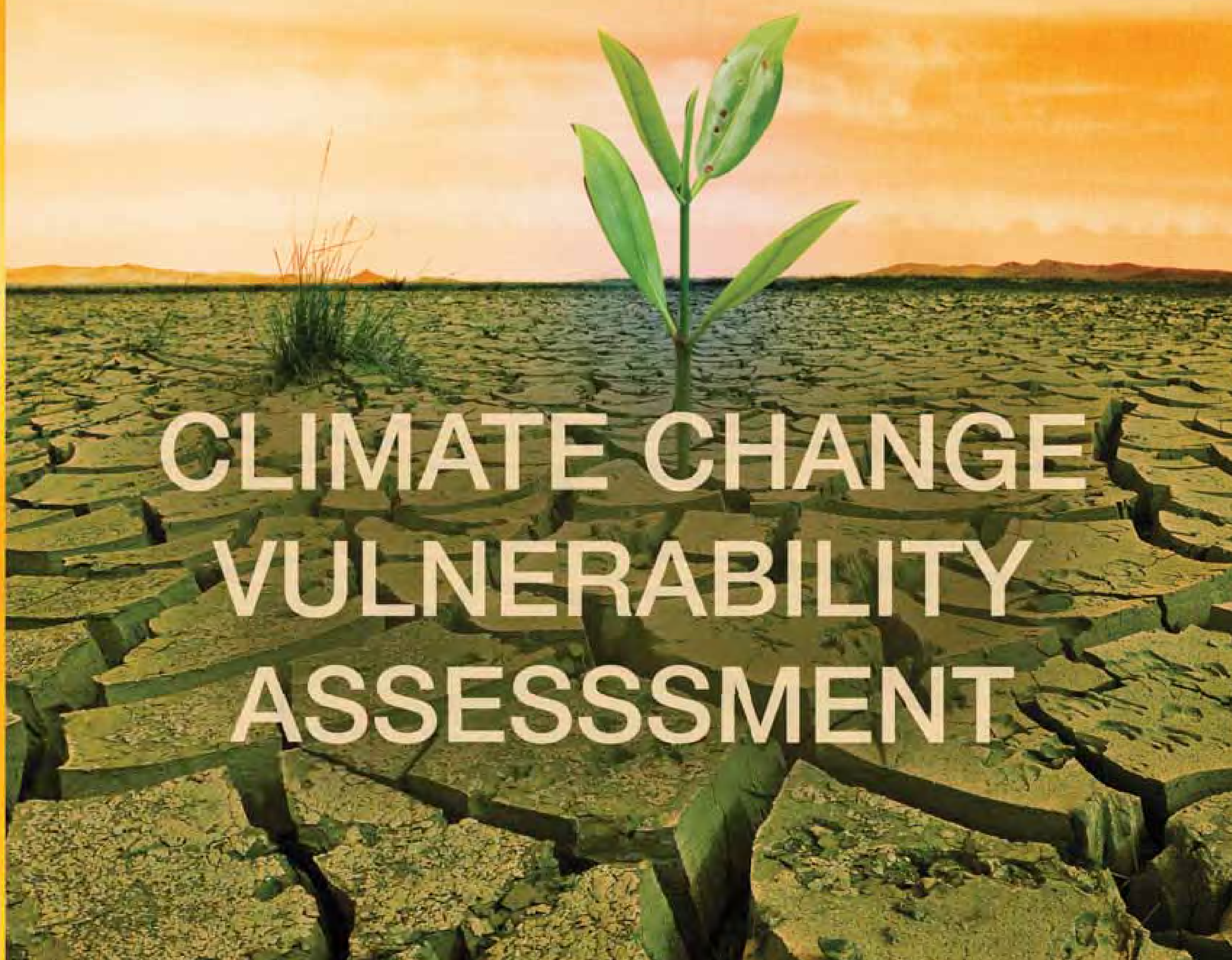
Brunei Darussalam-Indonesia-Malaysia-Philippines
East ASEAN Growth Area
(BIMP-EAGA)



CLIMATE CHANGE VULNERABILITY ASSESSSMENT

BIMP-EAGA CLIMATE CHANGE VULNERABILITY ASSESSMENT

APRIL 2015

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Abbreviations

ADB	Asian Development Bank
AIFSF	ASEAN integrated food security framework
ARMM	Autonomous Region in Muslim Mindanao
ASEAN	Association of Southeast Asian Nations
BAPPENAS	*Badan Perencanaan Pembangunan Nasional* (National Development Planning Agency, Indonesia)
BIMP-EAGA	Brunei Darussalam-Indonesia-Malaysia-Philippines East ASEAN Growth Area
CCC	Climate Change Commission
CDM	clean development mechanism
cm	centimeter
CO_2	carbon dioxide
CTI-CFF	Coral Triangle Initiative on Coral Reefs, Fisheries and Food Security
DENR	Department of Environment and Natural Resources
DILG	Department of Interior and Local Government
DOST	Department of Science and Technology
EEPSEA	Economy and Environment Program for Southeast Asia
ESDM	*Energidan Sumberdaya Mineral* (Ministry of Energy and Mineral Resource)
GCM	global climate model
GHG	greenhouse gas
GIS	geographic information system
GDP	gross domestic product
ha	hectare
HDI	human development index
IPCC	Intergovernmental Panel on Climate Change
KKP	*Kementerian Kelautandan Perikanan* (Ministry of Marine Affairs and Fisheries, Indonesia)
KLH	*Kementerian Lingkungan Hidup* (Ministry of Environment, Indonesia)
km	kilometer
km^2	square kilometers
kW	kilowatt
LGU	local govenrment unit
LT	long-term
MCM	million cubic meter
MGB	Mines and Geosciences Bureau
MinDA	Mindanao Development Authority
mm	millimeter
mt	metric ton

Mt.	Mount
MW	megawatt
m^3	cubic meter
NOAH	Nationwide Operational Assessment of Hazards
PAGASA	Philippine Atmospheric, Geophysical and Astronomical Services Administration
RCP	representative concentration pathway
RMD	Roadmap to Development
R&D	research and development
SOCSARGEN	South Cotabato, Cotabato, Sultan Kudarat, Sarangani, and General Santos City
SPI	standardized precipitation index
SRES	Special Report: Emission Scenarios
SSME	Sulu-Sulawesi Marine Ecoregion
ST	short-term
TCM	thousand cubic meters
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change
W	watts
W/m^2	watts per square meter
WWF	World Wide Fund for Nature

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[1] ADB. 2008. *Technical Assistance to the aSEA for Institutional Development for Enhanced Subregional Cooperation in the aSEA Region*. Manila.

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Executive Summary

Purpose of the Study

This report summarizes the findings of a rapid climate change vulnerability assessment conducted on the Brunei Darussalam-Indonesia-Malaysia-Philippines East ASEAN Growth Area (BIMP-EAGA), which comprises parts of the Indonesia, Malaysia and the Philippines, and Brunei Darussalam. The purpose of the report is to raise awareness among policy and decision-makers on BIMP-EAGA's vulnerability to climate change and the need for collaboration in implementing adaptation measures. The rapid assessment was conducted, particularly in the context of food, water and energy security.

Findings of the study are intended to support the BIMP-EAGA member countries in recognizing the risks posed by climate change, pinpoint hotspots, assess gaps in preparedness, and guide future actions to enhance climate resilience. This study also aligns with efforts toward strengthening the integration of the Association of Southeast Asian Nations by 2015 by informing climate change discussions.

The methodology followed these steps: (i) scope the study in the context of BIMP-EAGA's development plan and assessment focusing on food, water, and energy security; (ii) review existing climate-related hazards and past studies on the subregion's vulnerability to climate change; (iii) gather information on climate change projections; (iv) assemble indicators on climate change hazard exposure; sensitivity of food, water and energy resources; and institutional adaptive capacity; (v) apply geospatial analysis to identify hotspots by combining information on three vulnerability factors and their indicators; (vi) assess existing adaptation efforts and identify preparedness gaps; and (vii) identify priority adaptation measures, organized into policy, investment, and capacity building components, including the need to strengthen subregional cooperation.

Vulnerability Assessment Framework

Vulnerability is the degree to which an area is susceptible to the adverse effects of climate change, specifically as manifested in increasing weather variability and projected long-term shift in the occurrence of extreme weather events. The vulnerability analysis framework follows a procedure originally endorsed by the United Nations Intergovernmental Panel on Climate Change, which applies the following 3 considerations in assessing vulnerability:

- Degree of exposure to climate change hazards;
- Sensitivity of natural environments and human populations exposed to these hazards; and
- Capacity of communities and institutions to adapt to climate change.

The study team collected and processed geospatial information on climate change exposure based on subregional climate modelling data, sensitivity of affected areas, and adaptive capacity. Integrated analysis is done through GIS overlay mapping, which is used to assess spatial patterns and to identify "hotspots" or sensitive areas with significant exposure to climate hazards and low adaptive capacity.

Climate Change Projections

Climate projections are based on plausible scenarios of what future greenhouse gas emissions will be like as driven by population and economic development patterns. For purposes of the study, climate projections were based on socio-economic development pathway scenarios that were derived from the World Bank Climate Research Program. The regional projections from this database are based on the results of nine global climate models and are statistically downscaled to a spatial resolution of approximately 50 x 50 kilometers. The overall predicted pattern of climate change for BIMP-EAGA, as suggested by the study, shows increased climate variability and severity of extreme events in the coming decades. These projections validate an earlier study by the Asian Development Bank on climate change in Southeast Asia (2009),[2] which projected the intensification in climate pattern in the coming decades with the associated rise in the frequency and intensity of extreme weather events.

Projections derived from models, no matter how advanced, are not to be regarded as predictions of actual future climate. Rather, these projections provide simulations of future climate under a variety of hypothetical development and greenhouse emissions scenarios, and (more recently) alternative global policy choices. The projections are driven by assumptions in any case, and should be interpreted properly and with caution in light of unavoidable and considerable uncertainty.

Vulnerability Mapping

For purposes of rapid vulnerability assessment, the study team initially used the spatial analysis results from Maplecroft,[3] a web portal that provides quantitative vulnerability assessment of different regions to changes in major climate parameters over the next 30 years. Maplecroft's climate change vulnerability index is obtained for each point on the map (at 22 kilometer spatial resolution) through the weighted overlaying of 3 component indices or sub-indices: an exposure index with an assigned weight of 50%, and sensitivity and adaptive capacity indexes with assigned weights of 25% each.

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2 Asian Development Bank. 2009. *The Economics of Climate Change in Southeast Asia: A Regional Review*. Manila.

3 https://www.maplecroft.com/about/introducing-maplecroft/.

The vulnerability index, categorized from low to extreme, combines the risk of exposure to climate change with the current human sensitivity to such exposure and the institutional and economic capacity to adapt to the potential impacts of climate change. Results of the study show that BIMP-EAGA's vulnerability to climate change appears to be relatively lower compared to other parts of Southeast Asia (i.e., lower Mekong, northern Philippines, Eastern Sumatra, and the major river deltas of Myanmar and Thailand). However, high to extreme vulnerability hotspots are found in parts of Central and South Kalimantan; Southeastern Papua; Maluku; Gorontalo; parts of Sulawesi in Indonesia; parts of Sarawak in Malaysia; and portions of Central Mindanao and the entire Northeastern and Northwestern Mindanao in the Philippines.

Using GIS methodology, an independent validation of the vulnerability risk mapping obtained from Maplecroft was also carried out for the BIMP-EAGA subregion. The validation mapping used a limited number of factors compared with Maplecroft, but the results of the vulnerability ranking are generally consistent with the vulnerability pattern from the Maplecroft risk mapping.

Implications for the Subregion

Results of the vulnerability assessment shows Brunei Darussalam with medium to high climate change exposure due mainly to the higher dry season temperature and the related heat stress occurrence as well as the higher rainfall intensities during the wet season. Increased summer temperature will have an important impact on Brunei Darussalam because it could adversely affect the productivity of its workers, vast numbers of whom work in the oil and gas fields and are exposed to the elements. Higher dry season temperature will also increase the occurrence of wildfire in surrounding forests and prolonged smoke haze with its accompanying health risks on concentrated urban populations. Heavier rainfall occurrence will increase flooding and landslide hazards to which Brunei Darussalam's more densely packed inhabitants would be exposed.

In Indonesia, areas with low coastal slope are vulnerable especially to sea level rise because a small increase in sea level will affect large areas. Although there are many areas with low coastal slope in Central and South Kalimantan, their population densities are low. Thus, the vulnerability of most of Kalimantan is rated medium with only the more populated areas near the coastal zone of Banjarmasin in South Kalimantan and Samarinda in East Kalimantan with high vulnerability rating due to their sensitivity to sea level rise. In addition, South Kalimantan has the highest rate of deforestation, causing increased flooding and reduced water availability during the dry season. These areas have become more vulnerable to the effects of climate change due to the projected increase in rainfall intensity and longer duration of dry spells.

Almost the entire coast of Sulawesi has medium to low levels of vulnerability to sea level rise because of its steep coastal slopes (about 1.5° to 3°). This implies that an increase in sea level will not inundate large areas. However, in some locations, such as the western coastlines of Central and South Sulawesi, the level of vulnerability is medium because the coastal zone is quite flat and populated. South Sulawesi has high population density compared to other provinces in Sulawesi and there is considerable dependence on agriculture and fisheries that are sensitive to climate impacts. The rivers in this part of Sulawesi are also vulnerable to sea water intrusion. In South Sulawesi, most of the agricultural, livestock, and mining activities are concentrated in the watershed areas of Jeneberang-Walanea and Sadang, where the ecosystem is more exposed to degradation.

For Maluku, the hazard brought about by climate change is mainly due to the projected sea level rise. The coastline has recorded an increase in sea level of about 0.76 centimeters annually. Due to the island's low population density, the vulnerability index for Maluku is rated medium to high.

Papua has more than 40 million hectares of forest covering approximately 65%–75% of the province and has relatively low population density. The vulnerability index of Papua is medium, especially in North and West Papua because its coastline has high slope. Southeast Papua has flat coastal areas, degraded coral reef and coastal ecosystems, and is highly vulnerable to sea level rise compared to the rest of Papua. The adaptive capacity of Papua is low due to high poverty incidence and lack of infrastructure.

The exposure factor for Malaysia, particularly Sabah, was found to be a more dominant vulnerability factor than sensitivity and adaptive capacity. Indeed, the adaptive capacity of all Malaysian states is relatively high in comparison to other countries in Southeast Asia. However, Sabah is ranked high in vulnerability to climate hazards exposure, particularly to flooding and droughts.

In the Philippines, the Northern Mindanao provinces, especially Northeastern Mindanao, are highly vulnerable to climate change extreme events, such as typhoons, due to their proximity to the Philippines' typhoon belt. Portions of Central Mindanao (e.g., Maguindanao, North Cotabato, and Sultan Kudarat), along with Davao del Norte and Compostela Valley in Southeastern Mindanao are among the top 20 provinces that are susceptible to floods with about 20%–42% of their total land area prone to flooding. Bukidnon, Davao Oriental, and Sarangani provinces in Mindanao are included in the top 20 provinces that are susceptible to landslide. Zamboanga City and the provinces of South Cotabato and Sarangani are highly vulnerable to drought.

Needed Measures

Countries that comprise BIMP-EAGA on the whole have fairly adequate legislations, policies, and plans that are in place in relation to climate change adaptation. However, there is room for improvement. For example, the effectiveness of climate change adaptation programs for managing climate change can be enhanced by developing synergy of adaptation action activities among sectors. This is because climate resilience practices do not depend on a single government ministry or agency but necessarily involves all sectors (i.e., all levels of government, the private sector, and the community).

Recommended items for fund sourcing and investments include: (i) improved watershed management; (ii) the technical modernization and improvement of weather station networks, facilities, tools, technology, and databases; (iii) the establishment of river basin gauging stations, tidal gauging stations, and buoys in remote areas; and (iv) the improvement of recovery, organization, processing, and storage of data; (v) the regular maintenance of irrigation facilities to reduce water losses; and (vi) a comprehensive system for monitoring watersheds, ecosystems, and natural resources under changing environmental conditions.

Investments in meteorological and hydrological observations include the following: (i) the modernization of weather observation systems, data processing, and communications; (ii) the installation of automated stations in remote areas; (iii) the establishment of more river basin gauging stations; (iv) the improvement in the operation of specialized meteorological stations (e.g., agro-meteorological, Doppler radar stations, etc.); (v) the improvement in data processing, archiving, storage, and recovery; and (vii) the improvement of current databases and development of modern open-source databases.

Investments to improve aerological, upper-air and remotely sensed observations entail funding of station networks and technical modernization. Investments on tidal and sea observations include the establishment of more stations (e.g., tidal gauges and buoys) and the development of observation networks and database management.

The following areas for capacity building are suggested: (i) integrated vulnerability assessment to formulate climate change adaptation and/or mitigation measures at various levels; (ii) climate fit crop programming to support the food basket strategy of BIMP-EAGA; (iii) climate-based cropping mix for sustainable farming, especially in highly vulnerable agricultural areas; (iv) access and use of geospatial and social science data to arrive at reliable sea level rise predictions, and develop ocean-atmosphere-watershed modelling and prepare inundation maps; (vi) techniques to engage stakeholders in the development of strategic plans for adapting to climate change; (vi) understanding of nearshore currents, circulation patterns, and coastal upwelling effects on natural systems and productivity; (viii) ocean-atmosphere-watershed modelling, including the determination of the potential impacts of storm surges and floods; (ix) capability to formulate more realistic predictions of sea level rise; and (x) implementation of habitat protection and restoration projects.

Technical assistance is needed in the following areas: (i) data on investment requirements, costs, and production capacities of renewable energy sources; (ii) updated studies on local emission factors, carbon credits, and greenhouse gas inventories; (iii) downscaling of climate models to the provinces, municipalities, and individual islands; (iv) improved land use selection through appropriate evaluation tools (e.g., economic valuation); (v) modelling of watershed and ecosystem services under various future climate and socioeconomic scenarios; (vi) integrated natural resources information systems to enable stakeholders to adopt climate smart silvicultural practices that consider factors, such as the climatic conditions, species, soil types, water requirements and resistance to pests; (vii) assessment of the long-term and local effects of climate change; (viii) use of geospatial data to enable communities to understand risks due to climate change; (ix) studies on the impacts of upstream-downstream water use policies on communities; and (x) modern climate monitoring and forecasting.

Conclusions and Recommendations

Numerous actions can be taken to enhance climate resilience in BIMP-EAGA as shown in the menu of possible actions described above. For the most part, these actions are not new ideas. These have appeared in one variant or another in assessments and plans drawn up by the BIMP-EAGA national governments through their respective planning and development authorities, climate change commissions, academic and research institutions, and also by subnational entities (e.g., regional development councils). Food, water, and energy concerns feature prominently in these existing national plans.

The challenge for enhanced climate resilience is how to weave identified measures into a practical action plan at the local level (e.g., provinces, cities, or federal states) so that these are not viewed as standalone remedies but as an integrated (and continuously evolving) solution that is a product of a transformational mind-set change on how to plan for sustainable development in the face of climate uncertainty. A second major challenge is financing. Yet, a third challenge is how to build on synergies between sustainable development and climate resilience, and specifically between resource use efficiency and climate change adaptation, which is also key to competitiveness in a more open regional economy.

Economic uncertainties created by the advent of regional economic integration will be compounded by looming threats from increasing weather variability, extreme weather events, and long-term climate change. In this sense, managing uncertainty (in its various forms, not just climate change) will be the dominant challenge in charting the region's sustainable development future.

There is broad scientific consensus that climate change will alter the physical environment (e.g., hydrologic cycle, terrestrial, and marine ecology) in important ways. Despite continuing advances in climate change science, uncertainty regarding outcomes will remain. It is not possible to predict with precision the size and form of the impacts, particularly at the local level, where adaptation decisions have to be made. National and regional policymakers should not wait for climate change uncertainty to be cleared up by science before taking action, because such uncertainty is unavoidable. Rather, there is need to fundamentally alter planning and decision-making strategies by taking on an adaptive approach to sustainable development—one that confronts uncertainty head-on and proactively manages its implications.

Even with the widely available national action plans for climate resilience, the time and spatial scales in which practical climate change adaptation decisions need to be made are at the local level. This is where resilience initiatives embodying uncertainty-based adaptive planning and drawing from a wide array of options should be initiated. Climate change resilience is fundamentally about managing uncertainty. This requires awareness-raising, practical risk-based planning methods, information and decision support systems, templates and examples, and sustained capacity building. Mind-set change is important to emphasize, and one where the BIMP-EAGA countries can work cooperatively.

In practice, such an approach would entail: (i) considering a variety of plausible futures and/or scenarios that are understood by stakeholders; (ii) considering a variety of possible adaptation strategies and measures that take into account constraints (i.e., institutional, informational, and financial); (iii) favouring actions that are flexible and/or reversible and robust to uncertainties; (iv) using an iterative learning approach based on probing and experimenting; (v) instilling a "habit" of monitoring results and updating vulnerability assessments; and (vi) adjusting plans in light of knowledge gained.

A BIMP-EAGA cooperation framework for climate resilience could focus on assisting local planners and policymakers to ensure that development decisions, including new initiatives and investments that are spurred by the emerging regional economic integration, are not planned "business as usual". That is, decisions must pay attention to present day risks of increasing climate variability and extreme weather, and be robust to the uncertainties of future climate change. Such a fundamental change in approach needs to be supported with sound knowledge base and decision support systems that enable local planners and decision-makers to identify and assess climate risks in an informed manner.

An analogy that may help BIMP-EAGA policymakers appreciate more intuitively the scope of this mind-set change is to think of climate resilience not as a sort of protective coat of remedial measures that is applied on top of the usual fabric of development (as in building more dams to avert future water scarcity or seawalls to protect coastlines). These have short-term uses but are not long-term solutions and are costly, if not also prone to unintended maladaptation effects. Rather, the fabric of development must be woven in a different way, such that resilience is a built-in feature. This means, for example, using water and energy resources more efficiently, increasing agricultural productivity, and closely regulating development in vulnerable coastal zones.

It should also be clarified that such a fundamental shift in development planning is anchored on the premise that development and climate change resilience form a continuum. The aim is not to curtail development or to differentiate development from adaptation, but to ensure that development is not planned in the usual fashion. Development and climate resilience are mutually reinforcing. Indeed, there is strong economic logic in blending the aims of development and adaptation because investments that tap this synergy will pay for themselves regardless of the uncertainty that is inherent in climate change scenarios.

A concomitant major challenge is financing. Assuming that climate resilience plans that embody a fundamental shift in development thinking are spawned, a subregional cooperation framework to facilitate financing for integrated climate resilience initiatives that is targeted at the local level is a worthwhile initiative for BIMP-EAGA policymakers. Here, a subregional body akin to a clearinghouse could be established to facilitate working with financial institutions, in particular, climate funds and their intermediaries. It would also be timely in view of the substantially increased funding anticipated for climate change mitigation and adaptation. Opportunities for seeking funds from the Green Climate Fund or the Adaptation Fund should be explored. There is contentious, yet imminent, progress that is being made towards a new international climate accord. Climate-related funds are expected to be considerably expanded, including under the unprecedented "loss and damage" provisions.

While not contradicting the fundamental link and continuity between development and climate resilience, it is on the aspect of financing—specifically, to access climate funds—where clarifying particular objectives of development as distinguished from climate change resilience takes on practical importance. Again, this is simply to make sure that development initiatives are not planned "business as usual" and that climate funds are used in an effective way. Assisting BIMP-EAGA local governments in preparing resilience plans that meet this norm is another important role for the envisioned clearinghouse.

