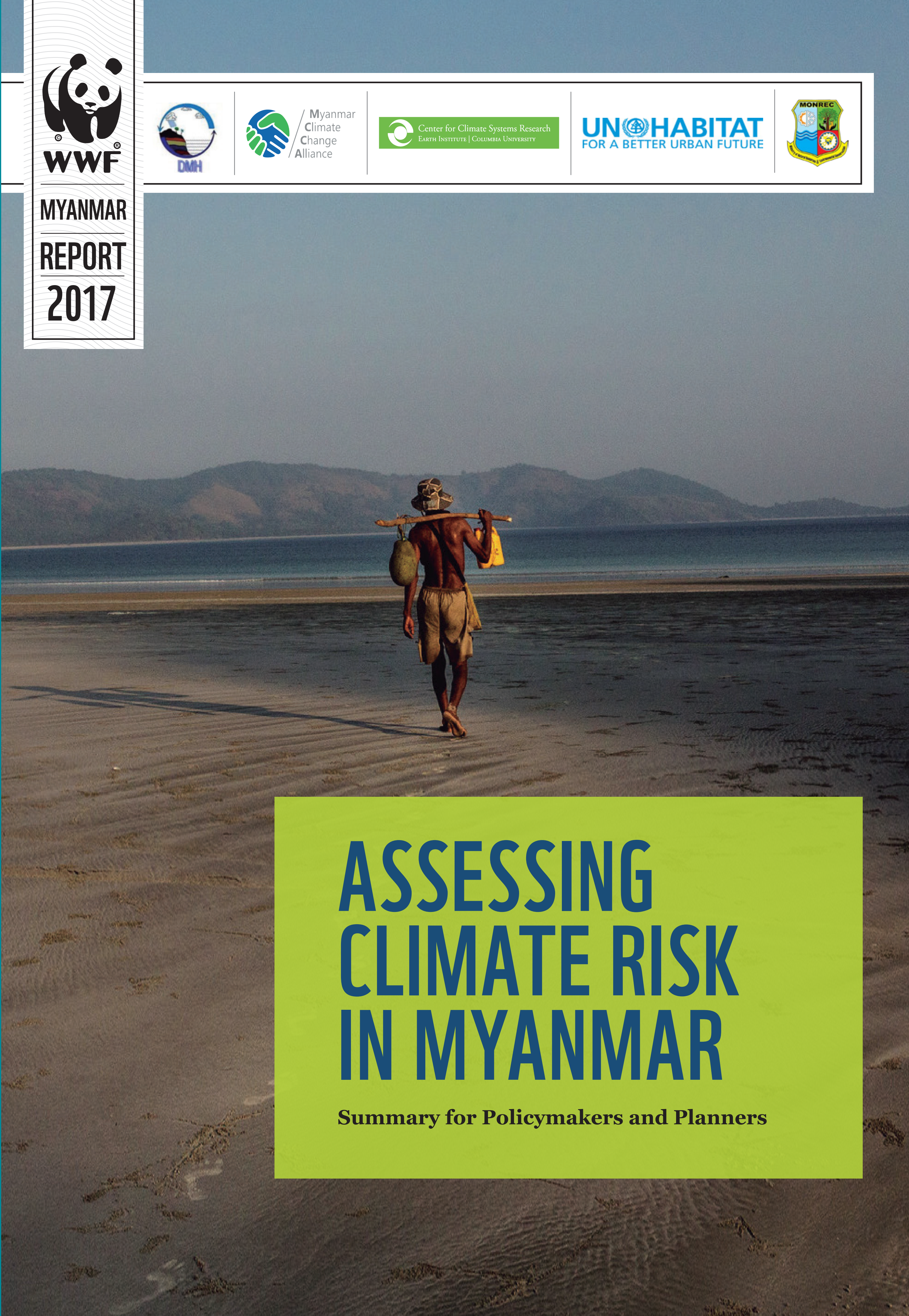

WWF

MYANMAR

REPORT

2017

DMH

Myanmar Climate Change Alliance

Center for Climate Systems Research
Earth Institute | Columbia University

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ASSESSING CLIMATE RISK IN MYANMAR

Summary for Policymakers and Planners

ACKNOWLEDGEMENTS

We would like to especially thank the Department of Meteorology and Hydrology (DMH) for generously providing historical rainfall and temperature data from 19 stations across Myanmar for the historical analysis. This report would not have been possible without their support.

This work was made possible with funding from The Leona M. and Harry B. Helmsley Charitable Trust. Myanmar Climate Change Alliance is funded by the European Union.

Design: One Big Robot
Photos: Minzayar Oo, Lee Poston, Martin Harvey, James Morgan, Stephen Kelly, and Stockphotos
Published March 2017

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CITATION

Horton, R., De Mel, M., Peters, D., Lesk, C., Bartlett, R., Helsingen, H., Bader, D., Capizzi, P., Martin, S. and Rosenzweig, C. 2017. *Assessing Climate Risk in Myanmar: Summary for Policymakers and Planners*. New York, NY, USA: Center for Climate Systems Research at Columbia University, WWF-US and WWF-Myanmar, UN-Habitat Myanmar.

ACCOMPANYING TECHNICAL REPORT

The Summary for Policymakers is a synthesis of the 2017 technical report, Assessing Climate Risk in Myanmar: Technical Report. The technical report contains in-depth analyses and regional projections by season.

Note: Like all future projections, climate projections have uncertainty embedded within them. Sources of uncertainty include data and modeling constraints, the random nature of some parts of the climate system, and limited understanding of some physical processes. In this report, the levels of uncertainty are characterised using state-of-the-art climate models, multiple scenarios of future greenhouse gas concentrations, and recent peer-reviewed literature. The projections are not true probabilities, and scenario-planning methods should be used to manage the risks inherent in future climate.

ASSESSING CLIMATE RISK IN MYANMAR

Summary for Policymakers and Planners

March 2017

WWF · DMH · Myanmar Climate Change Alliance · Center for Climate Systems Research, Earth Institute | Columbia University · UN-HABITAT FOR A BETTER URBAN FUTURE · MONREC

ABOUT THE INSTITUTIONS

Department of Meteorology and Hydrology

The Department of Meteorology and Hydrology (DMH) is under the control of the Ministry of Transport and Communications. DMH responsibilities include taking precautionary measures against and minimising the effects of natural disasters, by issuing meteorological information, warnings, news, alerts, and special outlooks. DMH supports public weather services, information, data, and weather forecasts, providing advice and observations to decision-makers, policy makers and different sectors.

Columbia University's Center for Climate Systems Research

The Center for Climate Systems Research (CCSR) is the home of a cooperative relationship between Columbia University and the NASA Goddard Institute for Space Studies (GISS) and a research centre of the Earth Institute at Columbia University. CCSR was established with the objective of providing enhanced understanding of Earth's climate and its impacts on key sectors and systems. CCSR plays a large role in the dissemination of climate change research and information to governments, local and international organisations, educational institutions, and stakeholders.

WWF

For more than 50 years, WWF has been protecting the future of nature. The world's leading conservation organization, WWF works in 100 countries and is supported by close to 5 million members globally. WWF's unique way of working combines global reach with a foundation in science, involves action at every level from local to global, and ensures the delivery of innovative solutions that meet the needs of both people and nature.

Myanmar Climate Change Alliance

The Myanmar Climate Change Alliance (MCCA) programme is an initiative of Myanmar's Ministry of Natural Resources and Environmental Conservation, implemented by the United Nations Human Settlements Programme (UN-Habitat) and the United Nations Environment Programme (UN-Environment) and funded by the European Union. It aims at mainstreaming climate change into Myanmar's development agenda by raising awareness of policy-makers and public opinion, formulating policies, strengthening coordination, building technical capacities and helping communities to adapt.

ADVANCE Partnership

ADVANCE is a partnership between WWF and the CCSR at the Earth Institute. Launched in 2015, ADVANCE facilitates adaptation by providing new ways of generating and integrating climate risk information into conservation and development planning, policies, and practice. ADVANCE envisions a future where the world is using co-generated climate risk information based on the best-available science to guide conservation, development, and disaster risk reduction to benefit human well-being and ecosystem health.

ACRONYMS AND ABBREVIATIONS

CCSR – Center for Climate Systems Research

CMIP5 – Coupled Model Intercomparison Project Phase 5

DMH – Department of Meteorology (Myanmar)

EM-DAT – Emergency Events Database

ENSO – El Niño-Southern Oscillation

GCM – General Circulation Model

IPCC – Intergovernmental Panel on Climate Change

MCCA – Myanmar Climate Change Alliance

MoNREC – Ministry of Natural Resources and Environmental Conservation (Myanmar)

NASA – National Aeronautics and Space Administration

NASA GISS – NASA Goddard Institute for Space Studies

NASA NEX-GDDP – NASA Earth Exchange Global Daily Downscaled Projections

NOAA –National Oceanic and Atmospheric Administration (United States)

RCP – Representative Concentration Pathway

UN-Environment – United Nations Environment Programme

UN-Habitat – United Nations Human Settlements Programme

VA – Vulnerability Assessment

WMO – World Meteorological Organization

WWF – World Wide Fund for Nature

CONTENTS

EXECUTIVE SUMMARY

This brief aims to help decision-makers across sectors in Myanmar incorporate climate change risks into planning and investment decisions by summarising key messages from a detailed technical analysis of climate change in Myanmar that is released alongside this report.

> "THE CRITICAL FIRST STEP IN BUILDING MYANMAR'S RESILIENCE TO CLIMATE CHANGE IS TO GENERATE CLIMATE RISK INFORMATION, BASED UPON THE BEST-AVAILABLE SCIENCE, WHICH ILLUSTRATES THE MAGNITUDE OF CLIMATE CHANGE MYANMAR WILL LIKELY SEE OVER THE COMING CENTURY."
>
> DIRECTOR GENERAL, DEPARTMENT OF METEOROLOGY AND HYDROLOGY

Specifically, this brief does the following:

- **Provides climate risk information,** including observed historical climate and future projections of temperature, rainfall, sea level rise and extreme weather events.
- **Highlights how climate change will affect sectors** such as biodiversity and ecosystem services, coastal zones, health, agriculture, infrastructure, water resources, and urban areas.
- **Provides on-the-ground examples of how climate risk information is being used** by the Myanmar Climate Change Alliance (MCCA) to support local planning in the Ayeyarwady Delta and the Central Dry Zone.
- **Supports a flexible adaptation approach, providing a range of possible future climates in Myanmar,** which helps address changes and impacts already underway and guides planning for changes that are likely to worsen in the future for Myanmar's people, ecosystems, and economy.

Based on analyses of 19 observed weather stations, the climate in Myanmar is already changing:

- Between 1981 and 2010, average temperatures increased by 0.25°C.
- The pace of warming has been faster inland than in coastal areas, and the rise in daily maximum temperatures has been greater than the daily average.
- Annual total rainfall increased slightly between 1981 and 2010, with a greater rate of increase in coastal areas than in inland ones.
- In coastal areas the increases occurred throughout the year, while in inland areas the increases occurred mainly during the monsoon season.
- Research suggests that the summer monsoon season has become shorter by approximately one week, on average (Lwin, 2002).

