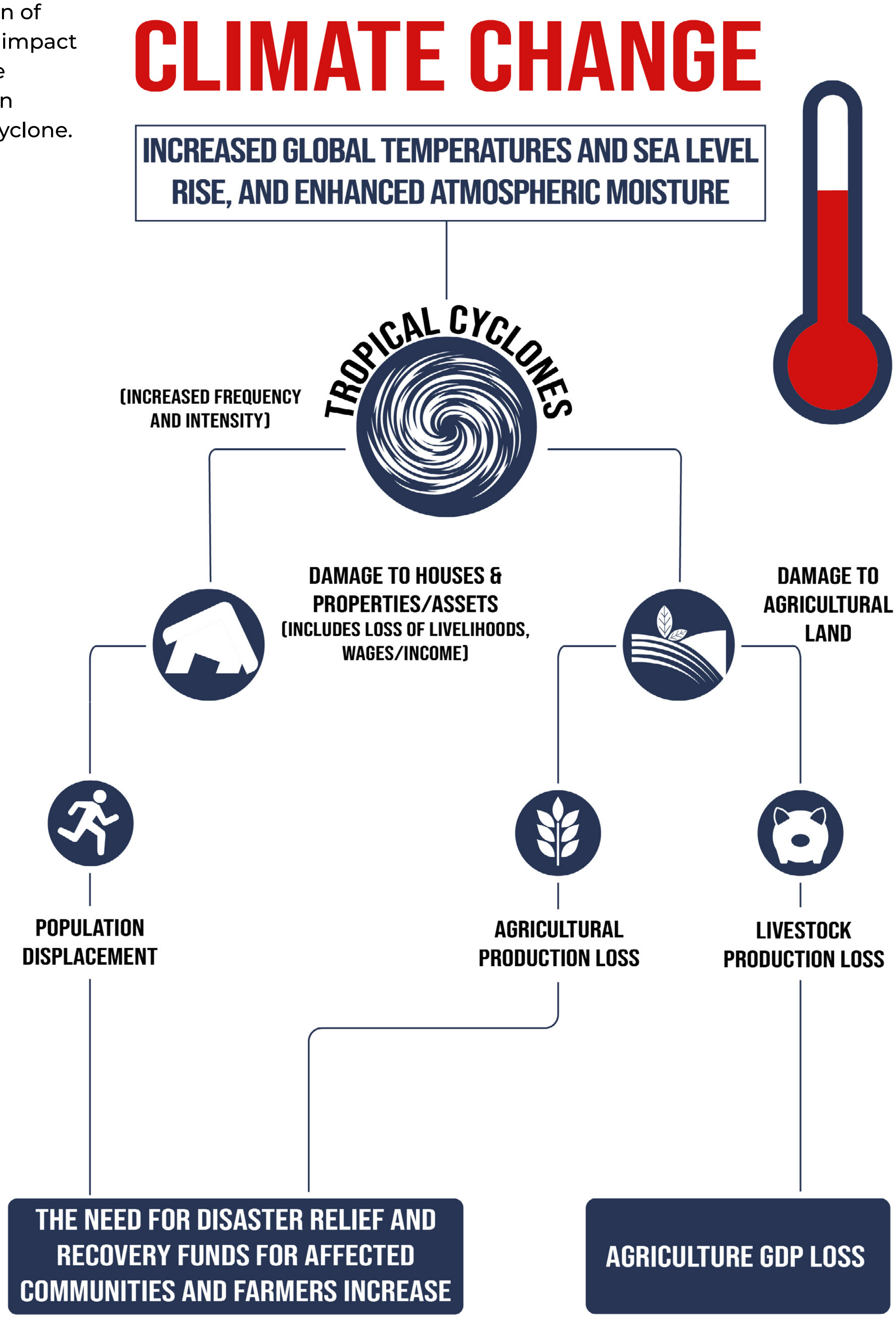


Figure 7
Illustration of potential impact of climate change on tropical cyclone.



Understanding Shared Socioeconomic Pathways (SSPs)

The future climate is uncertain. Scientists provide different plausible scenarios of climate change in order to aid the estimation of impacts. The scenarios are based on different levels of greenhouse gas (GHG) emissions and are called the *Shared Socioeconomic Pathways (SSPs).*[12]

SSPs are scenarios of projected socioeconomic global changes up to 2100. They are used to derive greenhouse gas emissions scenarios with different climate policies. The availability of these climate projections for multiple SSPs allows us to explore climate changes across a range of very different possible futures.

To inform projections of future risk, drought and tropical cyclone hazards are assessed under different projected climate scenarios and selected greenhouse gas concentration pathways, Shared Socioeconomic Pathways (SSPs), namely, **SSP2-4.5** and **SSP5-8.5**.

WHY NEW SCENARIOS TO CLIMATE STUDY?

- **Socio-economic scenarios are used to derive emissions scenarios without (baseline scenarios) and with climate policies (mitigation scenarios).**
- **Emissions scenarios used to derive climate change projections.**
- **Climate change projections and socio-economic scenarios used to evaluate climate impacts and adaption measures.**

12. O'Neill et al. 2013 "A new scenario framework for climate change research: the concept of shared socioeconomic pathways," https://www.researchgate.net/publication/258161885_A_New_Scenario_Framework_for_Climate_Change_Research_The_Concept_of_Shared_Socioeconomic_Pathways

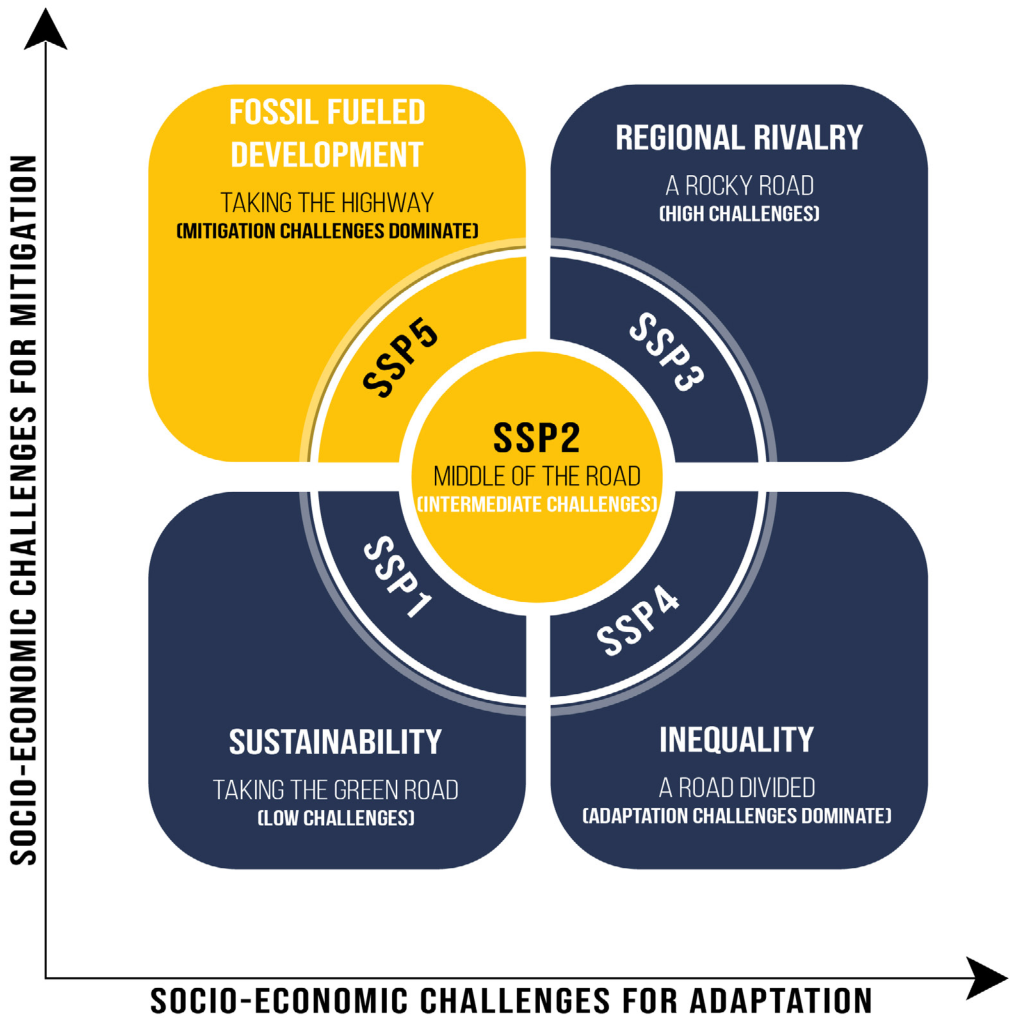


Figure 8
SSPs mapped on the challenges to mitigation/adaptation space.

WHY WERE SSP2-4.5 AND SSP5-8.5 CHOSEN?

SSP2 was selected as the ***most likely pathway*** that poses ***moderate challenges*** to adaptation and mitigation, as well as to understand the intermediate effects of GHG emissions and atmospheric concentration.

SSP5 was selected as the likely probable ***extreme pathway*** over the region that poses ***high challenges*** for mitigation and low challenges for adaptation, as well as to understand the effect of high GHG emissions and atmospheric concentration.

THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC) SIXTH ASSESSMENT REPORT ASSESSED THE PROJECTED TEMPERATURE OUTCOMES OF A SET OF 5 SCENARIOS THAT ARE BASED ON THE FRAMEWORK OF THE SSPS, AS FOLLOWS:

SSP	Scenario	Estimated warming (2041-2060)	Estimated warming (2081-2100)	Very likely range (2081-2100)
SSP1-1.9	Very low GHG emissions: CO2 emissions cut to net zero around 2050	1.6 °C	1.4 °C	1.0-1.8 °C
SSP1-2.6	Low GHG emissions: CO2 emissions cut to net zero around 2075	1.7 °C	1.8 °C	1.3-2.4 °C
SSP2-4.5	Intermediate GHG emissions: CO2 emissions around current levels until 2050, then falling but not reaching net zero by 2100	2.0 °C	2.7 °C	2.1-3.5 °C
SSP3-7.0	High GHG emissions: CO2 emissions double by 2100	2.1 °C	3.6 °C	2.8-4.6 °C
SSP5-8.5	Very high GHG emissions: CO2 emissions triple by 2075	2.4 °C	4.4 °C	3.3-5.7 °C

Why are gender and social inclusion important?

Women and men, children and the elderly, as well as persons with disabilities (PWD), experience, perceive, and are affected by risks differently. Everyone may be equally exposed to a hazard, but women, men, the elderly, children and PWD have different levels of vulnerability and access to resources, and have therefore developed different coping mechanisms /skills. Accordingly, disaster risk assessment should be gender and socially inclusive; in other words, there will be consequences when gender and social aspects are excluded.

POSSIBLE CONSEQUENCES:

- **Inaccurate risk assessments;**
- **Inappropriate policy responses, prioritization and risk financing at national and community levels;**
- **Design of inappropriate interventions to minimize risk and vulnerability and increase coping capacity;**
- **Ineffective disaster risk reduction interventions and outcomes**

To eliminate the consequences as described above, gender and social aspects should be included in the risk assessment process, leading to more responsive and effective disaster risk reduction interventions.

The importance of gender and social inclusion for effective disaster risk management has been widely recognized by both global and regional communities. Articulating the importance of gender and social inclusion, and investing in gender-responsive and inclusive disaster risk management and resilience building, is critical for achievement of the Sustainable Development Goals and the Sendai Framework for Disaster Risk Reduction by 2030. At the regional level, the ASEAN Secretariat has a key role to play

GENDER AND SOCIAL INCLUSION IN DISASTER RISK MANAGEMENT AND RESILIENCE BUILDING ARE CRITICAL FOR INCLUSIVE DISASTER RISK REDUCTION. THIS STUDY ALIGNS WITH THE ASEAN REGIONAL FRAMEWORK ON PROTECTION, GENDER AND INCLUSION IN DISASTER MANAGEMENT. IT PROPOSES DEVELOPING DEMOGRAPHIC PROFILES OF COMMUNITIES IN THE MOST HAZARD-PRONE AREAS, AS IDENTIFIED IN THIS STUDY.

in addressing the issues of protection, gender and inclusion (PGI) in disaster risk management, which is clearly manifested in the ASEAN Regional Framework on Protection, Gender and Inclusion in Disaster Management 2021-2025 (ARF-PGI). The ARF-PGI supports the implementation of the AADMER Work Programme 2021-2025, which includes an outcome on vulnerable groups, as well as key outputs integrating gender and social inclusion throughout the priority programmes, ensuring that women, children, youth, people with disabilities, and other vulnerable groups are empowered to act as agents for disaster risk management, leaving no one behind.

How to integrate gender and social inclusion?

The ASEAN Regional Framework on Protection, Gender and Inclusion in Disaster Management offers the ASEAN Member States a range of options to propose country-specific intervention while considering national and local circumstances. One of the vital indicators suggested by the Framework is increased collection and utilization of disaggregated data, minimally by gender, age and disability, to inform development of disaster management programmes. Aligning with the Framework, this study proposes developing demographic profiles of the communities residing in the most hazard-prone areas identified by this study.

Integration of Sex, Age and Disability Disaggregated (SADD) Data

Incorporation of SADD data and information into tropical cyclone and drought related disaster risk management is crucial for policy makers to be able to assess the situation and develop appropriate, evidence-based strategy and policy.

2. TRANSBOUNDARY TROPICAL CYCLONE RISK ASSESSMENT

2.1. NOTABLE TROPICAL CYCLONE EVENTS IN CAMBODIA, THE PHILIPPINES, AND VIET NAM

The northern parts of Southeast Asia are prone to tropical cyclones. Cambodia, Lao PDR, the Philippines, Thailand and Viet Nam face risk from the western Pacific and Myanmar faces tropical cyclone risk from the Indian Ocean. This study focuses on transboundary tropical cyclone risk in Cambodia, the Philippines and Viet Nam. The Philippines is a global tropical cyclone hotspot and has a long history of intense super storms. In Cambodia and Viet Nam, tropical cyclones are typically milder and usually only receive the 'tropical storm' classification. All of these tropical cyclones can cause extensive damage due to strong winds, storm surges and corresponding coastal flooding, pluvial flooding and rainfall-triggered landslides.

Tropical cyclones (also known as typhoons in the study region) are formed and gain strength over warm sea waters, and they tend to slow down once they make landfall. Many of the storms that affect the Philippines are formed over the Pacific Ocean, while those that affect Cambodia and Viet Nam are often formed over the water body to the east of Viet Nam. However, typhoons that form in the Pacific Ocean can also regularly travel beyond the Philippines and may gain extra strength before making landfall in Viet Nam and affecting neighboring countries such as Cambodia. These transboundary tropical cyclones pose a significant threat to the region.

The main aim of this section is to demonstrate the expected changes in the intensity and frequency of tropical cyclones, and to present the probability of economic losses from potential extreme events under both historical and future climate conditions. This information is critical for decision-makers, as it enables them to effectively allocate their limited resources towards reducing the impact of tropical cyclones in Cambodia, the Philippines, and Viet Nam.

NOTABLE (TRANSBOUNDARY) EVENTS IN SOUTHEAST ASIA

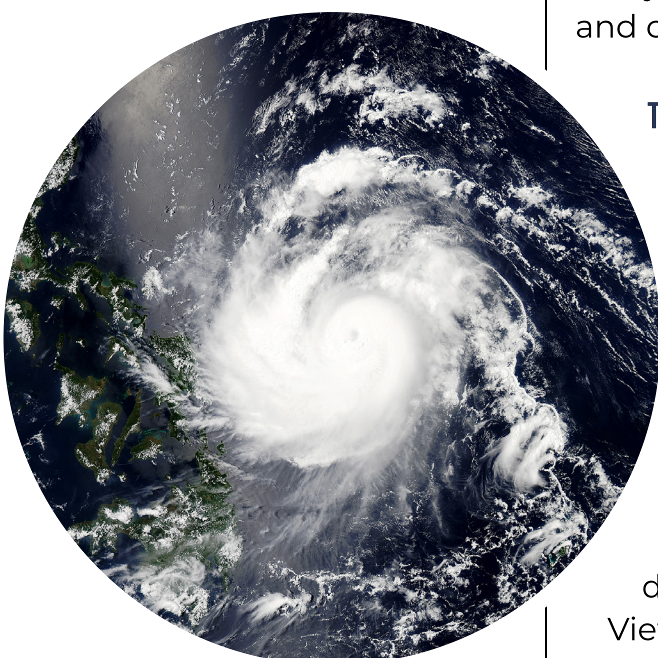


Photo: Cyclone Noul Approaches The Philippines by NASA Earth Observatory is licensed under CC BY 2.0

TYPHOON RAMMASUN (2014)

Typhoon Rammasun was a category 5 super typhoon. It formed over the Pacific Ocean on July 9, 2014 and dissipated on July 20, 2014 over Northern Viet Nam. In the Philippines the typhoon affected 1 million people, killed 38, and completely destroyed approximately 112,000 buildings (510 impact database). In Viet Nam the typhoon caused 27 deaths, flooded 6000 buildings and completely destroyed 750. (Reliefweb, 2014).

TYPHOON NARI (2013)

Typhoon Nari formed on October 8, 2013 over the Pacific Ocean, crossed the Philippines and dissipated on October 16, 2013 over Viet Nam. It killed 13 people in the Philippines, displaced 43,000, damaged 16,500 houses because of strong winds, and flooded several villages (UNOCHA, 2013). Despite the winds being weaker in Viet Nam, the impacts there were greater. The storm killed 22 people, 614 houses collapsed, 13,131 houses were severely damaged and 96,000 houses were flooded (UNCT Viet Nam, 2013).

TYPHOON BETTY (1987)

Typhoon Betty was a category 5 super typhoon that formed in the Pacific Ocean on August 8, 1987 and dissipated above central Viet Nam on August 19. In the Philippines the cyclone killed at least 9 people and completely destroyed 343 houses, causing approximately 600 people to become homeless (UN DHA, 1987). In Viet Nam the cyclone also killed 9 people, collapsed approximately 14,500 buildings and severely damaged another 165,000 buildings (UN DHA, 1987).

2.2. METHODS

Diagnostic metrics

To express the current and future tropical cyclone risk in Cambodia, the Philippines, and Viet Nam, the following metrics are used:

- **Houses destroyed:** The number of houses (single and multi-family residential houses) that are expected to be completely destroyed, estimated based on the historical rate of destroyed houses given similar wind conditions. The majority of the completely destroyed houses are vulnerable buildings. This metric can further be used to estimate the number of displaced people and the total monetary loss.

- **Monetary loss:** This is the estimated total monetary losses (in USD 2021). This includes losses from all damage and their indirect impacts (not only destroyed houses),and is based on a model that predicts destroyed houses and is then adjusted to include all other damages, calibrated to observed historical damages.

- **Welfare loss (also known as risk aversion adjusted losses):** Welfare loss takes into consideration the fact that a single, large damage event can be more undesirable than a large number of statistically equivalent small damage events. This is because for low-income individuals, large damages are likely to impact critical consumption items such as food and housing, whereas small damages may only affect non-critical consumption items such as entertainment. The difference between normal losses and welfare losses highlights the economic benefits of damage compensation schemes, such as insurance. For individuals who are wealthy or experiencing minor damage with little impact on their daily lives, the risk aversion adjusted losses are estimated to be around 0-10% higher than normal losses. On the other hand, for low-income individuals or those experiencing major damage relative to their income, the risk aversion adjusted losses can be 10-80% higher than normal losses. This highlights the importance of considering the impact of damages on different segments of society when evaluating the economic effects of disasters.

- **Number of people in destroyed houses by gender and disability status:** This group of metrics is used to show the impact of disasters across a few differentiated groups.

METRICS ARE USED TO CALCULATE EXPECTED ANNUAL FIGURES AND CONSTRUCT LOSS EXCEEDANCE CURVES TO GENERATE VALUABLE INFORMATION IN UNDERSTANDING THE LONG-TERM IMPACTS OF DISASTERS AND HELP PLAN AND PREPARE FOR MASSIVE DISASTERS.

These metrics are used to calculate expected annual figures and construct loss exceedance curves, which depict the exceedance probabilities for various impacts. These curves can be used to determine the probability of large impacts occurring in Cambodia, the Philippines, or Viet Nam individually or as a combination of these countries. For instance, the loss exceedance curve reveals the probability that the Philippines will experience a tropical cyclone that results in monetary losses exceeding USD 10 billion. This information is valuable for planning and preparing for very large disasters.

Expected annual figures, on the other hand, are calculated by combining all possible variations of tropical cyclones that may occur and expressing the average yearly impact. These figures are useful for understanding the combined long-term impacts of disasters on a country or region and can be compared to a country's GDP. For example, if the expected annual monetary loss in a country is 2% of GDP, this means that on average, 2% of the GDP is used for repairing damages caused by disasters.

Hazard

Hazards are potential events or conditions that have the potential to cause harm, injury, or damage to people, property, or the environment. To develop the hazard information for past climate conditions, the STORM database (Bloemendaal et al., 2020) was applied. The STORM database is based on the STORM model, which takes statistical characteristics of tropical cyclones, such as genesis location, track direction, and intensity, and uses these characteristics to sample realistic new tropical cyclone tracks. The database consists of 10,000 years of synthetically generated (sampled) tropical cyclone tracks for historical climate conditions. The statistical characteristics of these tropical cyclone tracks were derived from historical tropical cyclone tracks between 1980 and 2017 (Bloemendaal et al., 2020).

BASED ON THE STORM MODEL, STATISTICAL CHARACTERISTICS OF TROPICAL CYCLONE TRACKS WERE DERIVED FROM HISTORICAL TROPICAL CYCLONE TRACKS BETWEEN 1980 AND 2017 TO TEST REALISTIC AND NEW TROPICAL CYCLONE TRACKS

The tropical cyclone tracks in the STORM database were converted into wind fields using the Holland model (Holland, 1980). This model describes the local wind speed based on the air pressure in the eye of the tropical cyclone and the maximum wind speed of the tropical cyclone. This procedure was followed for the first 1000 years of tropical cyclones in the western Pacific from the STORM database (Bloemendaal et al., 2020), for a total of 22,500 different tropical cyclone tracks.

It is important to note that in calculating the wind fields, local variations in wind speeds due to objects such as buildings or trees, or geography such as mountains were not considered. This simplification greatly facilitates the analysis and makes this approach feasible. However, any possible errors from this simplification are corrected in the damage model, as it is calibrated on historical wind speeds that were calculated using the same approach.

Exposure

Exposure refers to the characteristics of people, property, and the environment that determine the potential for damage or loss in the event of a disaster triggered by a natural hazard, such as a tropical cyclone. In order to calculate the impacts of tropical cyclones, it is necessary to have exposure data that describe these characteristics.

For Cambodia, the Philippines, and Viet Nam, exposure data was collected at the administrative-2 level, which typically covers between 10,000 and 200,000 people. This administrative unit is used because it provides a good balance between data availability and spatial resolution. Information on the number of people, households, population density, poverty, the percentage of houses with strong roofs and walls, and data on gender, age, and disability was collected. Additionally, income distribution data was collected to investigate the impact of tropical cyclones on low-income people.

To further refine the analysis, a wealth index map for the three countries was used, which provides information at a 2.4 km resolution (Chi et al., 2022). The data on disability and gender was obtained from the national statistics in the three countries. For the Philippines, the 510 database (the Netherlands Red Cross) was used as the data source on the percentage of houses with strong roofs and walls, and household size. This data was updated with the latest population numbers from WorldPop data (2020) to match the most recent census data.