Introduction

The Brunei Darussalam-Indonesia-Malaysia-Philippines East ASEAN Growth Area (BIMP-EAGA) is comprised of Brunei Darussalam; the Indonesian provinces of Kalimantan, Maluku, Papua and West Papua, and Sulawesi; the states of Sabah and Sarawak, including the federal territory of Labuan, in Malaysia; and the Mindanao island and the Palawan province in the Philippines. BIMP-EAGA's development implementation plan for 2012–2016,[1] summarized in Appendix 1 of this report, aims to attain self-sufficiency in food and security of water and energy resources. To achieve this goal, efforts are underway to further develop the subregion's agriculture and fishery production as well as improve the management of water resources and energy utilization.

However, climate change presents a strategic challenge in attaining this goal. The subregion is particularly vulnerable to the impacts of climate change because a large proportion of its population depends on the natural environment for livelihood. This is compounded by limited awareness and capacity to respond to climate change. In view of this, the BIMP-EAGA Environment Cluster requested the Asian Development Bank (ADB) for technical assistance to support a study on how climate change could affect the subregion's prospects for food, water, and energy security. The report responds to this request.

The study provides a subregional perspective and summarizes the findings of a climate change vulnerability assessment that was conducted on the BIMP-EAGA. The geographic coverage of the study and priority economic corridors of the subregion are shown in Figure 1. The report aims is to inform and raise awareness, particularly among policy and decision-makers, on the impacts of climate change and the need for collaboration among BIMP-EAGA member countries in addressing climate change issues. A rapid vulnerability assessment focusing on adaptation and resilience was conducted to determine the subregion's readiness to address the impacts of climate change, particularly in the context of food security, water and energy, and their inter-dependencies.[2]

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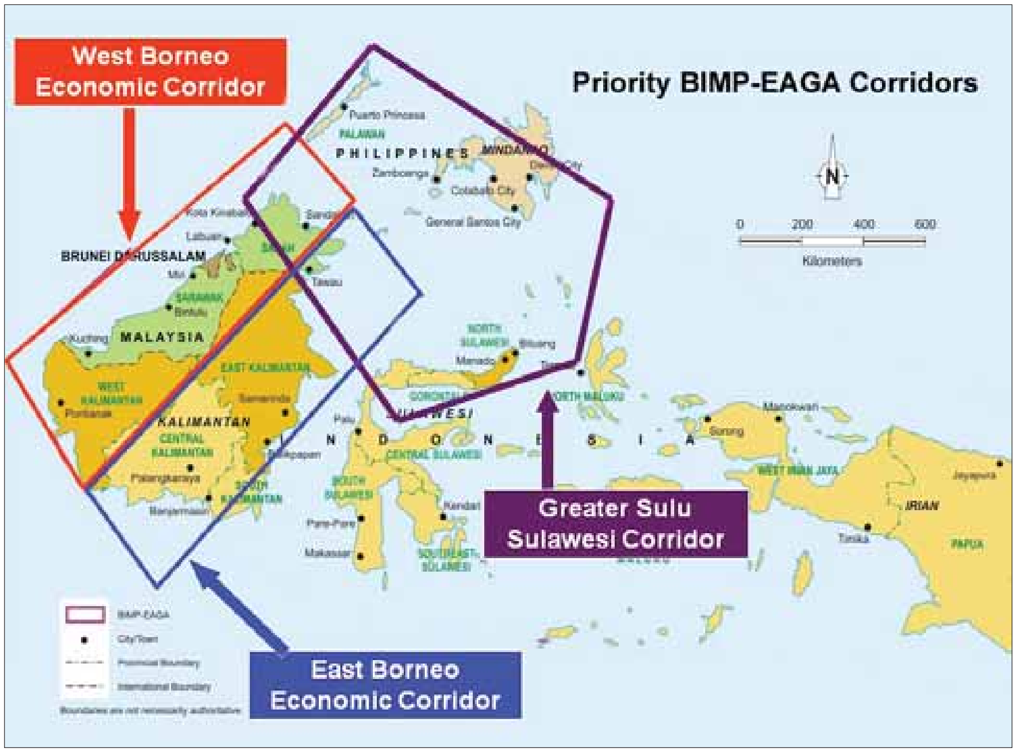
1 http://bimp-eaga.org/documents/.

2 Climate change provides a context for the interdependence (nexus) of water, food, and energy, in that energy is a major user of water (e.g., for cooling power plants and for producing biofuels), agriculture is a big consumer of water (for irrigation) and energy (for pumping). To meet growing urban water needs, energy use for water treatment will increase, as with possibly intensified energy use for water reuse (wastewater treatment) to augment supplies.

Figure 1 Priority Economic Corridors in BIMP-EAGA



Source: BIMP-EAGA (2012).

This report draws from the findings of the country-specific vulnerability assessments and provides a subregional picture on the BIMP-EAGA's current and indicative future climate conditions, socio-economic environment that contributes to the subregion's vulnerability to climate change, state of preparedness, and recommendations on adaptation measures and priorities. Findings of the study will support the BIMP-EAGA member countries in recognizing the risks posed by climate change, identifying hotspots, assessing preparedness and gaps in dealing with climate change, and guiding future policies and programs to enhance climate resilience. By informing climate change discussions, the study aligns with efforts toward regional integration within the Association of Southeast Asian Nations that is targeted by 2015.

Scope, Framework, and Methodology

The following questions were used as guide in the vulnerability assessment:

- What are the key exposure and the main consequences of climate change impacts on the environment and human well-being?
- What are the sensitivities leading to vulnerability and how effective are existing coping strategies?
- What are the adaptation responses that could address the projected impacts of climate change while helping build resilience in natural and human systems?
- What are the policies, capacities, and steps needed to effectively implement adaptation?

The study methodology followed the following steps:

- Scope the study in the context of BIMP-EAGA's development plan and assessment, focusing on food, water, and energy security;
- Review existing climate-related hazards and past studies on the subregion's vulnerability to climate change;
- Set up a geospatial database on climate change projections;
- Assemble indicators on climate change hazard exposure; sensitivity of food, water and energy resources; and institutional adaptive capacity;
- Apply geospatial analysis to identify hotspots by combining information on vulnerability factors and their indicators;
- Assess existing adaptation efforts and identify preparedness gaps; and
- Identify priority adaptation measures, organized into policy, investment, and capacity building, including the need to strengthen subregional cooperation.

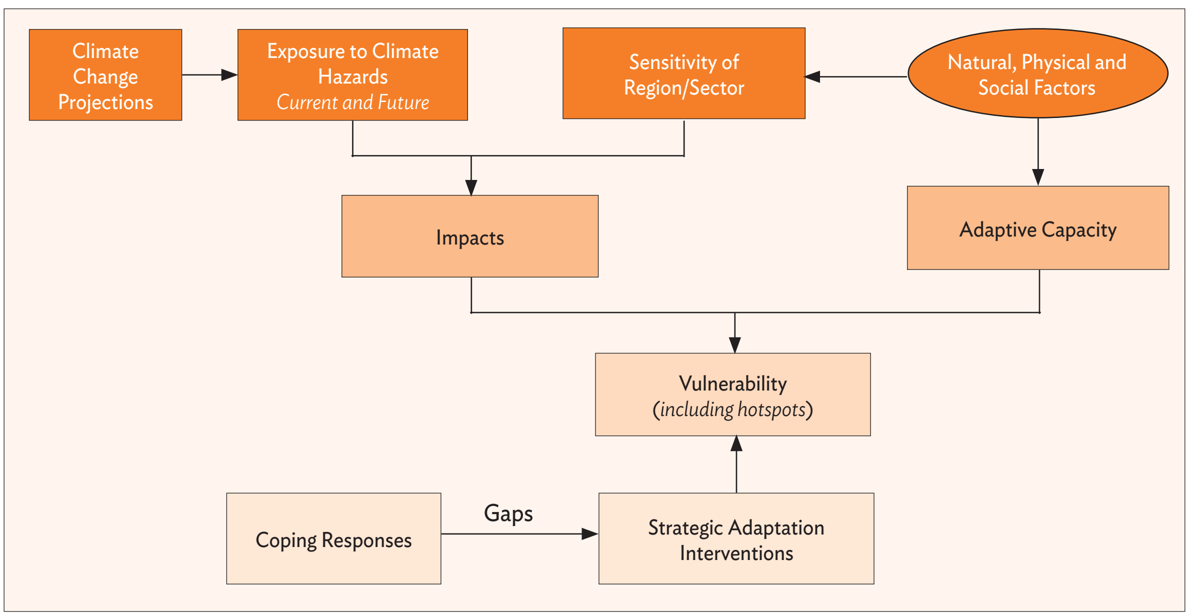
Vulnerability is the degree to which an area is susceptible to the adverse effects of climate change as manifested by increasing weather variability and the projected long-term shift in the occurrence of extreme weather events. The vulnerability analysis framework used in the study follows a procedure that applies the following considerations as originally endorsed by the United Nations Intergovernmental Panel on Climate Change (IPCC) (2007):

- Degree of *exposure* to climate change hazards;
- *Sensitivity* of natural environments and human populations exposed to these hazards; and
- *Capacity* of communities and institutions to adapt to climate change.

Exposure to climate hazards is influenced mainly by geographical location while sensitivity and adaptive capacity are context-dependent. For instance, a segment of the subregion's population may be considered more sensitive because their livelihood depends on rainfed agriculture. Adaptive capacity in turn depends on access to resources and support systems that enable communities to respond to climate threats. The vulnerability analysis framework with its component linkages area is shown in Figure 2.

Following the framework above, the study collected and processed geospatial information on climate change exposure based on regional climate modelling data, sensitivity of affected areas, and adaptive capacity. Integrated analysis was carried out through GIS overlay mapping to assess spatial patterns and to identify hotspots or sensitive areas with significant exposure to climate hazards and low adaptive capacity. A review of previous vulnerability assessments covering BIMP-EAGA is provided in Appendix 2.

Figure 2 **Framework for Vulnerability Assessment**



Source: ADB (2015).

Climate Change Projections

Assessing exposure to climate change hazards depends on predicting the direction and magnitude of climate change over a long time period, which introduces uncertainty and risk. In this context, climate change adaptation is fundamentally about managing risk.

Climate projections are based on plausible greenhouse gas (GHG) emissions in the future as driven by population and economic development patterns. Climate projections cannot preclude uncertainty despite significant advances in scientific understanding and climate modeling techniques. Nonetheless, the latest report from the IPCC (2014) states that:

- Warming is "unequivocal" and human influence on climate is clear.
- The period 1983–2012 is likely to be the warmest 30-year period over the last 1,400 years.
- Warming impacts are already evident around the globe (e.g., acidification of oceans, melting of arctic ice, and poorer crop yields in many parts of the world).
- Temperatures will increase over the coming decades and could reach 5°C above pre-industrial levels by the end of the century without concerted action on carbon.[3]

Uncertainty in climate projections is managed by using climate models that capture well the region's dominant climate features and by relying on more than one model. Another aim in climate projections is to quantify uncertainty so that the range of outcomes can be expressed probabilistically. This is done by using an ensemble of models that produces a range of projections that enables the application of statistical analysis.

Available climate projections are based on 2 sets of scenarios. The first set reflects socio-economic development pathways that were formulated in 2007 to support the *Fourth Assessment Report* of the IPCC. They are used to explore uncertainties behind trends in global socio-economic development that serve as key drivers of future GHG emissions. A second more recent set of scenarios are used to support the *Fifth Assessment Report* of the IPCC (2014), which reflects global policy choices for mitigating GHG and are described by the degree to which they actively mitigate, stabilize, or increase emissions. A summary of these scenarios and their correspondence is provided in Appendix 3. The appendix also summarizes the methods used in global climate change modelling, the use of multi-model ensembles, and techniques to downscale model results for regional or subregional analysis.

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3 Roughly corresponding to 2080–2100.

For purposes of rapid assessment, the study used climate projections based on the socio-economic development pathway scenarios from the World Bank Climate Research Program. Regional projections from this database are rooted on the results of nine global climate models and are statistically downscaled to a spatial resolution of approximately 50 x 50 kilometers (km).

Projections derived from models, no matter how advanced, are not to be regarded as predictions of actual future climate. Rather, these projections provide simulations of future climate under a variety of hypothetical developments and GHG emissions scenarios, and more recently, alternative global policy choices. The projections are driven by assumptions and should be interpreted properly and with caution in light of uncertainty.

The overall pattern of climate change predicted in BIMP-EAGA suggests an increase in climate variability and severity of extreme events in the coming decades. In particular, the findings show the following:

- Warming by an average of up to 1°C–1.5°C by mid century[4] with increased risk of heat wave occurrence,
- Substantial increase in the frequency of days that is considered as 'hot' in the present climate,
- Overall increase in rainfall with large spatial and seasonal variation,
- Enhanced rainfall variability that could increase the occurrence and duration of dry periods,
- Increased total annual rainfall, and
- Higher rainfall intensities that could increase the risk of flooding and landslide.

These projections validate ADB's climate change study on Southeast Asia (2009a), which reported that climate change in the region will intensify in the coming decades with an associated rise in the frequency and intensity of extreme weather events. The concomitant effects include more frequent heat waves, a significant rise in the number of heavy precipitation events, and the escalation in the number of tropical cyclones.

The ADB report also noted that flooding in low-lying areas poses significant risks to agriculture and infrastructure. Prolonged droughts during the dry season could become an increasing concern, particularly during the El Niño years. In forested areas, climate extremes will exacerbate fires and landslides. Indeed, forest fires have intensified and have spread over larger areas in Southeast Asia, including BIMP-EAGA, due essentially to the combined effects of rising temperature, declining rainfall, and aggressive land use changes.

Rising sea levels is already inducing salt water intrusion in coastal areas and will worsen the damage caused by typhoon-generated sea surges. In marine ecosystems, warmer temperatures have resulted in increased rates of coral bleaching and advancing sea levels, and coastal erosion is causing mangrove forests to retreat inland.

[4] Roughly corresponding to 2040–2060.

Similarly, findings from the climate projections database also corroborate an earlier assessment made by the United Nations Development Program (UNDP)[5] on Indonesia. The UNDP study showed that the mean annual temperature has increased at an average rate of 0.14°C per decade and that the frequency of hot days has increased significantly since 1960. UNDP's modeling-based climate projections indicate that mean temperature over Indonesia could increase by about 1°C by the 2060s with hot days projected to occur on 35%–79% of days throughout the year. Projections also indicate that the maximum amount of 1-day and 5-day rainfall is expected to increase in the future.

The projected increase in sea surface temperature throughout Indonesia due to GHG is about 0.8°C–1°C by 2020–2050 relative to the last climate period in the 20th century (1945). In fact, the trend in sea surface temperature increase for Indonesia is slightly higher than the global average of 0.75°C per decade (BAPPENAS,[6] 2010b).

Sea level rise due to global warming is projected to reach 35 centimeters (cm)–40 cm relative to the situation in 2000 and can significantly threaten large and small islands in Indonesia by 2050. East Kalimantan and Papua, particularly the southeastern portion of the province, will be most affected by the projected sea level rise. Figure 3 shows sea level rise projections in BIMP-EAGA at various levels of inundation (BAPPENAS, 2010a).

According to the Philippine Atmospheric, Geophysical and Astronomical Services Administration, Palawan is projected to have significant temperature increase of 0.9°C–1.1°C by the 2020s and 1.8°C–2.1°C by the mid century under the medium range GHG emission scenario. The temperature in Mindanao are projected to increase by 0.9°C–1.3°C in the 2020s and by 1.7°C–2.6°C by mid century.

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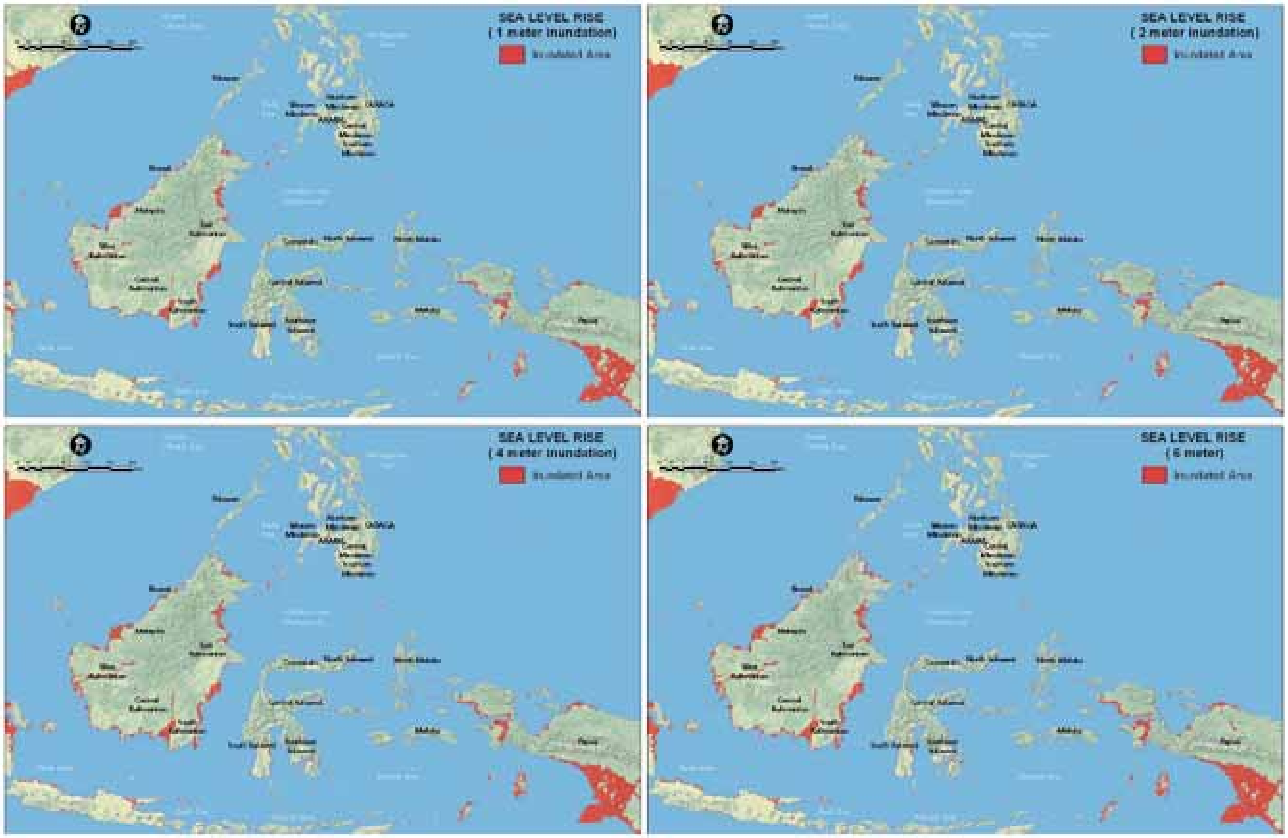
5 Karmalkar, A., et al. n.d. *UNDP Climate Change Profiles: Indonesia*. Retrieved from http://country-profiles.geog.ox.ac.uk.

6 *Badan Perencanaan Pembangunan Nasional* (National Development Planning Agency).

Figure 3 Projections on Sea Level Rise



Source: Sea Level Rise Maps and GIS Data. 2006. Centers for the Remote Sensing of Ice Sheets (CReSIS) at the University of Kansas and Haskell Indian Nations University.

Vulnerability Mapping

For purposes of the rapid vulnerability assessment, the study initially used the spatial analysis results from Maplecroft,[7] a web portal that provides quantitative vulnerability assessment of different regions to changes in major climate parameters over the next 30 years. Maplecroft's climate change vulnerability index is obtained for each point on the map (at 22 km spatial resolution) through a weighted overlay of the following component indices or sub-indices: exposure index with a weight of 50%, sensitivity and adaptive indexes with a weight of 25%, respectively. These component indices were constructed using the indicators listed below. The indicators used to construct these indices, including their weight assignments, are explained in Appendix 4.

- Exposure index (50%). Captures the level of potential exposure to extreme climate-related events (e.g., drought, cyclone, storm surge, wildfire, severe local storm, landslide, flooding and sea level rise) and predicted change in baseline climate parameters (e.g., air temperature, precipitation, and specific humidity). It combines future climate model data with information on past extreme events. The index is derived from 11 specific indicators.[8]
- Sensitivity index (25%). Measures the current human sensitivity to exposure, economic resources, general health and accessibility of health services, access to knowledge, population pressure, infrastructure, conflict, natural resource pressure, and agricultural dependency. It is derived utilizing a combination of national and subnational data. The index is comprised of 21 key indicators.[9]
- Adaptive capacity index (25%). Measures the ability or potential of a country's institutions, economy, and society to adjust to or to take advantage of existing or anticipated stress from climatic change. The index used by Maplecroft focuses

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7 https://www.maplecroft.com/about/introducing-maplecroft/.

8 Includes the following indicators and their respective weight: change in precipitation (6.67%), predicted change in air temperature (6.67%), predicted change in specific humidity (6.67%), susceptibility to sea level rise (10%), flood risk (10%), drought risk (10%), tropical storm and cyclone risk (10%), precipitation-related landslide risk (10%), severe storm risk (10%), wildfire risk (10%), and storm surge risk (10%).

