Oscar M. Lopez Center

IN PARTNERSHIP WITH

Climate Change Commission Philippines

2017

PHILIPPINE Climate Change ASSESSMENT

WORKING GROUP 2

Impacts, Vulnerabilities and Adaptation

2017 PHILIPPINE
Climate Change
ASSESSMENT

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Impacts, Vulnerabilities and Adaptation

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SUGGESTED CITATION:
Cruz, R. V. O., Aliño, P. M., Cabrera O. C., David, C. P. C., David, L. T., Lansigan, F. P., Lasco, R. D., Licuanan, W. R. Y., Lorenzo, F. M., Mamauag, S. S., Peñaflor, E. L., Perez, R. T., Pulhin, J. M., Rollon, R. N., Samson, M. S., Siringan, F. P., Tibig, L. V., Uy, N. M., Villanoy, C. L. (2017). 2017 Philippine Climate Change Assessment: Impacts, Vulnerabilities and Adaptation. The Oscar M. Lopez Center for Climate Change Adaptation and Disaster Risk Management Foundation, Inc. and Climate Change Commission.

ISSN: 2508-089X
Language: English

PUBLISHED BY:
The Oscar M. Lopez Center for Climate Change Adaptation and Disaster Risk Management Foundation, Inc.
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Porfirio M. Aliño, PhD

Dr. Aliño is a Professor at the University of the Philippines Marine Science Institute. A prolific author, he has written over 100 technical papers with nearly 50 ISI (International Science Index) articles published, establishing him as one of the top coral reef scientists in the South East Asian region.

Professor Aliño has received numerous awards including being one of the Outstanding Young Scientists in the Philippines in 1993, and the "Gawad Chanselor Award for Extension Work" in 2000 for his efforts in coral reef management in the Philippines. In 2003 he won the prestigious Hugh Greenwood Environmental Science Award under the National Academy of Science and Technology (NAST), and his publication of the first atlas of Philippine coral reefs was recognized as the NAST Outstanding Book Award for 2005. Recently, he was conferred the 2017 Pantas Award (Outstanding Research/Scientist category) by the Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development of the Department of Science and Technology.

Over his 30-year association with the University of the Philippines, he has been instrumental in developing coral reef fisheries and ecological research and has mentored many of the postgraduate students who are now among the best marine scientists in the Philippines.

Dr. Aliño received his PhD from James Cook University in 1990 following his earlier studies at the University of the Philippines, Diliman, where he obtained a Masters of Science in 1983 and a Bachelor of Science in 1978.

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Olivia Cabrera is currently teaching at the Institute of Environmental Science and Meteorology, University of the Philippines, Diliman. She has a PhD in Marine Science, major in Oceanography, and advocates that studies of weather and climate in the Philippines would be incomplete without studying the seas around us.

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Dr. Cruz is a full professor and Scientist III at the University of the Philippines Los Baños (UPLB). He obtained his bachelor and master's degrees in Forestry at UPLB and his doctoral degree at the University of Arizona. His interests include forestry, watershed management, environment and natural resources management, ecosystem and landscape management, upland development and climate change. He is a former dean of the College of Forestry and Natural Resources (2007-2011) and Chancellor of UPLB (2011-2014). He was also a member of the UN Intergovernmental Panel on Climate Change in 1992-1995; 1997-2000; and 2004-2007. Currently, he is a member of the Board of Directors of the Asia Pacific Forestry Network, and the Advisory Board of the *Forestry Science and Technology Journal* (the official journal of the Korean Forestry Society). He sits on the editorial boards of the following journals: *Ecosystems and Development; Climate, Disaster and Development Journal*; and *International Research Journal on Innovations in Engineering Science and Technology*. He is also a member of the National Pool of Experts of the Climate Change Commission, as well as the Program and Project Leader of the Program for Monitoring and Detection of Ecosystem Changes for Enhancing Resiliency and Adaptaton (MODECERA) of the Department of Agriculture.

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Dr. CP David is a licensed Geologist and Professor of Geology and Environmental Science at the University of the Philippines Diliman. On secondment from 2015 to 2017 to the Department of Science and Technology (DOST), Dr. David concurrently served as Executive Director of DOST Philippine Council for Industry, Energy and Emerging Technology Research and Development Innovation Council and Officer-in-Charge of the DOST Philippine Nuclear Research Institute. Previously, he served as Project Leader to various local and internationally-funded projects focusing mainly on climate change-related impacts on water resources and natural hazards. He received his PhD in Environmental Science and Geology from Stanford University in 2003. Dr. David is also a member of the National Panel of Technical Experts (NPTE) of the Climate Change Commission.

Laura T. David, PhD

Dr. Laura David is a Physical Oceanographer and Professor at the University of the Philippines Marine Science Institute who studies ocean physics and its effects on productivity and diversity. She is recognized as one of the country's pioneers in Ocean Remote Sensing. Her expertise is also being tapped to assist in matters related to climate change vulnerability and adaptation.

In 2010, she was recognized as one of The Outstanding Women in the Nation's Service and one of the two L'Oreal National Fellows. In 2011, she was given the Gawad Chanselor Natatanging Guro Award by the University of the Philippines, Diliman (UPD). She is currently the Chair of the Commission of Higher Education Technical Committee on Marine Science, a member of the National Panel of Technical Experts for the Climate Change Commission, and the Associate Dean for Research and Extension of the UPD-College of Science.

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Dr. Lansigan is a Professor of Statistics and Environmental Science at the University of the Philippines Los Baños (UPLB). He is currently the Dean of UPLB College of Arts and Sciences, and Chair of the UPLB Climate and Disaster Risks Studies Center. He is also Scientist 2 of the University System. Professor Lansigan is a member of the National Panel of Technical Experts of the Philippine Climate Change Commission. He was also a lead author of the Intergovernmental Panel on Climate Change Working Group II Second and Fifth Assessment Reports. He was Team Leader of the Department of Agriculture-Food and Agriculture Organization-Millennium Development Goal-Fund project on capacity building and climate change adaptation in the fragile ecosystem of Cordillera Region, Philippines. He was Team Leader of the Philippine Climate Change Adaptation Project component on Climate Change Resilience of Protected Areas. Dr. Lansigan served as Regional Team Leader of the Association of Southeast Asian Nations-Deutsche Gesellschaft für Internationale Zusammenarbeit Initiative on the Promotion of Climate Resilience in Rice and other Crops. He has received several national and international awards and recognitions. He has authored and co-authored books and book chapters, and articles published in peer-reviewed scientific journals. He is presently Editor-in-Chief of the *Journal of Environmental Science and Management*, and member of the editorial boards of two other scientific journals.

Rodel D. Lasco, PhD

Dr. Lasco has more than 35 years of experience in natural resources and environmental research, conservation, education and development at the national and international levels. His work has focused on issues related to natural resources conservation, climate change and land degradation. He is a member of the Intergovernmental Panel on Climate Change, the 2007 co-winner of the Nobel Peace Prize. He is also a member of the National Academy of Science and Technology in the Philippines. He is the Philippines Coordinator of the World Agroforestry Centre since April 2004. Concurrently, he is the Scientific Director of the Oscar M. Lopez Center. He is an affiliate professor at the University of the Philippines Los Baños. He is a multi-awarded scientist with over 80 technical publications in national and international journals. He pioneered research in the Philippines on climate change adaptation in the natural resources sector, the role of tropical forests in climate change/global warming, and the policy implications of the Kyoto Protocol. He also spearheaded the Philippine sub-global component of the global Millennium Ecosystems Assessment which is designed to assess the role of ecosystems and their biodiversity in providing services for human well-being.

Wilfredo Y. Licuanan, PhD

Dr. Al Licuanan is a Full Professor of the Biology Department and University Fellow of De La Salle University (DLSU). He is also the founding Director of the DLSU Br. Alfred Shields Ocean Research Center. He has been surveying and monitoring coral reefs for over 30 years and has led research teams to many previously unstudied reefs from all around the country including the Kalayaan (Spratly) Islands (where he discovered a coral species new to science), and the Pacific Ocean coasts from Luzon to Mindanao. He just completed a project funded by the Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development of the Department of Science and Technology that undertook a nationwide reassessment of the status of coral reefs.

Fely Marilyn E. Lorenzo, PhD

Dr. Fely Marilyn E. Lorenzo is the current chair of the Technical Committee on Nursing Education at the Commission on Higher Education (CHED) with almost 20 years of teaching experience. She was founding Director of the Institute of Health Policy and Development Studies of the National Institutes of Health and directed the research and policy development work there from 1999-2006. She continues to do policy research and analysis work with the UP-Manila Policy Hub, College of Public Health and School for Health Sciences, in the areas of Health Human Resource Development specifically in Universal Health Care and Health Systems Strengthening, Nursing Development and Health Worker Migration, Climate Change and Health; Health Care Reform and Financing; Tobacco Control; and Burden of Disease Determination. For her work, she has received numerous awards from institutions here and abroad. Dr. Lorenzo has a BSN degree from the University of the Philippines College of Nursing (1973), a Master's degree in Public Health from the Institute of Public Health UP Manila (1981), and a DrPH from the School of Public Health of the University of California at Berkeley majoring in Health Policy and Administration (1996). She is a registered nurse in the Philippines and the USA (California and Massachusetts). She is presently engaged as a freelance consultant to selected stakeholders.

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Dr. Samuel Mamauag is a post-Doc at the Marine Science Institute, University of the Philippines. He specializes in fish ecology and fisheries science. He is also interested in research pertaining to Coastal Resource Management.

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Dr. Eileen Peñaflor is a Remote Sensing Scientist and has been involved in various researches utilizing remotely sensed data in the field of coastal and watershed management, fisheries, coastal vulnerability assessment and climate variability. She has a Master's degree in GIS & Remote Sensing, which she earned in late 2003 at the Asian Institute of Technology in Thailand. She received her PhD degree in Marine Science at UP-Diliman in 2016 with her research on mass coral bleaching event occurrences in the Coral Triangle, one of the ecologically important marine regions in the world. She is currently affiliated with the Marine Science Institute in UP-Diliman.

Rosa T. Perez, PhD

Dr. Rosa Perez is an independent consultant and holds a doctoral degree in Meteorology from the University of the Philippines Diliman. Her areas of specialization include hydro-meteorology, disaster risk reduction and adaptation policies on climate change, even after retiring as the Division Head on Flood Forecasting of the Philippine National Hydro-Meteorological Services of the Philippine Atmospheric Geophysical and Astronomical Services Administration. She is also a member of the National Panel of Technical Experts of the Philippine Climate Change Commission, the National Research Council of the Philippines, and the Environmental Impact Assessment Review Committee of the Department of the Environment and Natural Resources. Recent projects and publications by Dr. Perez include the "Changing Philippine Climate: Impacts on Agriculture and Natural Resources", contributions of the Technical Working Group 2 of the Intergovernmental Panel on Climate Change (IPCC) to the 4th and 5th Assessment Reports and the Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation, and the United Nations Development Programme Adaptation Policy. She is currently one of the Lead Authors in the IPCC Special Report on the 1.5°C Global Warming.

Juan M. Pulhin, PhD

Dr. Pulhin is full Professor and former Dean of the College of Forestry and Natural Resources, University of the Philippines Los Baños. He also holds the title of Scientist III at the University in recognition of his scholarly outputs and international scientific standing. He has been a Visiting Professor at The University of Tokyo for four times in 2007, 2010, 2016 and 2017. He has more than 30 years of experience in natural resources education, research and development at the national and international levels. He has authored/co-authored more than 100 technical publications dealing with various aspects of forestry and natural resources and the human dimension of climate change. He has also co-authored/co-edited eight books on forest rehabilitation, impacts of forest tenure reform, climate change, and disaster risk reduction published by reputable publishers. He was a Coordinating Lead Author of the Human Security Chapter (Chapter 12) of the Intergovernmental Panel on Climate Change Working Group II Contribution to the Fifth Assessment Report (AR5) released last 2014, and a Lead Author of the adaptation chapter of the IPCC 2007 AR4. Dr. Pulhin earned his Bachelor of Science and Master of Science in Forestry at the University of the Philippines Los Baños and his Ph.D. in Geographical Sciences from The Australian National University.

Rene N. Rollon, PhD

Dr. Rollon is a full Professor and former Director of the Institute of Environmental Science & Meteorology (IESM), College of Science, University of the Philippines - Diliman. He studies various aspects of coastal marine science, with focus on mangrove and seagrass habitats. His involvement in research over the years includes national assessment of coastal resources, genetic connectivities, biodiversity studies, resilience and recovery of tropical coastal communities, coastal resource management, climate change vulnerability of coastal systems, impacts of typhoons and earthquakes, and blue carbon ecosystems. For two decades now, Dr. Rollon is also among the EMB-DENR pool of experts sitting as members of the technical committees reviewing applications for environmental compliance certificates (ECC) of various projects.

Maricar S. Samson, PhD

Dr. Maricar S. Samson is a mangrove restoration ecologist and a faculty at the De La Salle University - Integrated School. She worked on various aspects of mangrove restoration leading toward her doctoral degree in Environmental Science at the University of the Philippines Los Baños. Her researches and written works focused on management options for the restoration of abandoned, unused and underutilized brackish-water ponds in the Philippines. She has also worked in several projects dealing with the management of coastal zones including policy reviews.

Fernando P. Siringan, PhD

Dr. Siringan is a faculty member of the University of the Philippines Marine Science Institute where he specializes in marine/coastal ecology, sedimentology and seismic stratigraphy. He earned his PhD in Geology from Rice University and is currently investigating the role played by relative sea level and climate changes in the development of present-day coastal environments.

Lourdes V. Tibig

Ms. Tibig is a retired government servant, having worked with the Philippine Atmospheric Geophysical and Astronomical Services Administration as a meteorologist for 32 years. She has remained committed to climate change initiatives, both in government and the private sector. Currently, she has been appointed to the National Panel of Technical Experts of the Climate Change Commission. Her engagement in the field of climate change includes doing researches and projects on climate, climatology and climate trends, detection and attribution of observed impacts to climate change, and climate change adaptation. She has also served as referee for international journals on climate/climate change, in addition to being active in the preparation of Intergovernmental Panel on Climate Change (IPCC) global scientific assessment reports (AR); a Government Reviewer for IPCC AR4, Lead Author of the Working Group II Contribution to IPCC AR5 and participant in the scoping meeting for the IPCC Special Report on Climate Change, Oceans and the Cryosphere. Two of the books on climate change in the Philippines in which she had been a co-author had been awarded Most Outstanding Book of the Year in 2001 and in 2015 by the National Academy of Science and Technology, Philippines. She is currently one of the Lead Authors of the IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC).

Noralene M. Uy, PhD

Dr. Uy is an independent researcher and consultant working on climate and disaster resilience. She has worked in different capacities at international organizations such as the Asian Development Bank, United Nations Development Programme, United Nations International Strategy for Disaster Reduction, ASEAN Secretariat, and Asian Disaster Reduction Center. She has also worked with the Office of Civil Defense, the Provincial Government of Albay, and the City Government of San Pablo, Laguna.

Dr. Uy has published articles in peer-reviewed journals, and contributed chapters in internationally published books as well as served as a reviewer in international and local journals. Her research interests lie in climate change adaptation, disaster risk management, ecosystem management, and poverty reduction.

Dr. Uy holds a bachelor’s degree in Business Administration and a master’s degree in Development Economics from the University of the Philippines, and master and doctoral degrees in Environmental Studies from Kyoto University.

Cesar L. Villanoy, PhD

Cesar Villanoy holds a PhD in Physical Oceanography from the University of Sydney and is currently a professor at the Marine Science Institute of the University of the Philippines (UP-MSI). His research interests include characterizing the circulation - in embayments, between islands, or within straits - typical in archipelagos using a combination of methods that involve direct and/or remote observation, and modeling. Cesar is a member of the Philippine Association of Marine Science and the American Geophysical Union.

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Foreword

Climate change remains to be one of the most serious threats our humanity is facing today. As such, it is crucial to better understand how current and future vulnerabilities and sensitivities will impact the different sectors of our society. A better understanding of these vulnerabilities and sensitivities can serve as a guide for timely interventions and strategic decisions that build and further develop our resilience.

The Oscar M. Lopez Center partnered with the Climate Change Commission to produce the Philippine Climate Change Assessment Reports (PhilCCA) - a three-volume series which synthesizes scientific information from international and local literature in order to provide an assessment of climate change for the Philippines and to identify gaps in the scientific literature.

Last year, the PhilCCA Working Group 1 (WG1) Report on the "Physical Science Basis" provided the first comprehensive assessment of climate change science in the country. This year, the WG2 Report focuses on "Impacts, Vulnerabilities, and Adaptation". It contains an assessment of the current understanding of climate change impacts, vulnerabilities, and adaptation in the Philippines, with a focus on critical areas: ecosystems, freshwater resources, coastal systems and low-lying areas, agriculture and fisheries, and human health.

This report also presents a number of recommended areas of research for future studies that were identified based on the gaps that emerged and the uncertainties brought by climate change and its associated impacts. There is a clear need to continuously support further research to build evidence-based information that will guide decision and policy making, financial planning, and development of innovative technologies and solutions to help us better confront climate change.

At the Oscar M. Lopez Center, we continue to generate knowledge and science-based solutions that are translatable and actionable towards becoming a leading catalyst for climate resilience. We are grateful to the Climate Change Commission for embarking on this project with us, and to the dedicated scientists and experts who volunteered their wisdom, time, and effort in making this report possible.

To our readers, thank you for your confidence in us. We hope that you will find this report useful in your respective work and in jointly building a culture of resilience in our country.

MARIANNE G. QUEBRAL
Executive Director

RODEL D. LASCO
Scientific Director

Acknowledgement

The Oscar M. Lopez Center for Climate Change Adaptation and Disaster Risk Management Foundation, Inc. (Oscar M. Lopez Center) and Climate Change Commission (CCC) would like to thank the following for providing support, helpful feedback and suggestions during the preparation and review of this report:

Coordinating Author, Dr. Rex Victor Cruz,
Dr. Noralene Uy and all the chapter lead authors and contributing authors

Dr. Lilibeth Acosta-Michlik

Mr. Rico Belmonte

Thank you all for making the preparation of this Report possible!

Definition of Terms

Adaptation
Climate change adaptation refers to the process of making adjustments in natural and human systems as a response to actual or projected climate and its effects. Adaptation initiatives are conducted in an effort to reduce harmful effects and benefit from favorable opportunities.

Adaptation needs
The circumstances requiring action to ensure safety of populations and security of assets in response to climate impacts.

Anomaly
The deviation of a variable from its value averaged over a reference period.

Aquaculture
The managed cultivation of aquatic plants or animals such as salmon or shellfish held in captivity for the purpose of harvesting.

Average annual loss
The average annual loss is the estimated average loss annualized over a long time period considering the full range of loss scenarios relating to different return periods.

Baseline/reference
The baseline (or reference) is the state against which change is measured. It might be a 'current baseline', in which case it represents observable, present-day conditions. It might also be a 'future baseline', which is a projected future set of conditions excluding the driving factor of interest. Alternative interpretations of the reference conditions can give rise to multiple baselines.

Basin
The drainage area of a stream, river, or lake.

Biodiversity
The total diversity of all organisms and ecosystems at various spatial scales (from genes to entire biomes).

Biome
A biome is a major and distinct regional element of the biosphere, typically consisting of several ecosystems (e.g., forests, rivers, ponds, swamps within a region). Biomes are characterized by typical communities of plants and animals.

Climate
Climate in a narrow sense is usually defined as the 'average weather', or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. These quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the climate system. The classical period of time is 30 years, as defined by the World Meteorological Organization (WMO).

Climate change
A change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that the Framework Convention on Climate Change (UNFCCC), in its Article 1, defines climate change as: "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods." The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes.

Climate model
A numerical representation of the climate system based on the physical, chemical, and biological properties of its components, their interactions, and feedback processes, and accounting for some of its known properties. The climate system can be represented by models of varying complexity; that is, for any one component or combination of components, a spectrum or hierarchy of models can be identified, differing in such aspects as the number of spatial dimensions, the extent to which physical, chemical, or biological processes are explicitly represented, or the level at which empirical parameterizations are involved. Coupled Atmosphere-Ocean General Circulation Models (AOGCMs) provide a representation of the climate system that is near or at the most comprehensive end of the spectrum currently available. There is an evolution towards more complex models with interactive chemistry and biology. Climate models are applied as a research tool to study and simulate the climate, and for operational purposes, including monthly, seasonal, and interannual climate predictions.

Climate scenario
A plausible and often simplified representation of the future climate, based on an internally consistent set of climatological relationships that has been constructed for explicit use in investigating the potential consequences of anthropogenic climate change, often serving as input to impact models. Climate projections often serve as the raw material for constructing climate scenarios, but climate scenarios usually require additional information such as the observed current climate.

Climate variability
The variations in the mean state and other statistics (such as standard deviations, statistics of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability).

Co-benefits
The positive effects that a policy or measure aimed at one objective might have on other objectives, irrespective of the net effect on overall social welfare. Co-benefits are often subject to uncertainty and depend on local circumstances and implementation practices, among other factors. Co-benefits are also referred to as ancillary benefits.

Communicable disease
An infectious disease caused by transmission of an infective biological agent (virus, bacterium, protozoan, or multicellular macroparasite).

Confidence
The validity of a finding based on the type, amount, quality, and consistency of evidence (e.g., mechanistic understanding, theory, data, models, expert judgment) and on the degree of agreement.

Coral bleaching
The loss of coral pigmentation through the loss of intracellular symbiotic algae (known as zooxanthellae) and/or loss of their pigments.

Deforestation
The conversion of forest to non-forest.

Dengue fever
An infectious viral disease spread by mosquitoes, often called breakbone fever because it is characterized by severe pain in the joints and back. Subsequent infections of the virus may lead to dengue haemorrhagic fever (DHF) and dengue shock syndrome (DSS), which may be fatal.

Disaster
The severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread adverse human, material, economic, or environmental effects that require immediate emergency response to satisfy critical human needs and that may require external support for recovery.

Disaster management
The social processes for designing, implementing, and evaluating strategies, policies, and measures that promote and improve disaster preparedness, response, and recovery practices at different organizational and societal levels.

Disaster risk
The likelihood within a specific time period of disaster

Disaster Risk Management (DRM)
The processes for designing, implementing, and evaluating strategies, policies, and measures to improve the understanding of disaster risk, foster disaster risk reduction and transfer, and promote continuous improvement in disaster preparedness, response, and recovery practices, with the explicit purpose of increasing human security, well-being, quality of life, and sustainable development.

Disaster Risk Reduction (DRR)
Denotes both a policy goal or objective, and the strategic and instrumental measures employed for anticipating future disaster risk; reducing existing exposure, hazard, or vulnerability; and improving resilience.

Downscaling
A method that derives local- to regional-scale (10 to 100 km) information from larger-scale models or data analyses. Two main methods exist: dynamical downscaling and empirical/statistical downscaling. The dynamical method uses the output of regional climate models, global models with variable spatial resolution, or high-resolution global models. The empirical/statistical methods develop statistical relationships that link the large-scale atmospheric variables with local/regional climate variables. In all cases, the quality of the driving model remains an important limitation on quality of the downscaled information.

Drought
A period of abnormally dry weather long enough to cause a serious hydrological imbalance. Drought is a relative term; therefore any discussion in terms of precipitation deficit must refer to the particular precipitation-related activity that is under discussion. For example, shortage of precipitation during the

growing season impinges on crop production or ecosystem function in general (due to soil moisture drought, also termed agricultural drought), and during the runoff and percolation season primarily affects water supplies (hydrological drought). Storage changes in soil moisture and groundwater are also affected by increases in actual evapotranspiration in addition to reductions in precipitation. A period with an abnormal precipitation deficit is defined as a meteorological drought. A megadrought is a very lengthy and pervasive drought, lasting much longer than normal, usually a decade or more.

Early warning system
The set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities, and organizations threatened by a hazard to prepare to act promptly and appropriately to reduce the possibility of harm or loss.

Ecosystem
A functional unit consisting of living organisms, their non-living environment, and the interactions within and between them. The components included in a given ecosystem and its spatial boundaries depend on the purpose for which the ecosystem is defined: in some cases they are relatively sharp, while in others they are diffuse. Ecosystem boundaries can change over time. Ecosystems are nested within other ecosystems, and their scale can range from very small to the entire biosphere. In the current era, most ecosystems either contain people as key organisms, or are influenced by the effects of human activities in their environment.

Ecosystem-based adaptation
The use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change. Ecosystem-based adaptation uses the range of opportunities for the sustainable management, conservation, and restoration of ecosystems to provide services that enable people to adapt to the impacts of climate change. It aims to maintain and increase the resilience and reduce the vulnerability of ecosystems and people in the face of the adverse effects of climate change.

Ecosystem services
Ecological processes or functions having monetary or non-monetary value to individuals or society at large. These are frequently classified as

(1) supporting services such as productivity or biodiversity maintenance,

(2) provisioning services such as food, fiber, or fish,

(3) regulating services such as climate regulation or carbon sequestration, and

(4) cultural services such as tourism or spiritual and aesthetic appreciation.

El Niño-Southern Oscillation (ENSO)
The term El Niño was initially used to describe a warm-water current that periodically flows along the coast of Ecuador and Peru, disrupting the local fishery. It has since become identified with a basin-wide warming of the tropical Pacific Ocean east of the dateline. This oceanic event is associated with a fluctuation of a global-scale tropical and subtropical surface pressure pattern called the Southern Oscillation. This coupled atmosphere-ocean phenomenon, with preferred time scales of two to about seven years, is known as the El Niño-Southern Oscillation (ENSO). It is often measured by the surface pressure anomaly difference between Tahiti and Darwin or the sea surface temperatures in the central and eastern equatorial Pacific. During an ENSO event, the prevailing trade winds weaken, reducing upwelling and altering ocean currents such that the sea surface temperatures warm, further weakening the trade winds. This event has a great impact on the wind, sea surface temperature, and precipitation patterns in the tropical Pacific. It has climatic effects throughout the Pacific region and in many other parts of the world, through global teleconnections. The cold phase of ENSO is called La Niña.

Endemic
Restricted or peculiar to a locality or region. With regard to human health, endemic can refer to a disease or agent present or usually prevalent in a population or geographical area at all times.

Epidemic
The sudden occurrence in incidence rates clearly in excess of normal expectancy, applied especially to infectious diseases but may also refer to any disease, injury, or other health-related event occurring in such outbreaks.

Erosion
The process of removal and transport of soil and rock by weathering, mass wasting, and the action of streams, glaciers, waves, winds, and underground water.

Exposure
The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected.

Extreme weather event
An extreme weather event is an event that is rare at a particular place and time of year. Definitions of rare vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile of a probability density function estimated from observations. By definition, the characteristics of what is called extreme weather may vary from place to place in an absolute sense. When a pattern of extreme weather persists for some time, such as a season, it may be classed as an extreme climate event, especially if it yields an average or total that is itself extreme (e.g., drought or heavy rainfall over a season).

Flood
The overflowing of the normal confines of a stream or other body of water, or the accumulation of water over areas not normally submerged. Floods include river (fluvial) floods, flash floods, urban floods, pluvial floods, sewer floods, coastal floods, and glacial lake outburst floods.

Food security
A state that prevails when people have secure access to sufficient amounts of safe and nutritious food for normal growth, development, and an active and healthy life.

Gross Domestic Product
The monetary value of all goods and services produced within a nation.

Groundwater recharge
The process by which external water is added to the zone of saturation of an aquifer, either directly into a geologic formation that traps the water or indirectly by way of another formation.

Habitat
The locality or natural home in which a particular plant, animal, or group of closely associated organisms lives.

Hazard
The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources. In this report, the term hazard usually refers to climate-related physical events or trends or their physical impacts.

Hotspot
A geographical area characterized by high vulnerability and exposure to climate change.

Hydrological cycle
The cycle in which water evaporates from the oceans and the land surface, is carried over the Earth in atmospheric circulation as water vapor, condenses to form clouds, precipitates over ocean and land as rain or snow, which on land can be intercepted by trees and vegetation, provides runoff on the land surface, infiltrates into soils, recharges groundwater, discharges into streams, and ultimately, flows out into the oceans, from which it will eventually evaporate again. The various systems involved in the hydrological cycle are usually referred to as hydrological systems.

Impacts
The effects on natural and human systems. In this report, the term impacts is used primarily to refer to the effects on natural and human systems of extreme weather and climate events and of climate change. Impacts generally refer to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system. Impacts are also referred to as consequences and outcomes. The impacts of climate change on geophysical systems, including floods, droughts, and sea level rise, are a subset of impacts called physical impacts.

Income
The maximum amount that a household, or other unit, can consume without reducing its real net worth. Total income is the broadest measure of income and refers to regular receipts such as wages and salaries, income from self-employment, interest and dividends from invested funds, pensions or other benefits from social insurance, and other current transfers receivable.

Infectious disease
Any disease caused by microbial agents that can be transmitted from one person to another or from animals to people. This may occur by direct physical contact, by handling of an object that has picked up infective organisms, through a disease carrier, via contaminated water, or by the spread of infected droplets coughed or exhaled into the air.

Institutions
The rules and norms held in common by social actors that guide, constrain, and shape human interaction. Institutions can be formal, such as laws and policies, or informal, such as norms and conventions. Organizations—such as parliaments, regulatory agencies, private firms, and community bodies—develop and act in response to institutional frameworks and the incentives they frame. Institutions can guide, constrain, and shape human interaction through direct control, through incentives, and through processes of socialization.

Insurance
A family of financial instruments for sharing and transferring risk among a pool of at-risk households, businesses, and/or governments.

Integrated assessment
A method of analysis that combines results and models from the physical, biological, economic, and social sciences, and the interactions among these components, in a consistent framework to evaluate the status and the consequences of environmental change and the policy responses to it.

Integrated Coastal Zone Management (ICZM)
An integrated approach for sustainably managing coastal areas, taking into account all coastal habitats and uses.

Integrated water resources management (IWRM)
The prevailing concept for water management which, however, has been defined ambiguously. IWRM is based on four principles that were formulated by the International Conference on Water and the Environment in Dublin, 1992: (1) fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment; (2) water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels; (3) women play a central part in the provision, management, and safeguarding of water; and (4) water has an economic value in all its competing uses and should be recognized as an economic good.

Invasive species
A species introduced outside its natural past or present distribution (i.e., an alien species) that becomes established in natural or semi-natural ecosystems or habitat, is an agent of change, and threatens native biological diversity.

Landslide
A mass of material that has slipped downhill by gravity, often assisted by water when the material is saturated; the rapid movement of a mass of soil, rock or debris down a slope.

Land use and Land use change
Land use refers to the total of arrangements, activities, and inputs undertaken in a certain land cover type (a set of human actions). The term land use is also used in the sense of the social and economic purposes for which land is managed (e.g., grazing, timber extraction, and conservation). Land use change refers to a change in the use or management of land by humans, which may lead to a change in land cover. Land cover and land use change may have an impact on the surface albedo, evapotranspiration, sources and sinks of greenhouse gases, or other properties of the climate system and may thus give rise to radiative forcing and/or other impacts on climate, locally or globally.

Livelihood
The resources used and the activities undertaken in order to live. Livelihoods are usually determined by the entitlements and assets to which people have access. Such assets can be categorized as human, social, natural, physical, or financial.

Malaria
The endemic or epidemic parasitic disease caused by species of the genus Plasmodium (Protozoa) and transmitted by mosquitoes of the genus Anopheles; produces bouts of high fever and systemic disorders, affects about 300 million and kills approximately 2 million people worldwide every year.

Mean sea level
The surface level of the ocean at a particular point averaged over an extended period of time such as a month or year. Mean sea level is often used as a national datum to which heights on land are referred.

Monsoon
A tropical and subtropical seasonal reversal in both the surface winds and associated precipitation, caused by differential heating between a continental-scale land mass and the adjacent ocean. Monsoon rains occur mainly over land in summer.

Non-climate driver
An agent or process outside the climate system that influences a human or natural system.

Ocean acidification
The reduction in the pH of the ocean over an extended period, typically decades or longer, which is caused primarily by uptake of carbon dioxide from the atmosphere, but can also be caused by other chemical additions or subtractions from the ocean. Anthropogenic ocean acidification refers to the component of pH reduction that is caused by human activity (Intergovernmental Panel on Climate Change [IPCC], 2011, p. 37).

Opportunity costs
The benefits of an activity forgone through the choice of another activity.

Pacific Decadal Oscillation (PDO)
The pattern and time series of the first empirical

orthogonal function of sea surface temperature over the North Pacific north of 20°N. The PDO broadened to cover the whole Pacific Basin is known as the Interdecadal Pacific Oscillation (IPO). The PDO and IPO exhibit similar temporal evolution.

Poverty
A complex concept with several definitions stemming from different schools of thought. It can refer to material circumstances (such as need, pattern of deprivation, or limited resources), economic conditions (such as standard of living, inequality, or economic position), and/or social relationships (such as social class, dependency, exclusion, lack of basic security, or lack of entitlement).

Probable maximum loss
The maximum loss that could be expected for a given return period, for example of 100 years.

Projection
A potential future evolution of a quantity or set of quantities, often computed with the aid of a model. Unlike predictions, projections are conditional on assumptions concerning, for example, future socioeconomic and technological developments that may or may not be realized.

Reforestation
The planting of forests on lands that have previously contained forests but that have been converted to some other use.

Reservoir
A component of the climate system, other than the atmosphere, that has the capacity to store, accumulate, or release a substance of concern (e.g., carbon or a greenhouse gas). Oceans, soils, and forests are examples of carbon reservoirs. The term also means an artificial or natural storage place for water, such as a lake, pond, or aquifer, from which the water may be withdrawn for such purposes as irrigation or water supply.

Resilience
The capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation.

Return period
An estimate of the average time interval between occurrences of an event (e.g., flood or extreme rainfall) of (or below/above) a defined size or intensity.

Risk
The potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. Risk results from the interaction of vulnerability, exposure, and hazard. In this report, the term risk is used primarily to refer to the risks of climate-change impacts.

Risk assessment
The qualitative and/or quantitative scientific estimation of risks.

Risk perception
The subjective judgment that people make about the characteristics and severity of a risk.

Runoff
That part of precipitation that does not evaporate and is not transpired, but flows through the ground or over the ground surface and returns to bodies of water.

Salt-water intrusion
The displacement of fresh surface water or groundwater by the advance of salt water due to its greater density. This usually occurs in coastal and estuarine areas due to decreasing land-based influence (e.g., from reduced runoff or groundwater recharge, or from excessive water withdrawals from aquifers) or increasing marine influence (e.g., relative sea level rise).

Scenario
A plausible description of how the future may develop based on a coherent and internally consistent set of assumptions about key driving forces (e.g., rate of technological change, prices) and relationships. Note that scenarios are neither predictions nor forecasts, but are useful to provide a view of the implications of developments and actions.

Sea level rise
An increase in the mean level of the ocean. Eustatic sea-level rise is a change in global average sea level brought about by an increase in the volume of the world ocean. Relative sea-level rise occurs where there is a local increase in the level of the ocean relative to the land, which might be due to ocean rise and/or land level subsidence. In areas subject to rapid land-level uplift, relative sea level can fall.

Sea surface temperature (SST)
The subsurface bulk temperature in the top few meters of the ocean, measured by ships, buoys, and drifters.

From ships, measurements of water samples in buckets were mostly switched in the 1940s to samples from engine intake water. Satellite measurements of skin temperature (uppermost layer; a fraction of a millimeter thick) in the infrared or the top centimeter or so in the microwave are also used, but must be adjusted to be compatible with the bulk temperature.

Sea wall
A human-made wall or embankment along a shore to prevent wave erosion.

Sensitivity
The degree to which a system or species is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea level rise).

Stakeholder
A person or an organization that has a legitimate interest in a project or entity, or would be affected by a particular action or policy.

Storm surge
The temporary increase, at a particular locality, in the height of the sea due to extreme meteorological conditions (low atmospheric pressure and/or strong winds). The storm surge is defined as being the excess above the level expected from the tidal variation alone at that time and place.

Storm tracks
Originally, a term referring to the tracks of individual cyclonic weather systems, but now often generalized to refer to the main regions where the tracks of extratropical disturbances occur as sequences of low (cyclonic) and high (anticyclonic) pressure systems.

Stressors
The events and trends, often not climate-related, that have an important effect on the system exposed and can increase vulnerability to climate-related risk.

Sustainability
A dynamic process that guarantees the persistence of natural and human systems in an equitable manner.

Sustainable development
Development that meets the needs of the present without compromising the ability of future generations to meet their own needs (World Commission on Environment and Development [WCED], 1987).

Threshold
The level of magnitude of a system process at which sudden or rapid change occurs. A point or level at which new properties emerge in an ecological, economic, or other system, invalidating predictions based on mathematical relationships that apply at lower levels.

Tropical cyclone (Typhoon)
A strong, cyclonic-scale disturbance that originates over tropical oceans. Distinguished from weaker systems (often named tropical disturbances or depressions) by exceeding a threshold wind speed. A tropical storm is a tropical cyclone with 1-minute average surface winds between 18 and 32 m s–1. Beyond 32 m s–1, a tropical cyclone is called a hurricane, typhoon, or cyclone, depending on geographic location.

Tsunami
A wave, or train of waves, produced by a disturbance such as a submarine earthquake displacing the seafloor, a landslide, a volcanic eruption, or an asteroid impact.

Uncertainty
A state of incomplete knowledge that can result from a lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from imprecision in the data to ambiguously defined concepts or terminology, or uncertain projections of human behavior. Uncertainty can therefore be represented by quantitativemeasures (e.g., a probability density function) or by qualitative statements (e.g., reflecting the judgment of a team of experts).

Undernutrition
The temporary or chronic state resulting from intake of lower than recommended daily dietary energy and/or protein requirements, through either insufficient food intake, poor absorption, and/or poor biological use of nutrients consumed.

United Nations Framework Convention on Climate Change (UNFCCC)
The Convention was adopted on 9 May 1992 in New York and signed at the 1992 Earth Summit in Rio de Janeiro by more than 150 countries and the European Community. Its ultimate objective is the "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." It contains commitments for all Parties. Under the Convention, Parties included in Annex I (all Organisation for Economic Co-operation and Development [OECD] countries and countries with economies in transition) aim to return greenhouse gas emissions not controlled

by the Montreal Protocol to 1990 levels by the year 2000. The convention entered in force in March 1994. In 1997, the UNFCCC adopted the Kyoto Protocol.

Urbanization
The conversion of land from a natural state or managed natural state (such as agriculture) to cities; a process driven by net rural- to-urban migration through which an increasing percentage of the population in any nation or region come to live in settlements that are defined as 'urban centers'.

Vector-borne diseases
Diseases that are transmitted between hosts by a vector organism (such as a mosquito or tick); e.g., malaria, dengue fever, and leishmaniasis.

Vulnerability
The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

Vulnerability index
A metric characterizing the vulnerability of a system. A climate vulnerability index is typically derived by combining, with or without weighting, several indicators assumed to represent vulnerability.

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LIST OF ACRONYMS AND SCIENTIFIC UNITS

AAL	average annual loss
AFF	agriculture, fisheries, and forestry
AHP	ASEAN Heritage Park
AOGCM	Atmosphere-Ocean General Circulation Model
APTERR	ASEAN Plus Three Emergency Rice Reserve
AR4	Fourth Assessment Report
ASEAN	Association of Southeast Asian Nations
ASLR	accelerated sea level rise
AVHRR	Advanced Very High Resolution Radiometer
CBFM	Community-Based Forest Management
CCA	climate change adaptation
CCC	Climate Change Commission
CEPF	Critical Ecosystem Partnership Fund
CCVE	climate change, variability, and extremes
CGCM	Coupled General Circulation Model
cm/yr	centimeter per year
CRMC	Coastal Resource Management Certification
CSM	crop simulation model
CTI	Coral Triangle Initiative
DA	Department of Agriculture
DAR	Department of Agrarian Reform
DENR	Department of Environment and Natural Resources
DOH	Department of Health
DOST	Department of Science and Technology
DRR	disaster risk reduction
EM-DAT	Emergency Events Database
ENR	environment and natural resources
ENSO	El Niño Southern Oscillation
FAO	Food and Agriculture Organization
GCM	Global Circulation Model
GDP	Gross Domestic Product
GeoREVIEW	Geospatial-based Regional Environmental Vulnerability Index for Ecosystems and Watersheds
GFDL	Geophysical Fluid Dynamics Laboratory
GISS	Goddard Institute for Space Studies
GMMA	Greater Metro Manila Area
GVA	gross value added

Gwh	gigawatt hour
HAB	Harmful Algal Bloom
IBTRACS	International Best Track Archive for Climate Stewardship
ICZM	integrated coastal zone management
IEC	information, education, and communication
IFMA	Industrial Forest Management Agreement
IGBP/LOICZ	International Geosphere-Biosphere Programme/Land-Oceans in the Coastal Zone
INC	Initial National Communication
IPCC	Intergovernmental Panel on Climate Change
IRRI	International Rice Research Institute
IWRM	Integrated Water Resources Management
KBA	key biodiversity area
kg	kilogram
km	kilometer
km^2	square kilometers
kph	kilometer per hour
LIMax	Last Interglacial Maximum
LGU	local government unit
m	meter
mcm	million cubic meters
MDGF	Millennium Development Goals Achievement Fund
MGB-DENR	Mines and Geosciences Bureau of the Department of Environment and Natural Resources
mld	million liters per day
mm	millimeter
MODECERA	Monitoring and Detection of Ecosystem Changes for Enhancing Resiliency and Adaptation
MSL	mean sea level
MWSS	Manila Waterworks and Sewerage System
NCIP	National Commission on Indigenous People
NCR	National Capital Region
NFSCC	National Framework Strategy on Climate Change
NIA	National Irrigation Administration
NIPA	National Integrated Protected Area
NOAA	National Oceanic and Atmospheric Administration
NOAH	Nationwide Operational Assessment of Hazards
NPC	National Power Corporation
NPV	net present value
NWRB	National Water Resources Board
OFW	overseas Filipino worker
PA	protected area
PAGASA	Philippine Atmospheric, Geophysical and Astronomical Services Administration
PCAARRD	Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development
PDO	Pacific Decadal Oscillation
PML	probable maximum loss
PSWS	public storm warning signal
RA	Republic Act
RAI	Rainfall Anomaly Index
SCW	supercritical water
SLR	sea level rise
SODIS	solar water disinfection
SRES	Special Report on Emissions Scenarios
SST	sea surface temperature
SNC	Second National Communication
SWIP	small water impounding project
SWM	southwest monsoon
TGT	temperature gradient tunnel
TLA	Timber License Agreement
UKMO	United Kingdom Met Office
UPM NIH-IHPDS	University of the Philippines-Manila, National Institutes of Health-Institute of Health Policy and Development Studies
V&A	vulnerability and adaptation
WHO	World Health Organization
WNP	Western North Pacific

CHAPTER 1

Executive Summary

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1.1 SCOPE AND LIMITATION

This report is an assessment of the current understanding on climate change impacts, vulnerabilities, and adaptation in the Philippines. It focuses on ecosystems, freshwater resources, coastal systems and low-lying areas, agriculture and fisheries, and human health. The depth and breadth of assessment vary across chapters due to the uneven availability of literature specific to the Philippines. In cases where there are limited literatures specifically pertaining to the Philippines, the assessment of impacts and vulnerabilities to climate change in the country was inferred from published results of related studies in other countries.

To guide future research, each chapter presents recommended researchable areas considering the identified gaps as well as the uncertainties in climate change and the sectors that are covered in the report. While many published sources have been cited in this initial assessment, the findings acknowledge the need for further studies and validation on the impacts of climate change on various sectors, the degree and magnitude of current and future vulnerabilities, and the combination of adaptation options that can be best applied at various spatial and temporal scales. By encouraging researchers to sustain and magnify their ongoing research activities and eventually publish their work, more evidence-based knowledge can be translated into information that both science and policy communities can use to make well-informed, scientifically sound, and strategic decisions.

1.2 CURRENT VULNERABILITIES AND SENSITIVITIES

Probably more than temperature change, climate change-induced variability of rainfall is likely to have the greatest impacts in the country. The number of days with heavy rainfall in the latter part of the 20th century appears to be higher than the corresponding occurrence in the early part of the 20th century. Evidence shows that the intensity of extreme rainfall events is changing. Over Luzon, frequent rainfall events of greater than 350 millimeters have been recorded more in the last decade than the 275 millimeters rainfall events of the 1960s and 1970s (Thomas et al., 2012). A study of rainfall variations in the Philippines also suggests that total rainfall is decreasing in several parts of the country over the period 1950 to 1996. Decreasing total rainfall over climate types 1, 2, and 3 but increasing rates over climate type 4 are observed during the rainfall-sensitive months of February through May in the 10-year Rainfall Anomaly Index (RAI). In the 30-year RAI, results show negative trends for climate types 2 and 4 and positive trends for climate type 3 in February to May (Pajuelas, 2000). In the period 1961 to 1998, data from selected weather stations show a significant decrease in the number of rainy days in the Baguio, Daet, and Dumaguete stations (Manton et al., 2001).

The climatological variations of rainfall in the Philippines are influenced significantly by El Niño and La Niña episodes (Jose & Cruz, 1999; Estoque & Balmori, 2002), monsoons, and mesoscale systems (Cruz, Narisma, Villafuerte, Cheng Chua, & Olaguera, 2013). On whether the behavior of recent El Niño and La Niña events, and its associated impacts, could be directly attributed to climate change or other factors is still uncertain and the direct correlation with the El Niño Southern Oscillation (ENSO) on a per region basis is still not that fully ascertained (Yumul, Cruz, Servando, & Dimalanta, 2008). Analysis of rainfall records in the period of 1951 to 1992 shows positive rainfall amount trends in the western sections of Luzon and negative rainfall amount trends in Mindanao, Visayas, and Eastern Luzon. There is also a decreasing trend in rainfall associated with the southwest monsoon (SWM) in the past 50 years and an increasing trend in the number of "no rain" days suggesting a longer dry period during the SWM in recent decades over western Philippines (Cruz et al., 2013).

Studies indicate that the frequency and intensity of tropical cyclones originating in the Pacific have increased over the last few decades causing significant damage in affected countries (Cruz et al., 2007). Some studies however claim that there are no definitive evidences yet that the frequency and intensity of tropical cyclones are increasing (David, Racoma, Gonzales, & Clutario, 2013; Yumul et al., 2008). Nevertheless, three typhoons with the highest ever recorded maximum gustiness—Typhoons Reming, Loleng, and Yolanda (international names: Durian, Babs, and Haiyan, respectively)—occurred during the last two decades.

Below is a list of key vulnerabilities and sensitivities across various chapters in this report.

Ecosystems

- Terrestrial ecosystems in the Philippines have been radically altered, especially in the last century. The main drivers of ecosystems change are anthropogenic in nature resulting in ecosystems' reduced ability to provide life-sustaining services. Climate change will exacerbate the degraded condition of forests and biodiversity in the country.

- There are diverse impacts of climate change on natural and managed terrestrial ecosystems with varying sensitivities and vulnerabilities based on limited studies in the Philippines along with what can be inferred from studies around the world. Observed impacts of climate change are highly varied within and across regions, provinces, sectors, ecosystems, species groups, and natural resources. However, there are still a lot of uncertainties on the specific effects of climate change on tropical forests such as those in the Philippines. There are very limited studies on how Philippine forests have changed as a result of shifts in past and current climate. For instance, most of the Philippine forests along the eastern seaboard are frequently battered by tropical cyclone but there is no comprehensive and long-term study yet that has been conducted to understand the impacts of tropical cyclones on forest structure, architecture, biodiversity, and functions. In general, forest ecosystems and biodiversity are most vulnerable to tropical cyclones, high temperature, and long dry periods.

- Long dry periods during El Niño events were observed by local communities to be associated with increase in fire occurrences that have altered grasslands, agroecosystems, and forests in central Luzon (Lasco et al., 2005). In addition, the local communities attributed the increase in timber poaching with El Niño as the dry weather condition makes it easier to cut and transport logs from the forests to the market. Further, the local communities noted that the flowering habit of several trees in the natural forests is also prematurely triggered. In contrast, the late onset of rainy season was observed to reduce the soil moisture that caused reduction in growth of some trees and deaths in others (Lasco et al., 2005).

- The Philippines continues to lose its rich biodiversity resources and is one of the world's most threatened hotspots. The key drivers of biodiversity loss include land conversion, deforestation due to logging and conversion to agricultural land, mining, introduction of exotic species, and pollution. Climate change and variability, as manifested by warming temperature and delayed onset of rainy season, affect the flowering and fruiting of some trees. Some plants and wildlife are also being pushed out of its preferred habitat ranges as temperature rises.

- Based on the Philippine Atmospheric, Geophysical and Astronomical Administration (PAGASA) data between 1900 and 2013, forests in Luzon have been battered by more than 500 to a few thousand tropical cyclones. These caused damages to plants and animals and altered the ecosystems structure, composition, and function. In contrast, forests in river basins of Mindanao and Visayas have been visited by far less tropical cyclones in the same period. Between 2011 and 2040, projections of PAGASA show that around 1.8 million ha of forests in all river basins would likely experience at least 2 meter per second (m/s) maximum wind velocity. However, no study has been conducted yet to investigate how the forests in various parts of the country are affected by tropical cyclones.

Freshwater Resources

- Water supply is vulnerable to variability in river flows. Consequently, potential implications of changed rainfall patterns for water supply include lower flows resulting in water shortages. Intense rainfall events may not recharge groundwater at the rate experienced when rainfall is spread more evenly across the season. On the other hand, lower than the average rainfall during the dry season may affect soil porosity and vegetation condition leading to reduced infiltration rates and groundwater recharge. It is estimated that under the full range of Special Report on Emissions Scenarios (SRES) scenarios, increased water stress will be experienced by 2020 and 2050.

- The rise in temperature, particularly during the summer and normally drier months, and during ENSO events, has resulted in the increasing frequency and intensity of droughts (Cruz et al., 2007). The El Niño-related drought of 1982 to 1983 not only affected thousands of agricultural areas but also multipurpose reservoirs where very low water levels were recorded. The Metropolitan Water Sewerage System (MWSS) reported an equivalent of 20% shortfall in water production during the ENSO-related drought event of 1991 to 1992 resulting in water rationing in many low water pressure areas of Metro Manila. The National Power Corporation reported drastic curtailment of the generating capacity of various hydropower plants particularly in Luzon and Mindanao during the ENSO-related drought event of 1991 to 1992. The three major multipurpose dams of Angat, Magat, and Pantabangan in Luzon experienced power generation losses of about 31% of the expected power generation for October 1991 to March 1992 (Jose, Francisco, & Cruz, 1999). The hydropower generation of the Angat dam was hardest hit with a total deficit of 333.38 Gigawatt hours (GWh) from the second quarter of 1997 up to the third quarter of 1998.

- Extreme rainfall events likewise cause heavy damages in the country. The excessive rainfall in 2004, 2006, 2008 and 2009 caused massive landslides and floods, such as those in Aurora and Quezon in 2004 and Iloilo in 2008. Excessive rainfall also caused the remobilization of lahar deposits, resulting in the avulsion of rivers and flashfloods such as in 2006 in Legazpi City and its vicinity due to Typhoon Reming. Heavy rains also trigger excessive flooding that destroys communities along riverbanks, fishponds, agricultural lands, roads and bridges, and other infrastructure such as caused by perennial flooding in the Cagayan River Basin, Pampanga-Agno River Basin, Bicol River Basin, and the Jalaur River Basin in Iloilo. Lastly, excessive rainfall also triggers landslides as experienced in Guinsaugon in Southern Leyte and Masara in Compostela Valley in 2006 and 2008, respectively (Yumul et al., Cruz, Servando, & Dimalanta, 2011). Metro Manila has experienced the highest rainfall events recorded within the last forty years. Tropical Storm Ketsana (local name: TS Ondoy) brought 347.5mm of rainfall within a period of 6 hours resulting in unparalleled floods over the entire Metro (Abon et al., 2011).