In Viet Nam, poverty and household size data from the World Bank (2022) was used, which was updated with WorldPop data (2020) to match the latest census data. Data on the percentage of houses with strong roofs and walls could not be found, so the country average from the Philippines was applied.

For Cambodia, the latest population census data from 2019 was used, for the population count and household count per district. Poverty data could not be found, so the national average for Cambodia was used, differentiating between urban and rural areas. Similarly, data on the percentage of houses with strong roofs and walls could not be found, so the country average from the Philippines was applied.

Impact

An impact model was developed, to calculate the number of houses destroyed and the number of houses with minor damage in each district, given the wind speed input. This model is based on a machine learning approach that uses historical data on tropical cyclone damage in the Philippines to train the model to predict future damage. The following factors are used as indicators for damage: wind speed, population density, poverty, percentage of houses with a strong roof, and percentage of houses with strong walls. The equation for the model is as follows:

$$\%\ \textit{houses destroyed} = f(\textit{wind speed}, \textit{poverty}, \textit{density}, \%\ \textit{strong wall}, \%\textit{strong roof})$$

AN IMPACT MODEL BASED ON MACHINE LEARNING UTILISING HISTORICAL DATA ON TROPICAL CYCLONE DAMAGE IN THE PHILIPPINES WAS DEVELOPED TO PREDICT FUTURE DAMAGE AND TAKE EARLY ACTIONS.

The model is similar to one developed by the Netherlands Red Cross (510) and is currently used by the Philippines Red Cross to forecast damage and take early actions to prevent damage. The same dataset used was the same as the 510 model, which encompasses 12 historical tropical cyclones between 2012 and 2016, and has damage records for approximately 1600 damaged municipalities. However, a random forest algorithm as used by the Red Cross was applied, instead of linear regression.

The model using the entire 510 database and a random forest algorithm from scikit-learn was used. After conducting a feature importance analysis, the number of features was reduced to the five most important ones: wind speed, population density, poverty, percentage of houses with a strong roof, and percentage of houses with strong walls. The model was then fine-tuned by adjusting the number of trees, the maximum number of features per tree, the minimum number of samples per leaf, and the sample selection bias correction was then applied. The sample selection bias correction gives more weight to underrepresented samples, and in this case, a simplified method was used to give twice the weight to the damage from small historical tropical cyclones that the model struggled with (Utor (2013), Hagupit (2014), Kalmaegi (2014), and Sarika (2016).

The model was tested by using it on 11 historical tropical cyclones and leaving one out, to measure its performance. Each historical tropical cyclone was left out once, and the total performance measure was the mean error between the 12 tests. Based on this, some models were shortlisted based on the Mean Absolute Error and Mean Bias Error. For these shortlisted models, the damage for all 1000 years of tropical cyclones in the STORM database (historical climate conditions) was calculated. The expected annual houses destroyed for the shortlisted models was then compared with the mean annual houses destroyed from 2012, 2014, 2015, and 2016 (excluding 2013 because it included super typhoon Haiyan). The model with the best match to the expected annual houses destroyed was selected, which was a model with 100 trees, a minimum of 50 samples per leaf, a maximum of 4 features per tree, and the simplified sample selection bias correction technique applied. The Mean Absolute Error of the model is 4.98%, and the expected annual houses destroyed in the Philippines is 90,533, according to the model, compared to 112,046 based on historical data. The same model and same dataset were used to calculate the number of houses with minor damage.

Loss

Based on the calculated number of houses destroyed and damaged, the total monetary value of the loss was estimated. This was done by correlating the impact on houses to the total loss from historic events using the EM-DAT global disaster database (Guha-Sapir et al.).This ensures that the estimate from this study covers all economic losses and not just losses to houses.

Percentages of the replacement values were assigned to all damage levels on the houses, from minor to complete damage. It was assumed that houses with minor damage have lost 5% of their replacement value, while destroyed houses have lost 100%. The sum of minor and complete damages to houses is used as an indicator for total loss, by taking the loss in EM-DAT from the 12 tropical cyclones that this study's model was based upon and correlating it to the damage to houses in these events. By calibrating the loss model, all types of loss will be taken into account without explicitly modeling them.

CALCULATING THE NUMBER OF HOUSES DESTROYED AND DAMAGED BY CORRELATING THE IMPACT ON HOMES TO THE TOTAL LOSS FROM HISTORICAL EVENTS, THE TOTAL MONETARY VALUE OF THE LOSS WAS ESTIMATED TO HELP PROVIDE ACCURATE AGGREGATE LOSS NUMBERS OVER MULTIPLE EVENTS.

This approach can provide accurate aggregate loss numbers but may underestimate the loss in regions with relatively few houses compared to other exposure, and may overestimate the loss in areas with a relatively high number of houses compared to other exposure. In rural areas other exposure relative to houses may be from agriculture, whereas in urban areas this other exposure will be made up of office and industrial buildings. Since the model resolution is municipalities with approximately 50-100 thousand people, it is expected that there are always some other exposure types for each computational unit. Errors may also occur for relatively small wind speeds that do not cause damage to houses but do damage agriculture crops or other exposure. This error is expected to be local for some events but in aggregates over multiple events the numbers are expected to be more accurate.

Welfare Loss

Disasters often have a disproportionate impact on low-income individuals, as even a small monetary loss can have a significant impact on their well-being. Traditional methods of measuring disaster losses, such as asset loss estimates, do not accurately reflect the impact of a disaster on society. To address this issue, welfare economics provides tools to convert monetary losses into a unit that represents the amount of utility derived from these losses (see Figure 9).

There are two commonly used methods in welfare economics: risk aversion and equity weights. The risk aversion approach, as described by Kind et al. (2017), is more widely accepted by economists and has a direct link to insurance, making it easier to understand intuitively. It is based on the idea that individuals are willing to pay extra to avoid large losses, as these losses have a disproportionate effect on their well-being.

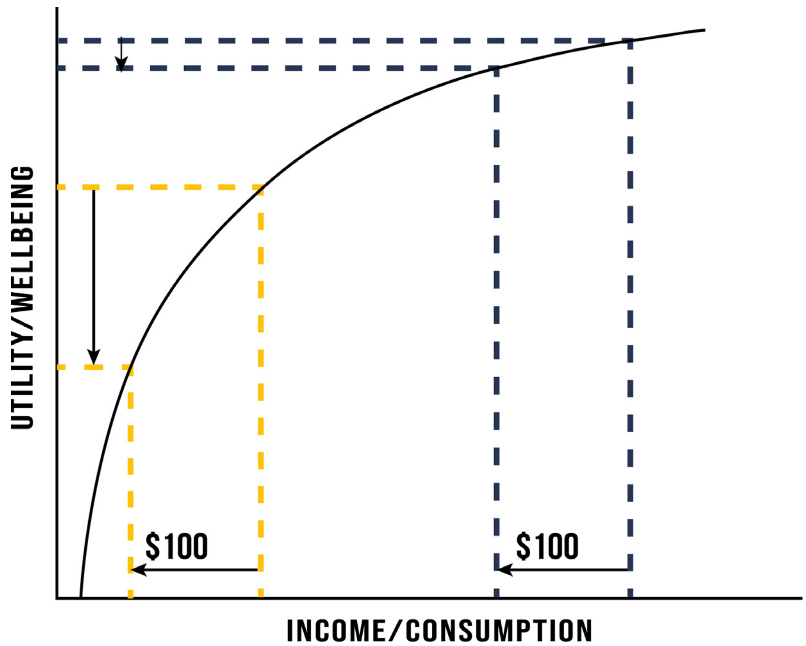


Figure 9
Utility curve that is applied to translate monetary losses into welfare losses (Kind et al., 2017).

The risk aversion factor indicates how much more someone is willing to pay to avoid disaster losses. For example, a risk aversion factor of 1.1 indicates that someone is willing to pay 10% more than the expected annual damage to avoid disaster losses. This factor is typically higher for low-income individuals than for high-income individuals. This method is only applicable when losses are not fully covered by insurance or assistance programs.

To calculate the consumption loss required to calculate risk aversion, the entire financial recovery process of a household must be simulated. The approach of Markhvida et al. (2020) was followed and insights from Hallegatte et al. (2017) was incorporated, who suggest that a portion of a person's consumption comes from the government and is therefore resilient to losses. An assumption was made that insurance and/or assistance programs cover 30% of disaster losses.

It should be noted that there are many assumptions in these calculations, and therefore the results of the risk aversion calculation should be considered a rough estimate only.

Expected Annual Figure

The expected annual houses destroyed, people affected, monetary loss and welfare loss are calculated by the following formula:

$$EAD = \sum_{i=0} \frac{E_i}{T}$$

Whereby E_i is the houses destroyed /loss in event i, T is the number of years represented by the events (i.e. 1,000 years) and EAD is the Expected Annual Damage (either houses destroyed or monetary loss).

Climate Change

For future risk assessment, the same approach was used as for historical risk, but with an alternative version of the STORM database (Bloemendaal et al., 2022). This version is based on statistical characteristics of tropical cyclones, which were derived from climate models. Four climate models were applied to the period between 2015 and 2050, as described in Bloemendaal et al. (2022). However, the tropical cyclone intensities in these models are known to be underestimated, so a bias correction was applied based on the differences between the model intensities and the actual intensities observed from 1980 to 2017. This correction is only available for the RCP8.5

scenario, but the differences in impact between the different emission scenarios are small before 2050 (Bloemendaal et al., 2022). Unfortunately, no data is available for the period after 2050. The four models used in this study are also part of the Coupled Model Intercomparison Project[13] (CMIP) that is used by the Intergovernmental Panel on Climate Change[14] (IPCC).

13. CMIP Overview, https://wcrp-cmip.org/cmip-overview/#overview

14. Intergovernmental Panel for Climate Change (IPCC), https://www.ipcc.ch/

Climate model	Description
CMCC-CM2-VHR4	Developed by Euro-Mediterranean Centre on Climate Change (CMCC) Foundation, largely based on the Community Earth System Model (CESM) operated at National Centre for Atmospheric Research (NCAR) in the United States (Cherchi et al., 2019).
CNRM-CM6-1-HR	Developed by Centre National de Recherches Météorologiques and Cerfacs, both in France (Voldoire et al., 2019)
EC-Earth3P-HR	Developed by a consortium of 27 European institutes (Haarsma et al., 2020)
HadGEM3-GC31-HM	Developed by Hadley Centre Global Environment Model 3 from the UK meteorology office (Roberts et al., 2019)

Table 1
Four different climate models applied in this study.

2.3.
RISK ANALYSIS FOR HISTORICAL CLIMATE

Hazard analysis

The map in Figure 10 illustrates the 10-minute sustained wind speeds which are surpassed once in approximately 50 years. The map indicates that the Philippines is significantly more susceptible to extreme wind speeds due to tropical cyclones compared to other ASEAN countries under historical climate conditions. Notably, the center of the Philippines experiences such wind speeds, whereas wind speeds considered typhoon intensity are infrequent by historical (1980-2018) standards in Cambodia and Viet Nam.

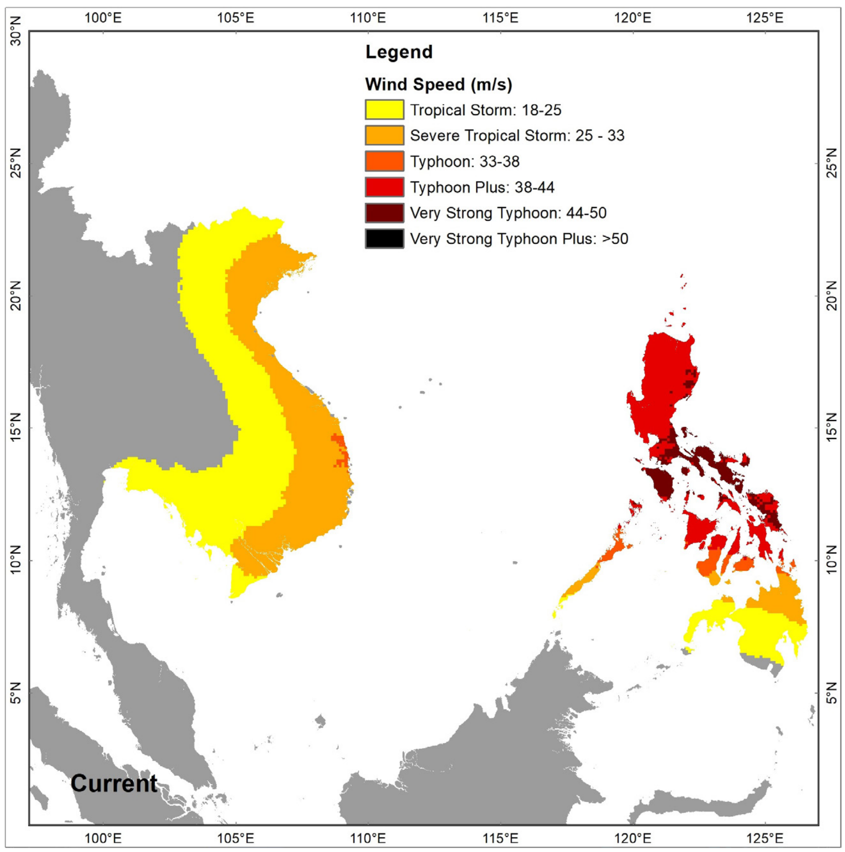


Figure 10
Ten minute sustained wind speeds with a 50-year return period in Southeast Asia given historical climate conditions.

Risk analysis

Table 2 presents the average annual impacts of tropical cyclones based on historical (1980-2018) climate conditions. The results show that the Philippines is the most affected country in terms of the number of houses destroyed, monetary damage, and welfare loss. The country is estimated to lose approximately 0.5% of its GDP annually due to tropical cyclone damage. On the other hand, Cambodia and Viet Nam experience an annual loss of 0.1% and 0.05% of their respective GDPs. The impact of tropical cyclones is further amplified by the welfare loss, which can add an additional 10-25% to the damage caused by these events. This is due to the fact that low-income individuals are disproportionately affected by disasters and are theoretically willing to pay extra to avoid large losses. The larger risk aversion in the Philippines is attributed to the greater catastrophic impact of tropical cyclones and higher levels of income inequality in the country. These results highlight the potential benefits of tropical cyclone risk transfer schemes, such as insurance.

Country	Number of houses destroyed per year	Monetary loss (thousands of USD per year)	Welfare loss (thousands of USD per year)
Cambodia	950	12,930	1,650
Philippines	91,000	2,058,000	443,000
Viet Nam	22,000	463,720	66,970
Total	**113,950**	**2,535,000**	**511,600**

Table 2
Expected annual impacts from tropical cyclones for historical climate.

Figure 11 provides a visual representation of the expected annual monetary losses due to tropical cyclones in each country, based on historical climate conditions. The map highlights the fact that the Philippines is much more prone to damage from tropical cyclones compared to Cambodia and Viet Nam. In the Philippines, the center of the country is most at risk, while the south and northwest regions are relatively less affected. On the other hand, Viet Nam is more likely to experience damage from tropical cyclones than Cambodia, although the magnitude of the losses may be smaller. These results provide a useful tool for disaster risk management, as they help identify areas that are most vulnerable to tropical cyclone damage and inform the development of targeted risk reduction strategies.

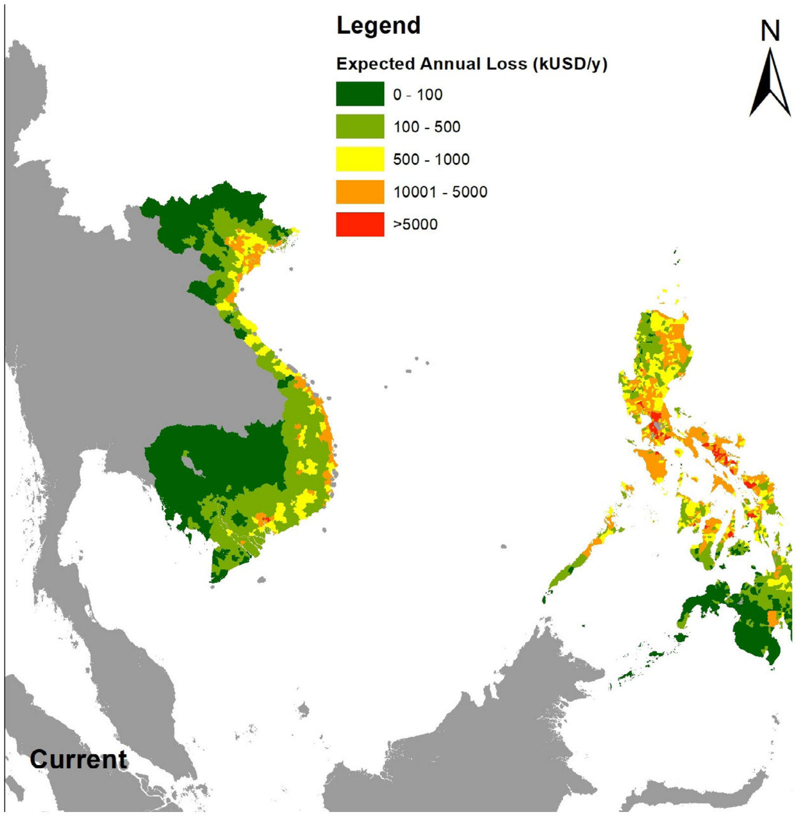


Figure 11
Expected annual monetary loss for the historical climate in thousands of USD per year.

Figure 12 displays the exceedance curves for monetary loss for Cambodia, the Philippines, and Viet Nam. These curves illustrate the likelihood of monetary losses from tropical cyclones exceeding a certain amount, based on historical climate conditions. For example, the figure indicates that a loss of USD 8.1 billion from tropical cyclones is exceeded roughly once in every 100 years in the Philippines. The graph demonstrates that in Cambodia, the probability of losses from tropical cyclones exceeding a few hundred million USD is low, and for Viet Nam, losses are unlikely to go beyond USD

2 billion. In the Philippines, monetary losses in the billions of US dollars from tropical cyclones are quite frequent, and total losses exceeding USD 10 billion are expected to occur approximately every 200 years.

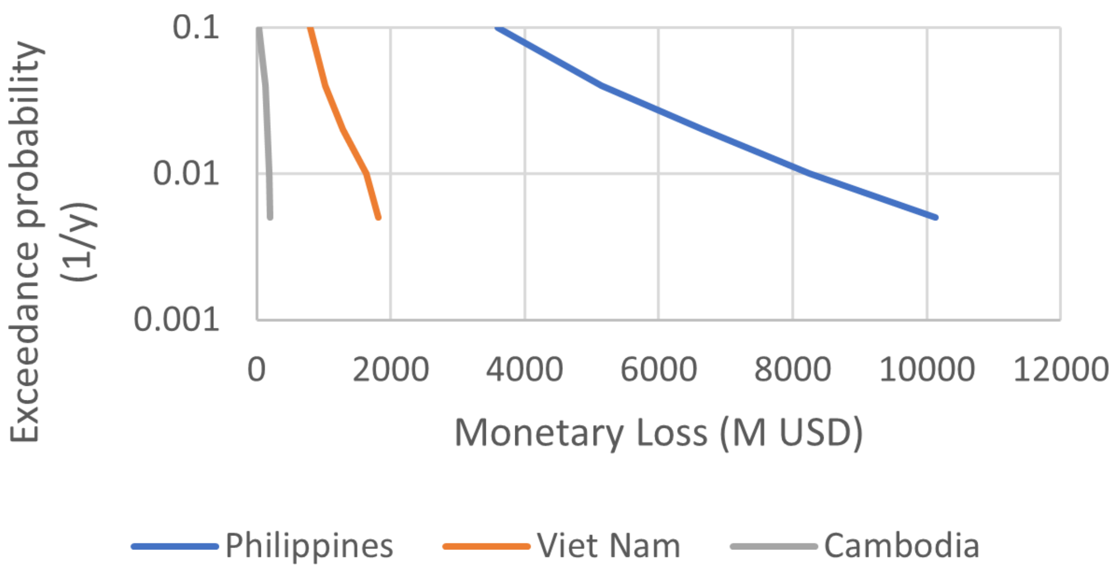


Figure 12
Loss exceedance curve for monetary loss for historical climate.

Probability of simultaneous impact in multiple ASEAN countries

Some of the possible tropical cyclones in Southeast Asia are transboundary. This means that multiple countries in Southeast Asia are affected at the same time in catastrophic ways. About 24% of the damage from cyclones occurs in such events (i.e. >1000 houses destroyed in at least 2 countries). This shows that tropical cyclones are a transboundary problem in Southeast Asia.

Figure 13 presents the likelihood of transboundary tropical cyclones that cause significant damage in three countries simultaneously. This figure shows the damage exceedance curve of tropical cyclones that destroy at least 1000 houses in three countries, at least 1000 houses in two countries, and the damage exceedance curve of all damage in Cambodia, the Philippines, and Viet Nam. This is based on the damage calculated for 22,500 tropical cyclone tracks from the STORM database (Bloemendaal et al., 2020), which spans over a period of 1000 years in the western Pacific region. The results indicate that only 18 cyclones would result in the destruction of more than 1000 houses in each of Cambodia, the Philippines, and Viet Nam, which represents a return period of approximately 56 years. This highlights not only the rarity of such events, but also the importance of addressing the transboundary nature of tropical cyclones in Southeast Asia. The storm tracks for these 18 cyclones are depicted in Figure 14.

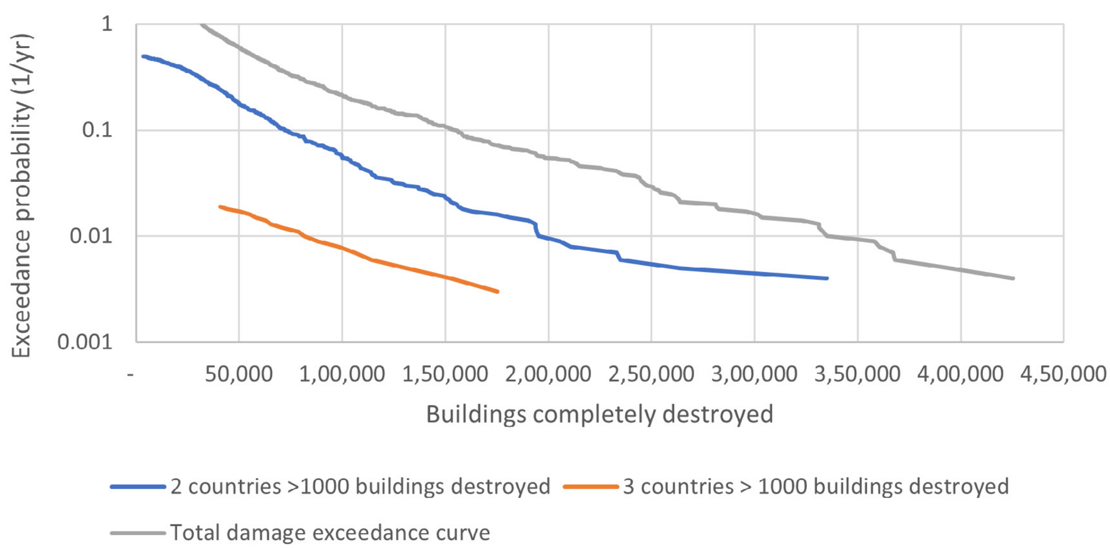


Figure 13
Damage exceedance curve showing how often tropical cyclones of different magnitudes occur identifying the transboundary nature of these events.