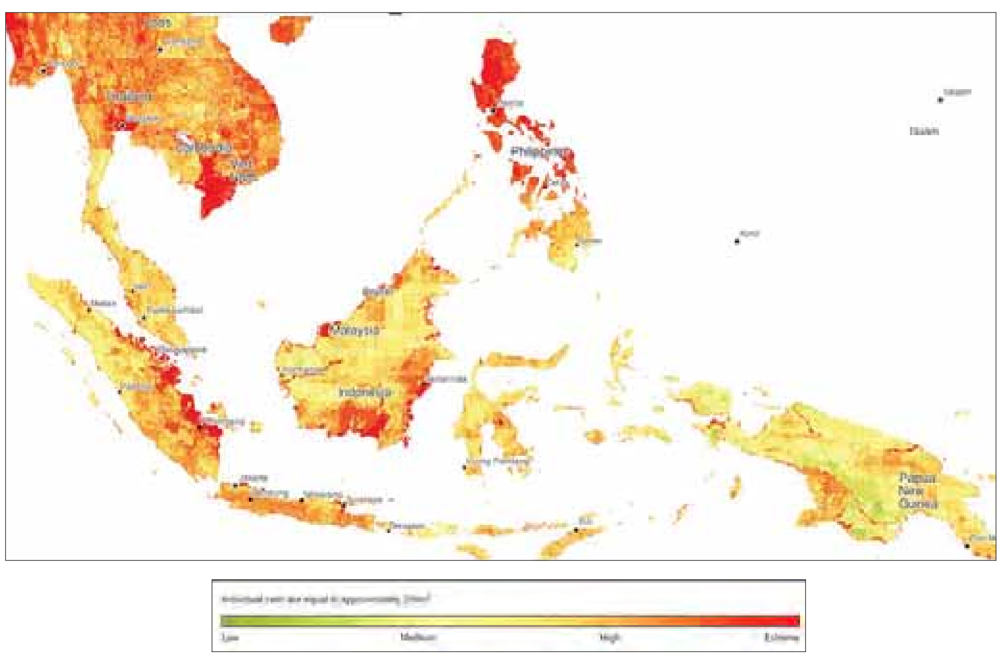
9 Includes the following indicators and their respective weights: poverty density index, 2013 (12.3%); livelihood assets index, 2013 (3.1%); maternal mortality rate, 2010 (5.1%); children under 5 underweight, latest 1999–2011 (5.1%); prevalence of undernourishment in total population, average 2010–2012 (5.1%); primary enrolment ratio, latest 2000–2011 (3.9%); adult literacy rate, latest 2000–2011 (3.9%); population density, 2011 (10.3%); rate of population change, 1990–2015 (5.1%); estimated travel time to nearest city, 2000 (5.1%); telephone lines and/ or subscriptions per 100 population, 2012 (5.1%); access to water and sanitation index, 2014 (5.1%); conflict and political violence index, 2013 (2.6%); refugees, 2011–2013 (1.3%); internally displaced persons, 2011 (1.3%); population density for persons over 65 years, 2011 (2.6%); water stress index, 2013 (4.6%); human appropriation of net primary productivity, 1995 (4.6%); soil degradation, 1990 (1.5%); gross loss in forest cover, 2000–2005 (4.6%); and agricultural land use, 2005–2006 (7.7%).

on the macro level, structural factors (e.g., governance and the economy). Fifteen indicators are used to derive this index.[10]

The vulnerability index, categorized from low to extreme, combines the risk of exposure to climate change with human sensitivity to such exposure as well as the institutional and economic capacity to adapt to the potential impacts of climate change. The risk index maps for the BIMP-EAGA subregion are shown in Figures 4–7. These maps show BIMP-EAGA's vulnerability to climate change appears to be relatively lower compared to other parts of Southeast Asia (i.e., lower Mekong, northern Philippines, Eastern Sumatra, and the major river deltas of Myanmar and Thailand). However, high to extreme vulnerability hotspots are found in segments of Central and South Kalimantan; Southeastern Papua; Maluku; Gorontalo; and North, West, Southeast and South Sulawesi in Indonesia; parts of Sarawak in Malaysia; and portions of Central Mindanao and the entire Northeastern and Northwestern Mindanao in the Philippines.

These hotspots by and large also correspond to areas with high to very high climate change exposure risk (expounded in Appendix 4) and areas with high population densities, high carbon dioxide (CO_2) emissions from land use change resulting mainly from biomass burning, extensive deforestation, and high water stress as shown in Figure 8.

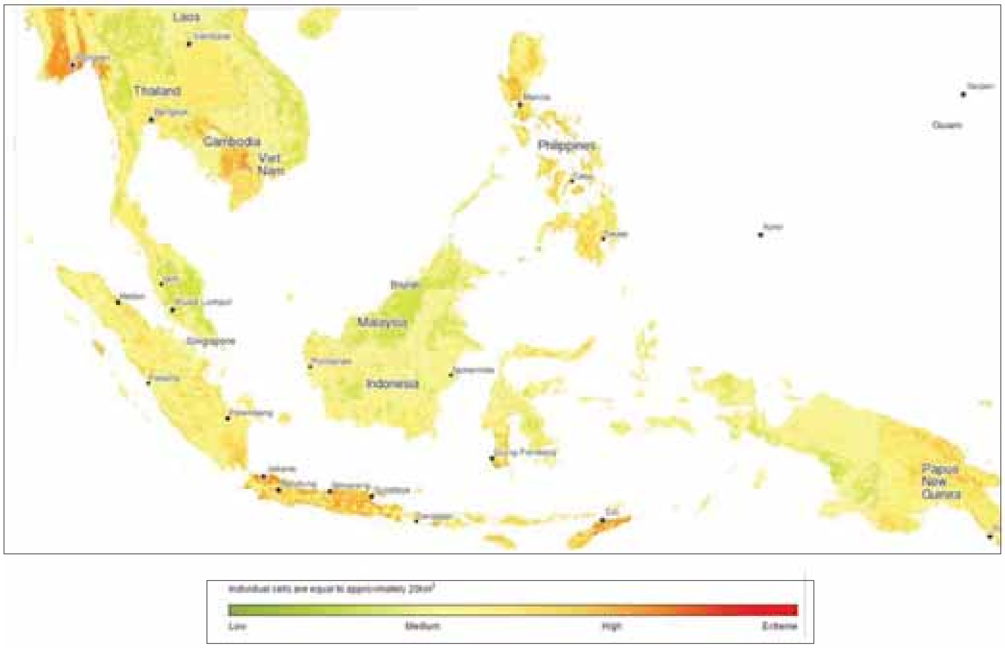
Figure 4 **Exposure to Climate Change Hazards**



Source: Maplecroft (2014).

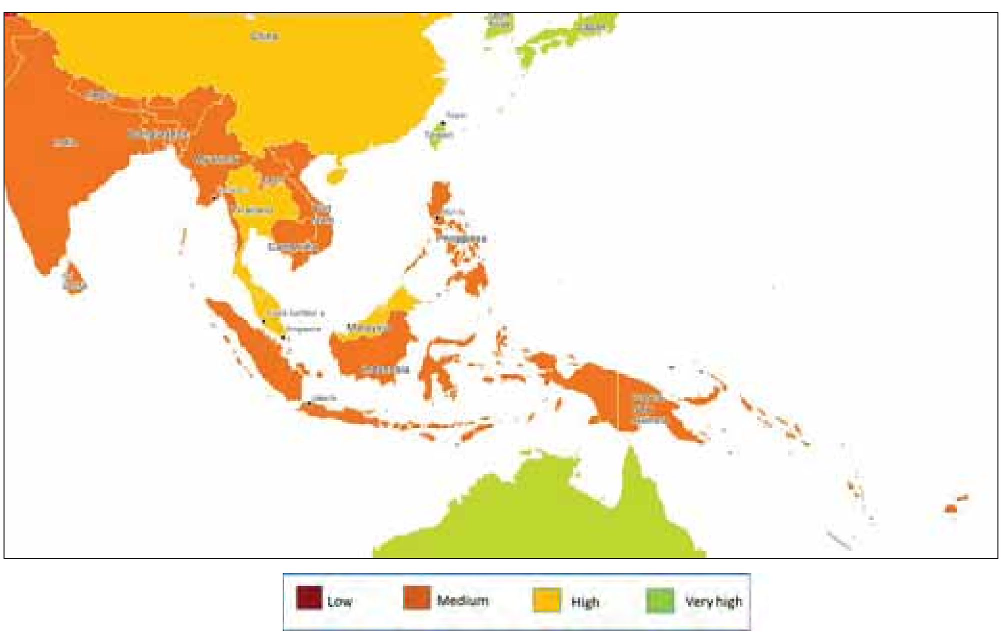
[10] Includes the following indicators and their respective weight: innovation pillar, 2012–2013 (5.71%); expenditure on research and development, 2006–2011, percentage of gross domestic product (GDP) (5.71%); gross completion rate, first degree, 2000–2012 (8.57%); regime stability index, 2013 (5.71%); government effectiveness index, 2013 (11.43%); corruption risk index, 2013 (5.71%); knowledge on climate change, 2010 (2.86%); energy security (short-term) risk index, 2014 (5.71%); water security index, 2014 (5.71%); food security index, 2013 (5.71%); agriculture, value added as a percentage of GDP, 2003–2011 (8.57%); GDP per capita (constant purchasing power parity), 2007–2011 (11.43%); external debt as a percentage of GDP; 2010–2011 (2.86%); net official development assistance received per capita, 2011 (5.71%); and life expectancy, 2012 (8.57%).

Figure 5 Sensitivity of Human Populations



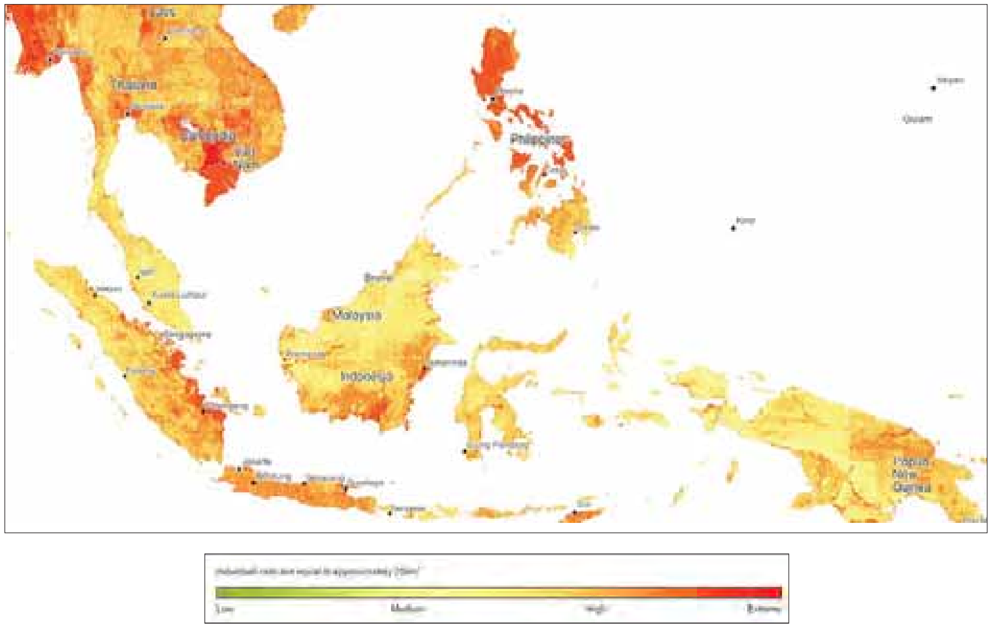
Source: Maplecroft (2014).

Figure 6 Adaptive Capacity of Countries



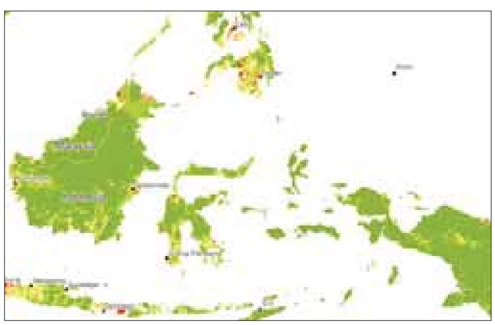
Source: Maplecroft (2014).

Figure 7 Climate Change Vulnerability



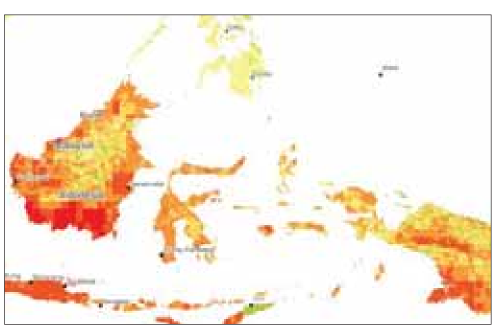
Source: Maplecroft (2014).

Figure 8 Factors Linked to Vulnerability

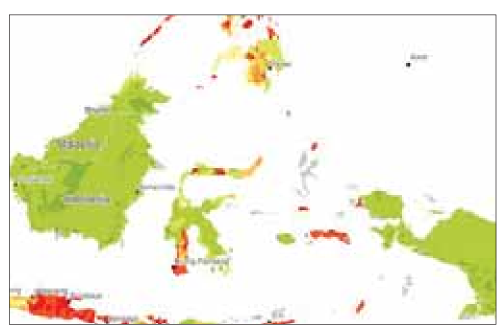


(a) Population Density

(b) Extent of Deforestation



(c) CO_2 Emissions from Land Use Change



(d) Water Stress

Source: Maplecroft (2014).

Independent validation of the vulnerability risk mapping obtained from Maplecroft was carried out using GIS methodology, which is discussed in detail in Appendix 5. This index mapping has limitations in that it uses fewer number of indicators compared to Maplecroft and mainly shows a comparison of vulnerability among areas within the subregion. Nevertheless, it is based on a reliable database on climate change projections that was obtained from the World Bank climate portal, which were in turn generated from an ensemble of downscaled global climate models that is described in Appendix 3.

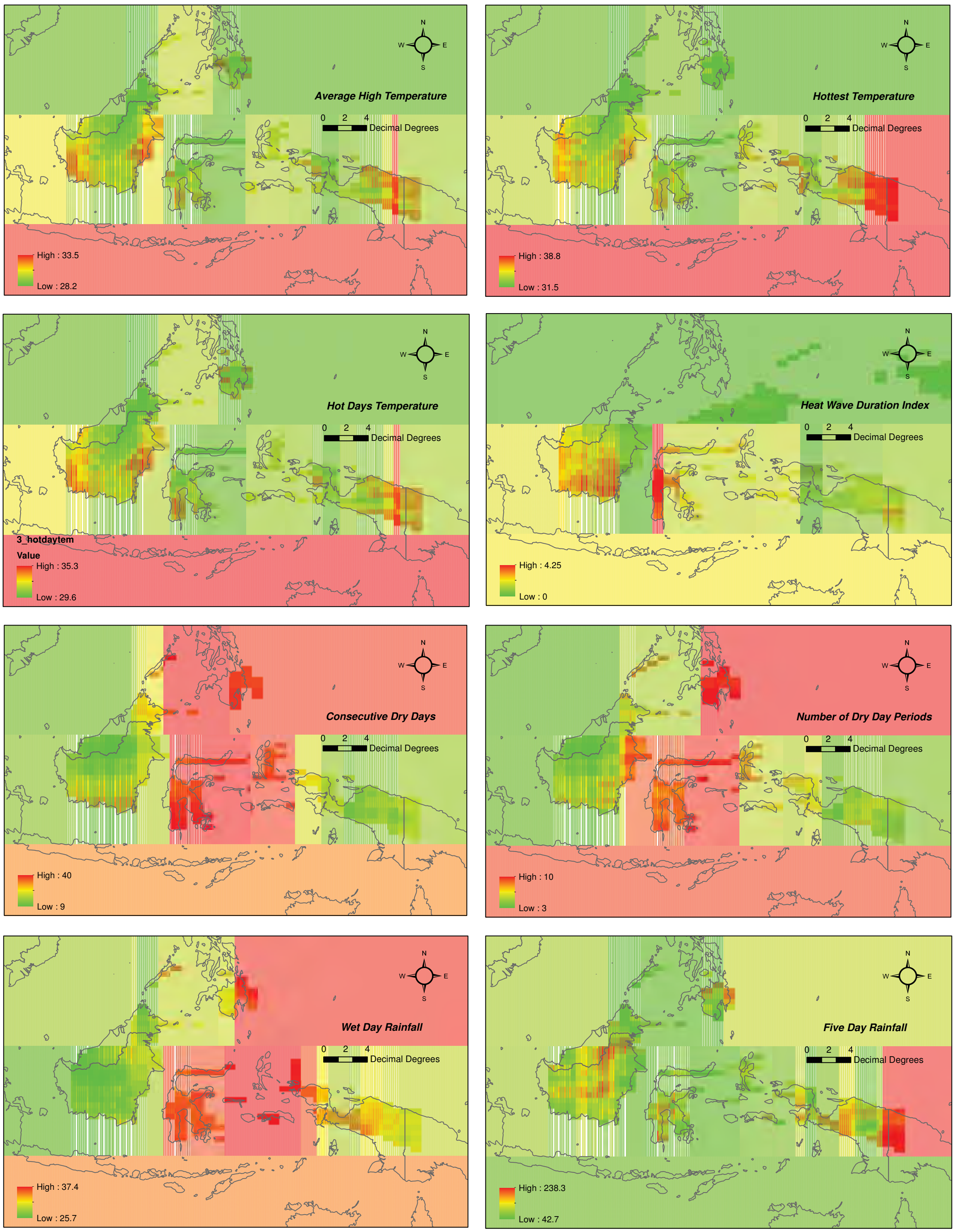
The multivariable exposure, sensitivity, and adaptive capacity index maps were generated for the subregion by assuming equal weights for all the indicators. Similar to Maplecroft, the adopted weights of the resulting vulnerability map, as established from the sensitivity analysis, were 50% for exposure, 25% for human sensitivity, and 25% for adaptive capacity.

The following 8 climate projection variables or indicators from the World Bank climate portal were included in the exposure index mapping: (i) average high temperature, (ii) hottest temperature, (iii) hot days temperature, (iv) heat wave duration, (v) consecutive dry days, (vi) number of dry day periods, (vii) wet day rainfall, and (viii) 5-day rainfall. These exposure indicators were normalized and given equal weights in the index mapping. The mapped exposure indicators are shown in Figure 9 and are described as follows:

- The average high temperature indicator map shows the monthly mean of daily maximum temperatures in the area in °C;
- The hottest temperature indicator map shows the maximum temperature per month and year in the area in °C;
- The hot days temperature indicator map shows the temperature in the area in °C that exceeds the hottest 10% of all days per year;
- The heat wave duration index indicator map exhibits the number of days per year within the intervals of at least six days of maximum temperature that is greater than the normal maximum temperature plus 5°C for the historic period (the normal maximum temperature for historic period is a 5-day running mean);
- The consecutive dry days indicator map shows the largest number of consecutive dry days (with daily precipitation of less than 1 millimeter [mm]) per year in the area;
- The number of dry day periods indicator map shows the number of consecutive dry day periods in the area of a length greater than 5 days per year;
- The wet day rainfall indicator map shows the percent of wet days per year with rainfall greater than the 90th percentile wet day precipitation (only days with precipitation greater than 1 mm are considered wet); and
- The 5-day rainfall indicator map depicts the maximum 5-day precipitation total per year in the area in mm.

In terms of human sensitivity, the following variables or indicators were used in the study: percent flood plain, multihazard economic loss risk, multihazard frequency, relative water stress index, and total population. For purposes of the rapid assessment and due to limitations in available geospatial data, irrigation equipped area was the only indicator of

Figure 9 Mapping of Climate Change Hazards Exposure Indicators

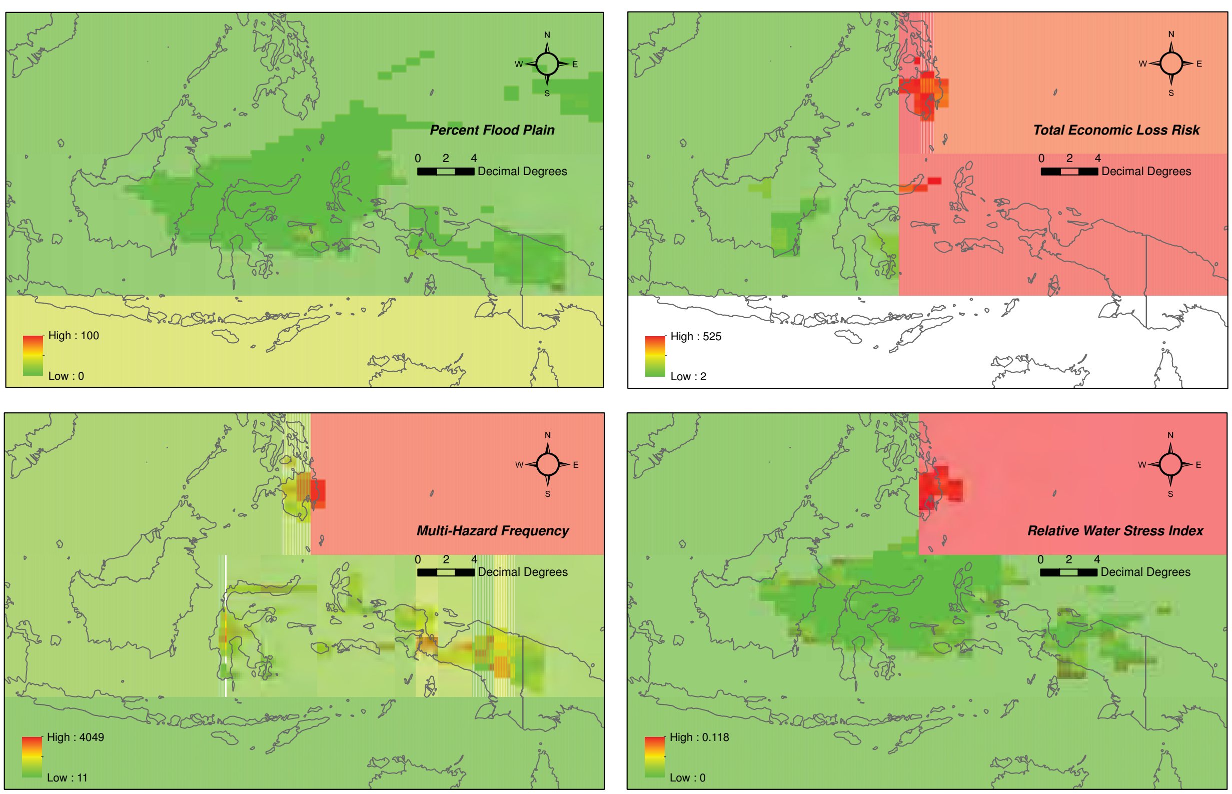


Source: ADB (2015).

adaptive capacity that was considered in the study. These sensitivity and adaptive capacity indicators were likewise normalized and given equal weights in the index mapping. Results of the mapping exercise are shown in Figure 10 and are described as follows:

- The percent flood plain indicator map shows the percentage (0%–100%) of floodplain area for each grid cell (0.5 x 0.5 decimal degree or approximately 50 km x 50 km);
- The total economic loss risk indicator map shows the global multihazard total economic loss risk deciles that is derived from originally 2.5 x 2.5 minute grid considering 6 common environmental hazards (i.e., cyclones, droughts, earthquakes, floods, landslides, and volcanic eruptions);
- The multihazard frequency indicator map shows the global multihazard frequency index based on summated single-hazard decile values that are derived from 2.5 x 2.5 minute grid. The hazards that were considered include cyclones, droughts, earthquakes, floods, landslides, and volcanic eruptions;
- The relative water stress index indicator map shows the demand index in excess of renewable water resources;
- The total population indicator map shows the grid cell (0.5 x 0.5 decimal degree or approximately 50 km x 50 km) population as of 2000; and
- The irrigation equipped area indicator map presents the areas in square km (km^2) per grid cell (0.5 x 0.5 decimal degree or approximately 50 km x 50 km) that are equipped with irrigation facilities.

Figure 10 Mapping of Climate Change Sensitivity and Adaptive Capacity Indicators



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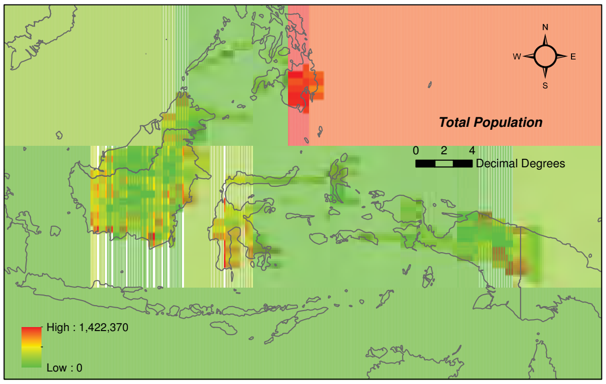
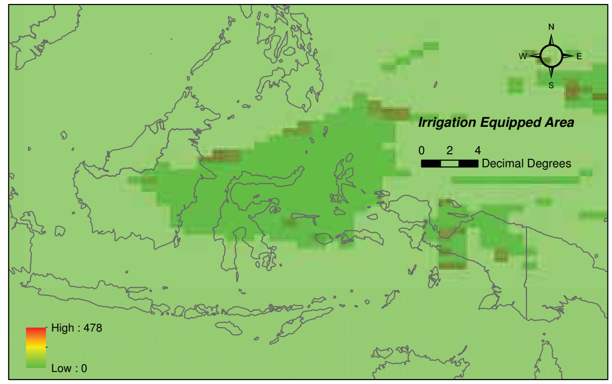
Mapping of Climate Change Sensiviity and Adaptive Capacity Indicators *continued*





Source: ADB (2015).