- Based on vulnerability studies, the most vulnerable regions to tropical cyclones in the country are the National Capital Region (NCR), Southern Tagalog, Cagayan Valley, Central Luzon, the Cordillera Administrative Region, and Bicol Province (Yusuf & Francisco, 2009). A more recent study suggests that Visayas and Mindanao are likewise becoming more at risk due to an increasing number of tropical cyclones entering the southern part of the country (David et al., 2013).

- The most vulnerable to drought are areas experiencing seasonal aridity and recurrent droughts and manifest conditions and effects of desertification processes such as major rice, corn and other grain-producing and moisture-deficit areas in: (i) Northern tip of Luzon (Region I - Ilocos Sur and Ilocos Norte; Region II - Cagayan Valley); (ii) Mindanao (Region IX - Zamboanga del Norte and Zamboanga del Sur; Region X - Bukidnon, Lanao del Norte, and Misamis Oriental; Region XI - Davao del Sur and Davao Oriental; Region XII - South Cotabato, General Santos, and Sarangani; Autonomous Region in Muslim Mindanao [ARMM] - Maguindanao); (iii) provinces in the western portions of the country with Type 1 and Type 3 climate; and (iv) provinces in the central parts of the country with Type 3 climate (Department of Agriculture [DA], Department of Agrarian Reform [DAR], Department of Environmental and Natural Resources [DENR], & Department of Science and Technology [DOST], 2010).

Coastal Systems and Low-lying Areas

- The vulnerability of the Philippine coasts to sea level rise is attributed to physical and socio-economic factors (Perez, Amadore, & Feir, 1999). Foremost of these factors are excessive groundwater withdrawals especially in major urban centers including Metro Manila. Other factors that contribute to the vulnerability of coastal integrity include beach mining as that in La Union (Siringan et al., 2005); coastal modifications as that in Banabang-Molino-Balayan Coast (David, et al., 2010); and mangrove removal as in Kampumpong River, Batangas City (David et al., 2010).

- Rivers and estuaries are experiencing changes in ecosystem structure, function, and services due to siltation from upland logging and saltwater intrusion from sea level rise. River bank erosion and flooding events brought about by mismanaged coastal areas and extreme atmospheric events threaten adjacent communities. Food security and livelihoods are at risk from climate and non-climate impacts to fish spawning and nursery areas in river and estuarine habitats in the Coral Triangle (Coral Triangle Initiative [CTI], 2011). Moreover, rare freshwater mammals like the Irriwaddy dolphins are at risk due to changes in food source and habitat.

- Mangroves are changing in ecosystem structure, function, and services due to overexploitation from domestic use (e.g., firewood) and livelihoods (e.g., logging, boat building). Clearing to make space for fish ponds and residential settlement has also dramatically reduced the distribution of mangroves as has happened in Bais and Banacon Bays (Walters, 2003). Food security and livelihoods are at risk from climate and non-climate impacts to fish spawning and nursery grounds in the mangrove forests in the Coral Triangle (CTI, 2011).

- Erosion, exacerbated by mismanaged watershed and extreme atmospheric events, has consequently altered the silt-clay ratio in the coastal sediment. Changes in silt-clay ratio have been shown to affect seagrass community, leaf biomass, and species richness (Terrados et al., 1998). This is of concern because seagrass communities provide a wide array of ecosystem services such as enhancement of coastal stability, nursery grounds for numerous fishes, and habitat for economically important food fish such as the rabbit fish (*danggit*).

- Coral reefs are experiencing changes in ecosystem structure, function, and services due to overexploitation from fishing and coral harvesting (e.g., using coral skeletons for lime production, or as raw materials for building roads); increasing sedimentation from logging (to provide space for the monoculture production of palm oil) and other land-based pollution; and coral bleaching and degradation from increasing sea surface temperature and ocean acidification (CTI, 2011).

- Observed climate change impacts on coastal systems include: (i) damage to property (e.g., hotels, resorts, houses, and boat) during tropical or low pressure; (ii) coral bleaching and increasing number of crown-of-thorns starfish; (iii) impacts to livelihood and tourism in vulnerable coastal areas; (iv) relocation of a number of houses because of coastal erosion; (v) washing out of houses, boats, and trees during tropical cyclones; (vi) decrease in fish catch during tropical cyclones; (vii) increased risks of mangrove areas, coral reefs, and marine protected area and beaches; (viii) storm surge inundation; and (ix) loss of lives.

- The Philippines is located in the western side of the Pacific. This makes the archipelago naturally exposed to tropical cyclones, storm surges, and the consequences of the ENSO and the Pacific Decadal Oscillation (PDO). Four major cities of the Philippines (Manila, Cebu, Davao, and Puerto Princesa) are all located in coastal areas. In addition, the majority of the country's more than a hundred million population also reside within 60 km of the coast. Filipinos, likewise, have one of the highest per capita fish consumption of 23 to 43 kg/year. Moreover, fisheries and fisheries-associated livelihoods are one of the main economic sectors of the Philippine society. This combined natural exposure and heavy reliance on the coastal system makes the Philippines highly vulnerable to climate change.

Agriculture and Fisheries

- In general, major impacts to agricultural production include higher incidence of pests and diseases, low crop productivity/yield, stunted growth, delays in fruiting and harvesting, declining quality of produce, increased labor costs, and low farm income (Tolentino & Landicho, 2013).

- Agricultural production is adversely affected by highly variable rainfall patterns and distribution that are observed more frequently in recent years. Agricultural crops, particularly rice, are very sensitive to water and temperature stress. Dry spells or heavy rainfall occurring immediately after seedlings are planted or seeds are sown cause the plants to die due to water or heat stress (Peñalba, Elazegui, Amit, Lansigan, & Faderogao, 2012).

- An analysis of temperature trends and irrigated field experiments at the International Rice Research Institute (IRRI) showed that increased temperatures brought about a 10% decline in grain yield for each 1°C increase in growing season minimum temperature in the dry season (Peng et al., 2004). In particular, a 1°C increase in minimum temperature during summer decreases yield by 64 kg/ha. Similarly, rice yield diminishes by 36 kg/ha for every 1% increase in the share of wet days (Bordey, Launio, Quilang, Tolentino, & Ogena, 2013).

- Climate anomalies due to ENSO can cause substantial loss in crop production. In 1997 to 1998, El Niño caused a 100% loss in production during the dry season and more than 33% loss during the wet season. The 2004 El Niño caused an 18% dry season and 32% wet season production losses. Records from the National Irrigation Administration (NIA) indicate that rice yield fell by more than two cavans (1 cavan = 50 kg) per hectare below average in both the wet and dry season cropping periods of 1990 as a result of drought and tropical cyclones (Peras, Pulhin, Lasco, Cruz, & Pulhin, 2008). The 1999 La Niña brought around 26% and 45% production losses during the dry and wet seasons, respectively (Rola & Elazegui, 2008).

- Significant decrease in the production of several fruit crops were reported in 1998 to 1999 during the worst ENSO episodes that ever hit the country. The long drought condition in 1997 to 1998, together with the changing seasonality of rainfall, most likely caused the reduction in the production of these fruits.

- Within the Coral Triangle, fisheries are experiencing changes in species composition, distribution, and yield of fish and invertebrates due to overfishing, increasing sea surface temperature, and changes in ocean circulation (CTI, 2011). Climate change has also been seen to affect physiological processes and the seasonality of biological rhythms, altering food webs, and, consequently, fish production in the area. Climate impacts on coral reefs, including coral bleaching and ocean acidification, are likely to impact fisheries associated with these habitats. Consequently, food security and livelihoods are at risk.

- Expectedly, the impacts of climate change on poor farmers are more profound than the impacts on rich farmers due mainly to the limited sources of income.

Human Health

- As a developing country, the Philippines is experiencing an era where infectious disease is still rife. With public health systems already challenged, increasing development is taking its toll on the human population through pollution of natural systems. This is exacerbated by occurrences of extremes of climate events that increase vulnerability and challenge coping mechanisms.

- Perceived and empirically shown sectoral impacts of climate change to human health include: (i) increased incidences of diseases and illnesses; (ii) insect- and rodent-borne diseases (dengue, leptospirosis, and malaria); (iii) water-borne diseases (schistosomiasis and cholera); (iv) food-borne diseases (diarrheal diseases and typhoid); (v) respiratory diseases (asthma, bronchitis, and respiratory allergies and infections); and (vi) heat-related illnesses (sunstroke, sunburn, heat stress or exhaustion, dehydration) (Duhaylungsod & Mendoza, 2005).

- Many of the biological organisms linked to the spread of infectious diseases are especially influenced by fluctuations in temperature, rainfall, and humidity. Correlation analysis shows that dengue and malaria are most sensitive to the effects of temperature, relative humidity, and rainfall (Amadore, 2005).

- Most of the ASEAN member states are at increased risk of surged dengue fever transmission caused by drought conditions which: (1) increase water storage around houses leading to elevated Aedes aegypti populations, and (2) elevate ambient air temperatures leading to reduced extrinsic incubation period for the virus in vector mosquitoes increasing vector capacity and increased respiratory illness due to haze from uncontrolled burning of tropical forests when extreme drought occurs (Anyamba, Chretien, Small, Tucker, & Linthicum, 2006).

1.3 FUTURE VULNERABILITIES

Based on PAGASA report (2011), downscaled output of the ECHAMS model under the A1B scenario suggests a decrease in rainfall by 2020 in most parts of the country except Luzon. By 2050, it is expected that Visayas and Mindanao will be drier than normal. Large decreases in rainfall and longer drier periods will affect the amount of water in watersheds and dams, thereby limiting agricultural and energy production. As far as extreme rainfall is concerned, however, the number of days with heavy rainfall (e.g., greater than 200 mm) is expected to increase with global warming by the year 2020 and 2050.

Ecosystems

- Extreme events including excessive rains, floods, landslides, and droughts could adversely affect forest ecosystems and species. Excessive rains could enhance surface soil erosion and hasten soil fertility loss that will affect growth of plants and cause degradation of surface waters, river, lakes, and coastal and marine ecosystems. Heavy rains could also induce landslides in steep areas with thick soils and fractured rock layers. Increase in the frequency and intensity of droughts could trigger forest fires, defoliation, and growth loss. As an example, the extended drought in Mexico in the 1950s caused the boundary between ponderosa pine (Pinus ponderosa) forest and the pinion-juniper (Pinus edulis and Juniperus monosperma) woodland to shift 2 km (Allen & Breshears, 1998).

- Using the Holdridge life zones to classify Philippine forest types, it is projected that most of the tropical forest types in the Philippines could expand as temperature and rainfall increase (Lasco et al., 2008b). Without any anthropogenic influence, the potential vegetation at current temperature and rainfall would be dominated by the dry tropical, moist tropical, and wet tropical forest life zones. The dry forests are the most vulnerable forest types as it could be totally eliminated with at least a 1°C rise in temperature and a 25% rise in rainfall. Moist forests are also vulnerable especially under higher rainfall increase. On the positive side, there will be a significant increase in rain forest types as rainfall increases.

- Changes in forests, agricultural areas, and other land uses are likely based on projections under various emission scenarios and climate projections in combination with anthropogenic influences (Snelder, van Weerd, van't Zelfde, & Tamis, 2013; Gordon et al., 2002). A decline in forest areas will likely happen in large parts of the Northern Sierra Madre Natural Park under scenario A1. Under F1 scenario, an upward shift of mountainous forest types and a slight decline in area of the forests. The projected changes in climate and land use are likely to cause changes in the quality of forest habitats that could alter bird species distribution. Under the A1 scenario, the models predict a considerable decrease in most forest bird species. The same is true for endemic and red list bird species (Snelder et al., 2013).

- Around 1 million ha of natural forests in the country are at varying levels of vulnerability (Government of the Philippines, 2014). Most of these highly vulnerable natural forests are located in the provinces of Davao del Sur, Leyte, Sarangani, Sultan Kudarat, and Zamboanga del Norte that are projected to experience reduced rainfall and increasing frequency of drought condition. The natural forests could be at risk from grass, brush, and forest fires that could be triggered by drought conditions.

- Approximately 1 million ha of grasslands are highly vulnerable to climate change in the future. Most grasslands in the uplands are prone to fires particularly during extended periods of dryness and lack of rainfall during summer months. Fires originating from intentional burning in farming and grazing areas could be enhanced and spread to adjacent areas and cause damages to adjoining forests, tree plantation and reforestation areas, agroforestry areas, and residential areas.

- Around 0.38 million ha of Community Based Forest Management (CBFM) areas are likely to be affected by climate-related hazards particularly droughts and tropical cyclones. Most CBFM areas in Mindanao including Surigao del Sur, Zamboanga del Norte, Sultan Kudarat, and Davao del Sur are likely to be highly vulnerable. The CBFM areas in these provinces are likely to be affected by drought that are expected to increase and could be exacerbated by the projected increase in temperature in Mindanao and decrease in rainfall. Productivity of agroforestry areas in most CBFM areas are likely to decrease due to extended and more intense dry season.

- As of 2008, there is more than 1 million ha of industrial forestry areas, of which 0.75 million ha are covered by 152 Industrial Forest Management Agreements (IFMAs) and more than 0.3 million ha covered by 6 Timber License Agreements (TLAs) (Forest Management Bureau [FMB], 2008). Some 0.9 million ha of IFMA areas that are variably vulnerable to climate change, of which about 0.3 million ha in the province of Sultan Kudarat, Zamboanga del Norte, Surigao del Sur, Misamis Oriental, and Davao del Sur are highly vulnerable to climate change. The growth and development of tree plantations in IFMA areas could be slowed down by the projected decrease in rainfall and increase in temperature in these provinces.

- Reforestation areas, plantation forests, and upland cultivated farms will continue to be vulnerable to extreme temperature, long dry spell, extreme rainfall, and tropical cyclone. These events can reduce the growth performance of trees, crops, and other plants due to the reduction in land productivity as a result of enhanced soil loss during heavy rains and soil moisture deficiency during extended dry period. Lakes, rivers, and other freshwater ecosystems in vulnerable areas are likely to be affected by excessive siltation resulting from heavy soil erosion and landslides that are induced by excessive rainfall events. Excessive rainfall could trigger debris flows and mudflows that could also destroy lakes and rivers along with the aquatic life therein.

- A study using Maxent and a suite of climate scenarios on the consequences of climate change on geographical distributions and habitat suitability of 14 threatened forest tree species in the Philippines (Garcia, Lasco, Ines, Lyon, & Pulhin, 2013) reveals seven species (*Afzelia rhomboidea; Koordersiodendron pinnatum; Mangifera altissima; Shorea contorta; Shorea palosapis; Shorea polysperma; Vitex parviflora*) that are likely to benefit from future climate due to the potential increase in their suitable habitats. In contrast, seven species (*Agathis philippinensis; Celtis luzonica; Dipterocarpus grandiflorus; Shorea guiso; Shorea negrosensis; Toona calantas; Vatica mangachapoi*) were found likely to experience decline in their suitable habitats.

- Seasonal change in temperature (e.g., number of days above a certain temperature, photoperiod [amount of daylight], seasonal weather [tropical cyclones, floods]) could alter the timing of flowering, fruiting, shoot growth, and leaf fall of forest trees and other plants, and its interactions with other organisms such as pollinators, predators, seed dispersers (Coley, 1998; Corlett & LaFrankie, 1998; Harrington, Woiwod & Sparks, 1999; Visser & Both, 2005). Although some individual plant species will be adversely affected with changes in phenological events due to changes in climatic seasonality, there are those who believe that species diversity as well as the phenological patterns in the tropics moderate the impacts of climate change (Corlett & LaFrankie, 1998). Change in species composition and interactions could trigger outbreaks of pests and diseases.

- Based on studies conducted in Southeast Asia, warmer temperature and changes in rainfall will likely alter the species composition of forests. Ranges of several plants and bird species including bats could shift upward while species that thrive better in warmer and wetter condition could become more dominant over those that thrive in colder and drier condition.

- Adverse impacts on forestry areas and resources are expected to multiply in a warmer climate. Changes in the forest ecosystem can lead to unfavorable conditions for certain highly sensitive species. Drier conditions can lead to increased incidence of forest fires. Traditions and livelihoods of forest communities may be altered and can lead to further degradation of the environment (PAGASA, 2011).

Freshwater Resources

- Based on the latest downscaled Global Climate Models, the country, particularly Luzon, will experience increased rainfall and therefore increased river flows resulting in higher potential for flooding during the wet season (Tolentino et al., 2016).

- Large decreases in rainfall and longer drier periods will affect the amount of water in watersheds and dams thereby limiting agricultural and energy production (PAGASA, 2011). Changes in rainfall and temperature will be critical to future inflow in the Angat reservoir and Lake Lanao. The Angat reservoir and Lake Lanao are expected to have a decrease in runoff in the future and will be insufficient to meet future demands for water (Jose & Cruz, 1999).

- ENSO events will invariably affect the water balance of watersheds in the country. In general, runoff will likely increase during El Niño events and decrease during La Niña events. The change in runoff will depend on how strongly a watershed will be influenced by ENSO (Cruz et al., 2003).

- It is projected that the frequency of tropical cyclones could decrease while there is evidence that the amount of rainfall associated with tropical cyclones are increasing that can cause more intense floods and rain-induced landslides. In areas where rainfall could be intense during wet season, flooding events pose danger to human settlements and infrastructure in terms of landslides and mudslides (PAGASA, 2011).

- Changed rainfall patterns may lead to lower flows resulting in water shortages due to the inability to store excess water for use in the dry season. In addition, intense rainfall events may not recharge groundwater at the rate experienced when rainfall is spread more evenly across the season. Finally, lower than average rainfall during the dry season may also affect soil porosity and vegetation condition leading to reduced infiltration rates and groundwater recharge (Miller, Alexander, & Jovanovic, 2009).

- Municipalities along the banks and flood plains of the Pasig-Marikina River basin (namely Manila, Mandaluyong, and Marikina) and CAMANAVA areas (namely Caloocan, Malabon, Navotas and Valenzuela) are likely to be at high risk from flooding due to extreme events in 2050. For a 1-in-100 year flood in 2050 under the A1FI and existing infrastructure scenarios, more than 2.5 million people will be affected in such high population density areas as Manila, Quezon City, Pasig City, Marikina City, San Juan, and Mandaluyong City. More roads (around 158.9 km) will likely be flooded by inundation depths of 8 to 50 cm (Muto, Morishita, & Syson, 2010).

Coastal Systems and Low-lying Areas

- Coastal areas are vulnerable to sea level rise, shifting water budget, monsoon rains, and sea surface temperature. The Philippines is projected to be affected by a 51% reduction in coastal wetland area under A2 scenario in 2100. Specifically, Ilocos, Cagayan Valley, Central Luzon, Central Visayas, and Western Visayas are projected to lose over 50% of their existing coastal wetlands by 2100 (Mcleod et al., 2010). High sea level rise could inundate low-lying areas and estuaries and cause erosion of beaches and saltwater intrusion in coastal aquifers (Paw & Thia-Eng, 1991).

- A future sea level rise may bring about extensive coastal land use changes, particularly within large urban centers. There will be areas prone to high erosion, frequent flooding, salt intrusion, inundation, or submergence which could create numerous economic setbacks, unemployment, population migration, and disruption of social amenities. Adequate port facilities especially in Manila may have to be built to offset the gradual sea level rise so that these ports remain viable (Paw & Thia-Eng, 1991).

- Annual damage costs in terms of: (i) annual cost of economic damage caused by the sum of coastal flooding and river flooding, (ii) dry land loss, (iii) salinity intrusion, and (iv) human migration relative to Gross Domestic Product (GDP) are projected to be highest in the Philippines. In 2100, damage costs represent 0.31% of GDP under B1 and 0.28% of GDP under A2. The NCR will be most affected with annual damages estimated to be USD 6.3 billion under B1. Considering adaptation, annual damage costs in the Philippines are reduced by between 68 and 99% (Mcleod et al., 2010).

- In addition, the country is estimated to lose 52.29% of its coastal GDP due to the potential intensification of storm surges. Four of the cities most likely to be impacted by intensified storm surges are identified as San Jose, Manila, Roxas, and Cotabato based on percent of area exposed (Dasgupta, Laplante, Murray, & Wheeler, 2009).

- The total current value of lands and structures threatened by sea level rise is estimated at PhP 1.04 billion which produce social services estimated at PhP 12.54 million (Bayani, Dorado, & Dorado, 2009).

Agriculture and Fisheries

- Temperature changes coupled with changes in rainfall regimes and patterns could decrease crop yields and increase incidence/outbreaks of pests and diseases, both in plants and animals (PAGASA, 2011). Process-based crop simulation models indicate that yields of rice and other crops tend to decrease from 8 to 14% for every 1°C increase in temperature depending on location in the Philippines (Comiso, Espaldon, Lansigan, Blanche, & Sarigumba, 2013).

- Extreme climate events could influence poverty by affecting agricultural productivity and raising prices of staple foods that are important to poor households. A study using simulated extreme climate indicators finds that climatic extremes exert substantial stress on low income populations especially the urban, wage-labor-dependent stratum due to their extreme exposure to food price increases. Since food is a major expenditure, this group's overall consumption falls with rising prices, pushing them below the poverty threshold of consumption (Ahmed, Diffenbaugh, & Hertel, 2009).

Human Health

- Based on a model constructed for forecasting climate change sensitive diseases, for every 1°C increase in temperature, the mosquito population increases ten-fold. Hence, there will be increased bite rate of mosquitoes with increased temperature. In NCR, for every 1°C increase in recorded minimum temperature, an expected 233 cases of dengue is predicted to occur. In addition, for every unit of increase of relative humidity, dengue cases will rise by about 31 cases. However, for every unit of increase of monthly rainfall, dengue cases will decline by 615 per 1,000 cases. This is the same for malaria that will be reduced by 89 per 1,000 cases for every unit of increase of monthly rainfall (Lorenzo et al., 2011).

- In the case of cholera, cholera cases will increase by 26 per 1,000 cases for every unit of monthly rainfall, by nearly 8 cases for every unit of maximum temperature, and by 662 per 1,000 cases for every unit of relative humidity. It is expected to decline by almost two cases for every unit of maximum temperature (Lorenzo et al., 2011).

- The potential impacts of climate change are projected to be USD 5 to 19 million by 2050 in terms of loss of public safety, increased vector- and water-borne diseases, and increased malnutrition from food shortages during extreme events (Lorenzo et al., 2011).

1.4 ADAPTATION

Ecosystems

- As an overarching framework and strategy for adaptation of forest ecosystems, an integrated ecosystem-based management approach to address the linked vulnerabilities of forest ecosystems with other ecosystems in a landscape unit or a river basin is proposed under the National Framework Strategy on Climate Change (NFSCC) 2010-2022. Mainstreaming climate change adaptation strategies in policies, plans, and programs of national and local government is a strategic objective.

- To address projected impacts of climate change on natural and managed forest ecosystems, it is necessary to undertake the following: comprehensive review of policies on managing forest ecosystems (Lasco et al., 2008); assessment of adaptation strategies for natural ecosystems and local communities living within and around forests (Lasco, 2012); and development of more refined climate change scenarios using downscaling techniques to better estimate changes in rainfall and temperature (Lasco et al., 2008).

- Biodiversity dampens the overall vulnerability since the myriad of species having similar ecosystem functions allow for adaptation of the environment to slow changes. There would be a need therefore to conserve and protect the different riverine, estuarine, and coastal habitats. Corollary to this, mismanagement of the increased utilization of the coastal zone could further exacerbate vulnerability of coastal areas. Human activities that lead to increase in inputs of nutrients and pollutants in aquatic and marine ecosystems, increased extraction of commodities such as fish and related resources, and increased construction of coastal engineering structures could alter the natural buffering capacity of these biodiverse habitats. Stricter enforcement of laws and regulations on foreshore areas of rivers, estuaries and the coasts as natural buffer zones by coastal local government units (LGUs) could reduce the vulnerability of aquatic and marine habitats to climate change.

- For biodiversity, there would be a need to mainstream adaptation strategies to climate change in policies, plans, and programs of national and local government. To achieve this, the strategic priorities are to: (i) establish national baselines, standards, and indicators for monitoring progress in implementing biodiversity conservation programs; (ii) strengthen vertical and horizontal coordination among government agencies, civil society groups, academe, and other organizations in implementing biodiversity conservation and adaptation strategies to climate change; (iii) protect vulnerable ecosystems and highly threatened species from climate change impacts; (iv) develop institutional capacities in biodiversity conservation and climate change adaptation at the national, regional, and local levels; (v) establish scientific basis for measuring the impacts of climate change scenarios on ecosystem and species diversity; (vi) mobilize sustainable funding support to climate change adaptation programs (Climate Change Commission [CCC], 2010).

- Specific adaptation options could include conservation and management of vulnerable species, assisting local communities that are highly dependent on forests at risk, and adopting biodiversity based adaptation and mitigation strategies such as maintaining and restoring native ecosystems; protecting and enhancing ecosystem services; managing habitats of endangered species; creating refuges and buffer zones; and establishing networks of terrestrial, freshwater and marine protected areas taking into account climate change (Lasco et al., 2008a).

- Other essential adaptation measures for forests and biodiversity could include: (i) in situ and ex situ conservation to help endangered species adapt to climate change; (ii) strict enforcement of forest and related laws to promote judicious use of land, trees, and other forest resources; (iii) improved planning and implementation; and (v) long-term monitoring of forests and biodiversity with changing climate to improve understanding of the impacts of climate change, and responsive research and development agenda.

Freshwater Resources

- Adaptation in the water sector could be enhanced through: (i) capacity building of all sectors, (ii) provision of funds for climate change programs, (iii) strong political will, (iv) uplifting the socio-economic conditions of the poor, (v) strong commitment from all sectors, (vi) improve management and conservation of water; (vii) enhancing the conditions of major watersheds; and (viii) coordination among institutions concerned with water resources.

- Challenges exist in the application and integration of advanced climate information in the process of strategic planning for water resources development and management. Specific research-related priorities for water resources may include: (i) impacts of extreme weather events; (ii) assessment of adaptation strategies focusing on water infrastructure, flooding, drought, and increasing water use efficiency; (iii) hydrologic modeling to assess the combined impacts of climate, land use, and vegetation cover types on the hydrological processes in the watershed; (iv) identifying most vulnerable river basins; (v) simulation of water allocations of reservoirs, and (vi) build up of datasets on rainfall, evapotranspiration, inflow/outflow, and wind speed/direction for cloud seeding and other activities.

- Water supply and demand management including the maximization of potential water resources availability through: (i) integrated watershed and ecosystem management to promote greater synchronization of upstream and downstream development, and (ii) building capacity to capture excess water during the wet season such as by building small water impounding project for irrigation purposes, practice of water augmentation, and water harvesting techniques could help reduce the adverse impacts of climate change on water resources. Likewise, maximization of and reducing inefficiencies in the use of water such as by practicing soil and water conservation techniques in agriculture; regular maintenance of irrigation facilities particularly, distribution canals to reduce water losses during transmission and distribution; and reduction in leakages and pilferages of domestic water supply could also alleviate the impacts of climate change.

- One of the major limitations to adaptation for freshwater resources sector is the absence of adequate data and information on rainfall, river discharge, soil moisture, groundwater depth, water quality, rates of surface water, and groundwater withdrawal by major user groups. There would be a need to prioritize the establishment of continuous comprehensive watershed and ecosystem monitoring to build up the needed databases and information for planning and decision making.

Coastal Systems and Low-lying Areas

- The Philippines' Initial National Communication on climate change identified six adaptive measures with potential to make coastal resources more adaptive to accelerated sea level rise (ASLR) such as: (i) selective protection after comprehensive cost-benefit analysis; (ii) long-term planning in the perspective of coastal zone management to include proper resources exploitation and usage; (iii) disaster mitigation and preparedness tie-up with climate change issues; (iv) setting in place and enforcing of policies and regulations on habitation and construction; (v) inclusion of measures to address climate change in the integrated coastal zone management (ICZM) program; and (vi) information and education campaign to include government and the general public.

- The NFSCC provides for the enhancement of resilience of coastal and marine ecosystems and communities, including tourism industries, to climate change. Its strategic priorities are: (i) establish marine reserve networks through active participation of local communities; (ii) determine optimal clustering and locations of marine reserves according to "source and sink"; (iii) prioritize protection/management of mangroves, estuaries, sea grasses, coral reefs and beaches as a management unit to derive maximum benefits from synergistic interactions of these five ecosystems that result in enhanced marine productivity; (iv) strengthen sustainable, multi-sectoral and community-based coastal resource management mechanisms and ecotourism endeavors; and (v) manage and expand the sink potential of marine ecosystems such as coral reefs and mangroves (CCC, 2010).

- ICZM is not only a strategy for promoting the sustainability but also the resilience of coastal systems by: (i) adopting the precautionary principle approach in the management of coastal resources, (ii) providing the coastal stakeholders ample opportunities to actively participate in all aspects of coastal management, (ii) devolving responsibility and resources to local level decision-makers, (iv) maintaining healthy and productive coastal and upstream ecosystems, and (v) allocation of coastal resources to uses that provide the greatest long-term community benefits without compromising the ecosystem's health.

- The leading constraints to successful adaptation in coastal systems include: (i) lack of political will, (ii) weak enforcement of laws and regulations, (iii) inadequate capability to implement adaptation strategies, (iv) inadequate logistics and financing, (v) lack of sufficient knowledge and information about the coastal systems, and (vi) poor transportation facilities and other social infrastructures.

- In marine ecosystems, programmatic research to: (i) study further the relationships between climate change, runoff and overfishing and consider these areas as the three major issues that affect the biodiversity of marine ecosystems, and (ii) enhance international cooperation aimed at curbing the impacts of climate change on coral reefs could facilitate adaptation (Lasco, Cruz, Pulhin, & Pulhin, 2011).

- There are trade-offs in adaptation so decisions would need to take into account social and economic as well as ecological concerns. Therefore, in order to take advantage of the opportunities to enhance the adaptive capacity of coastal communities through the Philippine local government code, there would be a need for local capacity development.

- There is a strong need to address information and research gaps. There are still uncertainties on the magnitude of local future scenarios and consequently lack of quantitative predictions of local future coastal changes. There would be a need to develop predictive models based on multi-stressor observations and experiments in detailed levels of space and time. Assessments of valuation of coastal ecosystem services, as well as adaptation costs and benefits are much needed. All these science-based data would then have to be communicated to decision-makers and institutions so that their role in the transition towards a climate-adapted archipelago may be identified and realized.

Agriculture and Fisheries

- The NFSCC aims to address vulnerabilities in the country's agricultural sector by building the resilience of food production systems through mainstreaming of sustainable agriculture and aquaculture and related developments in the sector. The objective is to protect and enhance ecosystems and ecosystem services to secure food and water resources and livelihood opportunities.

- The strategic priorities in building the resilience of the agricultural sector include: (i) reduce climate change risks and vulnerability of natural ecosystems and biodiversity; (ii) increase the resilience of agricultural communities through the development of climate change-sensitive technologies, establishment of climate-proof agricultural infrastructure and climate-responsive food production systems, and provision of support services to the most vulnerable communities; (iii) improve climate change resilience of fisheries through the restoration of fishing grounds, stocks, and habitats, and investment in sustainable and climate change-responsive fishing technologies and products; (iv) expand investments in aquaculture and in other food production areas; (v) strengthen the crop insurance system as an important risk sharing mechanism to implement weather-based insurance system; and (vi) strengthen sustainable, multi-sectoral and community-based resource management mechanisms (CCC, 2010).

- In the agriculture sector, improvement of the enabling conditions and environments such as: (i) creating enabling environment for private investments in agriculture, (ii) climate-fit crop programming and climate-based cropping mix in highly vulnerable agricultural areas, (iii) production maximization in climate-proofed farming areas, particularly those with moderate rainfall, (iv) developing policy environments for sustainable development of highland ecosystems, (v) increasing local capacity to compete with global products within local markets, and (vi) harmonizing food and bio-energy development and other economic uses of agricultural products could build the resilience and promote adaptation to climate change (Government of the Philippines, 2014).

Human Health

- The NFSCC emphasizes the formulation of proper climate-sensitive interventions by the health sector to ensure a healthy and disease-resilient citizenry. It proposes these strategic priorities: (i) assessment of the vulnerability of the health sector to climate change; (ii) improvement of sensitivity and increase in responsiveness of public health systems and service delivery mechanisms to climate change; and (iii) establishment of mechanisms to identify, monitor, and control diseases brought about by climate change, and improve surveillance and emergency response to communicable diseases, especially climate-sensitive water-borne and vector diseases (CCC, 2010).

- Integrated, participatory, and multi-level adaptation responses are suggested by the Department of Health (DOH) and World Health Organization (WHO) (2012). This includes: (i) coordinated responses from forestry, water, energy, and health sector; (ii) mainstreaming responses in local and national plans and programs; (iii) building partnerships between public and private sector; (iv) blending modern with indigenous techniques; and (v) providing adequate financing, human resources, and facilities.

- There is an existing inventory of good practices that reduces vulnerabilities to climate-related diseases that could provide guidance in formulating adaptation responses to climate-induced health risks. These practices can be classified according to its nature (i.e., institutional, political, environmental, sanitation and cleanliness, individual or family-based, community or barangay-based, health care, and others).

- Adaptation in the health sector will be constrained by the absence of a national facility dedicated to the assessment of vulnerability to various climate-related health risks. There will be a need to establish this facility that will be responsible also for the monitoring and surveillance of climate-related diseases. Inadequate competence of health personnel at the local level will limit the responsiveness of health service provision at the community level where it will be most needed. Capability building programs would be needed to develop the competence of local health service providers especially in communication of the potential health risks associated with climate change to various audiences. There will also be a need to augment the existing budget of local health facilities for the establishment of health baseline and other essential activities on top of its regular functions and programs.

- Increased research on: (i) the scale and nature of health risks from climate change; (ii) effectiveness of interventions to protect health; (iii) health implications of adaptation and mitigation decisions taken in other sectors, (iv) improvement in decision support systems and surveillance, and (v) estimation of resource requirements will be important.

- Relevant cross-disciplinary research for health protection in the following areas will also be necessary: (i) improved vulnerability and adaptation assessments that focus on particularly vulnerable populations and encompass complex causal pathways; (ii) quantitative estimation of the effectiveness of health adaptation measures; (iii) surveillance, monitoring, and observational systems that link climate, health, and economic impact data and provide a basis for early warning systems as well as development of future scenarios; and (iii) assessment of the health co-benefits of alternative climate mitigation policies.

- Improvement in local land use and development planning and implementation could help reduce undue exposure of residential areas to climate related and other geohazards. In addition, proper location of new economic and population centers in areas with low exposure to geohazards could reduce the damages due to climate related disasters. Likewise rationalizing development of transportation, communication and other infrastructures could minimize adverse impacts of climate change on local and national economy.

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CHAPTER 2

Ecosystems, their Properties and Services

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2.1 EXECUTIVE SUMMARY

Climate change will exacerbate the degraded condition of forests and other ecosystems, and biodiversity in the country. The impacts of climate change on natural and managed ecosystems with varying sensitivities and vulnerabilities are diverse based on limited studies in the Philippines along with what can be inferred from studies around the world. There are very limited studies on how Philippine forests have changed as a result of shifts in past and current climate. Forest ecosystems and biodiversity are most vulnerable to tropical cyclones, high temperature, and long dry periods. Climate change and variability as manifested by warming temperature and delayed onset of rainy season affect the flowering and fruiting of some trees. Some plants and wildlife are also being pushed out of its preferred habitat ranges as temperature rises.

Long dry periods during El Niño events were observed by local communities to be associated with increase in fire occurrences that have altered grasslands, agroecosystems, and forests in Central Luzon. Further, the local communities attributed the increase in timber poaching to El Niño events as the dry weather condition makes it easier to cut and transport logs from the forest to the market. In addition, local communities noted that the flowering habit of several trees in the natural forest is also prematurely triggered. In contrast, the late onset of rainy season was observed to reduce the soil moisture that caused reduction in growth of some trees and deaths in other.

Based on the Philippine Atmospheric, Geophysical and Astronomical Service Administration (PAGASA) data between 1900 and 2013, forests in Luzon have been battered by more than 500 tropical cyclones that conceivably caused damages to plants and animals and altered the ecosystems structure, composition, and functions. In contrast, forests in river basins of Mindanao and Visayas have been visited by far less tropical cyclones in the same period. Between 2011 and 2040, projections of PAGASA show that around 1.8 million hectares (ha) of forests in all river basins would likely experience at least 2 m/s maximum wind velocity. However, no study has been conducted yet to investigate how the forests in various parts of the country are affected by tropical cyclones.

Key climate-related hazards in the coastal areas include sea level rise (SLR), changes in temperature and rainfall, tropical cyclones, and storm surge that often result in flooding, erosion, subsidence, salinization, and deterioration of coastal ecosystems including mangroves.

Reforestation areas, plantation forests, and upland cultivated farms will continue to be vulnerable to extreme temperature, long dry spell, extreme rainfall, and tropical cyclones that can reduce the growth performance of trees, crops, and other plants due to the reduction in land productivity as a result of enhanced soil loss during heavy rains and soil moisture deficiency during extended dry period. Lakes, rivers, and other freshwater ecosystems in vulnerable areas are likely to be affected by excessive siltation resulting from heavy soil erosion and landslides that are induced by excessive rainfall events. Excessive rainfall could trigger debris flows and mudflows that could also destroy lakes and rivers along with the aquatic life therein.

A study using Maxent and a suite of climate scenarios in the Philippines reveals that seven species (*Afzelia rhomboidea; Koordersiodendron pinnatum; Mangifera altissima; Shorea contorta; Shorea palosapis; Shorea polysperma; Vitex parviflora*) are likely to benefit from future climate due to the potential increase in their suitable habitats. In contrast, seven species (*Agathis philippinensis; Celtis luzonica; Dipterocarpus grandiflorus; Shorea guiso; Shorea negrosensis; Toona calantas; Vatica mangachapoi*) are likely to experience decline in their suitable habitats.

Based on studies conducted in Southeast Asia, warmer temperature and changes in rainfall will likely alter the species composition of selected plants, bird species, and bats, and forests ranges could shift upward. Species that thrive well in warmer and wetter conditions could also become more dominant over those that thrive in colder and drier conditions.

There are no specific policies governing climate change adaptation (CCA) in natural ecosystems in the Philippines. While there are several Philippine policies on natural resource management with indirect effects on climate change, very few directly address the adaptation to and mitigation of climate change. An integrated ecosystem-based management approach is proposed under the National Framework Strategy on Climate Change (NFSCC) 2010-2022. Mainstreaming CCA strategies in policies, plans, and programs of national and local government is a strategic objective.

To address projected impacts of climate change on natural and managed ecosystems, the following actions could be undertaken: a comprehensive review of policies on managing forest ecosystems; an assessment of adaptation strategies for natural ecosystems and local communities living within and around forests; research in marine ecosystems to enhance international cooperation aimed at curbing the impacts of climate change on coral reefs; further study on the relationships between climate change, runoff, and overfishing and consideration of these areas as the three major issues that affect the biodiversity of marine ecosystems; and development of more refined climate change scenarios using downscaling techniques to better estimate changes in rainfall and temperature.

2.2 SCOPE AND LIMITATION

"An ecosystem is a dynamic complex of plant, animal, and microorganism communities and the nonliving environment interacting as a functional unit" (Millenium Ecosystem Assessment, 2003). Ecosystem services on the other hand refer to the benefits people obtain from ecosystems. There are four major types of ecosystem services: provisioning services such as food, water, timber, and fiber; regulating services that mitigate climate change, floods, diseases, wastes, and water degradation; cultural services that include recreational, aesthetic, and spiritual benefits; and supporting services including soil formation, carbon sequestration, and nutrient cycling (Millenium Ecosystem Assessment, 2003). Human well-being and sustainable development are dependent on the uninterrupted flow of ecosystem services. However, the integrity of ecosystems is under serious threat from overutilization of land and other natural resources arising from urbanization, industrialization, mining, agriculture and forest production, and other human activities. These threats are compounded by the intensification of climate change. This report assessed changes in several ecosystems and ecosystem services in relation to climate change and other stressors. The uneven depth and breadth of discussions across major ecosystems in the country is mainly due to the varying availability of related studies on climate change and ecosystems in the Philippines. In large part, the discussion centers on forests and biodiversity. Discussions on coastal ecosystems are limited in this chapter but more elaborate discussions can be found in Chapter 4 of this report.

2.3 CURRENT SENSITIVITY AND VULNERABILITY

The limited studies in the Philippines along with what can be inferred from studies conducted elsewhere around the world suggest varying impacts of climate change on natural and managed ecosystems with different ranges of sensitivities and vulnerabilities.

The Philippines is one of the world's most threatened hotspots as it continues to lose its rich biodiversity resources (Critical Ecosystem Partnership Fund [CEPF], 2001). There are 145 animal species in the country that are either endangered or threatened of which 34 are mammals, 79 are birds, 18 are reptiles, and 14 amphibians (Department of Environment and Natural Resources [DENR], 2004). The key drivers of biodiversity loss are many: deforestation due to logging and agricultural expansion, land conversion to built up areas and other land uses, mining, introduction of exotic species (CEPF, 2001; PAWB, 2009), and pollution (Cruz et al., 2013). Between 1969 and 1988, 2,000 square kilometers (km^2) were logged annually, three times the global rate for tropical forest conversion. With dwindling forests, logging has recently been banned in all natural forests. However, Philippine forests continue to be degraded mainly due to illegal logging activities, timber poaching, charcoal making, and fuelwood gathering. Forest cover is down to about 20% from around 70% of the country's total land area in early 20th century (Figure 2.1). Similarly, coastal and marine ecosystems have been over-exploited through the years. The loss of mangroves in the country is the major cause of coastal biodiversity degradation. From about 500,000 ha in early 1920s, mangrove forest has declined by more than 50%, and recently estimated at 247,362 ha after a series of dramatic decline (Pulhin, Gevana, & Pulhin, 2017). Illegal and unregulated fishing in many municipal waters drastically reduced the fish catch in major fishing grounds in the country.

Overall, natural ecosystems in the Philippines have been radically altered, especially in the last century. The main drivers of ecosystems change are anthropogenic activities. As a consequence, its ability to provide ecosystem services has been highly degraded. The impacts of degraded natural capital have been manifested in numerous ways, sometimes with catastrophic results. For example, flooding has become more common as a consequence of impaired hydrology and mismanaged watersheds. In addition, there are also governance issues that constrain the country's ability to conserve its biodiversity resources. There are overlapping mandates amongst DENR, local government units (LGUs), National Commission on Indigenous People (NCIP) and other government agencies in the management of forestlands creating confusion on the ground.

There are more than 10 million people, mostly very poor, who depend on agriculture production in the uplands. The government is promoting mining activities to reduce this dependency but many of the mining areas overlap with key biodiversity areas. The issue is compounded by the introduction of exotic species that has altered the species interactions in terrestrial and freshwater ecosystems with likely adverse impacts on its functions and services.

It is expected that climate change will have direct and indirect negative impacts that will increase the stress on natural ecosystems and biodiversity in the Philippines. Globally, there is strong evidence that the range of plant species and even biomes are shifting as a result of warming climate (Scholes et al., 2014). However, there is still high uncertainty on the specific effects of climate change on tropical forests such as those in the Philippines. This is particularly true considering the absence of sufficient empirical data on the direct impacts of climate change on ecosystems and biodiversity; and on the indirect impacts of climate change, extremes, and variability, as drivers of human activities are known to have adverse impacts on ecosystems and biodiversity.

There are very limited studies on how Philippine forests and other ecosystems have changed as a result of shifts in past and current climate. One such study in southern Philippines showed an expansion of tropical montane rainforest during the last glacial maximum indicating that temperature was lower than present day, and the high values of total pollen count and low percentage of mangrove pollen reflect a low sea level. During the last deglacial and the Holocene, tropical upper montane rainforest was limited to high altitudes, demonstrating a great increase in temperature. At the same time, mangroves developed as sea level rose. During the early Holocene, the large quantities of pollen from wet environment taxa, pteridophytes, mangroves, and lowland rainforest taxa, demonstrate a much warmer and wetter climate in the west Pacific (Bian et al., 2011). Another study shows that Association of Southeast Asian Nations (ASEAN) Heritage Parks (AHP) in the Philippines, where endangered plants and animals thrive, are highly sensitive to climate change particularly those areas in higher elevation including rain and mossy forests (Cruz et al., 2013). What is lacking are data on how Philippine forests and its biodiversity have already been affected by climate change.

Strong winds and tropical cyclones are major drivers of change in the country's forest cover. Frequent tropical cyclones and strong winds have shaped the architecture of Philippine forests and to a large extent influenced the rich biodiversity in forests particularly the composition and distribution of many plants and animals. Historically, the Philippine forests have been exposed to strong tropical cyclones. Based on PAGASA data between 1900 and 2013, forests in Luzon have been battered by more than 500 tropical cyclones that conceivably caused damages to plants and animals and altered the ecosystems structure, composition, and functions. In contrast, forests in river basins of Mindanao and the Visayas have been visited by far less tropical cyclones in the same period. Between 2011 and 2040, projections of PAGASA show that around 1.8 million ha of forests in all river basins would likely experience at least 2 m/s maximum wind velocity. There is however no study has been conducted yet to investigate how the forests are affected by tropical cyclones.

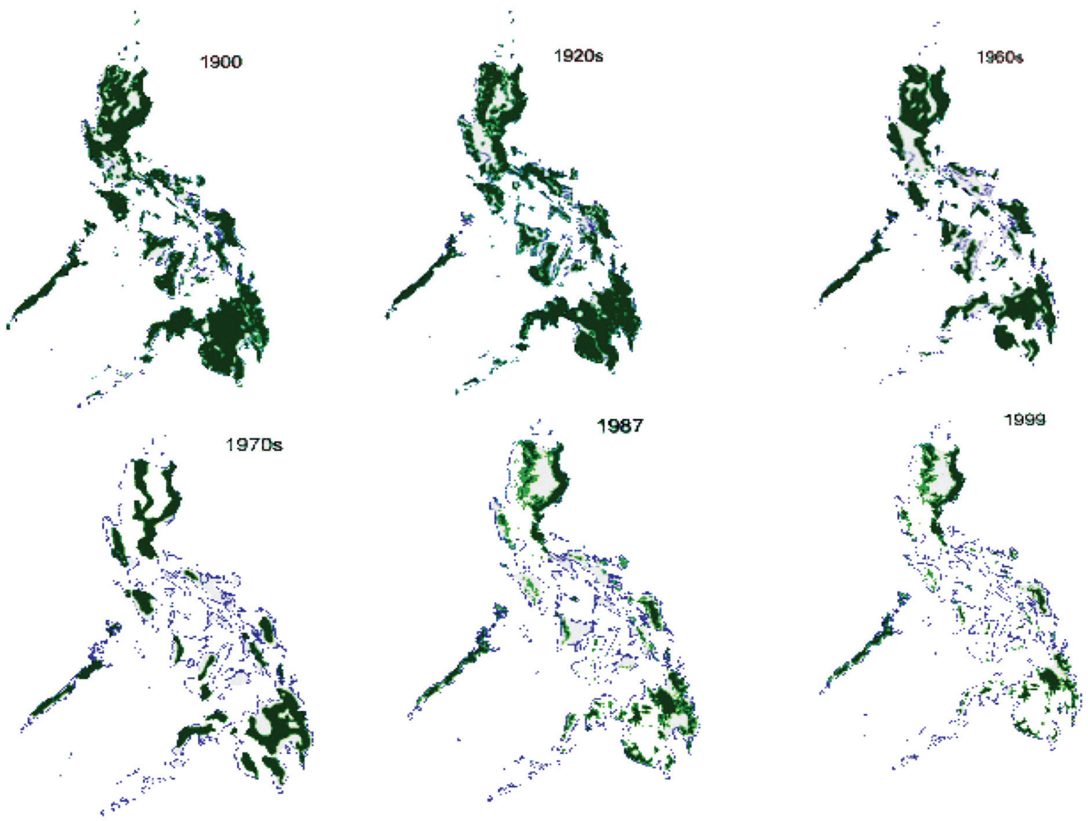

Figure 2.1 Decline of forest cover in the Philippines since 1900s (Dolom & Dolom, 2006)

2.4 KEY FUTURE IMPACTS AND VULNERABILITY

2.4.1 Forests

To date, there are only three researches on the impacts of climate change on Philippine forests. The first one is at the forest biome level (Lasco, Pulhin, Sanchez, Villamor, & Villegas, 2008d), the second one is at the tree species level (Garcia, Lasco, Ines, Lyon, & Pulhin, 2013), and the third study investigated bird species (Snelder, van Weerd, van't Zelfde, & Tamis, 2013).

The first study showed in general that tropical forest areas in the Philippines would expand as temperature and rainfall increase but not for all forest types (Lasco et al., 2008c). It utilized the Holdridge life zones, an ecological classification system based on the three climatic factors: rainfall, heat (bio-temperature), and humidity (potential evapotranspiration ratio) to classify Philippine forest types. A life zone is a group of associations related through the effects of these three major climatic factors. Initially, the study simulated the potential ecological zones in the country assuming there was no influence of humans. Then a number of synthetic scenarios of temperature and rainfall changes were used to simulate how the ecological zones may shift with climate change.

Without any anthropogenic influence, the potential vegetation at current temperature and rainfall would be dominated by the dry tropical, moist tropical, and wet tropical forest life zones. Such a condition must have existed when the Spanish colonizers first set foot in the Philippines in the 1500s. Increasing temperature and rainfall resulted in a re-distribution of forest zones. The dry forests are the most vulnerable forest types as it will be totally eliminated with at least a 1°C rise in temperature and a 25% rise in rainfall (Figure 2.2). Moist forests are also vulnerable especially under higher rainfall increase. On the positive side, there will be a significant increase in rain forest types as rainfall increases.