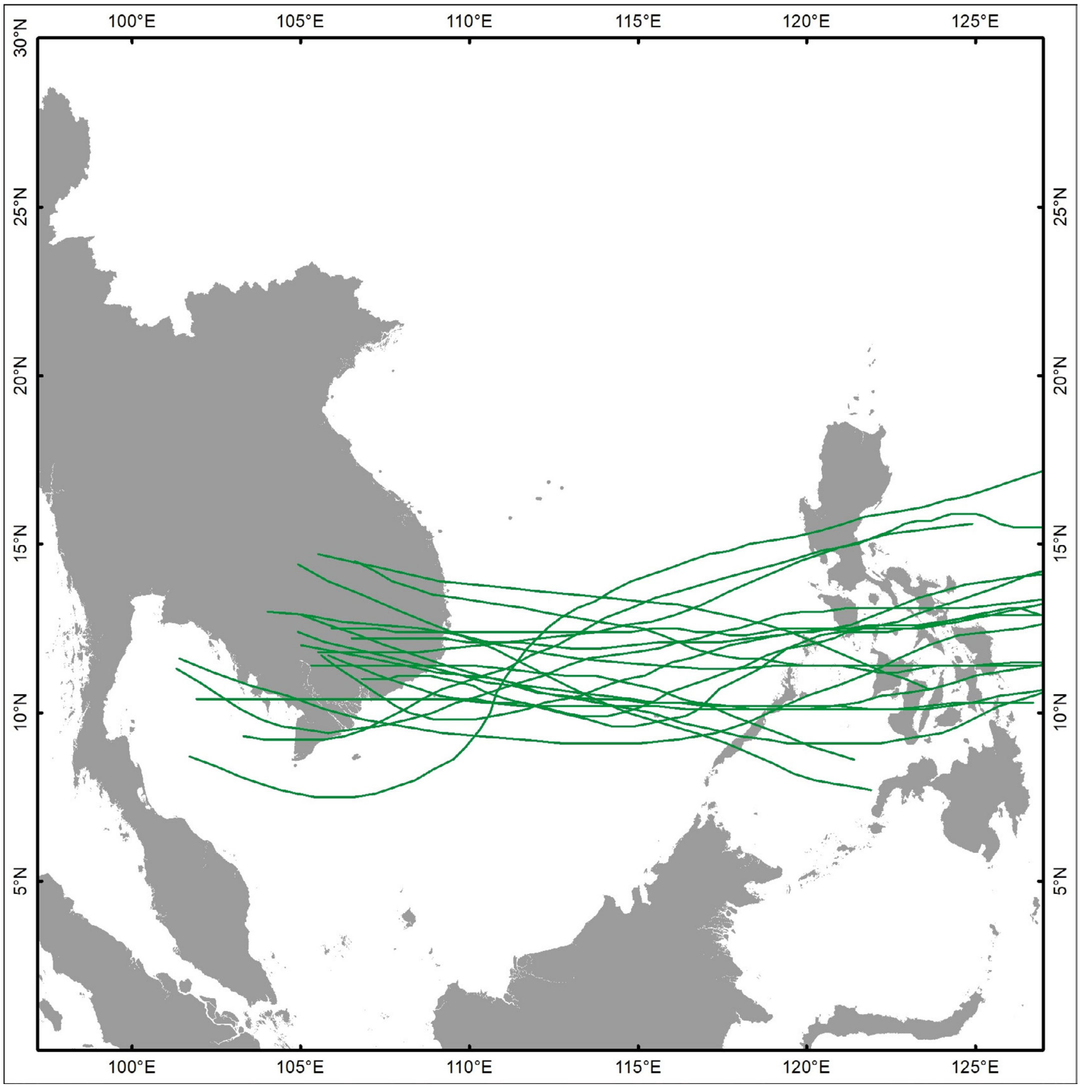


Figure 14
Eighteen tropical cyclone tracks from the STORM database (Bloemendaal et al., 2020) that can cause the destruction of more than 1,000 houses in three different ASEAN countries (Cambodia, the Philippines, and Viet Nam).

The events that destroy 1,000 houses in at least two countries (Philippines and Viet Nam or Cambodia and Viet Nam) are much more common. In the STORM database, it was found that there were 497 tropical cyclones that could cause such transboundary events. This corresponds to a return period of about once every two years given current climate conditions.

2.4.
RISK ANALYSIS FOR FUTURE CLIMATE

The frequency and intensity of tropical cyclones are expected to change as a result of climate change. However, there is limited information available about these changes and much of the understanding of future tropical cyclones is based on a recent study by Bloemendaal et al. (2022). This study only provides data for the period between 2015-2050 for the SSP5-8.5 scenario. For short-term climate change predictions, the differences between emission scenarios are minor, and the Global Climate Model used is more important than the emissions scenario.

Bloemendaal et al. (2022) analyzed four different Global Climate Models: CMCC-CM2-VHR4, CNRM-CM6-1-HR, EC-Earth3P-HR, and HadGEM3-GC31-HM (more information in table 1, section 2.2). The models are made for similar purposes but because they are developed by different teams using different assumptions they may differ in results. Therefore, they are commonly used in ensembles (groups of models), such as the Coupled Model Intercomparison Project (CMIP), which is also used by the Intergovernmental Panel on Climate Change (IPCC). The models can produce substantial differences in their estimates and can be considered as an uncertainty range.

It is important to note that the study by Bloemendaal et al. (2022) presents the climate for the 2015-2050 period, and the current climate is likely to be somewhere in between the historical climate and these future climate model results.

Hazard analysis considering future climate

Figure 15 displays four maps that illustrate the 10-minute sustained wind speeds that are expected to be surpassed once in approximately 50 years under four different climate models. The maps highlight that the Philippines will still be significantly more vulnerable to extreme wind speeds resulting from

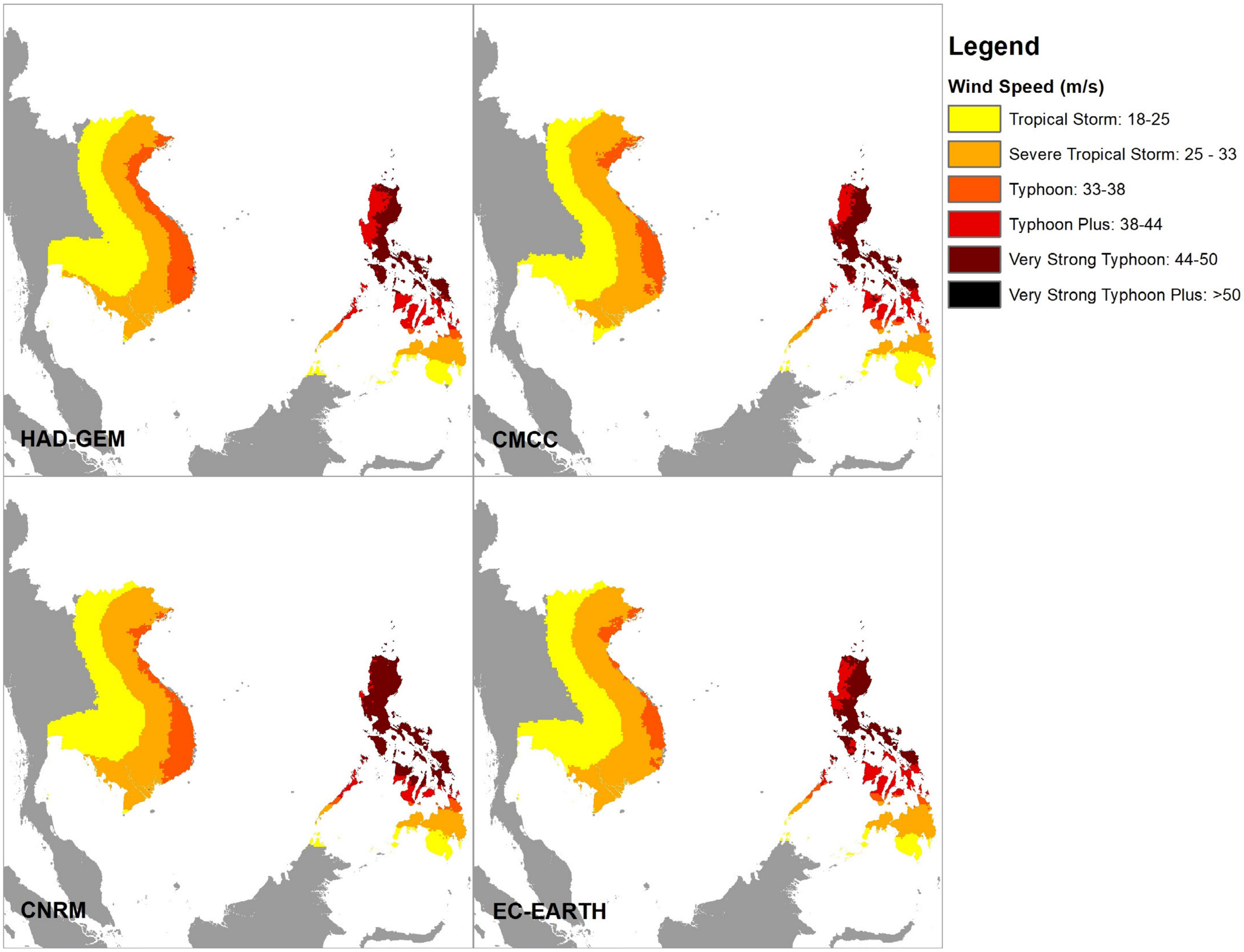


Figure 15
Ten minute sustained wind speeds with a 50 year return period in Southeast Asia given 2015-2050 climate conditions for four different climate models.

tropical cyclones compared to other ASEAN countries. However, under these models, large regions of Viet Nam will experience wind speeds that are considered typhoons, and Cambodia and Lao PDR will encounter more extreme wind speeds. Even Bangkok in Thailand may face tropical storm conditions with 10-minute sustained wind speeds that can cause considerable damage. All models agree that wind speeds will intensify, but the HadGEM3-GC31-HM and CNRM-CM6-1-HR models predict the most severe increases.

Risk analysis considering future climate

Table 3 illustrates the range of potential future monetary loss from tropical cyclones, as estimated by four different global climate models. These projections take into account changes in hazard factors such as the frequency and intensity of storms, but do not consider changes in exposure, such as population growth or declining household size, or changes in vulnerability, such as improved construction practices.

Country	Expected Annual Houses destroyed (Thousands per year)		Expected Annual Monetary loss (Millions of USD per year)	
	Low	High	Low	High
Cambodia	1.4 (+40%)	2.0 (+100%)	18 (+38%)	26 (+100%)
Philippines	104 (+14%)	132 (+45%)	2,417 (+17%)	2,975 (+45%)
Viet Nam	47 (+113%)	48 (+118%)	973 (+109%)	1,001 (+115%)
Total	**152 (+33%)**	**182 (+59%)**	**3,408 (+34%)**	**4,002 (+58%)**

Table 3
Future annual expected monetary loss due to tropical cyclones. This is the range based on the outcomes of four different global climate models for the period 2015-2050 with the SSP5-8.5 scenario. Between brackets is the percentage increase compared to historical climate.

As seen in Table 3, Cambodia and Viet Nam are expected to experience the largest increases in risk, when compared with the historical climate. Although the Philippines will suffer the most among the three countries on an absolute risk metric term, Viet Nam will suffer from the highest increase in losses, percentage-wise, from the baseline historical climate. The results from the models are in general agreement about the increase in risk in Viet Nam, while the CNRM model is the main contributor to the extreme increase seen in Cambodia. All models provide similar results for the number of houses destroyed and monetary loss metrics.

Figure 16 compares the historical climate loss exceedance curves with those estimated by the four global climate models. The curves indicate that extreme events in Viet Nam in particular may become much more severe, with a 1-in-200-year event potentially causing up to USD 4-5 billion in damages in the future, compared to less than USD 2 billion under historical climate conditions. The CNRM model predicts the largest increases in risk, but there is some disagreement among the models regarding the future intensity of frequent events in the Philippines and rare events in Cambodia.

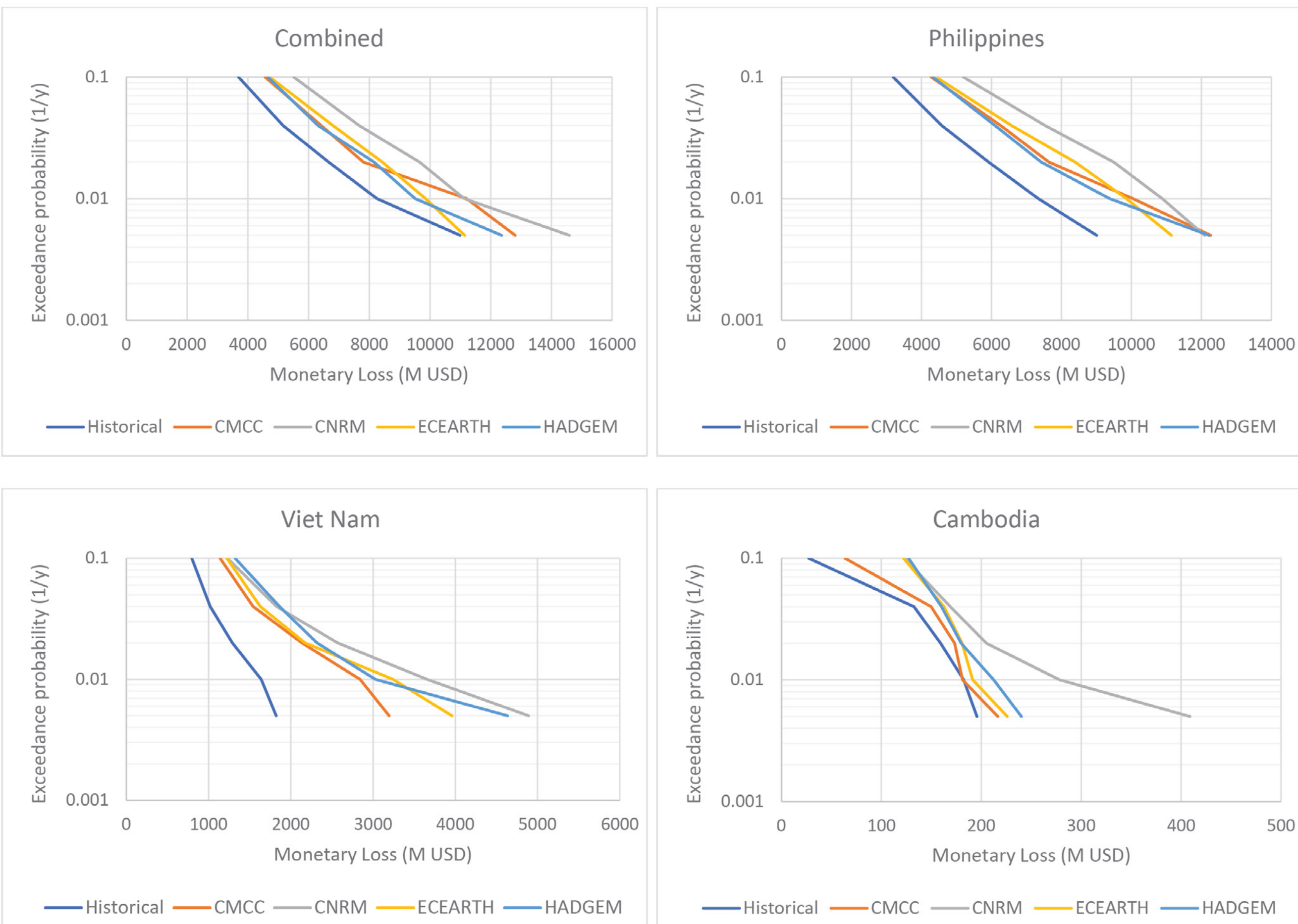


Figure 16
Loss exceedance curves of monetary loss for four different climate models and historical climate. This is for the SSP5-8.5 scenario for the period of 2015-2050.

Figure 17 shows the future expected annual monetary loss maps for the four different climate models. The four different models give a very similar geographic distribution of future risk with only minor differences among the models. Especially the coastal provinces in the north and center of Viet Nam will experience large increases in expected annual losses. This highlights the importance of adapting to future tropical cyclone risk in these regions.

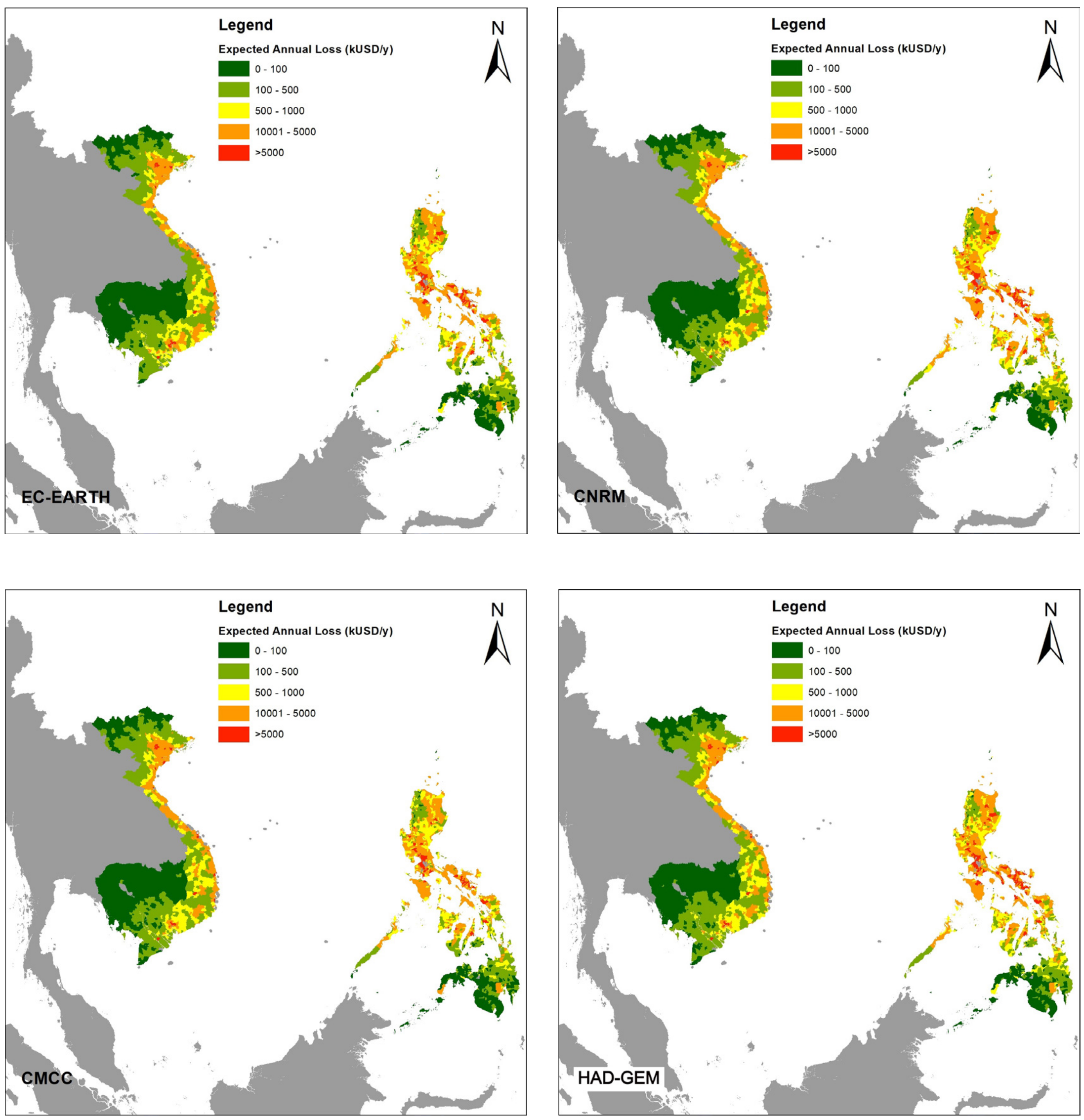


Figure 17
Future expected annual monetary loss in thousands of USD per year, based on four different global climate models for the period of 2015-2050 using the SSP5-8.5 emissions scenario. The four different climate models can be regarded as an uncertainty range.

Change in the probability of transboundary events

According to the results from the four global climate models, transboundary events in Southeast Asia are expected to become much more frequent and will account for a larger share of the total expected annual loss. Under historical climate conditions, only about 24% of the damage was caused by transboundary events. However, in the near future, this could increase to 30-37% depending on the climate model considered. This points to the need for countries in the region to work together and coordinate their disaster risk management efforts to better prepare for and respond to transboundary tropical cyclones.

Table 4
Future transboundary tropical cyclone risk in Cambodia, the Philippines, and Viet Nam combined, for RCP8.5 2015-2050, using 4 different climate models.

Climate model	Percentage of damage from transboundary events	Return period, 3 countries each having >1,000 buildings destroyed (yr)	Return period, 2 countries each having >1,000 buildings destroyed (yr)
Historical climate	24%	1:56	1:2.0
CMCC-CM 2-VHR4	30%	1:23	1:1.4
CNRM-CM 6-1-HR	37%	1:13	1:1.1
EC-Earth3 P-HR	31%	1:22	1:1.1
HadGEM3-GC31-HM	34%	1:28	1:1.2

HANOI, THE POLITICAL CENTER AND ONE OF THE TWO ECONOMIC HUBS OF VIET NAM, WITH A POPULATION OF 20 MILLION, IS AN EXAMPLE OF A THRIVING CITY IN THE ASEAN REGION WHICH IS AT SIGNIFICANT RISK AS TROPICAL CYCLONES ARE PROJECTED TO INCREASE ACROSS THE REGION BECAUSE OF CLIMATE CHANGE IMPACTING ALL SECTORS.

Who is at risk?

The risk of tropical cyclones is projected to increase across the region because of climate change and projected population growth, impacting all sectors. For example, Viet Nam is becoming a global manufacturing hub centered around Hanoi and Ho Chi Minh City. Geographically, the most significant changes in tropical cyclone risk will occur in northeastern and central eastern Viet Nam, including the metropolitan area of Hanoi. Home to approximately 20 million people, Hanoi serves as the political center and one of the two economic hubs of Viet Nam. The second economic hub Ho Chi Minh City is also at considerable risk. This could damage production locations or could disrupt the workforce and cause downtime days. In the Philippines, northeastern Luzon may experience heightened tropical cyclone risks, while the southern region (Mindanao) is expected to remain a relatively low-risk area. Northeastern Luzon produces most of the rice.

Coastal regions and flat delta areas are especially at risk because tropical cyclones typically slow down over land and become stronger in coastal areas. Furthermore, tropical cyclones can cause storm surges at sea that can cause coastal flooding in these coastal areas. Sea level rise (not included in this analysis) can further exacerbate the impact on coastal areas due to tropical cyclones because the storm surges will be further increased by a higher mean sea level. Sea level rise can be both caused by rising seas (e.g. because of climate change) or by subsidence (e.g. due to groundwater extraction).

All types of buildings can be vulnerable to extreme winds, but small differences in the design and the strength of materials used as well as the construction quality, such as how well the roof is secured to the rest of the building, the quality of a metal deck in an industrial building, and the presence of shutters

WHEN DISASTER STRIKES, HOUSEHOLDS THAT SPEND MOST OF THEIR INCOME ON NECESSITIES CAN EXPERIENCE A SUBSTANTIAL DECLINE IN THEIR STANDARD OF LIVING SINCE THEY HAVE LITTLE OR NO EXTRA INCOME FOR RECONSTRUCTION.

to protect windows, can significantly influence the extent of damage during a storm. The immediate surroundings of a house also play a crucial role in wind damage; structures shielded by trees or other buildings experience lower wind loads compared to those situated in open fields. As a result, lower quality houses outside urban areas may be particularly susceptible to wind damage.