Climate change vulnerability index maps for BIMP-EAGA were generated, as further discussed in Appendix 5, based on the vulnerability mapping of the normalized exposure, sensitivity, and adaptive capacity indicators. Summary results of the vulnerability mapping exercise are shown in Figure 11.

Figure 11a presents the generated multivariable exposure index map for the BIMP-EAGA subregion using six climate variable indicators mentioned previously. All of these climate variables are normalized and the multivariable exposure index map is generated by assuming equal weights (12.5%) or equal degree of importance for all the variables. The generated exposure vulnerability indices in the subregion vary from 0.08 to 0.75.

Figure 11b shows the generated sensitivity index map for the study area. Likewise, normalization is done for all sensitivity indicators. The index map is generated by assuming equal weights (20%) or same degree of importance for all five sensitivity variables. The computed sensitivity vulnerability indices in the subregion vary from 0 to 0.58. Note that the parameters are focused on human sensitivity. A limitation of the study is that it does not adequately cover ecosystem sensitivity, even though the factors used indirectly impact on natural ecosystems (e.g., multihazard frequency, relative water stress index).

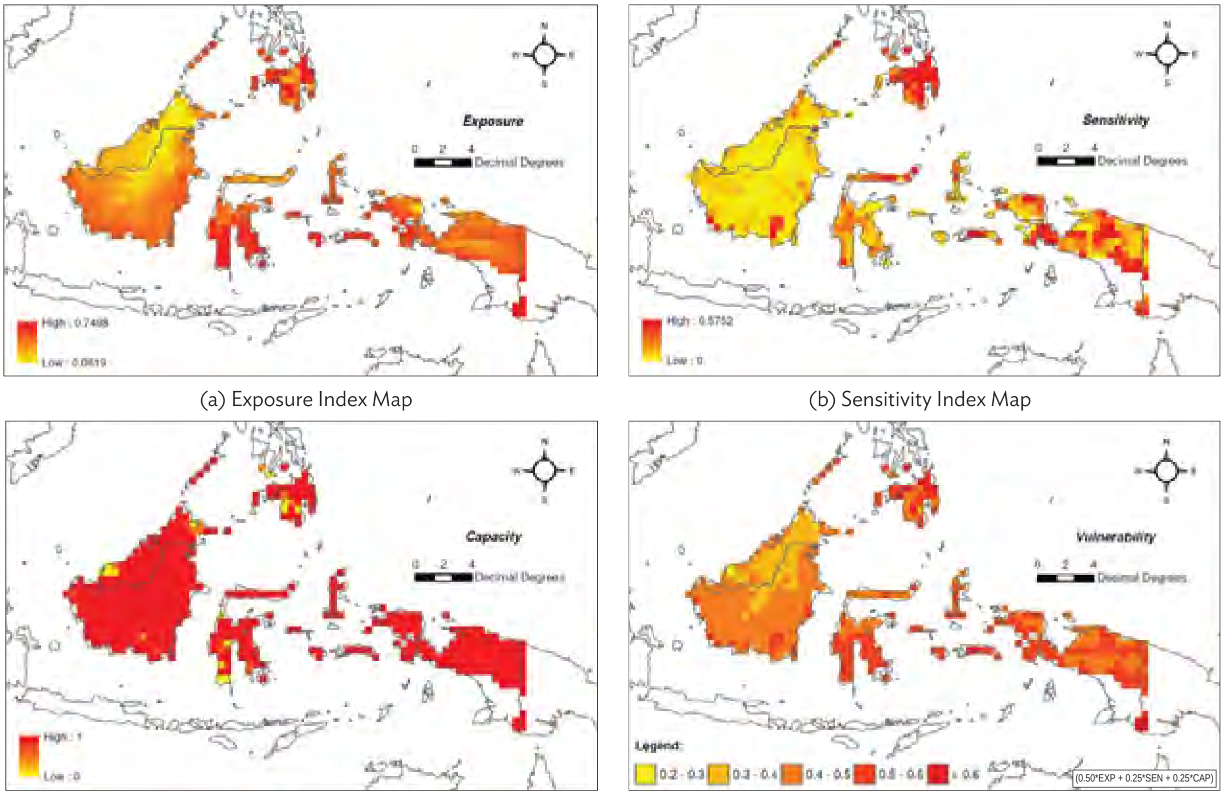
Figure 11c shows the adaptive capacity index map, which is based only on the irrigation equipped area indicator. Hence, most areas have vulnerability indices of 1. This parameter, which reflects water management capacity, is important but is not adequate to fully describe adaptive capacity. This is a limitation of the study.

Lastly, Figure 11d presents the overall climate change vulnerability index map of the BIMP-EAGA subregion using the generated exposure, sensitivity, and adaptive capacity indices. As mentioned previously, the adopted weights are 50% for exposure, 25% for human sensitivity, and 25% for adaptive capacity similar to the weights in Maplecroft.

The exposure index map in Figure 11a shows extreme climate change exposure[11] in South Maluku, South and Southeast Sulawesi, and West Papua in Indonesia; and Northern and Western Mindanao as well as the northern portion of Palawan in the Philippines. On

[11] Exposure indices greater than 0.60.

Figure 11 Climate Change Index Maps of BIMP-EAGA



(a) Exposure Index Map

(b) Sensitivity Index Map

(c) Adaptive Capacity Index Map

(d) Vulnerability Index Map

Source: ADB (2015).

the other hand, high exposure to climate change[12] is observed in East, South, and West Kalimantan, North Maluku, Papua, and Central and West Sulawesi in Indonesia; the federal territory of Labuan in Malaysia; and Central, Eastern, and Southern Mindanao in the Philippines.

The sensitivity index map in Figure 11b illustrates extreme human sensitivity[13] in portions of South Kalimantan, Maluku, Papua and West Papua, and North and South Sulawesi in Indonesia; Central, Eastern, and Northern Mindanao as well as the northern portion of Palawan in the Philippines. The sensitivity of other regions to climate change varies from low to high.[14]

The adaptive capacity index map in Figure 11c demonstrates high vulnerability for almost the entire subregion except for South Sulawesi in Indonesia, Sabah and Sarawak in Malaysia, and some portions of Southern Mindanao in the Philippines due to the availability of irrigation infrastructure (the lower the adaptive capacity, the higher the risk index).

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12 Exposure indices ranging from 0.45 to 0.60.
13 Sensitivity indices greater than 0.45.
14 Sensitivity indices ranging from 0 to 0.45.

The resulting climate change vulnerability index map for BIMP-EAGA in Figure 11.d shows high to extreme vulnerability in Maluku, South and Southeast Sulawesi, and portions of Papua and West Papua in Indonesia; and most parts of Mindanao and Northern Palawan in the Philippines. On the other hand, moderate to high vulnerability is noted in the coastal areas of Brunei Darussalam; Kalimantan and portions of North Maluku, Papua and West Papua, and North and Central Sulawesi in Indonesia; and Sabah and Sarawak in Malaysia; and Central Mindanao as well as the southern portion of Palawan in the Philippines. Vulnerability classification (i.e., low, moderate, medium, high, and extreme) is further discussed in the following chapter.

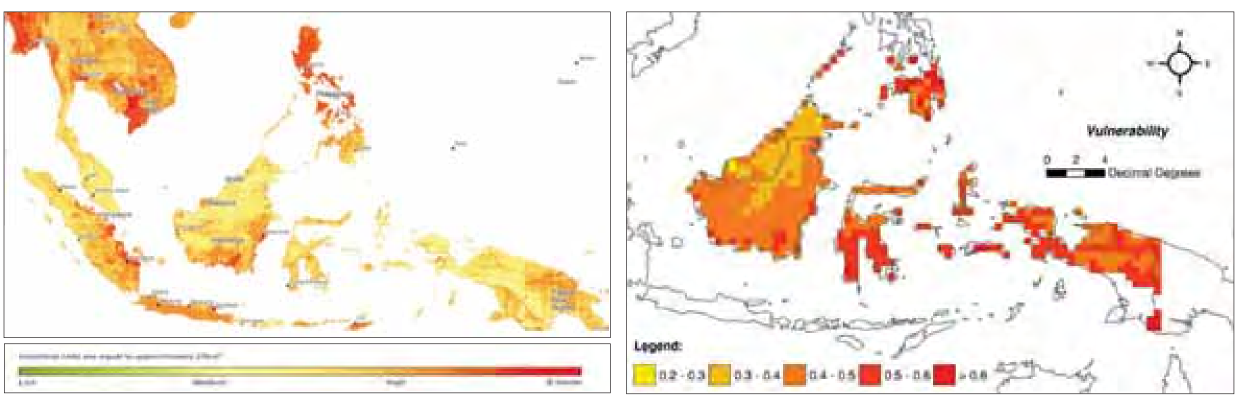
Hotspots of Vulnerability

A comparative visualization of the vulnerability hotspots in BIMP-EAGA is shown in Figure 12. In the left panel (Figure 12.a), Maplecroft's risk mapping shows that the vulnerability ranking of BIMP-EAGA with reference to the whole of Southeast Asia is in the range of medium to high, with portions of Mindanao and Southern Kalimantan approaching extreme.

The right-hand panel (Figure 12.b) shows the result of the subregional vulnerability mapping that was carried out in this study, which focused on BIMP-EAGA. Although the validation mapping for the study used only a limited number of factors compared with the Maplecroft mapping, the results of the vulnerability ranking are generally consistent with the vulnerability pattern indicated in the Maplecroft risk mapping.

In the discussion on hotspots below, reference is made to the regional (left panel) and subregional (right panel) risk index maps that are shown in Figures12.a and 12.b, respectively. These are supplemented by local studies on climate change vulnerability that were drawn from various country studies and/or sources.

Figure 12 **Comparative Risk Index Mapping**



(a) Maplecroft (b) This study

Source: Maplecroft (2014) and ADB (2015).

Exposure and Sensitivity

Hotspot areas of exposure to climate hazards include Maluku, West Papua, and South and Southeast Sulawesi in Indonesia; and Northern and Western Mindanao as well as the northern portion of Palawan in the Philippines. The extremely high exposure in Mindanao and Palawan are the result of the occurrence of frequent and large number of consecutive dry day periods and partially to the high temperature and precipitation as well as the long rainfall duration. On the other hand, the high to extreme exposure in Papua and West Papua are attributed to the average high and extremely hot temperature, the high precipitation, and the long rainfall duration. All indicators or climate variables contribute to the extremely high exposure of the islands of Maluku and South and Southeast Sulawesi. Brunei Darussalam has medium to high climate change exposure due mainly to the increased dry season temperature and the related heat stress occurrence, and the higher rainfall intensities during the wet season.

Hotspots of human sensitivity include portions of South Kalimantan, Maluku, Papua and West Papua, and North and South Sulawesi in Indonesia; and Central, Eastern and Northern, Mindanao and the northern portion of Palawan in the Philippines. The extreme human sensitivity in Mindanao and Palawan are due largely to the high total economic loss risk owing to the frequent occurrence of multihazards (e.g., cyclones, droughts, earthquakes, floods, and landslides), the high water demand in excess of renewable water resources, and the high population in some areas. On the other hand, the extreme sensitivity in some portions of South Kalimantan are attributed to the large percentage of floodplain areas in the region that are prone to flooding, the high total economic loss risk due to the frequent occurrence of environmental hazards, the high relative water stress index, and the high population density. Lastly, the extreme sensitivity of portions of Maluku, Papua and West Papua, and North and South Sulawesi are largely attributed to the frequent occurrence of environmental hazards, the high relative water stress index, and the high population density.

Most areas in the entire BIMP-EAGA subregion are hotspots of adaptive capacity except for small portions in southern Mindanao in the Philippines, western Malaysia, and southern Sulawesi in Indonesia. This is because adaptive capacity in this vulnerability mapping was limited to irrigation equipped area as the indicator. Based on the available data gathered, only these areas are equipped with irrigation facilities, thus most areas in the entire BIMP-EAGA subregion were assigned a vulnerability index of 1.0. As earlier noted, this is a limitation of the study.

Vulnerability

Indonesia

In **Kalimantan**, the vulnerability index is medium with only the more populated areas near the coastal zone of Banjarmasin in South Kalimantan and Samarinda in East Kalimantan with high vulnerability rating due to their sensitivity to sea level rise. South Kalimantan also has the highest rate of deforestation and is therefore vulnerable to the effects of increased flooding, drought, and changes in seasonal rainfall pattern resulting from climate change.

In addition, most of the population in East and South Kalimantan live in watershed areas that are prone to degradation. Moreover, wide expanse of forests is converted to palm oil plantation or is exploited for mining. In comparison, many areas in Central and South Kalimantan have low coastal slope and population density.

For **Maluku**, the hazard from climate change is mainly due to the projected rise in sea level. When computed from 1960 to 2008 on the basis of the sample ocean data assimilation, sea level rise in Indonesia is 0.8 mm/year, subsequently rising to 1.6 mm/year since 1960 and then to 7 mm/year since 1993. The highest increase occurred in the north of Papua island, Java Sea, Banda Sea, and the major part of the waters of Indonesia to the east. The vulnerability index of Maluku is rated medium to high.

In **Sulawesi**, where the coastal slopes are quite high (about 1.5°–3°), nearly the entire coast of the island has medium to extreme levels of vulnerability to sea level rise. Steep coastal slopes mean that rise in sea level will not inundate large areas. However, in some areas, where the coastal zone is quite flat and populated (e.g., the western coastlines of Central and South Sulawesi), the level of vulnerability is medium to extreme. South Sulawesi has high population density compared to other provinces in Sulawesi, and there is considerable dependence on agriculture and fisheries, which are sensitive to climate impacts. The rivers in this part of Sulawesi are also vulnerable to sea water intrusion. In addition, most of the agricultural, livestock, and mining activities in South Sulawesi are concentrated in the watershed areas of Jeneberang-Walanae and Sadang, where the ecosystem is more exposed to degradation. On the other hand, this area also has high adaptive capacity in terms of infrastructure, socio-economic resources, and access to technology. Overall, Sulawesi is assessed as more vulnerable compared to Kalimantan and Papua.

Papua has more than 40 million hectares (ha) of forest covering 65%–75% of the province and has relatively low population density. The vulnerability index level of Papua is medium to high, especially in North and West Papua, where the coastline has high slope. A simulation study by Indonesia's BAPPENAS did not find areas with coastal inundation even thoughthe south coast of Papua has a gently sloping beach due to the dense tree canopy cover around that area (BAPPENAS, 2010c). It is the southeast part of Papua that has high vulnerability compared to the rest of province. Southeast Papua has flat coastal areas that are extremely vulnerable to sea level rise and its coral reefs and coastal ecosystem are degraded. The adaptive capacity in Papua is low due to the high poverty incidence and lack of infrastructure (i.e., relatively low road density, electricity coverage area, and telecommunication infrastructure).

The exposure factor for **Malaysia**, particularly for Sabah, is a more dominant factor in determining vulnerability than the sensitivity and adaptive capacity factors. Based on the Malaysian Meteorological Department's surface observation stations data, the west coast of Peninsular Malaysia recorded an increase in rainfall by 6%–10% for the period 2000–2007 relative to the period 1990–1999. Central Pahang and the coastal Kelantan showed a decrease in rainfall by 4%–6%. On the other hand, East Malaysia, Sarawak, and Sabah recorded an increase in rainfall by 6%–10% and by more than 10%, respectively, during the same period.

The highest sea level rise rate was recorded between 1993 and 2010 in the offshore areas of Sabah-Brunei-Sarawak, followed by its neighboring coastlines in Sibu, Miri, Brunei, and Labuan. The Malaysian Meteorological Department expects more extreme hydrological conditions to occur. It is expected that the annual mean surface temperature in 2100 will increase by 2.9°C–3.5°C in Sabah and by 3.0°C–3.3°C in Sarawak. Meanwhile, the maximum projected monthly rainfall during the same period is expected to increase by 9% in Sabah and 32% in Sarawak. The projected climate change impacts in Sabah and Sarawak include extreme changes in the river flow that will cause flooding in Tawau in Sabah and Kemena, Saribas, and Batang Luparin in Sarawak.

Increased summer temperature will have an important impact on **Brunei Darussalam** because it could adversely affect the productivity of its workers, vast numbers of whom work in the oil and gas fields and are exposed to the elements. Higher dry season temperature will also increase the occurrence of wildfire in surrounding forests and prolonged smoke haze with its accompanying health risks on concentrated urban populations. Heavier rainfall occurrence will increase flooding and landslide hazards to which Brunei Darussalam's more densely packed inhabitants would be exposed.

For the **Philippines**, the Northern Mindanao provinces, especially Northeastern Mindanao, has high vulnerability to climate change extreme events (e.g., typhoons) due to their proximity to the country's typhoon belt. Portions of Central Mindanao (e.g., Maguindanao, North Cotabato, and Sultan Kudarat), along with Davao del Norte and Compostela Valley in Southeastern Mindanao are among the top 20 provinces that are susceptible to floods with about 20%–42% of the total land area prone to flooding. On the other hand, Bukidnon, Davao Oriental, and Sarangani provinces in Mindanao are included in the list of the top 20 provinces that are susceptible to landslides with more than half of the land area prone to landslides. Zamboanga City and the provinces of South Cotabato and Sarangani are highly vulnerable to drought.

The Palawan hotspots to high exposure to storm hazards include the Cagayancillo, Balabac islands in the southern tip of the Palawan mainland, southern Bataraza, Rizal, Rio-Tuba, Quezon, Española, Narra, and the Sto. Niño-Aborlan boundary, Puerto Princesa, Ulugan Bay and Honda Bay areas, Babuyan San Rafael, Araceli and Dumaran, San Vicente and Malampaya Sound and the northeast east coast of El Nido. The entire area of Bugsuk and Pandanan islands between the southern Palawan mainland and the Balabac islands are highly susceptible to floods. Major portions of Coron, the interior mountain ranges of Mount (Mt.) Mantalingahan and Mt. Gantung in Rizal-Bataraza area, the mountain range of Cleopatra's Needle north of Puerto Princesa City, the mountainous portions of San Vicente, and the eastern portion of El Nido are highly susceptible to rainfall induced landslides. The outer fringes of the islands of Busuanga, Coron and Culion, El Nido, Magsaysay, Cuyo, Araceli, Bugsuk, Pandanan and Balabac islands, a major portion of the eastern coast of Palawan mainland, and portions of the western coast are highly susceptible to storm surge inundation.

In Mindanao, the hotspots with fairly high exposure to climate change extreme events (e.g., typhoons) are the Dinagat and Siargao islands in Surigao del Norte in the northern tip of Mindanao, and a small portion of the northeastern coasts of Surigao del Sur, Davao Oriental and Compostela Valley. This is due to their proximity to the country's typhoon belt. Some portions of the Zamboanga Peninsula, Maguindanao, Sultan Kudarat, Sarangani, Bukidnon and North Cotabato, and the small islands of Basilan, Jolo and Tawi-Tawi in the southernmost tip of Mindanao, near Sabah in Malaysia also have fairly high exposure.

Portions of Central Mindanao (e.g., Maguindanao, North Cotabato, and Sultan Kudarat), along with Davao del Norte and Compostela Valley in Southeastern Mindanao are among the top 20 provinces that are susceptible to floods, according to the Mines and Geosciences Bureau. This is due to the lack of natural drainage that renders about 20%–42% of the land area susceptible to floods. According to the Mines and Geosciences Bureau, Bukidnon in Central Mindanao and Davao Oriental and Saragani in Southern Mindanao are among the top 20 provinces that are susceptible to landslides with more than half of the land area prone to landslides due to their mountainous terrain. Zamboanga City and the provinces of South Cotabato and Sarangani are highly vulnerable to drought due to water stress and extreme heating events (e.g., hot temperatures).

Overall, the hotspot areas for climate change vulnerability in BIMP-EAGA are evident in Gorontalo, the entire Maluku, and South and Southeast Sulawesi in Indonesia as well as North and West Mindanao in the Philippines. On the other hand, some hotspots may also observed in small portions of east and south Mindanao and Northern Palawan in the Philippines; as well as in Kalimantan, Papua and West Papua, and Central, North, and West Sulawesi in Indonesia. These hotspot areas that were identified in the vulnerability mapping are due largely to exposure to high and extreme values of climate variables that cause multi-environmental hazards as well as to high and extreme human sensitivity.

Implications for the BIMP-EAGA Countries and the Subregion

Indonesia (Kalimantan, Sulawesi, Maluku, and Papua)

Food Security

Agriculture

In both Kalimantan and Sulawesi, the total area devoted to rice production increased significantly in 2010–2012. Thirty six percent of rice production in Kalimantan is found in the south surrounding Banjarmasin. Similarly, Sulawesi's rice-producing area is concentrated in the southern part around Ujung Pandang, which accounts for about 60% of the area planted to rice in the island. Unless measures to store more water and to regulate water use are initiated in these climate-vulnerable areas, increased water stress due to climate change will have adverse impacts on rice production and food security.

National rice production increased from 54 million tons in 2004 to 60 million tons in 2008 (Central Bureau of Statistics,[15] 2009). However, the increase in rice production is not sufficient to meet demand due mainly to population growth estimated at 1.5% annually. It is also worth noting that unlike in the past, most Indonesians now depend on rice as their staple food. Estimates show that the food vulnerable population in the country reached 47 million in 2012, which implies that 19.5% of Indonesia's population are rated low in terms of food security (rice, corn, and cassava).

Drier temperatures may worsen the effects of land conversion to expand agricultural areas to attain food security. For example, a government project covering 1 million ha of peat land in Central Kalimantan in 2001 was converted to rice fields. For various reasons, including faulty drainage system design, this project caused excessive drying of peat lands that have now become susceptible to fire occurrence during the dry season (Boehm and Siegert, 2001).

Dry spells intensified by climate change, especially during periods coinciding with the El Niño cycle, could worsen the occurrence of forest fires and their attendant effects on soil erosion and watershed degradation, which will adversely affect agricultural areas downstream. Large forest fires occurred in 1997 and 1998, during which 1.8 million ha of land was destroyed (Siegert and Hoffmann, 2000).

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[15] *Biro Pusat Statistik.*

Coral Reefs

In terms of food resources derived from coastal and marine resources, sea level rise combined with increased sea surface temperature and ocean acidification caused by the uptake of carbon dioxide from the atmosphere poses a big threat to BIMP-EAGA's sensitive coastal and marine resources. These resources are vital food sources and are already under pressure from human-induced degradation and over-exploitation. Ocean acidification, in particular, could result in coral communities that can no longer produce calcium carbonate at rates that are sufficient for maintaining coral reef structures that serve as fish habitat and spawning areas. Indonesia has the largest coral reef area in the world, covering around 60,000 km^2 or 18% of the world's coral reefs. Most of its coral reefs are located in the Coral Triangle in which BIMP-EAGA forms the core. However, nearly 43% of the country's coral reefs are in damaged condition with climate change adding even more pressure.