The country's climate is projected to shift dramatically in the coming decades:

- In every region in Myanmar, temperatures are expected to rise by the middle of the 21st century by 1.3°C–2.7°C. Warming varies by both season and region, with the cool (November–February) and hot (March–May) seasons projected to see the most warming.
- The eastern and northern hilly regions are projected to see the most dramatic warming among all regions of Myanmar, with hot season average temperatures rising by up to 3°C.
- During 1981–2010, Myanmar had about one day of extreme heat per month. In the future, projections show that Myanmar could experience anywhere from four to 17 days of extreme heat each month.
- Changes in rainfall patterns are projected to vary by region and season, with increases projected during the monsoon season, while both increases and decreases are possible the rest of the year.
- Sea level rise projections for the coastline range from 20 cm to 41 cm by mid-century. Although projected changes in cyclone severity and frequency are still uncertain, coastal flooding both during and independent of cyclones will worsen as sea levels rise.

Many interventions will be required to address the risks identified in this brief and associated longer technical report. In general, decision-makers and planners in Myanmar should do the following:

- Change practices in specific sectors, e.g. crop choices, planting patterns, and water-use efficiency for agriculture.
- Strengthen infrastructure, including the use of ecosystem-based adaptation approaches such as mangrove forests to help protect communities from frequent floods.
- Protect forests and other ecosystems that provide services that help build climate resilience for people, such as safeguarding clean drinking water and preventing erosion.
- Assess conservation strategies to support adaptation for ecosystems and biodiversity (e.g. wildlife corridors to upland or inland areas).
- Develop disaster preparedness and response strategies to cope with increasing heat stresses, changes in the hydrological cycle, and extreme events.

INTRODUCTION

Myanmar is one of the countries most affected by extreme weather events (Kreft *et al.*, 2016). Recent events such as Cyclone Nargis in 2008, the extreme heat waves of 2010, and flooding in 2015 have had disastrous impacts on Myanmar's people, environment, and economy. Climate change threatens to compound the frequency and intensity of these events.

It is essential to understand and quantify the changes in climate that are already taking place in Myanmar and those likely to occur over the coming century. This report describes the country's climate and recent climate trends, and outlines how climate conditions are projected to change by the

2020s (defined as the time period from 2011–2040)

2050s (defined as the time period from 2041–2070)

Projections include changes in temperature, precipitation, and sea levels. The report analyses extreme events, reviews key climate processes such as the monsoon, applies climate risk information to selected sectors, and describes how local vulnerability assessments and adaptation planning activities are utilising climate risk information. The report should be seen as a contribution to the broader work on climate change and to official projections being carried out by DMH and the Regional Integrated Multi-Hazard Early Warning System (RIMES), which are due to be released in the near future.

Local and regional decision-makers need to be aware of the changes that will directly affect the areas they govern. By understanding these climate risks, they can take action now to prevent the worst impacts of climate change from happening in communities in Myanmar and around the globe.

> “ONE OF THE BEST WAYS TO BUILD CLIMATE RESILIENCE IS TO HARNESS THE POWER OF ECOSYSTEMS AND THE NUMEROUS BENEFITS THEY PROVIDE TO PEOPLE; FROM FORESTS, THAT HELP PROVIDE CLEAN DRINKING WATER AND REDUCE FLOODING DOWNSTREAM, TO COASTAL MANGROVES THAT PROVIDE CRITICAL DEFENCES AGAINST COASTAL EROSION AND INCREASINGLY INTENSE CYCLONES.
>
> DIRECTOR GENERAL, DEPARTMENT OF METEOROLOGY AND HYDROLOGY”

METHODS

Temperature and precipitation projections were developed using the NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP) dataset released in 2015 (NASA, 2015). The NEX-GDDP dataset includes downscaled projections (0.25 degrees, ~25 km resolution) from the 21 climate models and scenarios for which daily scenarios were produced and distributed under the Coupled Model Intercomparison Project Phase 5 (NASA, 2015, CMIP5, 2016). The CMIP5 GCM simulations were developed in support of the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) (IPCC, 2013). Sea level rise projections were developed using model outputs from the CMIP5 GCMs, along with other data sources and methods that account for land-based ice loss and changes in land water storage (Horton *et al.*, 2015).

CHAPTER 1:

HOW CAN CLIMATE RISK INFORMATION SUPPORT PLANNING IN DIFFERENT SECTORS?

1.1 BIODIVERSITY AND ECOSYSTEM SERVICES

1.2 COASTAL ZONES

1.3 HEALTH

1.4 AGRICULTURE

1.5 INFRASTRUCTURE

1.6 WATER RESOURCES

1.7 URBAN AREAS

Climate projections can help decision-makers consider future risks resulting from climate change. Measures must be taken to build resilience to the potential impacts that these changes may pose to ecosystems, livelihoods, infrastructure, and economic growth. Planning for a range of possible futures can foster a flexible approach to adaptation that keeps options open. Climate impacts will often affect several sectors in different ways, while responses and adaptation measures taken in one sector may also have implications for other sectors.

1.1 BIODIVERSITY AND ECOSYSTEM SERVICES

IMPACTS

Climate change will impact ecosystems and species in multiple ways, including direct effects of changing temperatures and rainfall patterns, and indirect effects as people respond to climate change. As Myanmar continues to rapidly develop, ecosystems and biodiversity will be particularly vulnerable to human responses to climate change, with people potentially further degrading ecosystems or impacting biodiversity as they build resilience to climate change.

- Range-restricted species, slow-moving species, low-dispersal species, and species already facing high threats are likely to be the most vulnerable to climate change.
- All types of services provided by ecosystems for people will be affected by climate change, especially in conjunction with other direct human impacts such as deforestation and land degradation. For instance, diverse and healthy forests can reduce flooding from heavy rainfall and coastal storms.

WHAT NEEDS TO BE DONE?

- Reduce existing human impacts on ecosystems that provide important benefits to local populations, such as upstream forests that reduce flood risk or coastal mangroves that support fisheries.
- Plan for indirect effects of climate change on ecosystems and biodiversity, i.e. impacts from human responses to climate change, such as migration, expanding agricultural areas, land use change, or infrastructure development.
- Update existing protected area management plans and species action plans to account for the changes described in this report.
- Monitor species and ecosystem responses to changing temperatures and rainfall, along with on-going re-evaluation of the effectiveness of climate-adapted conservation measures.
- Compile and apply local knowledge about weather impacts on ecosystems and species in planning adaptation actions.

ASSESSING CLIMATE RISK TO NATURAL CAPITAL AND ECOSYSTEM SERVICES

Using climate projections described in this report, analyses of ecosystem services show how key benefits provided by forests, such as clean drinking water and sediment and flood retention, are likely to change as temperatures increase and rainfall patterns change across the country (Mandle *et al.*, 2016). The assessment demonstrates how ecosystems contribute to climate resilience and the need to keep them intact as the effects of climate change increase.

Figure 1.1. *Potential change in sediment retention under high climate change scenario RCP 8.5.*
Source: Mandle *et al.*, 2016.

1.2 COASTAL ZONES

IMPACTS

Myanmar's extensive coastline will experience rising seas and increasingly frequent and extreme hazards, with the Ayeyarwady Delta region likely to be the most affected. Sea level rise alone will cause larger areas to be inundated during storm surges and coastal floods, further augmented by increasing storm intensity. Combined with other important factors such as salinity levels and ocean acidification, these changes will significantly impact populations, infrastructure, and biodiversity and ecosystems.

WHAT NEEDS TO BE DONE?

- Take into account projected changes in climate and rising sea levels, as well as other changes such as saline intrusion and ocean acidification, in all coastal-based development activities.
- Identify and monitor thresholds for ecosystems—tipping points at which they will no longer provide benefits to people—and plan to avoid crossing them where possible.
- Plans for reforestation in coastal areas to ensure replanted areas survive future flooding.
- Perform studies and assessments of coastal flood recurrence rates and inundation areas.

1.3 HEALTH

IMPACTS

Changing rainfall patterns, warming temperatures, changes in extreme heat, and other extreme weather events pose major challenges to the health sector. Heat waves and increasing frequency of very hot days, coupled with high humidity, can cause severe health complications and are a significant cause of weather-related deaths. The elderly and young are most at risk, while outdoor workers can also be severely affected by heat. More intense rainfall may result in more severe and frequent flooding, which poses an immediate threat to safety and can cause disease outbreaks.

WHAT NEEDS TO BE DONE?

- Consider implications of large increases in extreme heat in public-sector plans.
- Develop interventions to prevent heat exposure (e.g. increasing cooling, ventilation, or insulation of buildings, and creating cooling stations) and other adaptation measures to combat heat-related deaths.
- Develop regional flood warning systems, evacuation plans, and potential solutions for water supply and sanitation challenges during extreme flooding, to avoid spreading water-borne disease.

1.4 AGRICULTURE

IMPACTS

Climate change will significantly affect food security, nutrition, and livelihoods, as crops and livestock are sensitive to numerous climate variables and vulnerable to extreme weather events.

WHAT NEEDS TO BE DONE?

- Enact resilience-building measures such as improved water efficiency, best management practices to reduce soil loss, and planting of species with greater tolerance to extremes like droughts and floods.
- Maintain forests upstream to help reduce flood risk and provide other benefits such as sediment retention for water quality and water provision for farmers downstream.

1.5 INFRASTRUCTURE

IMPACTS

Any risks that climate change poses to critical infrastructure systems in Myanmar, such as energy, transportation, buildings, water supply and wastewater, and telecommunications also pose a direct risk to livelihoods that depend on them.

WHAT NEEDS TO BE DONE?

- Plan, develop, site, and design infrastructure based on climate risk.
- Survey current and future infrastructure vulnerabilities, including interdependencies among various systems to prevent cascading failures from one system to another.
- Use temperature projections to alter the design of power systems so they can operate under extreme temperatures, and to plan for more frequent peak-load scenarios.
- Assess possible relocation of buildings, roads, and railways projected to be in future flood plains or facing immediate threats from sea level rise, and identify evacuation routes.
- Improve resilience of telecommunications infrastructure such as cell phone towers to allow other infrastructure systems, as well as decision-makers, to maintain vital communication during a disaster.

1.6 WATER RESOURCES

IMPACTS

Increasing rainfall variability and intensity of extreme events make it unlikely that steady, predictable seasonal water flows will be maintained in the future. Year-to-year variation of seasonal water flows will increase as a result of climate change. Projections for the cold and hot seasons in Myanmar span a range that suggests seasonal rainfall could either increase or decrease, while an increase in precipitation is projected for the wet season.

WHAT NEEDS TO BE DONE?

- Ensure that the water resources sector engages others in integrated water resource management (IWRM), including upstream and downstream land users, to develop a more integrated approach to managing increasing variability.
- Collaborate across sectors and scales to manage uncertainties in seasonal water flows (e.g. changing operations of reservoirs and dams), with a goal of maintaining water and hydropower supply while minimising flood risk.
- Ensure that water resource managers address water scarcity in the dry season by working with other regions to secure additional drinking water sources where needed.
- Encourage the disaster risk reduction sector to begin developing plans for increasingly frequent and intense hazards such as flooding and drought, and work with farmers to implement flood defences and water-efficiency measures.

1.7 URBAN AREAS

IMPACTS

During extreme events in urban areas, failures in one infrastructure system—such as energy, transportation, or water infrastructure—can quickly cause failures in other systems, leading to broad and rapidly emerging crises.

WHAT NEEDS TO BE DONE?

- Analyse vulnerabilities of urban areas today, and assess how they might fare under future climate conditions.
- Develop indicators of at-risk neighbourhoods, which could include household income, age, stability of infrastructure, water quality and availability, sanitation, and access to transportation and social networks.
- Once these vulnerabilities are known, assess how the indicators will change due to the climate projections presented in this report.

CHAPTER 2:

WHAT IS THE PRESENT CLIMATE IN MYANMAR?