Agricultural crops can also suffer from extreme winds. Large crops with relatively small root systems, such as corn, are especially vulnerable. Rice, a critical crop in Southeast Asia, is prone to strong winds and flooding caused by tropical cyclones during its later growth stages. Extensive damage to locally consumed crops like rice may contribute to local food shortages, necessitating increased food imports, which can be costly in years of already high global food prices. This, in turn, could lead to increased food costs that disproportionately affect the poor, who allocate a substantial portion of their income to food. Strategic food reserves, maintained either on a national or ASEAN level, could be a potential solution to this issue. Another option is transitioning to crops less sensitive to tropical cyclones, such as root crops or low-growing leafy greens.

Impact on the income

Tropical cyclones have a significant impact on the lives of low-income people. When the damage caused is severe, and households lose a significant portion of their assets, the consequences can be devastating. Households that spend most of their income on necessities and have little or no extra income for reconstruction are particularly vulnerable and can experience a substantial decline in their standard of living after a disaster.

Figure 18 highlights the disparities in the welfare loss in different regions, with the highest welfare loss seen in areas outside of major cities such as Manila, Hanoi, Ho Chi Minh City, and Phnom Penh. This is because the population in these cities have relatively high incomes compared to the rest of the country. When a household experiences catastrophic damage and loses a large portion of its assets, it can lead to a severe decline in living standards. Households that spend most of their income on necessities have limited resources to recover from the damage, making them particularly vulnerable to the effects of tropical cyclones. Figure 18 also reveals that the Philippines has more welfare loss than Cambodia and Viet Nam. This is partly driven by income inequality, and because damage in the Philippines is more often destructive rather than minor. However, some of these results may also be due to the fact that income distribution data in the Philippines is of a finer resolution than

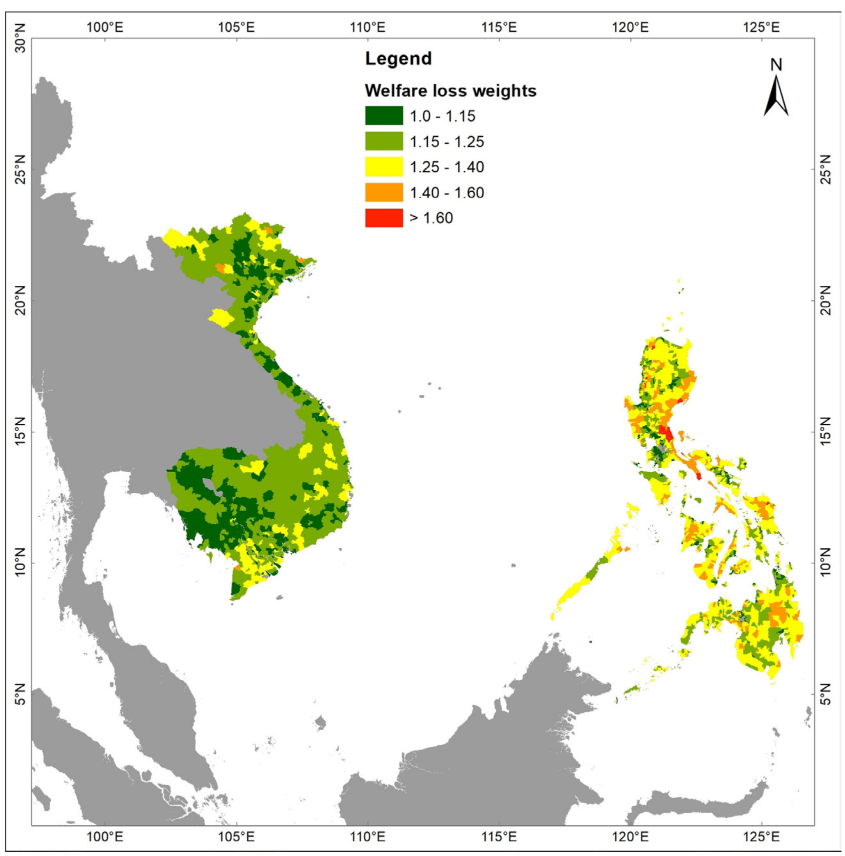


Figure 18
Welfare loss weights (ratio between welfare loss and basic loss) under historical climate conditions.

in Cambodia and Viet Nam, so the very low-income earners are better represented in the Philippines dataset. Given the non-linear nature of the risk aversion metric, this can result in a slight underestimation of the risk aversion in Cambodia and Viet Nam.

Additionally, the welfare loss metric can also be used to compare different compensation schemes and evaluate which schemes are the most beneficial for society. This can help to prioritize investments in compensation schemes, ensuring that resources are used in the most effective way to reduce the impact of tropical cyclones on society.

Gender and disability

Table 5 presents the estimated annual number of individuals exposed to the risk of building collapse, broken down by gender and disability. For Cambodia and the Philippines, the data includes those with moderate to severe disabilities as defined by the relevant national statistics bureau. In the case of Viet Nam, while the disability data is not specified by type, it is still included in the table. There are slight variations in the gender and disability distribution across the three countries, which are reflected in their respective exposure to building collapse risk, as shown in Table 5. It is important to note that fatality rates tend to be higher for vulnerable populations such as women, the elderly, young people, and individuals with disabilities. This increased vulnerability is not accounted for in this study, making it crucial to consider the number of individuals exposed to building collapse risk when developing gender and disability-sensitive risk reduction programs.

Country	Expected number of men in destroyed buildings annually	Expected number of women in destroyed buildings annually	Expected number of disabled people in destroyed buildings annually
Cambodia	1,989 (48.6%)	2,098 (51.3%)	115 (2.8%)
Philippines	188,304 (50.7%)	183,354 (49.3%)	6,536 (1.7%)
Viet Nam	38,808 (49.9%)	38,943 (50.1%)	2,688 (3.4%)
Total	**229,101 (50.5%)**	**224,395 (49.5%)**	**9,339 (2.1%)**

Table 5
Expected number of people in destroyed buildings annually, by gender and disability status for the historical climate (1980-2018) and based on exposure data from the national census bureaus.

2.5. INTERPRETATION AND DISCUSSION ON THE RESULTS

This section provides an interpretation of the tropical cyclone analysis. It addresses the key takeaways, main recommendations and includes a discussion on the study's uncertainty. The goal is to help policymakers use this research to plan for further actions.

Increase in frequency and severity of tropical cyclones

The results from the four different climate models in the study indicate that the frequency and intensity of tropical cyclones in Southeast Asia, particularly in Cambodia and Viet Nam, is expected to increase significantly in the future. Although the increase is not as extreme in the Philippines, it still represents a considerable increase. Given these projections, it may be necessary to re-evaluate the wind maps used in the building codes, enhance enforcement of existing building codes, invest in strengthening buildings, and improve emergency response. Another aspect to consider is workforce development. The governments should start building the awareness and technical capacities of architects and engineers to address the increased risk, while developing strategies, and/or implement forecast-based action schemes to better prepare for the potential impacts of these storms.

Wind maps in the building codes

Building codes provide crucial design guidelines for engineers, architects and builders to ensure the safety and stability of buildings. One essential aspect of these guidelines is addressing a building's capacity to withstand extreme events, such as extreme wind loads. Adhering to building codes helps prevent developers from compromising safety to cut costs, and as such, compliance is often mandatory. Building codes serve as an indispensable guide for developers, architects, and structural engineers.

BASED ON THE RESULTS OF THIS STUDY, IT IS RECOMMENDED THAT COUNTRIES UPDATE BUILDING PRACTICES AND WIND ZONE MAPS BY CONSIDERING STRONGER WINDS—AS A RESULT OF CLIMATE CHANGE—IN THE FUTURE RATHER THAN RELYING ON HISTORICAL OBSERVATIONS.

At present, the Philippines and Viet Nam have established their own building codes. Structural engineers in Cambodia generally follow international building codes for most structures (Vong Seng & Mom Mony, 2008). Building codes typically draw on best practices from other countries and are updated regularly as new construction techniques become available.

Wind loads are addressed in building codes by specifying the wind forces that different parts of a structure must be able to withstand. Codes often account for varying wind loads within a country. For instance, the Philippine building code differentiates between three wind zones, each with its own construction requirements (Pacheco et al., 2005). A wind zone map, created by PAGASA, is provided so that structural engineers can reference the requirements for a specific location, based on historical wind speed observations. A similar approach is used in the Vietnamese building codes, which base structural requirements on the 50-year wind speed return period, which varies across the country (Le Truong Giang et al., 2010).

Since buildings constructed today are expected to last for decades, it is crucial to update building practices in anticipation of climate changes. This ensures that as many buildings as possible are prepared for stronger winds. Consequently, based on the results of this study it is recommended to update the wind zone map for the Philippines based on climate change wind speed projections, rather than relying on historical observations. It may be necessary to add an extra zone to the wind map to account for stronger winds in the future. Similarly, it is recommended that Viet Nam use wind speed maps that incorporate future wind conditions instead of relying solely on historical data. For Cambodia, it is suggested that structural engineers implementing international building codes also incorporate future wind speeds, rather than historical ones, into their designs. This approach maintains the familiar basic framework for local structural engineers and doesn't require differentiating between building types, as all building types are already covered in existing guidelines. Thus, only the load for calculations needs to be adjusted, rather than the building type-specific requirements.

Adherence to building codes

Adhering to building codes can present significant challenges in certain areas. These codes can be strict and demand that all structures, including houses, adhere to specific standards. An example of this is in the Philippines, where a building permit is required for every structure and is only granted if the designs meet the building code standards. Such requirements inevitably raise the cost of construction, which can be a burden for low-income housing projects. Additionally, finding the necessary engineering expertise to meet these codes can be difficult in some areas. Because of

ONE SOLUTION FOR RESILIENT BUILDINGS COULD BE PROVIDING SAFE TEMPLATE DESIGNS FOR HOUSES (MEETING BUILDING CODE STANDARDS) AND COST-EFFECTIVENESS TO BUILD BECAUSE SIMPLY IMPROVING THE BUILDING CODE IS INADEQUATE TO MAKE COMMUNITIES MORE RESILIENT TO STRONG WINDS.

these issues, some buildings are constructed without the necessary permits, or permits are granted for designs that don't align with the building code. Furthermore, sometimes, the actual buildings differ from the approved designs that had initially met the building code. This issue tends to be more pronounced in certain regions compared to others.

Therefore, simply improving the building code is not enough to make communities more resilient to strong winds. While the current building codes may already differentiate between types of buildings, as is the case in the Philippines, there is room for making it easier for low-income housing to meet these codes and hence remove some of the incentives not to adhere to them. This could be done by relaxing some of the standards for houses but another solution could be to provide template designs for houses that are both safe (meeting building code standards) and cost-effective to build. For instance, after the destruction unleashed by Typhoon Yolanda (Haiyan) in 2013, the National Housing Authority in the Philippines provided such templates. Another approach could involve better training for the construction workforce, local engineers and officials in certain areas. This would help them understand the technical requirements and the importance of the building codes, leading to both better adherence to and more consistent enforcement of these codes.

Increasingly a transboundary problem

These findings suggest the need for a regional approach to addressing the impacts of tropical cyclones in Southeast Asia. With the increased likelihood of transboundary events, it is important for countries to work together to share information and resources, and to develop coordinated risk reduction and response strategies. This could involve improved collaboration between governments, international organizations, and the private sector to provide effective aid and

WITH THE LIKELIHOOD OF TRANSBOUNDARY EVENTS INTENSIFYING, SOUTHEAST ASIAN COUNTRIES NEED TO COLLABORATE AND SHARE RESOURCES AND INFORMATION TO ADDRESS TROPICAL CYCLONES' IMPACTS AND DEVELOP COORDINATED RISK REDUCTION AND RESPONSE STRATEGIES.

support in the aftermath of a storm. By taking a regional approach, Southeast Asian countries can benefit from each other's experiences and expertise, and ensure that they are better prepared for the increasing threat of tropical cyclones in the future. For example, in Viet Nam authorities and the community can prepare themselves better with the data and information on the storm characteristics and intensity which are shared from the locations in the Philippines where the same tropical storm has gone, through prior to heading towards Viet Nam. The data collected by the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) on the storm can be shared with Viet Nam Meteorological and Hydrological Administration to take informed actions. On the preparedness to response side, the ASEAN countries have already made agreements on required rice reserves to deal with disasters (ADB, 2018).

Compensation and risk transfer schemes

This study highlights the importance of implementing compensation schemes and risk transfer mechanisms, such as insurance and social protection instruments, that can help alleviate the burden of tropical cyclones on low-income populations. Particular attention should be paid to vulnerable groups such as persons with disability (PWD) and low-income populations for whom losses may have disproportionate impacts on welfare. Social protection instruments can include food transfers, service fee waiver programs, microfinance and cash transfer programs that provide direct assistance in the form of cash for the poor with the long cost of operating and inherent flexibility, to scale up during the disaster emergencies. Another example of successful social protection programs in Southeast Asia is the Pantawid Pamilyang Pilipino Program (4Ps). 4Ps is the Philippines' poverty reduction strategy that provides conditional cash grants to extremely poor households to improve their health, nutrition and education -

TO ALLEVIATE THE BURDEN OF TROPICAL CYCLONES ON LOW-INCOME POPULATIONS, ESPECIALLY VULNERABLE GROUPS SUCH AS PERSONS WITH DISABILITIES (PWD) AND LOW-INCOME POPULATIONS, EXEMPLARY INITIATIVES SUCH AS THE PANTAWID PAMILYANG PILIPINO PROGRAM (4PS) IN THE PHILIPPINES, WHICH PROVIDES CONDITIONAL CASH GRANTS TO IMPOVERISHED HOUSEHOLDS, COULD BE REPLICATED IN ASEAN COUNTRIES.

particularly of children.[15] Such approaches could be considered for disaster relief and be replicated in more ASEAN countries.

By providing financial support to households affected by tropical cyclones, such compensation schemes can help prevent households from falling into extreme poverty, which is particularly important given the devastating impact of tropical cyclones on low-income populations. Thus, these compensation schemes can be seen as a vital tool in ensuring that the impact of tropical cyclones is mitigated, and their consequences are not felt as acutely by low-income populations.

Social impact

Tropical cyclones have significant negative social consequences, including loss of life, population displacement, disrupted livelihoods, and educational setbacks. Historically, the Philippines has been particularly susceptible to these impacts. However, with the rising frequency and intensity of tropical cyclones, countries like Cambodia and Viet Nam may increasingly face similar social challenges in the future.

The impacts of tropical cyclones differ among social groups, and the social impact is often much larger for marginalized groups. However, without high-resolution and differentiated data, it remains very difficult to quantify the disproportionate effect of tropical cyclones on different social groups and specific communities. More data on the vulnerability of different groups is required for improved disaster preparedness, response and recovery. This data can be gathered by preparing detailed demographic profiles of the communities residing in the most high-risk areas shown in Figure 17. This detailed data on communities at high risk could provide valuable insights about unequal impacts of disasters, to help local and national authorities design targeted disaster risk management measures in such

15. The Government of the Philippines, Pantawid Pamilyang Pilipino Program, https://www.officialgazette.gov.ph/programs/conditional-cash-transfer/

THE RESULTS PRESENTED IN THIS STUDY SHOULD BE CONSIDERED AS A GENERAL TREND AND AN INDICATION OF THE RISK RATHER THAN PRECISE PREDICTIONS. ALTHOUGH THE MODELS PROVIDE THE BEST POSSIBLE ESTIMATES, ONE CAVEAT IS THEIR LIMITED ABILITY TO PREDICT TROPICAL CYCLONES' FREQUENCY AND SEVERITY ACCURATELY.

a way that these unequal impacts are countered. In current risk assessments such unequal impact among groups often remains hidden, and this could lead to ineffective measures which do not make the best use of limited resources. Developing community profiles on those who reside in the highest-risk areas enables us to understand their ways of life, resources and livelihoods, which then enables gender and socially-inclusive disaster risk reduction programming.

Uncertainty

It is important to keep in mind that there is always uncertainty in any risk analysis. The results presented in this study should be considered as a general trend and an indication of the risk, rather than precise predictions. When making decisions based on these results, it is essential to consider the uncertainty in the models and make sure that the decisions are robust to potential variations in the risk.

The damage model used in this study is based on reported damages from historical tropical cyclones in the Philippines, which may not fully reflect the damages that could occur in Cambodia and Viet Nam. Additionally, secondary effects such as storm surges, extreme rainfall, and landslides are only indirectly reflected in the damage model, which could lead to further uncertainties in the results. It is also possible that buildings in Cambodia and Viet Nam may be designed for lower wind loads than assumed by the model, which could make them more vulnerable to damage.

Finally, it is important to note that global climate models, which were used in this study, are uncertain by nature and have limited ability to accurately predict the frequency and severity of tropical cyclones. Although the models provide the best possible estimates, nevertheless there is still a degree of uncertainty in their results.

3. TRANSBOUNDARY DROUGHT RISK ASSESSMENT

TRANSBOUNDARY DROUGHTS IN SOUTHEAST ASIA MAINLY OCCUR DUE TO REGIONAL AND GLOBAL PHENOMENA SUCH AS EL NIÑO AND THE INDIAN OCEAN DIPOLE (IOD). THE SEVERITY OF DROUGHTS ALSO DEPENDS ON THE SEVERITY OF CLIMATE CHANGE, AND AT THE LOCAL LEVEL, SEVERITY MAY VARY DUE TO LAND USE/ LAND COVER PRACTICES.

The concept of transboundary drought (also called "regional drought") used in this study refers to drought that occurs across wide regions, spanning the boundary of more than one country in the ASEAN region. A boundary can be the country's political or administrative boundaries, or physical natural resource boundary, such as transboundary rivers which delineate the original catchment area of the river (for example, Cambodia, Thailand, and Viet Nam, which are located in the Lower Mekong River Basin).

Transboundary droughts mainly occur due to regional and global phenomena such as El Niño and the Indian Ocean Dipole (IOD).[16] Much of Southeast Asia lies within the tropical climatic zone, with temperatures above 25 degree Celsius throughout the year. The region is strongly influenced by the Asian monsoons, which bring significant amounts of rainfall to parts of Southeast Asia. The severity of droughts also depends on the severity of such phenomena, the ocean–atmospheric processes and climate change. However, drought severity at the local level may still vary due to land use/land cover practices.

The science-based evidence suggests that climate change has profound implications for both transboundary droughts and the way that drought risks are transmitted. Climate change exacerbates droughts by making them more frequent, longer and more severe. A number of related studies and reports have been undertaken, including the ASEAN and UNESCAP's *"Ready for dry years"*. This report indicates that the future could be even worse and with climate change, many more areas are likely to experience extreme conditions with severe consequences. The ASEAN and UNESCAP's study was done based on the Representative Concentration Pathways (RCPs) introduced in the 5th Assessment Report (AR5) of IPCC. Complementing the study done by ASEAN and UNESCAP, this study has been undertaken using the socioeconomic narratives or "Shared Socioeconomic

16. The Australian Government's Bureau of Meteorology, The Indian Ocean Dipole (IOD), http://www.bom.gov.au/climate/enso/history/ln-2010-12/IOD-what.shtml

Pathways" (SSPs) introduced in the latest AR6 of IPCC. The SSP-based scenarios refine the RCP-based scenarios, providing economic and social reasons for the assumed emission pathways and changes in land use. This study involves a complex scientific process, therefore in order to guide decision makers and other relevant stakeholders to understand it, the steps taken for this assignment are illustrated below.

Figure 19
A workflow describing the process employed in this study (Source: prepared by the authors adopted from different various sources).

3.1. NOTABLE DROUGHT EVENTS IN CAMBODIA, THE PHILIPPINES, AND VIET NAM

Cambodia: Drought events induced by El Niño have negative effects on agricultural production in Cambodia. Historical data reveals that, on average, rice production declines by 10 percent during El Niño. From 1997 to 2002, droughts caused a 20 percent decline in rice production. The 2010s droughts related to El Niño damaged 14,000 hectares of transplanted rice, 3500 hectares of rice seedlings, and 5500 hectares of other crops.[17] Drought was reported as one of the major problems affecting farmers and Cambodia's food security. A survey done by the Cambodia Rice Federation (CRF) with its members, comprising more than 100 agriculture cooperatives, showed that 30 to 40% of their dry seasonal paddy was affected by drought, causing them to replant the paddy. The remaining 60% was recovered but the yield dropped from 4 to 3 tons. It was reported that the 2020 harvest was smaller and the season was delayed for a few months. The areas reported to be affected by drought were Kampong Thom, Battambang, Kampong Cham, Banteay Meanchey, with slight impacts in Kampong Chhnang and Kampong Speu and Takeo.[18] In 2019, the Mekong River Commission (MRC) reported that Cambodia experienced water levels declining steadily over the month of November (with measurements taken of the Mekong River at Kampong Cham), starting from almost five meters down to approximately three meters. Similarly, at the station in Phnom Penh, water levels declined from around four meters to just below three meters. This places the river at the lowest levels it has been in these areas, during this period, over the past 40 years.

Philippines: Between 2018 and 2019, the Philippines was heavily drought affected induced by El Niño. PAGASA reported unusually warm sea surface temperatures (SST) in the central and eastern equatorial Pacific (CEEP), which started in November 2018. Rainfall analyses showed that impacts of the below-normal rainfall conditions in provinces of Western Mindanao and Ilocos Norte were already significant. Drought

17. ReliefWeb, Striking a Balance: Managing El Niño and La Niña in Cambodia's Agriculture, https://reliefweb.int/report/cambodia/striking-balance-managing-el-ni-o-and-la-ni-cambodias-agriculture

18. ReliefWeb, Cambodia, Drought in the Northwest Region, https://reliefweb.int/report/cambodia/cambodia-drought-northwest-region-0600-aug-25-2020

CAMBODIA
IN THE 2010S, DROUGHTS DAMAGED 14,000 HECTARES OF TRANSPLANTED RICE, 3500 HECTARES OF RICE SEEDLINGS, AND 5500 HECTARES OF OTHER CROPS.

PHILIPPINES
FROM NOVEMBER 2018-22 JANUARY 2019, DROUGHT DAMAGED 13,600 HECTARES OF AGRICULTURE CROPS, AND AGRICULTURE LOSSES WERE ESTIMATED AT USD 25.6 MILLION.