Mangroves

Sea level rise is an existing threat to Indonesia's mangrove forests, which like coral reefs are important habitat and spawning ground for fish and other marine food sources. Indonesia has the world's second largest mangrove forest after Brazil. The Ministry of Forestry[16] recorded mangrove forest cover in Indonesia at 5.5 million ha in 2011 from 7.7 million ha in 2006 (KLH,[17] 2012), of which 7.2% are in damaged condition. South Kalimantan is one the most vulnerable areas to sea level rise in BIMP-EAGA Indonesia. It also has the fastest rate of decline in mangrove area in the subregion (KLH, 2012). Papua has the largest mangrove cover with 1.0 million ha with 95.8% in good condition (KLH, 2012) but will be highly susceptible to future sea level rise, especially in the flat coastal areas (e.g., southeastern part of Papua).

Seagrass

Sea grass beds are also vital links in the marine ecosystem that support the subregion's fishery.[18] As plants living in shallow coastal waters, critical factors for seagrass growth include carbon dioxide, light, nutrients, suitable substrate, and temperature, all of which are affected by climate change. Here again, Papua is most vulnerable to the impacts of climate change with 621,000 ha of sea grass beds, most of which (95%) are in good condition.

Water Security

The availability of surface and groundwater in Indonesia varies in quantity and quality for each island. Similarly, the supply of water also affects the needs of the population and its activities (e.g., agriculture and industry). In Kalimantan and Papua, water during the rainy season is abundant with 389,689 cubic meters (m^3) and 381,763 m^3, respectively. On the other hand, water demand is only 2,505 m^3 and 117 m^3, respectively. Papua has high water supply and low demand due to its low population density estimated at 12.6 persons/km^2 and limited demand for irrigation with only 0.5% of the national rice area. Kalimantan has a population density of 21 persons/km^2 and comprises 6% of the total area planted to rice in Indonesia.

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16 *Kementerian Kehutanan.*

17 *Kementerian Lingkungan Hidup* (Ministry of Environment).

18 Fishery is as important as agriculture in attaining food security.

The availability of water depends on the catchment area (i.e., forests). In Indonesia, Papua has the largest expanse of forests area with 42.2 million ha, followed by Kalimantan with 38.3 million ha, Sulawesi with 13.8 million ha, and Maluku with 7.3 million ha. Low infrastructure development in Papua has contributed to the preservation of its forests, which increased in forest cover since 2009. On the other hand, factors contributing to forest pressure in Kalimantan include the following: exploitation, conversion to oil palm and agriculture, logging, mining, infrastructure development, and forest fires (KLH, 2012).

Communities have access to clean water from taps, boreholes, wells, and protected springs. However using 2010 data, the Central Bureau of Statistics showed that drinking water met only 55% of the needs of the Indonesian population.

Energy Security

The objective of national energy development is to reduce oil consumption in the national energy consumption portfolio and to increase non-oil energy consumption. On the basis of Presidential Regulation No. 5/2006 on the National Energy Policy, the contribution of renewable energy, as one of the non-oil energy sources, will increase to 17% of the national energy demand by 2025. Renewable energy sources that will have significant impacts on climate change are hydropower and biofuel. These energy sources are targeted to contribute around 8% of the national energy demand. Therefore, the adaptation action for ensuring the capacity of these energy sources in supporting national energy self-reliance is important.

Kalimantan has installed micro hydropower of 400 kilowatts (kW), Sulawesi with 138 kW, and Papua with 601 kW. Some catchment areas have some potential for hydropower energy. These include Papua with an estimated 22,400 megawatts (MW), Kalimantan with 21,600 MW, Sulawesi with 10,200 MW, and Maluku with 430 MW (ESDM, 2013). The increased variability of rainfall, combined with higher rainfall intensities that cause more sediment loads and debris flow in rivers can have negative impacts on the operation of existing hydropower facilities, especially the smaller systems in Kalimantan and Sulawesi. On the other hand, if properly designed to mitigate their well-known environmental effects, storage reservoirs for the harvest of rainwater and the generation of renewable hydro energy, will be useful in attenuating the future effects of more variable rainfall pattern to ensure water security and reduced dependence on carbon-emitting fuels.

Malaysia (Sarawak and Sabah) and Brunei Darussalam

In a report by the Economy and Environment Program for Southeast Asia (Yusuf and Francisco, 2009), the exposure factor for Malaysia, particularly for Sabah, is more dominant in determining the country's vulnerability index compared to the sensitivity and adaptive capacity factors. The report showed that the adaptive capacity of all Malaysian states is relatively high in comparison to other areas in Southeast Asia. Sabah is ranked high in vulnerability to climate hazards exposure, particularly to flooding and droughts. Results from a satellite-based drought monitoring and warning system by the Institute of Industrial

Science, University of Tokyo (Takeuchi, 2014) indicated that Sabah experienced the highest number of drought days. On the opposite extreme, Sabah experienced several major floods and some of the more devastating events that include Tropical Storm Greg in December 2006, extreme flooding in the Padas Catchment in January 2014, and flooding that hit the west coast of Sabah in October 2014 with recorded 147 mm of rain within 24 hours.

Food Security

The extensive harvesting of sea-based export commodities (tuna, skipjack, and bonito) result in changes in resources use, characterized by increased fishing effort and in the number of purse-seine net trawlers. These have already resulted in reduced fish stocks and the effects on productivity and sustainability of the marine ecosystem will be compounded by additional pressure from climate change impacts.

Malaysia is a major exporter of palm oil and any changes in climate variables will affect palm oil production. It is estimated that palm oil yields could decrease by approximately 30% when the temperature increases by 2°C above the optimum levels and decrease in rainfall by 10%. Rice production may fall if the temperature rises above 34°C. In the event of changes in climate variability, rubber production will also be significantly affected. An increase in annual temperature above 30°C, coupled with a reduction in mean annual rainfall below 1,500 mm, will retard growth and prolong immaturity, and reduce production by 10%.

In Brunei Darussalam, concern is on the possibility of substantial losses in rainfed wheat. Agricultural production may be severely affected by the delayed rainy season and extreme climate events due to the El Niño Southern Oscillation as well as increased soil salinity (ADB, 2009). Projected sea level rise is likely to result in significant losses to coastal ecosystems that support fisheries.

Water Security

It is common for Malaysian states that are ranked among the top five in terms of sensitivity to climate hazards (i.e., Sabah, Pulau Pinang, Kelantan, Terengganu, and Perlis) to experience extreme droughts and flooding. During extreme rainfall and flows, more frequent and severe flooding is expected as well as more soil erosion incidences. On the other extreme, water shortage from severe droughts (particularly due to the El Niño Southern Oscillation phenomenon) reduces inflows to reservoirs, decreases stream flows, which in turn affect water abstraction and lessens the recharge of groundwater, which affect the quantity of freshwater supply.

Brunei Darussalam may get affected by the decreasing precipitation and an increase in hot days and warm nights (heat stress). Extreme weather events that are associated with El Niño were reported to be more frequent and intense during the past 20 years. Water resources in marginal areas are likely to be vulnerable to climate change.

Energy Security

In 2012, the calculated energy reserve margin for Peninsular Malaysia was 33%, Sabah with 19.6%, and Sarawak with 95% (Energy Commission, 2011). Disruption in transportation includes the use and conditions of roads and railways as well as aviation safety.

Philippines (Mindanao and Palawan)

Food Security

Mindanao has been called the "land of promise" because it has abundant rainfall and few typhoons, and has river basins and fertile soil. It is also called the Philippines' food basket, with the capacity to feed the whole country and the rest of East ASEAN. It supplies over 40% of the country's food requirements and contributes more than 30% to the national food trade.[19] In the past, Mindanao's evenly distributed tropical climate types made it ideal for year-round crop production. Historically, typhoons traversed Mindanao only once every 10 years on average. However, in what is believed to be a signal change in the region's climate pattern, 2 strong tropical storms have recently hit Mindanao: Sendong in 2011 and Pablo in 2012, causing heavy human casualties and infrastructure damage. Northern Mindanao is particularly vulnerable to extreme rainfall because of its proximity to the Pacific typhoon belt.

In Mindanao's Surigao del Norte province, rice production projections for 2020 to 2050 show that there will only be a 5% probability of exceeding the minimum yield of 1.75 metric tons (mt)/ha during normal years and a 5% and a 7% probability of exceeding the minimum yield of 1.25 mt/ha during El Niño and La Niña years, respectively.[20]

Out of 33 km^2 land area in Surigao City, around 5.51 km^2 and 3,880 persons in the Surigao del Norte province are highly exposed to hazards from extreme climate events. About 8.6 km^2 of agricultural land or 49% of the total agricultural land of 17.8 km^2 that is highly exposed to extreme climate events are projected to incur potential damages of around P27 million from floods and rainfall-induced landslides. A 1-meter sea level rise is projected to adversely impact 132.5 million km^2 of land covering 17 towns in Surigao del Norte, with the town of Del Carmen covering the most flood-prone area of 29.4 million km^2 (Balangue 2013a).

Similar to Mindanao, the major economic activity in Palawan is agriculture based. About 61.4% of the total employed individuals in 2012 were engaged in agriculture 42.1% in farming (crop production and livestock and poultry industry), 17.9% in fishing, while only 1.4% of those employed were in forestry-related activities. Palawan's rice production decreased by 4.0% from 329,689 mt in 2011 to 316,599 mt in 2012. The area for rice production declined from 98,311.7 in 2011 to 96,151 in 2012. Hence, the rice sufficiency level slightly declined by 8% from 160% in 2011 to 152% in 2012. In 2011, the total irrigated area was 19,217 ha or 30% of the total potential irrigable area. Should droughts occur, the remaining 46,411 ha or 70% with no irrigation system can no longer be used for agriculture.

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19 National Economic Development Authority. *Mindanao Strategic Development Framework 2010–2020*.

20 Second National Communication on Climate Change: Philippine SNC Project (Project ID #0037339). The Philippines: Enabling Activities for the Preparation of the Second National Communication on Climate Change to the UNFCCC is a project of the Government of the Philippines and the Global Environment Facility through the United Nations Development Programme. The Department of Environment and Natural Resources serves as the implementing partner/national executing agency. This project is administered by the Interagency Committee on Climate Change through the Environment Management Bureau as its Secretariat.

Of the 51,555 persons engaged in agriculture in Palawan (42.35% of total households surveyed under the Department of Interior and Local Government-Community Based Monitoring System), 26,504 households stated that they experienced a reduction in crops harvested in 2011–2012 due to pests (48.5%), drought (24.21%), typhoons (4.1%), floods (2.1%), and decreased water supply from irrigation (0.8%). In terms of livestock production, 14,204 households or 40.89% of the total households surveyed stated that they experienced a decrease in livestock production due to typhoons, floods, and extreme hot weather conditions (PPDO-DILG-CBMS, 2011–2012).

Under a business as usual situation in San Vicente, Palawan, a decline in the production of rice and assorted crops is projected to occur in the next 25 years. This is due to farm management deficiencies (11.7%); climate-related impacts (8.3%); the potential impacts of insect infestation (7.2%); waste from harvesting, transporting, processing, and wasteful consumption of food products (6.4%); and the increasing demand for food (4% annually). If no additional areas will be developed for agricultural production, the productivity of the current rice production areas are projected to decline within the first 4 years and will continue up to the 25th year (Balangue, 2013a).

Palawan experienced a decline in the average annual increase in fish production from 21.3% (2000–2007) to 9.8% (2011). Some 13,156 fishing households stated that they experienced decreased fish catch in 2011–2012 due to increased competition, fewer fishes, and the occurrence of coral bleaching. Only 13.4% (109.2 km^2) of Palawan's reefs are in excellent to good condition and the remaining 86.6% are in fair to poor condition.[21]

In the forestry sector, Balangue (2013a) assessed that the forests in San Vicente, Palawan are relatively young, fragile, unstable, and consist mostly of hardword species. The opening stock of the forest resources was estimated at 25.6 million cubic meters (MCM) valued at P20.6 billion. Under a worst case climate change scenario, the opening stock of forest resources will be reduced to 20.1 MCM valued at P19.6 billion. Hence, climate change extreme events, such as typhoons resulting in rain-induced landslides, are projected to cause losses to forest resources estimated at 2.1 MCM and valued at P1.7 billion annually.[22]

Water Security

The largest watersheds in the Philippines are in Mindanao (i.e., Lake Lanao Watershed Reservation in Marawi City, Lanao del Sur [180,460 ha] and the Kabulnan River Watershed Forest Reserve [116,452 ha] spanning the provinces of Sultan Kudarat, Maguindanao, and South Cotabato). Regions IX, X, XI and XII in Mindanao are among the top 5 regions with the highest water resources potential, most of which are from surface water. Nonetheless, increasing water demand, especially from agro-industrial users, has resulted in a number of cities experiencing water stress (e.g., Cagayan de Oro, Davao, and Zamboanga). These highly urbanized cities rely mostly on groundwater for water supply, resulting in uncontrolled withdrawal from groundwater aquifers in recent years. It is projected that by 2025, the deficit in water supply are as follows: Zamboanga City with 73%, Cagayan de Oro City with 65%, and Davao City with 45%. In Opol, Misamis Oriental, the local water supply is further threatened

21 ADB. 2014. *State of the Coral Triangle Philippines*. Manila.

22 Government of the Philippines, Climate Change Commission and the Global Green Growth Institute. 2014. *Demonstration of the Eco-town Framework in San Vicente, Palawan, Philippines*. Manila and Seoul.

by saltwater intrusion from coastal flooding, the projected reduction in seasonal rainfall, and the increase in temperature due to climate change.

In Palawan, around 84.4% of the total households have access to safe drinking water. This is lower than the national average of 88.9%. In San Vicente, Palawan, Balangue (2013a) conducted a vulnerability assessment of the water system facilities. Vulnerability was defined by exposure as a function of effect factors (e.g., drying of streams, flash flooding, knocking down of trees in streams, and siltation); sensitivity was defined as a function of the impacts of climate-related events; and adaptive capacity was defined as a function of existing deterring factors. Potential climate-related threats that were identified include heavy rains, typhoons, and increased drought occurrence. His findings show that the current aggregate water production capacity of the existing water system is 1.9 MCM/year, 15% of which is consumed by households and businesses that are connected to the water system. Projections on total water demand for domestic, irrigation, ecotourism, and physical and economic development are 17 million MCM in 2020 and 36 MCM in 2050. It is projected that future water demand will exceed water supply, resulting in a deficit of about 16 MCM in 2020 and 34 MCM in 2050.

Energy Security

Electricity reaches only 54% of the 4.8 million households in Mindanao with the Autonomous Region of Muslim Mindanao registering the lowest level of households with electricity at 27.8%. In Palawan, only 106,434 households or 58% of the total potential households have access to electricity. The rated capacity of power plants in Mindanao is 2,087 MW and Palawan is 82.5 MW. Mindanao has relied heavily on hydropower to meet its power requirements. With El Niño (drought), the existing capacity from hydropower plants will not be able to provide the needed energy and power requirements of Mindanao. Hence, additional power generation capacity is needed to support the growing economy. In terms of potential capacity, Region X (Northern Mindanao) ranks first with almost 680 MW of potential hydropower capacity, followed by Caraga with 280 MW. For geothermal energy, Mindanao has a 50 MW (Mindanao III) geothermal project in Mt. Apo, the country's highest mountain. Around 180 MW of geothermal resources are located in Regions X and XII. For ocean or wave energy, Mindanao can be a conducive site for the development of ocean energy projects employing technology, such as the ocean thermal energy conversion. There are eight potential projects with an estimated capacity of 24 MW. Surigao de Norte has the highest potential wave energy capacity with 15 MW. For energy from biomass, Mindanao has two committed biomass projects that will be commissioned in 2015[23] with 11.6 MW potential capacity in Maguindanao.

According to the Philippine Energy Plan, 2013–2030 (Department of Energy, 2014), power plants, refineries and depots, power transmission and distribution systems, fuel distribution systems (e.g., barges, pipelines, fuel stations), oil, gas and geothermal rigs and solar photovoltaic systems are subject to climate trends (e.g., sea level rise, increasing rainfall, strong typhoons, increasing temperature and drought). The direct impacts of these climate

[23] Department of Energy, Government of the Philippines. 2014. Mindanao Energy Plan, 2013–2030. Powerpoint presentation for the stakeholders consultation. Zamboanga City. February, 2013.

trends are coastal inundation, flooding, soil erosion, landslides and toppling of infrastructure and water supply reduction. These in turn could cause forced power outages and the interrupted operation of power plants and other energy systems, and interruption in fuel supply and power. Consequences would result in economic slowdown.

BIMP-EAGA Initiatives

Trade in BIMP-EAGA is highly dependent on natural resources, which are already under heavy pressure from current exploitation and are increasingly susceptible to climate change impacts. The advent of free trade, ushered by the ASEAN integration, will add stimulus in exploiting the subregion's agro-industrial and fisheries resources given its strategic location in both the ASEAN and East Asia; its vast resource endowment that is relatively untapped in Borneo, Sulawesi, and Papua; and its comparative advantage in terms of geographic access to regional markets. This in turn will spur more investments in land development and infrastructure by national governments, as each vie to improve productivity and competitiveness as rapidly as possible in order to establish a foothold in the region's fast growing open economy.

The risk lies in poor planning and haphazard land development and infrastructure provision, which will increase sensitivity and vulnerability to climate change impacts. The capital assets exposed to climate change hazards, whether productive resources or infrastructure, are bound to expand more rapidly in the subregion as an outcome of the ASEAN economic integration. Accelerated land development will have to incorporate resilience safeguards (e.g., site selection, water supply), whereas infrastructure development will require provisions for climate proofing (e.g., proper location, increased drainage capacity, and structural strength). Both will entail increased development costs and financing, and a marked departure from "business as usual" development planning to avoid maladaptation to climate change impacts.

While economic integration and increased trade offer tremendous opportunities for the subregion, these developments will happen in an environment of increased uncertainty. A common source of public concern is diminished government protection as free trade regimes "level the playing field" and restrict government options to directly support producers (e.g., farmers, fishers, and industries). Governments will expectedly turn its attention to infrastructure rather than direct subsidies as the principal means to support domestic producers and presumably through novel instruments for social protection insurance (e.g., for vulnerable farmers and small enterprises) and other forms of indirect support (e.g., market information).

Institutional uncertainty over government support, which is the focus of ongoing public and policymakers' concern over the impacts of regional economic integration and free trade, provides an incomplete picture as it will be compounded by increased climate variability. As explained earlier, the projected future climate will be characterized by increased risk of extreme weather events, heat and water stress, prolonged drought occurrences, heavier rainfall, rising sea level and exposure to sea surges, inland flooding, and landslide hazards.

State of Preparedness to Climate Change Challenges

Brunei Darussalam

Brunei Darussalam's position on climate change management was articulated formally in the country statement presented at the 18th Session of the United Nations Framework Convention on Climate Change (UNFCCC) in Doha in 2012. The main elements of the response of Brunei Darussalam cited in this statement include the following: (i) the introduction of environmental impact assessment in project planning and implementation; (ii) land use optimization through the adoption of vertical (hence, more compact) development in national housing schemes; (iii) conservation of carbon sink resources by maintaining more than 50% of the total land area under forest cover and apportioning a percentage of built-up areas as green areas; (iv) promoting environmentally sound technology and products and enhancing public awareness on environmentally friendly lifestyle and resource efficiency (e.g., efficient use of energy and water in daily consumption practices); (v) promoting an initiative on green buildings, in particular adopting energy efficient design; and (vi) promoting renewable energy to contribute 10% of the country's energy mix by 2030.

It is also actively engaged in regional initiatives related to climate change resilience, notably the Coral Triangle Initiative on Coral Reefs, Fisheries and Food Security (CTI-CFF)[24] on the coastal and marine front, where it has applied for membership. On the terrestrial arena, Brunei Darussalam has pledged to preserve 3,300 km^2 of its tropical forests or 58% of its land area as part of a tripartite forest conservation program known as the "Heart of Borneo" initiative with Malaysia and Indonesia. This initiative also reinforces the country's contribution to climate change mitigation on global initiatives (e.g., reduced emissions from deforestation and forest degradation and enhancement of carbon stocks as well as land use change and forestry).

Due to its comparatively vast financial resources, its overall capacity for climate change adaptation is inherently strong. Notwithstanding these notable initiatives, it would be beneficial for Brunei Darussalam to put together a formal plan, supported by institutional mechanisms, for enhanced climate change preparedness. Some of the notable features of the plan could include the establishment of a national climate change apex body to conduct comprehensive climate change vulnerability assessments and formulate

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24 The CTI-CFF was launched in 2007 as a six-country (Indonesia, Malaysia, Papua New Guinea, Philippines, Solomon Islands, and Timor Leste) program of regional cooperation to protect the Coral Triangle's economic and environmental assets.

resilience plans, document assessments, and climate change preparations (e.g., official communication to the UNFCCC).

Indonesia

In accordance with the Indonesian Presidential Decree No. 16/2015, the agency known as BP REDD+,[25] along with the National Council on Climate Change, has been absorbed into the newly merged Ministry of the Environment and Forestry as part of a massive government restructuring. Former leaders of BP REDD+ may be kept as advisors of the new Directorate General of Climate Change Oversight, one of nine directorates general that was established during the restructuring and merging of the Ministry of Environment and Ministry of Forestry.

Indonesia's National Action Plan for Climate Change Adaptation (*Rencana Aksi Nasional-Adaptasi Perubahan Iklim*) is a planning document that describes the national development strategy and action plan for climate change resilience. Its objective is the implementation of a development system that is sustainable and resilient to the impacts of climate change and is directed towards developing economic and livelihood resilience, and maintaining the sustainability of environmental services of the ecosystem. It provides direction in the formulation of the National Medium Term Development Plan (*Rencana Pembangunan Jangka Menengah*) and the National Annual Plan (*Rencana Kerja Pemerintah*). At the regional level, the National Action Plan for Climate Change Adaptation guides regional governments in formulating their respective climate change strategies and action plans.

The Ministry of National Development Planning formed a climate change coordination team to enhance efficiency and effectiveness in realizing action plans on climate change mitigation and adaptation. It is composed of six working groups that are tasked to identify resilience measures in agriculture; forestry and peat lands; energy, transportation and industry; waste; cross-sectoral initiatives; and an overall adaptation strategy.

Food Security

Aligned with BIMP-EAGA's food basket strategy, the government is working to introduce climate proofing measures to protect infrastructure that is vital to agricultural production and food transport. This initiative is undertaken in combination with strategies to expand agricultural production areas, introduce innovative technology, strengthen institutional capacity, and develop information and communication systems to disseminate reliable climate information. Specific initiatives include the *Merauke* Integrated Food and Energy Estate development in Papua, a masterplan to accelerate and expand Indonesia's economic development, a program to adapt food production systems to increased weather variability and long-term climate change, acceleration of food diversification initiatives, and regulatory measures to ensure environmental sustainability of palm oil production.

[25] REDD+ goes beyond deforestation and forest degradation, and includes the role of conservation, sustainable management of forests, and enhancement of forest carbon stocks.

Water Security

Programs are also implemented to protect watersheds and conserve forest areas. Presidential Instruction No. 10/2011 aims to regulate the issuance of new permits for forest and peat land utilization. Other national initiatives include the National Movement for Forest and Land Rehabilitation (*Gerakan Nasional Rehabilitasi Hutandan Lahan*), the Clean Rivers Program (*Program Kali Bersih*), and land subsistence and land slide hazard mapping. Programs have been launched to mobilize local households in Kalimantan and Sulawesi to plant five trees each year. Under a green city program initiative (*Kota Hijau*) of the Ministry of Public Works, local governments throughout Indonesia are encouraged and supported to increase the portion of urban areas that are allocated for parks and natural vegetation to enhance the physical appearance and to regulate the urban microclimate. Presidential Decree No. 25/2011 promotes the reduction of carbon emissions caused by deforestation and forest degradation.