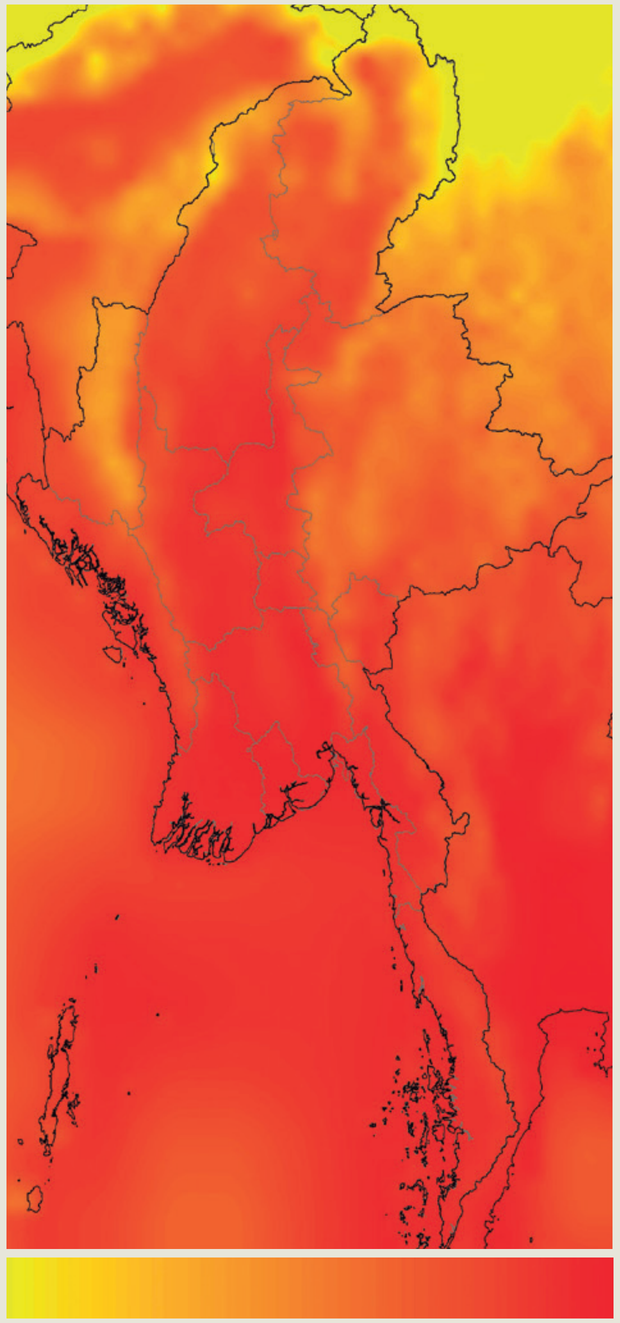


Figure 2.1. Baseline annual average temperature climatology across Myanmar (1980-2005) from climate model outputs.

Source data: NASA NEX GDDP, 2015

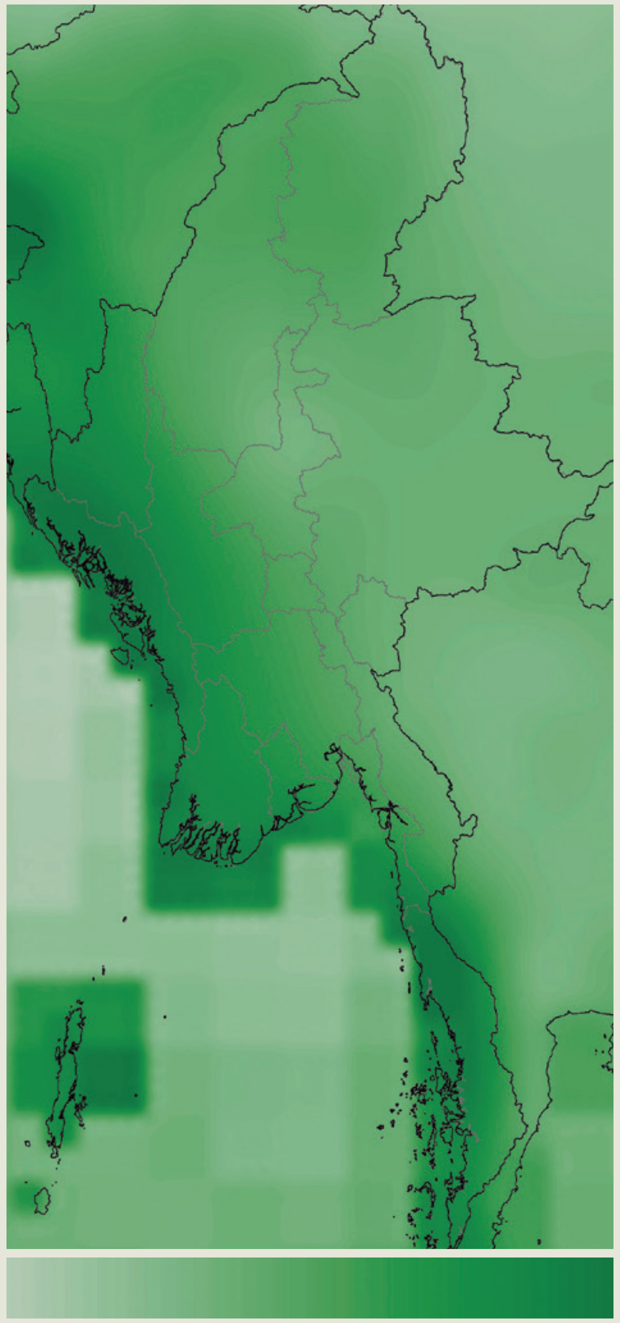


Figure 2.2. Baseline annual precipitation climatology across Myanmar (1980-2005) from climate model outputs.

"THE STREAMS ARE OUR MAIN SOURCE OF DRINKING WATER, BUT MANY OF THEM HAVE DRIED UP DUE TO THE INCREASE IN TEMPERATURE. NOW WE HAVE TO WALK FOR MORE THAN 15 MINUTES TO COLLECT WATER, AND EVEN LONGER IN THE SUMMER"

U SAW MYA, BAGO REGION

Myanmar experiences a tropical monsoonal climate with three seasons: the March-to-May hot season, the June-to-October wet season, and the November-to-February cool season, which vary by region. The climatology of annual baseline temperature and precipitation across Myanmar is shown in Figures 2.1 and 2.2, respectively.

EXTREME EVENTS

- The Central Dry Zone is especially prone to excessive heat events and drought.
- The rainy coasts, such as the Rakhine, Southern Coastal, and Yangon Deltaic areas, have slightly cooler annual maximum temperatures but are prone to flooding.

TEMPERATURE

- The Yangon Deltaic region has the highest mean annual temperature.
- The Northern Hilly region has the lowest mean annual temperature.

RAINFALL

- Myanmar receives most of its rainfall during the rainy (monsoon) season.
- The hot and cool seasons bring little rainfall, with the cool season especially yielding very little rainfall for all regions.
- Coastal regions experience much greater amounts of annual rainfall than inland areas.
- The highest annual rainfall is in the Rakhine coastal region, followed by the Ayeyarwady Delta.

CHAPTER 3:

IS MYANMAR'S CLIMATE ALREADY CHANGING?

Myanmar has experienced climate change over recent decades, based on data from 19 weather stations.

TEMPERATURE

- Average daily temperatures increased by about 0.25°C per decade, and daily maximum temperatures by 0.4°C per decade, between 1981 and 2010. These rates are comparable to global averages for the same time frame (IPCC, 2014).
- Inland regions warmed faster than coastal, in terms of both average temperature (0.35°C per decade increase in inland regions versus 0.14°C per decade coastally) and maximum temperature (0.57°C increase per decade inland versus 0.23°C increase per decade along the coasts) (Figure 3.1).

RAINFALL

- As in most of the world, precipitation trends between 1981 and 2010 are more ambiguous than temperature trends (Figure 3.2), due to a combination of large natural variability and small trends relative to baseline average amounts.
- Annual total rainfall has increased in coastal areas by 157 mm (4.5%) per decade. Increases in inland annual precipitation have been more moderate at 37 mm (2.5%) per decade. These small gains are driven by slightly wetter monsoon months, as no trend was detected during the dry season.
- This increase in total rainfall was not accompanied by a rising trend in the number of rainy days, implying that the intensity of rainfall events has risen over the 1981–2010 period.

Figure 3.1. *Trends in daily average and daily maximum temperatures on average across 9 inland (blue) and 10 coastal (green) weather stations, 1981-2010.*
Weather station data provided by DMH (2015).