VIET NAM
DROUGHT CONDITIONS IN 2019 IMPACTED 54,400 HECTARES IN THE SOUTH-CENTRAL REGION ALONE, MAKING UP 15 PERCENT OF THE TOTAL CROPS IN THE REGION.

conditions were reported in the MIMAROPA Region (provinces of Occidental Mindoro, Oriental Mindoro, Marinduque, Palawan and Romblon, Region IX (provinces of Zamboanga del Norte, Zamboanga del Sur and Zamboanga Sibugay), Region XII (provinces of Davao del Sur, Davao del Norte, Davao Oriental, Davao Occidental and Compostela Valley), the Bangsamoro Autonomous Region in Muslim Mindanao (BARMM) and Metro Manila, where 10 provinces declared a State of Calamity according to the National Disaster Risk Reduction and Management Council (NDRRMC). Five municipalities in Cotabato Province (Region XII) were reported to be affected by the dry spell from November 2018 to 22 January 2019. While PAGASA declared a weak El Niño lasting until June, agriculture regions were suffering its worsening effects, with the Department of Agriculture reported damage to over 13,600 hectares of agriculture crops, comprising mostly rice (81%) and some corn (19%). The agriculture losses were estimated at PhP 1.33 billion (USD 25.6 million). Local media reported that the drought also affected farmers and livestock due to the lack of grass or hay for foraging. A total of 51 local government units (LGUs) declared a state of calamity due to the dry spell. Mindanao was reported as the most affected region, where poverty levels are the highest in the country.[19]

Viet Nam: Drought in the Lower Mekong Region has a serious impact on crop production and food security in Viet Nam. The Department of Water Resources, Ministry of Agriculture and Rural Development (MARD), reported that drought conditions in the north-central region lasted for several months in 2019, due partly to the El Niño condition that started in 2018 and continued into 2019. Nearly 14,900 hectares of crops were estimated to be affected. In the south-central region, about 54,400 hectares were impacted, making up 15 percent of the total crops in the region. According to the Viet Nam Disaster Management Authority (VNDMA), the Mekong Delta and Central Highlands

19. UNOCHA Humanitarian Response, Southeast Asia: Drought - 2019-2020, https://www.humanitarianresponse.info/en/disaster/dr-2019-000113-phl

regions have been facing abnormal weather that could be attributed to climate change. The Mekong River levels in June and July of 2019 were reported to significantly fall below the water levels in previous years, raising concern of exacerbated drought and saline intrusion for the entire Mekong Delta in the 2019-2020 dry season. Drought, water shortage, and saltwater intrusion affected nearly 82,000 households and exposed a higher number of vulnerable people in the Mekong Delta region to significant water shortage risks. A total of 13 out of the 63 provinces of Viet Nam were reported to be affected and three provinces (Kien Giang, Ben Tre and Tien Giang) declared a state of emergency.

3.2. METHOD

To project the future risk, drought hazard is assessed under different projected climate scenarios using general circulation models (GCMs)[20] to estimate rainfall frequency and intensity under selected greenhouse gas (GHG) concentration pathway, e.g., Shared Socioeconomic Pathways (SSPs)[21] such as SSP2-4.5 and SSP5-8.5. The technical description of future climate scenario development is discussed in the following sub-sections.

TRANSBOUNDARY IMPACTS OF DROUGHT TRIGGERED BY EL NINO EVENT

The impact of El Niño and droughts were felt across borders and throughout the region. Droughts and water scarcity had been experienced throughout the region due in part to seasonal dry periods exacerbated by the El Niño weather phenomenon and climate change. The El Niño event of 2018/2019 highlights the interconnectedness of the region and the importance of cooperation and collaboration between the countries in addressing transboundary drought.

20. https://www.ipcc-data.org/guidelines/pages/gcm_guide.html

21. https://unfccc.int/sites/default/files/part1_iiasa_rogelj_ssp_poster.pdf

The proposed process of climate impact modeling for the identification of extreme events for Southeast Asia consists of six methodological steps, as shown in Figure 20 below.

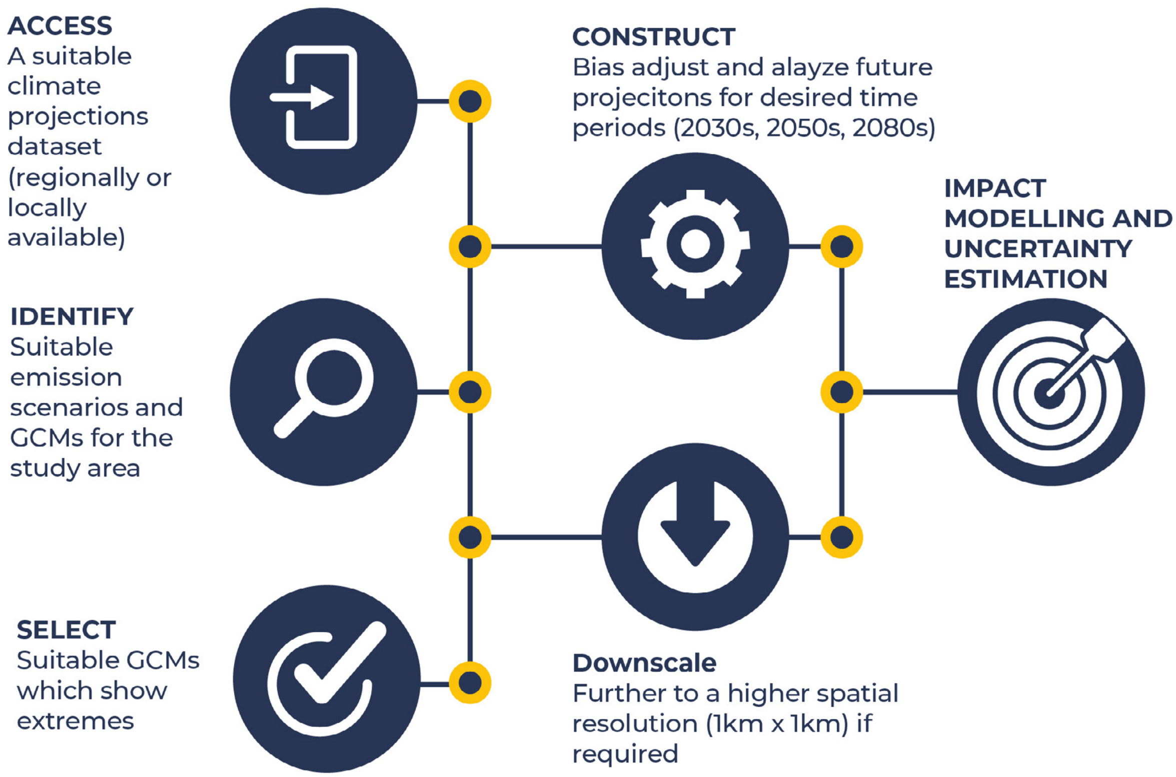


Figure 20
Schematic impact modeling for assessing risk using downscaled GCMs.

Historical as well as projected climate data are needed for the analysis. There are several sources of globally and regionally available historical meteorological datasets. The Climate Hazards Group InfraRed Precipitation with Station (CHIRPS)[22] precipitation data, with 5km-by-5 km resolution, is available from 1981 to date. The Asian Precipitation - Highly-Resolved Observational Data Integration Towards Evaluation (APHRODITE)[23] project precipitation data from Japan's Research Institute for Humanity and Nature (RIHN) and the Meteorological Research Institute (MRI) of Japan Meteorological Agency (JMA), with 25x25 km2 resolution, is available from 1951 to 2007. For temperature, the European Centre for Medium-Range Weather Forecasts (ECMWF)'s ERA5 reanalysis temperature data have been available since 1950. In addition, *in situ* observed

22. https://www.chc.ucsb.edu/data/chirps

23. http://aphrodite.st.hirosaki-u.ac.jp/

meteorological data (rainfall and temperature) over a longer period are also needed for result verifications and GCM bias corrections.

On selecting climate projection data, the ADPC-EOS team acquired future climate change data with acceptable horizontal resolution to assess impacts of future climate relevant sectors for the whole Southeast Asia. The phase 6 of the Coupled Model Intercomparison Project (CMIP6) datasets, the latest dataset, are used for the analysis. The NASA Earth Exchange (NEX) Global Daily Downscaled Projections (GDDP) dataset, or NEX-GDDP-CMIP6 dataset, which has future climate change scenarios from 32 GCMs under 2 emission scenarios (i.e., SSP2-4.5 and SSP5-8.5) with 25x25 km2 resolution provides a good database for starting the analyses.

APPLICABILITY OF THE DIAGNOSTIC TO THE FUTURE

Climate projections do not attempt to forecast the actual day-to-day changes of the system. Instead, they try to predict whether climate seasonal, annual or decadal averages or extremes will be higher, lower or the same as climatological averages.

2030s (NEAR FUTURE)
Useful for near planning purposes
Considers 2016 to 2045, 30-year period climate pattern

2050s (MEDIUM-TERM FUTURE)
Useful for midterm planning purposes
Considers 2036 to 2065, 30-year period climate pattern

2080s (DISTANT FUTURE)
Useful for long term planning purposes
Considers 2066 to 2095, 30-year period

ADPC-EOS TEAM OBTAINED FUTURE CLIMATE CHANGE DATA WITH SUFFICIENT HORIZONTAL RESOLUTION TO ASSESS THE IMPACTS OF FUTURE CLIMATE-RELEVANT SECTORS FOR SOUTHEAST ASIA.

All GCMs of the CMIP6 are not applicable for all regions of the globe. Based on the region of interest, GCMs are required to be selected from the available GCMs under CMIP6. As the present study suggests identifying extreme events in the future with an aim to understand the possible maximum hazardous level for the target areas, it is logical to identify those models amongst the suitable CMIP6 models that depict the extreme events in the future in the Southeast Asian region. It is also suggested to use the **2050-time horizon (taking an average from 2036-2065)** and the **2080-time horizon (taking an average from 2066-2095)** to generate the future climate change scenarios based on the current climate (rainfall and mean temperature from 1985-2014) for the same study area.

It must be noted that since the resolution of CMIP6 datasets is coarse, the results of this study are reliable at the national level at best. A detailed analysis of climate change at local scales will require a future comprehensive analysis of local impacts of climate change, incorporating local and high-resolution climate variables that cannot be obtained directly from coarse resolution projections.

Drought hazard modeling

Hazard assessment and mapping characterize the hazards in terms of their spatial distribution, frequency and intensity. Drought hazard assessment defines and describes the drought in terms of its physical characteristics, magnitude and severity, probability and frequency, and areas affected.

The intensity of drought is derived and illustrated using the Standardized Precipitation Evapotranspiration Index (SPEI). The SPEI has many advantages over other drought indices, such as the Palmer approach, which requires more variables for supply-and-demand modeling of soil moisture. The SPEI is used for this study because of their suitability for indicating the impact of drought on agricultural crops and production. The SPEI are calculated from daily and monthly precipitation records using the ClimPACT[24] tool which can compute the SPEI for up to three intervals of time (i.e., 3-, 6-, 12 months). This temporal flexibility makes the SPEI useful in both long-term hydrological applications and short-term agricultural applications. The negative and positive values of SPEI stand for drought and wet conditions and values are generated annually, as well as for different seasons.

THE SPEI HAS MANY ADVANTAGES OVER OTHER DROUGHT INDICES AND IS SUITED FOR INDICATING THE IMPACT OF DROUGHT ON CROPS AND PRODUCTION.

Drought frequency is computed for climatological periods and variation of drought at different locations. Spatial and temporal variation of drought are investigated for different seasons and annually. The probability of occurrence of drought is computed based on the frequency distribution and expressed in percentage. The occurrences in varying drought categories are analyzed in different time steps of 3, 6 and 12 months so as to compute the indices. The occurrence of moderate to extreme droughts in different durations for each year are analyzed spatially. Drought occurrences are investigated based on the frequency of the events for each drought category in each duration and on the total period of the study. Several weather-related data sources and soil moisture are used to compute and validate the SPEI. Historical drought events are needed to validate the drought risk assessment models.

The classification system of SPEI values shown in Table 6 defines drought severity, while Table 7 describes the

FACTS ABOUT SPEI

Standard Precipitation and Evapotranspiration Index (SPEI) is among the most commonly used drought assessment indices worldwide. SPEI uses both precipitation and temperature, thereby considering the influence of global warning and climate change to some extent.

24. https://climpact-sci.org/

duration used for the index analysis. They also define the criteria for a "drought event" for any of the time scales. **A drought event occurs at any time when the SPEI is less than or equal to -1**. The accumulated magnitude of drought is defined as the positive sum of the SPEI for all the months within a drought event. Figure 21 describes the methodology for the drought hazard assessment using the SPEI.

SPEI values are calculated for the target areas based on the selected Global Climate Models (GCMs) and scenarios for three future time horizons of 2030s, 2050s and 2080s, and for the seasons listed below. In this assignment, the 1985-2014 period is considered as the reference period.

Table 6
Drought Severity defined by the Standardized Precipitation and Evaporation index (SPEI).

SPEI Values	Drought Category or Severity
2.0 +	Extremely wet
1.5 to 1.99	Severely wet
1.0 to 1.49	Moderately wet
-.99 to .99	Near Normal
-1.00 to -1.49	Moderate drought
-1.50 to -1.99	Severe drought
<-2.00	Extreme drought

Table 7
Duration used for the index analysis.

Duration	Corresponding Months
Dry Season	November-April
Wet Season	May-October
Annual	November -October

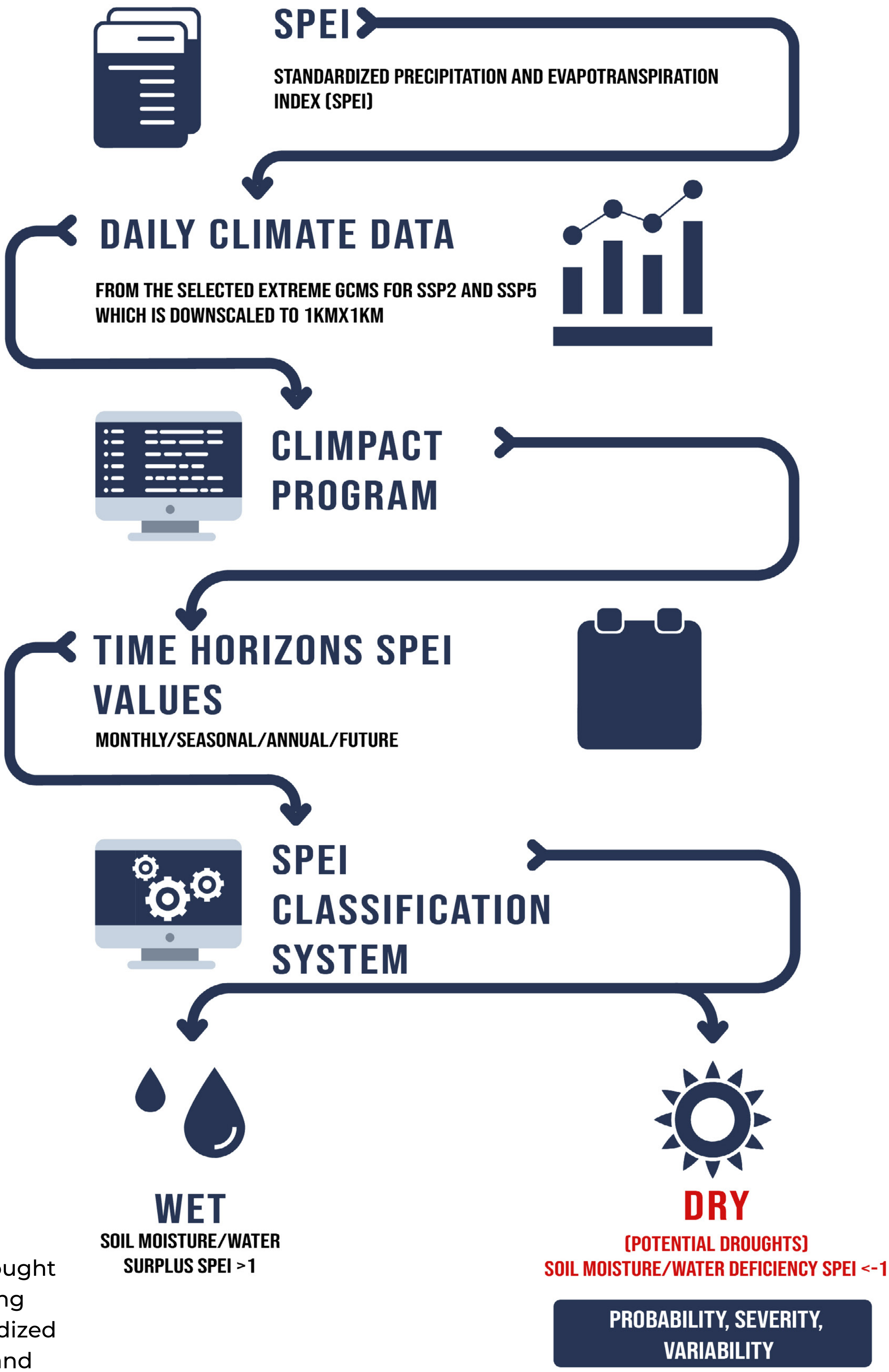


Figure 21
Schematic drought hazard mapping using Standardized Precipitation and Evapotranspiration Index (SPEI).

Exposure

Exposure assessment for drought is focused on the possible impact of drought on the population and croplands in Cambodia, the Philippines, and Viet Nam. The exposure approach is illustrated in Figure 22. The main population datasets are derived from the latest national census of population and housing. The population datasets are collected from the General Statistics Office of Viet Nam,[25] Philippine Statistics Authority[26] and Cambodia National Institute of Statistics,[27] and supplemented with the World Population Prospects 2022 issued by the United Nations' Department of Economic and Social Affairs, Population Division.[28] These datasets consist of worldwide population datasets (by country) from the year 1951 to 2021, as well as projected (estimates) annual population datasets from the years 2022 to 2100 which is useful for estimating the future exposure to drought.

Cropland datasets are collected from the global land use land cover (LULC) data derived from the European Space Agency (ESA)'s Sentinel-2 imagery at 10-meter resolution. It is a composite of LULC maps throughout the year 2020 categorized into 10 land cover classes[29] including crop areas. In addition, ADPC, through its SERVIR-Mekong project, has developed detailed land cover maps[30] for the Lower Mekong region that were also used for this TA.

25. General Statistics Office of Viet Nam: gso.gov.vn

26. Philippine Statistics Authority, Republic of the Philippines: psa.gov.ph

27. National Institute of Statistics of Cambodia: nis.gov.kh

28. World Population Prospects - Population Division - United Nations: https://population.un.org/wpp/Download/Standard/MostUsed/

29. https://www.arcgis.com/apps/instant/media/index.html?appid=fc92d38533d440078f17678ebc20e8e2

30. https://servir.adpc.net/tools/regional-land-cover-monitoring-system

The exposure assessment between the probability and severity of droughts from different climate scenarios and time horizons, and element at-risk such as crop and rice paddy fields are done in the GIS environment as illustrated in Figure 22 below. The result of the exposure assessment shows the estimated area of crop and rice paddy field which is potentially exposed to different levels of probability and severity of drought occurrence.

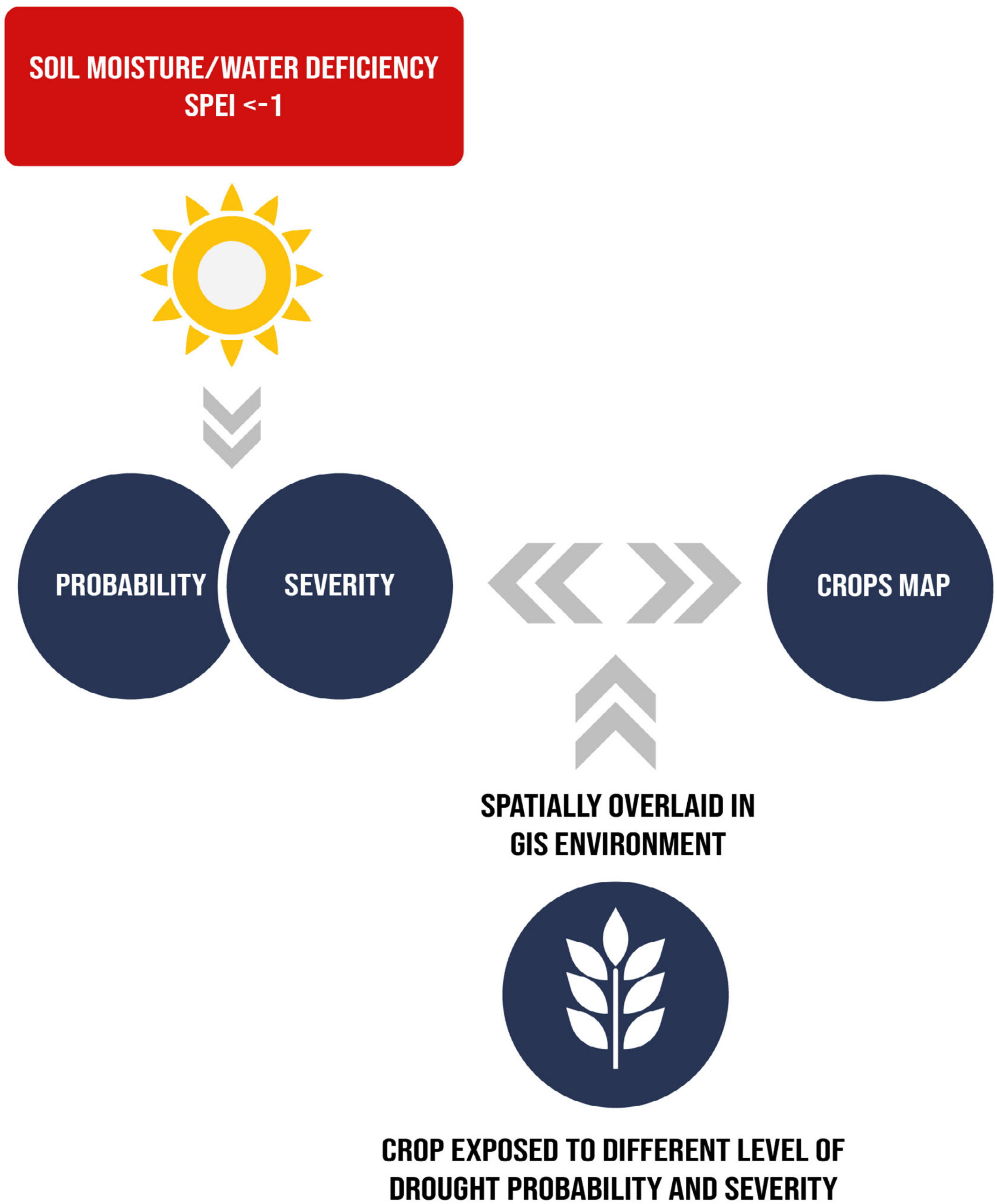


Figure 22 Schematic illustration of exposure assessment.

3.3.
RISK ANALYSIS FOR HISTORICAL CLIMATE

THE PROBABILITY OF DROUGHT OCCURRENCE WERE CALCULATED USING HISTORICAL CLIMATE DATA BETWEEN 1985-2014. CAMBODIA, THE PHILIPPINES, AND VIET NAM ARE EXPECTED TO EXPERIENCE DROUGHT WITH A 30-40% PROBABILITY ANNUALLY.

Climatologically, occurrences of drought in Southeast Asia have heavily been influenced by the El Niño Southern Oscillation (ENSO) and its warm and dry phase. During the El Niño events - usually associated with the late onset and early finish of the rainy season —weak monsoons and less tropical cyclone activity are expected, which lead to drier conditions throughout the region. In this assignment, the current risks were calculated using historical climate data for the period of 1985-2014. This is considered as the baseline period.

For a better understanding of the effects of climate change and the potential changes in precipitation and temperature, the **Standardized Precipitation and Evaporation Index (SPEI)** is used for the drought hazard mapping in this assignment. The SPEI is an extension of the Standardized Precipitation Index (SPI), which is designed to consider both precipitation and potential evapotranspiration (PET) in determining wetness and dryness. Thus, unlike the SPI, the SPEI captures the main impact of increased temperatures on water demand. Like the SPI, the SPEI can be calculated on a range of timescales from 1-48 months. At longer timescales (>~18 months), the SPEI has been shown to correlate with the self-calibrating PDSI.