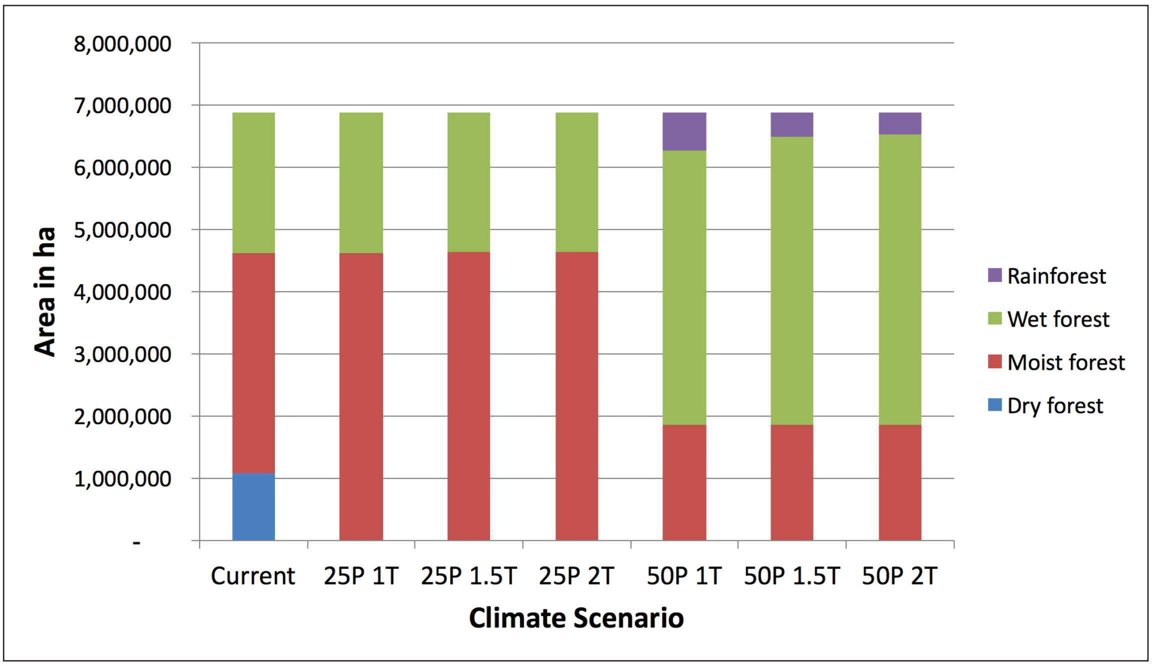

Figure 2.2 Changes in forest zones in the Philippines at different climate scenarios: 25% increase in rainfall, 1°C rise in temperature (25P1T); 25% increase in rainfall, 1.5°C rise in temperature (25P1.5T); 25% increase in rainfall, 2°C rise in temperature (25P2T); 50% increase in rainfall, 1°C rise in temperature (50P1T); 50% increase in rainfall, 1.5°C rise in temperature (50P1.5T); 50% increase in rainfall, 2°C rise in temperature (50P2T) (Lasco, et al., 2008d)

The second study aimed to evaluate the consequences of climate change on geographical distributions and habitat suitability of 14 threatened forest tree species in the Philippines (Garcia et al., 2013). Based on the principle of maximum entropy, it utilized a machine algorithm called Maxent to estimate a target probability distribution and habitat suitability of the selected species. Threatened forest tree species occurrence records and sets of biophysical and bioclimatic variables were inputted to Maxent program to predict current and future distribution of the species. The values of the trends in projected rainfall and maximum and minimum temperature by 2040 were determined as the median value of 13 global change projections reported in the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4), which are climate model inter-comparison phase three (CMIP3) model projections (IPCC, 2007). The specific models are: CSIRO_mk3.5, GFDL_CM2.1, GISS_EH, ECHAM5, NCAR_CCSM3.0, HAD_GEM1, BCR_bcm2.0, CCCMA_cgcm3.1, CNRM_CM3, GISS_ER, MROC3.2_MedRes, NCAR_PCM1 and HADCM3, each forced with an A1B greenhouse gas scenario.

The study showed that seven species (*Afzelia rhomboidea; Koordersiodendron pinnatum; Mangifera altissima; Shorea contorta; Shorea palosapis; Shorea polysperma; Vitex parviflora*) were found to likely benefit from future rainfall and temperature scenarios due to the potential increase in their suitable habitat, while the other seven species (*Agathis philippinensis; Celtis luzonica; Dipterocarpus grandiflorus; Shorea guiso; Shorea negrosensis; Toona calantas; Vatica mangachapoi*) will likely experience decline in their suitable habitat (Figure 2.3).

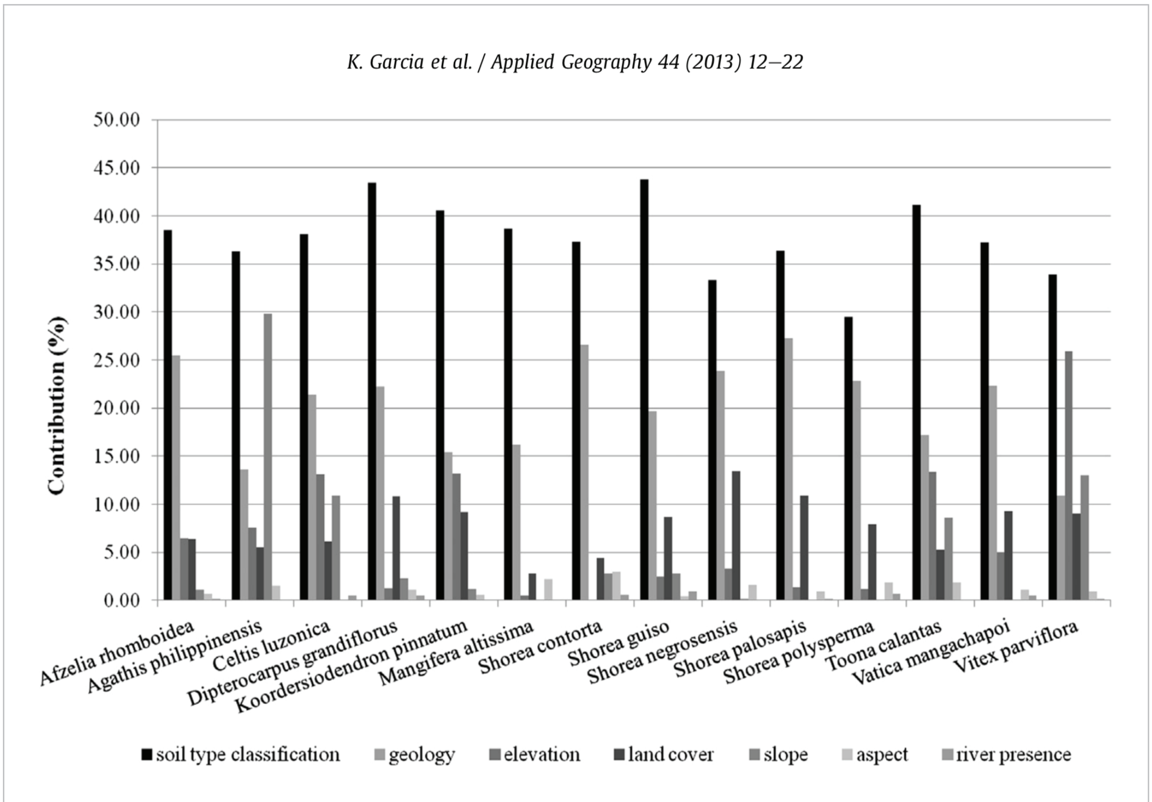

Figure 2.3 Percent change in habitat suitability of the 14 threatened forest tree species with base and projected climate scenarios by 2040 (Garcia et al., 2013)

The third study investigated climate change impacts of bird species in northern Luzon using a similar technique as the second study (Snelder et al., 2013). Future climate data by 2040 used for modelling were derived from the IPCC AR4 model data from CIAT (available at http://www.ccafs- climate.org/data/). The model used is UKMO – HADCM3 (Gordon et al., 2002), with scenario SRES A1B and downscaled with the Delta method (see: http://www.ccafs- climate.org/downloads/docs/Downscaling- WP- 01.pdf) to a resolution of 30 arc seconds. In all scenarios, lowland Dipterocarp forest is strongly declining because of transitions of natural forested areas into agricultural land use and distance to road effects. A decline will happen within large parts of the Northern Sierra Madre Natural Park under scenario A1 (the worst case scenario, with agricultural land use being dominant over forest within the park plus the impact of a newly planned road dissecting and opening up the park has been taken into consideration; not to be confused with the A1 IPCC SRES scenario) showing an upward shift of mountainous forest types and a slight decline in area in scenario F1 (with forest habitat types being dominant within the park over agriculture—but not outside the park—plus a moderate impact of the newly planned road; not to be confused with the IPCC SRES scenario) for mountain forests. Moreover, the effects of climate and land use changes on bird species distribution are partly following the changes in forest habitats. Under the A1 scenario, the models predict a considerable decrease in most forest bird species. The same is true for endemic and red list bird species (Snelder et al., 2013).

The limited studies that have been conducted in the Philippines showed that climate change could cause some shifts in forest distribution both at the biome level and at the plant and animal species level. These conclusions are consistent with the latest IPCC report on terrestrial ecosystems (Scholes et al., 2014).

In addition to the three specific studies in the country cited above, there are some studies particularly at the species level done within South and Southeast Asia (SEA) and elsewhere with results that may be indicative of the potential impacts of climate change in Philippine forest ecosystems and biodiversity. Hughes, Satasook, Bates, Bumrungsi & Jones (2012) predicted that climate change and vegetation cover changes could lead to decline in bat species richness in SEA. Another study by Menon, Islam and Peterson (2009) projected that most ranges of several species of nuthatches (Sittidae) in Asia would retreat along the southern fringes and at lower elevations, with the largest shrinkage in ranges expected in SEA and peninsular India.

Warmer temperature could alter species composition in forests by limiting the cold-adapted species while favoring warm-adapted species. In addition, the proportion of woody species relative to grasses and herbs could also be altered as shown by the studies of Harte and Shaw (1995) and Chapin et al. (1995).

Seasonal change in temperature (e.g., number of days above a certain degree Celsius), photoperiod (amount of daylight), seasonal weather and extreme events (tropical cyclones, floods) could alter the timing of flowering, fruiting, shoot growth, and leaf fall of forest trees and other plants, and its interactions with other organisms (e.g., pollinators, predators, seed dispersers) (Coley 1998; Corlett & LaFrankie 1998; Harrington, Woiwod & Sparks, 1999; Visser & Both, 2005). Although some individual plant species will be adversely affected with changes in phenological events due to changes in climatic seasonality, there are those who believe that species diversity as well the phenological patterns in the tropics moderate the impacts of climate change (Corlett & LaFrankie, 1998). Change in species composition and interactions could trigger outbreaks of pests and diseases.

Extreme events including excessive rains, floods, landslides, and droughts could adversely affect forest ecosystems and species. Excessive rains could enhance surface soil erosion and hasten soil fertility loss that will affect growth of plants and cause degradation of surface waters, river, lakes and coastal and marine ecosystems. Heavy rains could also induce landslides in steep areas with thick soils and fractured rock layers. Increase in the frequency and intensity of droughts could trigger forest fires, defoliation, and growth loss.

2.4.2 Coastal and Marine Ecosystems

Most of our coastal and marine ecosystems are in varying stages of deterioration, due to the combined impacts of natural stressors and human activities. Coastal erosion, bleaching of coral reefs, loss of sea grass, and conversion of mangrove areas are commonly associated with the deterioration of coastal and marine ecosystems in the country. These have downstream effects in terms of the coastal community livelihoods, thus lowering their adaptive capacity. Coastal erosion is a combined effect of the natural wave action and poor development growth in the area. With climate change, erosion potentials will be enhanced.

Sea level rise, changes in temperature, rainfall, tropical cyclones, and storms are the key climate-related hazards in the coastal and marine ecosystems of the country. Associated with these hazards are climate-related problems that include erosion, flooding, deterioration of coastal ecosystems, including mangroves, and salinization. These problems are either caused or exacerbated by SLR and tropical cyclones.

Sea level rise could alter river flows that in turn could change the distribution of salinity and freshwater in mangrove areas and could eventually reduce their species diversity and zonation. Mangroves respond to SLRs by changing productivity, area extent, or species diversity, and by species migration. The above response of mangroves to SLR is determined by sedimentation rates, erosion rates, and the ability of mangrove species to migrate inland to agricultural areas.

Increase in ocean temperatures could kill corals and adversely affect other marine resources, as observed in the 1998 El Niño episode. Coral reefs are well adapted to their environment; however, many species live at or close to their temperature thresholds. Mere 0.5°C increase in sea surface temperature above the normal summer maximum have been observed to trigger coral bleaching in many areas (Asian Development Bank [ADB], 2009).

In 1998 to 1999, the first massive bleaching in the Philippines was observed in Batangas, followed by several observations around the Philippines. It was noted that coral bleaching was correlated with abnormally high sea-surface temperatures (Arceo, Quibilan, Aliño & Licuanan et al., 2001; Licuanan & Gomez, 2000).

Most reefs of northern Luzon, West Palawan, Visayas, and parts of Mindanao were affected.

Marine species that are already near their thermal maxima could decline with increase in temperature (Cheung et al., 2009, 2010). Increase in temperature by 2 to 3°C above the current average decreased the activity and survival of some marine invertebrates in a study by Nguyen et al. (2011) in Singapore.

Higher carbon dioxide in the atmosphere makes ocean water acidic. This could disrupt the carbonate chemistry and make reef, shell, and bone formation difficult. Ocean acidification results when atmospheric carbon dioxide (CO2) is absorbed by oceans resulting in more acidic waters. The acidic ocean water decreases the ability of many marine organisms to build their shells and skeletal structure that could slow down the overall growth of marine organisms, slow down reproduction, and thus reduce abundance. Acidic ocean waters could also suppress reef formation and production (Hoegh-Guldberg et al., 2007).

Increased rainfall in the Philippines can cause nest inundation and mortality and potentially increase fungal pathogen loads. Juveniles rely heavily on oceanic plankton that is often scarce but becomes abundant around patchily distributed oceanic upwellings. The general poleward movement of planktonic biomass with temperature and a reduction of biomass within upwellings will make food resources more scarce and difficult to locate (Bickford, Howard, Ng, & Sheridan, 2010).

Predicted increases in the number and severity of tropical storms will likely cause more structural damage to reef and sea grass systems. Increased tidal activities will likely damage sea grasses while greater local rainfall will increase surface run-off and sedimentation (Bickford et al., 2010).

2.4.3 Ecosystem Biodiversity

It is estimated that in less than 50 years, amphibians and reptiles in SEA will have reached or exceeded most limits in their ability to adapt to the effects of climate change and that temperature-dependent sex determination, higher metabolic rates, and less bio-available water will have severe and irreversible effects on these organisms. In the Philippines, where it is expected to get wetter, amphibians and reptiles will face other challenges. Heavier rainfall may lead to increased mortality of amphibians that breed in slow flowing water, as eggs and tadpoles are more likely to get washed away or damaged by stronger torrents. Similarly, mortality of reptiles and amphibians that lay their eggs on land may increase due to nest flooding and increased fungal growth on eggs (Bickford et al., 2010).

Out of 107 species, 26 species (24.30%) are categorized as Highly Vulnerable, 48 species (44.86%) are Moderately Vulnerable, 27 species (25.23%) are Vulnerable and 6 species (5.61%) are Least Vulnerable to climate change. A total of 74 species (69.16%) considered Highly Vulnerable and Moderately Vulnerable are mostly direct developers (42 species), arboreal (30 species), and are distributed in high altitude forest habitats (13 species) above 1,000 meters above sea level (MASL). The 29 species with a conservation status of Critically Endangered and Endangered on the list of 74 species are considered Highly to Moderately Vulnerable to the effects of climate change (Alcala, Bucol, Diesmos, & Brown, 2012).

The potential impacts of climate change and adaptation in AHPs are shown in Table 2.1.

Table 2.1. Potential impacts of climate change and adaptation in AHPs (Cruz et al., 2013)

Sensitivity of AHP	Potential Impact	Potential Adaptation Measure
Areas > 1,000 MASL	Loss of species, in-migration of species from lower elevation due to warming	Rationalized access to high elevation
Endangered birds	Loss of species, migration to more suitable areas due to warming and degradation of habitats	Identification and conservation of key habitats and stricter regulation of wildlife trade, ex situ conservation

Table 2.1. Continued

Endangered mammals, reptiles, amphibians, and insects	Loss of species, migration to more suitable areas due to warming and degradation of habitats	Identification and conservation of key habitats and stricter regulation of wildlife trade, ex situ conservation
Endangered plants	Migration to more suitable areas due to warming, alteration of fruiting and flowering habits, loss of species due to extreme events (droughts, fires, landslides, tropical cyclones)	Strict protection and conservation of identified remaining stands and communities, ex situ conservation
Rainforests and mossy forests	Loss of species, alteration of species composition, shift of forest line to higher elevation due to warming, conversion to drier forest type	Strict protection of remaining forests, ex situ conservation, genetic resources conservation

Carpenter et al. (2008) published an International Union for the Conservation of Nature (IUCN) Red List for stony corals of the world. In this Red List, 225 species or one third of all the coral species were classified as having elevated risk of extinction (i.e., Vulnerable, Endangered, and Critically Endangered IUCN categories). This emphasized the impact of increased sea surface temperatures (SSTs) globally as well as the effect of local human activities.

2.5 ADAPTATION

2.5.1 Adaptation Plans and Programs

The NFSCC 2010-2022 recommends an integrated ecosystem-based management approach to addressing the country's multiple vulnerabilities to climate change. For river basin management, the objective is to manage watershed ecosystems and multi-polar environments through the River Basin Management (RBM) approach based on these strategies: (i) rehabilitate and develop watershed resources through resource use and governance improvement; (ii) enhance vulnerability and adaptation assessments; (iii) enhance ecosystem services to control droughts, floods, and landslides; (iv) institute a comprehensive RBM governance strategy; (v) establish appropriate and participatory institutional arrangements with LGUs, private sector, and civil society organizations; and (vi) reduce climate change risks and vulnerability of watershed ecosystems and biodiversity through ecosystem-based management approaches, conservation efforts, and sustainable environment and natural resources-based economic endeavors such as ecotourism (Climate Change Commission [CCC], 2010).

Moreover, for biodiversity, the objective is to mainstream adaptation strategies to climate change in policies, plans, and programs of national and local government. To achieve this, the strategic priorities are to (i) establish national baselines, standards, and indicators for monitoring progress in implementing biodiversity conservation programs; (ii) strengthen vertical and horizontal coordination among government agencies, civil society groups, academe, and other organizations in implementing biodiversity conservation and adaptation strategies to climate change; (iii) protect vulnerable ecosystems and highly threatened species from climate change impacts; (iv) develop institutional capacities in biodiversity conservation and CCA at the national, regional and local levels; (v) establish scientific basis for measuring the impacts of climate change scenarios on ecosystem and species diversity; and (vi) mobilize sustainable funding to support CCA programs (CCC, 2010). Specific adaptation options could include conservation and management of vulnerable species, assisting local communities that are highly dependent on forests at risk and adopting biodiversity-based adaptive and mitigative strategies such as maintaining and restoring native ecosystems; protecting and enhancing ecosystem services; managing habitats of endangered species; creating refuges and buffer zones; and establishing networks of terrestrial, freshwater, and marine protected areas taking into account climate change (Lasco et. al., 2008d).

Finally, an understanding of the adaptive capacity of AHPs is important as this would indicate whether the system can absorb changes in climate (including extreme events and variability) without damage or whether climate change will lead to negative consequences. The key determinants of adaptive capacity of AHPs are identified as (1) land use/zone plan implemented; (2) management plan implemented; (3) boundary delineated; (4) protection/conservation program; (5) development and rehabilitation program; (6) information, education, and communication (IEC)/community outreach program; (7) research/ technical development program; (8) ecotourism development program; (9) community development program; (10) partnership with non-government organizations (NGOs), LGUs, etc.; (11) available maps; (12) adequate protection laws; (13) laws/regulations enforced; (14) plan harmonized with regional plan; (15) adequate and trained staff; (16) adequate equipment/facilities; (17) adequate roads/other infrastructure; (18) adequate budget; (19) good resource information base; and (20) participatory governance.

Specific interventions which can facilitate the adaptation of AHPs to climate change could include (1) restoration of degraded ecosystems; (2) extension of the ecosystem network in AHPs; (3) establishment of new AHPs; (4) climate change research and monitoring; (5) ex situ conservation of vulnerable species; (6) mainstreaming and integration of climate change concerns into AHP management plans; (7) periodic assessment of climate change impacts, vulnerability, and adaptation; (8) regular reporting of the assessment of climate change impacts and adaptation in AHPs; (9) standardization of methods for research, monitoring, and assessment of climate change impacts and vulnerabilities; (10) integration and coordination of AHP management plan with local development plans; (11) harmonization of agenda for research and monitoring in all AHPs; (12) assistance in accessing fund sources for AHPs; (13) local community development; (14) participatory governance; (15) capacity building program; and (16) IEC program (Cruz et al., 2013).

The role of natural ecosystems for CCA is increasingly being recognized globally. In the Philippines, there was a clamor for more mangrove forests establishment in the aftermath of Typhoon Haiyan (local name: Yolanda), perhaps the strongest typhoon ever to hit land, for greater protection from storm surges. A household survey of residents along coastal areas hit by Typhoon Haiyan showed that there was a mixed perception on the role of mangroves in reducing storm surge damage. In Tacloban City, most residents observe less housing damage in areas with mangroves while in Ormoc City the opposite was true (Delfino, Carlos, David, Lasco, & Juanico, 2016). Another study showed that mangrove forests can recover after Typhoon Haiyan and that individual species have different abilities to resist storm surges (Carlos, Delfino, Juanico, David, & Lasco, 2016).

Recent study indicates that local communities play a significant role in mangrove conservation (Pulhin et al., 2017). Their appreciation of mangrove's multiple benefits like storm surge break, carbon sequestration, and provision of mangrove goods and services encourage active involvement in mangrove rehabilitation programs that can enhance their resiliency from climate change impacts.

2.5.2 Adaptation Policies

There are no specific policies governing CCA in natural ecosystems in the Philippines. Table 2.2 summarizes the main features of selected Philippine policies on natural resource management, and their respective possible relation to climate change. As may be expected, very few of these government policies directly address the adaptation to and mitigation of climate change. However, many of them have indirect effects.

Table 2.2. Summary of Philippine policies on natural resources management and their impacts relating to climate change (Lasco, Gerpacio, Sanchez, & Delfino, 2008b)

Philippine Policies	Brief Policy Description	Impacts Relating to Climate Change, Variability or Risks	
		Positive	Negative
Dec 1976: Presidential Decree No. 1067 – The Water Code of the Philippines	Revises and consolidates the laws governing the ownership, appropriation, utilization, exploitation, development, conservation, and protection of water resources	Rationalized access to high elevation	

Table 2.2. Continued

Philippine Policies	Brief Policy Description	Impacts Relating to Climate Change, Variability or Risks	
		Positive	**Negative**
June 1977: Presidential Decree No. 1152 – Philippine Environment Code	Establishes specific environment and natural resource management policies and prescribes environment quality standards	Promotes environmental protection which indirectly enhances resilience to climate risks	None
June 1978: Presidential Decree No. 1586 – Establishment of the Environmental Impact Assessment (EIA) System of the Philippines	Pursues comprehensive and integrated environmental protection supporting socio-economic development	Provides a good platform for the inclusion of climate risks to projects	Currently, climate change not explicitly included in the guidelines.
June 1988: Republic Act No. 6657 – Comprehensive Agrarian Reform Program (CARP)	Promotes a more equitable distribution and ownership of all public and private agricultural lands; and provides incentives to landowners to invest the proceeds of the program in promoting industrialization, employment, and privatization of public sector enterprises	Can provide farmer-beneficiaries with incentives to invest in farm development and/or modern production technologies that can minimize the impacts of climate change	Eventual cultivation of marginal lands by resource-poor farmers makes the natural ecosystem and local community more vulnerable to the impacts of climate variability. Landlord-farmer contracts negating land reform can mean low income for the farmers, leaving them little resources to cope with climate risks.
1998: Republic Act No. 8550 – The Philippine Fisheries Code	Rational and sustainable development, management, and conservation of fishery and aquatic resources in Philippine waters	By rationalizing use of aquatic resources, enhances the resilience of natural and social systems to adapt to future climate change.	None
Presidential Decree 705 – The Revised Forestry Code of the Philippines	Provides the country's fundamental forestry laws and policies; reinforced the use of license/ lease agreements to utilize natural resources	Includes a provision aimed at preventing flooding and excessive soil erosion and maintaining the hydrological integrity of watersheds	The increase in the number of Timber License Agreement (TLA) holders led to increased deforestation.
DENR Administrative Order No. 15-90 – Regulations Governing the Utilization, Development and Management of Mangrove Resources	To sustain optimum productivity by conserving, protecting, rehabilitating, and developing remaining mangroves, more with corporate collaboration than individual initiatives	Enhances the protective capability of mangroves against strong currents, winds. and high waves	None

Table 2.2. Continued

Philippine Policies	Brief Policy Description	Impacts Relating to Climate Change, Variability or Risks	
		Positive	**Negative**
June 1992: Republic Act No. 7586 – National Integrated Protected Areas System (NIPAS) Act	Regarded as the main strategy in biodiversity conservation through the establishment of a comprehensive system of integrated protected areas	Conservation strategies may increase the resilience and adaptive capacity of the local community to climate-related risks.	None
1995: Executive Order No. 263 – The Community-Based Forest Management (CBFM) Program	Integrated and unified different upland community programs and projects to ensure the sustainable development of forest land resources	CBFM program provides economic benefits to communities with appropriate market linkages, making them less vulnerable to climate variability. Enhances carbon sequestration through tree farms and agroforestry systems.	None
1997: Republic Act No. 8371 – Indigenous People's Rights Act	Recognize, protect, and promote the rights of indigenous cultural communities to their ancestral domains to ensure economic, social, and cultural well-being	Could lead to capacity building of indigenous communities that will enhance their resilience to climate risks.	None
March 1995: Republic Act No. 7942 – Philippine Mining Act of 1995 and Presidential Decree 1899 – Establishing Small-Scale Mining as a New Dimension in Mineral Development	Promotes rational exploration, development, utilization and conservation of all mineral resources, and safeguarding the environment and protecting the rights of affected communities	Increase income for small miners that could lead to greater ability to cope with climate risks.	Destruction of natural resources could lead to greater vulnerability to climate risks such as landslides and soil erosion.
1999: Republic Act No. 8749 – The Philippine Clean Air Act	A comprehensive national multisectoral framework for an air quality management program to reduce greenhouse gas (GHG) emissions	Improved air quality helps reduce the negative impacts of climate variability on human health	None
Aug 2006: Green Philippine Highways Project	Involves planting more than 500,000 ornamental and forest trees along a total of 3,439 km of major national highways from north to south Philippines	Trees ameliorate microclimate possibly leading to health benefits that enhances resilience to climate risks. Enhances carbon sequestration in planted trees.	Unplanned tree planting near major roads could increase climate hazards such as falling trees during tropical cyclones.
Jan 2007: Republic Act No. 9367 – Biofuels Act of 2006	Promotes the use of alternative transport fuels	Will mitigate toxic and GHG emissions	Could lead to monoculture plantations of biofuel crops that are more vulnerable to climate risks.

2.5.3 Link Between Adaptation and Mitigation

Sound management of natural ecosystems could also lead to climate change mitigation as explained in more detail in Working Group 3's Contribution to the 2018 Philippine Climate Change Assessment on Mitigation of Climate Change. For example, protection of existing forests by reducing deforestation and forest degradation will prevent the release of CO2 to the atmosphere. New plantings such as being done in the National Greening Program will enhance sequestration of carbon from the atmosphere. Thus, there is a great potential to obtain synergy between adaptation and mitigation in the management of natural ecosystems.

2.6 Implications to Sustainable Development

Natural ecosystems are natural capital which contributes to the attainment of sustainable development at the national and local level. They provide vital ecosystems services that enable nations and communities to pursue holistic development.

For example, natural ecosystems could enhance resilience of local communities to climate hazards through ecosystems-based adaptation (EbA). EbA includes a range of local and landscape scale strategies for managing ecosystems to increase resilience and maintain essential ecosystem service and reduce the vulnerability of people, their livelihoods, and nature in the face of climate change (Colls, Ash & Ikkala, 2009). EbA addresses the role of ecosystem services in reducing the vulnerability of natural-resource dependent societies to climate change. It is a set of adaptation policies or measures that address jointly the vulnerability of ecosystems and the role of ecosystem services in reducing the vulnerability of society to climate change, in a multi-sectoral and multi-scale approach. Uy and Shaw (2012) describe a participatory ecosystem resilience assessment approach for EbA planning considering ecological, physical, economic, social, and institutional dimensions applied to six ecosystems (i.e. mountain, riverine, urban, agricultural plain, estuarine, and coastal) in Infanta, Quezon.

In the Philippines, the province of Albay has shown ways by which natural ecosystems management can help enhance the people's resilience to climate hazards as shown in Table 2.3. Further research is needed to study the costs and benefits of adapting EbA for climate resilience in the country.

Table 2.3. Example of interventions of Albay LGU and their potential benefits for adaptation (Lasco & Delfino, 2009; Lasco, Delfino, Pulhin & Rangasa 2008a)

Interventions	Potential benefits for adaptation
Mangrove rehabilitation	Coastal mangroves provide storm protection, coastal defenses, and water recharge, and act as safety barriers against natural hazards such as floods, hurricanes, and tsunamis, while wetlands filter pollutants and serve as water recharge areas and nurseries for local fisheries.
Clean-up of rivers and creeks	May reduce the occurrence of floods and the damage it may cause – a simple and effective solution that protects both communities and natural capital.
Integrated disaster and climate risk management	Natural ecosystems can reduce vulnerability to natural hazards and extreme climatic events and complement, or substitute for, more expensive infrastructure investments to protect coastal and riverine settlements.

2.7 UNCERTAINTIES AND KEY RESEARCHABLE AREAS

The National Climate Change Action Plan (NCCAP)'s strategic priority on environment and ecological stability identifies the following research needs (CCC, 2011):

1. Climate change mitigation and adaptation strategies for key ecosystems developed and implemented;
2. Management and conservation of protective areas (PAs) and key biodiversity areas (KBAs);
3. Policy studies on how environmental laws can strictly be implemented (i.e., enablers and barriers);
4. Building capacity for Integrated Ecosystem-based Management Approach to PAs and KBAs;
5. Institutionalization of natural resource accounting (policy framework and methodologies);
6. Impact modelling for ecosystem sector;
7. Improve understanding of how higher temperatures, enhanced CO2, and other climate changes, acting in conjunction with other stresses, are influencing or may influence ecosystems, ecosystem services, and biodiversity;
8. Evaluate the potential climate feedbacks associated with changes in ecosystems and biodiversity on land and in the oceans;
9. Assess the potential of land and ocean ecosystems to limit or buffer the impacts of climate change through specific management actions; and
10. Improve observations and modelling of terrestrial and marine ecosystems and their interactions with the climate system.

There is very limited information on the impacts of climate change on natural ecosystems and their biodiversity pool. There would be a need to model climate change impacts at the ecosystems and species levels (Lasco, 2012). Future studies would need to look at how climate change and the accompanying change in forest types will affect biodiversity at species level with special emphasis on rare, threatened, and endangered species (Lasco et al., 2008c).

Key researchable areas could include (1) examining the links between biodiversity and climate change such as (i) the role of biodiversity and ecosystem services and the climate system, (ii) impacts of climate change on ecosystem services and (iii) biodiversity adaptation measures; (2) placing more emphasis on the impact of people on ecosystems and more attention on the human dimension of ecosystem dynamics; and (3) implementing EbA strategies so that humans and ecosystems will be better able to cope with risks associated with current climate and future climate change (Lasco, Uebelhor & Follisco, 2011).

Additionally, increasing basic biodiversity research (e.g., inventories, monitoring, species descriptions, ecosystem services and resource valuation, etc.) and experimental approaches to determine the effects of increased temperatures and variability in rainfall on amphibian and reptile growth, reproduction, behavior, and feeding ecologies would be important. In particular, research on indicator taxa (e.g., leaf litter specialists, stream obligates, the lungless frog, apex predators, etc.), large-scale and long-term monitoring programs at designated high-impact sites, applied programs to establish biodiversity corridors between protected areas, and comparisons of historical and contemporary species distribution, abundance, and richness data would be most relevant (Bickford et al., 2010). There would also be a need to conduct field studies to determine the status of Philippine amphibian populations, and to separate (if possible) the effects of climate change from those resulting from other factors such as habitat contraction and fragmentation and from direct human exploitation (Alcala et al., 2012).

Key concerns in the AHPs on the potential changes in ecosystems and biodiversity loss due to climate change include (i) absence of mainstreaming and integration of climate change in AHP management; (ii) lack of site-specific information on the impacts and vulnerabilities of AHPs; (iii) absence of AHP-specific assessment of impacts and vulnerabilities to climate change; (iv) no monitoring system specific for tracking climate change impacts and vulnerabilities; and (v) limited integration of AHP management into local development plans (Cruz et al., 2013). Detailed studies would be needed such as (i) in-depth assessment of the impacts, vulnerability, and adaptation of AHPs to climate change; (ii) financing CCA in AHPs; (iii) improvement of the system for AHP monitoring, information, and knowledge management; (iv) establishment of regional and national networks of long-term monitoring goals; and (v) training and institutional needs of AHPs.

Research priority to ecosystems that support important livelihoods would be essential. To address projected impacts of climate change and sustain the country's forest resources, a comprehensive review of policies on managing forest ecosystems in the country would be fundamental (Lasco, et al., 2008b). The assessment of adaptation strategies for natural ecosystems and local communities living within and around forests would be necessary (Lasco, 2012). In marine ecosystems, research would be needed to (i) enhance international cooperation aimed at curbing the impacts of climate change on coral reefs and (ii) study further the relationships between climate change, runoff, and overfishing, and consider these areas as the three major issues that affect the biodiversity of marine ecosystems (Lasco et al., 2011). Equally important is the development of more refined climate change scenarios using downscaling techniques to better estimate changes in rainfall and temperature (Lasco et al., 2008c).

Among the emerging issues and key uncertainties identified in Scholes et al. (2014) include:

- Detecting the presence and location of thresholds in ecosystem response to climate change, and specifically the type of thresholds characterized as tipping points;

- The issue of biophysical interactions between ecosystem state and the climate, over and above the effects mediated through greenhouse gases;

- Uncertainty in predicting the response of terrestrial and freshwater ecosystems to climate and other perturbations, particularly at the local scale;

- The consequences for species interactions of differing phenological or movement-based responses to climate change are insufficiently known and may make projections based on individual species models unreliable;

- Studies of the combined effects of multiple simultaneous elements of global change are needed as a supplement to the single-factor experiments;

- The effects of changes in the frequency or intensity of climate-related extreme events on ecosystem change are probably equal to or greater than shifts in the mean values of climate variables but are insufficiently studied and are seldom adequately represented in Earth system models;

- Understanding of the rate of climate change that can be tracked or adapted to by organisms is as important as understanding the magnitude of change they can tolerate;

- The capacity for, and limits to, ecological and evolutionary adaptive processes are only known in a few cases requiring the development and testing of human-assisted adaptation strategies for their cost-effectiveness in reducing risk; and

- The costs of the loss of biodiversity and ecosystem services as a result of climate change is known for only a few cases, or is associated with large uncertainties; as are the costs and benefits of assisting ecosystems and species to adapt to climate change.

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CHAPTER 3

Freshwater Resources and their Management

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3.1 EXECUTIVE SUMMARY

The climatological variations of rainfall in the Philippines are influenced significantly by seasonal monsoons, El Niño and La Niña episodes, and mesoscale systems. Tropical cyclones (TCs), in particular, contribute significantly to monthly and seasonal rainfall totals in the country. More than temperature change, it is perceived that the resulting climate change-induced variability of rainfall, through changes in the frequency and intensity of the above mentioned atmospheric processes, will have the greatest impact in the country.

Based on global climate models (BCM2, CNCM3 and MPEH5) to run two possible scenarios (A1B and A2) and downscaled to calculate for projected Philippine rainfall, all studies agree on a general increase in rainfall for 2020, 2050 and beyond. However, the same models show higher variability in rainfall with increased peak rainfall during the wet season and longer dry conditions during the dry seasons. Such variability in rainfall directly translates to changes in water supply dynamics spatially and year-on-year depending on TC tracks and prevailing mesoscale events.

Water supply is vulnerable to variability in river flows and the rate of replenishment of groundwater resources. Consequently, potential implications of changing rainfall patterns for water supply include lower flows resulting in water shortages. Moreover, intense rainfall events may not recharge groundwater at the rate experienced when rainfall is spread more evenly across the season. On the other hand, lower than average rainfall during the dry season and/or prolonged continuous dry days may affect soil porosity and vegetation conditions leading to reduced soil infiltration rates and consequently lower groundwater recharge. It is estimated that under the full range of Special Report on Emissions Scenarios (SRES) scenarios, increased water stress will be experienced by 2020 and 2050.

The Philippines is one of the countries at greatest risk from present climate-related hazards such as TCs, especially in the northern and eastern parts, floods, landslides, and droughts. Observed changes in extreme events and severe climate anomalies include (1) increased occurrence of extreme rains causing floods and landslides; (2) droughts associated with El Niño Southern Oscillation years causing massive crop failures, water shortages, and forest fires in various parts of the country; and (3) increase in the frequency of cyclones entering the Philippines particularly in the Visayas-Mindanao regions. Although there is no clear trend in typhoon intensity, three typhoons with the highest ever recorded maximum gustiness—Typhoons Reming, Loleng, and Yolanda (international names: Durian, Babs, and Haiyan, respectively)—occurred in the last two decades. Needless to say, these also come typically with a disruption in the water infrastructure in place, be it for irrigation or for domestic consumption.

A variety of adaptation measures are undertaken by communities such as reforestation, soil and water conservation, community-based early warning system, irrigation management, construction of small impoundments and reservoirs, and capacity building, among others, and by water user institutions including water rationing, forest protection, infrastructure rehabilitation, and information, education, and communication, among others. Adaptation in the water sector could be enhanced through: (i) capacity building of all stakeholders, (ii) provision of funds for climate change programs, (iii) strong political will, (iv) uplifting the socio-economic conditions of the poor, (v) strong commitment from all sectors, and (vi) coordination among institutions concerned with water resources. Lastly, while many of these are done at the local level, a national strategy which integrates technical solutions, social interventions, and enabling policies could provide long-lasting solutions.

As for research and development, focus could be provided on the application and integration of advanced climate information in the process of strategic planning for water resources development and management. Specific research-related priorities for water resources could include (i) impacts of extreme weather events on natural reservoirs; (ii) assessment of adaptation strategies focusing on water infrastructure, flooding, drought, and increasing water use efficiency; (iii) hydrologic modeling to assess the combined impacts of climate, land use, and vegetation cover types on the hydrological processes in the watershed; (iv) identification of the most vulnerable river basins and communities; (v) simulation of water allocations of reservoirs; and (vi) meaningful analysis of data on rainfall, evapotranspiration, inflow/outflow, and wind speed/direction for cloud seeding and other activities.

3.2 METHODS AND PROCEDURE

One of the major impacts of the projected increase in temperature and changes in rainfall is the enhancement of the hydrologic cycle (Barros et al., 2014; Parry, Canziani, Palutikof, van der Linden, & Hanson, 2007). It is projected that in most areas that are already receiving large amounts of rainfall, increase in evapotranspiration due to warming temperature will cause further increase in rainfall. This will enhance surface runoff and likely increase the occurrences of larger than usual flood events. It will also likely increase surface soil erosion and siltation of rivers, lakes, coastal, and marine ecosystems. In steep and rugged areas, increase in rainfall could trigger landslides. On the other hand, in drier areas and seasons, increase in evapotranspiration would increase the stress on sources of freshwater. Furthermore, low flow in rivers will likely decrease and this could affect the availability of water for irrigation. Dams, reservoirs, hydropower plants, water supply systems, and other water-related infrastructures are inherently vulnerable to changing temperature and rainfall. Hence, it is essential that the impacts of future climate on the hydrologic cycle are assessed properly so that appropriate adaptation measures can be deployed promptly.

Assessment of future impacts of climate change on water requires long-term series of empirical database on climate, stream flow measurements, and other hydrologic processes so that changes in these processes could be jointly assessed with changes in rainfall and temperature and coupled with changes in human activities. Short-term impacts of climate on water resources could be directly observed using appropriate monitoring tools. However, impacts of future climate change on water could be assessed using predictive models. A study by Tolentino et al. (2016) modeled several Philippine river basins using climate change projections and concluded that for most basins, a net increase in stream flow is expected. However, the increase in stream flow mainly occurs during the wet season through extreme rain events which does not necessarily contribute to the availability of water for domestic and agricultural use.

Several modeling techniques are utilized in studies to assess water resources in the light of climate change. WalBal, a lumped conceptual model that has two main modeling components, water balance and calculation of potential evapotranspiration using the Priestly-Taylor radiation method, is used to determine rainfall-runoff relationships (Jose & Cruz, 1999). A Rainfall Anomaly Index (RAI) is used to study rainfall variations (Pajuelas, 2000). The Geospatial-based Regional Environmental Vulnerability Index for Ecosystems and Watersheds (GeoREVIEW) uses a geospatial-based environmental vulnerability index to assess the vulnerability of the La Mesa Watershed (Tiburan, Saizen, & Kobayashi, 2013).

3.3 CURRENT SENSITIVITY AND VULNERABILITY

3.3.1 Amount, Frequency, and Intensity of Rainfall

Probably more than temperature change, it is in the resulting climate change-induced variability of rainfall that will have the greatest impact in the country. The number of days with heavy rainfall in the latter part of the 20th century appears to be higher than the corresponding occurrence in its early part. Over Luzon, frequent rainfall events of greater than 350 millimeters (mm) are recorded more in the last decade than the 275 mm events of the 1960s and 1970s (Thomas, Albert, & Perez, 2012). Despite this, a study of rainfall variations in the Philippines also suggests that total rainfall is decreasing in several parts of the country over the period 1950 to 1996. Decreasing total rainfall over climate types 1, 2, and 3 but increasing rates over climate type 4 are observed during the rainfall-sensitive months of February through May in the 10-year RAI. In the 30-year RAI, results show negative trends for climate types 2 and 4 and positive trends for climate type 3 in February to May (Pajuelas, 2000). In the period 1961 to 1998, data from selected weather stations show a significant decrease in the number of rainy days in Baguio, Daet, and Dumaguete stations (Manton et al., 2001).

Two rainfall trends are revealed in a study to investigate the temporal and spatial features of rainfall in the Philippines (Akasaka, Morishima & Mikami, 2007). The first mode reveals the increase of rainfall amount in the entire Philippines during the onset of the southwest monsoon while the second mode represents the contrast between rainfall patterns between the west and east coasts during the rainy season. The rainy season starts simultaneously over the entire west coast in the middle of May and withdraws gradually starting from the north around November. Meanwhile on the east coast, the rainfall amount increases during the latter part of the year rather than in May due to the weakened monsoon through around early November. These regional differences between west and east coasts are considered to correspond to the seasonal changes of the Asian summer monsoon coupled with orographic effect (Akasaka et al., 2007).

The climatological variations of rainfall in the Philippines are influenced significantly by El Niño and La Niña episodes (Jose & Cruz, 1999; Estoque & Balmori, 2002), monsoons, and mesoscale systems (Cruz et al., 2013). For example, in the period 1951 to 1992, analysis shows positive rainfall trends in the western sections of Luzon and negative rainfall trends in Mindanao, Visayas, and Eastern Luzon. This implies that the increasing rainfall trends in the western section of Luzon may have some relation with the possible changes in the southwest monsoon activity while the decreasing trends in the eastern sections of Luzon, Visayas, and Mindanao may be attributed to possible changes in the northeast monsoon activity (Jose, Francisco, & Cruz, 1999).

Prolonged El Niño Southern Oscillation (ENSO) events have exhibited seasonal rainfall sign reversals in the Philippines with a similar evolution in atmospheric circulation (Lyon & Camargo, 2009). The La Niña event of 1975 to 1976 gave the highest positive rainfall anomaly in climate type I (including Metro Manila) while the El Niño event of 1982 to 1983 registered the lowest negative rainfall anomaly for climate type III (Central and Western Visayas including most parts of Mindanao) (Pajuelas, 2000). However, a climatological analysis of the southwest monsoon (SWM) rainfall for the period June to September of 1961 to 2010 on the western part of the Philippines shows no above normal rainfall events associated with La Niña years and few occurrences of below normal rainfall associated with El Niño events. Of course, all residents of Metro Manila experienced TS Ketsana (Ondoy) where record rainfall amounts were measured in 2009, which is an El Niño year (Abon, David, & Pellejera, 2011).

There is evidence for a decreasing trend in rainfall associated with the SWM in the past 50 years and an increasing trend in the number of "no rain" days suggesting longer dry periods during the SWM in recent decades over western Philippines (Cruz et al., 2013). However, the 2012 SWM event brought about record rainfall amounts in Central Luzon never before experienced (Heistermann et al., 2013). There are large differences in the anomaly patterns between any two El Niño/La Niña episodes; thus, it would be difficult to infer from past rainfall anomaly patterns the corresponding patterns for any particular episode in the future. In addition, the possibility of predicting the occurrence of droughts and floods at rain gauge stations in the Philippines solely from sea surface temperatures (SSTs) over the Central Pacific Ocean would be difficult due to statistical method deficiencies (Estoque & Balmori, 2002). On whether the behavior of recent El Niño and La Niña events and their associated impacts could be directly attributed to climate change or other factors is still uncertain, and the direct correlation with ENSO on a per region basis is still not that fully constrained (Yumul et al., 2008). However, any perturbations in the cycle can be interpreted as a possible representation of climatic uncertainty (Yumul, Dimalanta, Servando, & Hilario, 2010).

Studies indicate that the frequency and intensity of TCs originating in the Pacific have increased over the last few decades causing significant damage in affected countries (Cruz et al., 2007, Cinco et al., 2016). Other studies dispute this by explaining that the so-called global trend in increase in TC intensity, duration, and frequency is not readily noted in the Philippines and that it appears that regional variability is more the norm than the exception (Yumul et al., 2008). In fact, based on the International Best Track Archive for Climate Stewardship (IBTRACS) TC archive, the number of TCs forming in the western Pacific is decreasing starting in the 1970s (David, Racoma, Gonzales & Clutario, 2013). In terms of TC intensity, there is also no clear trend (David et al., 2013). However, three typhoons with the highest ever recorded maximum gustiness (i.e., Typhoons Reming, Loleng, and Yolanda) occurred during the last two decades. A most recent study that dissected the impact of TCs per region in the country suggests that up to 54% of the rainfall in Luzon is attributable to TCs and that this has increased by up to 19% from 15 years ago (Bagtasa, 2017).

Projections from archived data and probabilistic models for rainfall in the Philippines still do not reach a consensus on the true impact of climate change in rainfall. However, all studies point towards an overall higher variability in rainfall intensity and frequency for both geographic and temporal considerations.

3.3.2. Hazards and Risks from Rainfall

The Philippines is one of the countries at greatest risk from present climate-related disasters ranking in the top 20 in the periods 1971 to 1980 and 1981 to 1990 (Brooks & Adger, 2003). It is also identified among the top countries with highest risk to climate-related hazards in different indices such as the World Risk Index 2016 (Alliance Development Works and United Nations University-Institute for Environment and Human Security [UNU-EHS], 2016), Verisk Maplecroft's Natural Hazards Risk Atlas 2015 (Verisk Maplecroft, 2015), and the Global Climate Risk Index 2017 (Kreft, Eckstein, & Melchior, 2016). The country is not only exposed to TCs especially in the northern and eastern parts, but also to floods, landslides, and droughts (Yusuf & Francisco, 2009). Probabilistic risk analysis estimates that the Philippines experiences an average annual loss (AAL) of USD 8.45 billion (equivalent to 3.11% of 2013 Gross Domestic Product [GDP]) as a consequence of natural hazards including USD 4.07 billion for cyclonic wind, USD 2.54 billion for storm surge, and USD 545.43 million for flood. For probable maximum loss (PML), the 100-year PML is estimated at USD 21.89 billion for cyclonic wind and USD 3.82 million for storm surge (United Nations International Strategy for Disaster Reduction [UNISDR], 2015b). Based on vulnerability studies, the most vulnerable regions in the country are identified as the National Capital Region, Southern Tagalog, Cagayan Valley, Central Luzon, the Cordillera Administrative Region, and Bicol Region (Yusuf & Francisco, 2009). A more recent study suggests that Visayas and Mindanao are likewise becoming more at risk due to an increasing number of TCs entering the southern part of the country (David et al., 2013). Tropical cyclone activity is shown to be enhanced (reduced) during the boreal summer of El Niño (La Niña) events, which is related to the increase (decrease) of mid-level atmospheric moisture, as diagnosed using a genesis potential index. The subsequent evolution shows development of an anomalous anticyclone (cyclone) over the Western North Pacific (WNP) in El Niño (La Niña) and the well-known tendency for below (above) average rainfall (Lyon & Camargo, 2009). On the west side (over South China Sea), a 40-year observation between 1960 and 2000 of extreme TCs highlight that the most important weather pattern was alternating sequences of years with many extreme events followed by years where such events did not appear. These sequences produced a long periodicity in the range of 20 years (Rozynski, 2008).

Landslides and floods generally occur during sustained wet weather and in extreme events. Residents in the uplands and those residing on the riverbanks or channels or at the base of hills are exposed to such risks. Landslides and erosion in the uplands may also cause siltation of water supply for residents. In Iloilo City, residents are vulnerable to flooding, reduced water availability during droughts, and the possibility of reduced local supply of agricultural products during such events (Miller, Alexander, & Jovanovic, 2009). Post analysis of the extreme flood event brought by Typhoon Ondoy (international name: Ketsana) in Metro Manila in 2009 shows that anthropogenic factors including (i) a decrease in river channel capacity through encroachment of houses, siltation from deforestation, and garbage; (ii) disappearance of 21 kms of small river channels; (iii) urbanization accelerating runoff concentration and reducing infiltration losses; (iv) loss of natural retention areas; and (v) land subsidence exacerbated the impacts of torrential rains (World Bank, 2010). Geohazard maps developed by the Mines and Geosciences Bureau of the Department of Environment and Natural Resources (MGB-DENR) identify the top provinces prone to flooding in the country as Pampanga, Nueva Ecija, Pangasinan, Tarlac, Maguindanao, Bulacan, Metro Manila, North Cotabato, Oriental Mindoro, and Ilocos Norte. Based on a flood risk analysis conducted for the Greater Metro Manila Area (GMMA), a majority of the area is found to be vulnerable to severe flood inundation due to its location on naturally flood prone lands such as the floodplains along the Marikina, Pasig, and San Juan Rivers, tidal flats along Manila Bay, and lakeshore and deltaic landforms around Laguna Lake (Badilla et al., n.d.).

The anomalous meteorological-climatological events in 2006 and a subsequent dry spell in 2007 during the rainy season demonstrate the devastating impacts of extreme weather events such as flooding and landslides in the Visayas and Mindanao, and water and power shortages in Luzon (Yumul et al., 2010). The excessive rainfall which characterized the years 2004, 2006, and 2008 resulted in numerous problems, including (i) the artificial damming of rivers, which breached and led to flash-floods, and the depositing of debris and logs (for instance, in Aurora-Quezon in 2004 and Iloilo on Panay Island in 2008); (ii) the remobilization of lahar deposits, resulting in the avulsion of rivers and flashfloods (for example, the 2006 event in Legazpi City and its vicinity due to Typhoon Reming); (iii) excessive flooding, leading to the destruction of communities along riverbanks, as well as fishponds, agricultural lands, and road and bridge arteries, and isolating villages (such as flooding in the Cagayan River Basin, Pampanga-Agno River Basin, Bicol River Basin and the Jalaur River Basin in Iloilo); and (iv) mass wasting, mostly landslides, which caused great destruction (such as the landslides in Guinsaugon in Southern Leyte and Masara in Compostela Valley in 2006 and 2008, respectively) (Yumul et al., 2010). There is a statistically significant relationship between the frequency of intense hydro-meteorological natural disasters, exposure, and climate hazards. Estimates for the period 2001 to 2010 suggest that average rainfall deviation increases by another eight mm per month (moderate scenario) could be associated with an increase in the average frequency of hydro-meteorological disasters in the Philippines by an average of around 0.35 disaster a year, or an additional disaster every three years. If the increase in average rainfall hits 12 mm per month (high scenario), an increase of one disaster every two years can be expected (Thomas, Albert, & Perez, 2013).