Energy Security

Towards energy security, the Indonesian government has been working to expand the utilization of renewable energy sources in the provinces covered by BIMP-EAGA, particularly in terms of small hydropower installations aimed at enhancing climate resilience in these areas. This effort is combined with the development of innovative and adaptive technology for the establishment of bioenergy plantations.

Malaysia

The overarching policy tool for Malaysia in relation to climate change is the National Policy on Climate Change, approved by the Cabinet in 2009. It provides a framework to mobilize and guide government agencies, industries, and communities in addressing climate change challenges. In addition, the National Green Technology Policy that was launched in 2009 seeks to promote low carbon technology and ensures sustainable development while conserving the natural environment and resources. Other relevant policies, laws, and regulations that indirectly address climate change issues include the National Policy on the Environment and National Forestry Policy.

There have been numerous projects and programs undertaken by implementing agencies, especially by the National Hydraulic Research Institute Malaysia of the Ministry of Natural Resources and Environment, particularly in the development of models to project climate change variability. The latter also acts as the main support agency for other organizations that are engaged in climate change adaptation and mitigation programs. Some of these programs or studies in BIMP-EAGA are: *Study of the Impact of Climate Change on the Hydrologic Regime and Water Resources of Sabah and Sarawak* (2010); *Study of the Impact of Climate Change on Sea Level Rise in Malaysia* (2010); and *Study of Sea Level Rise in Kuala Kedah, Kuala Terengganu, Kota Kinabalu, and Kuching* (2011).

A study on the *Scoping Assessment on Climate Change Adaptation in Malaysia: Summary* (Solar, 2011) was undertaken by the Economic Planning Unit under The Office of the Prime Minister to assess the economic costs and benefits of mitigation and adaptation measures in specific sectors. Under the Tenth Malaysia Plan: 2011–2015, RM[26]5 billion has been allocated for flood mitigation programs, among which is the application of an integrated flood management approach through improved flood forecasting and warning, public awareness campaigns, and disaster preparedness. A total of RM98.6 million has been allocated to the Department of Irrigation and Drainage to manage and develop irrigation and drainage systems specifically for Sabah. This includes the implementation of flood mitigation programs to systematically address the destructive effects of flooding.

Food Security

Towards food security, the Malaysian Federal Government has allocated $152.9 million from the 2013 budget for agricultural development in Sabah. There is a joint initiative between the state and federal government to transform Kota Belud into a rice granary. A range of innovative techniques will be introduced under this initiative, including double-cropping and flood mitigation, together with a tertiary level water management system. In Sarawak, the aim is to put in place new land development schemes under the Ministry of Modernization of Agriculture that will develop food baskets in Bintangor near Tanjung Manis.

Sabah is famous for its extensive coastal and mountain rainforests, and island and coral reef ecosystems that are rich in biodiversity. There are currently six parks gazetted under the 1984 Parks Enactment.[27] Tun Mustapha Park is the largest protected area covering 1.0 million ha. There are 22 protected areas in Sarawak, including the United Nations Organization for Education, Science, and Culture World Heritage Site, Mt. Mulu National Park, which is under the protection of the Sarawak Forestry Department. Forest reserves have also been established in Sabah and Sarawak (e.g., Deramakot Forest Reserve and Kelawat Forest Reserve). Efforts to enhance the national seed bank are also underway to ensure the survival of genetic stocks.

Most climate change adaptation and mitigation programs in Malaysia are planned and executed at the national level. These include the National Coastal Zone Physical Plan *for East Malaysia* (already completed) and the Integrated Shoreline Management Plan for Malaysian coastlines. The use of a national coastal vulnerability index is currently being expanded nationwide.

Malaysia's *Green Technology Roadmap Baseline Study for Agriculture and Forestry* was endorsed in 2013. The study aims to identify current green technology initiatives and barriers and establish an enabling environment and framework of action plans for the development of green technology specifically in the agriculture and forestry sector. In addition, a Green Technology Master Plan was developed and completed in 2011 to translate the National Green Technology Policy into implementable initiatives. A GreenTech program is providing financing to promote the development of green technology. An initial fund of RM1.5 billion was made available in 2010–2012 and was increased to RM2.0 billion to extend the program to 2015.

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26 Malaysian ringgit.
27 These include the following terrestrial parks: Crocker Range; Mt. Kinabalu; and Tawau Hills and marine parks: Pulau Tiga, Tunku Abdul Rahman, and Turtle Island.

Malaysia is also involved in food security-related regional undertakings, such as the CTI-CFF, Heart of Borneo, and Sulu-Sulawesi Marine Ecoregion. As discussed earlier, food security is a top priority for the CTI-CFF, especially in relation to fisheries development and the protection of marine ecosystems. The development of a region-wide early action plan for climate change adaptation for the nearshore marine and coastal environment and small island ecosystems is one of the climate change-related activities of the program. Similarly, the Sulu-Sulawesi Marine Ecoregion program, headed by the Sabah Department of Fisheries under the auspices of CTI-CFF, aims to improve the management of seascapes to ensure sustainable use of resources. A large-scale aquaculture production of high value species is envisioned for Sarawak's Tanjung Manis Halal hub in an effort to manage the risks of reduced wild-catch fish supply due to climate change.

Water Security

The challenges faced by Malaysia in maintaining its supply of water resources include the following: (i) lack of a single formally constituted entity that is empowered to plan, coordinate, and execute integrated water resource management; (ii) the National Water Resources Council while constituting a good coordinating body for water affairs has not been provided with the legal mandate to carry this out;[28] (iii) water is a state matter as provided in Ninth Schedule, Article 74 of the Federal Constitution, which allows states to manage water resources through the gazettement of water catchments and control of development through outdated state legislations; and (iv) substantial financial allocation is required for climate change adaptation and mitigation measures.

Energy Security

To enhance energy security, the strategy adopted by Malaysia's Ministry of Energy, Green Technology and Water is to ensure adequate energy supply by using a mix of sources including: natural gas (i.e., prioritize indigenous resources for local consumption and establish storage for substitute fuels); renewable energy (i.e., introduce feed-in tariff to support the growth of renewable energy and prioritize renewable energy to be dispatched to the grid); coal (i.e., secure long-term contracts with suppliers and have multiple coal supplier countries); nuclear (i.e., explore the possibility of using nuclear power); hydropower (i.e., develop feasible and viable hydro projects and examine hydro potential in Sarawak, which is estimated to exceed 20,000 MW); and energy efficiency (i.e., increase efforts to manage demand and introduce explicit laws on efficient use of energy).

Philippines

The Philippines established a Climate Change Commission in 2009. It is tasked to coordinate, monitor, and evaluate the government's plans and programs on climate change. The Commission spearheaded the formulation of the National Framework Strategy on Climate Change in 2010 and the National Climate Change Action Plan in 2011. The framework strategy was reinforced by the enactment of the Philippine Disaster Risk Reduction and Management Act of 2010 and the strengthening of the National Disaster Risk Reduction Management Council and the local Disaster Risk Reduction Management Councils. A cabinet cluster on Climate Change Adaptation and Mitigation was also

[28] A legal instrument is part of the enabling environment for integrated water resource management.

established in 2011. The cluster prepared a roadmap with components on policy services, vulnerability assessment and/or risk mapping, modeling and forecasting, capacity building, and sector-specific adaptation and mitigation actions. The cluster aims to ensure the adoption of climate change adaptation and mitigation measures by local government units, the national government, climate change mitigation agencies, and the general public; and ensure that these are incorporated in their respective annual work plan and budget.

The Philippine National Climate Change Action Plan, 2011–2028 (2011) identified 7 strategic priorities, comprising of the following: food security, water sufficiency, ecosystems and environmental stability, human security, climate smart industries and services, sustainable energy; and knowledge and capacity development. Activities that cut across these strategic priorities are gender and development, technology transfer, research and development, information, education and communication, and capacity building. The Philippine Development Plan, 2011–2016 also identified climate change issues and policy direction to address climate change related challenges.

The Philippines has about 39 projects addressing climate change adaptation and mitigation that are implemented by various government agencies. Notable among these are the Climate Change Adaptation Program supported by the World Bank; the Climate Forecast Applications for Disaster Mitigation with the Asian Disaster Preparedness Center and the Department of Interior and Local Government-National Disaster Risk Reduction and Management Council and local government units; Strengthening Capacities for Climate Risk Management and Disaster Preparedness supported by the Food and Agriculture Organization, the Department of Agriculture, and the Philippine Atmospheric and Geophysical and Astronomical Service Administration; and Adaptation to Climate Change and Conservation of Biodiversity of the Department of Environment and Natural Resources (DENR), supported by the German Organization for Technical Cooperation. DENR has launched a number of programs including the National Greening Program (P18 billion, 2014–2015), National Geohazards Assessment and Mapping, Watershed Characterization and Vulnerability Assessment, anti-illegal logging, air quality monitoring, and cadastral surveys.

The Philippine Department of Agriculture has a budget of P31 billion (2014–2015) for climate change programs, namely, Mainstreaming Climate Change Adaptation and Mitigation Initiatives in Agriculture, Climate Information System, Adaptation & Mitigation in Agriculture Knowledge Toolbox, Climate Smart Agriculture Infrastructure, Financing and Risk Transfer Instruments on Climate Change, Climate Smart Agriculture and Fisheries Regulations, and Climate Smart Agriculture Extension System. Programs of the Department of Agrarian Reform include Pilot-Testing of Climate Proofed Community and Community-Managed Potable Water Supply, Sanitation and Hygiene in Agrarian Reform Areas. The Department of Science and Technology-Philippine Atmospheric, Geophysical and Astronomical Service Administration is undertaking projects on Flood Modeling for Early Warning, remote sensing using satellite images for soil moisture mapping, and Project NOAH (Nationwide Operational Assessment of Hazards).

The National Climate Change Commission is implementing Project READY (Hazards Mapping and Assessment for Effective Community-based Disaster Risk Management), Multihazard Mapping of Major River Basins, Eco-town Pilot Projects, and the Climate Twin Phoenix Project. The Department of Public Works has a food control program that entails the upgrading of engineering design standards for flood control, drainage, and slope protection works, construction of rainwater collection systems, and slope protection works. The Department of Energy's mitigation strategies include renewable energy projects and programs on energy efficiency and conservation. The National Economic and Development Authority and the Department of Interior and Local Government are building the capacity of local governments through the project, Integrating Disaster Risk Reduction and Climate Change Adaptation in Local Development and Decision-making Processes. The Palawan Council for Sustainable Development and the European Union's Center for Appropriate Technology are implementing the Zero Carbon Resorts Project. The Mindanao Development Authority, in coordination with DENR, has MindaNOW!–Nurturing Our Water Program and Treevolution (i.e., massive tree planting).

The Philippine government appropriations for climate change adaptation and mitigation are estimated at P30[29] billion in 2013. The appropriations have increased by 2.5 times in real terms and 26% annually from 2008–2013, higher than the 6% growth in the national budget. While this funding is about 0.3% of gross domestic product, it falls short of the recommended 2% (Stern, 2006). Hence, the Philippine government introduced the People's Survival Fund that will be used for the financing of local government climate change adaptation and mitigation projects, in accordance with the Climate Change National Strategic Framework.[30]

The Mindanao Development Authority has a spatial development strategy called "Mindanao Development Corridors" to achieve physical integration among key economic clusters in Mindanao and prepare the island for greater economic cooperation with the BIMP-EAGA and other ASEAN countries in anticipation of the ASEAN integration by 2015. This entails the provision of common service facilities to strengthen the competitiveness of Mindanao's industries.

BIMP-EAGA Initiatives

Climate change risks present new challenges as well as opportunities for increased BIMP-EAGA subregional cooperation in coordinating policies, mobilizing investments, and strengthening capacity in climate change resilience. At the subregional level, current preparations for climate change resilience are still concentrated mainly along sectoral lines, most prominent of these is the CTI-CFF.

A climate-related activity under the CTI-CFF is the development of a Region-wide Early Action Plan for Climate Change Adaptation for the Nearshore Marine and Coastal Environment and Small Island Ecosystems, which focuses on establishing effective adaptation measures for coastal communities, with emphasis on strengthening capacity to conduct climate change vulnerability assessments and to plan for climate change resilience.

The working group of the CTI-CFF on climate change adaptation has identified sites where adaptation measures should be prioritized. The regional initiative is also actively engaged

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[29] Philippine peso.

[30] Government of the Philippines, Climate Change Commission. 2014. Powerpoint presentation for the Cabinet Cluster on Climate Change. Quezon City. 6 August.

Gaps and Measures to Enhance Preparedness and Address Gaps

in international outreach activities on climate change issues, for example through joint communiqués in past UNFCCC climate conferences.

Policy Measures

Within the context of implementing existing climate resilience programs, there are knowledge gaps and constraints that need to be overcome. These include: (i) support for capacity building, particularly in relation to the collection and analysis of scientific and traditional knowledge and the development of policy and adaptation to climate change; (ii) understanding the vulnerability of people to improve their capacity to make effective ecosystem and structural adaptation plans at the local, national, and regional levels; (iii) improved spatial planning; and (iv) the development of a framework to provide early warning on disaster and climate change hazards, and strategies to minimize risks and improve management systems.

The sustainability of forestry and biodiversity depends on the conservation of genetic resources through gene banks, seed centers and botanical gardens, sanctuaries, captive breeding centers, and rehabilitation centers. However, these are presently restricted by insufficient funds and funding mechanisms to support research on biodiversity and building capacity through training.

Current climate projection models need expansion and therefore necessitate emphasis on knowledge building. These models are required to provide clear parameters and guidance to extend research on the impacts of climate change on water resources, urban and rural drainage systems, catchment management, highway drainage, dam and reservoir safety and integrity, water supply allocation and distribution, irrigation water demand and efficiency, and hydrology analysis on flood risks. To address climate change adaptation in the coastal zone, in depth knowledge and understanding of storm patterns, intensity, duration, and frequency are required.

An important challenge in the agriculture sector lies in the complexity of needed technical innovation and the necessity for integration with other sectors (e.g., water). Policies to fill in capacity gaps that need attention with respect to climate resilience in agriculture include the following: (i) research on adaptation and mitigation options that take into account context and location specificities (e.g., soil types, crop types, management practices, and climate conditions); (ii) knowledge management arrangements for the sharing of information and experiences; (iii) formulation of adaptation action plans, focusing in particular on ecosystem-based agriculture; and (iv) institutionalization of financing assistance on climate resilience measures.

The countries that comprise BIMP-EAGA on the whole have fairly adequate legislations, policies, and plans in place in relation to climate change adaptation and mitigation. However, there is still much room for improvement. For example, in Sabah and Sarawak, perception interviews revealed that there is a significant challenge to overcome when it comes to governance, in part due to lack of sufficient technical expertise and financial limitations of local authorities.

Implementing adaptation measures does not depend on a single government ministry or agency. It necessarily involves all sectors (i.e., government at all levels, the private sector, and the community). Coordination is one of the main challenges in planning and implementing adaptation measures in the BIMP-EAGA countries, more so if linked to the political structure and system of governance that is decentralized. Coordination is crucial not only among government agencies at the central level, but also in terms of the relationship among all government levels from the central top to the bottom.

Efficient climate resiliency practices require cross-sectoral adaptation actions. Therefore, processes involved in adaptation policies and governance options cannot be limited to within sectoral initiatives. The effectiveness of programs for managing climate change can be enhanced by developing synergy of adaptation action activities among sectors.

The following sections provide a survey of possible climate change resilience measures grouped into investments and capacity building. Table 1 shows a prioritization of these measures expressed in terms of short- and long-term implementation time frame and area coverage.[31]

Investments

Items for fund sourcing and investments include: (i) watershed characterization and vulnerability assessment and improved watershed management; (ii) funding and technical modernization and improvement of station networks, facilities, tools, technology, and databases; (iii) improvement in recovery, organization, processing, and storage of data; (iv) regular maintenance of irrigation facilities to reduce water losses during transmission and distribution; and (v) a comprehensive system for monitoring natural resources, watersheds, and ecosystems under changing environmental conditions, including community-based monitoring systems of local government units as in the case of Mindanao.

Additionally, (i) investments in improved weather forecasting (i.e., meteorological and hydrological observations [technical modernization of observation, initial data processing, storage, archiving and communications processes and facilities]); (ii) the establishment of more river basin gauging stations, tidal gauging stations and buoys and automated stations in remote areas; (iii) improvement in the operation of specialized meteorological

[31] Most of the information was culled from the climate change action plans of BIMP-EAGA countries and consultations with stakeholders.

stations (e.g., agro-meteorological, Doppler radar stations, etc.); (iv) improvement of current databases and development of modern open source databases; (v) investments in reforestation, afforestation, and forest reclamation in priority river basin areas, including restoring and conserving rainfall catchment areas in river basin regions that become the sources of hydropower and geothermal energy stations.

Investments in restoration and the development of agricultural infrastructure that are climate proof include the following: (i) the development of a system that takes into account climate change; (ii) the development of water management technology that is adapted to climate change; and (iii) the rehabilitation and conservation of watershed to increase water absorption to reduce drought threats.

Investments in renewable energy include the following: (i) the expanded utilization of renewable energy sources to improve climate resilience; and (ii) the expanded utilization of renewable energy sources by optimizing the use of organic waste for the production of gas and energy in densely inhabited areas. This will reduce the load on the environment and increase the tolerance range of the area to highly extreme rainfall occurrence.

Capacity Building

The following areas for capacity building are recommended:

- Training on best practices on climate change and coastal resource management for local governments, communities, and the private sector of the BIMP-EAGA countries, in coordination with the CTI-CFF;[32]
- Training in integrated vulnerability assessment to formulate adaptation options at different levels and scales;
- Capacity on climate fit crop programming to support the food basket strategy of BIMP-EAGA;
- Climate-based crop mixing for sustainable farming and the maximization of production in highly vulnerable agricultural areas;
- Technical aid to access geospatial and social science data, reliable sea level rise predictions, and the development of ocean-atmosphere-watershed modelling;
- Training on geospatial data and inundation mapping;
- Techniques to engage stakeholders and to develop strategic plans for adapting to climate change;
- Study of nearshore currents, circulation patterns, and coastal upwelling effects on natural systems and productivity;
- Ocean-atmosphere-watershed modelling to account for the potential impacts of storm surge and event-related inland flooding;
- Predictive capability on sea level rise;
- Assessment and implementation of local and/or regional priority areas for habitat protection and restoration;

[32] CTI-CFF Goal 4 is on climate change adaptation measures achieved.

- Mainstreaming environment in other strategic pillars of BIMP-EAGA to create awareness among individuals, society, and organizations in the BIMP-EAGA countries on caring for the environment and implementing environmental protection and conservation activities with regard to other pillars of BIMP-EAGA (i.e., connectivity, food basket, and tourism);
- Increase the balance between socio-economic development objectives and the importance of maintaining quality and sustainable development among stakeholders, the private sector, and communities;
- Improve public awareness within the BIMP-EAGA community towards sustainable development of natural resources and the environment and on the phenomenon and impacts of climate change; and
- Increase the promotion of food mix policy.

Technical Assistance

Technical assistance is needed in the following areas:

- Data on investment requirements and costs (i.e. operating and maintenance expenses and projected revenues from the sale of electricity per technology and energy source, including potential installed capacity and actual production per energy resource);
- Updated studies on local emission factors, carbon credits, and GHG inventories, downscale climate models to provinces, municipalities and/or cities and individual islands;
- Evaluation tools for appropriate land use selection;
- Modelling of watershed and ecosystem services under future climate and socioeconomic scenarios;
- Integrated natural resources information system technology that enable concerned stakeholders to adopt climate smart silvicultural practices;
- Assessment of the long-term effects of climate change, especially at the local level (e.g., intensive pressure of human use in the coastal zone);
- Use of geospatial and social science data to develop visualizations and enable communities to understand climate change risks;
- Studies on the impacts of upstream water use policies on the coastal environment and communities;
- Climate monitoring and forecasting;
- Assessments to develop indigenous technology, including local wisdom on climate change;
- Assessments to expand the utilization of small-scale hydropower sources in isolated areas as part of the program on developing energy self-reliant villages that can encourage communities to preserve the environment and promote the sustainability of environmental services;
- Develop the capacity for analysis, prediction, and/or estimation of climate and/or weather, networks of climate information system, crop calendar, and networks and institutions of systems for communication;

- Design a system for monitoring and evaluation that will yield information on the progress in attaining targets of programs on adaptation to climate change; and
- Implementation of monitoring and evaluation of activities on adaptation to climate change.