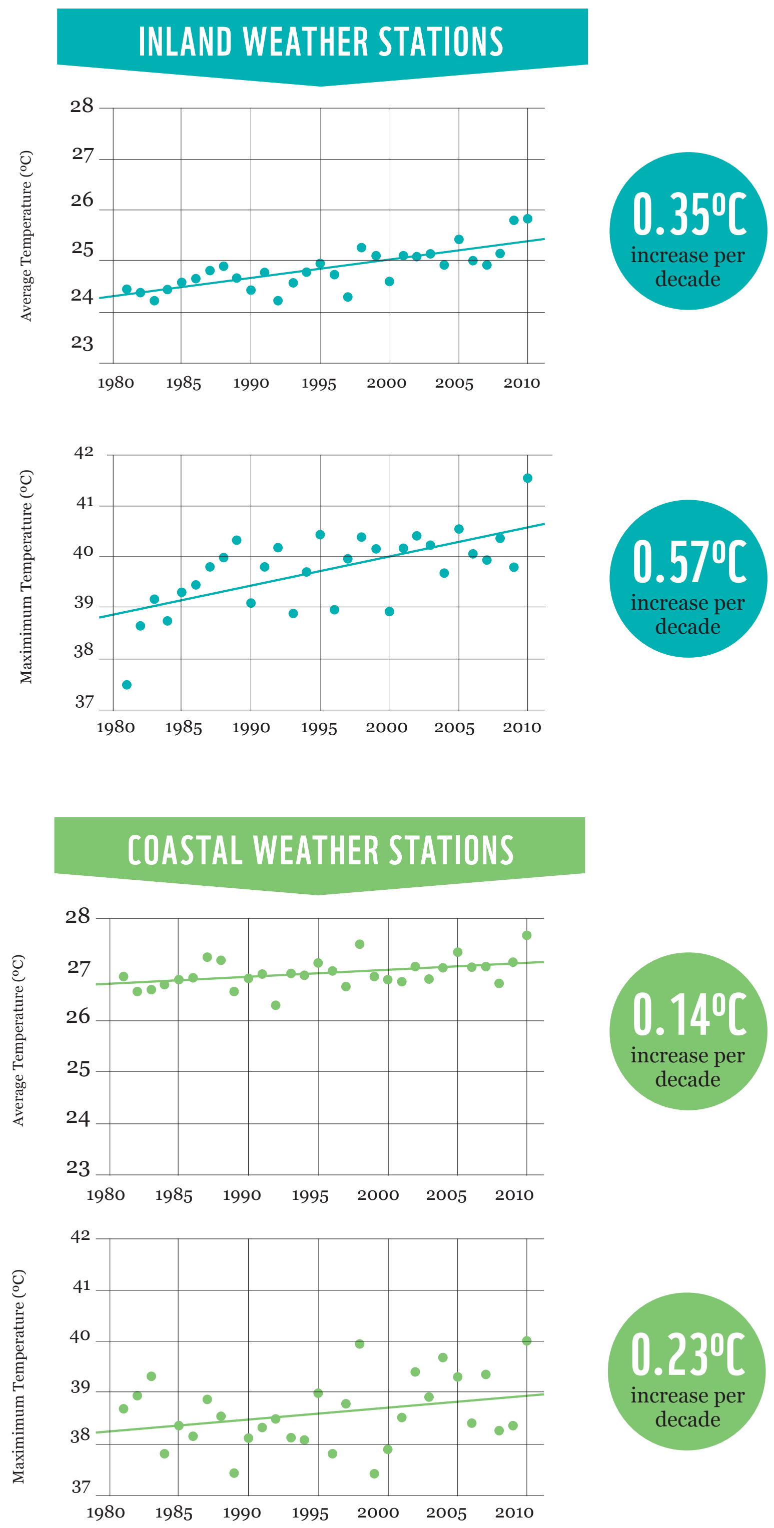
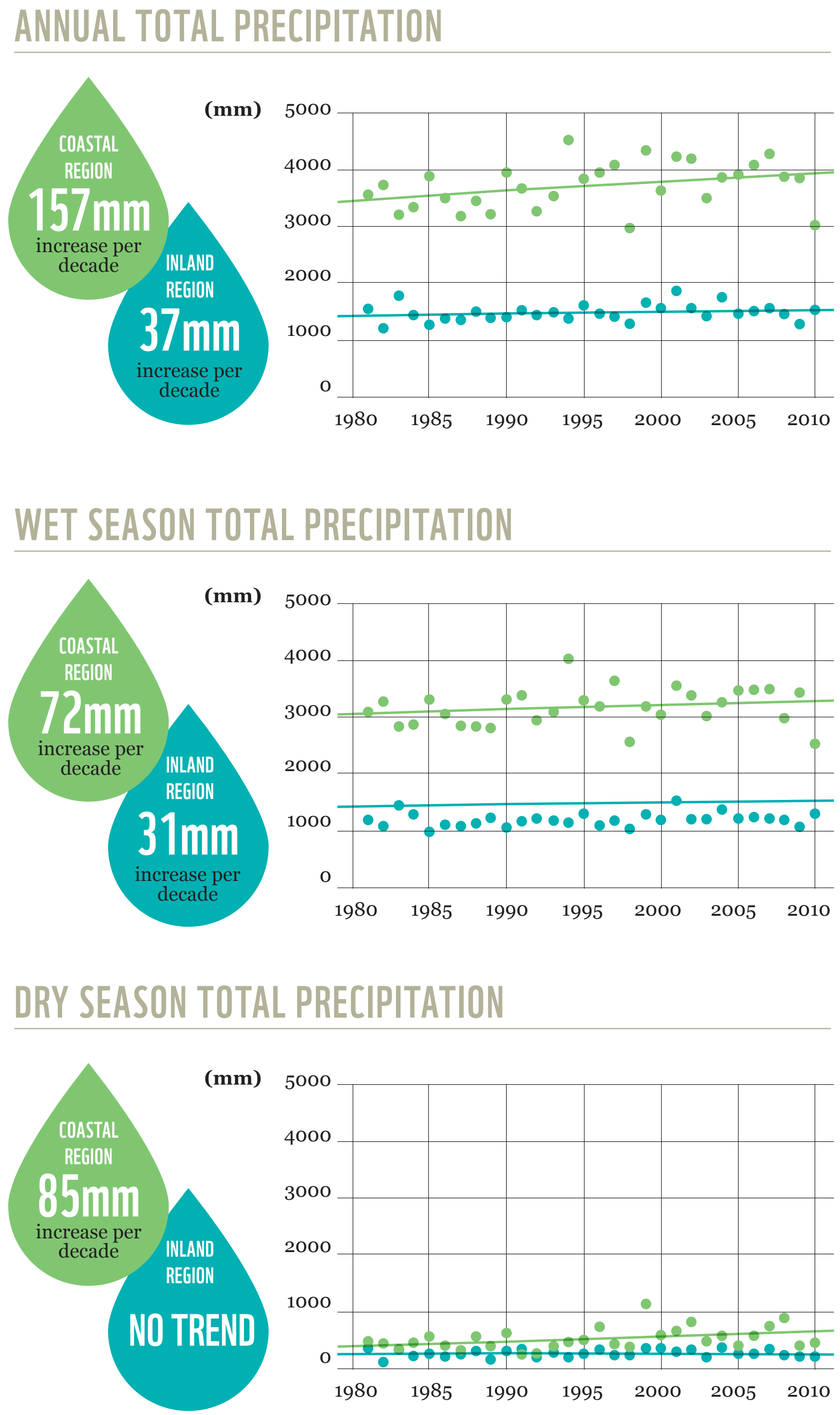


Figure 3.2. *Trends in total annual [top], wet season (June to October) [center], and dry season (November to May) [bottom] precipitation for 10 coastal (green) and 9 inland (blue) weather stations, 1981-2010.*
Weather station data provided by DMH (2015).



CHAPTER 4:

HOW MUCH WILL TEMPERATURES INCREASE IN THE FUTURE?

> WE'VE NOTICED WARMER DAYS SINCE 2004. WE NOW DEPEND ON DRINKING WATER FROM HAND-SCOOPED WATERHOLES," HE SAYS. "WE USED TO GET SPRING WATER BUT IT DRIED UP AND IT'S NOT AVAILABLE ANYMORE. WE'VE ALSO NOTICED THE QUANTITY OF WATER IN MANY STREAMS IS DECREASING.
>
> U WIN NYUNT, BAGO REGION

Myanmar's average annual temperature is expected to rise over the coming century, with the magnitude of warming varying by region and season (Figures 4.1 and 4.2, and Table 4.1).

- During the 2020s, national annual average temperatures are projected to rise by 0.7°C–1.1°C compared with the 1980–2005 base period, while warming trends may accelerate by mid-century, raising average temperatures by 1.3°C–2.7°C relative to the base period (Table 4.1).
- Wet season temperature increases are projected to be smaller than warm and cool season changes. By the 2050s, wet season (June to October) mean temperatures are projected to increase by 1.1°C–2.4°C, which is 0.3°C–0.5°C less than the projected warming during the remainder of the year.
- By the 2050s, temperatures in inland areas are projected to increase more than coastal ones. The Eastern and Northern Hilly regions may see the most dramatic warming, with hot season average temperatures projected to rise by up to 3°C.

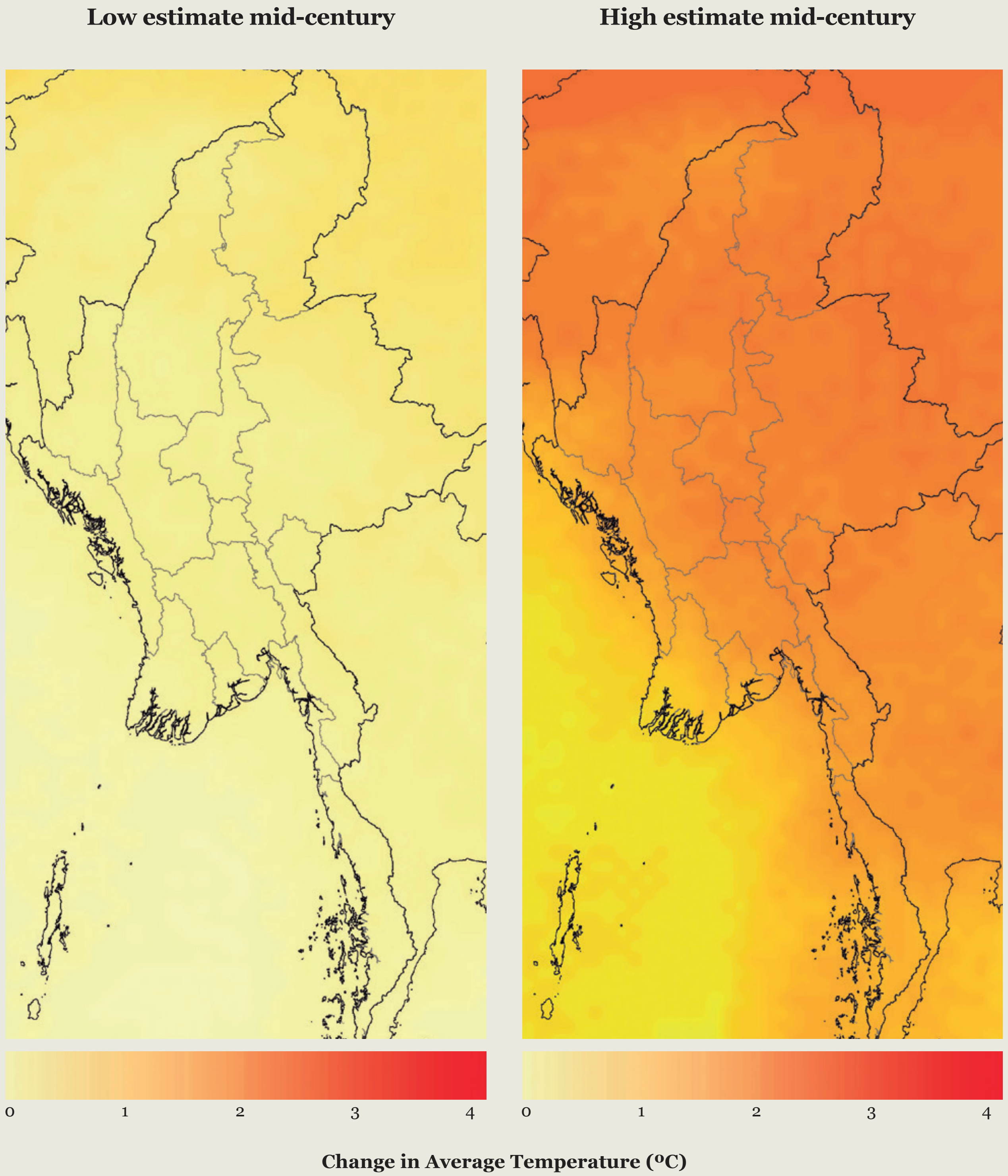


Figure 4.1. Average annual temperature change in mid-century relative to the 1980–2005 base period.
Note: Data source for temperature projections is NASA Earth Exchange Global Daily Downscaled Projections (NASA NEX GDDP, 2015).

Table 4.1. Projections for mean annual and seasonal temperature change above the baseline across Myanmar.

	Model baseline (1980 to 2006)	Warming by 2011-2040	Temperature range 2011-2040	Warming by 2041-2070	Temperature range 2041-2070
Annual	23.6 °C	0.7-1.1°C	24.2-24.7°C	1.3-2.7°C	24.8-26.2°C
Hot Season	25.1°C	0.8-1.2°C	25.9-26.3°C	1.4-2.9°C	26.5-27.9°C
Wet Season	25.1°C	0.6-1.1°C	25.7-26.2°C	1.1-2.4°C	26.2-27.5°C
Cool Season	20.5°C	0.7-1.2°C	21.2-21.6°C	1.3-2.8°C	21.8-23.2°C

* The NASA NEX baseline data reflects model values averaged over 0.25 degrees (~25km). For this and other reasons, the actual observed station temperatures may differ from the model baseline shown here.