Extreme weather events (i.e., drought, above normal temperature, prolonged dry season, and rainfall below normal) associated with El Niño were reported to be more frequent and intense in Southeast Asia in the past 20 years (Cruz et al., 2007). The rise in temperature, particularly during the summer and normally drier months and ENSO events, has resulted in the increasing frequency and intensity of droughts (Cruz et al., 2007). The most vulnerable to drought are areas experiencing seasonal aridity and recurrent droughts and manifesting conditions and effects of desertification processes such as major rice, corn, and other grain-producing and moisture-deficit areas in (i) Northern tip of Luzon (Region I-Ilocos Sur and Ilocos Norte; and Region II-Cagayan Valley); (ii) Mindanao (Region IX-Zamboanga del Norte, Zamboanga del Sur; Region X-Bukidnon, Lanao del Norte, Misamis Oriental; Region XI-Davao del Sur, Davao Oriental; Region XII-South Cotabato, General Santos, Sarangani; and Autonomous Region in Muslim Mindanao (ARMM)-Maguindanao); (iii) provinces in the western portions of the country experiencing type 1 and type 3 climate; and (iv) provinces in the central parts of the country experiencing type 3 climate (Department of Agriculture [DA], Department of Agrarian Reform [DAR], DENR, & Department of Science & Technology [DOST], 2010). The mean daily temperature in these areas, which ranges from 30 to 35°C and with relative humidity of 70 to 80%, induces depletion of soil organic matter and significant water loss through evapotranspiration. Thus, in prolonged dry periods, soil and water resources in these areas are not able to support crop production. Another study also identifies Central and West Mindanao including the provinces of Sulu, Basilan, Maguindanao, Lanao Del Sur, Lanao Del Norte, Davao Del Sur, Misamis Occidental, Sarangani, Zamboanga Del Sur, South Cotabato, Zamboanga Del Norte, North Cotabato, Sultan Kudarat, Siquijor, Tawi-tawi, Negros Oriental, Camiguin, Davao del Norte, Misamis Oriental, and Bukidnon as areas highly at risk to El Niño-induced drought (Manila Observatory, 2005).

Decreasing rainfall and increasing temperature commonly associated with ENSO have led to the increase in water shortage, particularly in parts of Asia where water resources are already under stress from growing water demands and inefficiencies in water use (Manton et al., 2001). The El Niño-related drought of 1982 to 1983 not only affected thousands of agricultural areas but also multipurpose reservoirs where very low water levels were recorded. The Metropolitan Water Sewerage System (MWSS) reported an equivalent of 20% shortfall in water production during the ENSO-related drought event of 1991 to 1992 resulting in water rationing in many low water pressure areas of Metro Manila. The National Power Corporation (NPC) reported drastic curtailment of the generating capacity of various hydropower plants particularly in Luzon and Mindanao during the ENSO-related drought event of 1991 to 1992. The three major multipurpose dams of Angat, Magat, and Pantabangan in Luzon experienced power generation losses of about 31% of the expected power generation for October 1991 to March 1992 (Jose et al., 1999). Metro Manila and its nearby municipalities suffered from water shortages because of the decrease in water production during the 1997 to 1998 El Niño episode from 3,200 million liters per day (mld) to 2,100 mld. The hydropower generation of the Angat dam was the hardest hit with a total deficit of 333.38 Gigawatt hours (Gwh) from the second quarter of 1997 up to the third quarter of 1998. As a result of the rainfall deficit in the Angat watershed, the total inflow of the Angat reservoir decreased to 842 million cubic meters (mcm) in 1997, equivalent to 60% below the average annual inflow of 2024.83 mcm. In terms of water level of the dam, the lowest reservoir water level on record occurred during El Niño years (i.e., on 17 July 1992 with 158.17 meters [m] and 2 September 1998 with 158.15 m) since 1968 when the dam was commissioned (Espinueva, 2002, as cited in Dolcemascolo, Subbiah, & Raksakulthai, 2002). More recenlty, the level of Angat Reservoir dipped below the critical 180-meter mark in El Niño year of 2010. An examination of the variations of seasonal and annual inflow at various major reservoirs in the country shows decreasing trends of inflow that closely correlates with rainfall. Minimal amounts of inflows and rainfall are found to be associated with the ENSO-related drought events of 1968, 1969, 1973, 1977, 1983, 1987, and 1991 (Jose et al., 1999). Still, during the first months of mild ENSO events, it is observed that strong TCs or those that bring much rainfall such as Typhoon Ondoy can occur (Abon et al., 2011).

The observed changes in extreme events and severe climate anomalies can be summarized as follows: (i) increase in hot days and warm nights; and decrease in cold days and nights between 1961 and 1998 (Cinco, de Guzman, Hilario & Wilson, 2014), (ii) increased occurrence of extreme rains causing landslides and floods in 1990 and 2004, (iii) droughts normally associated with ENSO years particularly in 1997 to 1998 causing massive crop failures and water shortages and forest fires in various parts of Philippines, and (iv) an increase in the frequency of cyclones entering the Philippines particularly in the Visayas-Mindanao regions (Cruz et al., 2007; David et al., 2013).

3.3.3 Risks and Damage and Loss Due to Tropical Cyclones

Typical paths of TCs per decade have been dynamic and may be shifting to central Philippines (Thomas et al., 2012). At least five main TC tracks have been identified: one crosses to the north of Manila; one traverses south of the capital; one passes east or north-east of the archipelago that either disappears or recurves in the Pacific; one forms in the China Sea to the west of the Philippines; and another recurves in the China Sea between the parallels 10° and 20°. As a result, some provinces are more frequently exposed to TC than others. Northern Luzon, Southeastern Luzon, and Eastern Visayas are identified as the areas highly at risk, particularly the provinces of Cagayan, Albay, Ifugao, Sorsogon, Kalinga, Ilocos Sur, Ilocos Norte, Camarines Norte, Mountain Province, Camarines Sur, Northern Samar, Catanduanes, Apayao, Pampanga, La Union, Nueva Ecija, Pangasinan, Masbate, Tarlac, and Western Samar (Manila Observatory, 2005). A study of observed extreme wind speeds in the Philippine Atmospheric, Geophysical and Astronomical

Administration's (PAGASA) stations in various parts of the country shows that severely extreme wind speeds of 185 kilometer per hour (kph) and above are experienced in several areas in various months. In Mindanao region, extreme wind speeds are observed in the northernmost portion (Rellin, Jesuitas, Sulpat, & Valeroso, n.d.; Cinco et al., 2015).

The seasonality and routes taken by TCs are significant due to the consequences for various parts of the islands. A comparative historical analysis of the total number of TCs experienced by each major region of the archipelago reveals that Northern Luzon receives by far the highest number but that there is little difference between Central Luzn, Southern Luzon, and Visayas, although two islands in the latter (i.e., Samar and Leyte) are among the 10 most exposed provinces. Mindanao, on the other hand, presents a very different profile with fewer TCs and a higher percentage of milder events proportionately than any other region. In relation to flooding, the archives of the Manila Observatory reveal that over 56% of all recorded incidents of flooding between 1691 and 1911 are directly attributed to TCs suggesting certain seasonality in their occurrence that corresponds to the peak in the latter's annual cycle between July and November (Bankoff, 2003). A more recent study reveals that on average 11 TCs make landfall every year: six in Northern and Central Luzon, two in Bicol and Southern Luzon, and three in Visayas/Mindanao. A slight increase in TCs passing by Visayas/Mindano is evident (David et al., 2013).

Eight major TC track patterns in the period 1945 to 2007 are classified, among which Types D and E (which forms in the Philippine Sea and follows a northward path) are identified as having the highest occurrence, 316 and 231, respectively, out of a total of 1,621 cases (Chu, Zhao, & Kim, 2010). The study also examined temporal variations in TC-related attributes such as frequency, intensity, and lifetime. For Type D storms, they found that TC activity has very likely undergone a decadal variation with two abrupt shifts occurring around 1987 and 1998 with three epochs characterized by the active 1945 to 1986 epoch, the inactive 1987 to 1997 epoch and the active 1998 to 2007 epoch. The increasing activity for Type D since 1998 is of particular concern because storms of this type are formed near the eastern Asian landmass. With regard to TC lifespan, it can be seen that six of the track types exhibit one abrupt shift. After the abrupt shift, Type D, along with four other types, shows an increasing level of storm days, indicative of longer mean storm days. This could suggest that steering flows over the WNP become weaker, making storms traverse more slowly and increasing the lifetime of the storms. In terms of change in TC intensity, seven of the track types exhibit abrupt shifts in the 1970s, particularly in 1971 to 1973 for Type D and in 1974 for Type E. A step-like change for Type D also occurred in 1998 with higher intensities, signifying stronger TC intensities in the last few years (Chu et al., 2010).

The Philippine coasts are highly vulnerable to storm surges especially during the TC season. The Project Nationwide Operational Assessment of Hazards (NOAH) identifies the coastal areas of Central Visayas, Southern Luzon, and Northeastern Mindanao as most vulnerable to high storm surges because of their gently sloping coasts and shallow bays and the frequent passage of TCs (Lapidez et al., 2014). Furthermore, storm surge inundation maps developed for GMMA considering PAGASA's public storm warning signal (PSWS) system and the probability that a particular storm surge height will be exceeded in a time period show that for PSWS 4 (i.e., very strong winds of more than 185 kph may be expected in at least 12 hours), large areas of Malabon, Manila, Obando, and Navotas will be inundated to up to 6 kilometers (km) but with different flow depths reaching 3.01 to 4 m for 1% probability of exceedance and 2.01 to 3m for 10% probability of exceedance (Tablazon et al., 2014). During Typhoon Yolanda, tsunami-like waves were generated in Tacloban because of the typhoon's rapid track speeds resulting in a large number of casualties (i.e., 2,646 dead and 701 missing) (Lagmay et al., 2013). Historically, deadly storm surge events in the country have been recorded including those events caused by (i) Typhoon Pablo (international name: Bopha) in Cateel, Boston, and Baganga in Davao Oriental in 2012 that killed 1,000 people, (ii) Typhoon Frank (international name: Fengshen) in Panay and Boracay islands in 2008 that killed 938 people, (iii) Typhoon Rosing (international name: Angela) in the Quezon province in 1995 that killed 936 people, and (iv) Typhoon Nitang (international name: Ike) in the Negros islands in 1984 that killed 1,400 people (Project NOAH, 2014).

The Global Assessment Report 2015 ranks the Philippines first with highest TC AAL in relation to capital investment (UNISDR, 2015a). Data from the Emergency Events Database (EM-DAT) and the World Bank show that TCs are the most frequent and destructive disaster causing high economic damage and loss estimated at USD 821 million for Typhoon Glenda (international name: Rammasun) in 2014, USD 10 billion for Typhoon Yolanda in 2013, USD 898 million for Typhoon Pablo in 2012, and USD 585 million for Typhoon Ondoy in 2009 (Guha-Sapir, Below, & Hoyois, n.d.; World Bank, n.d.). With regard to fiscal impacts, Typhoons Ondoy and Pepeng (international name: Parma) affected fiscal balance due to higher spending for infrastructure repair, emergency relief, assistance to affected populations, and losses in public revenue in 2010. Similarly, the government infused additional public spending estimated at USD

2.6 billion after Typhoon Yolanda and deficit increased to above 2% of GDP target in the next two years due to decline in tax revenue from the affected regions (National Economic and Development Authority [NEDA], 2013). Disasters also result in substantial impacts on regional GDP. In Typhoons Ondoy and Pepeng, regional damage and loss represented 10% of Region I's GDP, 9% of Regions II and IV-A's GDP, 7% of Region III's GDP, and 1.8% of the National Capital Region's GDP (Government of the Philippines, Asian Development Bank [ADB], United Nations [UN], World Bank, & Global Facility for Disaster Risk Reduction [GFDRR], 2009; Cinco et al., 2016). Figure 3.1 shows that among disasters in 1990 to 2015, TCs in recent decades contribute to high direct physical losses resulting in significant impacts on GDP.

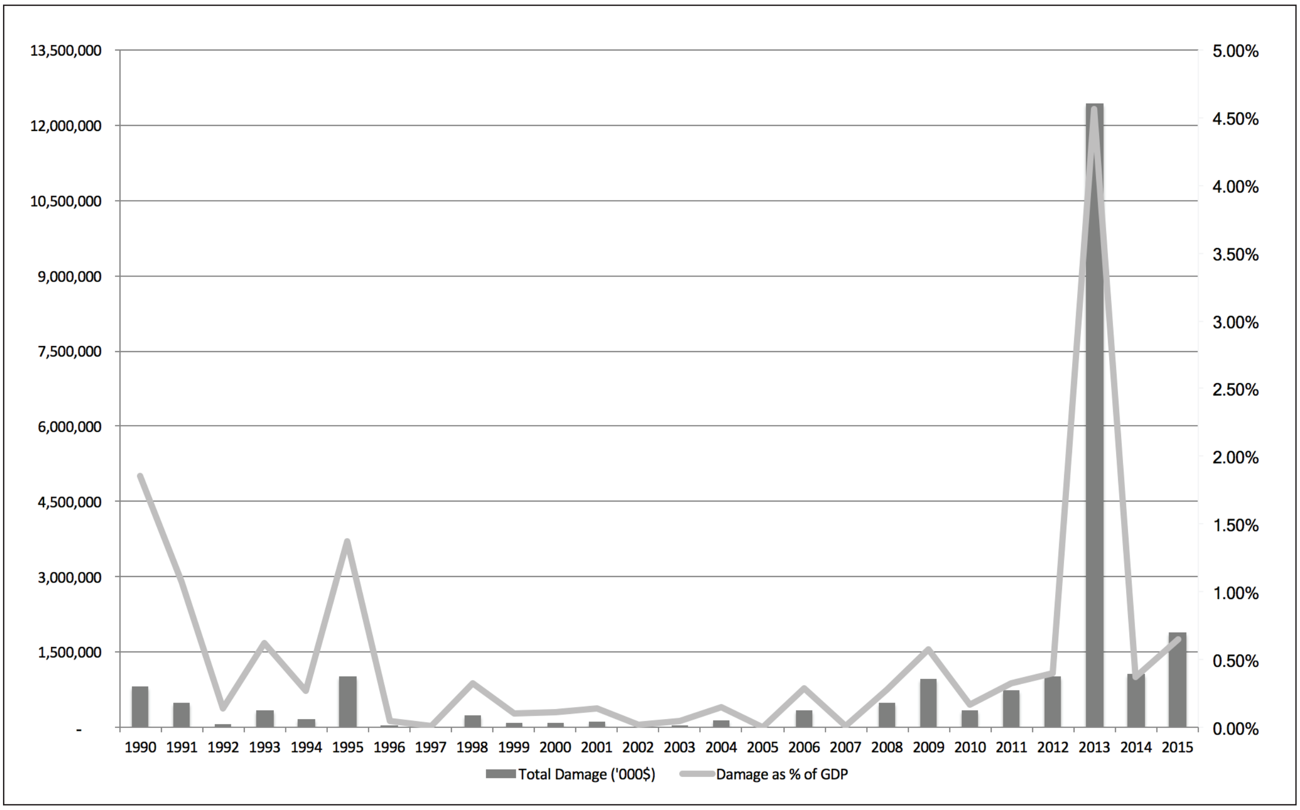

Figure 3.1 Direct physical losses from disasters as a percentage of GDP (Guha-Sapir et al., n.d.)

3.3.4 Vulnerability of Watershed Areas

Potential issues that can affect watershed management are identified as erosion, landslide, biodiversity loss, flood, and drought (Tiburan et al., 2013). In Bukidnon, a soil erosion evaluation and flood assessment show that many of the mountainous areas have high to very high erosion rates due to agricultural activities and no soil cover for most of the year. Short, extreme rainfall also produces higher net erosion compared to prolonged light to moderate rains (Clutario & David, 2014). A flood assessment in Quezon Province after the 2004 flashflood shows an inundated area of approximately 4,600 hectares (ha) in most parts of Infanta and partly of Real and General Nakar. In Infanta, the total volume of sediments deposited ranging from 0.017 to 1.5 m in thickness is estimated to be about 39 million m^3 (Adornado & Yoshida, 2010).

3.4 ASSUMPTIONS ABOUT FUTURE TRENDS

3.4.1 Climate Drivers

3.4.1.1 Rainfall and Water Availability

Based on an Atmosphere-Ocean General Circulation Model (AOGCM) simulation under A2 and A1B scenarios, results show a 10% increase in rainfall by 2099 compared to the mean rainfall for 1961 to 1990 over the Northeast Asian region including the Philippines. After the stabilization of the greenhouse gas concentration in 2100, the rainfall is enhanced during 30 or 50 more years due to the inertia inherent in the climate system. From empirical orthogonal function analysis, it would seem that the increased Northeast Asian summer rainfall due to global warming is contributed by the effect of the enhanced monsoon circulation in the decaying phase of El Niño rather than the mean linear increase of global climate or the circulation in the fast transitional period of ENSO (Lee, Kwon, & Baek, 2008).

As far as extreme rainfall is concerned, the number of days with heavy rainfall (e.g., greater than 200 mm) is expected to increase with global warming by the year 2020 and 2050 (Manila Observatory, 2011). Another climate downscaling simulation shows annual rainfall increase of 0.1% to 9.3% for the A1B scenario and -3.3% to 3.3% decrease/increase for the A2 scenario. It is further estimated that dry seasons will tend to become drier while the wet seasons will become wetter. The water balance showed that 42% of rainfall is converted into evaporation, 48% into streamflow, and 10% into deep seepage loss (Combalicer, Cruz, Lee, & Im, 2010).

Large variability in rainfall and longer drier periods will affect the amount of water in watersheds and dams thereby limiting agricultural and energy production (PAGASA, 2011). Changes in rainfall and temperature will be critical to future inflow in the Angat reservoir and Lake Lanao, with rainfall variability having a greater impact than temperature variability (Tables 3.1 and 3.2). The Angat reservoir and Lake Lanao are expected to have a decrease in runoff in the future and may be insufficient to meet future demands for water (Tables 3.3 and 3.4) (Jose & Cruz, 1999).

Table 3.1. Projected total water supply and demand for Angat Reservoir in the year 2050 (Jose & Cruz, 1999)

	Baseline	CCCM	GFDL	UKMO
Total water supply	5011	4409	5261	6614
Total water demand	15405	15405	15405	15405
Deficit	10394	10996	10144	8971

Table 3.2. Changes in annual rainfall, temperature and runoff for Lake Lanao water reservoir from 3 GCMs (Jose & Cruz, 1999)

GCM	Rainfall Ratio	Temp. Change	Runoff Change
CCCM	0.95	2.0	-2
UKMO	1.15	2.6	-12
GFDL	1.25	2.3	7

Table 3.3. Percent change in Angat water reservoir runoff based on incremental changes in precipitation (P) and temperature (T) (Jose & Cruz, 1999)

	P0	P10	P20	P-10	P-20
TO	0	8	18	-15	-25
T2	-1	8	17	-15	-26
T4	-1	7	17	-16	-26

Table 3.4. Percent change in Lake Lanao water reservoir runoff based on incremental changes in precipitation (P) and temperature (T) (Jose & Cruz, 1999)

	P0	P10	P20	P-10	P-20
TO	0	-1	4	-2	-17
T2	-2	-1	3	-2	-18
T4	-1	-2	1	-3	-19

An assessment of probable impacts of El Niño and La Niña on the water budget of the Angat, Bayongan, Mananga, and Manupali watersheds shows the following results: (i) El Niño is likely associated with a marked decrease in rainfall in some watersheds while in other watersheds, rainfall can remain unaffected depending on the duration and intensity of El Niño; (ii) in some watersheds, rainfall increases during La Niña while in other watersheds, no change in rainfall was observed; (iii) there are watersheds where total rainfall may not change due to El Niño or La Niña but changes in the variability or distribution of rainfall may take place and can have equally damaging if not more damaging impacts than changes in total amount of rainfall; (iv) runoff generally decreases during the El Niño years while runoff can either increase or decrease during the La Niña years; (v) runoff efficiency either increases or decreases during the El Niño and the La Niña years; and (vi) most impacts of El Niño and La Niña on various hydrologic processes are nonlinear requiring the integration of influences of other factors that affect the different hydrologic processes (Cruz et al., 2003).

The provinces most at risk to projected rainfall changes are Central, South and Southeast Luzon, and Eastern Visayas including Albay, Pampanga, Ifugao, Rizal, Cavite, Sorsogon, Laguna, Biliran, Batangas, Pangasinan, Masbate, Metro Manila, Tarlac, Nueva Ecija, Northern Samar, Aklan, Capiz, La Union, Western Samar, and Romblon (Manila Observatory, 2005).

3.4.1.2 Temperature Impact on Evapotranspiration

An increase in mean temperature of 0.6°C (the present condition) up to 2.2°C by the end of the century for the A1B scenario while an increase of 0.6°C in present condition to 3.0°C in the 2080s in the A2 scenario are estimated using the hydrologic BROOK90 model based on two scenarios (A1B and A2) from CGCM3 experiment (Combalicer et al., 2010). This will increase the evapotranspiration rate which is estimated to be at 5mm per day. The Moisture Availability Index (MAI) is the ratio of monthly rainfall to monthly evapotranspiration. The months with MAI of less than 1.0 are considered as dry months. The severity of drought is inferred from the length of months with MAI of less than 1.0.

3.4.1.3 Extreme Conditions: Tropical Cyclones and Monsoons

Tropical cyclones can contribute significantly to monthly and seasonal rainfall totals in the Philippines (Lyon & Camargo, 2009). An investigation of the possible impact of greenhouse global warming on the characteristics of TCs reveals a possible substantial general reduction of TC frequency when the atmospheric CO2 concentration is doubled and quadrupled. The weaker TC activity in the WNP seems to be associated with reduced convective instabilities. Despite the generally reduced TC activity, there is evidence of increased rainfall associated with the simulated TCs. The action of the TCs remain well confined to the tropical region and the peak of TC remains equatorward of 20° latitude in both hemispheres, notwithstanding the overall warming of the tropical upper ocean and the expansion poleward of warm SSTs (Gualdi, Scoccimarro, & Navarra, 2008). Trends in the average location where TCs form in the west Pacific reveal an increase in latitude and decrease in longitude for the last 20 years (David et al., 2013). In areas where rainfall could be intense during wet season, flooding events pose danger to human settlements and infrastructure in terms of landslides and mudslides (PAGASA, 2011). Bagtasa (2017) suggests an increasing trend in rainfall contribution by as much as 19% from TCs particularly for Luzon.

3.4.2 Non-climate drivers

3.4.2.1 Demand for Water

From 1988 to 2000, the agricultural sector has the highest demand for water resources in the country ranging from around 75 to 82% of the country's total water demand (National Statistical Coordination Board [NSCB], 2004). This is followed by domestic demand which constituted 12 to 17% of the total water demand and the industrial sector which recorded about 6 to 9% of the country's total water demand within the same period. Comparative trend analysis across the three sectors indicates that both the domestic and industrial sectors have increasing water demand while that of agriculture is declining through time (Pulhin, Ibabao, Rola, & Cruz, 2017). By the year 2016, the proportion of agricultural demand has significantly declined to 69.10% while that of industrial demand increased tremendously to 25.61%, reflective of the increasing rate of industrialization in the country.

The 2003 Philippine Environmental Monitor on water quality indicates that water demands in all three sectors will significantly increase by the year 2025 in both scenarios of low and high economic growth even not considering the potential impact of climate change (Ancheta et al., 2003). Even assuming a low scenario economic development, only 32% of the anticipated demand by 2025 will be met by the groundwater recharge.

It is estimated that under the full range of SRES scenarios, 185 to 981 million people in Southeast Asia will experience increased water stress by the 2020s and 2050s, respectively (Arnell, 2004 as cited in Cruz et al., 2007). David, Cayton, Lorenzo, and Santos (2014) studied the impacts of water scarcity and increasing demand and concluded that the cost of water will increase due to the combined effects of climate and non-climate drivers.

3.4.2.2 Major Anthropogenic Drivers

A confluence of anthropogenic factors is likely to shape the water demand and supply and hence the sustainability of water resources in the country. Among these are demographic factors, urbanization and increasing economic activities, and land use change (Pulhin et al., 2017). Demographic processes particularly population growth and migration create some of the greatest pressures on water resources quantity and quality. Based on the latest 2010 Census-based population projections, the Philippine population is projected to increase to 142 million by the year 2045 (Philippine Statistics Authority [PSA], 2016). With an addition of 50 million people in a span of only 35 years, a significant increase in the demand for the country's water resources can be anticipated which will pose a major challenge in meeting the water requirements of the households and the other sectors.

Urbanization is also expected to create pressure in the water sector. From 2007 to 2010, the urban population in the Philippines has increased from 35.5 to 41.8 million, respectively, or around 3% within the 3-year period. Considering the 45.3% level of urbanization in the Philippines as of 2010 and the anticipated additional 50 million population by 2045 (about 50% of which are likely to live in urban areas), this will put tremendous pressure on urban infrastructure including the need to establish more water system facilities to meet the increasing water demand of industries and urban population. Urbanization can also affect water quality with more population possibly putting human wastes into water systems (Boberg, 2005).

Land use changes, particularly the conversion of forest lands into other uses in many watersheds in the country, will likewise have adverse implications in the country's water resources. For instance, between 1988 and 2010, a total loss of 348,780 ha of forest cover or an annual loss of 15,854 ha in 22 years was observed in the 18 major river basins of the country (Pulhin et al., 2017). As of 2010, barely 25% of the total area of these basins is covered with forest vegetation. Continuous land use conversion to non-forest uses and the persistent degradation of the watersheds will have major negative impacts on the sustainability of water resources.

3.5 KEY FUTURE IMPACTS AND VULNERABILITY

3.5.1 Surface Water

Latest available data from the National Water Resources Board (NWRB) indicates that in 2016, the total amount of surface water available (125,790 mcm) has reached the negative at the national level, since the demand has surpassed the supply. Five of the twelve water resources regions have negative supply and hence cannot adequately meet the requirements of the major surface water users such as the irrigation, industry, and power sectors. Considering that the quality of water in many rivers and lakes are degenerating due to pollution and sedimentation, meeting future demand for surface water will be a major challenge even discounting the potential impacts of climate change.

A study of the Tigum-Aganan Watershed shows that water supply is vulnerable to variability in river flows. Consequently, potential implications of changed rainfall patterns for water supply include lower flows resulting in water shortages due to the inability to store excess water for use in the dry season. In addition, intense rainfall events may not recharge groundwater at the rate experienced when rainfall is spread more evenly across the season. Finally, lower than average rainfall during the dry season may also affect soil porosity and vegetation condition leading to reduced infiltration rates and groundwater recharge (Miller et al., 2009).

3.5.2 Groundwater

Based on the 2016 data from NWRB, the amount of groundwater granted to the domestic, agriculture, industrial, and power sectors is about 19% of total groundwater potential, however, much of these resources are in undeveloped regions such as in Central Mindanao. Furthermore, the 2003 Philippine Environmental Monitor published by the World Bank reported the absence of water-right permits in about 60% of the groundwater extraction resulting in indiscriminate withdrawal (Ancheta et al., 2003). With much of the groundwater extraction unrecorded, there is uncertainty as to whether future demands can be satisfied with the advent of climate change.

Large-scale land development projects such as mining and widespread land conversion may pose a substantial potential to aggravate the hazards posed by El Niño-induced drought through their disruption of groundwater resources (Holden, 2013). Overall, any development that will reduce the infiltration rate of rainfall will affect the water table of aquifers.

3.5.3 Floods

Municipalities in the Pasig-Marikina River basin (namely Manila, Mandaluyong, and Marikina) and CAMANAVA areas (namely Malabon and Navotas) are likely to be at high risk from flooding due to extreme events in 2050. For a 1-in-100 year flood in 2050, under the A1FI and existing infrastructure scenario, more than 2.5 million people will be affected in such high population density areas such as Manila, Quezon City, Pasig City, Marikina City, San Juan, and Mandaluyong City. More roads (around 158.9 km) will be flooded by inundation depths of 8 to 50 cm (Muto, Muroshita & Syson, 2010). Moreover, damage cost estimates of floods of three different intensities (1/10, 1/30, and 1/100) show flood-related costs ranging from PhP 5 billion (USD 109 million)—in a scenario where this is a 1-in-10 year flood master plan infrastructure is in place, and there is no climate change—to PhP 112 billion (USD 2.5 billion) in a scenario where planned infrastructure is not in place and climate change contributes to a 1-in-100 year flood (Muto et al., 2010).

3.5.4 Erosion and Sediment Transport

Increased sedimentation within the rivers is likely to be exacerbated due to changes in rainfall patterns. Dry conditions can affect the capacity of vegetation to hold soil, or the bearing capacity of soil. Often, normal as well as intense bursts of rainfall can mobilize and transfer sediments into rivers (Miller et al., 2009).

Most of the 18 major river basins in the country as shown in Table 3.5 have less than 20% forest cover largely due to conversion to agricultural areas (Cruz et al., 2015). It is likely that the increase in total rainfall and extremely excessive rainfall events could induce more surface soil erosion and increase siltation of rivers, lakes, and coastal and marine ecosystems. This will be particularly possible in river basins with low forest cover especially in deforested areas that were converted to agricultural areas and grasslands, and deforested areas with no vegetation cover.

Table 3.5. Land cover estimates for 18 major river basins in the Philippines (Cruz et al., 2015)

River Basin	Land Cover ('000 ha) 2010									
	Forest	Plant-ation	Culti-vation	Shrubs	Barren and Grass	Mang-rove	Marsh-land	Inland Water	TOTAL Area	% Forest
Abra	86	4	30	197	45	0	0	9	371	23
Abulog	216	0	78	120	10	3	0	7	433	50
Agno	110	6	290	169	83	0	0	27	685	16
Agus	75	0	22	9	2	0	0	33	141	53
Agusan	478	0	422	337	35	2	45	17	1,336	36
Bicol	29	0	226	18	16	2	0	8	299	10

Table 3.5. Continued

River Basin	Land Cover ('000 ha) 2010									
	Forest	Plant-ation	Culti-vation	Shrubs	Barren and Grass	Mang-rove	Marsh-land	Inland Water	TOTAL Area	% Forest
Buayan-Malungan	8	0	67	60	10	0	0	2	146	5
Cagayan De Oro	43	0	61	34	9	0	0	1	148	29
Cagayan	1,320	16	961	640	299	3	1	44	3,286	40
Davao	28	0	33	76	13	0	0	2	151	18
Ilog Hilabangan	3	0	95	101	4	1	0	2	206	2
Jalaur	6	6	155	77	11	1	0	11	266	2
Mindanao	243	0	1,096	489	105	1	78	25	2,037	12
Pampanga	169	0	585	158	133	0	1	71	1,118	15
Panay	7	5	148	59	13	2	0	24	257	3
Pasig-Laguna	24	0	92	89	114	0	0	99	418	6
Tagaloan	45	0	52	37	29	0	0	1	164	28
Tagum-Libuganon	25	0	80	44	5	0	0	4	158	16

3.6 SOCIAL IMPLICATIONS

3.6.1 Cost of Changes in Water Balance and Quality

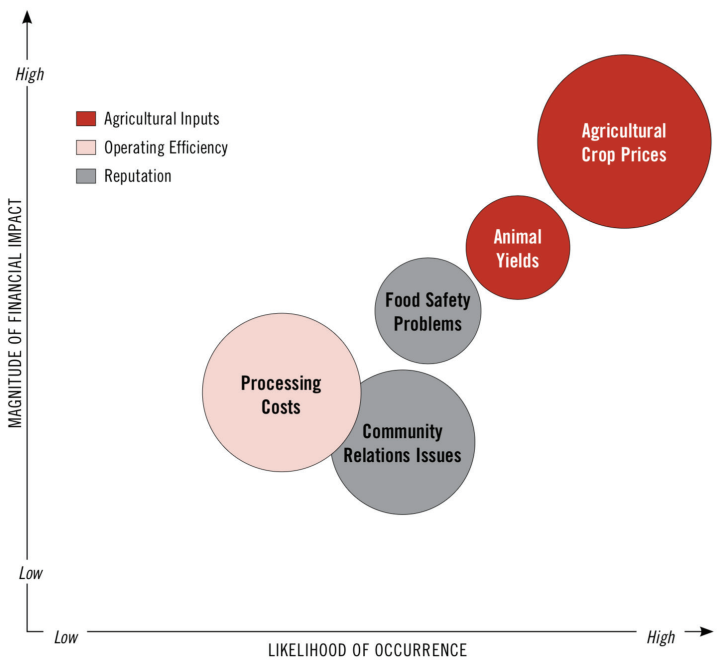

Figure 3.2 Likelihood and magnitude of the impacts of climate change and water scarcity on the F&B sector in South and Southeast Asia (Krechowicz et al., 2010)

Among the key findings on the potential financial impacts arising from climate change and water scarcity on Asia's food and beverage sector include (i) increased agricultural input prices and increased processing costs; (ii) rise in agricultural commodity prices and increased price volatility due to decreasing yields; (iii) increased processing costs through operational disruptions and treatment costs; and (v) food safety and stakeholder challenges (Figure 3.2) (Krechowicz, Venugopal, Sauer, Somani, & Pandey, 2010).

The main impact of climate change in water will be in terms of the increase in domestic water prices (NEDA, 2011). Obviously there will be many other factors in consideration of water pricing, however, the variability in rainfall in the future and its resulting effects on the replenishment of groundwater and sustaining the discharge in streams will have a marked impact (David et al., 2014).

In terms of irrigation water supply, most areas are projected to receive an increase in rainfall in the future. However, stream discharge modeling shows that while the overall volume available for irrigation will increase, the prolonged drought periods during the summer months will have an effect in meeting the demand for irrigation during this cropping season. Besides, the increase in rainfall will mainly be during the rainy season wherein farms are not needed to be irrigated anyway (Food and Agriculture Organization [FAO], 2014).

3.6.2 Cost of Damages Due to Floods and Droughts

Flood disasters result in substantial economic losses in the country. Data from 1980 to 2015 reveal that floods alone have affected more than 20 billion people and caused direct physical losses estimated at more than USD 3 billion (Guha-Sapir et al., n.d.). Table 3.6 shows the total population affected and amount of direct physical losses by floods in selected years in 1980 to 2015.

The Philippines experienced severe drought conditions associated with El Niño events during 1982 to 1983, 1990 to 1992, 1997 to 1998, 2005 to 2006 and 2009 to 2010 (Holden, 2013). The 1991 to 1992 El Niño-related drought events, in particular, caused agricultural production damages at various regions amounting to more than PhP 4 billion (Table 3.7) (Jose et al., 1999). It can be noted that four of the top five regions that sustained the greatest damage from El Niño are from Mindanao. Likewise it is observed that most of the agricultural areas affected by El Niño are planted to rice and corn. It is likely that the damages to rice and corn production areas were caused by the inadequate capacity of existing irrigation facilities to supply water under extremely limited rainfall condition.

Table 3.6. Total population affected and physical losses from floods from 1980 to 2015 (Guha-Sapir et al., n.d.)

Year	Total Population Affected [a]	Total Losses (USD million) [a]
1980	25,980	No data
1981	122	No data
1982	853	60
1985	444	No data
1989	47,500	No data
1990	50,236	43
1991	823	1,300
1993	24,485	37,000
1994	37,583	2,492
1995	72,185	700,800
1997	No data	76
1999	105,000	24,000
2000	2,103,716	4,080
2001	165,643	8,000
2002	91,300	1,842
2003	155,567	No data
2004	3,500	No data
2005	21,694	515
2006	192,946	14,157
2007	717,509	6,600
2007	86,747	39,577
2008	1,602,889	29,314
2009	1,083,276	50,589
2010	2,846,935	202,787
2011	2,218,828	75,330
2012	4,614,628	2,231,988
2013	4,500,338	No data
2014	102,955	No data
2015	880	No data

Table 3.7. Summary of agricultural production damages at various regions caused by the 1991 to 1992 El Niño-related drought event (Jose et al., 1999)

Area Affected (ha)							Estimated Damages (Php)
Region	**Rice**	**Corn**	**Vegetables**	**Fruit Trees**	**Other Crops**	**Total**	
1	2,851	679	527			4,057	34,362,920
2	2,285	6,950				9,235	92,589,760
CAR	429	4,049	262	132		4,872	45,059,033
5	4,099	456	43			4,598	30,609,764
6	70,990	454	368		28	71,840	856,743,835
7	35	187	87	1,767		2,076	5,426,660
8	7,591	1,177	1,353	38	28	10,187	86,298,944
9	7,974	8,689	2,564			19,227	227,601,981
10	2,387	28,552	1,381	13,640	130	46,090	232,649,997
11	21,156	56,589	1,265	90,987	1,684	171,681	1,304,986,686
12	38,263	74,763	2,390	1,320	1,183	117,919	1,178,603,224
Grand Total	158,058	182,543	10,240	107,884	3,053	461,782	4,094,932,804

3.7 ADAPTATION

3.7.1 Adaptation Options in Principle

According to the National Strategy Framework on Climate Change (NFSCC), the success of the country's adaptation efforts could depend on how the country's water resources are governed and managed (Climate Change Commission [CCC], 2010). Appropriate mechanisms could be established to protect and enhance the integrity of water resources towards environmental flows for biodiversity, agriculture, energy, and consumption of settlements and industries to reduce water sector vulnerability to climate change through participative water governance, resource management, and sectorial policy reform. To achieve this, strategic priorities could include (i) reducing climate change vulnerability of water resources through improved water governance and resource management mechanisms (David et al., 2014); (ii) mainstreaming climate change adaptation in water resources policies and development planning (NEDA, 2011); (iii) promoting waste sector reforms that will address the weak and fragmented institutional and regulatory framework; (iv) study, design, and implement innovative financing and incentive systems to stimulate water sector climate change adaptation investments and encourage community participation in water resources management; (v) climate-proof water-related infrastructures such as dams and impoundments for domestic water supply, irrigation, and energy generation; (vi) test and adopt "low cost, low regrets" water sector climate change adaptation technologies; (vii) enhance institutional and community capacity for Integrated Water Resources Management (IWRM); and (viii) establish science-based water resources information, climate projections, climate change impacts on major water resources and infrastructure, and adaptation technologies at scales relevant to communities, decision makers, and water resource managers (NEDA, 2012; CCC, 2010). The Philippines' Initial National Communication provides examples of adaptation measures such as (i) comprehensive watershed management and (ii) water allocation system and procedures for supply adaptation and (iii) enhancement of irrigation efficiency; (iv) introduction of low water use crops and efficient farming practices; (v) recycling (reuse) of water; (vi) improvement of monitoring and forecasting systems for floods and droughts; (vii) use of water pricing policies and structures; and (viii) promoting awareness of climate variability and change for demand adaptation (Government of the Philippines, 1999). Figure 3.3 describes the local to national linkages in managing climate risk in normal and abnormal years.

Other studies suggest adaptation options in the water sector. A study developed a system to generate future water allocation scenarios using inflow probabilistic forecasts in the NWRB reservoir model. This tool offers the opportunity of advanced climate information to anticipate and manage reservoir releases in a proactive manner in the Angat reservoir thereby reducing potential impacts of variability (Someshwar, Conrad, & Bhatt, 2009). A Manila case study examined adaptation options that could reduce the impact of 1-in-30 and 1-in-100 year floods including improving current practices, capacity building, and better coordination among local government and national flood management agencies, and structural measures such as dam construction, raising dikes, and improved pumping capacity that would reduce the impacts of floods. Results show that controlling flooding in the Pasig-Marikina River areas require construction of the Marikina dam (the economically viable option emerging in both scenarios), and building embankments and storm surge barriers (Muto et al., 2010). In addition, cost-effective options that could be considered include rational water management, planning to avoid mismatch between water supply and demand through policies and upgrading/rehabilitation of dams, changes in cropping patterns in agricultural areas, establishing rain water collection facilities, and early warning systems (PAGASA, 2011).

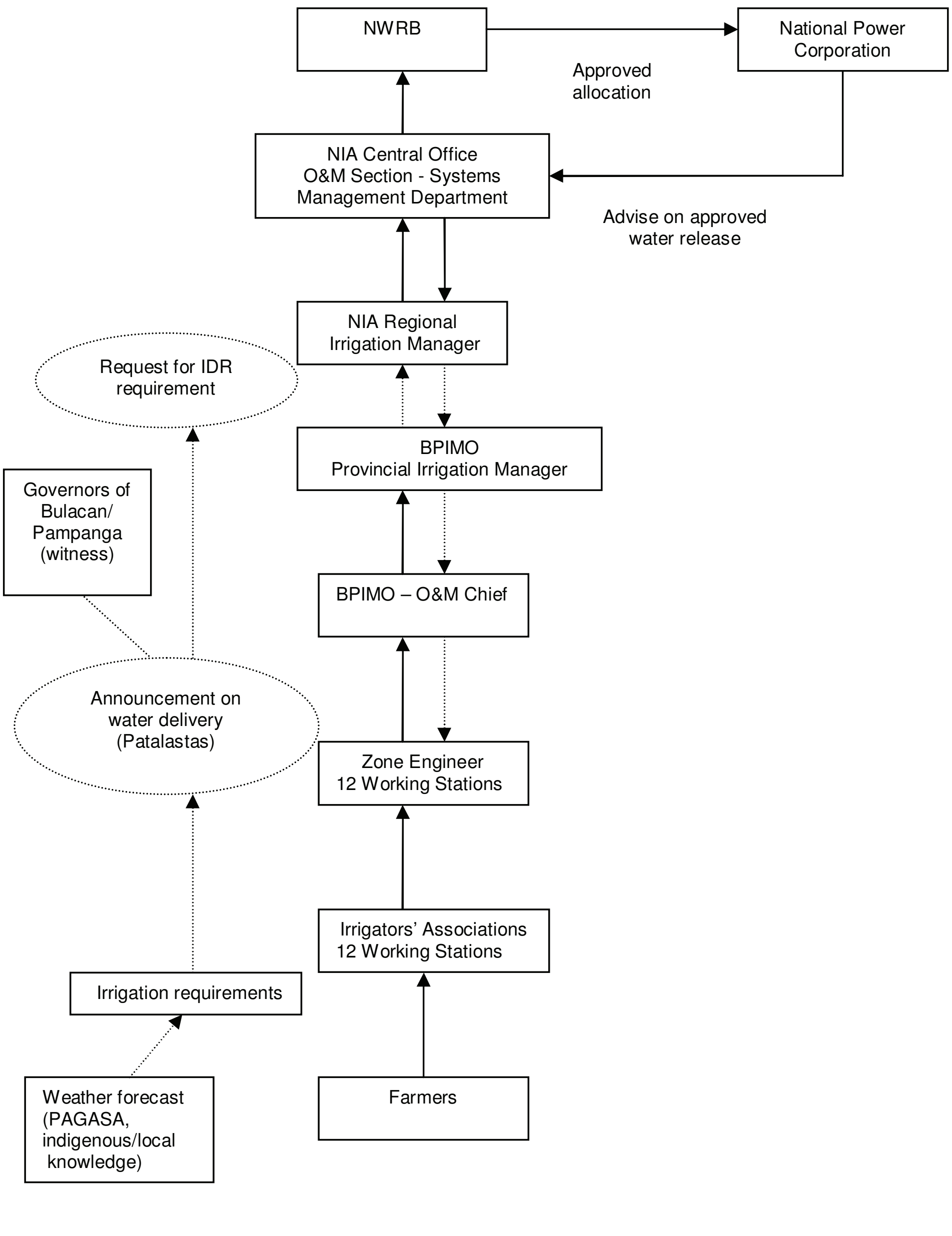

Figure 3.3 National-local linkage for climate-related concerns in normal and abnormal years (Rola & Elazegui, 2008)

Finally, water supply and demand management could be undertaken (Government of the Philippines, 2014). In terms of water supply management, potential water resources availability could be maximized through:

1. Improved watershed management including the adoption of integrated watershed and ecosystem management to promote greater synchronization of upstream and downstream development to minimize inefficiency and maximize the use of water and other natural resources;

2. Development of capacity to capture excess water during the wet season in order to have enough water stored for use during the lean months. A good example of this is building small water impounding project (SWIP) for irrigation purpose; and

3. Practice of water augmentation and water harvesting techniques including:

    - Rain harvesting;
    - Surface runoff collection and storage;
    - Water recycling;
    - Streamflow diversion; and
    - Ponding.

On the other hand, water demand management could be implemented with the objective of maximizing the use of water and minimizing the wastes of water through:

1. Practice of soil and water conservation techniques such as contour farming, mulching and terracing, hedgerows planting, and zero tillage;

2. Regular maintenance of irrigation facilities particularly, distribution canals to reduce water losses during transmission and distribution; and

3. Cultivation of less water-intensive crops.

3.7.2 Adaptation Options in Practice

Adaptation measures undertaken by water dependent institutions and communities are briefly discussed in this section. For the MWSS, short-term adaptation measures include: (i) water rationing through MWSS tankers to areas which have been affected due to low water pressure and intermittent or no water supply; (ii) rotation basis of water supply distribution and distribution effectiveness; (iii) water conservation through people's participation by reporting leaks, illegal connection, and voluntary consumers' reduction of water consumption; (iv) increased supply of water by artificial rainmaking operation of La Mesa reservoir at low level and maximized operation of existing wells; and (v) reduction of water waste and losses through repairs of leaks and incentives given for leak reports. For long term measures, the MWSS has been (i) tapping new water sources, (ii) expanding water supply facilities, (iii) augmenting or expanding distribution system, (iv) optimizing existing water supply system, and (v) reducing non-revenue water (Cruz, 2002).

The adaptation strategies of the National Irrigation Administration (NIA) to minimize the negative impacts of climate variability and extremes include: (i) reforestation; (ii) campaign on forest protection; (iii) physical rehabilitation; and (iv) release of excess water from the reservoir/dam especially in rainy season when the water level in the reservoir reaches the threshold to avoid flooding (Lasco, Cruz, Pulhin, & Pulhin, 2006). The NIA has been implementing the following adaptation strategies particularly during drier than normal conditions: (i) reduction of programmed area of irrigation; (ii) adjusting cropping calendar and farming activities; (iii) encouraging farmers to plant crops that require less irrigation; (iv) rotational scheme of irrigation and water distribution; (v) optimum utilization of rainfall and interim flows; (vi) improvement of irrigation systems to minimize water losses; and (vii) conjunctive use of shallow wells. For its long-term plans, NIA is planning to construct a new reservoir to utilize the Bayabas creek (Cruz, 2002).

For the NPC, the adaptation strategies are: (i) reforestation; (ii) information, education and communication; (iii) proper choice of species; and (iv) adjustment in schedule and implementation (Lasco et al., 2006). Specifically, some of their short-term plans include: (i) increased power generation contribution from non-hydro power plants; (ii) curtailment of power supply to customers during electricity supply deficiency through manual load shedding (brownout); (iii) voluntary load curtailment by affected industrial customers; and (iv) deferment of hydro-power plants maintenance work to compensate the decrease in hydro-electric capacity. Since it is expected that power requirement will significantly increase in the future, some of the long-term plans are the following: (i) construction of additional non-hydro plants like geothermal; (ii) utilization of new and renewable energy sources like solar, biomass, wind and tidal; and (iii) demand-side management programs (Cruz, 2002). In addition, the NPC and NWRB assess the potential impacts on water resources through reservoir operation simulations after receiving climate forecasts from PAGASA. These simulations determine the projected available water in reservoirs and serve as basis for water releases or allocation to various users (Dolcemascolo et al., 2002).

For communities, adaptation actions such as those being practiced in the Pantabangan-Carranglan Watershed are shown in Table 3.8. The cross-sectoral impacts of these actions, which are analyzed in Table 3.9, show higher investment costs and expenses for institutions to achieve positive impacts. In addition, adaptation to disasters related to extreme weather events are identified as: (i) community-based early-warning system, involving the gathering of data, interpretation of results and dissemination of forecasts and warnings to solicit appropriate response from the affected populace; (ii) sharing of best practices on being proactive in mitigating the ill-effects of disasters occurs together with intensive information and education campaigns focused on natural hazards and risks; (iii) capacity building for local government units (LGUs) through training, emphasizing the need for their communities to assume ownership of their disaster risk management programs; (iv) improved land-use planning and corresponding appropriate policies; and (v) public-private partnership through livelihood programs, housing projects, and disaster education (Lasco et al., 2006).

Table 3.8. Adaptation options to climate variability and extremes for water resources in the Pantabangan-Carranglan Watershed, Philippines (Lasco et al., 2006)

Climate Variability	Adaptation Options
General	Sloping Agricultural Land Technology (SALT) method of upland farming Implementation, intensification of reforestation program Strict implementation of forest laws Programs and research on ground water for households More funds from the national and local government Potable water is needed (more deep wells in each village) Construction of small water impounding project (SWIP) Cloud seeding Introduction of water conservation measures (SWIP, small water impounding structure, shallow tube wells) Stabilization of watershed
Water Shortage	Use of shallow tube wells Planting of new varieties of rice (i.e., Gloria rice) and other crops with less water requirements Rotation method/scheduling of irrigation Planting early maturing varieties of crops and vegetables Use of direct seeding method, which requires less water Use of other water sources (i.e., from the Atate River and Penaranda River, which are connected directly to the irrigation main canal)
Floods	None (wait for the next cropping season to cope) Repair the damages Close the main canal if possible Switch to other crops that can sustain floods and heavy rainfall Explore other livelihoods (swine production, squash, and saluyot farming, canton [noodle] making and fruit juice making) through Farmers' Business Resource Cooperative Construct fish ponds in flooded areas

Table 3.8. Continued

Floods	Switch to early maturing varieties of crops (i.e., from palay to corn) Attend seminars and trainings conducted by stakeholders about crop production

Table 3.9. Analytical matrix of cross-sectoral impacts in Pantabangan-Carranglan Watershed (Lasco, Cruz, Pulhin & Pulhin, 2011)

Adaptation Strategy for Water Resources	Effect on Forest Resources/ Agriculture	Effect on Institutions	Effect on Local Communities
Reforestation/ Agroforestry farming	+ Greater tree cover	– Higher investment cost	+ More income
Soil and water conservation measures	+ Increased yield	– Higher investment cost	+ More income
Water impoundment	+ Increased yield	– Greater expenses	+ More income – Greater expenses
Well construction	+ Increased yield	– Greater expenses	+ More income – Greater expenses
Cloud seeding	+ Increased yield	– Greater expenses	+ More income
Use of appropriate crops/varieties	+ Increased yield	– Greater expenses for research and development (R&D); technical assistance (TA); information, education and communication (IEC)	+ More income
Irrigation management	+ Increased yield	– Greater expenses for Implementation	+ Increased income
Tap other water sources (e.g., rivers)	+ Increased yield	– Greater expenses	+ Increased income
Fishponds in flooded areas	+Decreased pressure on forests and agricultural resources	– Additional expenses for TA	+ Increased income – Greater expenses
Repair of damaged infrastructure	0	– Greater expenses	0
Shift in livelihood	+ Less use of land	– Additional expenses for TA, training	+ Increased income
Strict implementation of forest laws	– Could affect crop production in areas deemed for forest	+ Strengthen role of regulatory agencies	+/– Promote peace but possibly lower income
Research on ground water	0	– Greater expenses for R&D, TA, IEC	0
Capacity building activities	+ Build up of mass of competent players	– Greater expenses for R&D, TA, IEC	+ Build up of mass of competent players

Legend: (+) positive impact; (–) negative impact; (0) no effect

3.7.3 Constraints to Adaptation and Adaptive Capacity

Challenges exist in the application and integration of advance climate information in the process of strategic planning for water resources development and management (Espinueva, 2002, as cited in Dolcemascolo et al., 2002). Cost is also a major constraint to the implementation of adaptation strategies since it will entail spending on, for example, the construction of a water-impounding structure (Lasco et al., 2006). Adaptation in the water sector could be enhanced through: (i) building the capacity of all sectors, (ii) providing funds for climate change programs, (iii) creation of a single body that will coordinate climate change activities, (iv) presence of a strong political will, (v) uplifting the socio-economic conditions of the poor, (v) presence of strong commitment of all sectors, and (vi) coordination among institutions concerned with water resources (Asia-Pacific Network for Global Change Research [APN], 2007).