Table 1 **Climate Change Resilience Measures**

Measures	Time Frame	Scope	Remarks
A. Environmental Sustainability Knowledge			
1. Research on storm surge to study long-term coastal movement	LT	N, R	Urgent
2. Research on the proper methods for establishing coastal forests for coastline stability	LT	N, R	
3. Study on the appropriate incentives for local governments and the private sector to implement climate change adaptation/ mitigation measures	ST	N, R	Urgent
4. Implementation of payment for environmental services schemes	ST	N	
5. Studies on costs associated with losses and damages from climate change	LT	N	Urgent; in accord with recent international agreements to compensate countries
6. Determination of limitations of ecological and biological sustainability under climate change scenarios	LT	N	
7. Ecological resilience and land use studies to support climate change adaptation and/or mitigation measures, such as infrastructure for shoreline stabilization	ST	N, R	Urgent
B. Food Security, Agriculture, and Natural Resources			
1. Forecasting and monitoring systems for floods, droughts, and other extreme climate events	LT	N, R	Urgent
2. Soil conservation measures (e.g., composting, terracing, contour planting)	ST	N	
3. Windbreaks and shelterbelts (e.g., wind resistant species, strips of trees, shrubs, and vines)	ST	N	
4. Engineering solutions (e.g., pipe irrigation)	LT	N	
5. Introduction of improved seeding techniques	ST	N	
6. Outdoor storage facilities for grains and other staple crops	ST	N, R	Possible common storage facilities
7. Climate-based cropping mix for sustainable farming especially in highly vulnerable agricultural areas	ST	N	Urgent

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Table 1 continued

Measures	Time Frame	Scope	Remarks
8. Integrated natural resources information system technology that enable concerned stakeholders to adopt silvicultural practices,(e.g., drought resistant species, wind firm species, water use efficient species, species that tolerate high carbon concentration and have high carbon sequestration, pest resistant species)	LT	N, R	Information sharing among BIMP-EAGA countries
9. Assessment and implementation of local and/or regional priority areas for habitat protection and restoration	LT	N, R	e.g., CTI-CFF
10. Mapping of agricultural areas in terms of flood, landslide, storm surge, and drought susceptibility and vulnerability	ST	N	Urgent; maps will need to be updated periodically
11. Greening programs (nationwide reforestation)	LT	N	Planted trees need maintenance and protection; replanting needed
12. Research on indigenous climate change resilient crop species	ST	N, R	Urgent; joint research among BIMP-EAGA countries
13. Information, education, communication and outreach activities on climate change and its impacts	ST	N, R	Joint education and outreach
14. Switch to various cultivars	ST	N	
15. Capacity development on climate fit crop programming to support the food basket strategy of BIMP-EAGA	ST	N, R	Urgent
16. Improve irrigation efficiency: regular maintenance of irrigation facilities to reduce water losses	LT	N	Urgent
17. Development of a comprehensive monitoring system for natural resources, watersheds, and ecosystems with due consideration of changing climatic and environmental conditions	LT	N	Urgent
18. Biodiversity corridors	LT	N	Link these to the economic corridors of BIMP-EAGA
19. Improved forest fire protection and control	ST	N, R	Urgent; regional cooperation is needed in case of haze problem
20. Mixed planting of slow growing and fast growing species for multistorey plantations	ST	N	
21. Introduction of low water use crops	ST	N	

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Table 1 continued

Measures	Time Frame	Scope	Remarks
C. Water Security			
1. Studies on the impacts of upstream water use policies on coastal communities and environments	ST	N, R	Joint research studies
2. Models for the assessment of watershed and ecosystem functions and services under future climate and socioeconomic scenarios; watershed characterization and vulnerability assessment	ST	N	Urgent; joint research studies
3. Comprehensive watershed rehabilitation and management	LT	N	
4. Water allocation procedures	ST	N	May need re-allocation over time
5. Water pricing policies and structure	ST	N	May need periodic review and revisions
6. Water augmentation and harvesting techniques, including rain harvesting, surface runoff collection and storage, stream flow diversion, and ponding	ST	N	Urgent
D. Energy Security			
1. Studies on renewable energy technology (e.g., investment requirements, costs, operating and maintenance expenses, projected revenue from the sale of electricity per energy source and technology)	ST	N, R	Urgent; joint research studies
2. Updating of country and/or local emission factors and GHG inventory	ST	N	Done periodically
3. Updating of studies on the potential installed capacity and actual production per energy resource	ST	N, R	Joint research studies
4. Computation of carbon credits to access financing (e.g., Low Emissions project proposal by the Mindanao Development Authority)	ST	N	
E. Capacity Development and Institutional Strengthening			
1. Entry points on how to move policy and information sharing within and/or between a sector and or established platform towards implementation;	ST	N	
2. Perception surveys (e.g., adaptation needs, barriers to climate change adaptation)	ST	N, R	Urgent
3. Policy effectiveness studies (e.g., Are vulnerabilities reduced as a result of the implementation of a policy? At what cost?)	ST	N	Urgent

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Table 1 continued

Measures	Time Frame	Scope	Remarks
4. Training in integrated vulnerability assessment to formulate adaptation options at various levels (regional, national, provincial, or city and/or municipal)	ST	N, R	Urgent; joint training activities
5. Downscale climate models to the provincial and municipal and/or city levels and individual islands	ST	N	
6. Evaluation tools for appropriate land use selection	ST	N, R	Joint training activities
7. Assessment of the long-term effects of climate change at the local level (e.g., intensive pressure of human use in the coastal areas)	ST	N, R	Joint training activities
8. Use of geospatial and social science data to develop visualizations to enable communities to understand climate change risks	ST	N, R	Urgent; joint training activities
9. Nearshore currents, ocean circulation patterns, and coastal upwelling effects on natural systems and productivity	ST	N, R	Joint training activities
10. Coupled ocean-atmosphere-watershed modelling to account for the potential impacts of storm surge and event-related inland flooding	ST	N, R	Joint training activities
11. Predictive capability on sea level rise and the impacts of sea surges	ST	N, R	Urgent; joint training activities

BIMP-EAGA = Brunei Darussalam-Indonesia-Malaysia-Philippines East ASEAN Growth Area, CTI-CFF = Coral Triangle Initiative on Coral Reefs, Fisheries, and Food Security, GHG = greenhouse gas, LT = long-term, N = national, R = regional, ST = short-term.

Legend: National: Location specific to a country

Long-term: Continuing activity (e.g., monitoring, maintenance, weather forecasting, reforestation and projects that require a long period to implement)

Regional: Can be joint activities among the BIMP-EAGA countries

Short-term: Has a certain duration (e.g., specific training)

Urgent: To be started soon.

Source: ADB (2015).

Conclusions and Recommendations

Numerous actions can be taken to enhance climate resilience in BIMP-EAGA as shown in the menu of possible actions listed in the preceding section. Many of these measures are drawn from existing national plans and ongoing programs by individual governments, and the rest from feedback that were obtained during stakeholder consultations, which were carried out as part of this study. The menu of actions identified range broadly from framing policies that point to climate change concerns as a national priority, to formulating strategic plans for climate resilience, improving coordination across national and subnational levels of climate action implementation, investing in climate resilient infrastructure, managing climate-related disaster risks, and strengthening knowledge and institutional capacity.

For the most part, these actions are not new ideas, including those recommended for specific areas of BIMP-EAGA in each country, as described further in the separate country assessment reports that are summarized in Appendixes 6–9. The proposed interventions have appeared in one variant or another in assessments and plans drawn up by the BIMP-EAGA national governments through their respective planning and development authorities, climate change commissions, academic and research institutions, and also by subnational entities (e.g., regional development councils). Food, water, and energy concerns feature prominently in these existing national plans. The gap lies in the limited capacity to implement, which in turn is influenced by institutional weaknesses (e.g., in risk-based decision-making, coordination) and financial constraints.

The challenges for enhanced climate resilience lie not in the lack of ideas or priorities on how to deal with the hazards, but—first, and perhaps foremost—on how to weave these into a practical action plan at the local level (e.g., provinces, cities, or federal states) so that actions are not viewed as standalone remedies but as an integrated (and continuously evolving) solution that is a product of a fundamental mind-set change on how to plan for sustainable development in the face of unavoidable uncertainty, and in which the risks and stakes are understood well by the populace and their local governments. A second major challenge is financing. A typical source of frustration in action planning exercises is that these are frequently destined for the bookshelf or the coffee table due to lack of financing. Yet, a third challenge is how to build on synergy between sustainable development and climate resilience, and specifically between resource use efficiency and climate change adaptation, which is also key to competitiveness in a more open regional economy.

As previously noted, economic uncertainties created by the advent of regional economic integration will be compounded by looming threats from increasing weather variability, extreme weather events, and long-term climate change. In this sense, managing uncertainty (in its various forms, not just climate change) will be the dominant challenge for charting the region's sustainable development future.

There is broad scientific consensus that climate change will alter the physical environment (e.g., hydrologic cycle, terrestrial, and marine ecology) in important ways. Despite continuing advances in climate change science, uncertainty about the outcomes will remain. It is not possible to precisely predict the size and form of the impacts, particularly at the local level, where adaptation decisions have to be made. Extreme weather events, like Typhoon Haiyan, which devastated central Philippines in 2013, are within the range simulated by climate models. Yet, when such an event actually occurs, its impacts are largely surprising and unpredictable—the very definition of a "black swan" event. Hence, national and regional policymakers should not wait for climate change uncertainty to somehow be cleared up by science before taking action, for such uncertainty is unavoidable and persistent. Rather, there is a need to fundamentally alter planning and decision-making strategies by taking on an adaptive approach to sustainable development, one that confronts uncertainty head-on and proactively manages its implications.[33] Development planners and policy decision-makers in the subregion should adopt such a preparedness stance. The traditional planning paradigm which shuns uncertainty (i.e., by attempting to devise precise forecasts) is no longer appropriate.

Even with the widely available national action plans for climate resilience, the time and spatial scales in which practical climate change adaptation decisions need to be made are at the local level. This is where resilience initiatives embodying uncertainty-based adaptive planning and drawing from a wide array of options should be initiated. Climate change resilience is fundamentally about managing uncertainty. This requires awareness-raising, practical risk-based planning methods, information and decision support systems, templates and examples, and sustained capacity building. Such mind-set change is important to emphasize, and one where BIMP-EAGA countries can work cooperatively to achieve.

In practice, such an approach would entail: (i) considering a variety of plausible futures and/or scenarios that are understood by stakeholders; (ii) considering a variety of possible adaptation strategies and measures that take into account constraints (i.e., institutional, informational, and financial); (iii) favoring actions that are flexible and/or reversible and robust to uncertainties; (iv) using an iterative learning approach based on probing and experimenting; (v) instilling a "habit" of monitoring results and updating vulnerability assessments; and (vi) adjusting plans in light of knowledge gained.

A BIMP-EAGA cooperation framework for climate resilience could focus on assisting local planners and policymakers in ensuring that development decisions, including new initiatives and investments spurred by emerging regional economic integration, are not planned "as usual". That is, decisions must pay attention to present day risks of increasing climate variability and extreme weather, and be robust to the uncertainties of future climate change. Such a fundamental change in approach needs to be supported with sound

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[33] Since uncertainty in climate change modelling is unavoidable, for instance, the aim should be to minimize uncertainty by choosing models that capture well the dominant climate feature of the region and by not relying on just one model. Another aim is to quantify uncertainty so that the range of outcomes can be expressed probabilistically. The latter was done by using an ensemble of models (and model runs) which then produced a range of climate change projections to which percentile-based estimates of likelihood can be applied

knowledge base and decision support systems that enable local planners and decision-makers to identify and assess climate risks in an informed manner.

An analogy that may help BIMP-EAGA policymakers appreciate more intuitively the scope of this mind-set change is to think of climate resilience not as a sort of protective coat of remedial measures that is applied on top of the usual fabric of development (as in building more dams to avert future water scarcity or seawalls to protect coastlines). These have short-term uses, but they are not long-term solutions and they are costly, if not also prone to unintended maladaptation effects. Rather, the fabric itself of development must be woven in a different way, such that resilience is a built-in feature. This means, for example, using water and energy resources more efficiently, increasing agricultural productivity, and closely regulating development in vulnerable coastal zones.

It should also be clarified that such a fundamental shift in development planning is anchored on the premise that development and climate change resilience form a continuum. The aim is not to curtail development or to differentiate development from adaptation, but to ensure that development is not planned in the usual fashion. Development and climate resilience are mutually reinforcing. Indeed, there is a strong economic logic to blending the aims of development and adaptation because investments that tap this synergy will pay for themselves regardless of the uncertainty inherent in climate change scenarios.

A concomitant major challenge is financing, assuming that climate resilience plans embodying a fundamental shift in development thinking are spawned across the region. A subregional cooperation framework to facilitate financing for integrated climate resilience initiatives that is targeted at the local level, is a worthwhile initiative for BIMP-EAGA policymakers. Here, a subregional body akin to a clearinghouse could be set up to facilitate working with financial institutions, in particular, climate funds and their intermediaries. It would be timely as well, in view of the substantially increased funding that is anticipated for climate change mitigation and adaptation. Opportunities for seeking funds from the Green Climate Fund or the Adaptation Fund should be explored. There is contentious yet imminent progress that is being made towards a new international climate accord. Climate-related funds are expected to be considerably expanded, including under the unprecedented "loss and damage" provisions.

While not contradicting the fundamental link and continuity between development and climate resilience, it is on the aspect of financing—specifically, in order to access climate funds—where clarifying specific objectives of development as distinguished from climate change resilience takes on practical importance.[34] Again, this is simply to make sure that development initiatives are not planned as usual and that climate funds are used in an effective way. Assisting BIMP-EAGA local governments in preparing resilience plans that meet this norm is another important role for an envisioned clearinghouse.

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[34] International mechanisms to support adaptation activities aim for funds to be targeted to "additional" activities specifically planned for climate resilience, as opposed to "regular" development activities. This requires two-step planning process. In the first step, a baseline scenario is established. This is defined as 'business as usual' development with no consideration of the likely implications of climate change. In the second step, an alternative scenario is defined. The alternative scenario describes key results or outcomes that are to be achieved by a set of interventions that explicitly address climate change concerns.

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Appendix 1
BIMP-EAGA Roadmap and Implementation Blueprint on Food, Water, and Energy Security

The Brunei Darussalam-Indonesia-Malaysia-Philippines East ASEAN Growth Area (BIMP-EAGA) subregional cooperation program, a subset of the Association of Southeast Asian Nations (ASEAN), was established in 1994 to address the socioeconomic development of less developed, marginalized, and far-flung areas, and narrow development gaps across and within the subregion. The *BIMP-EAGA Road Map to Development (RMD), 2006–2010* was formulated in 2004 to realize this objective. The road map is the principal strategy framework from which subsequent measures, programs, and projects are aligned.

Member countries of BIMP-EAGA developed the *Implementation Blueprint, 2012–2016* as part of the recommendations of the RMD midterm review and recent directives from the BIMP-EAGA summit and ministerial meetings to enhance the implementation of the strategic thrusts of the road map. Among its objectives, the blueprint aims to establish BIMP-EAGA as the food basket for the ASEAN and the rest of Asia to promote long-term food security; enhance connectivity within BIMP-EAGA, including power interconnection and the development of renewable energy; and ensure the sustainable management of the environment. The blueprint also aspires to streamline the strategic areas of the program, cognizant of the increasing impact of changes in the regional and global economic environment as well as the more recent global concerns (e.g., climate change) to the subregion's growth and development.

Food Security

Under the blueprint's food basket strategy, long-term food security in the subregion has been given top priority. Based on the food basket initiative framework, food security is defined as a condition that exists when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life. The blueprint listed desired improvements in the implementation of national food policies to achieve long-term food security. These include the following:

- Ensuring sustainable food production and increasing productivity and profitability through high value processing, and improvement in post harvest technology and facilities;
- Enhancing access to finance for micro-, small-, and medium-sized enterprises;
- Capacity building for farmers and fisherfolk to increase production and productivity;

- Optimizing land and water resource use for food production;
- Improving agriculture, livestock, and fisheries infrastructure;
- Addressing the impacts of climate change;
- Ensuring ecosystem and environmental integrity; and
- Providing incentives to the private sector to invest in the food supply/value chain.

In addition to the blueprint, ASEAN member states conceptualized the ASEAN integrated food security framework (AIFSF) to address long-term food security in the region. The AIFSF's strategic plan of action on food security identified climate change as one of the emerging issues of food security.

Emission of carbon dioxide equivalent in Indonesia and the Philippines increased by 42% and 46%, respectively, from 1990–2000 due to increasing production to meet the demand of a growing population and development aspirations. Since both countries are archipelagic, escalating carbon dioxide emissions will result in increasing temperature, which will affect the subregion through sea level rise and the destruction of coral reefs. This in turn will impact on fisheries.

In response, climate change adaptation and mitigation measures were incorporated in the AIFSF as part of its strategic thrust to address food security issues. These measures include conducting studies to identify climate change impacts on food security, identifying measures to adapt to and/or mitigate the impacts of climate change, and collaborating with sectoral bodies that address impact mitigation and adaptation to climate change.

BIMP-EAGA also monitors the progress of research and development efforts under the Philippine-Brunei Rice Research program as part of its strategic plan on food security. The program aims to develop improved rice varieties that is, among others, climate change ready. It is jointly implemented by the Brunei Agriculture Department, the Indonesian Center for Rice Research-Sukamandi, the Malaysian Agricultural Research and Development Institute, and the Philippine Rice Research Institute.

Moreover, member countries of BIMP-EAGA have consistently participated in global and regional environmental agreements and programs. However, policy formation, strategic planning, and implementation of environmental and climate management measures are being developed. Climate change initiatives in the BIMP-EAGA countries have thus far been focused at the national level. For instance, under the clean development mechanism of the Kyoto Protocol, comprehensive climate change strategy formulation for the subregion is an area for policy and planning that needs to be further addressed.

Water Security

The BIMP-EAGA RMD highlighted sustainable management of the environment to address the continuing decline in the subregion's natural resource base, notably threats to marine biodiversity from water pollution and a general decline in water quality. On the other hand, domestic water demand in BIMP-EAGA increased by 77% in 1980–2007 with resource demand in Brunei Darussalam and the Philippines growing at a faster rate compared to the rest of the subregion due to higher population growth. To meet demand, rivers have to be dammed, spring flows have to be captured, and underground aquifers have to be pumped, resulting in the disruption of the hydrological processes and its impact on habitats and the cultural, natural, and social functions of free flowing water.

National level actions and plans in BIMP-EAGA member countries have been put in place to address the deterioration of seawater and freshwater quality. These laws and/or policies focus mainly on water pollution control and management, toxic and hazardous materials, marine pollution as well as projects on integrated river basin management, persistent organic pollutants, and water quality management. Climate change will add another layer of challenge to water resource management in the subregion.

Energy Security

Infrastructure development, including energy infrastructure projects, has been identified in the BIMP-EAGA RMD as one of its strategic objectives to attain economic integration. Towards this end, the Master Plan for ASEAN Connectivity was launched in 2010 to synchronize ongoing sectoral strategies and plans of subregional programs with the ASEAN framework. One of the priority projects under the master plan is the Trans Borneo Power Grid: Sarawak to West Kalimantan Power Interconnection. The project will contribute to the optimal use of energy resources in the region by exporting surplus energy from Sarawak to West Kalimantan, generating additional income for Sarawak and improving the quality and reliability of supply and lowering the cost of power in West Kalimantan. It will also help diversify the energy portfolio by retiring old inefficient oil-based power plants. Interconnected power transmission systems within the region are necessary to improve power reliability and to enhance overall economic efficiency in an environmentally sustainable way.

On the other hand, energy production and consumption in BIMP-EAGA as key drivers of economic development are potential sources of major environmental damage. Although there have been some developments in promoting energy efficiency and renewable energy in the subregion, greater emphasis on these two aspects are still needed in the light of climate change and its link to fossil fuel use, especially in the energy and transportation sectors.

Mining and petroleum exploration development activities in BIMP-EAGA are also sources of potential environmental damage. Limited effective work has been done in this sector except for environmental management plans in specific sites. In addition, a low carbon development strategy has yet to be developed for the subregion.

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Appendix 2 Review of Previous Vulnerability Assessments on BIMP-EAGA

Climate Change Projections from the United Nations Development Program (UNDP) Study

The UNDP assembled observational and multi-model climate model data on various countries, including Indonesia.[1] Projections for Indonesia are indicative of the changes in climate that may be expected in the Brunei Darussalam-Indonesia-Malaysia-Philippines East ASEAN Growth Area (BIMP-EAGA) due to proximity. The UNDP findings are derived from a subset of 15 models from a 22-member ensemble that was used by the Intergovernmental Panel on Climate Change under phase 3 of the Coupled Model Inter-Comparison project. The climate model data uses a 250 x 250 kilometer resolution. Its assessment is helpful in providing an overview of the BIMP-EAGA subregional climate change pattern.

Observational findings from the UNDP climate change assessment on Indonesia show an increase in mean annual temperature by around 0.64°C since 1960. The rise in temperature has been faster in the larger western islands. Similarly, the frequency of hot days increased significantly in every season since 1960. On the other hand, mean rainfall decreased considerably in every season at an average rate of 7.8 millimeters (mm) per month or by 3.6% per decade since 1960.

Modelling-based climate projections indicate that mean temperature will increase by 0.9°C by the 2060s and by 1.2°C–3.7°C by the 2090s. The projected warming will more rapid over larger islands (e.g., Kalimantan). Hot days are projected to occur 35%–79% of the time by the 2060s and 48%–95% of the time by the 2090s. Rainfall is projected to change overall from -28 mm and +53 mm per month (-12%–+20%) by the 2090s with large spatial and seasonal variations in predicted rainfall changes. The easternmost islands (e.g., Papua and Maluku) will generally have the largest increase in rainfall (-6%–+38%) by the 2090s. Projections also indicate that maximum 1-day and 5-day rainfall are expected to increase in the future.

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[1] Karmalkar, A. *et al.* 2012. *UNDP Climate Change Country Profiles: Indonesia*. Retrieved from http://www.geog.ox.ac.uk/research/climate/projects/undp-cp/UNDP_reports/Indonesia/Indonesia.hires.report.pdf.

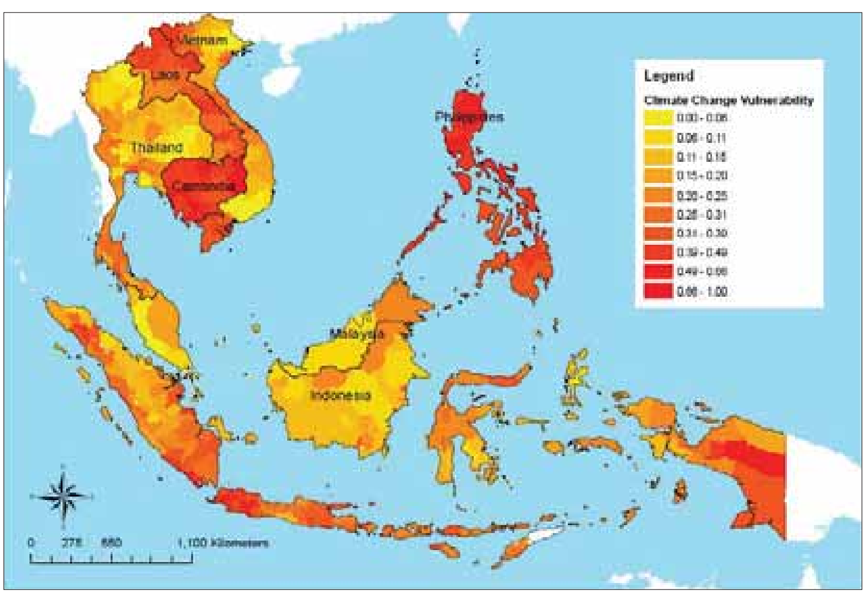
Economy and Environment Program for Southeast Asia (EEPSEA) Vulnerability Study for Southeast Asia

EEPSEA published a vulnerability assessment in 2009 that identified regions/districts/provinces in Southeast Asia that are most vulnerable to climate change impacts.[2] The assessment was carried out by overlaying climate hazard maps, sensitivity maps, and adaptive capacity maps following the vulnerability assessment framework of the Intergovernmental Panel on Climate Change.

Climate hazards included frequency of extreme weather events (e.g., droughts, floods, and cyclones), physical exposure to landslides, and inundation zones of a 5-meter sea level rise. Sensitivity was mapped by population density and location of important biodiversity resources. Adaptive capacity was mapped using various socio-economic indices (e.g., human development index [HDI]) and indicators of access to technology and availability of infrastructure.[3]

The overall index of climate change vulnerability is the average of each of the normalized indicators of exposure, sensitivity, and adaptive capacity. Vulnerable areas across Southeast Asia were ranked based on the overall index, including a ranking of areas within each country. Figure 2A-1 shows the resulting vulnerability ranking with the darker shaded areas indicating increased susceptibility to climate change.

Figure 2A-1 EEPSEA's Vulnerability Mapping for Southeast Asia



Source: Yusuf and Francisco (2009).

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2 Yusuf, A. and H. Francisco. 2009. *Mapping Climate Change Vulnerability in Southeast Asia*. Singapore: Economy and Environment Program for Southeast Asia.

3 An index for a parameter (X) at a given location is calculated by first taking the range of values for that parameter (Xmax - Xmin) and by using it as a denominator to derive a fraction (0–1). The numerator is the difference between the value of the parameter at that location and the minimum value of the data range.

At the subnational level, climate change vulnerability indices were derived by assessing exposure based on information from historical records of climate-related hazards that served as proxy for future climate risks (i.e., tropical cyclones, floods, landslides, tropical cyclones, floods, landslides, droughts, and sea level rise). Population density was used as a proxy for human sensitivity and ecological sensitivity was assessed using biodiversity information (i.e., protected areas). The adaptive capacity index was derived as a function of socio-economic factors, technology, and infrastructure.