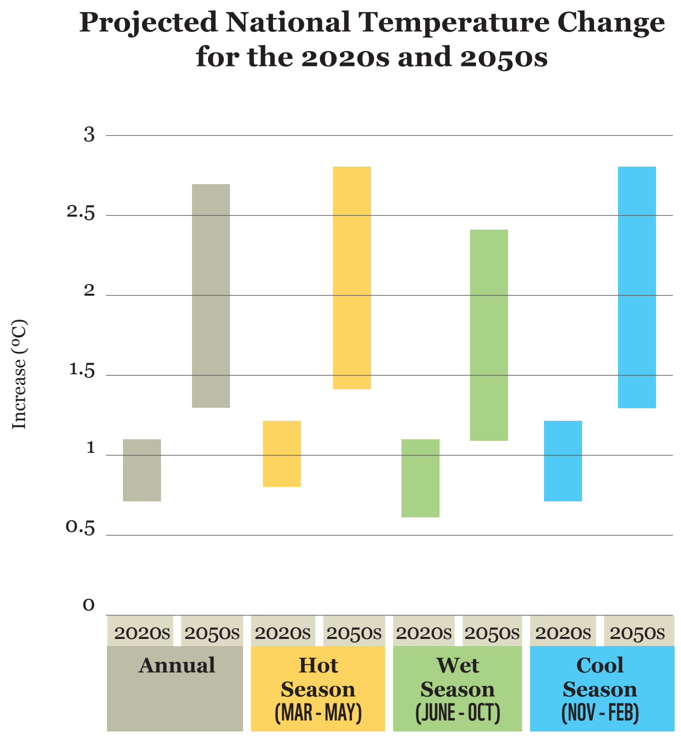


Figure 4.2. Range of average annual temperature change (low estimate to high estimate) relative to the 1980–2005 base period.
Note: Data source for temperature projections is NASA Earth Exchange Global Daily Downscaled Projections (NASA NEX GDDP, 2015).

CHAPTER 5:

HOW WILL RAINFALL CHANGE IN THE FUTURE?

WATER HAS BECOME LESS AVAILABLE OVER THE RECENT YEARS. IT TAKES ABOUT 20 MINUTES TO GET TO THE NEAREST SOURCE OF WATER. IT TAKES ABOUT FOUR TO FIVE TRIPS TO GET WATER BY MYSELF AND SOMETIMES 10 TRIPS IF NEEDED. IT'S ALSO NO LONGER COLD IN THE WINTER.

DAW SHIN NYAR, BAGO REGION

- The wet season is projected to see more rainfall, with total precipitation projected to increase in both the near and the long term compared with the 1980–2005 baseline. These changes could increase wet season flooding in some regions.
- It is uncertain whether cool and hot season precipitation will increase or decrease.
- By mid-century, rainfall during the hot season is more likely to increase than decrease, while cool season projected changes are less clear.
- A large percent change in a dry region can result in a smaller absolute change than a small percent change in a wet region.
- While rainfall extremes are expected to become more severe and frequent on a global scale, our analysis is inconclusive on these trends for Myanmar, as climate models are presently limited in projecting rainfall extremes.

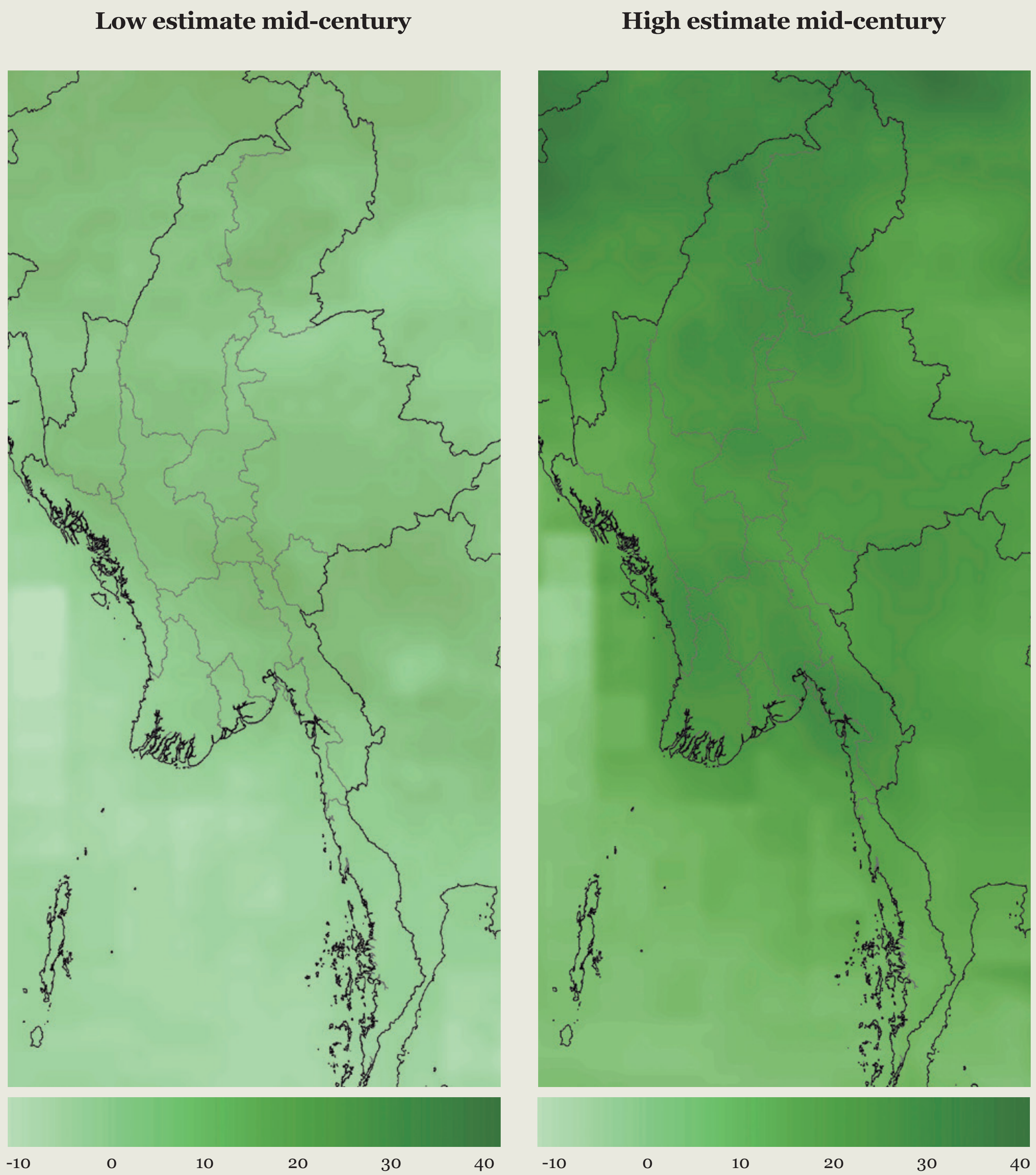


Figure 5.1. *Average annual rainfall percentage change in the mid-century relative to the 1980–2005 base period.*
Note: Data source for precipitation projections is NASA Earth Exchange Global Daily Downscaled Projections (NASA NEX GDDP, 2015).

Table 5.1. *Projections for mean annual and seasonal precipitation change relative to 1980–2005 across Myanmar.*

	Model baseline* (1980 to 2006)	Percent Change 2011-2040	Precipitation range 2011-2040	Percent Change 2041-2070	Precipitation range 2041-2070
Annual	2029	+1% to +11%	2039 to 2242	+6% to +23%	2146 to 2480
Hot Season	285	-11% to +12%	252 to 319	-7% to +19%	266 to 338
Wet Season	1657	+2% to +12%	319 to 1854	+6% to +27%	1753 to 2084
Cool Season	87	-23% to +11%	69 to 96	-12% to +11%	77 to 99

Source data: NASA NEX GDDP, 2015.
* The NASA NEX baseline data reflects model values averaged over 0.25 degrees (~25km). For this and other reasons, the actual observed station temperatures may differ from the model baseline shown here.

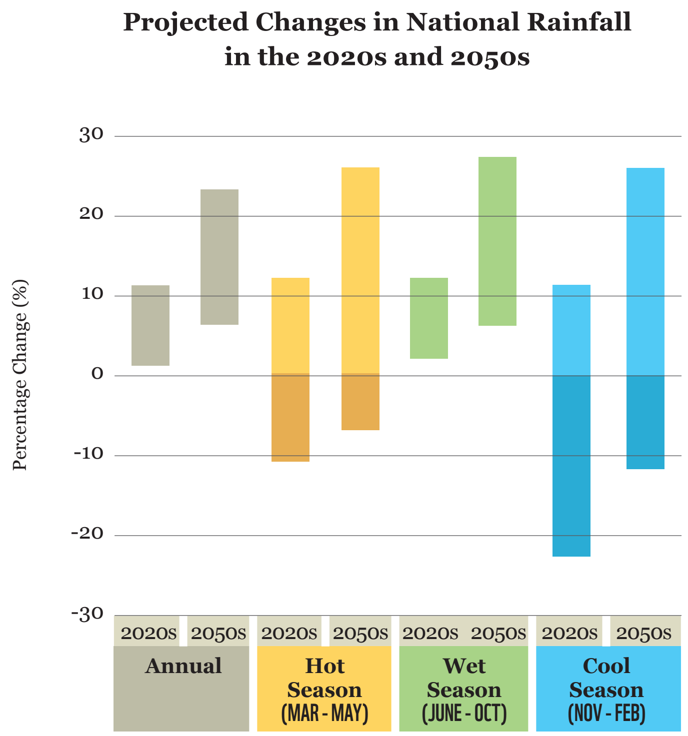
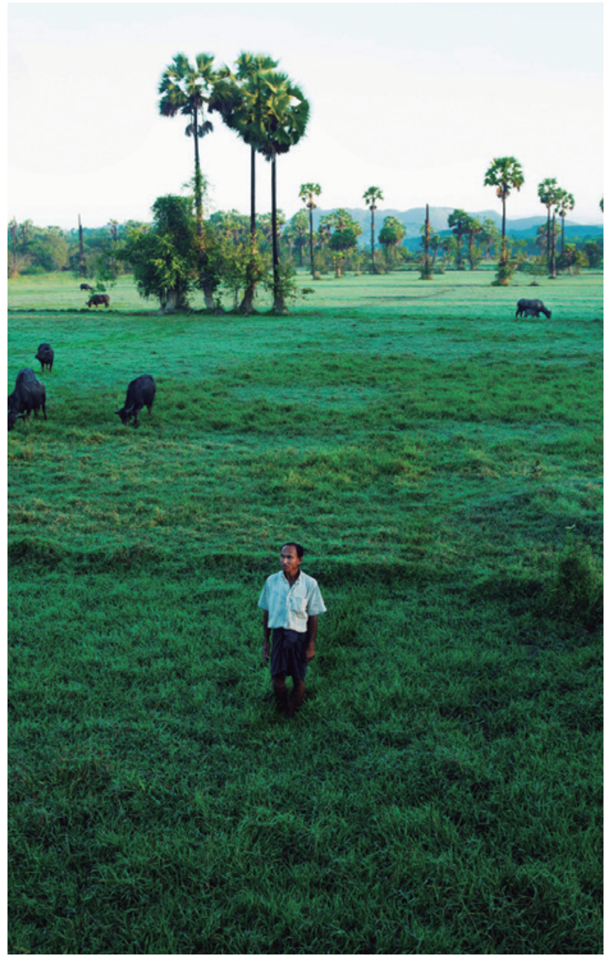


Figure 5.2. *Range of average annual rainfall percentage change (low estimate to high estimate) relative to the 1980–2005 base period.*
Note: Data source for precipitation projections is NASA Earth Exchange Global Daily Downscaled Projections (NASA NEX GDDP, 2015).



CHAPTER 6:

HOW MUCH WILL SEA LEVELS RISE?

Figure 6.1. *Middle-range projections of sea level rise above 2000–2004 base period levels in Myanmar (cm).*

Note: The middle range refers to the 25th-to-75th percentile of model-based outcomes for sea level rise projections.