One of the key constraints to effective adaptation in water resources sector is the absence of comprehensive adaptation plans that are integrated with the development plans of important watersheds and river basins and with local and national development plans. As shown in the previous section, many of the adaptation efforts of government agencies with water-related functions, including those initiated by LGUs, are not framed within a comprehensive adaptation plan and are mostly independent from other ongoing development programs. The current initiative of River Basin Control Office (RBCO) of DENR to develop climate responsive master development plans for the 18 major river basins in compliance with the provisions of the Climate Change Act of 2009 (Republic Act [RA] No. 9729) or the Disaster Risk Reduction and Management Law of 2010 (RA 10121) could facilitate integration of various adaptation efforts in the water sector. The climate responsive river basin plans could also provide the framework for the integration of adaptation and development programs of various water concerned government agencies along with the development plans of LGUs.

3.8 UNCERTAINTIES AND KEY RESEARCHABLE AREAS

In the strategic priority on water sufficiency, the national climate change action plan (NCCAP) identifies the following research needs (CCC, 2013):

1. Technology development for potable water production (e.g., desalination techniques, raw water treatment), and system for recycling.
2. Development of long-term observational systems for measuring and predicting hydrologic changes and planning management responses.
3. Improvement of network design for hydrologic data collection, monitoring the effects of climate change on stream flow behavior and methods of hydrologic analysis for water infrastructure projects. The more representative points available, the better the numerical estimation becomes.
4. Evaluation of water resources considering climate change, variability, and extremes (CCVE) issues.
5. Identification and assessment of coastal and inland wetlands.
6. Assessment of the potential of land, freshwater, and ocean ecosystems to increase net uptake of CO2 (and other greenhouse gases) and develop approaches that could take advantage of this potential without major adverse consequences.
7. Improvement of projections of changes in rainfall and other water resources at regional and seasonal time scales.
8. Improvement of tools and approaches for decision-making under uncertainty and complexity.
9. Development of vulnerability assessments of the diverse range of water users and integrative management approaches to respond effectively to changes in water resources.
10. Increase in understanding of water institutions and governance and design effective systems for the future.

11. Improvement of water engineering and technologies.

12. Evaluation of effects, feedbacks and mitigation options of water resource use on climate.

Moreover, specific research-related priorities are identified as: (i) impacts of extreme weather events such as floods, (ii) adaptation concerning water resources management, and (iii) sectorial interaction between water resource and hydropower (Cruz et al., 2007). Also, (i) modeling climate change impacts on water supply for domestic, power, and irrigation needs; (ii) identifying most vulnerable river basins; and (iii) assessing adaptation strategies focusing on water infrastructure, flooding, drought, and increasing water use efficiency are needed (NEDA, 2011; Lasco, 2012). Similarly, the use of hydrologic models that have the ability to assess the combined impacts of climate, land use, and vegetation cover types on the hydrological processes in the watershed could be explored (Cruz et al., 2003). To ensure the continuous and sufficient supply of water, a close coordination between PAGASA and authorities managing water resource projects would need to be established. The research needs for efficient operation of dams/reservoirs include: (i) quantitative rainfall forecasts within the catchment/drainage areas of dams; (ii) localized flood forecasts with a map showing the level and extent of inundation; (iii) upgrading/strengthening of flood forecasting systems for dam operation; (iv) improvement/construction of flood control structure downstream of dams. For simulation of water allocations of reservoirs, data on rainfall, evapotranspiration, inflow/outflow, and wind speed/direction, cloud seeding activities are needed. Finally, historical rainfall data (daily and monthly) and installation of more automatic weather stations would be necessary for water availability assessment (World Bank, UNISDR, National Hydrological and Meteorological Services [NHMS], & World Meteorological Organization [WMO], n.d.).

Overall, the following research gaps on freshwater resources were identified by Jiménez Cisneros et al. (2014):

- Assessment capacity is limited in general because time-series data on rainfall, river discharge, soil moisture, groundwater depth, water quality, rates of surface water, groundwater withdrawal by each sector, and information on already-implemented adaptations for stabilizing water supply are lacking in most watersheds

- Investigation on the partitioning of rainfall into evapotranspiration and runoff

- Relatively little is known about the economic aspects of climate-change impacts and adaptation options related to water resources

- More computing capacity is needed to improve spatial resolution and accuracy of methods for downscaling their outputs

- More research into novel ways of combining different approaches to projection of plausible changes in relevant climate variables

- Establishment of a proper baseline to isolate the effects derived from climate change from those anthropogenic causes

- Coupling of hydrological models, and the land-surface components of climate models, to data on water-management activities such as reservoir operations, irrigation, and urban withdrawals from surface water or groundwater to understand interactions among socio-ecological systems

- Long-term monitoring and studies on the impacts of climate change on water quality and water budget, and on climate associated risks and vulnerabilities, and cost-effective adaptation

The DOST through the Philippine Council for Agricultural, Aquatic Resources Research and Development (PCAARRD) is supporting the National Research and Development Program for Watershed Management in the Philippines (INWARD) and the Program for Monitoring and Detection of Ecosystem Changes for Enhancing Resiliency and Adaptation (MODECERA). These programs are monitoring 14 watersheds in various parts of the country to establish time-series data on climate, streamflow, water quality, soil, biodiversity, land use, and other human activities to support science- and technology-based policies and management decisions in watersheds. Similarly, DOST-Philippine Council for Industry, Energy and Emerging Technologies Research and Development (PCIEERD) also provides valuable information through the establishment of hydrometeorological stations, high resolution maps and access to remotely sensed data.

The sustained investment of the government in long-term, site-specific monitoring is expected to address the dearth of empirical data that constrains effective management and adaptation initiatives.

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CHAPTER 4

Coastal Systems and Low-lying Areas

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4.1 EXECUTIVE SUMMARY

The Philippines is located at the western side of the Pacific. This makes the archipelago naturally exposed to tropical cyclones, storm surges, and the consequences of the El Niño Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO). Recent studies have also shown the Philippines to be amongst the countries to experience the highest magnitude of increase in ocean temperature and sea level rise (SLR). At the same time, the four major cities of the Philippines (i.e., Manila, Cebu, Davao, and Puerto Princesa) are all located in coastal areas. In addition, the majority of the country's over 100 million population also reside within 60 km of the coast. Likewise, Filipinos have one of the highest per capita fish consumption of 23 to 43 kg/year. Moreover, fisheries and fisheries-associated livelihoods are one of the main economic sectors of the Philippine society. This combined natural exposure and enhanced reliance on the coastal system makes the Philippines highly vulnerable to climate change.

Biodiversity dampens the overall vulnerability since the myriad of species having similar ecosystem functions allow for adaptation of the environment to slow changes. There would be a need to conserve and protect the different riverine, estuarine, and coastal habitats. Corollary to this, increased human utilization of the coastal zone, if mismanaged, could further exacerbate vulnerability. Human activities that lead to increased input of nutrients and pollutants, increased extraction of commodities such as fish and materials, and increased construction of coastal engineering structures could alter the natural buffering capacity of these biodiverse habitats. Coastal local government units (LGUs) could support by encouraging the conservation of foreshore areas of rivers, estuaries, and the coasts as natural buffer zones.

Further, there may be a need to re-assess the locations of our population and economic centers. Future scenarios have identified areas prone to high erosion, frequent flooding, salt intrusion, inundation, or submergence. In order to not suffer from undue economic setbacks and disruption of social amenities, plans would have to be made to re-build where exposure is less. Specifically, concrete plans have to be made to accommodate population in low-lying islands that are vulnerable to SLR and storm surges. Attention may also be given so as not to disrupt transportation of goods and services, especially in times of disaster. Seaports may have to be retrofitted to adapt to SLR while major airports may have to be relocated.

There are trade-offs in adaptation so decisions would need to take into account social and economic as well as ecological concerns. In order to take advantage of the opportunities to enhance the adaptive capacity of coastal communities through the Philippine local government code, there would be a need, therefore, for local capacity development.

Finally, it should be noted that much of the information contained herein come from global scenarios and a handful of local studies. This highlights the need to address information and research gaps. There are still uncertainties on the magnitude of local future scenarios and consequently, lack of quantitative predictions of local future coastal changes. There would be a need to develop predictive models based on multi-stressor observations and experiments in detailed levels of space and time. Assessments of valuation of coastal ecosystem services, as well as, adaptation costs and benefits are much needed. All these science-based data would then have to be communicated to decision-makers and institutions so that their role in the transition towards a climate-adapted archipelago may be identified and realized.

4.2 INTRODUCTION: SCOPE AND KEY ISSUES

Many coastal classification systems exist for differing purposes and covering various sections of the world's coastline. The Intergovernmental Panel on Climate Change (IPCC) considers coastal systems as the interacting low-lying areas and shallow coastal waters, including their human components. This includes adjoining coastal lowlands that have often developed through sedimentation during the Holocene (past 10,000 years) but excludes the continental shelf and ocean margins. The International Geosphere-Biosphere Programme/Land-Ocean in the Coastal Zone (IGBP/LOICZ) research, on the other hand, considers ocean and landward boundaries to define coastal typology. The ocean boundary is taken as the continental shelf edge, delineated by the 200 m isobath while the landward boundary is the 200 m elevation giving rise to large variations in the relative amount of terrestrial land mass to be studied in different regions (LOICZ, 1995). A combination of these two definitions is used here following the simplified physical delineation of LOICZ (1995) but including the human components as in the IPCC.

Coasts undergo continual adjustment through different 'states' in response to varying wave energy and sediment supply and altered conditions external to the system (Figure 4.1) (Nicholls et al., 2007). The vertical interactions (e.g., air pollution and climatic changes) and horizontal interactions (e.g., sediments and nutrients) can trigger changes in internal thresholds as well as external conditions (Talaue-McManus, 2001). This natural variability of coasts can make it difficult to identify the impacts of climate change.

Climate-related ocean-atmosphere oscillations can lead to coastal changes. Monsoons have the highest influence on the coastlines of the Philippines (Botin, David, del Rosario, & Parrot, 2010), exposing them to high seasonal waves and associated flooding. The northeast monsoon (from December to February) affects the north and eastern Philippines as well as the northeast oriented passages between islands. The western side is affected the most by the southwest monsoon (from June to September) (Figure 4.2) (Villanoy, Salamante, & Cabrera, 2013). Another prominent oscillation is the ENSO phenomenon, an interaction between pronounced temperature anomalies and sea-level pressure gradients in the equatorial Pacific Ocean, with an average periodicity of two to seven years. Together with monsoon winds, ENSO also affects the strength of upwelling in key fisheries areas of the Philippines like that off of Zamboanga and Bohol Sea (Cabrera, Villanoy, David, & Gordon, 2011; Villanoy et al., 2011). The Philippines is also impacted by tropical cyclones most commonly from July to November (Mcleod et al., 2010).

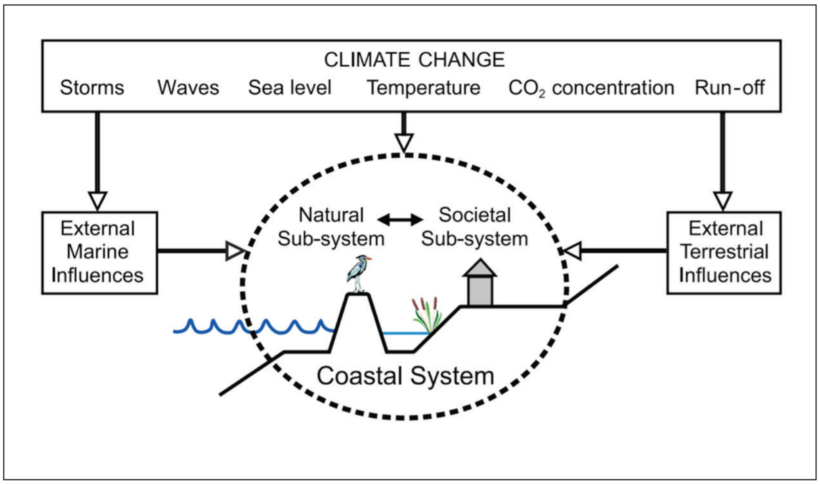

Figure 4.1. Climate change and the coastal system including external events that pose hazards and compromise natural functioning. Reprinted with permission: Figure 6.1 from Nicholls, R. J., P. P. Wong, V. R. Burkett, J. O. Codignotto, J. E. Hay, R. F. McLean, S. Ragoonaden & C. D. Woodroffe, 2007: Coastal systems and low-lying areas. Climate change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom.

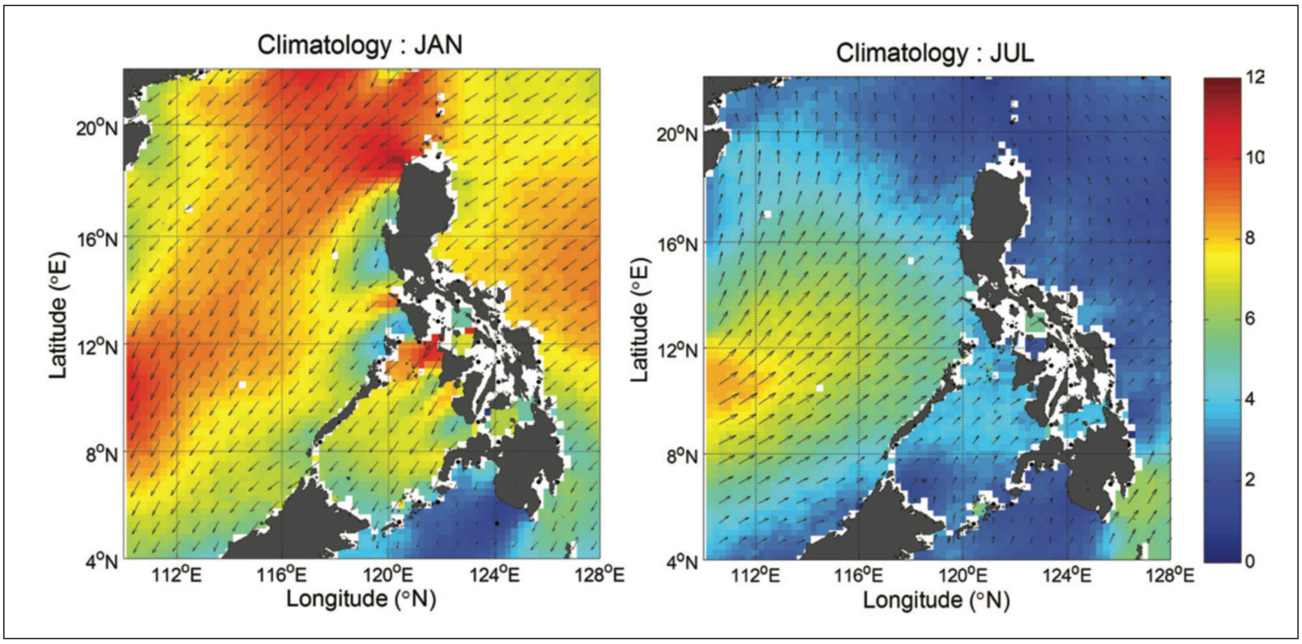

Figure 4.2. Typical monsoon wind patterns for the Philippines based on the 10-yr QUIKSCAT dataset (NE Monsoon on the left and SW Monsoon on the right). Colors denote speed (in m/s) while arrow length and angle denote magnitude and direction of wind vectors. (Villanoy et al., 2013)

Climate change hazards common to many islands of the Philippines are increasing temperatures and temperature anomalies, rising sea levels, and disturbed water budget. Temperature analysis of the Coral Triangle, using data from the National Oceanic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR), in 1985 to 2006 show a sea surface temperature (SST) increase of 0.2 to 0.4°C per decade (Figure 4.3) (Peñaflor, Skirving, Strong, Heron, & David, 2009). This is significant globally since the Coral Triangle is an area with the highest global coral ecosystem diversity with over 30% of the world's coral reefs, including 76% of the world's reef building corals and over 35% of the world's coral reef fish species. Located in the central Indo-Pacific, the Coral Triangle encompasses all or part of six countries including the Philippines, Indonesia, Malaysia, East Timor, Papua New Guinea, and the Solomon Islands. It is home to over 100 million people that depend on the coastal ecosystems of the Coral Triangle such as coral reefs, mangroves, and seagrass beds to provide food, building materials, coastal protection, support industries such as fishing and tourism, and many other benefits (Hoegh-Guldberg et al., 2009). Global sea level trends are equally most alarming with data from Topex-Poseidon, Jason-1, 2 from 1992 to 2014, showing highest increase for the Philippine side of the Pacific (Figure 4.4). As for water budgets, there is an observation of increasing number of tropical cyclones and increasing strength of storms being generated in the east side of the Philippines (Western Pacific) using data from 1945 to 2003 (Figure 4.5).

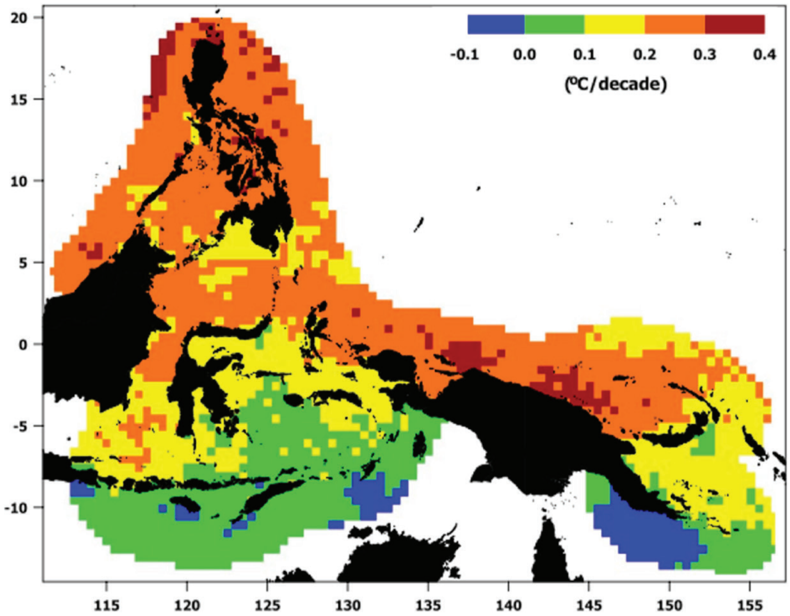

Figure 4.3. Sea surface temperature trends of the Coral Triangle based on the 21-year AVHRR dataset (Peñaflor et al., 2009)

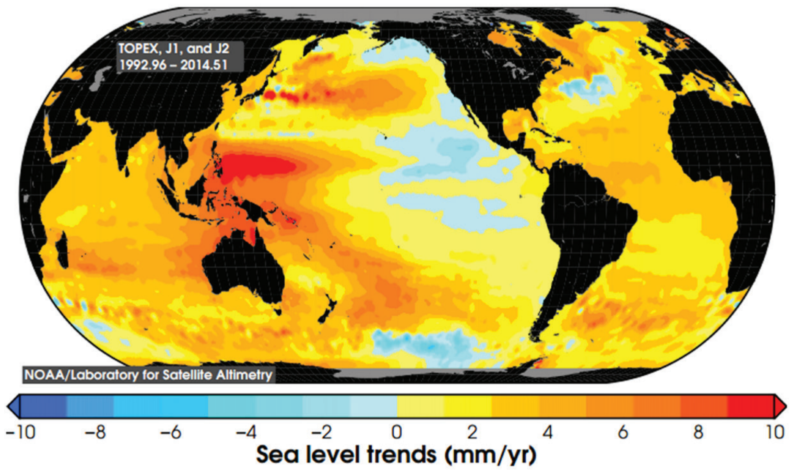

Figure 4.4. Global sea level trends based on the 22-yr Topex-Poseidon, Jason-1,2 data (NOAA National Environmental Satellite, Data, and Information Service, n.d.)

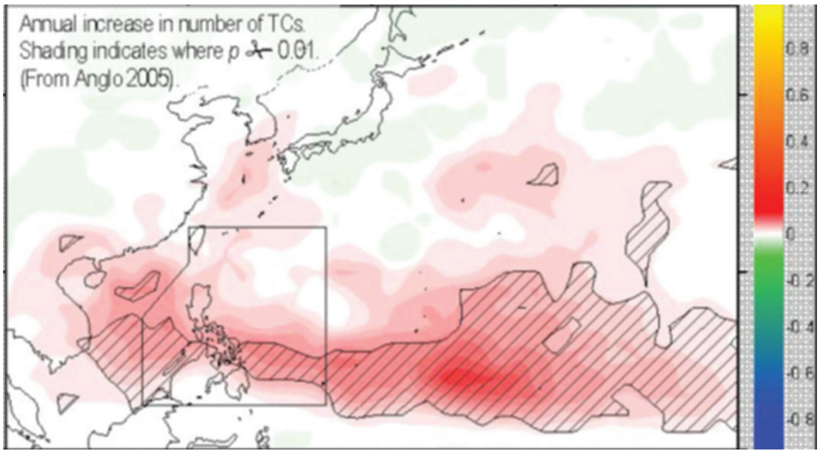

Figure 4.5. Analyzed increase in tropical cyclones in the Western Pacific as surmised from the tropical cyclone tracks data (from 1945 to 2003) of the Joint Typhoon Warning Center (Anglo, 2005)

4.3 CURRENT SENSITIVITY AND VULNERABILITY

4.3.1 Changes in the Behavior of Coastal Systems

4.3.1.1 Coastal Integrity

The vulnerability of the Philippine coasts to SLR is attributed to physical and socio-economic factors (Perez, Amadore, & Feir, 1999). In Manila Bay, the rapid increase from 1965 to 1982 of mean sea levels was primarily caused by the large withdrawal of groundwater (Emery & Aubrey, 1991 as cited in Yanagi & Akaki, 1994). This is because groundwater depletion can lead to local land subsidence. In Manila, sea level rose around 1.3 mm per year—similar to the global rate—until the early 1960s. After which it increased to about 2.6 cm per year, which is correlated with the increase in Metro Manila groundwater use until 1995 (Rodolfo & Siringan, 2006). In Cavite City, the significant increase in relative SLR of approximately 0.40 cm per year between 1963 and 1980 can be attributed to groundwater withdrawal resulting in land subsidence (Sales, 2009). Other factors that contribute to the vulnerability of coastal integrity include beach mining as that in La Union (Siringan et al., 2005); coastal modifications as that in Banabang-Molino-Balayan Coast (David et al., 2010); and mangrove removal as in Kampumpong River, Batangas City (David et al., 2010). On the other hand, it has also been demonstrated that the presence of extensive coral reefs help protect the associated shoreline against high-energy waves even under a climate change scenario (Villanoy et al., 2012).

4.3.1.2 Internal Seas and Upwelling Areas

Using skeletal oxygen and carbon isotopes from Porites corals in southwest Bohol, a study found that there was cooler SST of about 4°C in the Last Interglacial Maximum (LIMax) relative to the present SST of 28.6°C. This is attributed to intensified trade winds during LIMax resulting in increased upwelling of deeper, colder water in the vicinity of the equator (Ringor, 2006). Upwelling has been shown to support the fishing grounds of the Philippines with some areas being sensitive to monsoon as in Zamboanga (Villanoy et al., 2011) while others are seen to respond to ENSO events as that in Bohol Sea (Cabrera et al., 2011).

Sulu Sea was also seen to be 2.3 + 0.5 °C cooler than the present during the LIMax with a concomitant decrease in sea surface salinity. In addition, there are similarities between variations in surface salinity in the Sulu Sea, the western and eastern equatorial Pacific, and the Greenland ice-core record suggesting that the observed changes in salinity reflect large-scale rearrangement of atmospheric patterns throughout the Northern Hemisphere (Rosenthal, Oppo, & Linsley, 2003).

4.3.1.3 Marine Biogeochemistry

The combined effects of temperature, salinity, and wind on the water column stability and consequential Harmful Algal Bloom (HAB) in tropical waters were first modelled in Manila Bay (Villanoy, Azanza, Altemerano, & Casil, 2006). The combined effects of tropical cyclones and local weather events as influenced indirectly by climate change was also shown to affect the physico-chemical conditions of the coastal waters of Rizal and Sibutad in Zamboanga del Norte triggering the HAB occurrence of Pyrodinium bahamense var. compressum (Aquino, Flores, & Naguit, 2010).

4.3.1.4 Estuaries

Rivers and estuaries are experiencing changes in ecosystem structure, function, and services due to siltation from upland logging and saltwater intrusion from SLR. River bank erosion and flooding events, brought about by mismanaged coastal areas and extreme atmospheric events, threaten adjacent communities. Food security and livelihoods are at risk from climate and non-climate impacts to fish spawning and nursery areas in river and estuarine habitats in the Coral Triangle (Coral Triangle Initiative [CTI], 2011; Hoegh-Guldberg, 2009. Moreover, rare freshwater mammals like the Irrawaddy dolphins in Malampaya Sound are at risk due to changes in food source and habitat.

4.3.1.5 Mangroves

Mangroves are experiencing changes in ecosystem structure, function, and services due to unsustainable overexploitation from domestic use (e.g., charcoal, firewood) and livelihood (e.g., logging, boat building). Mangrove forests in the Philippines suffered the same fate of degradation for food and timber production (Primavera 1991, 2000; Melana, Melana, & Mapalo, 2000; Walters 2000, 2004). A mapping and monitoring assessment of the Philippine mangrove forests recorded a decrease in the total mangrove area of about 10.5% from 1990 to 2010 (Long, Napton, Giri & Graesser, 2014). Comparative analysis with selected historical mangrove area estimates showed that total mangrove area decreased by around 51.8% from 1918 to 2010. The remaining mangrove areas in the Philippines have been identified to be among the most vulnerable sites to climate change together with the small islands in the Pacific. The major reason behind is that mangroves occupying low-relief islands and/or carbonate settings have ordinarily low sediment supply rates and available uplands space (Alongi, 2002). Food security and livelihoods are also at risk from climate and non-climate impacts to fish spawning and nursery grounds in the mangrove forests in the Coral Triangle (CTI, 2011). Protection and restoration of mangroves stands have tended to be species monocultures and in areas that are not the natural habitat of mangroves, such as mudflats, sandflats, and seagrass meadows and are therefore largely less successful in terms of restoring its ecological and economic importance (Samson & Rollon, 2008; Primavera & Esteban, 2008).

4.3.1.6 Seagrasses

Though its ecological and economic importance rank highest among the biosphere, publication on the seagrass ecosystem, both scientific and in print media, receives less attention than corals and mangroves (Duarte, Dennison, Orth, & Carruthers, 2008). This may be due to the lack of public awareness on the ecosystem services that it can provide, thereby making it a least priority in management of coastal areas. Destruction of seagrasses is by far the most undocumented of the important marine ecosystems. Upland and mangrove forests deforestation are the main drivers for coastal erosion, thereby increasing the impact of sedimentation on seagrasses. Changes in silt-clay ratio in the coastal sediment have been shown to affect seagrass community leaf biomass and species richness (Terrados et al., 1998). This is of concern because seagrass communities provide a wide array of ecosystem services such as enhancement of coastal stability, nursery grounds for numerous fishes, and habitat for economically important food fish such as the rabbit fish (*danggit*).

4.3.1.7 Coral Reefs

Coral reefs have been documented to adapt to slow changes in the environment. For example, holocene reefs of Currimao in Northwestern Luzon developed in an overall aggradation mode from 9.86 kilo annum (ka) to 6.59 ka during deglacial SLR. During 9.2 to 8.2 ka, the accretion rate of Currimao reefs was as high as 10 to 13 m per kilo year (ky) as revealed by three cores. The minimum sea level was likely about 27 m below the current mean sea level (MSL) at 9.86 ka and rose to about 4 m below the MSL at 7.3 ka (Shen, Siringan, Lin, Dai, & Gong, 2010).

It is another matter, however, when chronic stress is further exacerbated by extreme climate change-related anomalies. As an example, the Coral Triangle, the epicenter of marine shallow water biodiversity, has the highest proportion of Vulnerable and Near Threatened coral species due to the chronic nature of anthropogenic disturbance which is compounded by the effects of climate change (Carpenter et al., 2008). Coral reefs are experiencing changes in ecosystem structure, function, and services due to overexploitation from fishing and coral harvesting (e.g., using coral skeletons for lime production or as raw materials for building roads), increasing sedimentation from logging (e.g., to provide space for the monoculture production of palm oil), and other land-based pollution. The degradation is exacerbated by increasing SST and decrease in ocean pH (commonly termed "ocean acidification"). This is because reef-building corals only thrive within a narrow temperature range of 23 to 29°C, and any extended exposure to increase in ocean temperature (e.g., 1°C for 4 weeks) will already result in coral bleaching. Mortality can ensue if the exposure is further prolonged or the ocean temperature is further increased. Just as seriously, the calcium carbonate-based skeletal structure of reef-building corals can be compromised with reduction in ocean pH. Subsequently, food security, livelihoods, and coastal tourism related to coral reefs in the Coral Triangle are at risk (CTI, 2011; Hoegh-Guldberg, 2009).

4.3.2 Exacerbating Factors

4.3.2.1 Increasing Human Utilization of the Coastal Zone

The Philippines is ranked in the top ten for largest population in low elevation coastal zone (McGranahan, Balk, & Anderson, 2007). A total of 4,251 coastal barangays out of a total of 41,992 barangays in the national database are identified as highly exposed to coastal river flooding. These barangays represent 10,210,740 individuals or 11.67% of the total population of the Philippines (Ignacio & Henry, 2013, based on 2006 statistics). Climate change will further exacerbate their situation.

In addition, coastal population growth has led to widespread conversion of natural coastal landscapes to agriculture, aquaculture, silviculture, as well as industrial and residential uses. The mariculture fisheries basket of the Philippines in Bolinao, Pangasinan, for example, has experienced significant environmental changes since the 1990s. By 2002, the consequence of intensive mariculture resulted in the first HAB (a dinoflagellate Prorocentrum minimum) in the area (San Diego-McGlone, Azanza, Villanoy, & Jacinto, 2008).

Human activities have direct impacts on the coastal ecosystem including drainage of coastal wetlands; beach forest deforestation and reclamation; and discharge of sewage, fertilizers, and contaminants into coastal waters. Extractive activities such as sand mining, hydrocarbon production, and harvest of fisheries and other living resources have led to changes in coastal integrity and biodiversity, including introduction of invasive species. Construction of seawalls and other engineering structures such as damming, channelization, and diversions of coastal waterways has resulted in hardening of the coast, changing of circulation patterns, and altering of freshwater, sediment, and nutrient delivery. Finally, rapid urbanization has many consequences including enlargement of natural coastal inlets; and dredging of waterways for navigation, port facilities, and pipelines that exacerbate saltwater intrusion into surface and ground waters (Nicholls et al., 2007).

4.3.2.2 External Terrestrial and Marine Influences

Even without any direct human activities at the coastal zone, beach topography has been observed to have significantly changed. La Union beach area is a good example (Paw & Thia-Eng, 1991). Numerous bays and coves in rural and urban coastal areas are experiencing changes in ecosystem structure, function, and services because of increasing sedimentation due to activities away from the coast such as upland logging, industrial, and other human activities. Increased sedimentation smothers coral reefs in adjacent coastal areas. Extreme storms that cause floods, landslide, and extensive erosion will further increase sedimentation and pollution from upland areas that can also increase the incidence of toxic microalgae and shellfish poisoning in coastal areas. Food security and livelihoods are at risk from climate and non-climate impacts to shellfish and finfish that inhabit bays and coves in the Coral Triangle (CTI, 2011).

Away from shore, maritime shipping activities also impact the coastal zone such as offshore maritime solid waste disposals, oil spills, and accidental grounding. The one hazard that is gaining attention internationally is ballast water contamination that brings about alien species into local waters (Sarinas et al., 2012). Changing climate has stressed the local species making it possible for accidentally introduced species (alien species) to become invasive.

4.3.2.3 Observed Effects of Climate Change on Coastal Systems

In Batangas (representing the northern part of the Philippines internal seas), climate change impacts perceived by locals include: (i) damage to historically resilient property (e.g., hotels, resorts, houses) during tropical cyclones or low pressure area; (ii) a number of houses relocated because of coastal erosion; and (iii) old houses and established trees washed out during tropical cyclones. Also observed are coral bleaching and increasing number of crown-of-thorns starfish (Acanthaster planci). Mangrove areas, marine protected areas, and beaches were also found to be at risk due to climate change. There is concern regarding impacts to livelihood and tourism in vulnerable coastal areas. Consequences of short-term extreme weather event disturbances such as decrease in fish catch during tropical cyclones are also unfortunately incorrectly attributed to climate change (Perez et al., 2013).

On the other hand in Palawan (representing the western part of the Philippine internal seas), the climate change impacts perceived by locals include: (i) water advancing towards houses; (ii) changes in fish species caught; (iii) houses and boats destroyed due to tropical cyclones (since Palawan has historically been almost tropical cyclone-free); (iv) coral bleaching outside the sanctuary; (v) decreased land area due to coastal erosion; (vi) increased mortality of traditionally gleaned shells along the coastline due to temperature increase (sea water was observed to have become hotter during 3 to 4 pm gleaning activity); and (vii) bangus fry collected for the past 5 to 6 years have declined significantly. Landslide and siltation extending up to 2 km on both sides of a river have also been attributed to climate change even as these may have actually been exacerbated by anthropogenic land use.

In both locations, changes in tropical cyclone pattern/intensity and the consequential flooding are identified as primary climate change hazards bringing high vulnerability to the sectors of fisheries, tourism, and housing in Batangas and fisheries and health in Palawan (Perez et al., 2013).

In Olango Island (representing the central part of the Philippine internal seas), locals are aware that natural occurring forcing factors such as monsoons, tropical cyclones, and consequential storm surges have major impacts on them including inundation, flooding, saltwater intrusion, coastal erosion, aquatic and terrestrial habitat damage, and property damage. Additionally, El Niño also brings about freshwater shortage and loss of crops. The concern is that climate change will aggravate the same and impact corals, seagrasses, land vegetation, fisheries, livelihood, infrastructure, transportation, and tourism in various ways (Mapalo, 1999).

While in Leyte (representing sites facing the Pacific), there are no specific observations of climate change impacts. Communities however expressed concern that there will be consequences at the household level including damage to property, cause of illness, loss of livelihood, damage to agricultural lands, cause of poverty, loss of life, and cause of family inconvenience and conflicts (Predo, 2010). These are reflected in the household perception surveys shown in Table 4.1.

Table 4.1 Household perceptions of impacts of climate change in coastal communities.

Category	Impact	Reference
Livelihood	Agriculture: • Damage to agricultural crops (i.e., coconut and abaca), farm structures, implements, and support facilities Fisheries: • Damage to fishing craft, gear, and other paraphernalia • Siltation of fishing grounds and critical habitats (i.e., sea grass and seaweed beds, coral reefs) • Marine fishery reserve destruction due to encroachment into the core area of the reserve	Capili et al., 2005; Nieves et al., 2009

Table 4.1. Continued

Category	Impact	Reference
Livelihood	Fisheries: • Damage to fishing craft, gear, and other paraphernalia • Siltation of fishing grounds and critical habitats (i.e., sea grass and seaweed beds, coral reefs) • Marine fishery reserve destruction due to encroachment into the core area of the reserve General: • Means of livelihood and income sources totally wiped-out • Lack of livelihood opportunities and/or limited employment opportunities	Capili et al., 2005; Nieves et al., 2009
Health	Diseases particularly among children due to lack of potable drinking water, sanitation problem, and food shortage	
Income groups	Small/municipal fishers and shellfish growers: 1. Temporary disruption/displacement from their livelihoods resulting to a decrease in or no fish catch/shellfish production and/or income 2. Increased cost of prime commodities such as fish, vegetables and other agricultural and fishery products 3. Total or partial damage to livelihood and household assets (e.g., fishing boat, fish cage, backyard animals, dwelling units, household properties, etc.) 4. Increased household costs for potable drinking water (resulting from saltwater intrusion on shallow wells) Poor micro-entrepreneurs and the self-employed: 1. Temporary dislocation from economic activities/livelihoods resulting in decrease in sales/profit or income 2. Increased prices of prime commodities 3. Partial damage to livelihood and property (including backyard animals) 4. Increased household budget for potable drinking water The employed and entrepreneurs living above poverty threshold: 1. Minimal to moderate displacement/loss of income from livelihoods 2. Increased prime commodity prices 3. Partial/minimal damage to their livelihoods and property Better-off families: 1. Decreased production and/or income 2. Minimal to insignificant damage to property	Sales, 2009

4.4 ASSUMPTIONS ABOUT FUTURE TRENDS

4.4.1 Environmental and Socio-economic Trends

Even as there is evidence that the frequency of storms may lessen, experts agree that strength of each of the storms will increase as the oceans warm. An assessment of the exposure of coastal cities to the consequential larger storm surges in addition to the scenario of a 1 m SLR (likely conservative scenario which includes thermal expansion and ice calving) shows that out of 393 cities, Manila accounts for 25% of the future coastal population exposure. Taguig, Caloocan, Davao, Butuan, Malabon, and Iloilo are also identified among the top 25 cities with the largest population exposures (Brecht, Dasgupta, Laplante, Murray, & Wheeler, 2012). In a similar study, over 25% of the increase in developing country urban population affected by future storm surges can be found in only three cities including Manila (3.4 million). Taguig and Caloocan are also cited among the top 25 ranked according to population vulnerability. Other cities in the Philippines whose coastal areas will be most affected by future increases in storm surges include Butuan and Cotabato. Estimates indicate that areas prone to storm surge in the Philippines account for more than 50% of the Gross Domestic Product (GDP) generated in their coastal regions (Dasgupta, Laplante, Murray, & Wheeler., 2009). The Philippines is ranked the highest, in both absolute and percentage terms, in 31 developing countries most vulnerable to storm surge risk by 2100, with projected exposure of 16 million people (41.7% of projected population in coastal cities over 100,000) (Brecht et al., 2012).

A coastal cities flood vulnerability index incorporating climate change impacts depicts Manila as having high vulnerability due to the economic disparity in the population and projected increased economic vulnerability by 2100 (Balica, Wright, & van der Meulen, 2012).

Extreme probability distributions of annual (peak) tropical cyclone duration with speeds greater than or equal to 120 knots are predicted. There is a tendency toward increase of maximum wind speeds and increase of duration of peak storms (Emanuel, Sundararajan, & Williams, 2008). The impacts of the latter are more critical since the tendency for shoreline erosion increases as the time of exposure to storm waves is increased. Consequently, increasing storminess for countries located in Southeast Asia (SEA) such as the Philippines make it imperative for coastal defenses to be able to withstand even twice longer events. Low-lying areas, especially river mouths and deltas, will become increasingly vulnerable to shoreline erosion and/or silting-up of navigational channels, as they will have to absorb much more wave energy (Rozynski, 2008).

4.4.2 Climate and Sea-level Ocean Change Scenarios

In the Coral Triangle region, projected climate hazards are identified as increasing sea temperatures, ocean acidification, SLR, longer and more intense floods and droughts, and more intense cyclones and other storms. These have severe consequences to coastal communities exposed to increasing vulnerabilities to human health and safety, food security, livelihoods, coastal infrastructure, and economic development due to coastal erosion, flooding, inundation, storm surge, and strong winds (CTI, 2011; Muto, Morishita, and Syson, 2010.).

Projections on future SLR indicate that mean sea level will rise to >22 cm at year 2030 (Yanagi & Akaki, 1994). IPCC (2013) projects the global mean SLR to be 17 to 38 cm by mid-century (2046-2065). Even under the most conservative scenario, sea level will be about 40 cm higher by the end of 21st century. This projected SLR could increase the annual number of people flooded in coastal populations in Asia from 13 to 94 million, of which 20% will occur in SEA including the Philippines (Cruz et al., 2007). It should be noted that the associated rate of SLR used in this conservative scenario is actually within what is currently being observed by satellite data for the SEA region. Satellite data gives a rate of 2 to 12 cm per decade, which translates to 0.2 to 1.2 m by 2100 (Strassburg et al., 2015).

Vulnerability analyses to SLR show that a 1-m rise in sea level (conservative scenario with thermal expansion and ice calving (Pfeffer, Harper, O'Neel, & O'Neel, 2008) will submerge 48% of the 200-hectare area of Navotas affecting a population of 54,145 in 8 barangays (Galgana, Abad, Villarin, & Vicente, 2004). Most areas along the coast of Manila Bay, including 19 municipalities in Metro Manila, Bulacan, and Cavite, could succumb to a 1 m SLR by 2100 (Perez et al., 1999). A similar study shows the areas around Manila Bay to be affected by 1 m and 2 m SLR (2-meter rise being the upper limit of the thermal expansion and ice calving model (Pfeffer et al., 2008) (Table 4.2). Specifically, a total area of 387 hectares of mainland Cavite will be exposed to such risk representing an increase to 60% from the present 10% affected by flooding (Sales, 2009).

Under the B1 scenario, 0.7% of the population in the Philippines will be affected by annual flooding in 2100 due to projected relative SLR of about 0.31 m. Under the A2 scenario with 0.45 m, Western Visayas (228,800 people flooded) and National Capital Region (NCR) (357,600 people flooded) will be most vulnerable in 2100. It should be noted that the scenarios used in this analysis is actually less than what is currently being observed by satellite data for the Philippines. Satellite data gives a 30-year trend of 4.5 to 8.5 cm per decade that translates to 0.45 to 0.85 m by 2100 (Strassburg et al., 2015).

Table 4.2. Areas around Manila Bay to be affected by 1 m and 2 m SLR (Partnerships in Environmental Management for the Seas of East Asia [PEMSEA], 2012)

Area	Areas Affected (ha)	Areas Affected (1 m SLR) (ha)	Percentage	Areas Affected (2 m SLR) (ha)	Percentage
Metro Manila	59,583.11338	5,374.99831	9.02	7,866.65644	13.20
Cavite	56,392.87218	1,608.96189	2.85	2,701.01703	4.79
Bulacan	67,631.40549	22,691.40857	33.55	27,967.61012	41.35
Pampanga	143,961.5744	30,115.33937	20.92	41,594.57421	28.89
Bataan	288,928.4713	37,959.70203	13.14	51,651.150	17.88

Another study projects that a 1 m rise in sea level will affect 16 regions, 64 out of 81 provinces, covering at least 703 out of 1,610 municipalities, inundating almost 700 million m^2 of land and potentially displacing at least 1.5 million Filipinos. Provinces that are highly vulnerable to a 1 m SLR include Sulu (79,728,300 m^2), Palawan (64,281,600 m^2), and Zamboanga del Sur (37,817,900 m^2) (Greenpeace, 2007).

4.5 KEY FUTURE IMPACTS AND VULNERABILITY

4.5.1 Consequences to Natural System

The Philippines is projected to be affected by a 51% reduction in coastal wetland area under the A2 scenario in 2100. Specifically, Ilocos, Cagayan Valley, Central Luzon, Central Visayas, and Western Visayas are projected to lose over 50% of their existing coastal wetlands by 2100 (Mcleod et al., 2010). High SLR could inundate low-lying areas and estuaries, cause erosion of beaches and saltwater intrusion in coastal aquifers (Paw & Thia-Eng, 1991).

As for low-lying small island ecosystems like Olango Island (land area 10 km^2), a study showed that the topography, hydrology, water current, tidal regime, and soil will be negatively affected by a predicted 30 cm by 2030 and 1 m by 2100 SLR. Among the major biological attributes of Olango Island, the mangrove forest, terrestrial vegetation, wildlife, and sanctuary are vulnerable to the predicted SLR (Mapalo, 1999).

4.5.2 Consequences for Human Society

A future SLR may bring about extensive coastal land use changes, particularly within large urban centers. There will be areas prone to high erosion, frequent flooding, salt intrusion, inundation, or submergence that could create numerous economic setbacks, unemployment, population migration, and disruption of social amenities. Adequate port facilities especially in Manila may have to be built to offset the gradual SLR so that these ports remain viable (Paw & Thia-Eng, 1991).

Specific site-studies show that coastal erosion and shoreline retreat can lead to the loss of about 300 structures, 283,085 m^2 of land, and 123,033 m^2 of beach along San Fernando Bay by the year 2100 with a 1m SLR scenario. The total current value of these threatened lands and structures is estimated at PhP 1.04 billion which produce social services estimated at PhP 12.54 million (Bayani, Dorado, & Dorado, 2009). In comparison, the average loss of rice farming due to tropical cyclones is Php 2.67 billion for the same region (Israel, 2012). The difference is one can recuperate from tropical cyclone damage but loss to SLR is permanent; thus, making low-lying islands such as Olango Island even more vulnerable to the predicted SLR which can impact on population, livelihood, infrastructure, transportation, and tourism (Mapalo, 1999).

4.6 COSTS AND OTHER SOCIO-ECONOMIC ASPECTS

4.6.1 Socio-economic Consequences Under Current Climate and Ocean Conditions

Climate-related disasters can cause damages totaling to as much as 46% of annual average household income in coastal communities (Predo, 2010). In terms of commodities, there are documented average economic losses due to tropical cyclones for top producers of mariculture fishes: milkfish in Pangasinan (87.8%), tilapia in Batangas (84.39%), and grouper in Surigao (72.68%) (Campos, 2010). This highlights the vulnerability of our food security.

4.6.2 Socio-economic Consequences of Projected Climate and Ocean Change

Annual damage costs in terms of (i) annual cost of economic damage caused by the sum of coastal flooding and river flooding, (ii) dry land loss, (iii) salinity intrusion, and (iv) human migration relative to GDP are projected to be high in the Philippines. By 2100, damage costs represent 0.31% of GDP under B1 and 0.28% of GDP under A2. The NCR will be most affected with annual damages estimated to be USD 6.3 billion under B1. Considering adaptation, annual damage costs in the Philippines are reduced by between 68% and 99% (Mcleod et al., 2010).

In addition, the country is estimated to lose 52.29% of its coastal GDP due to the potential intensification of storm surges. Four of the cities most likely to be impacted by intensified storm surges are identified as San Jose, Manila, Roxas, and Cotabato based on percent of area exposed (Dasgupta et al., 2009) .

4.7 ADAPTATION: PRACTICES, OPTIONS AND CONSTRAINTS

4.7.1 Current Trends and Proposals of Adaptation to Changes in Climate and Ocean Change

The Philippines' Initial National Communication (INC) on climate change identifies the following adaptation options: (i) assessment of current practices on crisis management; (ii) information and education campaign (IEC); (iii) guidelines and implementation of the integrated coastal zone management (ICZM); (iv) institutionalization of mangrove resources development; (v) public easements and buffer strips should be treated as separate lots during land surveys; (vi) LGUs should be required to reserve foreshore areas (critical areas for recreation/tourism, etc.); (vii) inclusion of wetlands, swamps, marshes in the National Integrated Protected Areas (NIPAs) under a category of wildlife sanctuary or unique ecosystem; (viii) a multi-hazard mitigation and protection plan for natural coastal areas must be developed; (ix) formulation and strict implementation of mining laws, reforestation of denuded watersheds to reduce river/coastal erosion; (x) requirement of geological, hydrometeorological, and structural engineering evaluation as part of the environmental impact assessment; and (xi) limitation of government subsidies or tax incentives to develop land sensitive to SLR (Government of the Philippines, 1999).

Furthermore, the National Framework Strategy on Climate Change (NFSCC) 2010 to 2022 provides for the enhancement of resilience of coastal and marine ecosystems and communities, including tourism industries, to climate change. Its strategic priorities are: (i) establish marine reserve networks through active participation of local communities to serve as sources of marine propagules to replenish biodiversity in shallow water habitats; (ii) determine optimal clustering and locations of marine reserves according to "source and sink"; (iii) prioritize protection/management of mangroves, estuaries, sea grasses, coral reefs, and beaches as a management unit to derive maximum benefits from synergistic interactions of these five ecosystems that result in enhanced marine productivity; (iv) strengthen sustainable, multi-sectoral, and community-based coastal resource management mechanisms and ecotourism endeavours; and (v) manage and expand the sink potential of marine ecosystems such as coral reefs and mangroves (Climate Change Commission [CCC], 2010). Results of a cost effectiveness analysis of adaptation options are presented in Table 4.3. Overall, eco-engineering or the use of ecosystems such as mangroves and riparian vegetation as an adaptation strategy against flooding and erosion is recommended.

Table 4.3. Cost effectiveness analysis for Batangas and Palawan (Perez et al., 2013)

Site	Objectives	Planned Adaptation Strategies	Cost Effectiveness Ratio (in USD)	Result
Batangas	Protect the coastline from eroding	Construction of a sea wall	0.16 million per linear km of erosion prevented	Mangrove reforestation is not only more cost effective, but also offers other co-benefits like additional sources of income, and preservation of marine biodiversity
		Mangrove reforestation	0.01 million per linear km of erosion prevented	
	Increase the number of households saved from tropical cyclone/flooding	Zoning provisions according to revised and Comprehensive Land Use Plan (CLUP)	.07 million per household (HH) saved	Although the improvement of tropical cyclone early warning systems with provision of emergency evacuation is the most cost effective, the construction of an integrated drainage and flood control system with livelihood diversification is highly acceptable among the stakeholders
		Improvement of tropical cyclone early warning system and provision of emergency evacuation and shelter	0.04 million per HH saved	
		Integrated drainage and flood control system and diversification of livelihood	0.10 million per HH saved	
Babuyan, Palawan	Protect the household from storm surges and loss of property, and minimize sand erosion	Breakwater construction	0.276 million per HH	Mangrove reforestation is cost effective in protecting the households and properties, and in minimizing sand erosion where mangrove has been seen to thrive well
		Dike/levee construction	0.032 million per HH	
		Mangrove reforestation	0.019 million per HH	
	Prevent river overflow and minimize siltation that cause damages to coconut plantations and fishponds	Riverbank rehabilitation using Vetiver grass	0.004 million per ha	The discussion on the planned options and cost effectiveness rations focused on prioritizing riverbed dredging at the same time also undertake riverbank rehabilitation using Vetiver grass alone
		Riverbank rehabilitation using Vetiver grass combined with mechanical method	0.034 million per ha	
		Dike construction	0.032 million per ha	
		River dredging	0.002 per ha	

Table 4.3. Continued

Site	Objectives	Planned Adaptation Strategies	Cost Effectiveness Ratio (in USD)	Result
	Protect households from inland flooding	Upland reforestation	926 per HH	The IEC is cost effective but success depends on the maturity of the residents to react accordingly
		IEC/establish early warning system and provision of temporary evacuation center	20 per HH	
		Relocate affected households to safer place	2,234 per HH	
Binduyan, Palawan	Protect households from strong waves and storm surges	Breakwater construction	0.277 million per HH	Officials agreed to prioritize seawall construction but at the same time, pursue mangrove reforestation appropriate for the area
		Mangrove reforestation	0.009 million per HH	
		Seawall construction	0.00089 million per HH	
		Relocation of affected households	0.0012 per HH	

In principle, several strategies are identified where adaptation could be integrated into such as coastal resources management/integrated coastal management (Sales, 2009), marine protected areas, and disaster management. Specific activities for adaptation could include skills enhancement, livelihood development, participatory land use planning, vulnerability assessment and mapping, and adaptation strategies identification and analysis (Predo, 2010). The Philippines' INC further identifies six adaptive measures to address accelerated SLR for coastal resources such as: (i) selective protection after comprehensive cost-benefit analysis; (ii) long-term planning in the perspective of coastal zone management to include proper resources exploitation and usage; (iii) disaster mitigation and preparedness tie-up with climate change issues; (iv) passage/implementation of policies and regulations on habitation and construction; (v) inclusion of measures to address climate change in the ICZM program; and (vi) IEC to include government and the general public.

Many adaptation practices in coastal areas can be found. In the Coral Triangle, the Philippine government under the CTI commits to Goal 4: Climate Change Adaptation Measures Achieved, which targets: (1) development and implementation of region-wide early action for climate change adaptation plan for the near-shore marine and coastal environment and small island ecosystems, and (2) establishment and fully operationalizing networked national centers of excellence on climate change adaptation for marine and coastal environments (CTI, n.d.). Perez (2003) identifies adaptation and capacity enhancing measures to adapt to climate variability and change (Table 4.4).