The spatial (extent) variation of drought occurrence probabilities was investigated for the different seasons defined in Table 6. Figure 23 and Figure 24 show the climatological drought occurrence probability based on the Standardized Precipitation-Evapotranspiration Index (SPEI) for Cambodia, the Philippines, and Viet Nam. The probability of drought occurrence is defined as a period of abnormally dry weather that lasts long enough to cause serious hydrologic imbalance. The probability of drought occurrence is typically expressed as a percentage or a decimal, with a higher value indicating a higher likelihood of drought. The two maps depict the historical drought occurrences during a dry season and the annual average, respectively. The northwestern, western and southwestern parts of Cambodia are expected to experience the highest likelihood of drought with 35-45% probability during a dry season and 30-40% probability annually. In Viet Nam, the south-central part and the Mekong Delta area showed the highest probability of drought occurrences with 35-45% during the dry season and 30-40% annually. Finally, the northern and southern regions of the Philippines are expected to experience drought with a 30-40% probability during the dry season and 25-35% annually.

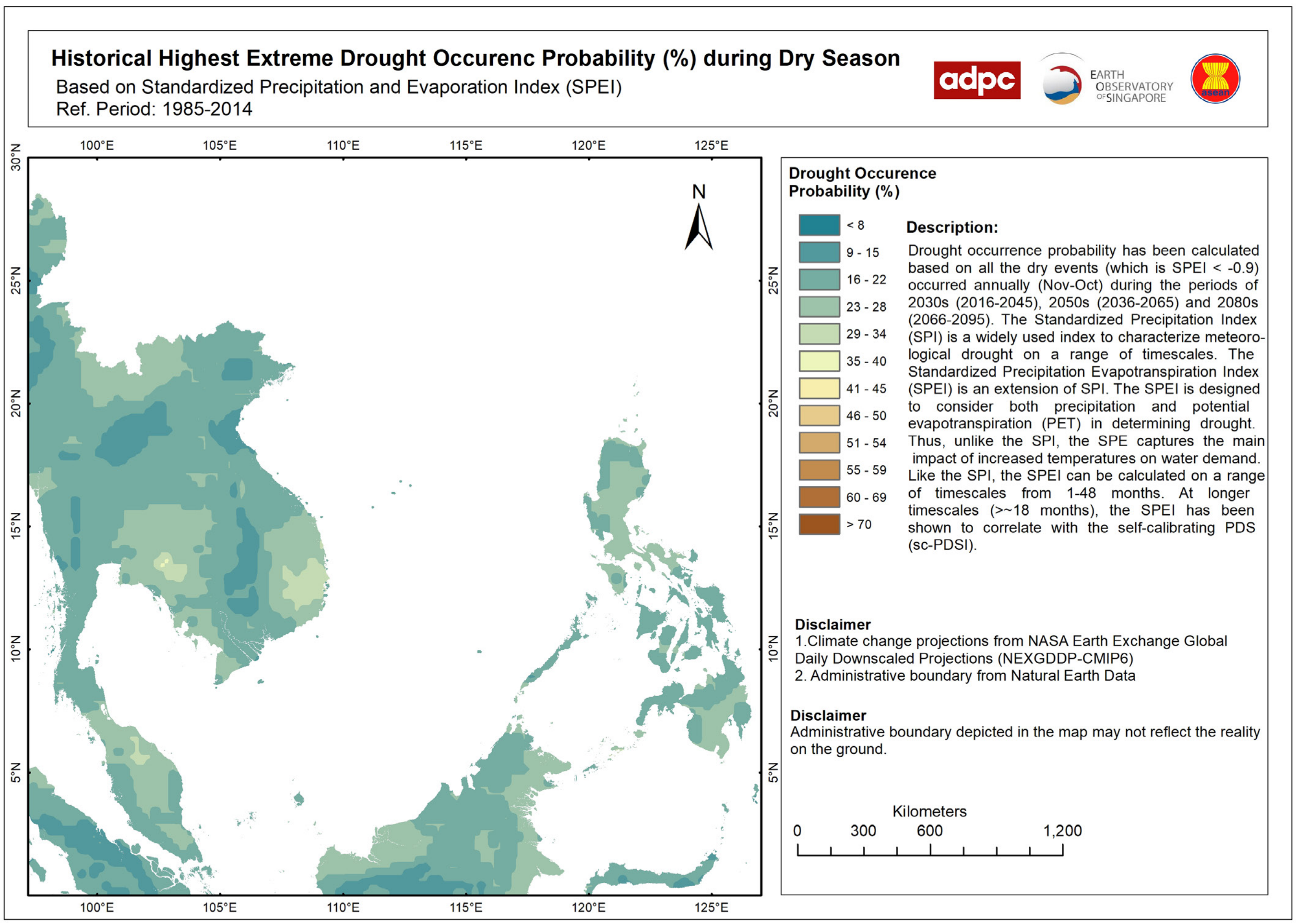


Figure 23
Drought occurrence probability (%) during dry season for the historical period (1985-2014).

3.4. RISK ANALYSIS FOR FUTURE CLIMATE

The study identifies future extreme events with an aim to understand the possible maximum hazardous level for the target areas. The projected scenarios of 2030s (taking an average from 2016-2045), 2050s (taking an average from 2036-2065) and 2080s (taking an average from 2066-2095) are generated for Southeast Asia, based on data from the baseline period of 1985-2014 and the GCMs.

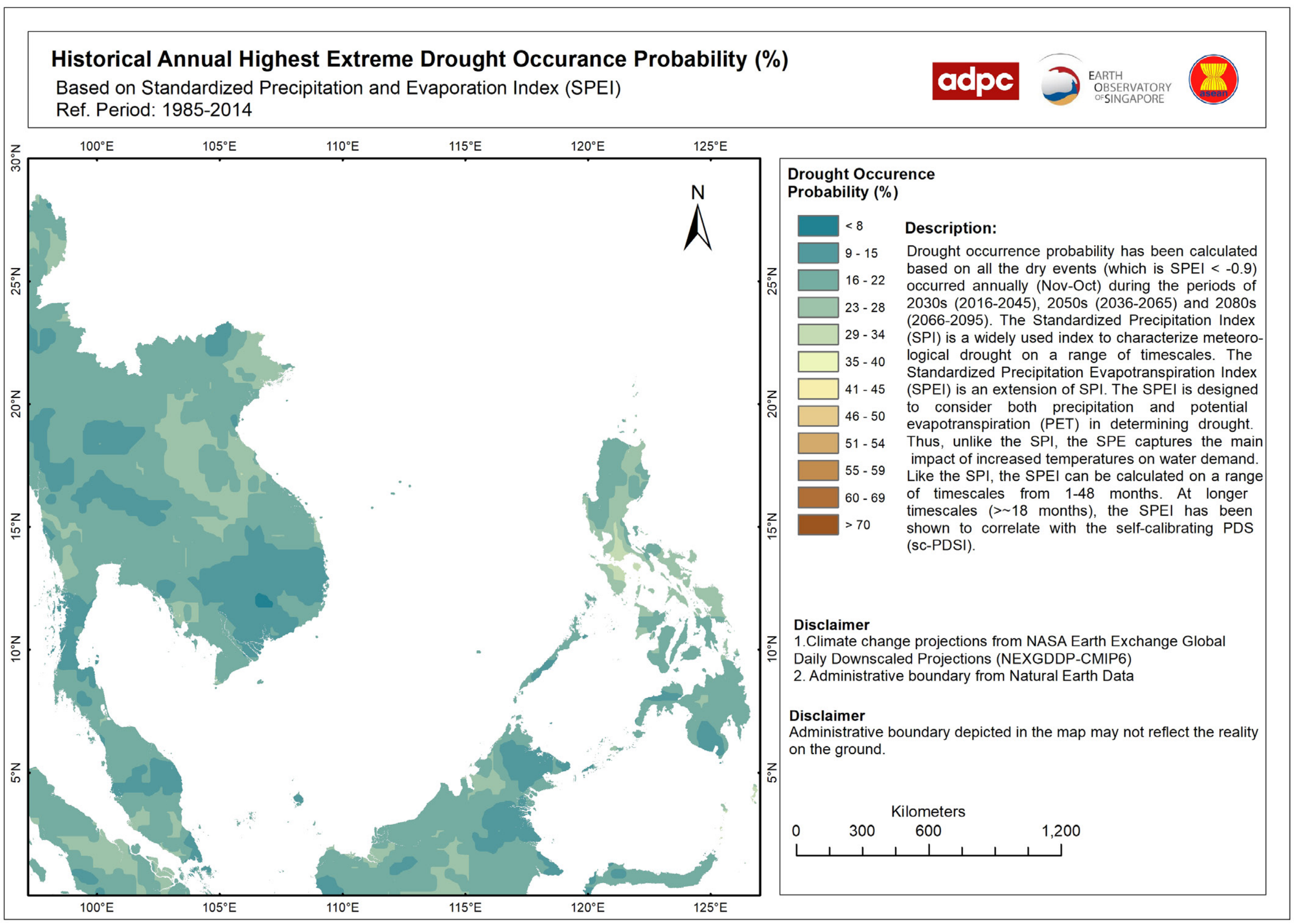


Figure 24
Annual-average drought occurrence probability (%) for the historical period (1985-2014).

Drought probability

The maps below depict the drought occurrence probability during the dry season for Cambodia, the Philippines and Viet Nam. The transboundary drought effect is linked to transboundary climate zones based on the extreme driest Global Climate Model (GCM) selected for the analysis. Results of two SSP scenarios, i.e., SSP2-4.5 and SSP5-8.5, are depicted in Figure 25 and Figure 26. The results show that the drought occurrence probability over the three countries is likely to increase by 60-80% for both the SSP scenarios. The northern and central parts of Cambodia may experience a higher number of

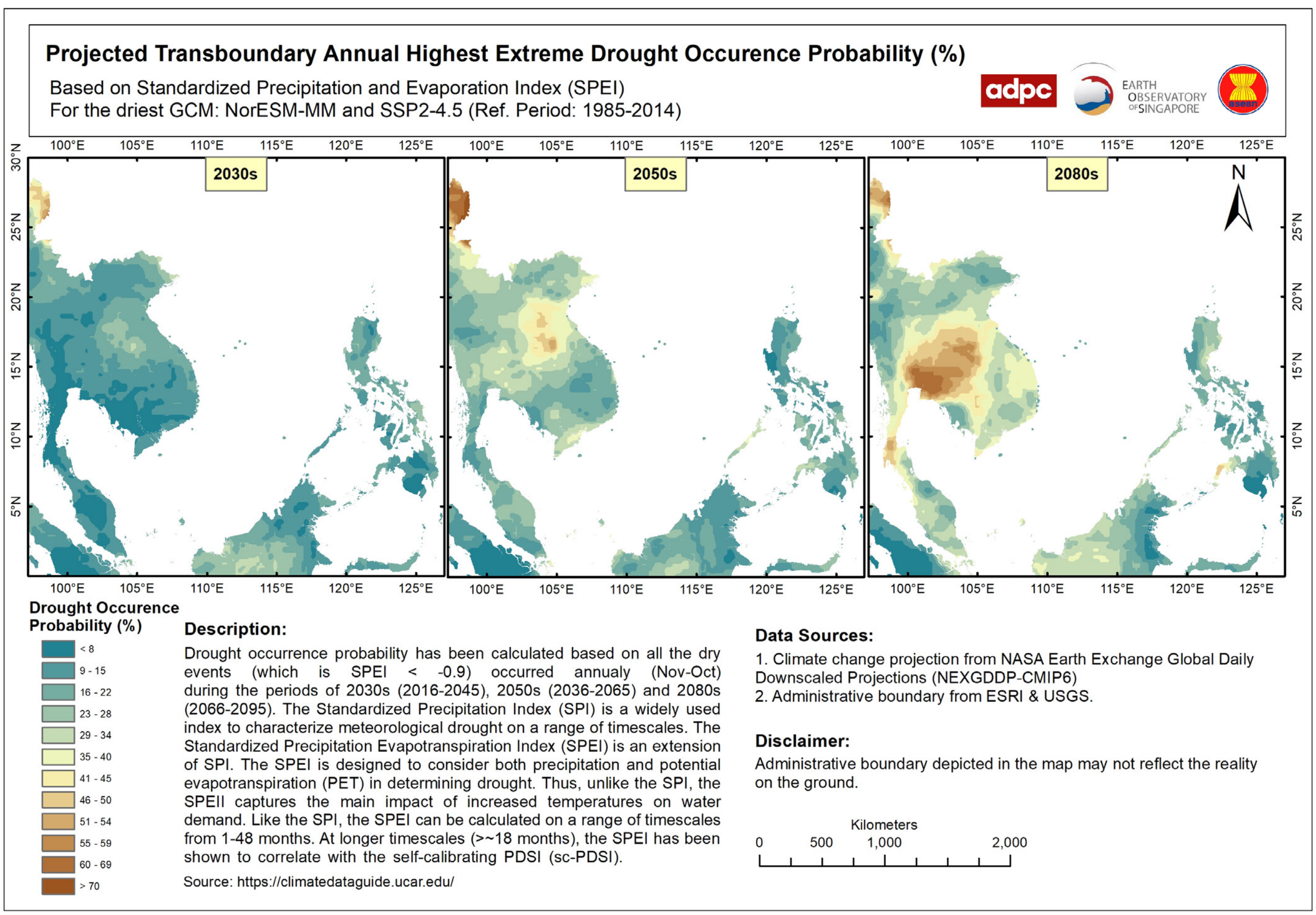


Figure 25
Projected drought occurrence probability (%) during dry season, using the SSP2-4.5 Climate Scenario.

drought events compared to other parts of the country and the region. The spatial variability of transboundary drought occurrence from Cambodia to southern Viet Nam covering the Mekong Delta is also visible. As a result, drought is more likely to affect Tonle Sap and Mekong River, passing through northern Cambodia to the Mekong Delta.

These maps show that the probability of drought occurrence will be much higher in the future, considering the effect of climate change.

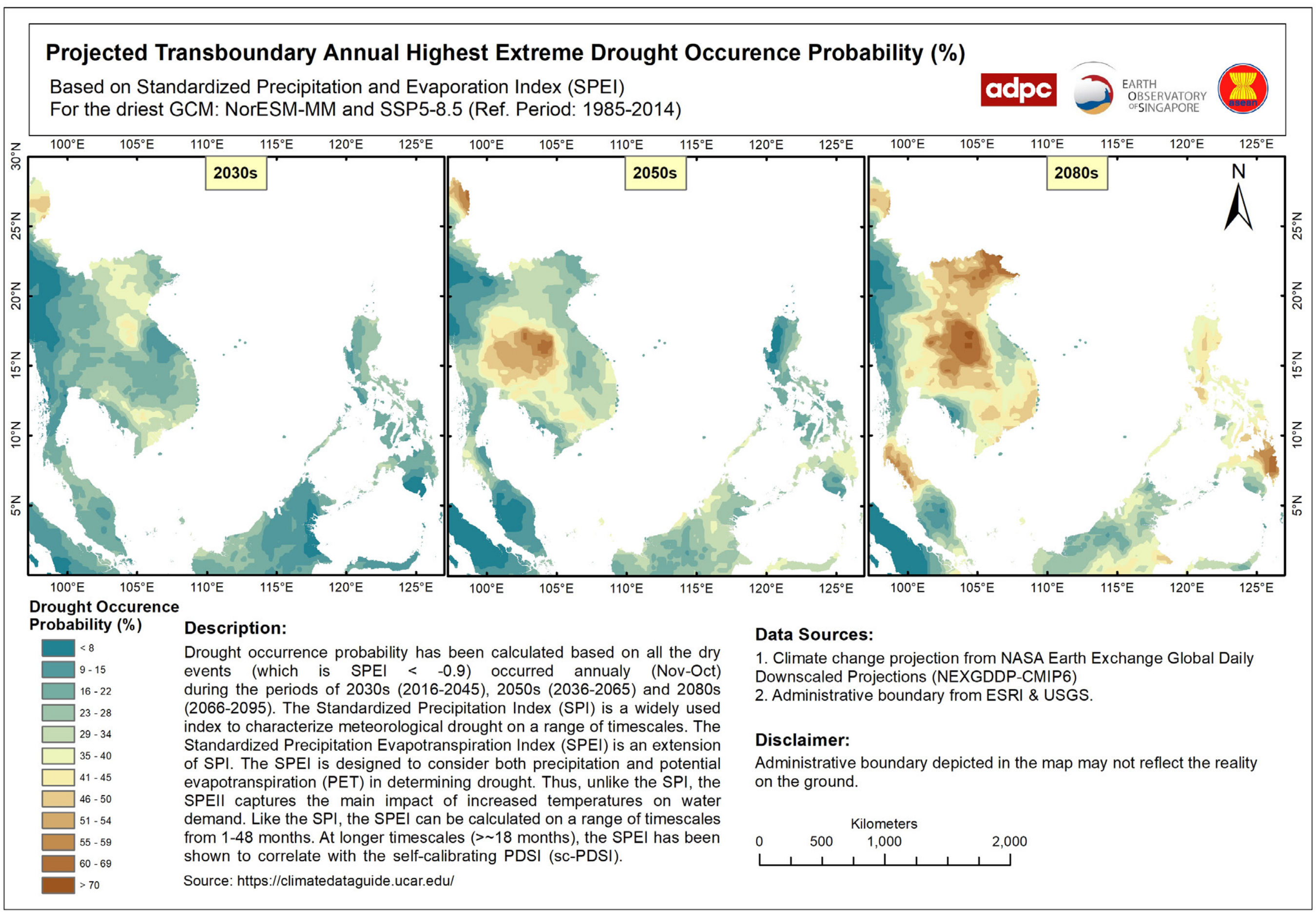


Figure 26
Projected drought occurrence probability (%) during dry season, using the SSP5-8.5 Climate Scenario.

Drought severity

Drought severity usually varies significantly over a country. While temperature plays a significant role in defining droughts for the dry season, other parameters such as large-scale changes in wind speed, air temperature, relative humidity, and geopotential height anomalies are also likely drivers of droughts in the region. Figure 27 and Figure 28 show the spatial distribution of projected drought severity during the dry season, using the SSP2-4.5 and SSP5-8.5 climate scenarios.

The results here indicate increased severity of drought for Cambodia and Viet Nam, considering future time horizons. By the 2080s, the whole of Cambodia could

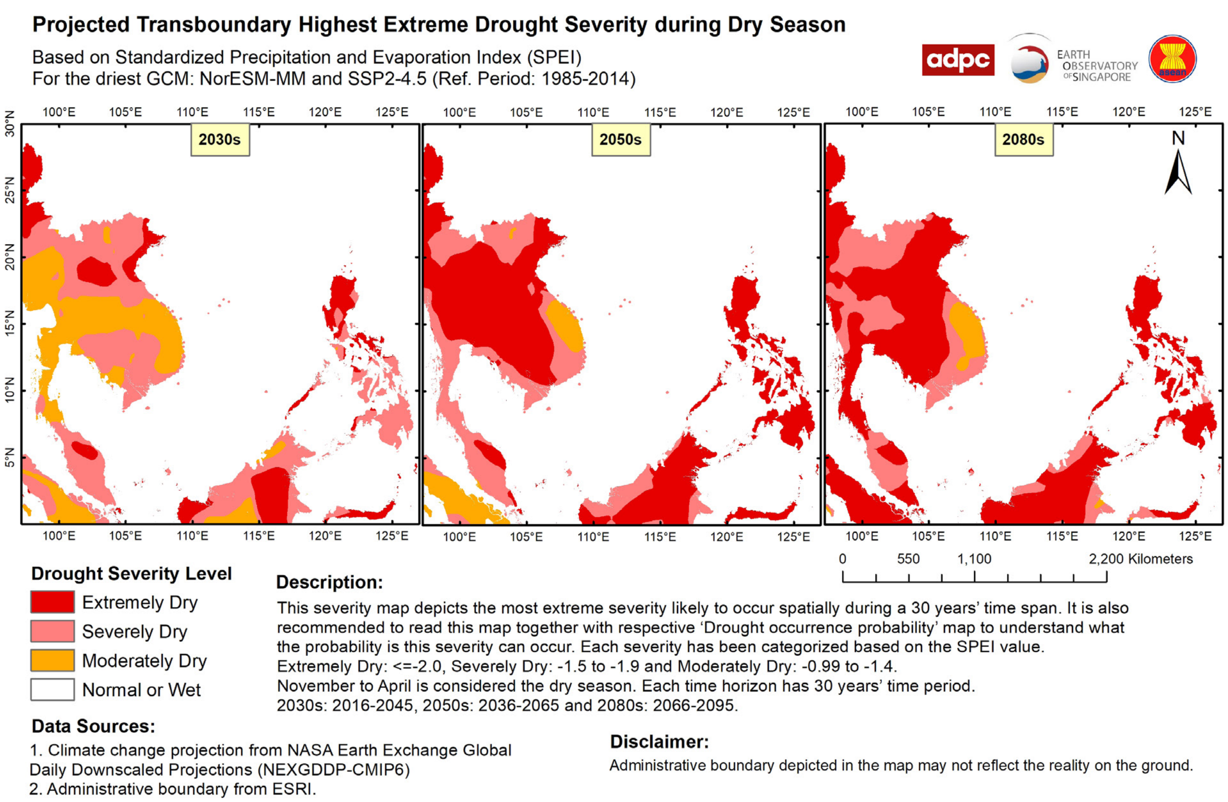


Figure 27
Projected drought severity during the dry season, using the SSP2-4.5 Climate Scenario.

be under threat from extremely dry conditions in the dry season.

Even though most of the GCMs show that the total annual and seasonal rainfalls would increase for all future time horizons, due to the inter-annual variability of rainfall influenced by phenomena like El Niño, drought events are likely to occur more frequently and more severely in the region including Cambodia, the Philippines, and Viet Nam. Decision makers can take this information to make decisions to tackle the impacts of future drought hazards.

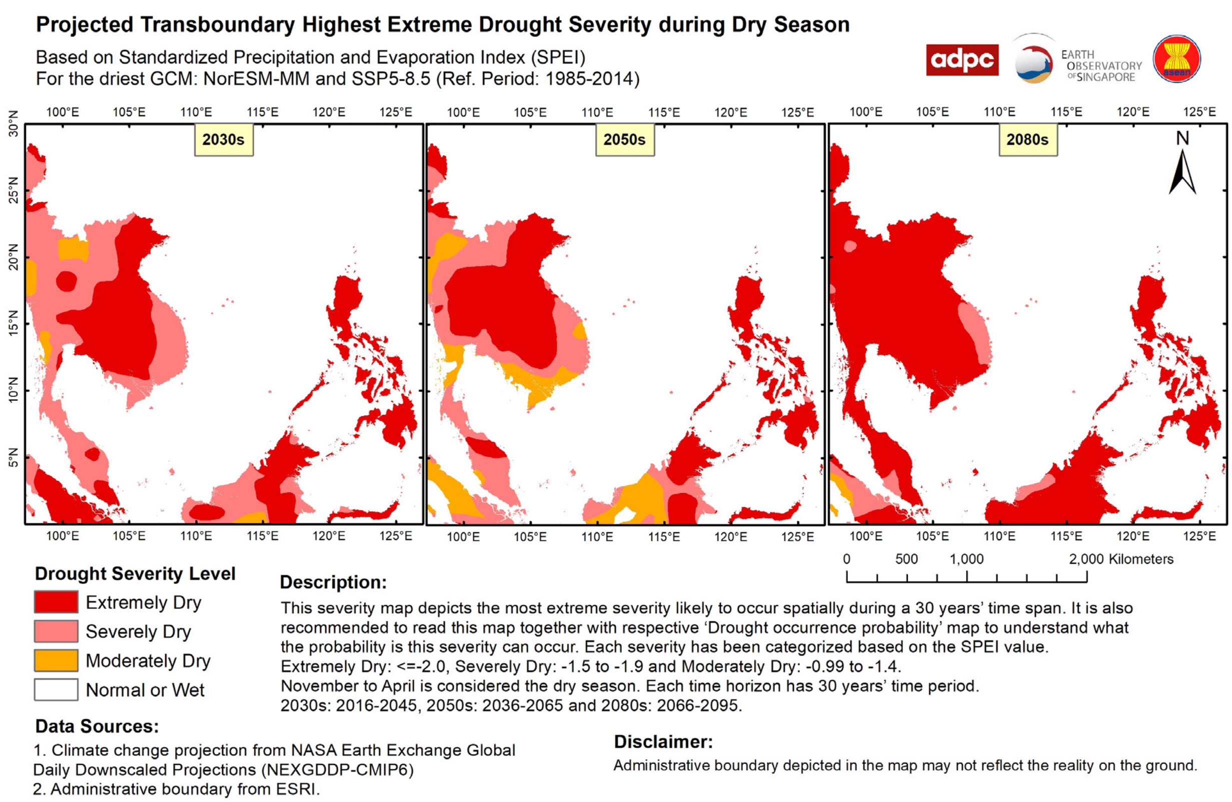


Figure 28
Projected drought severity during the dry season, using the SSP5-8.5 Climate Scenario.