> AS MOUNTING EVIDENCE FROM AROUND THE WORLD SHOWS, ONE OF THE BEST WAYS TO BUILD RESILIENCE IS TO HARNESS THE POWER OF ECOSYSTEMS AND THE NUMEROUS BENEFITS THEY PROVIDE TO PEOPLE; FROM FORESTS, THAT HELP PROVIDE CLEAN DRINKING WATER AND REDUCE FLOODING DOWNSTREAM, TO COASTAL MANGROVES THAT PROVIDE CRITICAL DEFENCES AGAINST COASTAL EROSION AND INCREASINGLY INTENSE CYCLONES.
>
> WWF, UN-HABITAT AND CCSR

Sea levels are projected to rise by between 5 cm and 13 cm in the 2020s along the entire coast of Myanmar, increasing to 20 cm to 41 cm in the 2050s, and 37 cm to 83 cm in the 2080s, with the potential for as much as a 122 cm increase (Figure 6.1, Figure 6.2). These projections take into account global and regional components that contribute to changes in sea levels, but they do not take into account local land subsidence, which can lead to sea level rise larger than shown here. It is important to factor in local coastal land subsidence when applying these sea level rise projections.

These projections would mean large increases in permanently flooded areas, and in the frequency and magnitude of flooding in coastal areas not permanently flooded along Myanmar's coastline. Projected increase in sea levels would carry flooding even farther inland in the future, resulting in even greater impacts. For example, it has been estimated that a 0.5 m rise in sea levels could cause the coastline to retreat by approximately 10 km in Myanmar's lowest lying areas like the Ayeyarwady Delta (Ministry of Environmental Conservation and Forestry and Department of Meteorology and Hydrology, 2012).

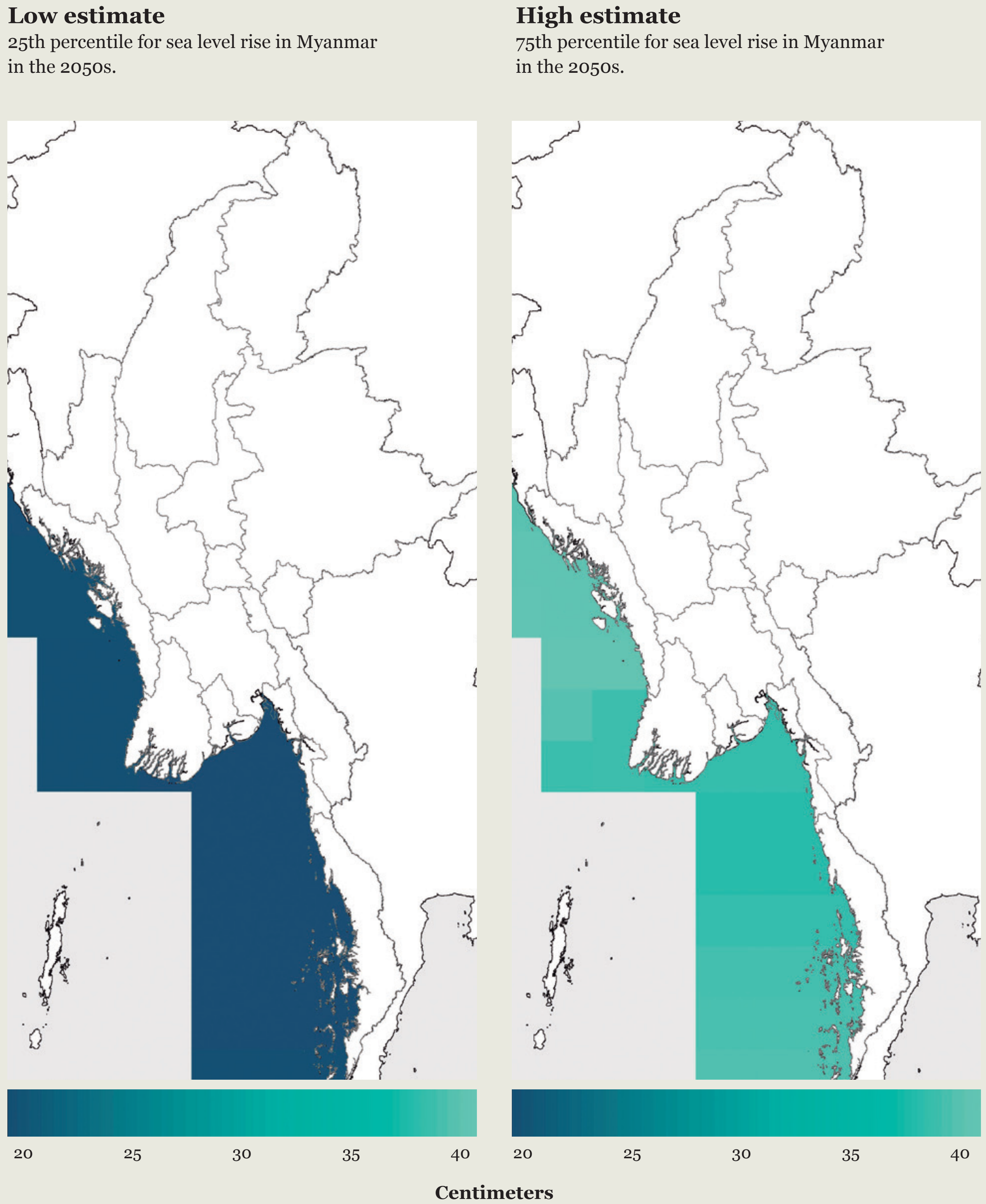
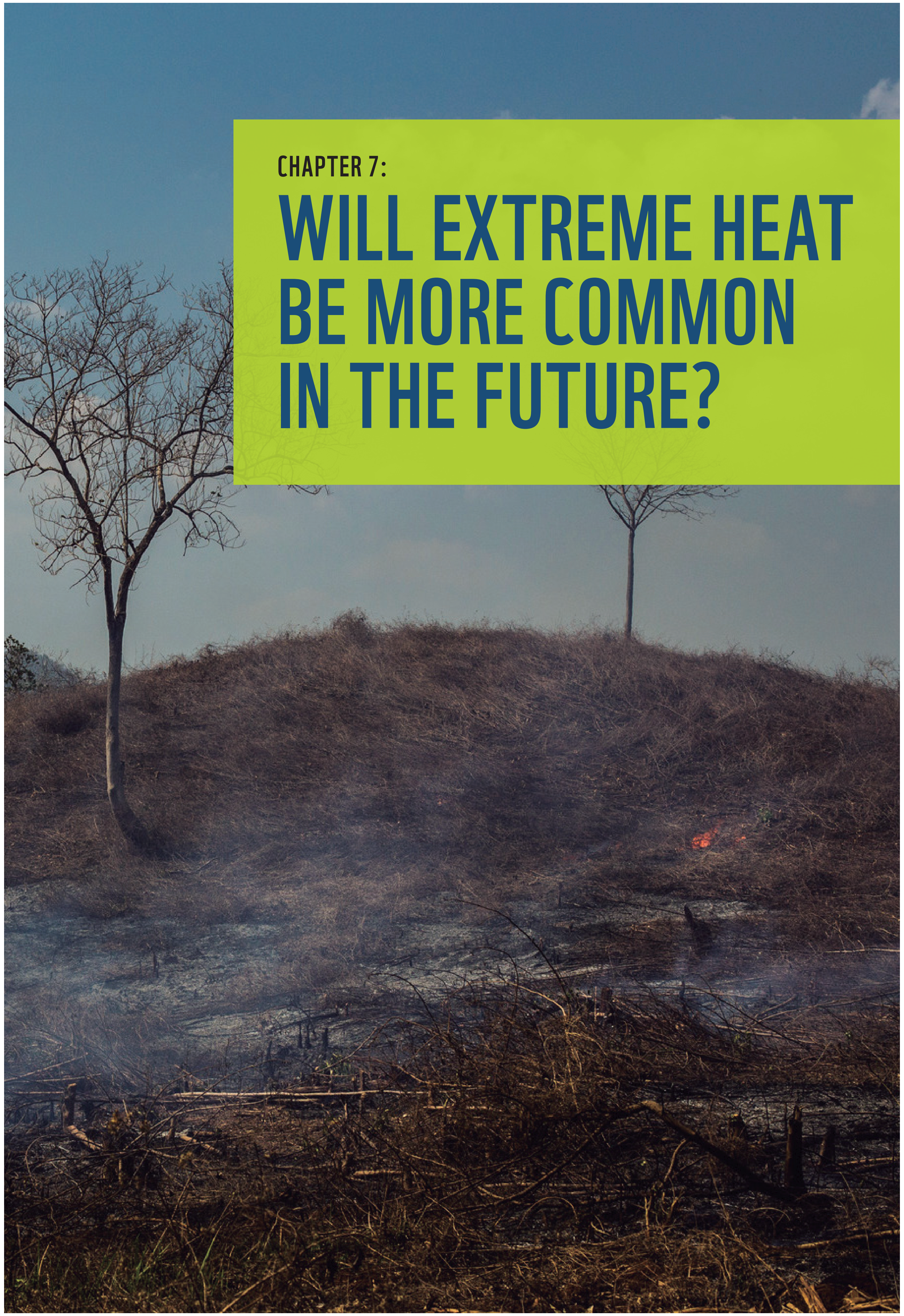


Figure 6.2. *Projected sea level rise along the coast of Myanmar in the 2050s relative to the 2000–2004 base period.*



CHAPTER 7:

WILL EXTREME HEAT BE MORE COMMON IN THE FUTURE?

Small changes in average temperature can result in disproportionate increases in the number of very hot days (Figure 7.1). A greater frequency of very hot days can cause severe damage to human health, ecosystems, crops, and infrastructure.

During 1981–2010, the average hottest day of the month during the hot season was 38°C in coastal areas and 39°C in inland areas. By the 2020s, this temperature is projected to occur three to six days per month, and seven to 17 days per month by the 2050s. In other words, what used to be the single hottest day of the month during the hot season may occur as often as every other day by 2041–2070.

April has experienced the most severe extreme heat days historically (reaching 38°C–39°C) and is also expected to see the highest increase in the incidence of such extreme heat days in the future (see Table 7.1 and Figure 7.2).