Table 4.4. Measures to enhance capacity to adapt to climate variability and change (Perez, 2003)

Adaptation Measure	• Modify setback policies to address climate change/SLR • Conduct research studies on salt water intrusion, fisheries, and aquaculture • Strengthen disaster management program • Improve tropical cyclone warning system • Improve flood prevention/protection • Shoreline stabilization/Preparation of hazard and vulnerability maps to floods and to probable SLR • Stop further conversion of mangrove into fishpond development

Table 4.2. Continued

Adaptation Measure (Continued)	• Put in place Integrated Coastal Management (ICM) and expansion of Coastal Environment Program (CEP) • Massive upland and coastal reforestation, including the expansion of community-based mangrove reforestation program • IEC, awareness program • Monitor SLR and climatological data: Tidal gauge stations (costly) vs. indigenous methods (staff gauges) • Install Geographical Information System
Capacity-enhancing measure	• Empower people in the management of coastal resources • Conduct inventory and survey coastal resources • Develop provincial environmental and natural resource accounting • Require industries to install desalination facilities for water sources, instead of groundwater withdrawal • Regulate installation of water pumping systems • Expand coverage for artificial reefs, marine sanctuary, and marine reserves. • Strengthen coordination between Department of Environment and Natural Resources (DENR) and LGUs • Implement appropriate land use and zoning • Strictly monitor and enforce mining laws (sand and corals) and other coastal management policies, laws and regulations • Formulate comprehensive coastal development plan • Develop/Improve watershed management, including identifying and developing potable water sources • Reactivate/re-orient Environment and Natural Resources Committee (ENRC) in the coastal municipalities • Implement Poverty Alleviation Program • Strengthen/enhance integrated waste management program, including adoption of coastal cleanup movements • Provide alternative livelihood and resettlement program

In Lingayen Gulf, Davao Gulf, Cebu, and Batangas Bay, long term planning based on ICZM principles has been implemented as a strategy to adapt to future SLR (Perez et al., 1999). In Cavite City, planned adaptation strategies implemented by the LGU include: (i) information campaigns/public advisories, (ii) relief assistance and evacuation of affected families and individuals, (iii) resettlement of vulnerable coastal families, (iv) provision of medical assistance to evacuees, and (v) construction of shoreline protection measures (e.g., rockwalls/breakwaters, seawalls) (Sales, 2009). Coastal communities are undertaking autonomous adaptation practices as shown in Table 4.5. Sources of information/knowledge on adaptation strategies are indigenous knowledge, media, and the community (Predo, 2010).

Table 4.5. Autonomous adaptation practices of coastal communities

Category	Autonomous Adaptation	Source
Climate/weather related disturbance	Temporary evacuation to designated centers • House relocation from coastal to safe upland areas • Shifting from light materials to more durable and stronger materials in house construction • Seeking the assistance of relatives for temporary relief and accommodation or loans • Procurement of battery operated radio sets as a source of weather forecast information	Nieves et al., 2009

Table 4.5. Continued

Category	Autonomous Adaptation	Source
Agriculture and fisheries	• Planting of root crops and other agricultural crops with short-farming cycles, resistant to changing weather patterns • Repair/procurement of new fishing craft and fishing gear (mostly provided as relief, donation or grant from various national government agencies [NGAs] and non-government organizations [NGOs]) • Gleaning for macro-invertebrates along tidal flats, fringing reefs, mangrove swamps and other areas • Mat making • Finding of alternative sources of income like laundry, domestic help, pedicab driving, construction worker/helper, baggage/mail carrier, etc.	Nieves et al., 2009
Health	• Resorting to herbal medicine • Availing of medical missions provided by NGAs and • NGOs	
Economy	• Out-migration to urban centers • Acceptance of food for work programs • Alternate farming and fishing or vice-versa • Budget tightening and the practice of economy measures	
Environment	• Mangrove reforestation • Water shed development • Seeking for government assistance for shoreline protection • Stopping of illegal fishing activities • Establishment of Marine Protected Areas (MPA)	
Economic	• Installation of rip-rap and used fishnets as barriers • Raising or recontsruction of homestead to safer ground • Safety and repair of fishing paraphernalia • Securing of household furniture and fixtures to higher ground • Sustainable livelihood activities	Almagro-Blanco, 2011
Social, Environmental and Spiritual	• Establishment and maintenance of vegetable gardens on vacant lots or pots • Communal vegetable gardening, mangrove planting and clean and green activities • Prayers • Membership in women associations and fisher groups	

Fisheries	• Longer time fishing in good weather
	• Complementary income sources:
	• Farming
	  • Other fisheries-related employment (e.g., fish drying and fish vending)
	  • Small business operation
	  • Handicraft making
	  • Labor during harvest in farms and fishponds
	  • Non-agricultural labor (e.g., tricycle cab driving and construction work such as house painting and carpentry)
		Uy, Takeuchi, & Shaw, 2011

Agriculture	• Change in planting schedule and cropping patterns • Diversification of crops planted – rice, corn, vegetables, and root crops	
Food Security	• Increase of household food stock • Diversification of food sources (e.g., drying fish and gathering shellfish) • Planting of root crops and vegetables	

Table 4.5. Continued

Category	Autonomous Adaptation	Source
Extreme weather events	• Reinforcement of houses • Reliance on traditional weather forecasting by fishermen	Uy, Takeuchi, & Shaw, 2011
Others	• Loans • Sale of assets (e.g. household appliance, land and livestock) • Outmigration • Reduction in expenditures on food and basic necessities • Change in attitude towards the environment • Praying to God	
Seaweed Farming	• Manual removal of algae ("lumot") and epiphytes ("lapa-lapa"), and mud • Transfer by financially better-off growers of farmed seaweed to a less crowded area where current flows freely • Lowering of the plant further from the water surface to prevent too much exposure to sunlight, especially during low tide • For enlarged thallus tips, loosening or untangling of string of filamentous plants • Harvesting of plants as soon as disease occurs	Campos, 2010
Grouper cage culture	• Location of cage to make it accessible, especially in times of natural calamity but secure from vandals and poachers • Transfer of cages to deeper water during period of continuous rain, preventing abrupt changes in temperature and salinity • Use of strong, weather- and pest-resistant, non-corrosive, and nonabrasive surface	
Tilapia cage culture	• Selection of sites where the terrain of the surrounding shore areas weakens or deflects strong winds and waves • Harvesting of stock before an announced strong tropical cyclone arrives	
Brackishwater milkfish pond culture	• Securing of fish stock by putting a net-fence on top of perimeter dike • Harvesting of stock before an announced strong tropical cyclone arrives	
Climate-related disasters	• Relocation of residence to a safe place permanently • Transfer to an evacuation area temporarily • Restructuring of housing unit • Building of stone breakwaters • Improvement of dike system or canal near residence • Change in land use to fit new condition • Change of livelihood and source of income • Preparation of household needs and safety precautions	Predo, 2010

The success of adaptation measures depend greatly on meeting the needs of various stakeholders that rely on this sector so that ecosystems improve while boosting local livelihoods and contributing to the national economy. For this, institutional measures would be essential such as: (i) implementing an integrated coastal resources management framework at the local level in several areas, including improved stakeholder participation, equitable sharing of economic benefits, as well as supporting legal and policy frameworks, and monitoring and information systems; and (ii) improved observation and research on coastal environmental change (and on the potential impacts of climate change on coastal areas) (World Bank, 2011).

4.7.2 Costs, Limits and Trade-offs in Adaptation

There are trade-offs in adaptation so decisions would need to take into account social and economic as well as ecological concerns. Table 4.6 describes how adaptation options can be evaluated. Among three adaptation options evaluated, planned protection was found to be the best strategy to pursue. This option yielded the highest net present value (NPV) of about PhP 148.63 million under the assumption that beaches were not resilient (Scenario A), and about PhP 126.78 million under the assumption that beaches were resilient (Scenario B), at a discount rate of 6% (Bayani et al., 2009).

Table 4.6. Summary of evaluation of adaptation options (Bayani et al., 2009)

Criteria	Business as Usual	Planned Protection	Retreat/Relocation
Economic feasibility (in million PhP)	NPV (6%): PhP 51.74 to 194.62 (Scenario A); PhP 45.6 to 122.37 (Scenario B)	NPV (6%): PhP 63.19 to 265 (Scenario A); PhP 57.05 to 192.75 (Scenario B)	NPV (6%): PhP 150.02 to 450.06 (Scenario A); PhP 143.88 to 377.81 (Scenario B)
Social feasibility	Some autonomous adaptation is currently ongoing. 70% of the respondents agreed that hardening by building bulkheads was acceptable.	65% of the respondents deemed the combination of hard and soft infrastructure acceptable.	65% of the respondents deemed the option acceptable.
Administrative feasibility	No need for monitoring and enforcement. No capital investment from the government needed.	Administration is relatively easy but will require investment from the government. Total investment requirement: PhP 57 million	Requires monitoring and enforcement of the setback policy (salvage zone). May require huge information collection and dissemination costs, and transaction costs. Entails huge investment by the government. Total investment requirement: PhP 1.15 billion
Legal/political feasibility	Although there is an ordinance prohibiting the construction of any structure along the salvage zone area, this is not fully enforced. As such, this option could prevail despite the existence of any regulation to the contrary.	There is potential for implementation. 82% of LGU respondents agreed to support the implementation of an infrastructure project.	There is potential for implementation. 64% of LGU respondents agreed to support the strategy.

4.7.3 Adaptive Capacity

Opportunities to enhance the adaptive capacity of coastal communities could be undertaken through: (i) the Philippine Local Government Code, which devolves the management of coastal resources in municipal waters to 832 coastal municipalities and 57 coastal cities; (ii) ICZM, which provides an effective framework for managing climate change impacts in the coastal zone; and (iii) environmental disaster management where a multi-hazard mitigation or protection plan for coastal hazards can be developed focusing on maximum reduction to threats to life, structures and economic production (Perez, 2003).

4.7.4 Constraints to Adaptation and Adaptive Capacity

Institutional challenges present barriers to adaptation. Lack of political will and proper enforcement of laws, rules, and regulations due to resource constraints challenge effective implementation of adaptation strategies based on sustainability criteria and standards (Sales, 2009). Moreover, building the capacity of municipal and village government officials would be critical (Uy et al., 2011). Local capacity development would be important to integrate adaptation strategies into ICZM, specifically in: (i) IEC activities for key local stakeholders such as the LGUs, civil society, the academe and the private sector; (ii) participatory risk, vulnerability and adaptation (V&A) assessment, planning, implementation, and evaluation; (iii) development and management of community-based projects in coastal resource management, alternative livelihood development, disaster/climate risk management and ecological waste management; (iv) creation of a multi-sectoral body for climate-sensitive ICZM planning and implementation; and (v) crafting and enforcement of appropriate laws, policies, and ordinances on disaster/climate risk management, and build partnerships between the LGU and NGOs, local academic and research institutions, particularly in the areas of community organizing and mobilization and participatory risk, V&A assessments (Sales, 2009).

In terms of knowledge and awareness, knowledge management is lacking making it necessary to establish community-based monitoring and surveillance systems to measure bio-physical and socio-economic changes in coastal areas including erosion patterns, coastal currents, tides, land use, population, and migration patterns, that will form part of a comprehensive database that will serve as input to V&A assessment and planning and the setting up of a community early warning system (Sales, 2009). Understanding of climate change adaptation, disaster risk reduction, and environmental stewardship has been found lacking at village level (Uy et al., 2011). There is low interest among local officials in coastal resource valuation and there is a lack of trained staff or expertise on coastal management (Perez, 2003). Promoting and increasing multi-stakeholder participation as well as capacity building of individuals and communities would be required (Uy et al., 2011; Sales, 2009).

Socio-economic conditions pose constraints to adaptive capacity. Global, national, and local market forces are constantly at play often creating increased demand, for example, for corals and aquarium fishes that even local officials are involved in smuggling (Perez, 2003). Physical facilities and social infrastructure such as farm-to-market roads, bridges, irrigation/canal systems, health centers, and school buildings are poor (Campos, 2010). Crop insurance and income diversification strategies are lacking (Campos, 2010; Uy et al., 2011).

4.8 CONCLUSIONS: IMPLICATIONS FOR SUSTAINABLE DEVELOPMENT

The principles of ICZM are based on sustainable development and thus, provide an opportunity to carry out a continuous, iterative, and consensus building process to achieve a set of goals, including adapting to the impacts of climate change. Among the benefits of ICZM include: (i) food security and other economic opportunities; (ii) improvement of fish catch/production; (iii) Coastal Resource Management Certification (CRMC) for the LGU; (iv) good institutional structure; (v) provision of alternative livelihoods; (vi) intergenerational equity; (vii) ecological/biodiversity integrity, resource generation; (viii) financial assistance; (ix) clearly defined and expanded local roles in ICZM; (x) empowerment of communities, increased sense of ownership; (xi) improved coastal resource base; (xii) political support; and (xiii) provision of training, technological transfer assistance (Perez, 2003). The key requirements for sustainability are as follows:

- The precautionary principle approach is used in the management of coastal resources
- Coastal stakeholders are given opportunities to actively participate in all aspects of coastal management
- Responsibility and resources must be fully devolved in local level decision-makers, who are closest to the resources to be developed.
- The maintenance of healthy and productive ecosystems is fundamental to the management of coastal areas
- Coastal resources should be allocated to uses that provide the greatest long-term community benefits that are compatible with the maintenance of the ecosystem's health

4.9 KEY UNCERTAINTIES, RESEARCH GAPS, AND PRIORITIES

4.9.1 Baseline Data and Future Scenarios

Based on the Philippines' Second National Communication (SNC), coastal areas need baseline data and monitoring on such physical aspects as long-term hydrologic and meteorological conditions and changes (e.g., sea level, storm surge, and tsunami wave heights). There are also constraints with respect to geophysical data such as weather, surface waves, sea level, or freshwater discharges since there are no detailed time series for the Philippines covering the past 50 years or more. It would be essential that access is provided to existing data and facilitate acquisition of new land cover, topographic, and bathymetric data to understand inundation patterns (Government of the Philippines, 2014).

Quantitative predictions of future coastal change remain difficult despite the application of improvements in technology to investigate and characterize large-scale shoreline changes. Uncertainties around future scenarios such as the magnitude of future SLR remain large and many SLR assessments are not provided at spatial or temporal scales most relevant for vulnerability assessment and adaptation planning (Wong et al., 2014). Scenarios of ocean temperature rise and acidification in the same spatial level is virtually non-existent.

4.9.2 Potential Consequences

The projection of the future impacts of climate change on natural systems is often hampered by the lack of sufficiently detailed data at the required levels of space and time. For coastal ecosystems, more work needs to be done to develop predictive models based on findings from multi-stressor experiments, both in the field and laboratory (Wong et al., 2014). In order to do these, observations of morphological processes, salinity intrusion, response of ecological systems (such as coral reefs to warm temperature), and availability of high resolution topographic information would need to be done in more sites and in more detail which entails increasing the quality and quantity of observing platforms (CCC, 2010). Multiple studies on effects on natural systems and productivity of changes in near shore currents, circulation patterns, and coastal upwelling would be important (Government of the Philippines, 2014).

Furthermore, there are significant gaps in vulnerability assessment of other specific coastal impacts such as diseases that could affect coastal areas, and on tourism and the required adaptation measures for port facilities.

Specifically, for the Coral Triangle, the research priorities are summarized in Table 4.7.

Table 4.7. Research priorities in the Coral Triangle (CTI, 2011)

Coastal system/sector	Research priority
River and estuary	• Assess vulnerability of river and estuarine systems to flooding and SLR to assess vulnerability of adjacent communities • Develop visualization tools including inundation maps for river banks, estuaries, adjacent settlements, and agricultural areas to support planning that leads to reduced risk to existing and new coastal settlements
Mangrove	• Assess vulnerability of mangrove forests to SLR and other climate hazards • Monitor SLR especially in mangrove forests where some changes are already occurring • Generate SLR projections in order to establish landward buffer areas to allow retreat of mangrove ecosystems • Conduct environmental impact analysis for all activities that would change coastal land use

Table 4.7. Continued

Coastal system/sector	Research priority
Bay and cove	• Adopt a ridge-to-reef approach to analyze cumulative impacts of land-and sea-based activities on marine and coastal ecosystems • Review national legislation on utilization and management of forests and water quality • Conduct environmental impact analysis for all activities that would change coastal land use
Coral reef	• Conduct baseline studies and monitor the condition of coral reefs especially the incidence of coral bleaching
Coastal community	• Conduct vulnerability assessments of coastal community to climate change • Monitor coastal erosion rates and assess the cost of eroded coastlines to facilitate cost benefit analysis for adaptation • Establish and strengthen early warning system for all hazards, natural and climate-related • Integrate climate change adaptation measures to reduce risk into existing local development policies and plans • Identify areas suitable for reclamation activities for eroding islands • Identify coastal areas appropriate for protection using seawalls and offshore buffers • Mainstream climate change adaptation in other sectors (for urban areas, transport, etc.)
Coastal infrastructure	• Assess the vulnerability of critical infrastructure in the coastal zone including port and harbors, fire and police stations, roadways, etc. to SLR, storm surge, and other climate impacts
Coastal livelihood and local economy	• Assess vulnerability of coastal livelihoods and business including coastal tourism, fishing, aquaculture, SLR, storm surge, and other climate impacts

4.9.3 Adaptation Options

While various adaptation measures are available at the local level, there remains insufficient information on assessment of adaptation options. More comprehensive assessments of valuation of coastal ecosystem services, adaptation costs and benefits that simultaneously consider both the gradual impact of land loss due to SLR, and the stochastic impacts of extreme water levels (storm surges, cyclones) would be needed, as well as other impacts such as salt water intrusion, wetland loss and change, and backwater effects (Wong et al., 2014).

Adaptation demands different decision regimes but adaptation, mitigation, and avoidance measures would still require integrating research that includes natural and social sciences. Governance of coastal adaptation and the role of institutions in the transition towards sustainable coasts are under researched (Wong et al., 2014). Research would also be needed to advance understanding of the linkages between vulnerability, adaptation, and disaster/climate risk management, with specific focus on the following: 1) socio-economic effects/impacts and costs of disaster/climate risks; 2) linkages between poverty, vulnerability, and gender concerns; and 3) documentation, sharing, and promotion of traditional knowledge and practices which enhance adaptation (Sales, 2009).

For the coastal zone in particular, there would be a need to improve the scientific and information base for ICZM to: (i) understand and analyze the present state of the coastal environment; (ii) prepare the ICZM program and evaluate its performance; (iii) understand the resilience and vulnerability of the coastal system to climate change and SLR; and (iv) formulate effective response strategies as well as conduct economic valuation of coastal resources (Perez, 2003). Table 4.8 provides other information needs in the coastal zone.

Table 4.8. Coastal zone information needs for adaptation (Government of the Philippines, 1999)

Coastal Resource Base	Social Organization in the Coastal Zone	Existing Environment and Resource-Related Programs	Institutional, Legal & Financial Capacity
Inventory of: • Existing coastal resources • Present use of coastal resources • Present status of coastal resources • Potential for present and future use	• Existence and character of human settlements (villages, towns) • Economic basis for human settlements • Existence of indigenous peoples and their traditional coastal activities	• Environmental regulatory programs • Fisheries management programs • Protected areas programs • Beach/erosion management programs • Pollution control programs • Other environmental management programs	• Relevant national level institutions • Relevant regional/ provincial-level institutions • Relevant local institutions • Survey of legal authorities related to coastal and ocean activities • Existing capacity building efforts, including those funded externally

Moreover, upstream water use policies need to be examined given impacts on coastal estuaries and bays (e.g., related to water extraction and exacerbated by drought).

4.9.4 Two-way Information Dissemination

Finally, despite the availability of potentially useful climate information, a gap exists between what is useful information for scientists and for decision makers. Reducing knowledge gaps in the understanding of the complex interactions between human and climate drivers and processes inducing changes would help to respond to them more efficiently. We could start by sharing best management practices and behavioral change following catastrophic events. From here, we can discern how differential recovery in communities can be a function of differential vulnerability. Then we can go towards an understanding of how integrated management strategies can work to reduce vulnerability.

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CHAPTER 5

Agriculture and Fisheries

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5.1 EXECUTIVE SUMMARY

Agriculture and fisheries are important sectors of the Philippine economy contributing to about one-tenth of the national gross domestic product (GDP) and a major provider of labor and employment, and livelihood opportunities. Climate change has profound effects and impacts on agriculture and fisheries threatening their sustainable development. Production systems and communities in agriculture and fisheries sectors are among the most vulnerable since poverty incidence is high. In general, the impacts of climate change and variability to agricultural production include higher incidence of pests and diseases, low crop productivity/yield, stunted growth, delays in fruiting and harvesting, declining quality of produce, increased labor costs, and low farm income.

Agricultural production is adversely affected by highly variable rainfall patterns and distribution that are observed more frequently in recent years. Agricultural crops, particularly rice, are very sensitive to water and temperature stress. Dry spells or heavy rainfall occurring immediately after seedlings are planted or seeds are sown cause the plants to die due to water or heat stress.

An analysis of temperature trends and irrigated field experiments at the International Rice Research Institute (IRRI) showed that increased temperatures brought about a 10% decline in grain yield for each 1°C increase in growing season minimum temperature in the dry season. In particular, a 1°C increase in minimum temperature during summer decreases yield by 64 kilogram (kg)/hectare (ha). Similarly, rice yield diminishes by 36 kg/ha for every 1% increase in the share of wet days.

Climate anomalies due to El Niño Southern Oscillation (ENSO) can cause substantial loss in crop production. The 1997-1998 El Niño caused a 100% loss in production during the dry season and more than 33% during the wet season. The 2004 El Niño caused 18% dry season and 32% wet season production losses. Records from the National Irrigation Administration (NIA) indicate that rice yield fell by more than two cavans (1 cavan = 50 kg) per ha below average in both the wet and dry season cropping periods of 1990 as a result of drought and typhoons. The 1999 La Niña brought around 26% and 45% production losses during the dry and wet seasons, respectively.

Significant decrease in the production of several fruit crops were reported in 1997-1998 during the worst ENSO episodes that ever hit the country. The long drought condition in 1997-1998 together with the changing seasonality of rainfall most likely caused the reduction in the production of these fruits.

Within the Coral Triangle, fisheries are experiencing changes in species composition, distribution, and yield of fish and invertebrates due to overfishing, increasing sea surface temperature (SST), and changes in ocean circulation. Climate change has also been seen to affect physiological processes and the seasonality of biological rhythms, altering food webs, and, consequently, fish production in the area. Climate impacts on coral reefs, including coral bleaching and ocean acidification, are likely to impact fisheries associated with these habitats. Consequently, food security and livelihoods are at risk.

Temperature changes coupled with changes in rainfall regimes and patterns could decrease crop yields and increase incidence/outbreaks of pests and diseases, both in plants and animals. Process-based crop simulation models indicate that yields of rice and other crops tend to decrease from 8 to 14% for every 1°C increase in temperature depending on location in the Philippines.

Extreme climate events could influence poverty by affecting agricultural productivity and raising prices of staple foods that are important to poor households. A study using simulated extreme climate indicators finds that climatic extremes exert substantial stress on low income populations especially the urban, wage-labor-dependent stratum due to their extreme exposure to food price increases. Since food is a major expenditure, this group's overall consumption falls with rising prices, pushing them below the poverty threshold of consumption.

Expectedly, the impacts of climate change on poor farmers are more profound than the impacts on rich farmers due mainly to the limited sources of income.

Adverse impacts on forestry areas and resources are expected to multiply in a warmer climate. Changes in the forest ecosystem could lead to unfavorable habitat conditions for certain highly sensitive species. Drier conditions could lead to increased incidence of forest fires. Traditions and livelihoods of forest communities may be altered and could lead to further degradation of the environment.

The National Framework Strategy on Climate Change (NFSCC) aims to address vulnerabilities in the country's agricultural sector by building the climate resilience of food production systems through mainstreaming of sustainable agriculture and aquaculture and related developments in the sector. The objective is to protect and enhance ecosystems and their services to secure food and water resources and provide livelihood opportunities.

The strategic priorities in building the climate resilience of agricultural sector include: (i) reducing climate change risks and vulnerability of natural ecosystems and biodiversity; (ii) increasing the resilience of agricultural communities through the development of climate-sensitive technologies, establishment of climate-proof agricultural infrastructure and climate-resilient food production systems, and provision of support services to the most vulnerable communities; (iii) improving the resilience of fisheries through the restoration of fishing grounds, stocks and habitats, and investment in sustainable and climate change-responsive fishing technologies and products; (iv) expanding investments in aquaculture and in other food production systems; (v) strengthening the agri-insurance system as an important risk sharing and transfer mechanism to implement weather-based insurance products; and (vi) promoting sustainable, multi-sectoral, and community-based resource management mechanisms.

There are several areas in the agriculture sector that would need to be addressed in order to provide conditions and environments that will enable the sector to be resilient and highly adaptive to climate change. These could include: (i) creating an enabling environment for private investments in agriculture; (ii) climate-fit crop programming and climate-based cropping mix in highly vulnerable agricultural areas; (iii) maximizing production in climate-proofed farming areas, particularly those with moderate rainfall; (iv) developing policy environments for sustainable development of highland ecosystems; (v) increasing competitiveness of local farmers with global products within local markets; and (vi) harmonizing food and bio-energy development and other economic uses of agricultural products.

5.2 METHODS AND PROCEDURE

There are a number of issues and processes impinging on agriculture and fisheries and also threatening sustainable development. These include: (i) rapid population growth, (ii) unregulated land use and land cover change, (iii) rapid urbanization, (iv) industrialization, and (v) climate change. These drivers of change exert pressure on already heavily stressed land and water resources, ecosystems, and communities. Changing climate characterized by increased temperature, erratic rainfall patterns, more intense extreme climate events, and sea level rise (SLR) have adverse effects and impacts and will increase the vulnerability of most of the already highly vulnerable sectors of society including biodiversity, agriculture and fisheries, and livelihoods. These drivers, threats, and factors are interrelated, multifaceted, and multidimensional. Figure 5.1 shows, for example, the relevant processes resulting in land degradation of production areas, biodiversity depletion and loss, and increased vulnerability to environmental risks (Fuentes & Concepcion, 2007). Climate change is expected to further exacerbate the degraded state of water and soil resources, coastal areas, biodiversity, and agro- and aquatic ecosystems resulting in soil loss and fertility depletion, and increased vulnerability which can impair agricultural productivity and pose greater risks to the agriculture and fisheries sector (Lansigan, 2011).

5.2.1 Analysis of Historical Climate

The complexity of the agriculture and fisheries sector, and the assessment of the effects and impacts of and vulnerability to climate change of elements or components of the sector, require knowledge-based and systems approaches employing the use of scientific assessment procedures and applications of objective methodologies. These include data analysis of long-term historical records, vulnerability and impact assessment procedures, systems modeling and simulation tools, climate scenario analysis, and socio-economic modeling and analysis (e.g. Matthews & Stephens, 2002; International Food Policy Research Institute [IFPRI], 2009). The systematic approach to the assessment of the effects and impacts of climate change is schematically illustrated in Figure 5.2 (International Water Management Institute [IWMI], 2001). The analysis involves the use of climate data at different scales, generated data from General Circulation Models (GCMs) for climate scenarios considered, application of downscaling and upscaling techniques to synchronize datasets used, and appropriate data acquisition and analysis procedures such as socio-economic surveys, and impact analysis and modeling techniques (IFPRI, 2009).

5.2.2 Analysis of Future Climate

Considering the long-term historical climate data for a number of locations in the Philippines, Cinco et al.

(2014) have analyzed the trends in the changing climate in the country over several decades. IRRI (2003) has also established an increase of 1.1°C in the mean minimum temperature in its station in Los Baños, Laguna over a decade spanning from 1960 to 2001. Analysis of available historical data has also shown statistically significant changes in the mean and variance of weather parameters. For example, the probability distribution of extreme daily rainfall events in Los Baños, Laguna have been found to have changed from a more or less uniform distribution to a skewed one based on analysis of historical data in 1959 to 2006 (Lansigan, de los Santos, & Hansen, 2007; Lansigan, 2011). Other studies also reported significant changes in statistical properties and distributions over certain areas in the Philippines (e.g. Lansigan et al., 2007; Philippine Atmospherical, Geophysical and Astronomical Services Administration [PAGASA], 2011; Cinco et al., 2014).

5.2.3 Crop Impact Modeling

Temperature gradient tunnel (TGT) experiments and simulation studies using process-based crop simulation models (CSM) have been used in a number of studies to evaluate the effects and impacts of climate change on crop growth and development (Matthews et al., 1995; Lansigan, Cruz & Lasco, 2008; Cruz et al., 2016). Effects of temperature increase and carbon dioxide fertilization on annual crops such as rice and corn are commonly studied (Lansigan & Salvacion, 2006; Lansigan, Cruz & Lasco 2008; Balderama, Alejo, & Tongson, 2016), but simulation studies on other crops in the Philippines such as tomato, peanut, and sugarcane are also reported (Lansigan & Salvacion, 2012). Experiments and simulation studies have consistently indicated the same adverse effects of climate change on crop yields, growth, and development although the extent of effects varies across locations, seasons, and crop varieties.

5.2.4 Socio-economic modeling and analysis

Analysis of anticipated climate change scenarios is facilitated by the use of GCMs (Intergovernmental Panel on Climate Change [IPCC], 2000). However, impact assessment studies require data at finer resolution. Thus, regional climate models (e.g. PRECIS model) are developed and used. PAGASA (2011) used the PRECIS model to provide updated climate data for future climate in the Philippines for different time periods. Other downscaling techniques are also applied such as the regression-type models, historical analogue procedure, and statistical downscaling model (Wilby et al., 2002). Statistical downscaling procedure is easier to use, and also provide reliable climate datasets for impact assessments. Downscaled datasets used in crop modeling are also linked with national scale socio-economic model (e.g. IFPRI's IMPACT Model, Rosegrant et al., 2016) to evaluate effects and impacts of climate change on food security and sustainable development. Efficient assessment of effects and impacts of climate change involves use of appropriate downscaling and upscaling tools to generate the required datasets.

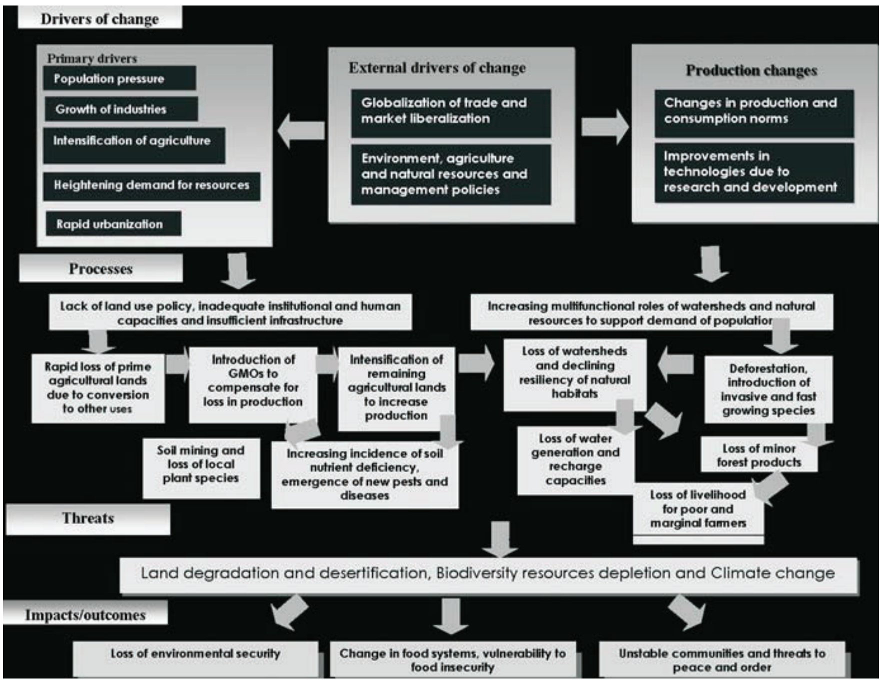

Figure 5.1. Key influences for land degradation and vulnerability to climate change and variability in the Philippines (Fuentes & Concepcion, 2007)

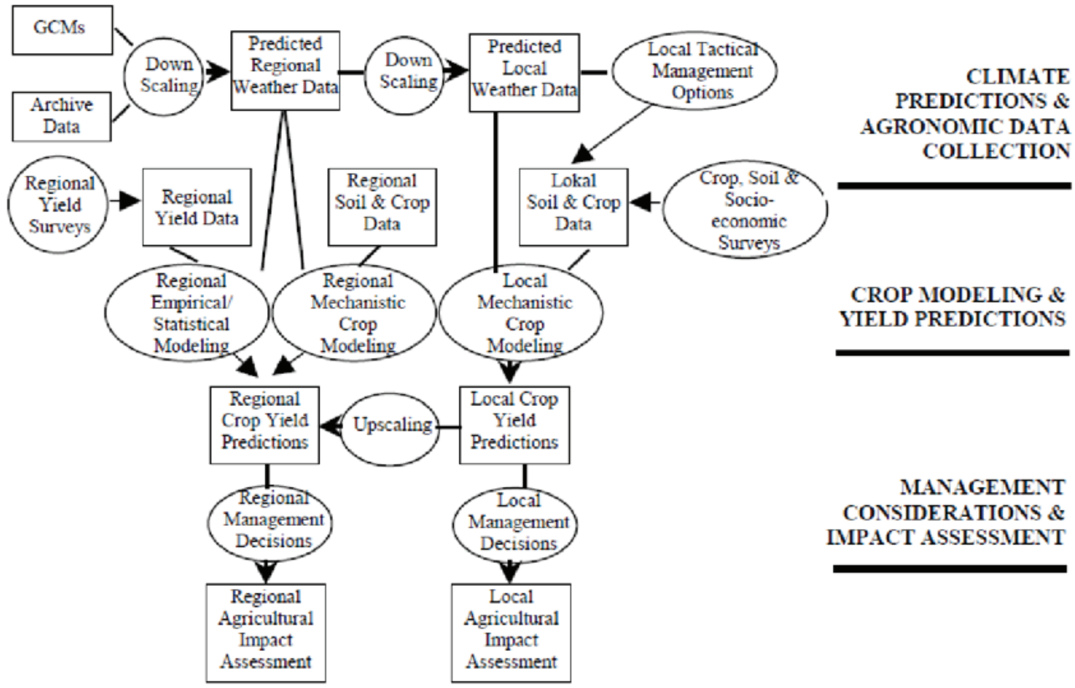

Figure 5.2. Framework for climate variability, crop forecasting and impact assessment. (IWMI, 2002)

5.3 IMPORTANCE OF AGRICULTURE AND FISHERIES

Agriculture and fisheries is an important sector of the Philippine economy. Figure 5.3 shows that this sector contributes to employment in the country second to the services sector. It provides a living for a third of the country's labor force. Figure 5.4 shows the percentage contribution of the agriculture sector to Gross Domestic Product (GDP) at constant 2000 prices from the period 1946 to 2010. During the last three years (from 2013 to 2015), the sector contributes about 10% to GDP with agriculture contributing an average of 8.1%; forestry, 0.1%, and fisheries, 1.8% (National Economic and Development Authority [NEDA], 2017). However, the sector grows slowly exhibiting an annual mean gross value added (GVA) of 1.0% for the period of 2013 to 2015. Moreover, during the last three years, the subsectors of agriculture and fisheries, namely, crops, livestock, poultry, and fisheries registered an annual average GVA growth of 0.2%, 2.2%, 3.4% and -0.4%, respectively (NEDA, 2017). GVA is defined as the difference between gross output and the intermediate inputs, with gross outputs of a production unit during a given period (given by the gross value of the goods and services produced during the period, and intermediate outputs referring to the value of goods and services used in the production process during the accounting period). The underperformance of crops and fisheries subsectors are partly attributed to the impacts of extreme climate variability such as El Niño episode and frequent tropical cyclones (TCs). About three-fourths of the poor who are vulnerable to climate risks are in the rural areas dependent on the agriculture and fisheries sector.

In value terms, the leading agricultural crops are rice, corn, sugarcane, coconut, banana, mango, pineapple, cassava, coffee, sweet potato, and eggplant. In terms of harvest area, the most extensively grown crops are rice, coconut, corn, sugarcane, banana, cassava, coffee, mango, sweet potato, and Manila hemp (Altoveros & Borromeo, 2007). The average annual share of rice and corn to the crops subsector is about 24.9% and 7.1%, respectively, for the period 2013 to 2015. On the other hand, commercial fisheries as well as municipal fisheries showed weak performance. A number of reasons for the underperformance have been cited such as frequent occurrence of TCs limiting fishing opportunities, decrease in population of some commercially important species in fishing areas, overexploitation of fishery resources, and illegal fishing practices and activities (NEDA, 2017).

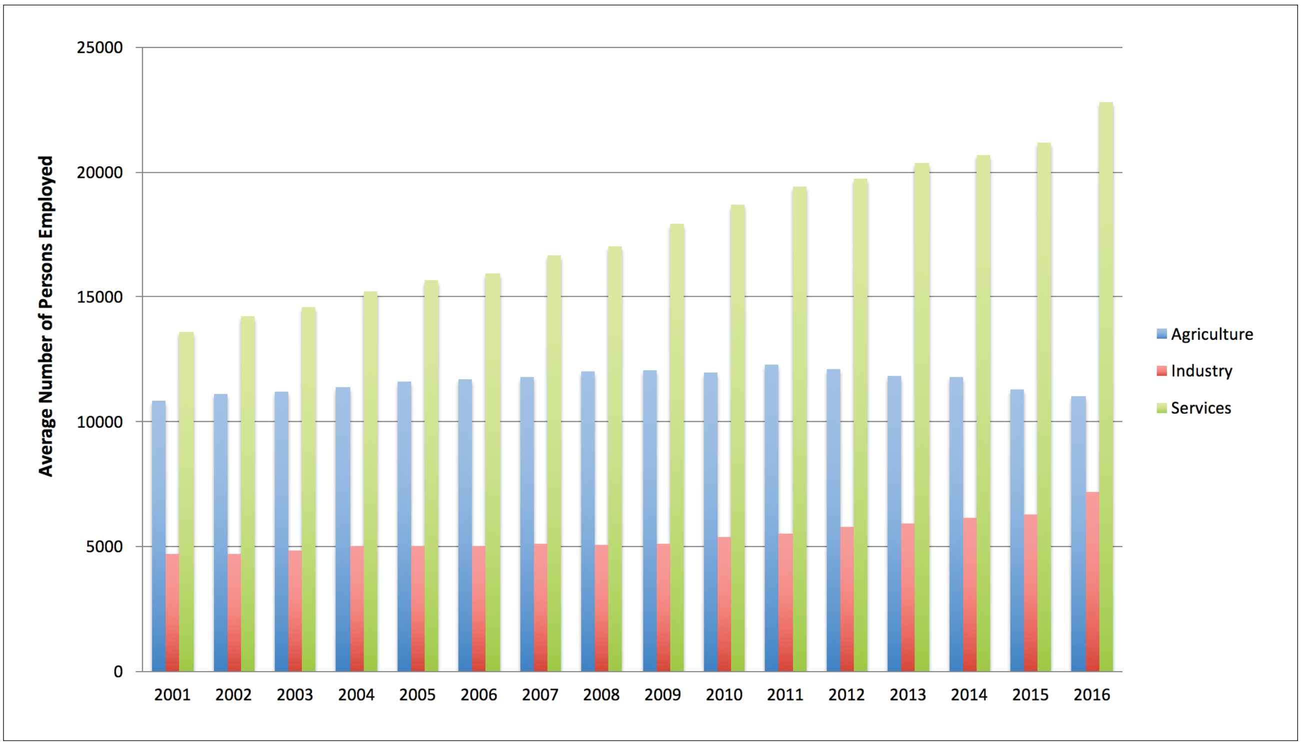

Figure 5.3. Average employment by major industry group, 2001-2016 (CountrySTAT Philippines, PSA, n.d.)

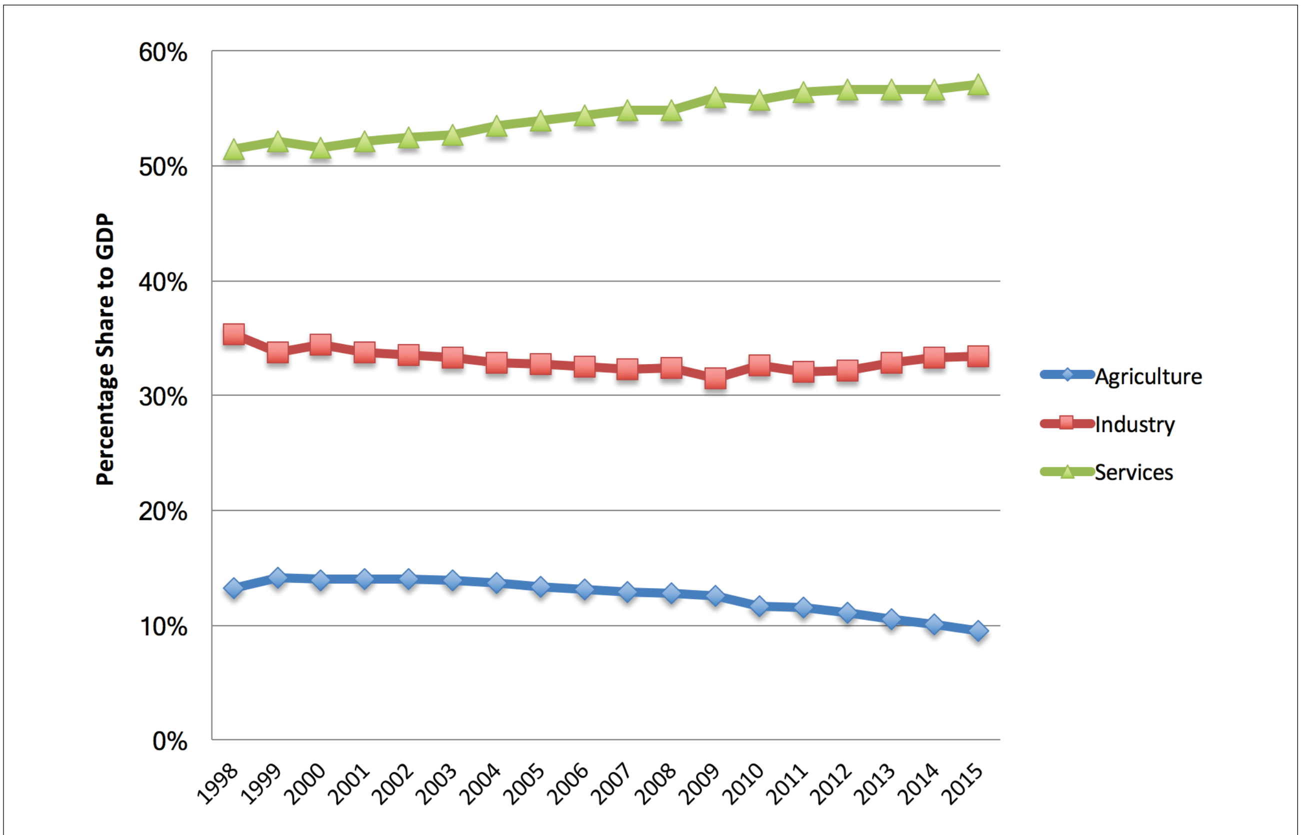

Figure 5.4. Contribution of the agriculture sector to GDP at constant 2000 prices (1998-2015) (CountrySTAT Philippines, PSA, n.d.)

5.4 CURRENT SENSITIVITY AND VULNERABILITY

Climate change threatens crop productivity thereby putting food security at risk (Comiso, Espaldon, Lansigan, Blanche, & Sarigumba, 2013). Assessments show that the significant differences in the total annual rainfall, together with the changes in the onset and recession of the rainy season, and the increase in nighttime temperatures could significantly influence agricultural planning and production and overall productivity of farming systems (Tibig, 2001 as cited in Comiso et al., 2013). The increase in temperature and rainfall during the summer increase agricultural production, while increasing temperature during the fall season reduces production (Lee, Nadolnyak, & Hartarska, 2012). Rice production in the Philippines is also severely affected by TCs (Lansigan, 2005). In general, major impacts to agricultural production include higher incidence of pests and diseases, low crop productivity/yield, stunted growth, delays in fruiting and harvesting, declining quality of produce, increased labor costs, and low farm income (Tolentino & Landicho, 2013).

All forms of climate variability and extremes have negative impacts to farming (Peras, Pulhin, Lasco, Cruz, & Pulhin, 2008). Rainfall is the most important climatic element in the Philippines because agriculture, influenced by the annual and seasonal variation of rainfall, plays an important role in the economy (Jose, 2001 as cited in Akasaka, I., Morishima, W., & Mikami, T., 2007; United Nations International Strategy for Disaster Reduction [UNISDR], 2015). Agricultural production is adversely affected by highly variable rainfall patterns and distribution that are observed more frequently in recent years. Agricultural crops, particularly rice, are very sensitive to water and temperature stress. Dry spells or heavy rainfall occurring immediately after seedlings are planted or seeds are sown cause the plants to die due to water or heat stress (Peñalba, Elazegui, Amit, Lansigan, & Faderogao, 2012). An analysis of temperature trends and irrigated field experiments using standard varieties such as IR-72 and IR-64 at IRRI showed that increased temperatures brought about a 10% decline in grain yield for each 1°C increase in minimum temperature in the dry season (Peng et al., 2004). In particular, a 1°C increase in minimum temperature during summer decreases yield by 64 kg/ha. Similarly, rice yield diminishes by 36 kg/ha for every 1% increase in the share of wet days (Bordey, Launio, Quilang, Tolentino, & Ogena, 2013). The decrease in crop yield may be due to a shorter maturity period and an increase in potential evapotranspiration as a result of increased daytime and nighttime temperatures, which are critical to dry matter production (Buan, Maglinao, Evangelista, & Pajuelas, 1996), and also inducing spikelet sterility. In terms of rice quality, transpirational cooling is suggested to be a key factor affecting chalkiness and head rice yield, and global warming in combination with other climate factors enable the crop to maintain a cool canopy (Zhao & Fitzgerald, 2013).

Climate anomalies brought about by ENSO events affect agricultural production in different ways. Rainfall variability can generate a feedback mechanism between solar radiation, air temperature, and soil moisture that affect the ecosystem carbon dioxide (CO_2) exchange. As examined in Alberto et al. (2012), both flooded and non-flooded rice ecosystems can potentially become weaker or stronger sinks of atmospheric CO_2 during ENSO events.

In irrigated systems, there can be a decline in production due to decreases in area harvested as compared to rainfed systems which are less buffered against drought stress and where land is taken out of rice production in response to El Niño events (Roberts, Dawe, Falcon, & Naylor, 2009). The reduction in area and yield due to severe El Niño in 1997 to 1998 caused a 100% loss in production during the dry season and more than 33% during the wet season throughout the country. The 2004 El Niño caused 18% dry season and 32% wet season production losses nationwide. Records from NIA indicate that rice yield fell by more than two cavans (1 cavan = 50kg) per ha below average in both the wet and dry season cropping periods of 1990 as a result of drought and typhoons (Peras et al., 2008). The 1999 La Niña brought about around 26% and 45% production losses during the dry and wet seasons, respectively (Rola & Elazegui, 2008). The inter-annual variation of rice production is found to have a significantly positive correlation with that of rainfall in the first half of the year in each region, except for Central Luzon, Ilocos Region, and Caraga Administrative Region (Morishima & Akasaka, 2008). This demonstrates the tendency of drought with the warm event of ENSO to decrease the harvest in the south of Southern Tagalog in the first half of the year (Morishima & Akasaka, 2008). In the Pantabangan-Carranglan Watershed, strong typhoons, droughts associated with El Niño episodes, and delayed onset of rainy season bring substantial impacts to a greater number of farmers compared to La Niña (intense rain), early onset of rainy season, and prolonged rain. The average income loss of farmers from El Niño based on the experience of 112 farmer-respondents was estimated at PhP 28,810 (USD 702) representing 68.54% of the average household farm income in 2003. This indicates that the absence or limited supply of water during El Niño and delayed onset of rainy season have more adverse impacts (Peras et al., 2008).

For fisheries, the Philippine total fish catch using a 34-year observation is shown to be very elastic in terms of chosen determinants (Daw-as, Paca, & Navarro, 2010). For example, a 1% change in fishing effort, rainfall, temperature, and humidity can bring about a drastic change in total fish production in commercial and municipal fishing. Within the Coral Triangle, fisheries are experiencing changes in species composition, distribution, and yield of fish and invertebrates due to overfishing, increasing SST, and changes in ocean circulation (Coral Triangle Initiative [CTI], 2011). Climate change has also been seen to affect physiological processes and the seasonality of biological rhythms, altering food webs, and, consequently, fish production in the area. Climate impacts to coral reefs, including coral bleaching and ocean acidification, are likely to impact fisheries associated with these habitats. Consequently, food security and livelihoods are at risk (David et al., 2008).

The biophysical and economic impacts on the agricultural sector can vary. A scenario analysis on the effectiveness of the Association of Southeast Asian Nations (ASEAN) Plus Three Emergency Rice Reserve (APTERR) indicates that, given a massive calamity impact of a 5% production shock in China and Indonesia, there will be a contraction in national consumption by about 3 to 4% in the countries affected, accompanied by a 30 to 50% increase in national consumer prices (Briones, Durand-Morat, Wailes, & Chavez, 2012). In the Philippines, sensitivity analysis shows that changes in rice yield and gross revenue per hectare due to extreme weather changes significantly affected overseas migration (Bordey et al., 2013). The number of total overseas Filipino workers (OFWs) is observed to increase by five persons per thousand population for every one metric ton decrease in average yield. In particular, the number of female OFWs increased by seven persons per thousand female population when a one metric ton decrease in average yield demonstrating that female overseas migration is more affected by extreme weather-related decline in rice productivity. Moreover, a gender-based climate change finance study cited the findings of an organization working with women farmers also in the Philippines that climate change can disproportionately affect women farmers because: (i) they have fewer assets to sell to cope when harvests of working women farmers collapse due to floods or droughts; (ii) more women than men fall into chronic indebtedness related to climate-induced crop failures because microcredit is largely targeted at women, and as managers of production and household expenses, they are under stronger pressure to bridge resource gaps; and (iii) they prioritize the food needs of male household members and children over their own during periods of food shortages when harvest is poor (Peralta, 2008).

The perceived impacts of climate change on agriculture and fisheries can also vary as shown in Table 5.1 below.