Croplands and rice areas potentially affected by extreme drought

Cropland datasets for the Philippines are collected from the global land use land cover (LULC) data derived from the European Space Agency (ESA)'s Sentinel-2 imagery at a 10-meter resolution. This is a composite of LULC maps throughout the year 2020 categorized into 10 land cover classes, including crop areas. In addition, ADPC, through its SERVIR-Mekong project, has developed detailed land cover maps for the Lower Mekong region, which are also used for Cambodia and Viet Nam to designate rice growing areas in the two countries.

Figure 29 below shows the distribution of croplands derived from the remote sensing imagery covering Cambodia, the Philippines, and Viet Nam.

To estimate the croplands and rice areas potentially exposed to drought, the drought hazard maps were

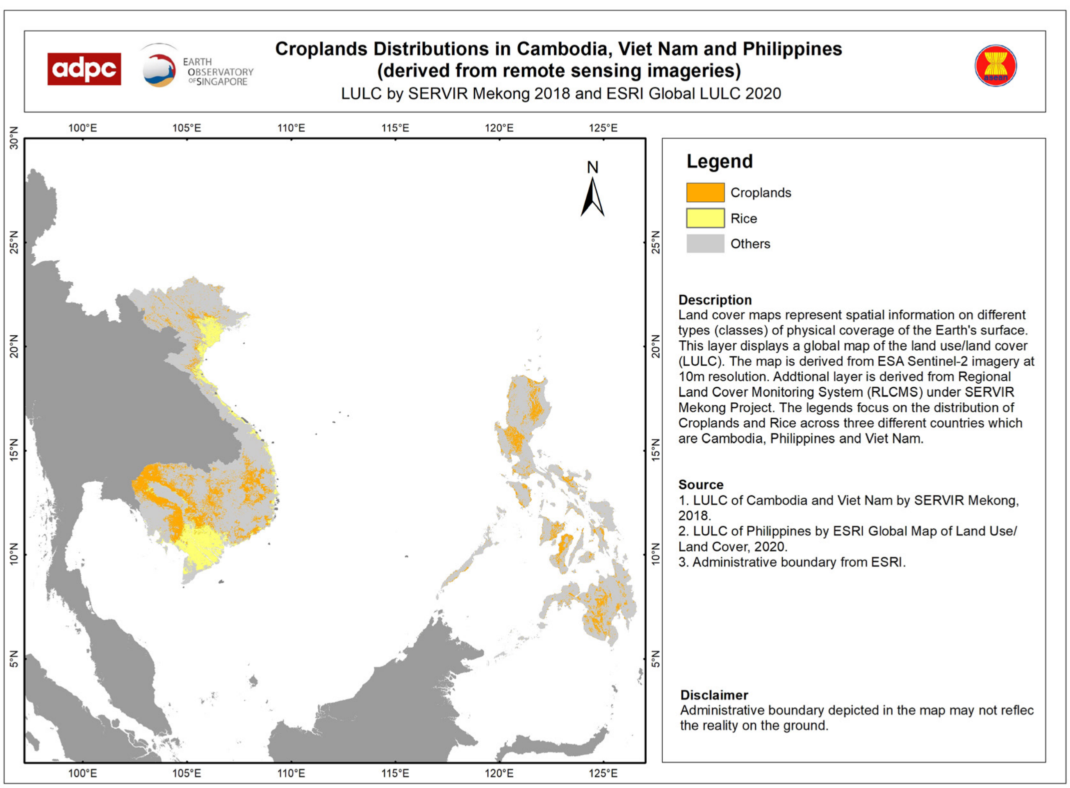


Figure 29
Croplands distribution in Cambodia, the Philippines, and Viet Nam derived from satellite imagery.

overlaid, in GIS environment, with the croplands and rice areas derived from the LULC maps. For illustration purposes, the drought severity maps were based on the highest extreme event during the dry season.

The results show that the cropland and rice areas exposed to severe and extreme drought are likely

Climate Scenario	Time Horizon	Cropland exposed to different level of severity of drought (%)			Rice exposed to different level of severity of drought (%)		
		Moderate	Severe	Extreme	Moderate	Severe	Extreme
Cambodia							
SSP2-4.5	2030s	16%	84%		16%	84%	
	2050s		16%	84%		12%	88%
	2080s		11%	89%		8%	92%
SSP5-8.5	2030s		11%	89%		12%	88%
	2050s	14%	23%	63%	21%	27%	52%
	2080s			100%			100%
Philippines							
SSP2-4.5	2030s			100%			
	2050s			100%			
	2080s		1%	99%			
SSP5-8.5	2030s			100%			
	2050s			100%			
	2080s			100%			
Viet Nam							
SSP2-4.5	2030s	48%	41%	11%	9%	68%	22%
	2050s	24%	52%	24%	7%	48%	45%
	2080s	40%	28%	32%	4%	63%	33%
SSP5-8.5	2030s	0%	67%	33%	0%	64%	36%
	2050s	14%	51%	35%	57%	11%	31%
	2080s	0%	24%	76%	0%	7%	93%

Table 8
Cropland and rice exposed to different levels of drought severity, under two different climate scenarios.

to increase in the future, when considering climate change projections. Under the SSP2-4.5 scenario, the cropland area of Cambodia potentially exposed to extreme drought is estimated to be 89% in the distant future and the rice paddy field areas are estimated at 88%. Under the same scenarios, the rice paddy field area of Viet Nam will most likely be exposed to severe and extreme drought in the future, estimated at 63% and 33 % respectively. The data for the Philippines only provides one class as crop and does not further differentiate between rice and other crops. The results of the analysis for the Philippines show that most of the croplands areas are most likely to be exposed to extreme drought, for both scenarios. The estimated changes of exposure of the croplands and rice areas can be seen in Table 8 above.

Populations residing in high risk areas

The population datasets were derived from the latest national census of population and housing. The population datasets were collected from the General Statistics Office of Viet Nam,[31] Philippine Statistics Authority[32] and Cambodia National Institute of Statistics.[33] It should be noted that the population data used for this potential impact assessment for Cambodia, the Philippines, and Viet Nam were gathered from the latest census of 2019.

In terms of vulnerable groups—such as persons with disability, children less than 5 years old and elderly aged over 65 years old—Figure 30 and Figure 31 (***pages 100 and 101***) provide a breakdown, by province, of these groups being exposed to extreme drought for Cambodia and Viet Nam. Similar data for the Philippines was not available for the analysis.

31. General Statistics Office of Viet Nam: gso.gov.vn

32. Philippine Statistics Authority, Republic of the Philippines: psa.gov.ph

33. National Institute of Statistics of Cambodia: nis.gov.kh

Climate Scenario	Time Horizon	Population potentially exposed to different levels of severity of drought (%)		
		Moderate	Severe	Extreme
Cambodia				
SSP2-4.5	2030s	28%	72%	0%
	2050s	0%	14%	86%
	2080s	0%	7%	92%
SSP5-8.5	2030s	0%	12%	88%
	2050s	19%	37%	45%
	2080s	0%	0%	100%
Philippines				
SSP2-4.5	2030s	0%	0%	100%
	2050s	0%	0%	100%
	2080s	0%	2%	98%
SSP5-8.5	2030s	0%	0%	100%
	2050s	0%	0%	100%
	2080s	0%	0%	100%
Viet Nam				
SSP2-4.5	2030s	17%	65%	18%
	2050s	10%	35%	55%
	2080s	11%	49%	40%
SSP5-8.5	2030s	0%	59%	41%
	2050s	39%	20%	41%
	2080s	0%	11%	89%

Table 9
Percentage of population exposed to different levels of drought severity, under two different climate scenarios.

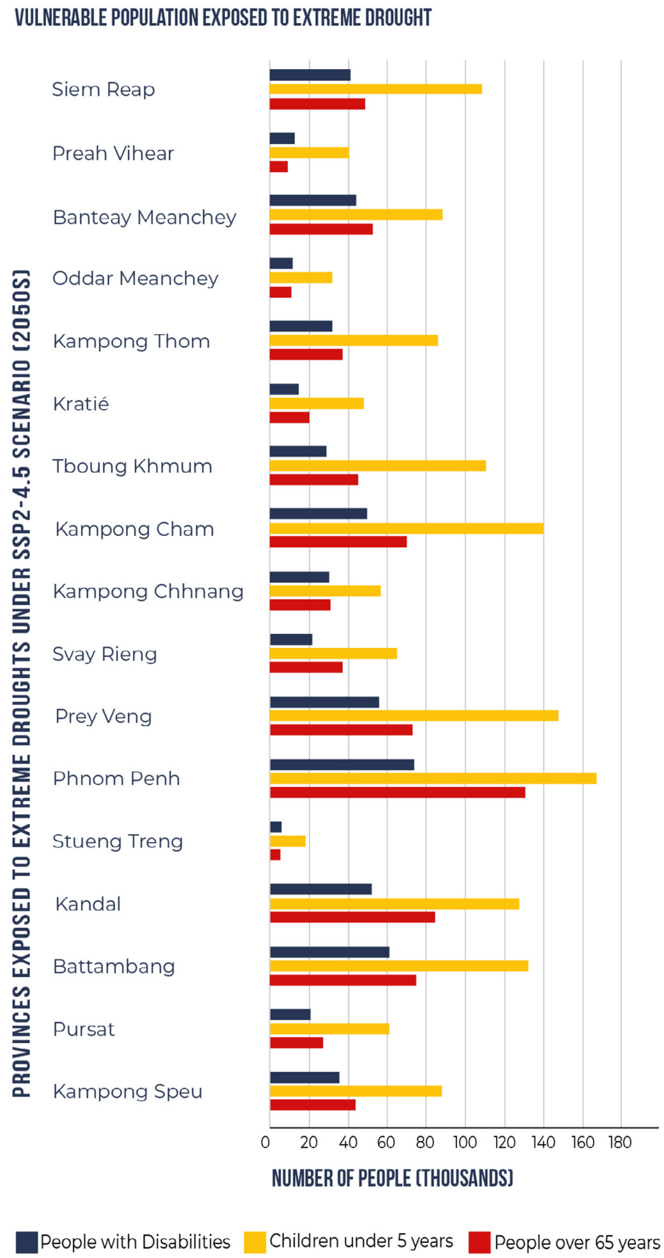
3.5. INTERPRETATION AND DISCUSSION OF THE RESULTS

This section provides an interpretation of the drought analysis. It addresses the key takeaways, key recommendations and a discussion on the uncertainty of the study. The goal is to help policy makers use this work to plan for further actions.

Increase in frequency and severity of drought

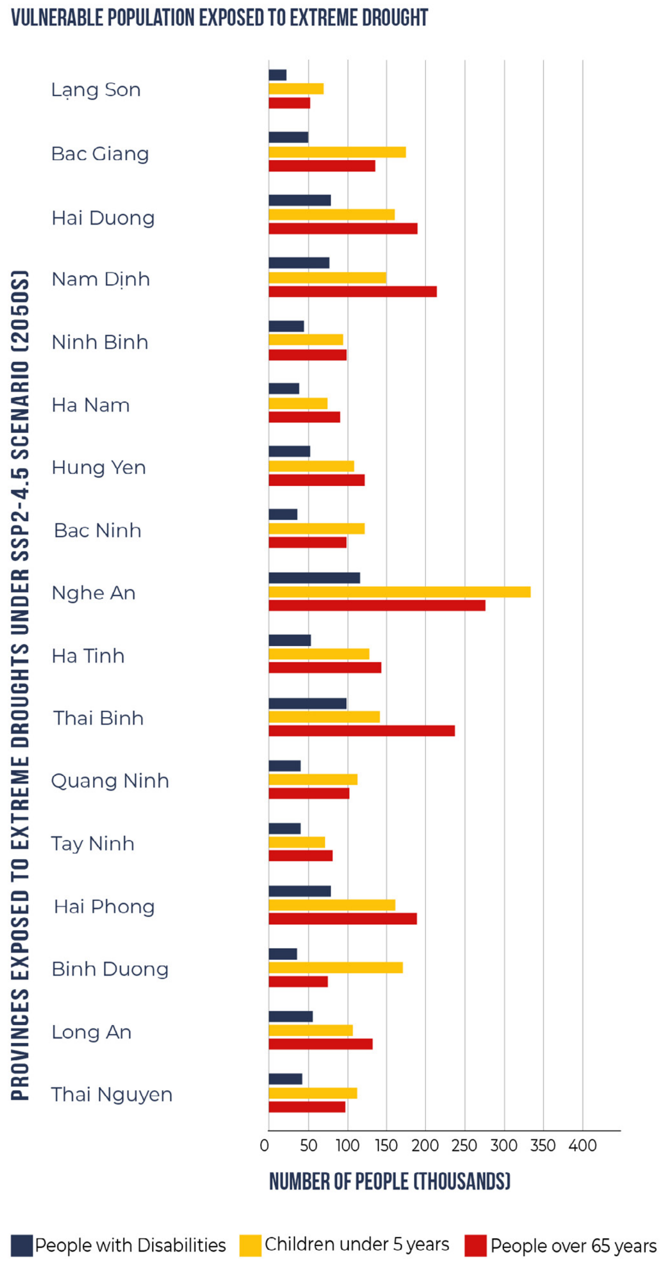
The drought hazard assessment conducted in this study reveals an increasing trend of both the occurrence probability and intensity of drought between now and the 2080s, if no action to mitigate the impact of climate change is taken. Among the 3 focus countries (Cambodia, the Philippines, and Viet Nam), the increase

Figure 30
Estimated number of people, by their vulnerability, potentially exposed to extreme drought (under SSP2-4.5 scenario for the 2050s time horizon) for Cambodia.



in drought occurrence probabilities is most concerning in Cambodia and Viet Nam (Figure 25 and Figure 26). It must be noted also that, although the focus of this study was only on Cambodia, the Philippines, and Viet Nam, the drought hazard assessment was conducted over the whole of Southeast Asia. The increasing trend of the drought occurrence probability is prominent in other countries such as Indonesia, Lao PDR, Myanmar, and Thailand as well.

Figure 31
Estimated number of people, by their vulnerability, potentially exposed to extreme drought (under SSP2-4.5 scenario for the 2050s time horizon) for Viet Nam.



When considering the intensity of drought, a similar observation can be made. Drought is expected to be more intense in the 2080s, when compared to the historical climate condition (today's state). In the worst-case scenario under this study, considering extreme climate scenarios and the SSP5-8.5, the analysis shows that the entire area of Cambodia and the Philippines could be under threat from an extreme drought during the dry season, while Viet

THE DROUGHT HAZARD ASSESSMENT CONDUCTED IN THIS STUDY REVEALS AN INCREASING TREND OF BOTH THE OCCURRENCE PROBABILITY AND INTENSITY OF DROUGHT BETWEEN NOW AND THE 2080S. VIET NAM IS EXPECTED TO FACE EXTREME AND SEVERE DROUGHT UNDER THE ASSUMED CLIMATE CONDITIONS.

Nam is expected to face extreme and severe drought, under the assumed climate conditions.

This finding is in alignment with the *"Ready for dry years"* joint study between the ASEAN Secretariat and the UN Economic and Social Commission for Asia and the Pacific (UNESCAP). As reported by that study, the cumulative impacts of drought in the region strike hardest at the poor and aggravate inequalities, while also degrading land and exacerbating potential conflicts.

More frequent and severe droughts can also be particularly damaging in countries where many people rely on agriculture for their primary income or livelihood, as is the case in Cambodia, the Philippines, and Viet Nam, and a few more ASEAN Member States such as Indonesia and Lao PDR.

This calls for priority actions that need to be taken by the ASEAN Member States. For example, in Cambodia, government measures to help reduce the impact of drought have focused on building irrigation systems, reservoirs and dams to retain water in times of need, as well as promoting the use of drought resistant seeds for farmers. While in Viet Nam, a good example of a measure taken is through the Water Efficiency Improvement in Drought-Affected Provinces (WEIDAP) – an ADB-funded project. The WEIDAP project is expected to improve water productivity in irrigated agriculture by replacing inefficient rice irrigation schemes with modernized systems using pipes (pressuring and gravity), upgraded canals, and impounding weirs designed for irrigation of high-value crops, such as mango, coffee, pepper and dragon fruit.

These kinds of measures can be good examples of actions to address the impact of droughts. It is also important to highlight the three priority areas of intervention suggested by the joint ASEAN and UNESCAP report, which include: (1) strengthening

THE POOR ARE STRUCK THE HARDEST DUE TO THE PROGRESSIVE IMPACTS OF DROUGHT IN THE REGION. THE ENSUING CONSEQUENCES ARE AGGRAVATED INEQUALITIES AND LAND DEGRADATION THAT CAN EXACERBATE POTENTIAL CONFLICTS.

drought risk assessment and early warning service, (2) fostering risk financing instruments that can insure communities against slow onset droughts and, (3) enhancing people's capacity to adapt to drought.

Increasingly a transboundary problem

Transboundary drought can affect food prices and food security in this region. Viet Nam is one of the ASEAN region's top rice exporters. Aside from the Philippines, many countries, including Indonesia, import rice from Viet Nam. As a result, the impact of drought could severely reduce rice production in Viet Nam which could be felt more widely by other countries relying on rice exports from Viet Nam. This could possibly lead to food price hikes and, eventually a food price crisis in the region. In addition to the impact on food prices, other cases involving transboundary drought impacts include a decline in water levels of rivers with resulting consequences on electricity generation for a wider region. For example, the Nam Ngum Hydropower station built on the Nam Ngum River provides an important opportunity for Lao PDR to export surplus power to Thailand. During the drought of 2007, hydropower generation was severely affected and the utilization rate of the power plant declined by 40%, impacting electricity exports to Thailand.

Another example of a potential transboundary implication of drought is when the drought affects more than one country with shared water resources. For example, if a river shared by two countries has a lower water level during a drought, the countries utilizing its waters will suffer from a water shortage. Tensions might build up between the downstream countries relying on the water resources and the upstream countries regulating water flows. As in the case of ASEAN Member States which share water resources from the Mekong River, such as Cambodia, Lao PDR, Thailand, and Viet Nam, Transboundary water challenges have become severe in the Mekong region under the accelerating impacts of climate change and hydropower development. These have presented downstream countries, including Viet Nam and especially in the Vietnamese Mekong Delta, with unprecedented risks. Hydropower developments along the main stem of the Mekong River and its tributaries cause transboundary effects within the Mekong River Region. On the one hand, the provision of hydropower triggers economic development and helps to meet the rising energy demand of the Mekong riparian countries such as Thailand and Viet Nam, but on the other hand, the negative impact of dam construction has had a serious effect on the Mekong River, resulting in severe floods and droughts, low water levels in dry season, and a decrease in the amounts of sediment carried by the river, with drastic consequences for biodiversity, fisheries and the livelihoods of the rural Mekong population.

A POTENTIAL TRANSBOUNDARY IMPLICATION OF DROUGHT IS BETWEEN COUNTRIES SHARING WATER RESOURCES, GIVING RISE TO THE POSSIBILITY OF TENSIONS BETWEEN DOWNSTREAM COUNTRIES RELYING ON THE WATER RESOURCES AND UPSTREAM COUNTRIES REGULATING WATER FLOWS. COOPERATION AND COLLABORATION BETWEEN THE COUNTRIES ARE VITAL IN ADDRESSING THE TRANSBOUNDARY IMPACTS OF DROUGHT.

As apparent in the discussion above, it is imperative to understand that transboundary impacts of drought can be complex, which highlights the interconnectedness of the region and the importance of cooperation and collaboration between the countries in addressing transboundary impacts of drought.

Social impact

Drought can create not only significant economic but also social problems, such as loss of lives, forced migration and displacement, water scarcity, conflicts between people when there is not enough water, and famine. The lack of rain can result in crop loss, reduced incomes and unemployment due to a decline in production. For Cambodia and Viet Nam, given the large rural population and substantial dependence on agriculture, droughts often lead to social, economic and environmental impacts. Water security is closely tied to food security. The vulnerability of many rural communities, with low levels of resilience and limited resources, means that droughts can have high costs.

It should be noted that it remains very difficult to quantify the disproportionate effect of droughts on different social groups and specific communities. More data on the vulnerability of different groups is required for improved disaster preparedness, mitigation, response and recovery. This data can be gathered by preparing detailed demographic profiles of the communities residing in the most high-risk areas of droughts. In the current drought risk assessments such unequal impact among groups often remains hidden and this could lead to ineffective measures which do not make the best use of limited resources.

DECISION-MAKERS MUST PRIORITIZE COST-EFFECTIVE DROUGHT MITIGATION MEASURES, RESPOND TO COUNTRY-SPECIFIC NEEDS, AND UTILIZE THIS DROUGHT RISK INFORMATION FOR LONG-TERM POLICY DEVELOPMENT AND PLANNING.

Uncertainty

Decision makers and other relevant stakeholders can make use of this drought risk information for long-term policy development and planning to prioritize drought mitigation measures across all the countries. However, since there is a degree of uncertainty inherited in the climate model for predicting the future scenarios, it is preferable for the stakeholders in Cambodia, the Philippines, and Viet Nam to consider several scenarios and develop adaptation and mitigation options, as well as the cost analyses of those adaptation and mitigation options, in order to prioritize measures that are cost-effective and respond to the specific needs.

4. TRANSBOUNDARY RISK AND SCENARIO PLANNING RECOMMENDATIONS FOR THE ASEAN REGION

This chapter outlines how the findings of this study on the transboundary disaster risk and scenario planning can directly contribute to the ASEAN Agreement on Disaster Management and Emergency Response (AADMER) Work Programme 2021-2025. The focus of the study was placed on the AADMER **Priority Programme 2:** Prevention and Mitigation, and **Priority Programme 3:** Preparedness and Response, and **Priority Programme 4:** Resilient Recovery.

ON PREVENTION AND MITIGATION

01.

CONSIDER THE IMPLICATION OF MORE INTENSE TROPICAL CYCLONES AND INCREASING WIND SPEEDS INTO EXISTING BUILDING REGULATIONS AND BUILDING CODES.

At present, the Philippines and Viet Nam have established their own building codes, and structural engineers in Cambodia generally follow international building codes for most structures. Building codes typically draw on best practices from other countries and are updated regularly as new construction techniques become available. Based on the findings of this study, it is recommended that Cambodia, the Philippines, and Viet Nam reconsider the wind zone maps in the building codes, improve the enforcement of building codes, and invest in strengthening buildings that are not in compliance with the building codes. Specifically, buildings in the Philippines need to be able to cope with extreme wind speeds (38-50 m/s), while buildings in many regions of Viet Nam and Cambodia need to withstand typhoons (33-38 m/s).