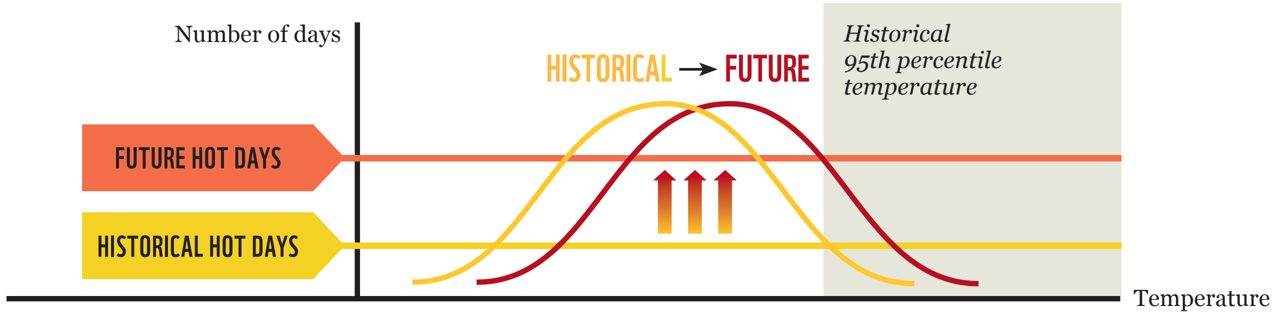
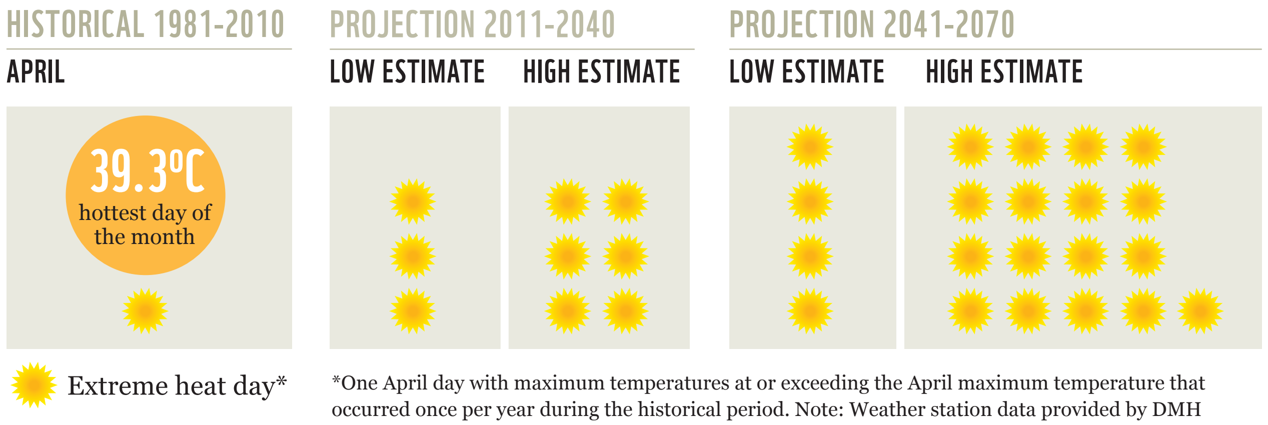


Figure 7.1. *Shifting distribution of future heat extremes in Myanmar.*

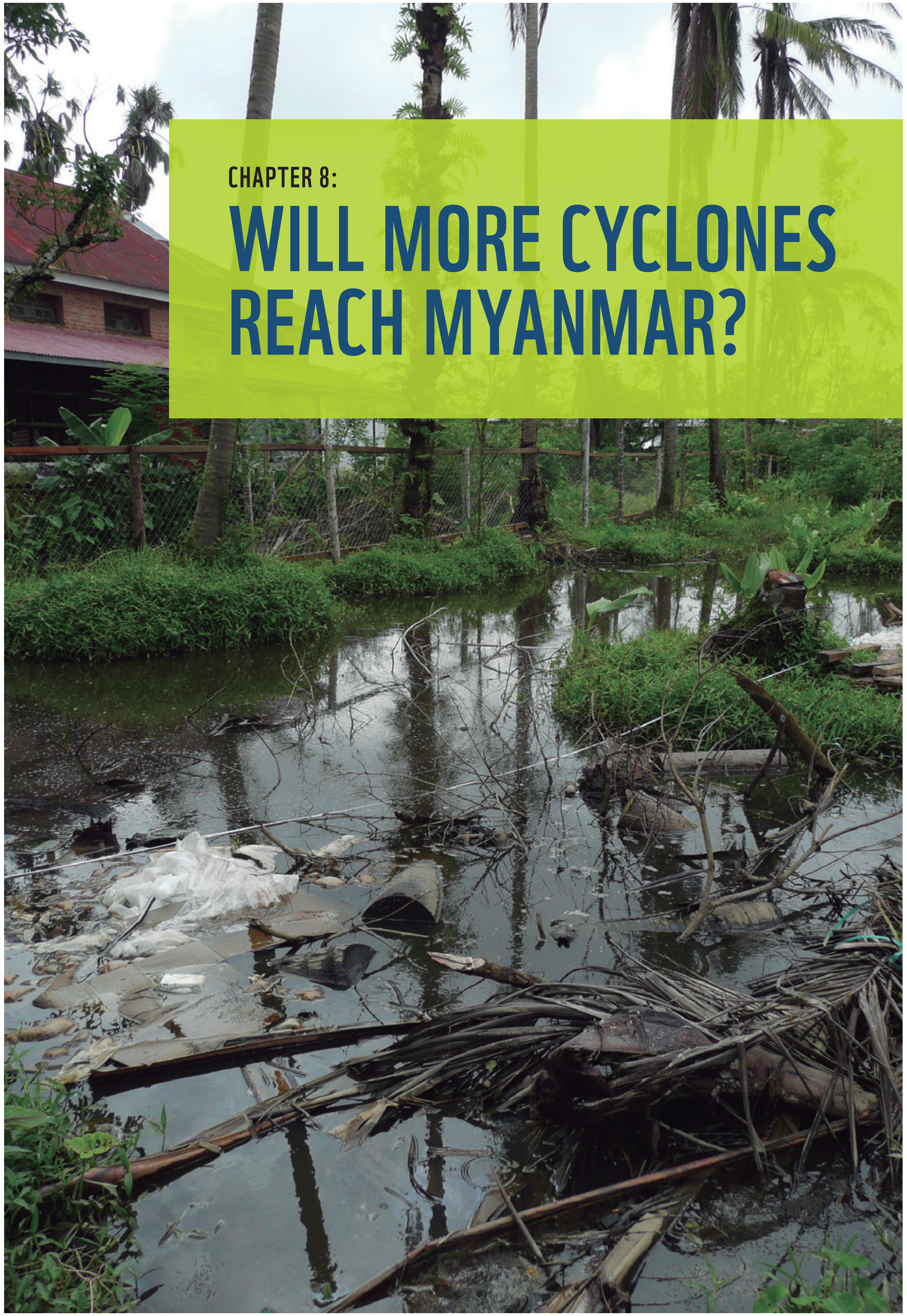
Table 7.1. *Projected 2011–2040 and 2041–2070 frequency of occurrence of the historical (1981–2010) daily 95th percentile temperatures in April (i.e., extreme heat days).*

Region*	Extreme heat day temperature 1981-2010	Historical frequency 1981-2010	Projected number of days per month hotter than historical extreme heat days from 1981-2010			
			2011-2040		2041-2070	
			Low estimate	High estimate	Low estimate	High estimate
Coastal	38.3°C	1 day	4 days	6 days	8 days	17 days
Inland	39.3°C	1 day	3 days	6 days	7 days	14 days

Figure 7.2. *Projected 2011–2040 and 2041–2070 frequency of occurrence of the historical (1981–2010) daily 95th percentile temperatures in a month (i.e. extreme heat days) for coastal regions in Myanmar.*



*One April day with maximum temperatures at or exceeding the April maximum temperature that occurred once per year during the historical period. Note: Weather station data provided by DMH (2015). Projections reflect the NASA NEX GDDP dataset.



CHAPTER 8:

WILL MORE CYCLONES REACH MYANMAR?

An average of 10 tropical cyclones form each year in the Bay of Bengal, of which only 6.4% reach land in Myanmar (Union of Myanmar, 2009).

There are two peaks in tropical cyclone activity in the country each year—the first occurring just prior to the onset of the monsoon season in April to May, and the second occurring in the post-monsoon season from October to November (Fosu and Wang, 2014).

Since 1990, the total number of tropical cyclones reaching Myanmar has increased, and there has been a rise in tropical cyclone events occurring just before the monsoon season, while those occurring after the monsoon season have decreased (Wang *et al.*, 2013).

CYCLONES AND CLIMATE CHANGE

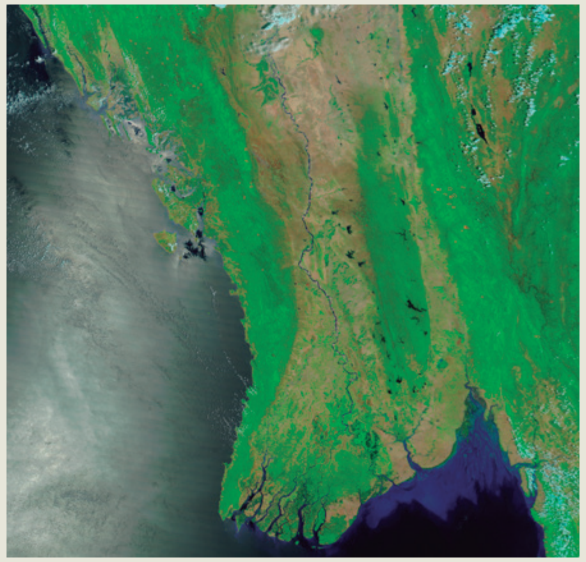
Natural variability, sparse historical data, and the limited ability of climate models to simulate tropical cyclones make it difficult to predict whether more cyclones will hit Myanmar in the future due to climate change (Christensen *et al.*, 2013; IPCC, 2013).

Still, climate change will likely lead to increasingly extreme precipitation near the centre of those tropical cyclones that do make landfall along the coasts of the Bay of Bengal, and globally the balance of evidence points towards an increase in maximum wind speeds and intensity of the strongest tropical cyclones as upper ocean temperatures increase (Christensen *et al.*, 2013; Knutson *et al.*, 2010).

This means low-lying coastal communities along the western border and the delta may be some of the most vulnerable in Myanmar in the coming decades, as they are increasingly exposed to a combination of sea level rise, storm surge, winds, and intense rainfall (Rao *et al.*, 2013).

CYCLONE NARGIS

Before



After

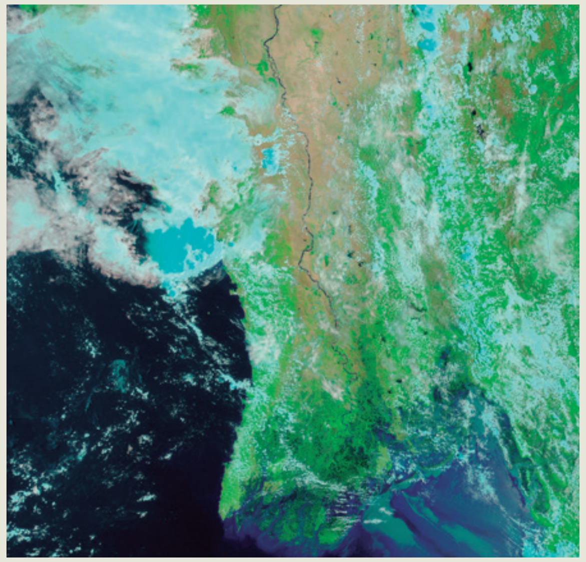


Figure 8.1. *NASA's Terra satellite image of the Myanmar coast on April 15th, 2008 (top), before Tropical Cyclone Nargis flooded the region, compared to NASA's Terra Satellite image of the coastal region on May 5th, 2008 (bottom), showing the devastation of flooding caused by Tropical Cyclone Nargis.*
Source: NASA/MODIS Rapid Response Team

Nargis hit Myanmar's Ayeyarwady Delta region on May 2, 2008, and ranks among the world's deadliest cyclones ever to make landfall (Kreft *et al.*, 2016):

- An estimated 140,000 people were killed (Tasnim *et al.*, 2015; Lin *et al.*, 2009).
- The storm surge was estimated to be 3 to 4 meters high and reached 50 km upstream from the mouth of the Yangon River (Tasnim *et al.*, 2015).
- Much of the damage to buildings resulted from the very high wind speeds and intense wave action, as well as inland flooding via irrigation channels connected to the main waterways. Figure 8.1 illustrates the low-lying topography of the region affected by Cyclone Nargis.