Table 5.1. Perception of impacts of climate change on agriculture and fisheries

Sector	Perceived impacts of climate change/climate variability and extremes	Reference
Agriculture	*Small farmers*: decline in crop production, income, food availability, and livelihood resources; health condition affected; more debt incurred especially by landless farmers *Average farmers*: decline in crop harvest, income, and livelihood sources; health condition may or may not be affected *Rich farmers*: decline in production and income; no change in food availability, livelihood, and health	Pulhin et al., 2007; Peras et al., 2008
	Rainy season: increase in agricultural production; overflow of the rivers resulting to destruction of crops; occurrence of soil erosion and decrease in soil fertility *Early onset of rainy season*: relatively high agricultural production due to early cultivation of upland resulting to higher income *Late onset of rainy season*: resorting to other sources of livelihood; insufficient farm production to meet family needs *La Niña*: flooding and excessive soil erosion make soils in the upland lose its fertility thereby damaging crops *El Niño*: low or non-productivity of crops due to lack of moisture; loss of income; extreme dryness increases the possibility of fire *Dry season*: damaged crops *Typhoons*: typhoons becoming stronger and bringing more rains	Amano, Amano, & Candelaria, n.d.
	Early onset of rainy season: increased yield for many farmers; early cropping; no need to water crops; favorable for some crops such as abaca and banana; appearance of blight and fungi; increased pest and diseases; rotten crops; decreased yield for some farmers *Delayed onset of rainy season*: crops dry up; decreased yield; crops produced are of poor quality; delayed planting; short period of time that farmers can plant	Pulhin, Lasco, Espaldon, & Gevana, 2009
	Income loss; loss/damage to crops; reduced soil fertility; sick or weak livestock; household food insecurity; loss of savings; loans	Peñalba et al., 2012
	Flooding of lowland farms; heavy siltation and sedimentation of farms; damaged crops/less harvest/less income; damaged irrigation facilities/dikes	

Table 5.1. Continued

Sector	Perceived impacts of climate change/climate variability and extremes	Reference
Agriculture	Changes in growing seasons; heat stress in plants and animals; increased yields (up to 2°C increase for some crops); increased outbreaks/incidence of pests and diseases; changes in hydrological cycle; changes in rainfall regimes; changes in crops and crop areas; more severe droughts and/or floods; deterioration of land cover/land resources; changes in water resources (irrigation); changes in frequency/intensity of extreme climate events; increased damage to crops and/or livestock; decreased productivity; increased soil erosion	Duhaylungsod & Mendoza, 2009
	During El Niño: cannot plant crops, or if planted already, take a long time for these to grow; crops/ rain-fed farmlands dry out; decrease in crop yield/ sometimes no harvest; rat infestation of farms, as well as sparrows and insects due to unavailability of other food sources; livestock and poultry get undernourished or die (no food as even the fodder dries out); size of coconut fruits and other vegetables shrink; soil is dry and cracked; lost moisture in soil; cracked land in the farms *During typhoon*: damages to crop leading to losses in yield, and sometimes total crop failure; rice fields washed out; difficulty in procuring seeds; sediments from landslides make the rice below over fertilized resulting in smaller grain filling inside the rice spikelet; damaged irrigation (in San Antonio); coconut fruit falls; it takes three years to resume normal production of coconut trees after a strong typhoon; some livestock/poultry also get washed away by flood waters	Tapia, Pulhin, & Peras, 2014
	Reduction in area cultivated; modification in choice of crops or cultivars; changes in agronomic practices (fertilizer use, irrigation, and control of pests and diseases); using farm wastes wisely; organic farming; use of sulfate-containing fertilizers; direct seeding crop establishment; planned cropping sequence and schedule; crop insurance	Pulhin, Peras, & Tapia, 2010
Fisheries	Reduced fish yield per catch; longer time spent in fishing; need to shorten fishing time due to typhoons; change fishing method; disruption of fishing schedules due to extreme heat; uncomfortable fishing conditions	Pana & Sia Su, 2012
	Income loss; low fish catch/less fishing days; danger at sea/loss of life; sickness/injury; damage to fishing equipment; unemployment; household food insecurity; loss of savings; loans	Uy et al., 2011
	Heavy siltation and sedimentation of fish ponds; destruction of fish pens/cages; less fish catch/income; destruction of fishing boats and gear; less income for fish processors/hired workers	Peñalba et al., 2012

5.5 ASSUMPTIONS ABOUT FUTURE TRENDS

Agriculture and fisheries in the country could be severely affected by temperature changes coupled with changes in rainfall regimes and patterns through decreases in yields and increased incidence/outbreaks of pests and diseases, both in plants and animals (PAGASA, 2011). Process-based crop simulation models indicate that yields of rice and other crops tend to decrease from 8 to 14% for every 1°C increase in temperature depending on location in the Philippines (Comiso et al., 2013). Longer dry months will reduce length of growing seasons and shorten available growing windows for rainfed farms (Tongson, Alejo, & Balderama, 2017).

Adverse impacts on forestry areas and resources are expected to multiply in a warmer climate. Changes in the forest ecosystem can lead to unfavourable conditions for certain highly sensitive species. Drier conditions can lead to increased incidence of forest fires. Traditions and livelihoods of forest communities may be altered and can lead to further degradation of the environment (PAGASA, 2011).

5.6 KEY FUTURE IMPACTS AND VULNERABILITY

In the preparation of the Second National Communication (SNC) to the United Nations Framework Convention on Climate Change (UNFCCC), a national vulnerability assessment for prioritized sectors had been undertaken. For the agriculture sector, rice was targeted. To assess its projected yields under elevated concentration of CO_2 (e.g., 390-, 420-, 450-, and 510-ppm CO_2), ORYZA2000 Rice Model runs were made in three representative provinces (i.e., Albay, Bohol, and Surigao del Norte). Assumptions made in the runs included no water and nitrogen limitations and under controlled pest incidence. All the model runs indicated decreasing yields under increasing CO_2 concentrations (Centeno, 2009, personal communication).

Simulation studies using process-based crop simulation models gave estimates of magnitudes of rice and corn yields as affected by climate change, particularly temperature increase and CO_2 fertilization. The study of Mathews et al. (1995) indicated varying responses under different GCMs, namely: 6.5% increase (Geophysical Fluid Dynamics Laboratory [GFDL]), 4.4% decrease (Goddard Institute for Space Studies [GISS]), and 5.6% decrease (United Kingdom Met Office [UKMO]). On the other hand, the Centeno, Balbarez, Fabellar, Kropff, and Matthews (1995) simulations under the same GCMs (e.g., GFDL, GISS, and UKMO) gave the estimated changes in rice productivity in each of the administrative regions in the country, also with varying responses (See Table 5.2). For the whole country, there was a 6.6% increase (GFDL), 14% decrease (GISS), and 1.1% decrease (UKMO). The responses in both model runs showed to be more or less in the same direction, even as the magnitude varied.

Table 5.2. Estimated changes in rice production from the regions and the whole country. (Centeno et al., 1995)

Region	Current	GFDL		GISS		UKMO	
		%change	t	%change	t	%change	t
NCR	125,559	2.6	156,476	-11.1	135,669	16.9	178,319
I	898,584	-3.8	864,238	-17.0	745,538	2.2	918,241
II	1,033,615	-3.8	994,108	-17.0	857,571	2.2	1,056,226
III	1,748,491	2.6	1,793,379	-11.1	1,554,911	16.9	2,043,730
IV	1,118,085	10.2	1,232,604	-6.2	1,048,730	-0.4	1,113,437
V	744,223	5.4	784,357	-32.0	506,260	-20.5	591,716
VI	1,183,887	11.9	1,324,583	-11.1	1,053,064	-7.4	1,096,816
VII	207,700	11.9	232,384	-11.1	184,749	-7.4	192,424
VIII	382,954	11.9	428,465	-11.1	340,637	-7.4	354,789
IX	399,038	18.5	473,040	5.7	421,617	11.1	443,166
X	531,777	10.5	587,861	-22.1	414,386	-39.5	321,605
XI	688,302	13.3	779,593	-16.9	571,880	01.4	678,580
XII	584,047	13.3	661,510	-16.9	485,259	-1.4	575,798
Totals	9,673,262		10,312,598		8,320,271		9,564,847
%change from current			6.6		-14.0		-1.1

A study showed both increases and decreases in rice yields but a consistent decrease in corn yield (Buan et al., 1996). Crop simulations in Isabela by Tongson et al. (2017) likewise showed mean corn yield reductions of 34 to 41% by 2050 and 41% decline in mean yields under best case scenario and 17% under the worst-case scenario by 2090. Growing days (days to maturity) were projected to be reduced by 7 to 9 days (7 to 8%) by 2050 and by 8 to 15 days (7 to 13%) by 2090, corresponding to 3 to 5% decrease in growing periods per degree rise for all scenarios. The study by Balderama et al. (2016) indicated projected corn yield reductions by up to 44% in 2020 and 35% in 2050 due to temperature and rainfall changes.

In another study, baseline scenario projections for 2004 to 2080 showed an estimated decline of agricultural productivity of 23.4% for the Philippines in the 2080s if carbon fertilization effect did not materialize. However, the Philippines is expected to maintain overall surpluses in agricultural trade over the projection period despite the decline of share of agriculture in gross value added. The projected impacts on agricultural production and trade in Southeast Asian countries are shown in Table 5.3 (Zhai & Zhuang, 2009).

Table 5.3. Projected impacts on agricultural production and trade in selected Southeast Asian countries.

	Indonesia	Malaysia	Philippines	Singapore	Thailand	Vietnam
Output						
Crop Agriculture	-13.4	-13.4	-22.5	-47.6	-29.4	-11.1
Rice	-15	1.6	-11.9		-36.3	-13.6
Other grain	-9.9	-52.6	-13		-26.5	-0.1
Other crops	-13.4	-31.1	-25.6	-47.6	-27.4	-7.4
Livestock	-4.4	-2.6	-0.3	105.1	12.6	-5
Processed food	-6.4	5.5	-4.2	12.7	-0.9	-14.2
Exports						
Crop Agriculture	-25.3	-49.2	-56.7	-49.2	-59.4	10.3
Rice	-17.1	-51.2	-73.2		-41.5	46.8
Other grain	-39.9	74.6	-48.8		-58.2	-11.2
Other crops	-25.1	-49.1	-56.7	-49.2	-60.3	9.8
Livestock	1.9	21.9	57.5	117.6	82.1	20.6
Processed food	-7.3	4.8	-7.4	13.8	-1	-21.6
Imports						
Crop agriculture	8.7	4.7	24.3	-0.4	11.9	-9.3
Rice	15	50.6	34.1	1.5	13.9	32.8
Wheat	-2.7	15.6	17.7	2.2	4	-15.3
Other grain	30.8	3.3	42.8	7.4	69	-27.6
Other crops	13.6	3.2	34.1	-0.6	12.1	-6.8
Livestock	-9.9	-16.4	-25.2	-4.2	-24.3	-12.2
Processed Food	-13.6	-14	-12.4	-1.9	-16.1	-16.7

Source: Zhai and Zhuang (2009)

Findings of agent-based simulations suggested that only a production support that was complemented with market support would cause a substantial reduction in vulnerability. However, this may not hold true when impacts of climatic and economic risks act together (Acosta-Michlik & Espaldon, 2008).

Results of Light Detection and Ranging (LiDAR)-derived flood inundation mapping showed that rice production would suffer decreasing yield because of the increasing frequency and magnitude of flood events. The total area of cultivation areas that could still use regular rice varieties would decrease as rainfall intensity increased (Yokingco, Toda, Lasco, & Pulhin, 2015; Yokingco, Pulhin & Lasco, 2016). Extreme climate events could influence poverty by affecting agricultural productivity and raising prices of staple foods that are important to poor households. A study using simulated extreme climate indicators found that climatic extremes exerted substantial stress on low income populations especially the urban, wage-labor-dependent stratum due to their extreme exposure to food price increases. Since food was a major expenditure, this group's overall consumption fell with rising prices, pushing them below the poverty threshold of consumption (Ahmed, Diffenbaugh & Hertel, 2009).

5.7 ADAPTATION

5.7.1 The Context for Adaptation

Agriculture in the Philippines is strongly dependent on water resources and climatic conditions, primarily because of the country's high sensitivity to climate hazards, such as TCs and associated storm surges, intense rain events, prolonged and extensive droughts (which in most cases are El Niño-related), and floods. At times, the combination of the main physical factors affecting agricultural production (i.e. soils, terrain, climate, and input availability) is less suited to farming. As a consequence, crop production is extremely sensitive to large year-to-year weather fluctuations. The increasing trends of temperatures and rising sea levels (particularly in agricultural areas found near the coasts so that saline water intrusion becomes a main problem) compounded by changes in rainfall patterns, including onset and duration of rainy and dry seasons, are increasingly being seen to add to the decreases in agricultural production. Moreover, crop diseases or pest infestations are also weather-dependent and tend to cause more damages, especially in areas with lower technological levels (Government of the Philippines, 2014).

5.7.2 Adaptation Options in Principle

The NFSCC aims to address vulnerabilities in the country's agricultural sector by building the resilience of food production systems through mainstreaming of sustainable agriculture and aquaculture and related developments in the sector. The objective is to protect and enhance ecosystems and ecosystem services to secure food and water resources and livelihood opportunities. To this end, the strategic priorities are: (i) reduce climate change risks and vulnerability of natural ecosystems and biodiversity through ecosystem-based management approaches, conservation efforts, and sustainable environment and natural resources (ENR)-based economic endeavors such as ecotourism; (ii) increase the resilience of agriculture communities through the development of climate change-sensitive technologies, establishment of climate-proof agricultural infrastructure and climate-responsive food production systems, and provision of support services to the most vulnerable communities; (iii) improve climate change resilience of fisheries through the restoration of fishing grounds, stocks, and habitats and investment in sustainable and climate change-responsive fishing technologies and products; (iv) expand investments in aquaculture and in other food production areas; (v) strengthen the crop insurance system as an important risk sharing mechanism to implement weather-based insurance system; and (vi) strengthen sustainable, multi-sectoral, and community-based resource management mechanisms (Government of the Philippines, 2014).

To be able to manage climate and climate change-related risks, agricultural communities require at minimum: (i) awareness that weather and climate extremes and climate change will impact on their operations; (ii) understanding of weather climate, including knowledge of historical weather and climate variability where they are located; (iii) tools by which they can describe extremes and variability; and (iv) access to early warning/forecasts and the ability to apply these to decision making (Government of the Philippines, 2014). In this regard, there are a range of options that can be used to adapt to the impacts of climate change including: (i) selection of appropriate planting date, (ii) use of traditional varieties and breeding of new varieties, (iii) site-specific nutrient management, (iv) alteration of farm management practices, (v) system of rice intensification, (vi) crop rotation, and (vii) rice and integrated pest management (Redfern et al., 2012).

As a strategy, agroforestry is believed to be critical to climate change adaptation (CCA) because of the diversity of direct and indirect benefits from the system, and the diversity of crop products. For example, the loss of one crop can be compensated by another crop, particularly woody perennials (Tolentino & Landicho, 2013). Multiple benefits including enhanced global and local ecosystem services, biological diversity, food security, and smallholder resilience could be realized by incorporating trees into a multifunctional, diverse landscape mosaic and agricultural system (Lasco, Delfino, Catacutan, Simelton, & Wilson, 2014). Related to agroforestry is the conservation agriculture with trees (CAT) strategy which follows the Landcare approach, with principles and practices founded on minimal soil disturbance; continuous mulching; pests and nutrients management; species rotations; integration of trees; and rainwater harvesting for sustainable crop production intensification leading to increased crop yields, soil organic matter, and soil moisture; and improved income and resilience of farmers to environmental stresses (e.g., drought, intense rainfall, typhoons) while reducing labor and capital costs (Mercado, Lasco, & Reyes, 2016).

Conservation farming village as an adaptation approach aims to transform traditional upland farming systems into sustainable upland production systems (e.g., by integrating agroforestry and other conservation farming technologies and practices) not only to address upland degradation but also to stimulate upland community development that is adaptive to climate change (Cruz et al., 2016).

Other adaptation options include: (i) improved management of soil and water resources to mitigate drought conditions and ensure water availability; (ii) flood and drought monitoring systems to respond appropriately to hazard events; (iii) soil conservation measures (such as composting and terracing); (iv) establishment of windbreaks (strips of trees, shrubs, and vines to reduce wind-related evaporation and damage associated with heavy rains); (v) engineering solutions (such as pipe irrigation which controls evaporation, percolation, and seepage); (vi) introduction of improved seeding techniques, small reservoirs, and improved outdoor grain storage facilities; (vii) improved livestock production; (viii) mapping of vulnerable agricultural areas; and (ix) research on indigenous resilient crop species (World Bank, 2011).

Measures that have the potential to increase the resilience of the forestry sector are shown in Table 5.4. In general, the main types of adaptation options in agriculture are shown in Table 5.5. Various adaptation options with the primary objective of attaining food security through improved yields, efficient use of production inputs, and optimal use of government resources for both the medium and the long term are provided in Table 5.6.

With regard to buffaloes and other livestock animals which are experiencing increasing incidents of animal heat stroke and proliferation of other pests and diseases brought by ENSO-related events and extreme weather brought by climate change, the preservation of animal genetic resources through cryobanking becomes an adaptation option. Cryobanking ex-situ conservation serves as a source of genetic materials of animals with superior traits. These can adapt to the environmental changes caused by current and predicted climate changes thereby: (i) preserving genetic sources from buffaloes and other domesticated animals as well as threatened indigenous species, and (ii) ensuring that the genetic diversity of animals is sustained (Villamor, 2016).

Table 5.4. Adaptation needs in the forestry sector (Government of the Philippines, 2014)

Adaptation Measure	Activity
Forest law enforcement	• Harvesting and utilization of timber and non-timber forest products • Rights of access to use forestlands for legitimate purposes • Land conversion and classification • Trade of forest products
Building institutional capacity for improved forest management	• Land capability evaluation to improve land use selection that will minimize impacts of improper land uses and minimize risks of damages and losses due to climate change and other stressors • Participatory land use planning tools and procedures • Comprehensive system for monitoring natural resources, watersheds, and ecosystems under changing environmental conditions • Models for assessment of watershed and ecosystem functions and services under future climate and socio-economic scenarios • Integrated Natural Resources Information System
Research and development of technologies	• Planting drought-resistant species in dry or vulnerably-dry sites • Planting of wind-firm species in typhoon belts • Improve species selection for i. Water-use efficient species ii. Wind-firm species iii. Drought-resistant species • Breeding and selection of climate-adapted trees i. Tolerate high carbon concentration ii. High carbon sequestration potential iii. Higher yield/fast growth

Table 5.4. Continued

Adaptation Measure	Activity
Research and development of technologies	iv. Drought-resistant v. Pest resistant • Employment of landscape approach in designing and locating plantations.
Adoption of measures to conserve biodiversity, soil and water	• Establishment of biodiversity corridors linking plantations to natural forests will reduce the patchiness of forests which is common in many areas that has been denuded in the past • Improved forest fire protection (fire susceptibility assessment tools) and control • Mixed planting of slow-growing and fast-growing species for multi-storey plantations • Use of contour planting in soil-erosion prone sites • Establishment of shelterbelts using wind-firm species to protect plantations
Strengthen community-based strategies	• Implement participatory land use zoning and planning that prohibits settlement in vulnerable places • Establish an effective and efficient early warning system to minimize risks associated with climate change • Build the different capital assets of local communities • Secure land and natural resources tenure and property rights • Develop more responsive institutions sensitive and supportive of the local needs and priorities

Table 5.5. Main types of adaptation options in agriculture (Government of the Philippines, 2014)

Technological	• Crop development
	  • new crop varieties to increase tolerance and suitability
	• Weather and climate information systems
	  • early warning systems that provide weather and climate forecast
	• Resource management innovations
	  • develop water management innovations, including irrigation
	  • develop farm-level resource management innovations

Government programs and insurance	• Agricultural subsidy and support programs
	  • modify subsidy, support, and incentive programs to influence
	  • farm-level production practices
	  • change assistance programs to share publicly the risk of farm-level income loss associated with disasters and extreme events
	• Resource management programs
	  • develop and implement policies and programs to influence farm-level and water resource use and management in light of changing conditions
	• Private insurance
	  • develop private insurance to reduce climate-related risks

Farm financial management	• Diversify source of household income • Develop alternative livelihood sources

Farm production practices	• Farm production
	  • diversify crop types and varieties to address environmental variations
	  • change intensification of production to address risks
	• Land use
	  • change location of crop/livestock production
	• Irrigation
	  • implement selective irrigation practices to address moisture
	  • deficiencies
	  • timing of operations
	  • change timing of farm operations to address changing growing
	  • seasons and changes in climate

Table 5.6. Adaptation options in the medium- and long- term (Government of the Philippines, 2014)

Adaptation options	Medium-term	Long-term
Government programs		
Review programs currently being implemented vis-à-vis climate change risks	x	
Mainstream climate change in plans/programs	x	x
Review subsidies such as fertilizers, seeds, etc.	x	
Modify subsidies, if necessary, and support services to influence farm level practices	x	x
Establish/support risk-transfer mechanisms (weather-based insurance)	x	x
Fund research and development of technologies	x	x
Establish/enhance post-harvest facilities	x	x
Enhance the implementation of the agrarian reform program for marginalized farmers	x	x
Technologies		
Crop varieties that increases tolerance and suitability	x	
Geographic Information System (GIS)-based mapping of climate, soil, and water resources for crop/variety matching	x	x
Water management innovations, including efficient and effective irrigation technologies	x	x
Decision support tools such as weather/climate forecast /information	x	x
Farmers' Field Schools/ demonstration farms	x	x
Farm production/management practices		
Crop diversification (vertical/horizontal)	x	x
Adoption of organic farming	x	x
Community-based seed production	x	x
Sustainable rice intensification	x	x
Rainwater collection for irrigation	x	x
Change of timing/calendar of farming activities to fit observed changes in growing seasons/local climates	x	x
Implemention of selective irrigation practices	x	x
Alteration of practices found to be unsustainable	x	x
Behavioral		
Change in consumption patterns	x	x
Farm financial management		
Diversification of livelihoods to augment family income	x	x
Establishment of cooperatives to lower costs of production inputs/develop marketing strategies	x	x
Empowerment of women in farm management	x	

Source: Government of the Philippines (2014)

5.7.3 Adaptation Options in Practice

Various studies illustrate adaptation options available to agriculture, forestry, and fisheries (Table 5.7). Adaptation practices vary among different socio-economic groups depending on the nature of their occupation and availability of resources (Peras et al., 2008). Multiple knowledge systems are utilized such as information systems and indigenous knowledge. Field research demonstrates that using advanced climate information in farm-level climate-related decisions in corn production system can lead to increased yield and farm income and can minimize risks due to climate variability (Lansigan, de los Santos & Hansen, 2007). In this regard, the Department of Agriculture (DA) prepared vulnerability maps for each of the 12 regions of the country using information from PAGASA and inputs from agricultural research institutions and other agencies such as water resources, irrigation department, and food security agencies on potential impacts to agriculture production (Dolcemascolo et al., 2002). Farmers prefer adaptation tools such as: (i) accurate and real-time climate information, (ii) accessible credit and crop insurance, and (iii) special assistance programs such as irrigation development and seed subsidy against seasonal climate variability (Reyes, Domingo, Mina & Gonzales, 2009a).

Table 5.7. Summary of adaptation options in agriculture, forestry, and fisheries in various studies

Sector	Adaptation options	Reference
Agriculture	Economic: 1. Liberalization of agricultural trade barriers 2. Changes in existing subsidies 3. Extensive review/analysis of and appropriate action on economic incentives, subsidies, taxes, pricing, and trade barriers Technological: 1. Changes in agricultural management practices 2. Natural rainfall management including water impounding dams and evaporation control 3. Cropping pattern adjustment according to the onset of the rainy season and observed frequency of tropical cyclones, including information dissemination to farmers and timely provision of farm weather services/advisories, early warning systems (PAGASA – DA) 4. Access to available data on soil fertility from Bureau of Soils and Water Management (BSWM), particularly on • Improved water management • Development of heat-resistant varieties/genetic breeding • Improved farm management • Organic farming • Diversified farming • Safe and judicious use of fertilizers/chemicals • Optimum/efficient use of fertilizers/chemicals • Increasing effectivity/flexibility of irrigation •Introduction of new least-cost technologies such as hydroponics • Improvement of post-harvest and bulk handling facilities (i.e., installation of grain drying facilities in strategic areas) Institutional: Institutionalizing agricultural drought management through: 1. Collaboration between managers of weather data, water resources, farmers, policy makers 2. Passage of legislative measures including those on land use conversion 3. Strengthening of extension services at the local government unit (LGU) level • Upgrade of food storage distribution system • Promotion and implementation of judicious land use planning	Government of the Philippines, 1999

Table 5.7. Continued

Sector	Adaptation options	Reference
Agriculture	Adjustment of cropping calendar Changes in management and farming techniques Use of heat-resistant varieties Diversified farming, intercropping, crop rotation Development of early warning systems Multi-purpose reservoirs, dams, water-impounding system Metering and pricing to encourage water conservation	Pulhin et al., 2010
	Lowland farms Late rains: Use of short-term varieties (early varieties) Shift to drought-resistant crops Use of adaptable species Supplemental watering Early rains: Installation of Small Water Impounding Project (SWIP)	Lasco, Cruz, Pulhin, & Pulhin, 2008
	Upland farms Use of appropriate variety of planting materials Shift to more tolerant crops Use of drought-resistant crops Use of prescribed fungicides/pesticides Installation of fire lines Strict implementation of forest laws Adoption of modern method of farming suited for upland (e.g., sloping agricultural land technology [SALT]) Visibility of enforcement agencies to the area Delay of planting	
	Undertake spiritual practices (e.g., pray) Plant crops other than rice Change usual food consumption Look for additional source of income Get help from family or relatives Borrow money from relatives Ask for help from neighbors Implement new farming techniques Consult village/municipal officials Sell valuables (e.g., jewellery, animal) Join farmers' cooperative Send a family member to the city or abroad to work Seek government assistance Temporarily stop farming to work in the city Temporarily work as agricultural laborer Migrate to another region or city Borrow money from bank Sell the farm and start other business	Acosta-Michlik & Espaldon, 2008
	Reduced consumption Pray or make offerings to Anito (local name for spirits, which may include deceased ancestors and nature-spirits) Avail of loans/credit facility Store food, firewood, medicine, and water Community and kinship ties Off-farm work Non-government organization (NGO) assistance Tree belts/wind breaks/hedgerows	Peras et al., 2008

Table 5.7. Continued

Sector	Adaptation options	Reference
	Crop diversification Asset disposal Forecast natural hazards/disasters based on community's indigenous traditional knowledge	Peras et al., 2008
	Rainfed agriculture Use of crop decision support systems Crop insurance Advanced seasonal outlook and crop forecasting Research initiatives on managing climate variability	Lansigan, 2002
	Change in planting schedule and cropping patterns Diversification of crops planted (rice, corn, vegetables, and root crops)	Uy et al., 2011
	Rice farming Overseas migration	Bordey et al., 2013
	Peanut and vegetable planting Make adjustments in the planting calendar	Narciso et al., 2013
	• Utilization of drought-submergence and saline-tolerant varieties and aerobic rice • Irrigation improvement through rehabilitation, restoration and repair of existing irrigation systems, improved water management using controlled irrigation technology, alternate wetting and drying (AWD), planting of trees in priority critical watersheds of existing irrigation systems/facilities, construction of adequate drainage systems in irrigated areas, provision of shallow-tube wells, construction of reuse facilities in irrigated areas, intensification of establishments and rainwater-harvesting structures • Application of organic/organic-based agriculture such as Agri-Kalikasan (modified rapid composting) and Balanced Fertilization Strategy; • Enhancing the technological improvement and support services through the Fertilizers, Irrigation and Infrastructure, Extension, Education and Training, Loans, Dryers (FIELDS) Program • Fertilization strategy that promotes organic agriculture while reducing the use of inorganic fertilizer (Balanced Fertilizer Technology) • Seeds improvement and seed provision • Crop varietal improvement that will address and promote varieties resistant to droughts, floods, salinity, and pest that are triggered by climate change • Initiatives that increase awareness on and promote advocacy for CCA • Loans and credit that will ensure crop insurance to minimize risks and losses in crop production • Dryers and other post-harvest facilities that will minimize losses and handle surplus in production	Government of the Philippines, 2014
	• Mixed farming (e.g., different types of vegetables, maize, and root crops are planted simultaneously) • Crop rotation • Expansion of areas cultivated • Ritual, asking their 'diwatas' (deities or spirits) for more harvest • Seasonal planting • Planting of trees in areas about to be abandoned • Ritual called 'mabah' offering to the deities to request for omens that would help them choose the fields for planting	Elbat & Alburo, 2012

Table 5.7. Continued

Sector	Adaptation options	Reference
	During El Niño: • Off-farm labor • Plant other crops like squash, watermelon, and vegetables • Depend on copra production • Wait for the rain • Land preparation while waiting for the rain • Use of water pump to get water from irrigation (San Antonio) • Use of chemical fertilizer • Poisoning the rats • Just persevere During typhoon: •Off-farm work (especially women finding jobs outside the community) • Asset disposal • Plant early/ harvest early • Mortgage of land • Loans • Barter system • Pray that typhoon would not bring much damage • Build barrier to protect crops from landslide • Being prepared and alert • Plant again after typhoon • Plant root crops • Use of carabao-pulled cart to transport produce • Boil drinking water • Filter water with cloth	Tapia et al., 2014
	Male farmers -Adjust rice planting: ahead or late based on the occurrence of flooding -Resow when seedlings are destroyed -Replant when there are available seedlings for transplanting -Buy seedlings from other farmers -Choose varieties with high yields and tolerance to flooding -Build higher dikes around the plot -Secure crop insurance -Store all farm machinery in secure places -Delay harvesting -Harvest whatever could be saved after flooding Women farmers -Stock food before and during flooding season -Spend less on unimportant commodities -Secure important assets and livestock by protecting them from floods -Take care of the nutrition and health concerns of family members -Seek assistance from the government (relief goods) -Secure loans for household needs and additional farming expenses from relatives and friends	Tatlonghari & Paris, 2013

Table 5.7. Continued

Sector	Adaptation options	Reference
Forestry	Tree plantation -Adjust silvicultural treatment schedules -Plant species that can adjust to variable climate situations -Proper timing of tree-planting projects or activities -Implement proper silvicultural practices -Construction of fire lines -Control burning -Supplemental watering	Lasco et al., 2006
	Grasslands -Supplemental feeding of dependents -Reforestation-adaptation of SALT method of farming in combination to organic farming -Promote Integrated Social Forestry (ISF) or Community-based forest management (CBFM) -Increase funds for forest protection and regeneration from national government -Increase linkage building of LGU-Government Organization (GO)-NGO -Introduction of drainage measures -Control burning -Introduction of drought-resistant species -Intensive information dissemination campaign among stakeholders	
	Natural forest -Safety net measures for farmers by local and national government -Coordination between LGUs -Cancellation of timber license agreement (TLA)	
Fisheries	-Longer time fishing in good weather -Complementary income sources-farming, other fisheries-related employment, small business operation, handicraft making, labor in farms and fishponds, non-agricultural labor	Uy et al., 2011

Farmers also often utilize local knowledge to cope with and adapt to the impacts of climate variability and possibly, climate change. These include changes in cropping patterns, change of crop, crop diversification, and agroforestry practices, among others (Tolentino & Landicho, 2013). Examples of the indigenous knowledge of farmers are shown in Table 5.8. In addition, the Subanens, the indigenous peoples of Mt. Malindang, Misamis Occidental, are observed to practice land and crop rotation, shift in agricultural crops, expansion of area of cultivation, out-migration, family planning, formation of organizations, and change in food consumption (Espaldon, 2008).

Table 5.8. Indigenous knowledge related to agriculture

Indigenous knowledge	Reference
'Onorio Lopez' calendar: a traditional calendar based on astronomy and where farmers check the movement of moon, high tide or low tide, to help them decide the timing of planting and harvesting By looking at grass nodes, flood depth can be determined By observing weather phenomena, yield can be ascertained Onset of rainy season: -frogs and rats move to higher areas - crabs have open holes on top Onset of dry season: - frogs and rats move to lower areas - holes on top of crabs close	Rola & Elazegui, 2008

Table 5.8. Continued

Indigenous knowledge	Reference
- fish catch is declining - movement of ants and sound of cicadas Signs indicating rains will come: • Moonless night • Cloudy and dim sky • Dragonflies/play/fly at low altitude • Stars are twinkling • Two months without rain • Presence of potholes in the riverbanks • Duck going to the roof of the house and showing their wings • Crescent shaped moon is like letter C • Earthworm rolling over dust • Small birds fly together at low altitude • Clouds are like cultivated land • Moon's shape is undesirable • Moon is oriented sideways • Moderate weather for planting season if it rains on the first day of the year • Warm weather signals rains • If stars look too near each other • Flowering of *talahib* grass (wild cane) • Few fruits of fruit trees signals excessive rains • Pigs playing and poultry nesting early signal typhoon • Dogs defecate in the middle of the street • Clouds are color orange • Thunder is present • Ants hoard their food • Ants carry eggs and food to a certain direction, there will be floods • Earthworms emerge from ground Drier conditions are to be expected when: • Crescent shaped moon is like a container catching dripping water • When the earth cracks • Moon is oriented center • Native orchids flower • Fruit harvests are good • Bright sun during mornings • Moon is unusually bright	Reyes et al., 2009a
Weeding is not done during El Niño to conserve water. Irrigation is done when there is no wind to preserve moisture. Use of herbal pesticide/botanical spray to control drought-induced diseases and pests thriving in trees/plants. The Muyung tribe of Ifugao combines the under-planting of annual and perennial crops in a secondary forest.	Passe, n.d.

Some best practice options for wet and dry season plantings are also recommended for specific crops. For the wet season, these are identified as: (i) coconut leaf pruning, (ii) diversified cropping (strip intercropping), (iii) waterlogged resistant varieties, (iv) alley cropping, (v) vetiver grass technology, and (vi) SALT. On the other hand, for the dry season, these include: (i) coconut leaf pruning, (ii) diversified cropping (strip intercropping), (iii) small farm reservoir, (iv) mulching, (v) tillage practices, (vi) drought-tolerant crops, (vii) wide row spacing for rainfall multiplication, (viii) composting, (ix) artificial dissemination, and (x) 'supak' method or forced feeding for cattle during long dry periods (Amano et al., n.d.). Landcare is observed to bring together the strong points of communities, institution, and their networks and a strong research support in order to attain ecologically sound conservation farming practices (Espaldon, 2008).

In the forestry sector, the National Greening Program (NGP) is a government priority which addresses poverty reduction, resource conservation and protection, productivity enhancement, and climate change mitigation and adaptation. It harmonizes all tree planting efforts of the government sector, private organizations, and civil society with the goal of planting 1.5 billion trees covering about 1.5 million ha for a period of six years from 2011 to 2016. As of December 2016, 1.3 billion seedlings were planted on a total area of 1.6 million ha (114% of the target) generating 3.2 million jobs (Government of the Philippines, 2016).

5.7.4 Constraints to Adaptation and Adaptive Capacity

There are several areas in the agriculture sector that would need to be addressed in order to provide conditions that will enable the sector to be resilient and highly adaptive to climate change (Government of the Philippines, 2014) such as:

1. creating enabling environment for private investments in agriculture;
2. climate-fit crop programming and climate-based cropping mix in highly vulnerable agricultural areas;
3. production maximization in climate-proofed farming areas, particularly those with moderate rainfall;
4. developing policy environments for sustainable development of highland ecosystems (500 to 1000 meters above sea level elevation) for future expansion areas for food and nutrition security without further intrusion nor desecration of remaining forestlands, considering that the highlands have ideal soil and agro-environment support for production;
5. increasing local capacity to compete with global products within local markets, including that for bulk production and quality management of farm products; and
6. harmonizing food and bio-energy development and other economic uses of agricultural activities, and technological support systems for food security.

Limited knowledge on climate change reveals the need for communicating climate change and sustainability that would make it possible for farmers to make appropriate decisions on how to cope and adjust (Pana & Sia Su, 2012). Challenges besetting risk management programs include: (i) absence of localized climate/weather forecast and lack of time-series data that can be used for developing forecasting models; (ii) limited options and inadequate agricultural credit services; (iii) lack of market orientation and appropriate crop insurance schemes; (iv) lack of irrigation facilities; and (v) the unsuitability of varieties and poor quality of seeds provided in seed subsidies (Reyes et al., 2009b). According to Bulacan rice farmers, they experience the following constraints to adaptive capacity: (i) reliability of weather forecast, (ii) inadequacy and timeliness of climate information, (iii) uncertainty of water availability, and (iv) the effects of climate-based policies on water allocation (Rola & Elazegui, 2008).

Capacity building in making use of climate information would help improve decision tools towards climate risk management strategies. As an example, important considerations for climate information to be more useful are availability of micro or site-specific forecasts with adequate lead time and accuracy; existence and awareness of options for using weather forecast to improve decisions and policies; and ability and willingness of decision and policy makers to adapt their decisions to available information (Rola & Elazegui, 2008).

For efficiency and efficacy, cross-sectoral impacts of adaptation strategies would need to be analyzed in considering appropriate adaptation actions.

5.8 IMPLICATIONS TO SUSTAINABLE DEVELOPMENT

The agriculture, fisheries, and forestry sector is very vulnerable to climate change (Comiso et al., 2013). Climate change is characterized by increased temperature, more intense extreme climatic events, erratic rainfall distributions, and SLR in low lying agricultural production areas threatening environmental stability and sustainable development. It also indirectly affects food security as productivity of crops, livestock, fisheries, and other food sources is reduced. Areas cropped or used for food production are also decreased. Reducing vulnerability to climate change requires an effective, holistic and integrative CCA strategy that will build up the resilience of communities and of ecosystems. This strategy involves reducing exposure and sensitivity of the agriculture and fisheries sector as well as enhancing the adaptive capacity of communities at different levels. CCA may be looked at as an investment that will ensure human security.

Among others, a supportive policy, planning, and institutional environment is essential with regard to: (i) agricultural research and development to introduce and transfer appropriate and efficient technologies to better understand the effect of climate change on crop cultivation; (ii) collection, conservation, and utilization of plant genetic resources; (iii) investment to revitalize public plant breeding programmes; and (iv) regulation of the seed sector to guarantee farmers' access to quality seeds (Redfern et al., 2012).

The 2030 Agenda for Sustainable Development recognizes the importance of a strong and sustainable agriculture in achieving the Sustainable Development Goals (SDGs) targets. Rural development and investments in agriculture (i.e., crops, livestock, forestry, fisheries, and aquaculture) can end poverty and hunger and bring about sustainable development (Food and Agriculture Organization [FAO], 2016). Agriculture is linked to many of the SDGs such as poverty alleviation, education, gender equality, water use, energy use, economic growth and employment, sustainable consumption and production, climate action, and ecosystem management. Since climate change poses a threat to global food production, it is therefore crucial that agriculture and fisheries be made more efficient and sustainable by shifting to more sustainable consumption and production approaches.

5.9 KEY RESEARCH GAPS

The National Climate Change Action Plan (NCCAP) strategic priority on food security identifies the following research needs (Climate Change Commission [CCC], 2013):

1. Studies on cost and benefit of adaptation and mitigation technologies
2. Development of site-specific climate-resilient crops, livestock, and aquatic species
3. Studies on climate resilient crops (other than rice), livestock, and aquatic species
4. Studies on emerging pests and diseases under changing climate
5. Studies on the analysis of food production areas versus biofuel production areas in the Philippines vis-à-vis climate change impact
6. Enabling mechanisms to translate scientific findings to policies
7. Development of linking strategies with the industry/community-based enterprises to upscale climate change related technologies
8. Studies to improve understanding and models of response of agricultural crops and fisheries to climate and other environmental changes
9. Development and improvement of technologies, management strategies, and institutions to enhance adaptation to climate change in agriculture and fisheries
10. Expand observing, monitoring, and early warning systems
11. Approaches to evaluate trade-offs and synergies in managing agricultural lands and in managing ocean resources
12. Development and improvement of technologies, management strategies, and institutions to reduce greenhouse gas (GHG) emissions from agriculture and fisheries and to enhance adaptation to climate change
13. Development and improvement of technologies, management strategies, and institutions to reduce net GHG emissions from agriculture, while maintaining or enhancing food production potential

Research on small producers' livelihoods in the context of CCA has the potential to unravel the economic, ecological, social and discursive conditions, and constraints to livelihood security. Research is required to (Resurreccion, Sajor, & Fajber, 2008; Lasco, 2012):

(i) better understand how livelihood security of small-scale fishers and farmers may be threatened by climate change combined with other social and environmental stressors;

(ii) explore mechanisms that could strengthen their adaptive capacities including research on agriculture and fisheries production systems, particularly in increasingly saline environments; instruments for tenure security and equitable access to other productive assets and infrastructure; and means to enhance accessibility to scientific information on climate and weather patterns relevant to local levels;

(iii) identify the potential and needs for livelihood transitions such as skills upgrading and education;

(iv) understand the factors and conditions that work to under-represent and exclude the voices of small producers in national and intermediate-level planning for adaptation and the effects that other mitigation efforts might have on their livelihoods and well-being; and

(v) assess the adaptation strategies for small-scale fishers and farmers.

A requirement to mainstreaming climate adaptation is a need to better understand the dynamics and combined impacts of various forms of climate variability and extremes to local communities as basis for development planning. In addition, limits and barriers for effective adaptation should be examined before appropriate adaptation practices can be mainstreamed in development projects (Peras et al., 2008). To scale up adaptation, there is a need for bottom-up assessment and planning, and for participatory action research that engages various stakeholders particularly the local communities to reduce vulnerability and enhance adaptive capacity (Peras et al., 2008). Research is needed to: (i) improve the science of climate change projection relevant to national and local levels; (ii) enhance capacity of researchers to conduct integrated assessment of climate change impacts, vulnerability, and adaptation; (iii) strengthen the science-policy-local action interface; (iv) adopting a more holistic approach to building the adaptive capacity of vulnerable groups and localities and their resilience to shocks; (v) build on the experience on indigenous adaptation strategies to enhance effectiveness of future adaptation; and (vi) develop and use adaptation metrics for planning and monitoring purposes to enhance adaptation effectiveness (Pulhin et al., 2010).

Moreover, modeling research using downscaled climate scenarios with finer resolution to simulate yields of crops, livestock, and fisheries in the future would be important (Lasco, 2012). For rice, it is important to intensify rice research and development as well as the promotion of its products so that there will be greater adoption of technology (Bordey et al., 2013). Specific research-related priorities can also look at sectoral interactions such as between irrigation and water resources; water resources and cropping systems; water resources and livestock farming; and water resources and aquaculture (Cruz et al., 2007).

Finally, as suggested in Porter et al. (2014), research and data gaps related to food security include:

- Closer attention to yield variability in the quantity and quality of food production especially food production experiments in which changes in variability reflect predicted changes for given climate scenarios;

- Adaptation studies for cropping systems should examine the impact of proposed adaptations when employed in the current climate and should be inclusive of the broader range of systemic and transformational adaptation options open to agriculture;

- Increasing the resolution to forecast impacts and changes in distribution and productivity of marine fish species and communities at the national and local ecosystem scale would provide valuable information to governments and stakeholders and enable them to prepare more effectively for expected impacts on food production and security offered by fisheries; and

- Food security studies are required to estimate the actual range of adaptations options available to farmers and other actors in the food system, and the implementation paths for these especially when possible changes in climate variability are included.

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CHAPTER 6

Human Health

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6.1 EXECUTIVE SUMMARY

As a developing country, the Philippines is experiencing an era where infectious disease is still rife. With public health systems already challenged, the country's natural systems are becoming more degraded due to increasing development that take an increasing toll on the human population. This is exacerbated by occurrences of extremes of climate events that increase vulnerability and challenge coping mechanisms.

Perceived and empirically shown sectoral impacts of climate change to human health include increased incidence of climate-sensitive diseases and illnesses such as: (i) vector-borne diseases (dengue, leptospirosis, and malaria); (ii) water-borne diseases (schistosomiasis and cholera); (iii) food-borne diseases (diarrheal diseases and typhoid); (iv) respiratory diseases (asthma, bronchitis, and respiratory allergies and infections); and (v) heat-related illnesses (sunstroke, sunburn, heat stress or exhaustion, and dehydration).

Many of the biological organisms linked to the spread of infectious diseases are especially influenced by fluctuations in temperature, precipitation, and humidity. Correlation analysis shows that dengue and malaria are most sensitive to the effects of temperature, relative humidity, and rainfall.

Most of the Southeast Asian islands are at increased risk of increased surged dengue fever transmission brought about by drought conditions. Drought increases the risk of improper water storage around houses leading to elevated *Aedes Aegypti* populations. More frequent droughts also raise ambient air temperatures which were observed to reduce the extrinsic incubation period for the virus in mosquitoes thereby increasing vector reproductive capacity. Increased respiratory illness due to haze from uncontrolled burning of tropical forests are reported when extreme drought occurs.

Based on a model constructed for forecasting climate change sensitive diseases, for every 1°C increase in temperature, the mosquito population increases ten-fold. Hence, it is expected that there will be increased bite rate of mosquitoes with increased temperature. In the National Capital Region (NCR), an expected 233 cases of dengue is predicted to occur for every 1°C increase in recorded minimum temperature. In addition, there will be a predicted increase of dengue cases by about 31 cases for every unit of increase of relative humidity. However, dengue cases are estimated to decline by 615 per 1,000 cases for every unit increase of monthly rainfall. This is the same for malaria which is expected to be reduced by 89 per 1,000 cases for every unit increase of monthly rainfall.

On the other hand, cholera cases are expected to increase by 26 per 1,000 cases for every unit of monthly rainfall, by nearly 8 cases for every unit of maximum temperature, and by 662 per 1,000 cases for every unit of relative humidity. It is expected to decline by almost 40 cases for every unit of maximum temperature.

The potential impacts of climate change are projected to be USD 5 to 19 million by 2050 in terms of loss of public safety, increased vector- and water-borne diseases, and increased malnutrition from food shortages during extreme events if no significant interventions are undertaken.

The National Framework Strategy on Climate Change (NFSCC) emphasizes the formulation of proper climate-sensitive interventions by the health sector to ensure a healthy and disease-resilient citizenry. It proposes these strategic priorities: (i) assessment of the vulnerability of the health sector to climate change; (ii) improvement of climate-sensitivity and increase in responsiveness of public health systems and service delivery mechanisms to climate change; and (iii) establishment of mechanisms to identify, monitor, and control diseases brought about by climate change, and improve surveillance and emergency response to communicable diseases, especially climate-sensitive water-borne and vector-borne diseases.

Integrated, participatory, and multi-level adaptation responses are suggested by the Department of Health (DOH) and World Health Organization (WHO). This will include coordinated responses from forestry, water, energy, and health sector; mainstreaming responses in local and national plans and programs; building partnerships between public and private sector; blending modern with indigenous techniques; and providing adequate financing, human resources, and facilities.

There is an existing inventory of good practices that reduces vulnerabilities to climate-related diseases that could provide guidance in formulating adaptation responses to climate-induced health risks. These practices are classified according to its nature (i.e., institutional, political, environmental, sanitation and cleanliness, individual or family-based, community or barangay-based, health care and others).

Adaptation in the health sector is constrained by the absence of a national facility dedicated for the assessment of vulnerability to various climate-related health risks. The establishment of a facility or making use and capacitating one that will be responsible for the monitoring and surveillance of climate-related diseases would be important. Inadequate competence of health personnel at the local level would limit the responsiveness of health service provision at the community level where it will be most needed. Capability building programs would be crucial to develop the competence of local health service providers especially in communication to various audiences of the potential health risks associated with climate change. There would also be a need to augment the existing budget of local health facilities for the establishment of health baseline and other essential activities on top of its regular functions and programs.

Increased health sector research on: (i) the scale and nature of health risks from climate change; (ii) cost-effectiveness of interventions to protect health; (iii) health implications of climate change adaptation (CCA) and mitigation interventions made by other sectors; (iv) improvement in decision support systems and disease surveillance in relation to climate changes; and (v) estimation of resource requirements for cost-effective interventions would be valuable.

Relevant research for health protection involving cross-disciplinary and inter-sectoral studies in the following areas would also be important: (i) improved vulnerability and adaptation assessments that focus on particularly vulnerable populations and encompass complex causal pathways; (ii) quantitative estimation of the effectiveness of health adaptation measures; (iii) surveillance, monitoring, and observational systems that link climate, health, and economic impact data and provide a basis for early warning systems as well as development of future scenarios; and (iv) assessment of the health co-benefits of alternative climate mitigation policies across different sectors.

6.2 METHODS AND PROCEDURE

This chapter utilizes review of literature to derive the contents of Health Sector Climate Change and Adaptation assessment and interventions. Several studies have been commissioned since 1999 and then again from 2010 by the National Economic and Development Authority (NEDA) and Department of Health (DOH), funded by the World Health Organization (WHO) and European Union (EU), that are cited as key sources of information and data referenced in this chapter.

The DOH has developed a framework for climate change and health to address the potential impacts of climate change to the health sector (Figure 6.1). The University of the Philippines Manila National Institutes of Health – Institute of Health Policy and Development Studies (UPM NIH-IHPDS) team under the Millennium Development Goals Achievement Fund (MDGF) 1656 Project undertook a climate change vulnerability assessment study for the health sector and proposed a Health Sector Climate Change Vulnerability and Adaptation Framework and integrated it with a vulnerability assessment and monitoring and evaluation framework as shown in Figures 6.2 and 6.3. These two frameworks described the relationship of health sector climate change vulnerability with ecologic and environmental factors identifying malleable factors that could be directly addressed by effective climate change and health interventions. The integration with a vulnerability assessment and monitoring and evaluation framework identifies approaches to monitoring and evaluation systems that DOH has established. Moreover, a DOH-commissioned research on the Economic Valuation of Climate Change and Adaptation for Health was recently completed. This study conceptualized a framework used for determining the cost-effectiveness of selected climate change adaptation interventions related to existing health programs (Figure 6.4).