This approach maintains the familiar basic framework for local structural engineers and doesn't require differentiating between building types, as all building types are already covered in existing guidelines. Thus, only the load for calculations needs to be adjusted, rather than the building type-specific requirements.

02.

CONSIDER INCREASING DROUGHT RISKS IN CROP INSURANCE PROGRAMMES, PARTICULARLY IN COMPENSATION SCHEMES TO PREVENT LOW-INCOME PEOPLE FROM FALLING INTO EXTREME POVERTY.

The larger risk aversion in the Philippines is attributed to the greater catastrophic impact of tropical cyclones and higher levels of income inequality in the country. These results highlight the potential benefits of tropical cyclone risk transfer schemes, such as insurance. This study recommends that the ASEAN Member States (AMS) develop specific compensation schemes according to the increased risk, in alignment with the national crop insurance programme guideline of the ASEAN Climate Resilience Network. Governments should inform farmers, particularly those who reside in the areas that are prone to disasters about the insurance benefits. Finally, the AMS should develop compensation schemes that will prevent low-income people from falling into extreme poverty after a tropical cyclone or due to increased exposure of croplands and people. These support mechanisms for at-risk communities should remain flexible to account for the uncertainties of the future climate change scenarios. The compensation schemes should also be gender and socially inclusive.

The Cambodia Drought Initiative, which is equivalent to a national drought plan, recognizes the impact of drought on rice cultivation, and explores the harsh impacts on families working in this sector, such as increased debt and food shortages. Accordingly, the Initiative focuses primarily on how to support small farmers affected by drought. Such initiative should be scaled up.

03.

DISAGGREGATE DATA ON THE VULNERABLE POPULATION, TAKING INTO CONSIDERATION DEMOGRAPHIC CATEGORIES WHEN CONDUCTING RISK ASSESSMENTS, WHICH CAN BE GATHERED BY PREPARING DETAILED DEMOGRAPHIC PROFILES OF THE COMMUNITIES RESIDING IN THE MOST HIGH-RISK AREAS.

Sex, Age and Disability Disaggregated (SADD) data often are not used in tropical cyclone and drought risk assessments. It is recommended that the SADD data is integrated in the process in order to quantify the impact of tropical cyclones and droughts that could affect various population groups differently. In addition, this study recommends that the ASEAN Member States prioritize developing risk profiles of the communities that coincide with the most hazard-prone areas, as indicated in this study.

ON PREPAREDNESS, RESPONSE AND RECOVERY

04.

CONSIDER TRANSBOUNDARY RISK SCENARIOS INTO EXISTING ASEAN RESPONSE PREPAREDNESS MECHANISMS.

The current response procedures and plans for the ASEAN region, such as the Standard Operating Procedure for Regional Standby Arrangements and Coordination of Joint Disaster Relief and Emergency Response Operations (SASOP) and the ASEAN Joint Disaster Response Plan (AJDRP), do not explicitly address transboundary risk scenarios. This study recommends that the regional drought and transboundary tropical cyclone scenarios developed from the study are used as case studies for deriving a truly transboundary response plan.

In addition, the current ASEAN Regional Disaster Emergency Response Simulation Exercise (ARDEX) focuses mainly on responding to disasters in a country. It does not account for the fact that some disasters, such as drought and tropical cyclones, will be transboundary in nature. Responding to the transboundary disasters requires cross-border cooperation. This study recommends that the ASEAN Member States, through the ASEAN Committee for Disaster Management (ACDM), initiate a dialogue on the cooperative efforts to respond to transboundary disasters. The transboundary drought and tropical cyclone scenarios developed from this study can be used as the scenarios for drills and simulation exercises.

05.

CONSIDER THE TROPICAL CYCLONE AND DROUGHT HAZARD INTENSITY PARAMETERS SUGGESTED BY THIS STUDY AS A TRIGGER MECHANISM FOR PRE-DISASTER ANTICIPATORY ACTIONS.

This study uses the tropical cyclones' wind speed and the Standardized Precipitation and Evaporation Index (SPEI) as the hazard intensity parameters for tropical cyclones and drought, respectively. It is recommended that the Technical Working Group on Anticipatory Actions, composed of technical organization partners of the ASEAN Secretariat, look into the suitability of these hazard intensity parameters for use as anticipatory action triggers.

For the purposes of triggering anticipatory actions for tropical cyclones and drought, this study recommends that the transboundary tropical cyclone and regional drought scenarios are considered. The threshold for triggering anticipatory actions will depend on the level of impacts acceptable to the countries. The study's impact assessment forms an initial view of the impact across the countries. In addition, the transboundary drought and tropical cyclone hazard and risk maps developed under this study will guide countries to enhance or develop national drought monitoring, forecasting, and early warning.

06.

CONSIDER INTEGRATING TRANSBOUNDARY HAZARD SCENARIOS INTO RECOVERY STRATEGIES, INCLUDING POST-DISASTER NEEDS ASSESSMENTS AND RESOURCE ALLOCATIONS AND SHARING FOR RECOVERY ASSISTANCE.

Transboundary disasters, which affect multiple ASEAN Member States at the same time or successively, could put pressure on the region's resources for conducting post-disaster needs assessments and mobilizing recovery assistance. This study recommends that the ASEAN Secretariat and the ACDM Working Group on Preparedness, Response, and Recovery (ACDM WG PRR) introduce transboundary hazard scenarios into regional strategies for recovery assistance planning.

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APPENDICES

1. Appendix A: Existing Global and Regional Policies, Initiatives, Plans and Strategies for Disaster Risk Assessment and Management Related to Tropical Cyclones and Droughts Relevant to the ASEAN Countries
2. Appendix B: Guidelines for Community Profiles for High-Risk Communities

APPENDIX A
EXISTING GLOBAL AND REGIONAL POLICIES, INITIATIVES, PLANS AND STRATEGIES FOR DISASTER RISK ASSESSMENT AND MANAGEMENT RELATED TO TROPICAL CYCLONE AND DROUGHT RELEVANT TO THE ASEAN COUNTRIES

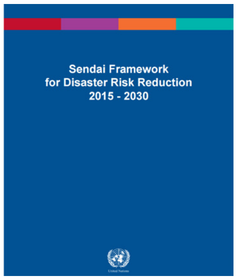
There are 45 relevant documents that have been reviewed for this report, consisting of 11 global documents, 16 regional documents and 18 national level documents from the ASEAN member states. The review focuses on their relevance for gender and social inclusion and includes disaster risk assessment and management for tropical cyclones and drought in the ASEAN member states. As drought and tropical cyclones are hydro-meteorological hazards and therefore considered to be extreme events significantly influenced by climate change, a number of reviewed documents focus on planning scenario planning for climate risk management.

From the perspective of gender equality and social inclusion, the following critical findings and gaps have been found:

The gap between scientific/technical scenarios and analysis of impacts on specific types of persons. There is a sizable gap between the detailed scientific climate change scenarios used to forecast and predict droughts and tropical cyclones and any analysis of impacts on the various population groups in any specific country or location. Presentation of climate scenarios and related predictions make only high-level references to impacts foreseen on "human systems," "human activities," "human health" and "anthropogenic causes" in a very general sense, with passing references to "empowerment of vulnerable groups" and consideration of "social factors."

The need for local community profiles to map vulnerable groups. Given the wide range of diversity and inequalities among communities and population groups found within the ASEAN member states, in order for policy makers to undertake effective scenario planning to protect the population in the face of upcoming droughts and tropical cyclones, it is essential to develop local population or community profiles. These community profiles should consider the proportion and location of population groups in terms of the relevant ethnicities, religions, poverty levels, migratory status and other factors which result in inequalities and greater vulnerability to disasters. These population profiles should also determine locations in which there is a high incidence of women-headed households, persons living with disabilities, internally displaced persons, and/or migration patterns driven by conflicts or lack of livelihood options.

National authorities must lead on developing gender-sensitive and inclusive DRM policies. While international frameworks and guidelines indicate a general consensus that "women and children are more vulnerable" to the impacts of droughts and tropical cyclones, it is the task of national and local authorities to formulate specific evidence-based policies which provide targeted support to address and mitigate these disproportionate impacts on women and children, as well as for other disadvantaged population groups.



Sendai Framework for Disaster Risk Reduction 2015 -2030[34]

The successor to the HFA, was adopted at the Third United Nations World Conference on Disaster Risk Reduction (WCDRR) in Sendai, Japan, in March 2015. It is the global blueprint and fifteen-year plan to build the world's resilience to disasters.

Sustainable Development Goals[35]

A universal call to action to end poverty, protect the planet and improve the lives and prospects for everyone, everywhere, of which, the 17 Goals were adopted by all UN Member States in 2015, as part of the 2030 Agenda for Sustainable Development which set out a 15-year plan to achieve the Goals

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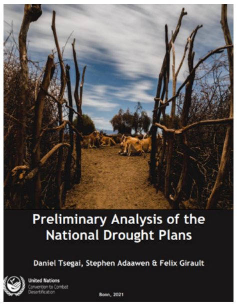
IPCC – 6th Assessment Report: Extremes, Abrupt Changes and Managing Risks[36]

The IPCC report concludes that in the near future, due largely to climate change, droughts in many parts of the world will become more severe, and tropical cyclones and storms can be expected to increase in intensity.

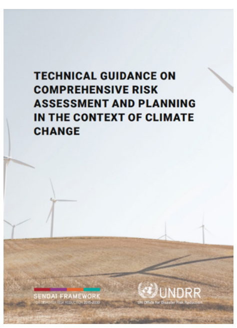
UNCCD Gender Action Plan[37]

The Convention recognizes the importance of women in the implementation of the Convention, and identifies critical areas for their engagement: (i) awareness-raising, and participation in the design and implementation of programmes; (ii) decision-making processes that men and women adopt at the local level in the governance of development, implementation and review of regional and national action programmes (RAPs and NAPs); and (iii) capacity-building, education and public awareness, particularly at local level through the support of local organizations.



UNCCD - Preliminary Analysis of National Drought Plans[38]

This study is the first attempt to analyze and learn from the first batch of about 35 National Drought Plans which have been completed and endorsed by the countries. Preliminary analysis of the drought plans indicates that drought impacts are more pronounced on water resources and agriculture. Generally, drought risk reduction at the country level is mostly reactive. Countries also recognize the gendered differentiation of drought impacts on women, men, and children. Much more importantly, the need for drought impact mitigation and policy to focus more on protecting women and young people as the most vulnerable sections of society is highlighted. Effective monitoring, forecasting, and impact mitigation for enhanced drought resilience are also widely emphasized across the NDPs. Gender mainstreaming and meaningful participation in planning and implementation for drought mitigation strategies, the need for adequate technology, policy framework, and expertise for effective drought monitoring and early warning, as well as cross- sectoral coordination, were also enumerated by country.



UNDRR – Technical guidance on comprehensive risk assessment and planning in the context of climate change[39]

The technical guidance offers a framework on how to apply comprehensive risk assessment and planning. It acknowledges that risks in the context of climate change are complex and systemic due to non-linear interactions among system components and the need for improved risk governance. The guidance can be contextualized to national and local needs.

34. Sendai Framework for Disaster Risk Reduction 2015-2030 | UNDRR

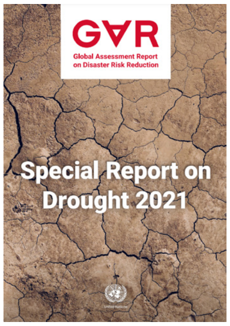
35. United Nations: Gender equality and women's empowerment

36. 10_SROCC_Ch06_FINAL.pdf (ipcc.ch)

37. https://www.unccd.int/resources/publications/gender-action-plan

38. Analysis of National Drought Plans.pdf (unccd.int)

39. Technical guidance on comprehensive risk assessment and planning in the context of climate change | UNDRR



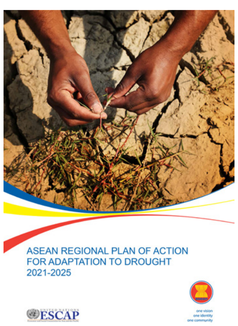
UNDRR - GAR Special Report on Drought[40]

The GAR Special Report on Drought 2021 explores the systemic nature of drought and its impacts on achievement of the Sendai Framework for Disaster Risk Reduction, the SDGs and human and ecosystems health and wellbeing.

United Nations Framework Convention on Climate Change

UNFCCC - Building Storm Resistant Houses[41]

The Building Storm-Resistant Houses project helps vulnerable families to adapt to climate change. A Women's Union in Da Nang complements the project by offering a revolving loan program to help finance these storm-resistant homes. This project has already helped hundreds of families reinforce and rebuild their homes. Building Storm-Resistant Houses was a Momentum for Change winner in 2014.



ASEAN Regional Plan of Action for Adaptation to Drought 2021-2025[42]

This document details the ASEAN Regional Plan of Action for Adaptation to Drought. The Plan is a joint effort of the Association of Southeast Asian Nations (ASEAN) and the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP). The plan aims to enhance coordination at various levels for achieving sustainable management of drought by considering the impact of drought on the livelihood of people, natural resources and ecosystem, agriculture, energy, and sustainable socio-economic development. It foresees the development of outputs through institutionalization; localization and communication; finance and resource mobilization; gender and social inclusion; multi-hazards approach; innovation; partnership; and synergy.

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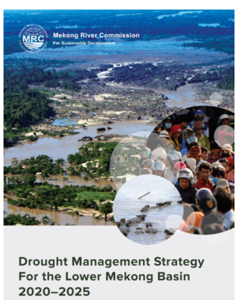
40. GAR Special Report on Drought 2021 | UNDRR

41. Building Storm-Resistant Houses | UNFCCC

42. ASEAN and UNESCAP (2021), ASEAN Regional Plan of Action for Adaptation to Drought (ARPA-AD) 2021-2025

Ready for the Dry Years: Building resilience to drought in South-East Asia
In another document produced by ASEAN and UNESCAP, this second edition of Ready for the Dry Years notes that the severity of two drought events in the ASEAN region during 2015-2016 and 2018-2020 exceeded anything recorded in the past twenty years. The series is part of the effort to mobilize region-wide action as drought risk intensifies. This edition combines rainfall data with other socio-economic indicators to show the hotspots where populations are most vulnerable to drought. It takes a holistic approach to understanding drought impacts by adopting a standard definition of drought across the region and by examining the issue from socioeconomic, health, environmental, and humanitarian perspectives. According to the report, compared with other disasters, droughts are fairly predictable, yet policy responses still tend to be largely reactive. The report builds a case for ushering in a paradigm shift towards more proactive drought management across Southeast Asia while leveraging the innovative measures underway within ASEAN Member States. It advocates for policies along three policy tracks: reduce and prevent; prepare and respond; and restore and recover.



MRC - Drought Management Strategy for the Lower Mekong Basin 2020-2025.
The document consists of five main groupings: Indicator monitoring, drought forecasting and early warning, capacity building in drought assessment and planning, mitigation measures, and information sharing and dissemination. The strategic goals were defined through a series of national and regional consultations.

National Disaster Management Plan for Brunei Darussalam[43]
The legal underpinning for DRR and disaster management is the 2006 Disaster Management Order, which has led to the development of plans and SOPs applicable to all hazards and to which all government entities and responding partners are expected to adhere. Overarching strategic frameworks integrate disaster preparedness, resilience, and climate change adaptation.

National Disaster Management Plan for Cambodia[44]
Cambodia's Law on Disaster Management (DM Law) was passed by the National Assembly in June 2015. This was a significant shift from a system of disaster management based only on subsidiary legislation, which had been in place since 1995. In contrast, the 2015 DM Law is a broader and more authoritative legislative mandate on disaster management. A legal framework for disaster management assigns legally binding roles and responsibilities, establishes institutions, and helps ensure allocation of resources and mechanisms for coordination amongst different institutions.

National Disaster Management Plan for Indonesia[45]
Disaster Management Law (No. 24/2007). The Disaster Management Law laid out Indonesia's principles of disaster management, including national and regional responsibilities, rights, and obligations. In addition, it laid the foundations for coordination among stakeholders – public and private – during the phases of a disaster response. It explicitly rejected any form of discrimination in delivery of assistance. The Law laid the groundwork for creation of BNPB and called for creation of regulations for that agency's operation, disaster funding, local disaster management capacity building, and coordination of international assistance. Presidential Regulation 8 of 2008, then, provided the authorities for BNPB and the agency's structure.

National Disaster Management Plan for Lao PDR[46]
National Strategic Plan for Disaster Risk Reduction (2010-2020). The first concrete step for comprehensive Disaster Risk Management (DRM) planning was the Disaster Management Country Strategy, which is a long term, phased master plan for DRR. The strategy outlines its goals, and implementation approaches for 2005, 2010, and 2020, including the budget for operations. Continued support has been provided since 2010 to develop and implement action plans in order to roll out this strategy

National Disaster Management Plan for Malaysia[47]
Malaysia's national guidelines on disaster management are based on Directive No. 20: National Policy and Mechanism on Disaster Management Relief, which acts as a framework for disaster relief management for the country. This directive was issued in 1997 by the National Security Council (NSC) of the Prime Minister's Department. It is made up of 29 titles and 13 appendixes. The objective of Directive No.20 is to provide a policy guideline on disaster management and rescue in accordance with the level of the disaster. It also provides a mechanism for managing roles and responsibilities of agencies that are involved in combating disaster.

National Disaster Management Plan for Myanmar[48]
Myanmar Action Plan on Disaster Risk Reduction 2017 (MAPDRR). The Myanmar Action Plan on Disaster Risk Reduction 2017 (MAPDRR) is a comprehensive action plan for risk reduction and management with prioritized interventions with overall targets through the year 2030. The previous plan, (MAPDRR, 2012) provided a framework for multi-stakeholder engagement in disaster risk reduction. It was established in 2012.

43. Brunei Darussalam (nidm.gov.in)

44. Microsoft Word - (2) 16_07_15_Number Page DM Law_English.doc (chfcambodia.net)

45. Law of the Republic of Indonesia No. 24/2007 Concerning Disaster Management. | UNEP Law and Environment Assistance Platform

46. Strategic Plan On Disaster Risk Management in Lao PDR 2020, 2010 and action plan (2003-2005) - Library records OD Mekong Datahub (opendevelopmentmekong.net)

47. 1997_policy_and_mechanism_of_national_disaster_management_and_relief_national_security_council_directive.pdf (rcrc-resilience-southeastasia.org)

48. mya179767.pdf (fao.org)

National Disaster Management Plan for Philippines[49]

National Disaster Risk Reduction and Management Act (DRRM Act, 2010). Republic Act 10121 provided a legal and institutional basis for DRRM and laid the groundwork for development of plans and policies and for implementation of projects pertaining to DRRM. The DRRM Act outlined provisions for the establishment of NDRRMC and laid out the Implementing Rules and Regulations for National, Regional, and Local DRRMCs and their respective powers and functions.

Disaster Management Plan for Singapore[50]

Whole-of-Government Integrated Risk Management (WOG-IRM) Policy Framework. The Singapore government implements a cross-ministerial policy framework through a Whole-of-Government Integrated Risk Management (WOG-IRM) process for DRR and disaster management. Developed in 2004, in the wake of the SARS crisis, WOG-IRM is intended to identify risks that may impact strategic outcomes and to implement a process to analyze and manage those risks. The WOG-IRM now sits within the country's overall WOG planning process to ensure that DRR and disaster management are appropriately resourced and communicated.

National Disaster Management Plan for Thailand[51]

The Disaster Prevention and Mitigation Act of 2007 (DPM Act 2007), effective 7 September 2007, sets out the main statutory framework for DRM and disaster response in Thailand. The law covers three major categories of disasters: 1) man-made and naturally-caused disasters, 2) disasters resulting from air raids during wartime, and 3) disasters resulting from sabotage or a terrorist attack. The law establishes the National Disaster Prevention and Mitigation Committee (NDPMC) as the top policy body for DRM. The law also establishes the Department of Disaster Prevention and Mitigation (DDPM) under MOI as the secretariat for the NDPMC.

National Disaster Management Plan for Viet Nam[52]

A 2015 review by the IFRC found that there are more than 100 legal instruments in Viet Nam that are relevant to Disaster Risk Reduction (DRR). The UN Office for Disaster Risk Reduction 2020 Status Report for Viet Nam notes a broad set of overlapping and interrelated laws and policies concerning disaster management. Most of the laws and regulations on natural hazards are concerned with high-risk hazards such as floods and storms, while other hazards were addressed in separate laws and regulations. The National Strategy for Natural Disaster Prevention, Response and Mitigation to 2020 was first prepared in 2007 with legal backing from the Prime Minister's Decision No. 173/2007/ QD-TTG. An updated National Strategy for Natural Disaster Prevention and Control to 2030 with a vision to 2050 was approved on 17 March 2021 by Prime Minister Decision No.379/2021.

National Disaster Management Plan for Timor-Leste

Timor-Leste does not have a stand-alone statutory framework for disaster management, and its disaster management structure is laid out in various legal instruments including:

- Draft Decree-Law Establishing the Organic Structure of the Civil Protection Authority (approved by the Council of Ministers on 15 December 2021; pending promulgation by the President);
- Civil Protection Law 2020;
- Government Resolution 3/2019 "Establishing the Inter-ministerial Council for Civil Protection and Natural Disaster Management"; and
- MoI Ministerial Diploma 28/2021.

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49. Republic Act No. 10121 | Official Gazette of the Republic of the Philippines

50. Singapore | Resilience Library (rcrc-resilience-southeastasia.org)

51. Microsoft Word - PUBLIC DISASTER PREVENTION AND MITIGATION ACT, B.E. 2550 (2007).doc (krisdika.go.th)

52. Decision No. 379/QD-TTg 2021 the National Strategy on natural disaster prevention through 2030 (luatvietnam.vn)

APPENDIX B
GUIDELINES FOR COMMUNITY PROFILES FOR HIGH-RISK COMMUNITIES

To ensure gender and social inclusion, community profiles should be prepared only for communities which are located in the zones at high risk of droughts or floods – the red zones on the hazard maps. The data compiled in these profiles should be quite detailed, should include both quantitative and qualitative data, and preferably be based on recent field research. These should include basic demographic data, ideally, sex-disaggregated, obtained from the reports issued by the national statistics office, including censuses and Household Income and Expenditure Surveys (HIES). Additional sources of relevant data include studies conducted by UNESCAP, Asian Development Bank, or social impact assessments from Post-Disaster Needs Assessments (PDNAs).

Recommended information comprising a Community Profile:

QUANTITATIVE DATA

- Frequency of types of disasters affecting this community – droughts and storm
- Deaths in each recent disaster - disaggregated by males and females
- Total population in this community
- Population disaggregated by males and females
- Population disaggregated by age groups
- Population disaggregated by ethnicities, and religion
- Poverty level
- Average annual incomes - disaggregated by males and females
- Percentage of men in the workforce
- Percentage of women in the workforce
- Percentage of female-headed households
- Percentage of persons with disabilities
- Average school completion level
- Literacy rate
- Language(s) spoken

QUALITATIVE DATA

- Types of housing – construction materials and styles
- Date and description of most recent disasters affecting this community – droughts and storms
- Main livelihoods activities of the men
- Main livelihoods activities of the women
- Prevalence and types of child labor
- Local adaptation practices – for droughts and storms
- Numbers and types of skilled professionals residing in the community – doctors, nurses, psychologists, teachers, engineers, etc.
- Evacuation centers – how many and at what distance are they?
- Early warning systems for droughts and storms – do these exist and are they effective?
- Disaster preparedness training – what did this consist of and when were they held?
- Local authorities in charge of disaster management – names, locations and contact details