Disaster Area Topography

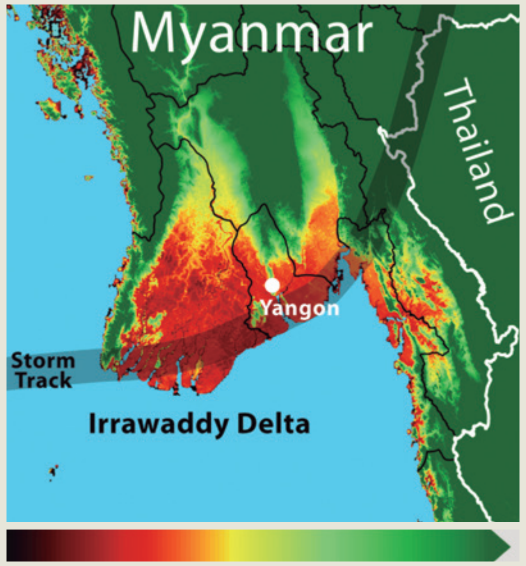


Figure 8.2. *Storm track and elevation of regions of Myanmar hit by Cyclone Nargis in 2008.*
Source: Robert A. Rohde, elevation data based on NASA SRTM.

Nargis was an unprecedented storm in Myanmar for several reasons:

- Its track initially moved across the Bay of Bengal towards the northwest, but shifted direction towards the east—unusual for cyclones in this area during the pre-monsoon period (Raju *et al.*, 2011).
- The cyclone passed over an area of unusually warm ocean waters extending deeper than normal, which provided extra energy to fuel the rapid strengthening of Nargis from a Category 1 to a Category 4 storm in just 24 hours (Lin *et al.*, 2009).
- Nargis made landfall across the Ayeyarwady Delta, where no known cyclones have made landfall in the historical record between 1977 and 2008 (Tasnim *et al.*, 2015; Fritz *et al.*, 2010). As residents had never experienced such severe storm surges, they may not have understood the danger posed by the storm, which likely increased its death toll.

CHAPTER 9:

IS THE MONSOON SEASON SHIFTING?

The summer monsoon accounts for between 75% (Sen Roy and Kaur, 2000) and 90% (Lwin, 2002) of Myanmar's total annual rainfall. Generally, the monsoon reaches southern Myanmar around the third week of May and withdraws at the beginning of October. The normal onset date of the monsoon for the entire country is considered to be June 1, while the withdrawal is more gradual and less systematic (Lwin, 2002). August is the wettest month, followed by July.

A study by Lwin (2002) demonstrated that the duration of the monsoon season in Myanmar has shortened due to both late onset and early withdrawal. Annual rainfall, monsoon rainfall, and monsoon strength have decreased, while the number of drought years have also declined (Lwin, 2002).

MONSOON AND CLIMATE CHANGE

Climate projections show an increase in total global monsoon rainfall through the end of the century, which can be attributed largely to the increase in atmospheric moisture content (Christensen *et al.*, 2013). The total surface area affected by the monsoon is also projected to increase. The projections in this report indicate that rainfall patterns will vary by region and season. Projections show that precipitation gains are most likely to occur during the monsoon season (consistent with global and regional projections for monsoon rainfall), whereas it is unclear whether precipitation will increase or decrease during the cool and hot seasons.

CHAPTER 10:

HOW ARE TOWNSHIPS IN MYANMAR USING THIS INFORMATION TO PLAN FOR ADAPTATION?

Facilitating local adaptation is one of the key objectives of the MCCA programme implemented by UN-Habitat and UN-Environment under the Ministry of Natural Resources and Environmental Conservation (MoNREC) and ts Environmental Conservation Department, with funds from the European Union.

In 2015, the MCCA selected one township in the Central Dry Zone, Pakokku (Magway Region) and one in the Ayeyarwady Delta, Labutta (Ayeyarwady Region), to conduct a Township Climate Change Adaptation Programme with the goal of helping communities adapt to the negative effects of climate change in the short, medium, and long term. This approach will be adopted at the national level and replicated in other townships (Fee *et al.*, 2017a; Fee *et al.*, 2017b).

The process is divided into three phases:

- **PHASE 1:**
  Climate data are used to provide historic views of changes—augmented with local perceptions and records to develop the vulnerability assessment (VA).
- **PHASE 2:**
  Adaptation measures are prioritised around three main objectives, based on the results of the VA: healthy ecosystems, a resilient economy, and resilient infrastructure.
- **PHASE 3:**
  Measures to maintain, restore, and enhance ecosystem services, socio-economic measures, and resilient architecture and spatial planning are implemented.

__Figure 10.1__ A community member in Pakokku lists the possible adaptation measures to reduce the effects of the projected changes. Projections, pictured in the background, have been presented to, and the potential hazards and relative impacts discussed with, the communities. This is part of the vulnerability assessment and forms the basis for the planning phase (MCCA/UN-Habitat-UN-Environment).

The VA gives township authorities and communities a clear view of how observed and future changes will affect their capacity to improve their living standards through development or to simply maintain them. The VA involves the township in studying what and where their main vulnerabilities are, and what needs to be done to mitigate or reduce the negative effects of climate change. This is a participatory process that corroborates the scientific and technical analysis with local 'ground-truthing' and the perceptions of local people.

Experts from CCSR and WWF, facilitated by MCCA, presented the projections to the communities in Pakokku and engaged them in envisioning the primary and secondary impacts of these changes (Figure 10.1 and Figure 10.2). This is an effective exercise as it allows communities to reflect on their current and future vulnerabilities and to prepare for the planning phase. Based on the assessments, the townships can adopt an Adaptation Plan, for instance organized around three pillars each with its own priority goals and specific activities, all of which are supported by the climate risk information documented in this report:

1. Maintaining and enhancing healthy ecosystems, given the high dependency of people on ecosystem services
2. Protecting and improving socioeconomic conditions by diversifying the economy and by increasing skills and education to promote employability, as well as migration with dignity where necessary
3. Ensuring that the people have access to resilient housing and community infrastructure to protect them from heightened risks of hazards

The townships can use this plan to guide programming and budgeting for adaptation efforts, but the plan also communicates investment priorities to donors and national authorities that can then be implemented in Phase 3. Possible interventions include green and grey infrastructure and management and planning solutions, such as the following:

- Building household-level water harvesting facilities
- Planting mangroves and reinforcing cyclone shelters
- Supporting vocational training
- Allocating funds to test salt-resistant crops

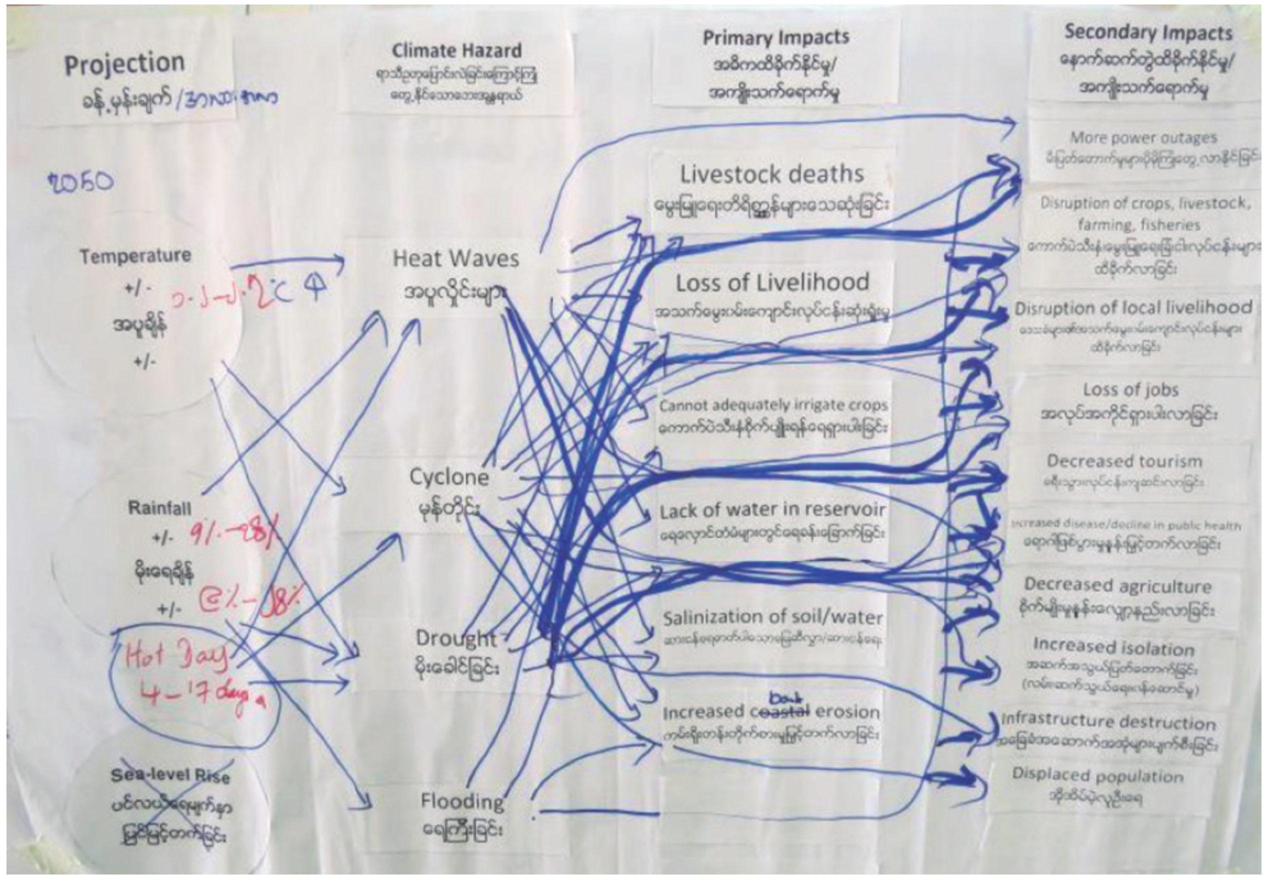


__Figure 10.2.__ Expected changes in climate will result in primary and secondary impacts on communities. This exercise is conducted in a participatory manner during local consultations, so that communities understand the actual consequences of climate change (UN-Habitat).

CONCLUSION

The effects of climate change in Myanmar are already being felt and will increase in the coming decades, challenging a vulnerable population highly reliant on climate-dependent livelihoods and ecosystem services. Vulnerability will increase in the future, with rising sea levels affecting the coastline and with increasing temperatures and changing monsoon rainfall threatening agriculture productivity and human health. Planning for change can help ensure that continued economic growth is climate-resilient.

Vulnerability assessments developed by MCCA in two highly vulnerable regions, the Central Dry Zone and the Ayeyarwady Delta, demonstrate how climate risk information can be used to inform planning. Replication of this process in additional townships will provide further opportunities to incorporate and address these critical climate risks.

Projections in this report and the accompanying technical report rely on the best available information, including the most recent global climate models and datasets, but precise projections of climate change (like all complex systems) are impossible given inherent uncertainties. One important way to manage uncertainty is through the demonstrated approach of showing a range of possible futures that could arise from climate change—rather than single ‘most likely’ numbers that can be misleading.

Further efforts, including the official climate projections (to be released by DMH in the coming months) coupled with the regular consultation of local communities demonstrated by the MCCA approach, are critical to create even greater understanding of how climate change is affecting Myanmar, so sectors and townships can make progress in the important process of building resilience.

“WE HAVE TO LOVE MOTHER NATURE AND APPRECIATE HOW IT BENEFITS US HUMAN BEINGS. ESPECIALLY NOW THAT NATURE IS AT THREAT.

MONK U PYINNYAR WUNTHA, KALONE HTAR VILLAGE”

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