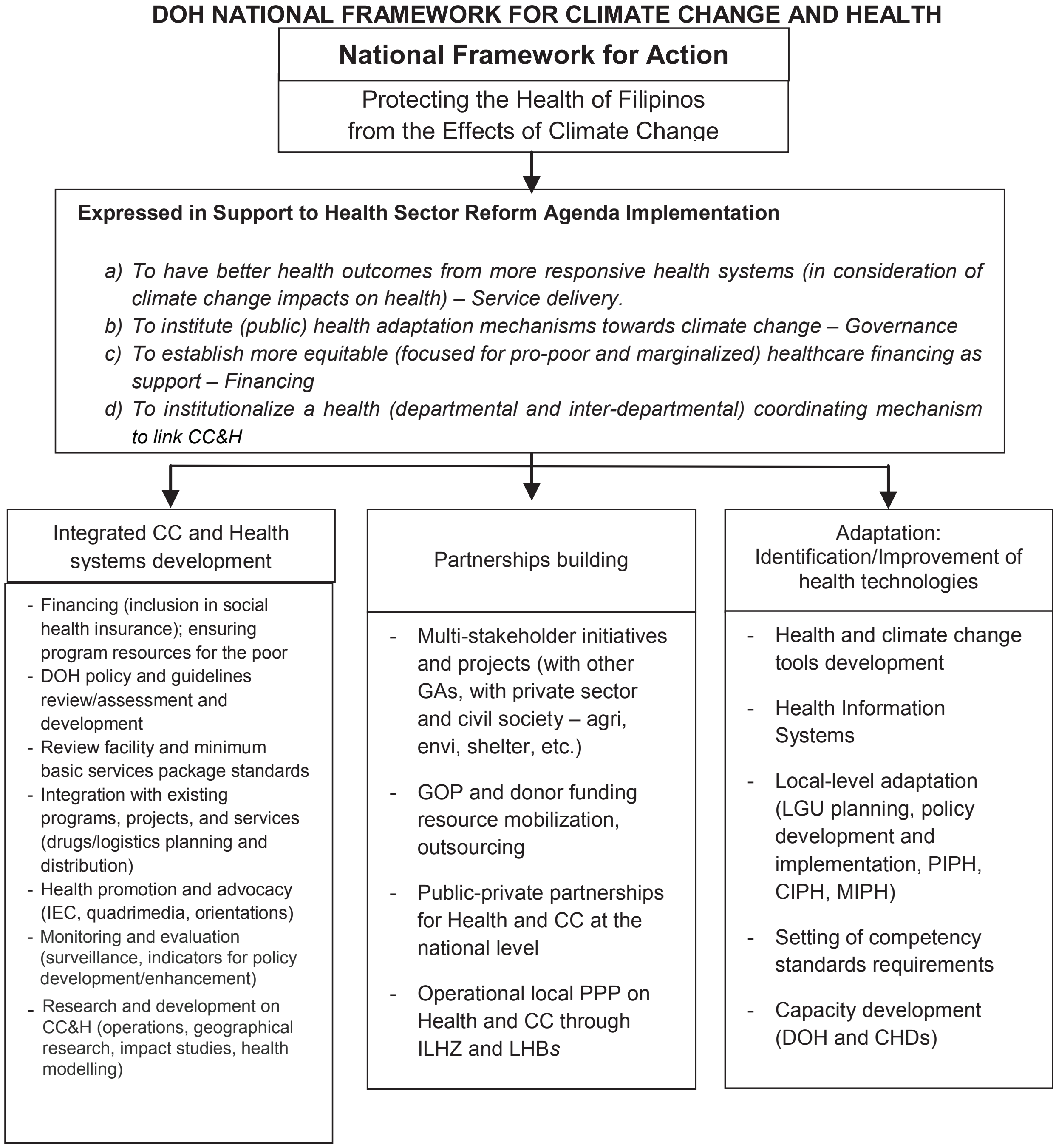


Figure 6.1. DOH national framework for climate change and health (DOH & WHO, 2012)

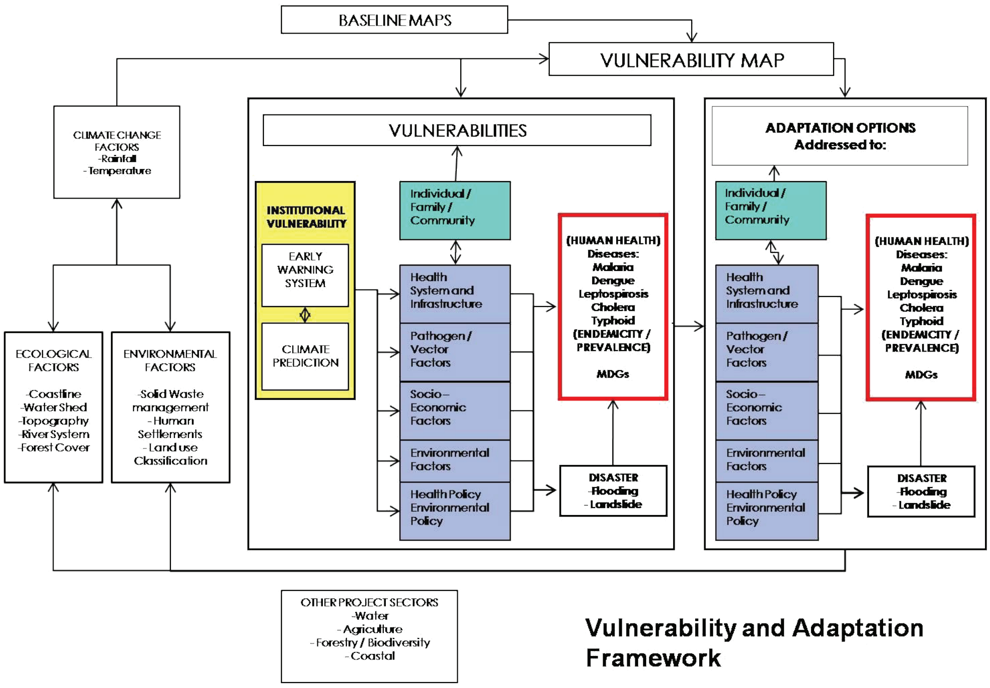


Figure 6.2. Climate Change Vulnerability and Adaptation Framework for the Health Sector (Lorenzo, et. al., 2010)

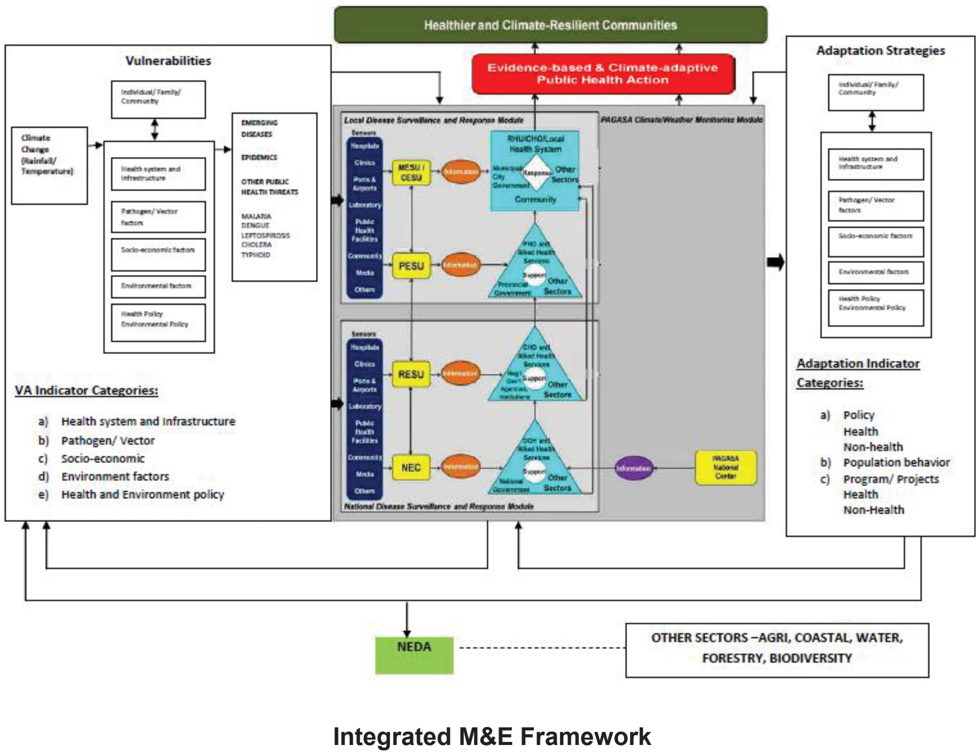


Figure 6.3. Integrated vulnerability assessment and monitoring and evaluation frameworks (Lorenzo, et. al., 2010)

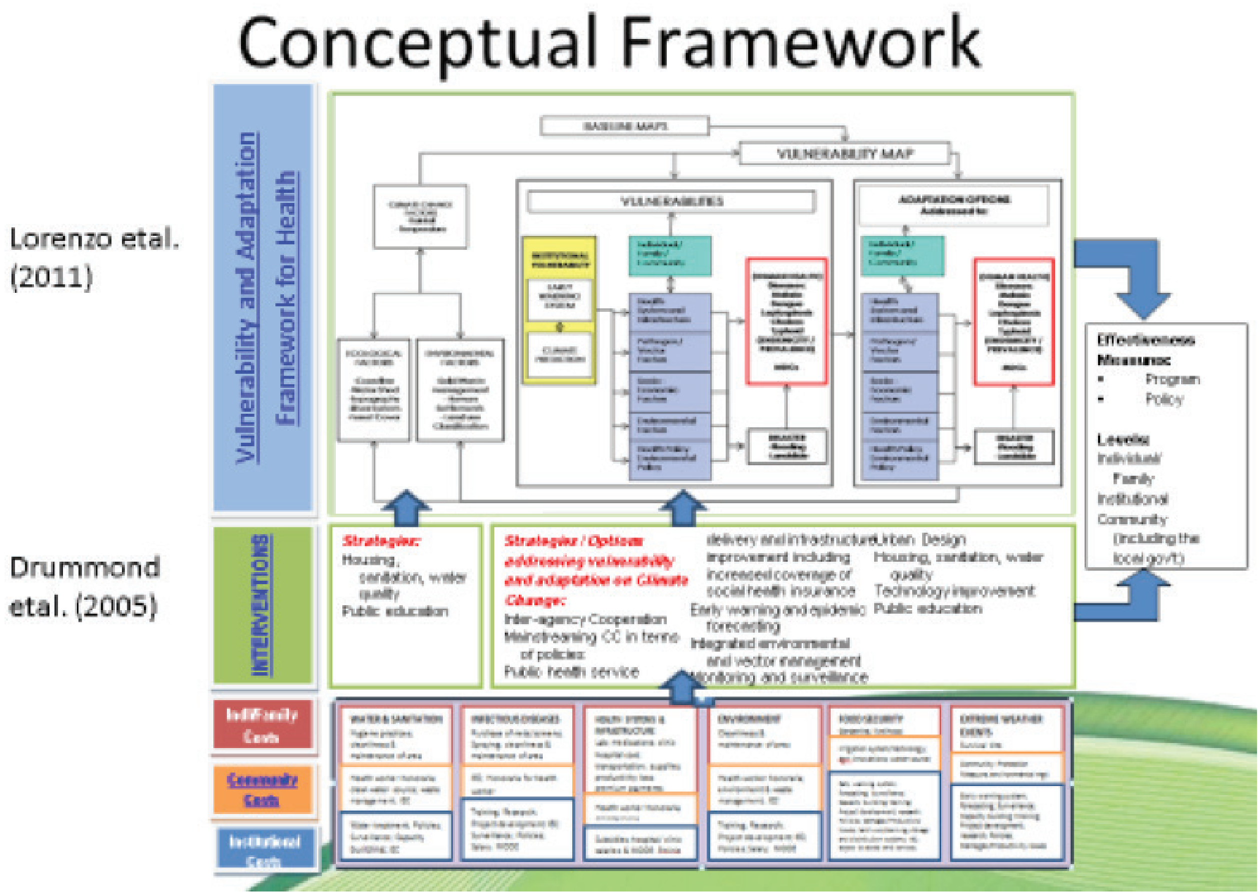


Figure 6.4. Economic valuation of climate change and adaptation for health study conceptual framework. (Lorenzo, et al., 2017a)

To support the preparation of the Philippines' Initial National Communication, a study was undertaken correlating an estimate of climate change effects on mean monthly weather data (minimum and maximum temperatures; rainfall and humidity; and mean sea-level pressure) with data on incidence of selected diseases from 1961 to 1993 in selected provinces and cities (Government of the Philippines, 1999).

6.3 STATE OF HEALTH IN THE PHILIPPINES

The health of Filipinos is described as "improving slowly" over the years. This could be attributed to the substantially improved health status through reform initiatives, applying advances in medicine, and progressive public health approaches. Total health expenditures in the years 2005 to 2011 is shown in Table 6.1. While data shows improvement over the years, it is also clear that the Philippines has not yet breached the WHO minimum standard for health investments. WHO specifies that at least five percent of Gross Domestic Product (GDP) must be invested in health by countries in order to ensure adequate health investments and, consequently, ensure better health outcomes.

Table 6.1. Total health expenditure as a percentage of GDP (National Statistics Coordination Board [NSCB], 2013)

Item	2005	2006	2007	2008	2009	2010	2011	Average Annual Growth Rate
Total Health Expenditure (in billion pesos, at current prices)	222	249	269	302	342	381	431	11.7
GDP (in billion pesos, at current prices)	5,678	6,271	6,893	7,721	8,026	9,003	9,736	9.4
Health Expenditure as % of GDP	3.9	4.0	3.9	3.9	4.3	4.2	4.4	2.1

Further data shows that Filipino health outcomes seems to have deteriorated when compared to health outcomes of selected Southeast Asian neighbors and the world median when tracked across different health care reform eras over 30 years. Table 6.2 shows details of selected outcome indicators that were compared in a health systems performance study (Lorenzo, et. al. 2017b).

Before 1978, or the pre-Primary Health Care (PHC) period, most of the selected Philippine indicators were at the same level or better than those of comparison countries and the world median. But after 30 years, in 2014 during the Kalusugan Pangkalahatan (KP) period, Philippine health status indicators were observed to be worse than that of the comparison countries and the world median. This downward trend is explained by rates of change of comparison countries that were observed to be steeper than the change that transpired in the Philippines. For instance, maternal mortality was higher in Vietnam (140 maternal deaths per thousand live births in the 1978 to 1990 period compared to the Philippines with only 110 maternal deaths per thousand live births in the same period). After 30 years, the maternal mortality rate of Vietnam decreased tremendously to 49 deaths per thousand live births, which is almost a 300% decrease. On the other hand, in the same period the Philippines registered an increase of 120 maternal deaths per thousand live births, indicating a worsened maternal death situation (Lorenzo et al., 2017)

Table 6.2. Health outcome indicators compared across health reform periods (Philippines, comparison countries and global median)

Health Outcome Indicators		Pre-PHC (1970-1977)	PHC adoption and expansion (1978-1990)	Devolution (1991-1998)	Health Sector Reform Agenda (HSRA) (1999-2004)	Fourmula 1 (2005-2010)	KP (2011-2013)
Life Expectancy (Years)	Thailand	60.8	68.5	72.0	74.0	75.0	75.6
	Vietnam	61.2	67.0	70.6	71.3	73.1	74.2
	Global Median	61.4	66.0	68.6	70.6	72.1	73.3
	Philippines	61.3	63.5	65.9	67.0	67.9	68.6
Maternal Mortality Ratio (Per 100,000 livebirths)	Thailand	ND	42.0	37.0	40.0	34.0	26.0
	Vietnam	ND	140.0	110.0	82.0	60.0	49.0
	Global Median	ND	96.0	89.0	80.0	69.0	61.0
	Philippines	ND	110.0	130.0	120.0	125.0	120.0

Table 6.2. Continued

Health Outcome Indicators		Pre-PHC (1970-1977)	PHC adoption and expansion (1978-1990)	Devolution (1991-1998)	Health Sector Reform Agenda (HSRA) (1999-2004)	Fourmula 1 (2005-2010)	KP (2011-2013)
Infant Mortality Rate (Per 1,000 livebirths)	Thailand	61.8	40.2	24.6	17.9	13.8	11.6
	Vietnam	53.6	42.6	31.8	26.0	22.1	19.5
	Global Median	63.9	46.7	30.8	23.8	18.7	16.6
	Philippines	54.9	49.9	34.7	29.3	26.3	24.0
Tuberculosis (TB) Prevalence (Per 100,000 population)	Thailand		211.0	214.1	260.5	195.7	152.0
	Vietnam		560.0	462.6	330.7	260.7	217.0
	Global Median		93.0	95.9	87.5	73.8	66.7
	Philippines		1003.0	912.3	733.0	564.0	461.0
TB Mortality Rate (Per 1,000 population)	Thailand		19.0	15.8	22.5	14.8	12.3
	Vietnam		52.0	43.1	31.3	24.5	20.0
	Global Median		6.5	6.5	5.2	3.9	3.5
	Philippines		55.0	49.0	39.7	32.3	28.0
Under-5 Mortality Rate (Per 1,000 livebirths)	Thailand	84.1	51.1	29.5	21.0	16.0	13.5
	Vietnam	80.8	61.3	42.7	33.5	27.9	24.5
	Global Median	101.6	65.9	43.5	31.8	24.9	20.4
	Philippines	122.7	88.6	67.0	55.1	43.6	36.3
Hypertension (HPN) Prevalence	FNRI (PH)			21.5	22.5	25.3	
	Philheart			18.3	22.5	23.0	28.0
Stunting (%)	Thailand		25.3	19.6		15.7	16.3
	Vietnam		62.7	52	38.96	30.2	19.4
	Global Median		39.6	35.7	32.7	27.8	23.8
	Philippines	60.2	45.57	39.37	33.8	32.3	33.6

Furthermore, the life expectancy of Filipinos which was comparatively higher than that of Vietnam or Thailand before 1978, improved from 61.3 to 68.6 years in 2014, but the Thais and Vietnamese have been shown to live longer than Filipinos with life expectancies of 75.6 and 74.2, respectively in 2014 (Figure 6.5). A comparative analysis of the slopes of change of Thailand and the Philippines for life expectancy improvements shows that the Thai rate of change is about twice as that of the Philippines. This indicates that the rate of life expectancy changes in the Philippines was much slower than that of Thailand and Vietnam. An analysis of the maternal mortality trend rate shows more problems. The Philippine maternal mortality rate posts a net gain of 0.3 while the Thai and Vietnamese mortality rate showed substantial reductions of 0.64 and 4.03, respectively. While the above trends are used to illustrate the problematic situation of the Philippines, other health outcomes exhibit similar trends and attest to the comparative decline of health outcomes in the country. Another health outcome stressor like unbridled climate change could exacerbate the unfortunate health situation of the Philippines.

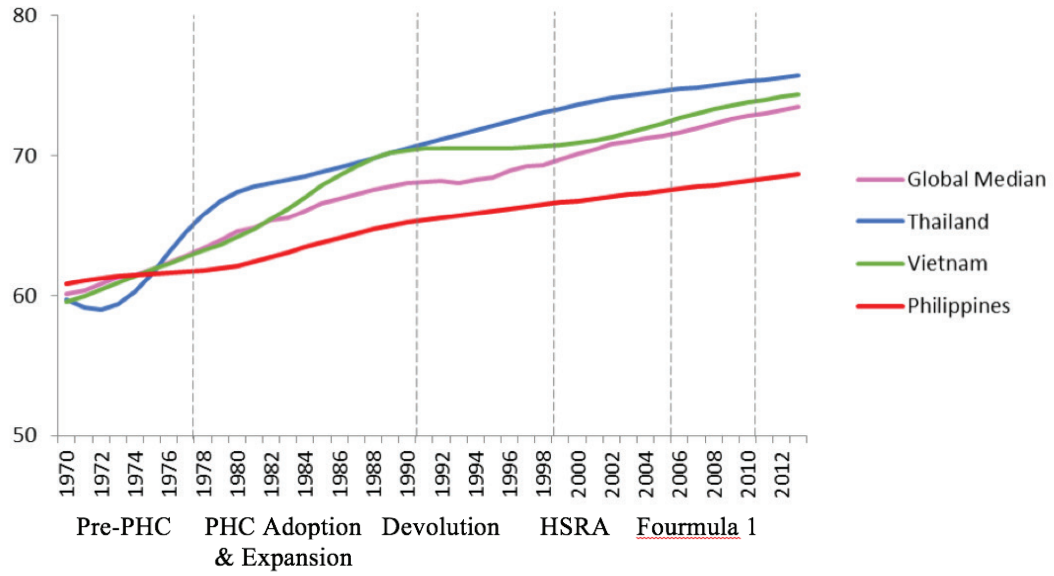


Figure 6.5. Life expectancy at birth (Philippines and comparison countries and global median at different reform eras) (Lorenzo, et al., 2017b)

Despite considerable progress in some areas, large disparities remain (WHO, 2012b). Social, economic, and geographic barriers result in inequity in access to services and explain the inequity in health outcomes. Poor people in greatest need for health care, namely, pregnant women, newborns, infants, and children, are underserved (Kwon & Dodd, 2011). As a developing country, the Philippines is experiencing an era where infectious disease is still rife. With public health systems already challenged, the country is approaching an era of increasing development where pollution of natural systems is taking its toll on the human population. This is exacerbated by occurrences of extremes of climate events that increase vulnerability and challenge coping mechanisms.

The challenges of the Philippine health system are characterized by the dominance of an independent private health sector, a disconnect between national and local authorities due to devolution, and the absence of an integrated curative and preventive network (WHO, 2012b). In addition, health vulnerabilities include technological inadequacy for diagnosis and treatment; inadequate health facilities and structures (not climate-proofed); and changing patterns of disease (DOH & WHO, 2012). To help local governments prepare for and respond to climate change, emergencies and natural disasters, the WHO Country Office, the EU and NEDA have been supporting efforts to develop tools—including an event-based surveillance system, health vulnerability and capacity assessments including vulnerability indices and maps, and advocacy and training materials (WHO, 2012a; Lorenzo et al., 2010; Lorenzo et al., 2015). These tools have been the content of national training programs in an effort to assist local communities to adapt effectively to climate change.

6.4 CURRENT SENSITIVITY AND VULNERABILITY

The vulnerability of the health sector - including individuals, families, communities, and health systems and infrastructure, among others - to climate change based on climate scenarios and vulnerability assessment is shown in Table 6.3. Some vulnerabilities were identified in families and communities in poor and climate change vulnerable situations. While some vulnerabilities such as poor hygiene are not directly correlated with climate change, they are present in poor and isolated communities and exacerbate the families' and communities' vulnerabilities. In addition, perceived and empirical impacts of climate change to human health include: (i) increased incidences of diseases and illnesses; (ii) insect-and rodent-borne diseases (dengue, leptospirosis, and malaria); (iii) water-borne diseases (schistosomiasis and cholera); (iv) food-borne diseases (diarrheal diseases and typhoid); (v) respiratory diseases (asthma, bronchitis, and respiratory allergies and infections); and (vi) heat-related illnesses (sunstroke, sunburn, heat stress or exhaustion, and dehydration) (Duhaylungsod & Mendoza, 2009).

All of the aforementioned health problems have correlations with climate change that are specified in international literature. However, climate change sensitive diseases that have public health significance mostly point to communicable diseases that affect a number of people at any given time such as the vector borne, water borne and food borne diseases.

There is strong evidence for the relationship of climate change and these aforementioned diseases. For example temperature increase of 1°C has been associated with increased reproduction and biting activity of mosquitos which act as vectors of some climate change sensitive diseases like malaria and dengue. The evidence is weaker for illnesses that affect individuals more such as upper respiratory tract infections and asthma. While important, these illnesses are considered less serious from a population perspective. Through time though, non-communicable diseases can add up and cause a considerable cumulative disease burden.

Many of the biological organisms linked to the spread of infectious diseases are especially influenced by fluctuations in temperature, precipitation, and humidity. Correlation analysis shows that dengue and malaria are most sensitive to the effects of temperature, relative humidity, and rainfall (Amadore, 2005). A study mapping weather elements and the incidence of dengue in the NCR shows that there is strong positive correlation between dengue incidence and periods of rain, high maximum and minimum temperature, and high humidity (Figure 6.6) (Lorenzo et al., 2010). In particular, monthly observations show that over a period of 14 years, dengue incidence follows high maximum temperature and its sudden drop (Figure 6.7) which occurs usually at the beginning of the rainy season. The value of this observation lies in the ability of the health system and the populace to predict the outbreaks of dengue based on weather changes.

Table 6.3. Climate change vulnerability in the health sector

Area/Sector	Climate Change Vulnerability
Individual, family, community	• Low immune system • Poor hygienic practices • Poor access to potable water • No access to health facilities • Exposure to vectors, contaminated water and food • Lack of climate change resistant shelters • Live in (exposure to) disaster prone areas (i.e., flood plains or watershed slopes)
Health Systems and Infrastructure	• Inequitable distribution of health system factors (i.e., clinics, hospitals, pharmacies, and human resources for health (HRH) that lead to population's lack of access to quality basic health services • Health information system not related to climate change leads to difficulty in monitoring climate change-related illnesses • Weak disease prevention and health promotion systems • Inability to respond properly and quickly to emergency/ disaster situations
Pathogen/vector factors	• Poor sanitation facilities and systems • Below standard solid waste management systems • Presence of vector habitats (e.g., canals and bodies of water)
Socio-economic factors	• Below poverty threshold level • Unable to afford or sustain recommended treatment
Environmental factors	• Human proximity to vector habitats (e.g., canals, bodies of water) • Temperature, rainfall, and relative humidity favor vector and pathogen growth
Health/environmental policy	• Lack of policies on regular monitoring and treatment of diseases • Lack of policies on maintenance of a sanitary environment • Weak implementation of existing policies on disease control

Source: Lorenzo et al. (2010) MDGF 1656: Conduct of Climate Change Vulnerability and Impact Assessment Framework, Development of a Monitoring and Evaluation Framework/System, and Compendium of Good and Innovative Climate Change Adaptation Practices

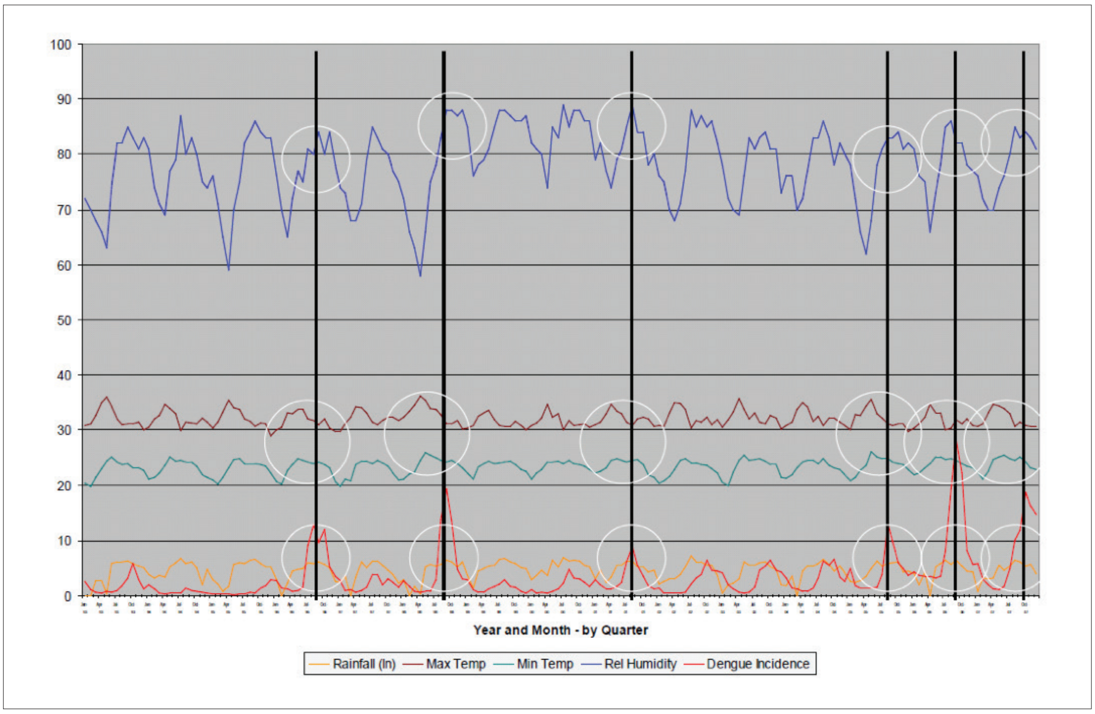


Figure 6.6. Weather elements and dengue incidence, NCR, 1993-2007 (Lorenzo, et al., 2010).

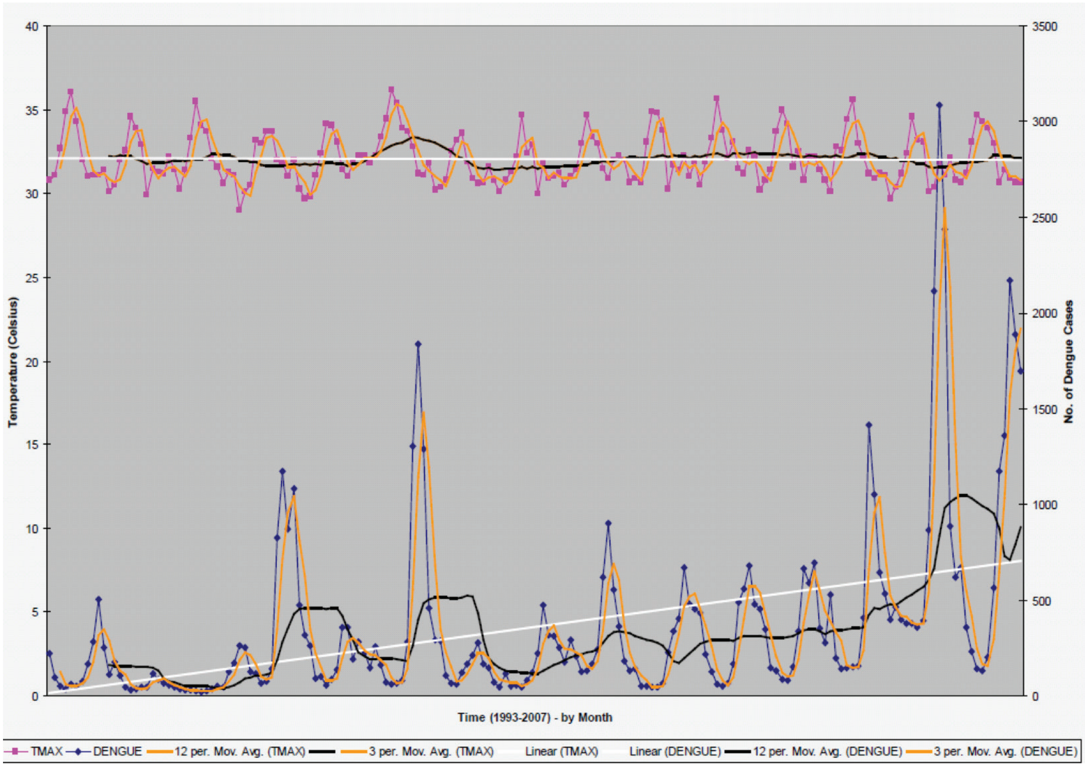
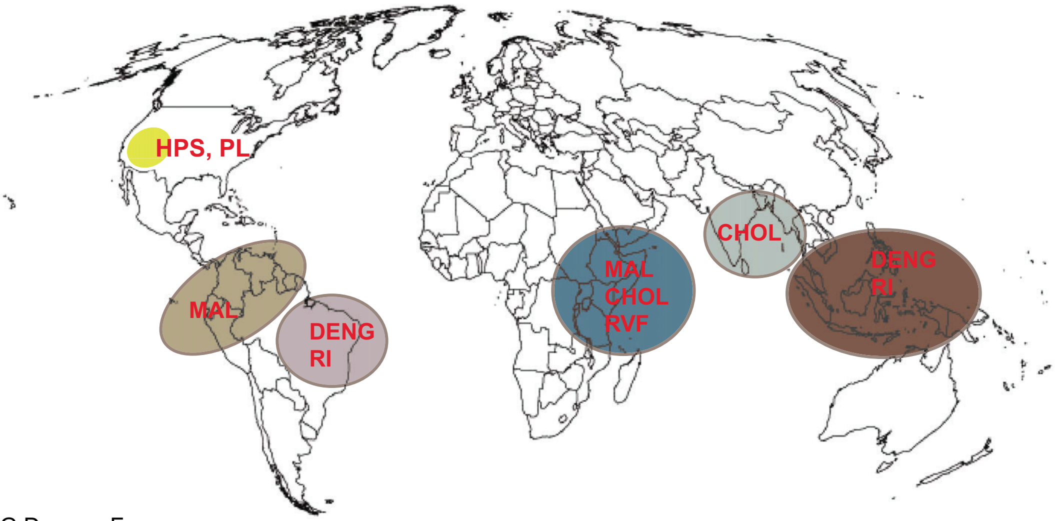


Figure 6.7. Maximum temperature and number of dengue cases (Lorenzo, et al., 2010).

Most of the Southeast Asian islands are at increased risk of increased dengue fever transmission caused by drought conditions during dry seasons or summers when the increased practice of improper water storage around houses was observed, leading to elevated *Aedes aegypti* populations. Drought conditions raise ambient air temperatures which will reduce the extrinsic incubation period for the virus in vector mosquitoes increasing vector capacity and occurrence of respiratory illness due to haze from uncontrolled burning of tropical forests (Anyamba, Chretian, Small, Tucker, &

Lithicum, 2006). The Philippines is a hotspot for potential outbreak of dengue fever as shown in Figure 6.8 which can be associated with weather variations over time. Predicted climate change trends might help in the forecast of dengue cases and lead consequently to more effective prevention. On the other hand, respiratory diseases have been observed to spike with weather variations (i.e., change from summer to rainy season and vice versa).



DENG Dengue Fever
RI Respiratory illness
CHOL Cholera
MAL Malaria
RVF Rift Valley Fever
HPS Hanta Virus Pulmonary Syndrome
PL Plague

Figure 6.8. Hotspots of potential elevated risk for disease outbreaks under El Nino conditions: 2006-2007 (Anyamba et al., 2006)

6.5 ASSUMPTIONS ABOUT FUTURE TRENDS

Endemic morbidity and mortality due to diarrheal diseases primarily associated with floods and droughts are expected to rise in Southeast Asia due to projected changes in the hydrological cycle associated with global warming (Confalonieri et al., 2007). Based on climate scenarios by Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) in 2020 and 2050 and vulnerability assessment, projections on climate-sensitive diseases include: (i) malaria to have 258 and 308 new cases by 2020 and 2050, respectively; (ii) new cases of cholera will number to 143 and 99 by 2020 and 2050, respectively; and (iii) dengue cases in the NCR will be 2,128 by 2020 and 1,735 in 2050 assuming that current prevalence trends persist over time. Both dengue and cholera impact models were found to be sensitive to monthly rainfall, maximum temperature, and relative humidity, whereas malaria is sensitive to monthly rainfall and maximum temperature. Disease impact models for dengue, malaria, and cholera were developed out of the available health data from NCR and from the Provincial Health Officers (PHOs) of the Provinces of Palawan, Pangasinan, and Rizal. Climate change data (rainfall, temperature, and relative humidity) used were furnished by PAGASA for the year 1992 to 2009, 2020, and 2050. The disease impact models were used to project disease impacts in 2020 to 2050. The predictive capacity of the models is highly dependent on the accuracy of the health and climate change data. The derived models used for prevalence forecasts need to be validated and more data that can relate climate variables to disease incidence and prevalence need to be collected more accurately (Lorenzo et al., 2010).

6.6 KEY FUTURE IMPACTS AND VULNERABILITY

Field observations show that for every 1°C increase in temperature, the mosquito population increases ten-fold. Hence, there will be increased bite rates of mosquitoes with increased temperature. In NCR, for every 1°C increase in recorded minimum temperature, an expected 233 cases of dengue is predicted to occur. In addition, for every unit of increase of relative humidity, dengue cases will rise by about 31 cases. However, for every unit of increase of monthly rainfall, dengue cases will decline by 615 per 1,000 cases. This is the same for malaria that is expected to be reduced by 89 per 1,000 cases for every unit of increase of monthly rainfall (Lorenzo et al., 2010). Dengue cases are more efficiently transmitted in densely populated areas (usually urban) than in areas with sparse populations (usually rural). Malaria cases however abound in rural environments because of the conducive mosquito breeding conditions in these areas.

In the case of cholera, cases are forecasted to increase by 26 per 1,000 cholera cases for every unit of monthly rainfall, by nearly 8 cases for every unit of maximum temperature, and by 662 per 1,000 cases for every unit of relative humidity. It is expected to decline by almost two cases for every unit of maximum temperature (Lorenzo et al., 2010). Again, these predictions are based on observation of current disease trends. However, since disease incidence and prevalence are influenced by multiple factors. It will be difficult to say that a certain temperature rise will eradicate cholera altogether. It must be realized that microbes struggle to survive and thus adapt to the changing environment including climate change.

The potential impacts of climate change are projected to be USD 5 to 19 million by 2050 in terms of loss of public safety, increased vector- and water-borne diseases, and increased malnutrition from food shortages during extreme events (Lorenzo et al., 2010).

6.7 ADAPTATION

6.7.1 Adaptation Options in Principle

The NFSCC emphasizes the formulation of proper climate-sensitive interventions by the health sector to ensure a healthy and disease-resilient citizenry. To manage health risks brought about by climate change, it proposes these strategic priorities: (i) assessment of the vulnerability of the health sector to climate change; (ii) improvement of climate-sensitivity and increase in responsiveness of public health systems and service delivery mechanisms to climate change; and (iii) establishment of mechanisms to identify, monitor and control diseases brought about by climate change, and improve surveillance and emergency response to communicable diseases, especially climate-sensitive water-borne and vector diseases (Climate Change Commission [CCC], n.d.). Although health is a priority sector, the wide range of adaptation options that agriculture, water, and disaster risk reduction (DRR) provide to reduce climate-induced health impacts is not fully recognized (Asian Development Bank [ADB], 2011). DOH identifies adaptation strategies in several areas as shown in Table 6.4. Adaptation options such as those shown in Table 6.5 could also be undertaken to address socio-economic and environmental vulnerabilities.

Table 6.4. Suggested adaptation strategies in the health sector (DOH & WHO, 2012)

Pillar	Cluster	Adaptation Strategy
Governance	Program/Systems Integration	• Establishment of cross sector activities and coordinative mechanisms (forestry, water, energy, agriculture) for integrated adaptation responses • Policy cover formulation for governance-plans and activities to proceed • Integrating climate change in the monitoring and evaluation systems
	Partnerships Building	• Development of specific strategies for community participation to improve resilience in anticipation of projected impacts • Forging of private-public partnerships for climate change and health activities • Establishment of cross sector activities (e.g., forestry, water, energy, agriculture) and coordinative mechanisms for integrated adaptation responses

Table 6.4. Continued

Pillar	Cluster	Adaptation Strategy
Regulation	Climate Change and Health Development	• National and local assessment on determination of climate change and health vulnerabilities and impacts, consider the parallel state and quality of biodiversity • Addressing the need for additional regulatory parameters to ensure safety of infrastructure and quality of health goods and services
	Policy and Systems Development	• Mainstreaming indigenous knowledge in consideration of adaptation mechanisms for health • Review of Climate Change Act vis-à-vis related legislation (i.e., Clean Air Act, Solid Waste Management, etc.)
	Program/Systems Integration	• Institutionalizing DRR and CCA into health regulatory system development and policies
Service Delivery	Policy and Systems Development	• In the area of capacities: training health personnel and acquisition of equipment for adaptation • Developing behavioral change communication on climate change and health • Identification of the current distribution and burden of climate-sensitive health determinants and outcomes • Addressing the need for additional researches and studies
	Program/Systems Integration	• Integrating climate change in the monitoring and evaluation systems • Integration of infectious disease programs with environmental health program (e.g., water and sanitation) • Establishment of integrated disease surveillance systems with emphasis on climate-sensitive diseases
Financing	Financing Climate Change	• Ensuring appropriate financing mechanism for CCA that is measurable, reliable, and sustainable • Inclusion of climate change programs and initiatives in the development of Provincial/City Investment Plans for Health • Sector-wide approach (pooling of resources) • Strengthening Philippine Health Insurance Corporation (PhilHealth) benefit package to address climate change related diseases

Source: DOH & WHO (2012)

Table 6.5. Adaptation options to address socio-economic and environmental vulnerabilities (Lorenzo et al., 2010)

Vulnerability	Adaptation Option/Activity
Socio-economic	• Assurance of adequate supply of potable water: solar water disinfection (SODIS), supercritical water (SCW) system • Water disinfection through the use of solar power (e.g., SCW system, SODIS) • Improve household sanitation • Floating toilet device • Regular house-spraying • Provision of insecticide-treated bed nets in malaria endemic areas • Implementation of education campaigns to eliminate breeding sites • Adoption of a risk-based approach to adaptation • Improved disease monitoring and surveillance systems • Early case detection and improved case management • Establishment of a multi-stakeholder coordination committee to manage national adaptation strategies

Table 6.5. Continued

Vulnerability	Adaptation Option/Activity
Socio-economic (Continued)	• Use of radio and television for information dissemination • Weather forecasting and early warning systems • Construction of climate resistant houses • Ban on precarious residential placements • Land zoning restrictions based on hydrological and risk assessment studies • Provision of a national disaster insurance fund • Mainstreaming of climate change into government policies
Environmental	• Release of sterile male vectors • Introduction of larvivarous fish in natural and artificial ponds and wetlands • Integrated water management • Integrated environmental management

Source: Lorenzo et al. (2010) MDGF 1656: Conduct of Climate Change Vulnerability and Impact Assessment Framework, Development of a Monitoring and Evaluation Framework/System, and Compendium of Good and Innovative Climate Change Adaptation Practices

6.7.2 Adaptation Options in Practice

Findings of a study describe the adaptation practices for health as shown in Table 6.6. Among the B'laan tribe in Sarangani province, the indigenous adaptation practices employed for human health include: (i) ritual called '*Damsu*', killing of native chicken as a means of offering to their deities in return for healing of a patient, (ii) consulting quack doctor or '*albularyo*', and (iii) using herbal medicine such as '*eskaan-bulan*' also known as '*sambung*' and '*ika*' or '*buyu*' (Elbat & Alburo, 2012).

Table 6.6. Adaptation practices in the health sector (Lorenzo et al., 2010)

	Dengue	Malaria	Leptospirosis	Cholera	Typhoid
Individuals and Family					
Use of treated or untreated mosquito nets	Proper use of nets at the right time and place	Proper use of nets at the right time and place			
Provision of screens and sealing of holes in houses	Prevent entry of mosquitoes	Prevent entry of mosquitoes			
Cleanliness of immediate household's surroundings	Removal of water in containers inside and outside the house	Removal of breeding grounds of mosquitoes inside and outside the house by practicing proper waste disposal	Elimination of damp areas conducive for rat's habitat. Clean drainage system often to prevent breeding grounds of rats		
Water, sanitation, and good hygienic practices				Source out water for drinking that is safe or free from contamination. Sterilize water before drinking.	

Table 6.6. Continued

Adaptation Practice	Dengue	Malaria	Leptospirosis	Cholera	Typhoid
Water, sanitation, and good hygienic practices				Store foods properly avoiding contacts with probable carriers of cholera. Practice sanitation and good hygiene in the family.	Same as cholera
Consciousness on good health maintenance	Early diagnosis and treatment of climate-change related diseases.				
Maintenance of pets at home that can reduce growth of vectors and pathogens	Breeding of larvivarous species of fish		Maintenance of cats that feed on rats		
Barangay or Community					
Presence of active barangay health workers	Report suspected cases to hospitals for immediate diagnosis and treatment	Microscopists for malaria only for immediate diagnosis and treatment of climate change-related diseases	Report cases of suspected infected persons for treatment	Refer cases to hospitals for diagnosis and treatment	Refer cases to hospitals for immediate diagnosis and treatment
Decanting	Spraying pesticides that are not toxic to human beings		Destroy rats and breeding grounds and habitat		
Provision of centralized clean water sources that are well protected and maintained whole year round				Spring development Prevention of water source contamination by sealing potential entry of pathogens/vectors	
Community ordinances: zoning and resettlement of high risk groups or informal settlers	Resettlement in dengue-free zones	Resettlement in malaria-free zones	Resettlement in elevated and non-flood prone areas	Remove sources of water contamination or resettlement contaminated groups	
Proper waste management system at community level	Removal of wastes that promote growth of pathogens/vectors Cleaning of waterways		Eliminate breeding grounds of rats	Removal of sources of contamination Location of water sources away from sewage/waste dumping areas	Prevent sources of pathogens/vectors coming waste/sewerage areas
Presence of manned and active health workers in barangay health centers (BHCs)	Regular diagnosis, treatment, and referrals/endorsement to hospitals that can treat diseases				

Table 6.6. Continued

Adaptation Practice	Dengue	Malaria	Leptospirosis	Cholera	Typhoid
Information and education campaign at the community level	BHCs with regular information campaign activities for the population on prevention/ adaptation measures of all diseases				
Health systems and infrastructure					
Presence of a network of complimentary hospitals complete with laboratory, medicines, and medical facilities within the province where costs of diagnosis and treatments are affordable.	Conduct thorough diagnoses and treatments of infected persons				
Health care systems	PhilHealth card necessary for each family				
Holistic health maintenance projects	Fourmula-1, Vaccination, Philippine Integrated Disease Surveillance and Response (PIDSAR), etc.	Fourmula-1, PIDSAR, malaria treatment medicines, etc.	Fourmula-1, PIDSARS, leptospirosis treatment medicines	Fourmula-1, PIDSAR, cholera treatment medicines	Fourmula-1, PIDSAR, typhoid treatment medicines
Pathogen/vector factors					
Innovative practices to eliminate vectors and pathogens.	Solar insecticide capture and destroy		Rats trapping	Floating Toilet Device	Floating Toilet Device
Regular spraying of chemicals that are non-toxic to human beings to eliminate pathogens and vectors inside and outside the house.	Regular and simultaneous spraying that kills mosquitoes and other insects, fungi, and other pathogens in all houses and breeding grounds in a barangay		Regular and simultaneous decanting by barangay level.		
Elimination of growth factors and habitat.	Cleaning of waterways, streams, and other water bodies, and proper sanitary practices at the household level		Cleaning of canals Removal of rat habitat and wastes	Avoid food spoilage by refrigeration and maintenance of clean and safe water sources	
Socio-economic factors					
Health subsidies in vulnerable communities or barangays.	Subsidies to all vulnerable families in the form of free or affordable health card.				
Provision of livelihood and income generating projects to increase income of vulnerable communities.	Planting, processing and marketing of medicinal plants proven to strengthen immune system; manufacture and marketing of decanting and trap gadgets; production and marketing of insect repellants; production, breeding and marketing of pets that feed on insects and rats.				
Environmental factors					
Forestation	Planting and management of integrated forest plantations that drive away mosquitoes		Planting of forest species that attract rats from residential areas.		

Table 6.6. Continued

Adaptation Practice	Dengue	Malaria	Leptospirosis	Cholera	Typhoid
Establishment, maintenance and management of sanitary landfills.	Eliminates breeding grounds of insects, pathogens and vectors.		Eliminates breeding grounds of rats.	Eliminates breeding grounds of insects, pathogens and vectors.	
Periodic cleaning and declogging of waterways, streams, and rivers to allow waterflow continuously.	Breeding grounds of mosquitoes in stagnant water are destroyed.		Flowing stream prevents deposition of wastes for rat food.	Clean and declogged waterways also washout pathogens and vectors that live on stagnant water.	
Health/environmental policy					
Policy on the integration of health and climate change education in primary and secondary education	Education on the prevention of dengue at home and in school	Education on the prevention of malaria at home and in school	Education on the prevention of leptospirosis	Education on the prevention of cholera	Education on the prevention of typhoid
Climate risk proofing policies	Adoption and implementation of adaptation measures for climate change-related health problems in all DOH projects				
Policy on mandatory coverage of population for health care system	Full coverage in highly vulnerable areas				
Policy on Strengthened Provincial Disaster Coordinating Council	Creation of a sub-council on disease-related disaster prevention and management				
Disaster preparedness policy	Nationwide capacity building of people on disaster preparedness brought about by climate change-related diseases				

Source: Lorenzo et al. (2010) MDGF 1656: Conduct of Climate Change Vulnerability and Impact Assessment Framework, Development of a Monitoring and Evaluation Framework/System, and Compendium of Good and Innovative Climate Change Adaptation Practices

6.7.3 Constraints to Adaptation and Adaptive Capacity

Three main categories of gaps are identified in the health sector (DOH & WHO, 2012) as follows:

Technical

Identification of vulnerabilities is a key step. Integral to the health program is identifying issues and gaps that will give an assessment of the present state of practice in climate change and health. There would be a need to develop a national health assessment that will look at the vulnerabilities at national and local levels considering the geographic and cross-sector variations in terms of socio-economics, agriculture, and institutions, among others. The same assessment would identify climate-sensitive health outcomes that will provide an understanding of the means to measure and identify response mechanisms.

Financial

Financing for climate change and health activities is important especially in the establishment of much needed health baselines that could be inputs to future Intergovernmental Panel on Climate Change (IPCC) assessment reports as well as regional climate and health correlation studies. Institutionally, there would be a need to identify mechanisms for integrating programs into the DOH so that institutional sustainability can be achieved. The recent province-wide investment plan for health (PIPH) is a very good window for advocating climate change and health activities as well as private-public partnerships platforms for these. Funding from outside sources could also be explored for pilot strategies and activities based on the national framework.

Capacity building

With the threat of climate change, developing the capacity of health systems to cope becomes the immediate adaptation mechanism that a country could utilize to decrease vulnerability to burden of diseases. In the Philippines, due to the devolution of health care delivery, the health sector coping capacity has been to a large extent a function of each of the local government units' availability and use of resources. Currently, local health systems have been coping in their own way, oblivious to climate change impacts. Local governments would need to recognize this aspect of vulnerability to climate change as that which adds to the present burden of disease in a locality. There would be a need for human resource development of personnel knowledgeable in climate change and health especially specialists (disease surveillance personnel and experts) as well as generalists who can understand the different disciplines (cross-sectors) and incorporate how each might mediate the health continuum. There would also be a need for: (i) integrated systems and mechanisms looking at possible private-public partnerships for CCA responses; (ii) data gathering mechanisms for integrated disease surveillance systems as a platform for long term data gathering; and (iii) readiness of health facilities to respond to climate change and to look at their corresponding resilience to increasing extreme climate events. In the area of communications, behavioral change communications for building community resilience is another gap that would have to be filled. This could include the development of behavioral change communications plans which are community-based and community-developed with the technical assistance of communications experts. It could take into consideration health-risk communication strategies in light of climate change effects.

6.8 UNCERTAINTIES AND KEY RESEARCHABLE AREAS

Health impacts of climate change and associated adaptation measures are the least explored in research and action partly due to the lack of specialized expertise in this area. Research and development would require attention and efforts to increase investment and development of capacities to manage new and dynamic health threats. Research priorities may include: (i) assessment of the vulnerability of the health sector to climate change; (ii) improvement of climate-sensitivity and increase in responsiveness of public health systems and service delivery mechanisms to climate change; and (iii) establishment of mechanisms to identify, monitor, and control diseases brought about by climate change (Lasco, 2012). Research would also be needed in: (i) identifying potential direct and indirect impacts of climate change on health on different gender and social groups; (ii) determining barriers to successful health-related planned and autonomous adaptation to climate change stressors; and (iii) overcoming such barriers through effective social, technological, institutional, and policy measures (Resurreccion, Sajor, & Fajber, 2008). Research could go more in-depth as to identification of systems of analysis and build up the evidence of climate parameters affecting certain diseases. Correlation studies of zoonotic diseases which may have the potential to form part of the climate-sensitive diseases would need to be undertaken in view of quite a number of animal diseases that have started to cross species in recent years. Biodiversity and climate change health impacts could be considered as another area for correlation study where terrestrial as well as marine species (the lack of them or the proliferation of certain others) will have an effect on the health of human populations (DOH & WHO, 2012).

The key uncertainties and knowledge gaps in the health sector include (Smith et. al., 2014):

- The uncertainty of the extent to which society will strengthen public health interventions such as provision of water and sanitation, and early warning and response systems for disasters and epidemics as these will help to protect health from climate risks

- Increased research on: (i) the scale and nature of health risks from climate change; (ii) effectiveness of interventions to protect health; (iii) health implications of adaptation and mitigation decisions taken in other sectors, (iv) improvement in decision support systems and surveillance, and (v) estimation of resource requirements

- Relevant research for health protection from cross-disciplinary studies, including public health decision makers, in these areas: improved vulnerability and adaptation assessments that focus on particularly vulnerable populations and encompass complex causal pathways; quantitative estimation of the effectiveness of health adaptation measures; surveillance, monitoring, and observational systems that link climate, health, and economic impact data and provide a basis for early warning systems as well as development of future scenarios; and assessment of the health co-benefits of alternative climate mitigation policies

- In the longer term, research will need to make the best use of traditional epidemiologic methods while also taking into account the specific characteristics of climate change including the long-term and uncertain nature of the exposure and effects on multiple physical and biotic systems, with the potential for diverse and widespread effects, including high-impact events

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This is the Report of the Philippine Climate Change Assessment (PhilCCA) Working Group 2 Team, which was organized in 2013 by the Oscar M. Lopez Center for Climate Change Adaptation and Disaster Risk Management Foundation, Inc. (Oscar M. Lopez Center) in partnership with the Climate Change Commission (CCC). The Report is the second assessment of the three volumes of PhilCCA. Following are the topics covered in the Report:

Ecosystems
Freshwater resources
Coastal systems and low-lying areas
Agriculture and fisheries
Human health

Leading scientists in the Philippines reviewed all best available scientific publications from international and local literature to provide a comprehensive assessment of the current understanding on climate change impacts, vulnerabilities, and adaptation in the Philippines. By sharing these current scientific information in the Philippines to climate researchers, adaptation and mitigation practitioners, and policy makers, the report can serve as key reference towards science-based and informed planning, decision-making, and resilience-building.

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December 2017