The EEPSEA study is essentially an assessment of current vulnerability that utilized historical information on climate hazards to assess exposure. The BIMP-EAGA vulnerability assessment validated and improved on the climate change exposure aspect of the EEPSEA study by using data from regional climate change modelling.

Asian Development Bank (ADB) Study on the Economics of Climate Change in Southeast Asia

ADB's 2009 study on Southeast Asia noted that the frequency and intensity of extreme weather events have increased in recent decades.[4] Observed effects include more frequent heat waves, significant increase in the number of heavy precipitation events, and a rise in the number of tropical cyclones. These climatic changes have led to massive flooding, landslides, and droughts in many parts of Southeast Asia, causing extensive damage to property and assets, and injury to and loss of human life. Overall, climate change in the region is projected to intensify in the coming decades with an associated rise in the frequency and intensity of extreme weather events.

The synthesis report notes that flooding in low-lying populated areas (e.g., coastal regions and river basins) is expected to adversely affect agriculture and damage infrastructure. Prolonged droughts during the dry season could become an increasing concern, particularly during El Niño years, resulting in crop failure, increased water unavailability, and reduced hydropower generation. Rising sea levels have already accelerated salt water intrusion in agricultural areas. The decline in grain production and industrial crops could in turn impact on the region's livestock industry. By 2100, higher temperatures are likely to cause a decline in rice yield potential by up to 50% on the average compared to1990 levels.

Current climate extremes have been reported to contribute to an increase in disasters (e.g., fires and landslides) in forested areas. Forest fires have intensified and spread over larger areas due mainly to the combined effects of rising temperatures, declining rainfall, and aggressive land use changes during the past two decades.

Marine ecosystems are highly vulnerable to climate change impacts. Warmer temperatures have resulted in increased rates of coral bleaching and advancing sea levels and coastal erosion. These in turn have caused mangrove forests to retreat inland.

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[4] ADB. 2009. *Economics of Climate Change in Southeast Asia: a Regional Review. Manila.*

Climate Change Studies on Brunei Darussalam

Brunei Darussalam has a small population of 0.4 million in 2010. Earlier reports have indicated that the Sultanaate has positive estimated net migration of 2.7 persons per 1,000 population in 2009. The country hosted 76,000 foreign workers in 2006, comprising close to one-fifth of the total population at that time. A considerable proportion of these workers came from the Philippines.

Demand for land is met through the conversion of natural areas into settlements and in some cases, nearshore ecosystems are reclaimed. This has resulted in loss of habitat and environmental services. Although urban centers link BIMP-EAGA to the world and serves as nodes for the internal movement of people, goods, and services, urbanization has also polluted the air, water, and land and has exerted pressure on services and resources, such as water supply, where demand is partly met by overpumping the aquifers while impervious areas for recharge are diminished.

Trade in BIMP-EAGA is highly dependent on natural resources. Oil and gas are the main export products based on value, accounting for about 66% of total export value in 2004. A large proportion of these commodities comes from Brunei Darussalam, where oil and gas production represented 68.8% of gross domestic product in 2006, with increased in trade volume over recent years. The impacts of extensive harvesting of sea-based export commodities (tuna, skipjack, and bonito) result in changes in resources use, with increased fishing effort and number of purse-seine net trawlers, consequently, reducing fish stocks while endangered species taken as by-catch. For oil and gas, this may increase the risk of sea pollution. While the extraction and production of these commodities may have substantially contributed to the economy of BIMP-EAGA, their environmental costs and sustainability can be seen in its impact on existing resource use patterns.

Climate Change Studies on Indonesia

Indonesia is among the countries most vulnerable to the impacts of climate change. It has a long coastline, small islands, and coastal zones that is home to 50%–60% of the population. These areas are highly susceptibility to natural disasters (e.g., tidal waves, abrasion, pollution, flooding, typhoon damage, and sea level rise). An estimated 43% of the country's coral reefs are damaged and mangrove areas are inundated. The agriculture sector is also highly vulnerable to climate change due to loss of forest cover and reduced water supply.

In almost all of the Java Island and the eastern part of Indonesia (e.g., Bali, West Nusa Tenggara and East Nusa Tenggara), there is an increasing trend in rainfall from December to February. On the other hand, significant decreasing trend in rainfall has been observed from July to August in almost all of Indonesia, except in West Java, Maluku, Papua, and South Sulawesi (BAPPENAS, 2010b). The average sea surface temperature in Indonesia is projected to increase by as much as 0.6°C–0.7°C in 2030 and by 1.0°C–1.2°C in 2050 (BAPPENAS, 2010b). One of the immediate impacts of sea surface temperature rise is the depletion and movement of fishing stocks away from Indonesian waters.

Sea level rise is estimated to occur at an average of 0.6 centimeters (cm)/year to 0.8 cm/year, with the highest increase of 2.5 cm/year (BAPPENAS, 2010a). The spatial pattern of sea level rise shows the highest occurrence north of Banda Sea, the Indian Ocean, Java Sea, Papua Island, and the seas of east Indonesia.

The National Council of Climate Change (2009) reported that in the West Java Province, there has been a declining trend in harvested paddy rice since 2001 due to land conversion from agricultural to non-agricultural uses. Previous analysis on vulnerability shows Bali, Java, and North Sumatera with high vulnerability indices compared to other parts of Indonesia due mainly to problems with water availability (Yusuf and Francisco, 2009). The Bali-Java regions are already experiencing deficit in water balance.

Past studies on increased risk of flooding show that almost all of Indonesia is vulnerable to flood hazards. According to the *National Atlas of Flooding Index of Indonesia*, Bali-Java and Sumatra have the largest vulnerable areas (Indonesian National Board for Disaster Management, 2009). Extreme risk of flooding is projected particularly in the downstream areas of Eastern Sumatra and Java; most parts of Eastern, Southern, and Western Kalimantan, Southern Papua, and Eastern Sulawesi (BAPPENAS, 2012).

Drought has also become an increasingly frequent phenomenon during the dry season. The projected hazard intensity of drought tends to increase from 2010–2015 to 2025–2030 (BAPPENAS, 2010a). Drought risk is significant in the Bali-Java region, most areas in northern Sumatera, and parts of Nusa Tenggara and South Sulawesi.

In response, the Government of Indonesia has made adaptation a critical national priority and an integral part of the challenges that is facing the nation. The government has prepared the *Indonesia Climate Change Sectoral Roadmap* (BAPPENAS, 2010c) in anticipation of the challenge from climate change. The roadmap covers 2010–2029 and sets national goals, sectoral targets, milestones, and priorities for action on climate change adaptation and mitigation covering all affected sectors of the economy. This roadmap can be used to supplement information on actions appropriate for BIMP-EAGA. In addition to the sectoral roadmap, some of the studies that have been conducted by the various agencies, ministries, and universities in Indonesia are listed in Appendix 7.

Climate Change Studies on Malaysia

The federal territory of Labuan and the states of Sabah and Sarawak in Malaysia, which form part of BIMP-EAGA, have vulnerable coastlines facing the South China Sea and the Sulu-Sulawesi/Celebes Seas. Many places within the BIMP-EAGA subregion are the remaining repository of the earth's biodiversity, the most outstanding of which are the Sulu-Sulawesi Marine Ecoregion (SSME) and the Heart of Borneo. The subregion is also in the apex the Coral Triangle covering 6.4 million square kilometers (km^2) and holds 75% of all species of the corals known to science.

The results of a scoping study presented at the Malaysia Second National Communication to the United Nations Framework Convention on Climate Change

(UNFCCC) (2011) indicated moderate increase in average temperature by 1°C–2°C that would benefit some in the agricultural sector but would be detrimental to most produce, such as rice production, which is projected to decline by 4.6%–6.1% at 1°C temperature change and by 9.6%–10% at 2°C temperature change (Siwar et al., 2009). Climate variation of this magnitude is likely to exceed environmental thresholds in which habitats and ecosystems would be able to recover, resulting in significant losses in biodiversity. Typhoons frequently develop over the western Pacific and move westward across the Philippines from April to November. During this period, southwesterly winds over the north western coast of Sabah and Sarawak can strengthen by 20 knots or more (Ministry of Science, Technology and Innovation, 2009a).

Sustainable fisheries for local consumption and live reef fish export contribute significantly to the economy of Malaysia. The potential economic contribution of Malaysia's coral reefs is $23,000–$271,000/year based total economic value (Maritime Institute Malaysia, 2006). Ocean acidification due to climate change could result in coral communities that can no longer produce calcium carbonate at rates that are sufficient to maintain coral reef structures. Coordinated reduction in carbon emissions and other factors will be required for coral reefs to maintain its current state. Malaysia can strengthen its reef ecosystems by reducing other stressors to the maximum extent possible (Ministry of Science, Technology and Innovation, 2009b).

Malaysia has developed climate change adaptation strategies for coastal and marine habitats (UNFCCC, 2011). Many of the proposed adaptation responses include improved ecosystem management, water resource management, and securing agricultural production. These efforts focus on assessments for resource efficiency and optimization of economic benefits (United Nations Environment Program, 2011). Various actions on climate change that are reflected in the National Plan of Action for the Coral Triangle Initiative on Coral Reefs, Fisheries, and Food Security, including the SSME, are ongoing or have been completed (Ministry of Science, Technology and Innovation, 2009b; ADB, 2014). However, given the magnitude of the climate change challenge, more adaptation efforts are needed.

Climate Change Studies on the Philippines

The Philippines' Second National Communication on Climate Change to the UNFCCC in 2014, stated that projections on monthly mean temperature and rainfall pattern for Surigao del Norte in Mindanao showed a shift to warmer temperature and increasing rainfall from the current situation to the mid century (2050). Coastal inundation due to a 1-meter rise in sea level will result in total land loss of 142.7 million square meters. Projections on the future impacts of climate change on agricultural productivity showed a 5% probability for rice production to exceed the minimum yield of 1.75 metric tons/ha during normal years with a 5%–7% probability of exceeding the minimum yield of 1.25 metric tons/ha during El Niño and La Niña years, respectively. In the forestry and watershed sectors, the top five provinces with highly vulnerable forestry projects are in Mindanao.

The Climate Change Commission has several projects on vulnerability assessments as bases for adaptation and mitigation measures in Mindanao and Palawan. These include the following: (i) Climate Twin Phoenix in the Mindanao cities of Cagayan de Oro and Iligan and the municipalities of Baganga, Boston, and Cateel in Davao Oriental; and New Bataan in Compostela Valley; (ii) Eco-town projects in San Vicente in Palawan and four towns in the Siargao province; (iii) Mainstreaming Climate and Disaster Risks in the Comprehensive Land Use Plan, together with the Housing and Land Use Regulatory Board.

In terms of climate projections and geohazard mapping, the Philippine Atmospheric, Geophysical and Astronomical Services Administration has climate profiles and projections for Palawan and 10 Mindanao cities/provinces. Its analysis of rainfall and tropical cyclones in the the Autonomous Region in Muslim Mindanao, Northern Mindanao, SOCSARGEN region (South Cotabato, Cotabato, Sultan Kudarat, Sarangani, and General Santos City), and Zamboanga indicate that these areas can be developed as food baskets because they are seldom hit by tropical cyclones.[5]

The Mines and Geosciences Bureau (MGB) has produced geohazard maps with a scale of 1:50,000 covering 1,634 cities and municipalities.[6] MGB conducted more detailed geohazard mapping with a scale of 1:10,000 and has completed ground surveys covering 1,147 local government units as of June 2014 (MGB, 2014). Similarly, the National Mapping and Resource Information Authority produced elevation maps, land cover and/or planimetric maps, land cover and/or slope and/or soil and/or geologic maps, land use and/or land condition maps, topographic maps, and maps on areas exposed to risks due to floods, ground shaking, and severe wind.

Climate Change Adaptation: Best Practices in the Philippines (2012) contains 100 case studies, including Puerto Princesa in Palawan, Siargao in Surigao del Norte and the province of Zamboanga del Norte in Mindanao.

The Commission on Population study, *Population and Climate Change* (2012), showed the relationship between population (i.e., size, growth rate, density, and percentage urban population), human well-being (i.e., HDI, human poverty index, rankings on flood susceptibility and landslide susceptibility) and the EEPSEA's climate change vulnerability assessments of the 40 most vulnerable provinces in the Philippines. The list includes the Mindanao provinces of Bukidnon, Compostela Valley, Davao del Norte, Davao Oriental, Maguindanao, North Cotabato, and Sultan Kudarat.

The *Philippine Human Development Report 2012/2013: Geography and Human Development* contains the HDI and poverty incidence, depth, and severity incidence for each of the 76 provinces in the country from 1997 to 2009, including maps showing local spatial data on HDIs, agro-ecological zones, climate types, level of urbanization across provinces, and poor or lagging places and local spatial dependence in income growth.[7]

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5 Government of the Philippines, Philippine Atmospheric, Geophysical and Astronomical Services Administration. 2011. *Climate Change in the Philippines*. Manila. Retreived from http://pagasa.dost.gov.ph/index.php/climate-agromet/climate-change-in-the-philippines.

6 See www.mgb.gov.ph.

7 Human Development Network. 2012. *Philippine Human Development Report 2012/2013: Geography and Human Development*. Manila. Retrieved from http://hdn.org.ph/20122013-philippine-human-development-report/.

The project on Integrating Disaster Risk Reduction and Climate Change Adaptation in Local Development Planning and Decision-making Processes[8] has assisted several local government units in identifying and mapping hazards as well as vulnerable population and agricultural areas. To date, 80 provinces are being assisted in the preparation of their provincial hazard profiles (with hazard maps) as input in mainstreaming climate change adaptation and disaster risk reduction into their respective provincial development and physical framework plans. Surigao City was chosen as a pilot area for mainstreaming climate change adaptation/disaster risk reduction in its comprehensive land use plan. Provinces in Mindanao that are covered by the project include Agusan del Norte, Agusan del Sur, Bukidnon, Camiguin, Compostela Valley, Davao Oriental, Sarangani, South Cotabato, Surigao del Norte, and Surigao del Sur, Zamboanga del Norte, Zamboanga del Sur, and Zamboanga Sibugay.

In terms of water supply and availability, the Davao river basin in Mindanao has water availability of only 2,368 cubic meters per capita, less than Asia's average of 3,558 cubic meters per person (World Bank, 2003). Increasing water demand has resulted in a number of regions and at least 9 key urban centers experiencing water stress, including Cagayan de Oro, Davao, and Zamboanga.

The 2014 study by the World Wildlife Fund for Nature and the Bank of the Philippine Islands on *Business Risk Assessment and the Management of Climate Change Impacts* covered 16 major Philippine cities, including Butuan, Cagayan de Oro, Davao, General Santos, Zamboanga in Mindanao; and Puerto Princesa in Palawan. It used 3 vector analysis on (i) climate and/or environmental exposure utilizing the same parameters as the WWF-Australia (2009) study,[9](ii) socio-economic sensitivity, and (iii) adaptive capacity or the city's ability to implement adaptation strategies. The data covered a 20-year period from 1990–2010. The cities rated themselves above average scores for adaptive capacity.

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[8] Joint project of the Government of the Philippines, National Economic and Development Authority, UNDP, the Australian Agency for International Development, and the New Zealand Agency for International Development.

[9] Hoegh-Guldberg, O. *et al*. 2009. *The Coral Triangle and Climate Change: Ecosystems, People and Societies at Risk*. Brisbane: WWF-Australia.

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Appendix 3 Climate Change Modeling and Downscaling

For purposes of this study's rapid vulnerability assessment, there was need for a readily accessible database on climate change projections for the Brunei Darussalam-Indonesia-Malaysia-Philippines East ASEAN Growth Area subregion. The study used data from World Bank's Climate Research Program,[10] in particular the climate analysis tool or "Climate Wizard". This climate database is provided in a web portal that enables users to access climate change information for any location. Projections are based on the results from 9 global climate models that were run under 3 scenarios corresponding to low, moderate, and high greenhouse gas (GHG) emissions. These scenarios are described in the Intergovernmental Panel on Climate Change (IPCC) *Special Report: Emission* Scenarios (SRES) (2000). They reflect socio-economic development pathways and are used to explore uncertainties behind trends in global socio-economic development that serve as key drivers of future GHG emissions. Projections are statistically downscaled to a spatial resolution of 0.5° or approximately 50 x 50 kilometers (km). Data for 3 time periods are available: historical reference (1961–1990), mid century (2046–2065), and end-century (2081–2100).

Climate models in the IPCC *Fifth Assessment Report* (2013) were re-run based on a new set of scenarios to generate projections that more directly reflect global policy choices for mitigating GHG emissions. The new scenarios are called "representative concentration pathways" (RCPs) and are identified by their total radiative forcing, measured in watts per square meter (W/m^2), in year 2100 relative to 1750. They describe the degree in which GHG emissions are actively mitigated, stabilized, or increased. Table 3A-1 shows the new scenarios and the corresponding radiative forcing, carbon dioxide concentration, and representative climate policy.

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10 The World Climate Research Program develops global climate projections through its Coupled Model Intercomparison Project roughly every 5–7 years. These projections are used by the IPCC to prepare periodic assessment reports. Scenarios of climate-related risk events are taken from the outputs of global climate change models (GCMs). These scenarios are images of alternative futures that are neither predictions nor forecasts. Rather, each scenario is an alternative picture of how the future may unfold, specifically in terms of GHG that drive global warming, and consequently climate change.

Figure 3A-1 Scenarios Used in the IPCC *Fifth Assessment Report* (2013)

RCP Scenario	Radiative Forcing (W/m^2)	CO_2 Concentration by Year 2100	Representative Climate Policy
RCP 2.6	2.6	421	Mitigation
RCP 4.5	4.5	538	Stabilization
RCP 6.0	6.0	670	Stabilization
RCP 8.5	8.0	936	Business as usual

CO_2 = carbon dioxide, m^2 = square meter, RCP = representative concentration pathway, W = watts.

Note: Based on projected CO_2 concentrations, RCP 2.6 roughly corresponds to SRES B1, RCP 4.5 and RCP 6.0 roughly corresponds to SRES A1B, and RCP 8.5 to SRES A2.

Source: IPCC (2013).

The table above shows the following:

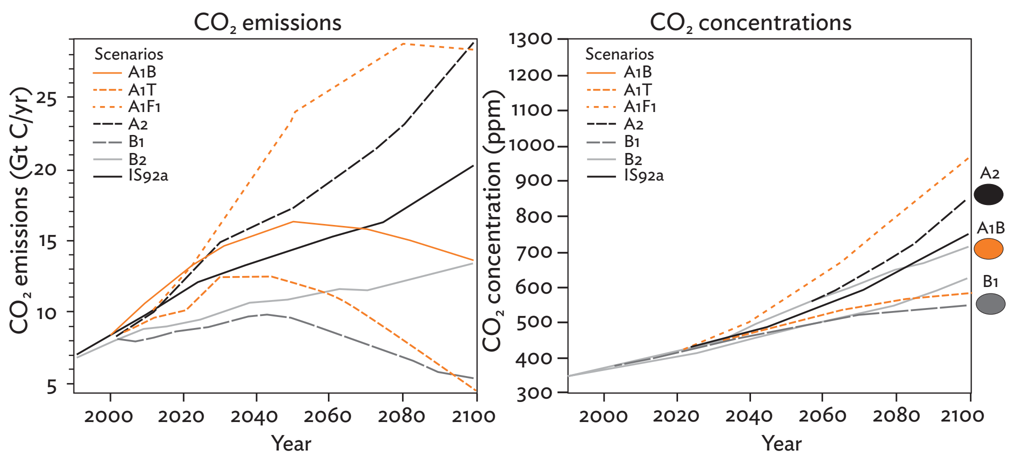
- **RCP 2.6.** Representative of scenarios in the literature leading to very low GHG concentration levels. It is a so-called "peak" scenario with radiative forcing level that first reaches a value around 3.1 W/m^2 by mid century and then returning to 2.6 W/m^2 in 2100. This scenario implies that GHG emissions (and indirectly emissions of air pollutants) are reduced substantially over time.
- **RCP 4.5.** Stabilization scenario where total radiative forcing is stabilized before 2100 through a range of technology and strategies for reducing GHG emissions.
- **RCP 6.0.** Another stabilization scenario where total radiative forcing is stabilized after 2100 without overshoot through a range of technology and strategies for reducing GHG emissions.
- **RCP 8.5.** Characterized by increasing GHG emissions over time that is representative for "business as usual" scenarios in the literature leading to high GHG concentration levels.

The correspondence between the SRES scenarios that were used in the IPCC *Fourth Assessment Report* (2007) and the RCP scenarios that were used in the latest IPCC *Fifth Assessment Report* (2013) is shown in Figure 3A-1 and Table 3A-1.

Processed information (specifically downscaled data) on multi-model ensemble projections on climate change that are based on the latest RCP scenarios is not yet readily available. For purposes of the present study, and specifically for the purpose of examining uncertainty in future climate conditions, the study used climate projections that are based on the SRES socio-economic development pathway scenarios.

Coupled Atmosphere-Ocean General Circulation Models are main tools that are used in projecting climate change. They simulate the interaction of the atmosphere, oceans, land surface, and ice using scenarios. Climate models balance incoming energy with outgoing energy from the earth. Energy imbalance results in a change in the average temperature of the earth. Climate change analysis is complex because there many climate projections from different models that run with a range of emissions scenarios. It is important to use

Figure 3A-1 **Scenarios Used in the IPCC *Fourth Assessment Report* (2007)**



- **A2 (pessimistic)** very heterogeneous world; continuously increasing populations; economic development is primarily regionally oriented and technological change is more fragmented.
- **A1B (median)** technological change in the global energy system is *balanced* across all sources, i.e., not too heavily dependent on one particular energy source.
- **B1 (optimistic)** convergent world with rapid change toward service and information-oriented economies, reductions in resource-use intensity, and introduction of clean technologies.

C = carbon, CO_2 = carbon dioxide, Gt = gigaton, ppm = parts per million.

Source: IPCC (2007).

ensemble analysis that combines results from multiple climate change models (GCMs) and to quantify the range of possibilities for future climate (i.e., assess uncertainty).

Models are typically run with spatial resolutions of 250 km–600 km. Increasingly powerful computing resources has enabled a new generation of GCMs to generate high-resolution outputs. However, the outputs from most of the existing GCMs are still too coarse for meaningful use in impact assessments at the national and subnational levels. Information at a fine-scale resolution is necessary for realistic assessment of climate change impacts (as basis for adaptation planning). Downscaling or regionalization techniques allow spatial refinement of existing global climate models. These techniques add fine-scale information to a parent GCM large-scale projection and in doing so can resolve features to a scale of 50 km or less. Downscaling enables more precise representation of local geographic features (e.g., mountain topographies, river basins, and complex deltas and coastlines). Hence, projections are more useful for planning national and basin-scale adaptation responses.

There are 2 methods for downscaling future climate projections to generate higher resolution projections: dynamical downscaling (also referred to as "regional climate modelling") and statistical downscaling (or "empirical" modelling). In dynamical downscaling, a regional climate model is run using a nested modelling approach for a predefined region in which the boundary conditions are generated or "driven" by a parent GCM. Since this method of downscaling is based on physical laws (rather than statistical properties of historical climate), it has the advantage of being able to produce a full suite of different output variables. However, the disadvantage is that it is computationally very demanding and errors (biases) from the driving GCM are preserved or propagated in the downscaling process.

Statistical downscaling uses empirical statistical methods. It is not as computationally demanding as dynamical downscaling because it is not based on physical laws. It can be applied to a large set or ensemble of GCM simulations, enabling the quantification of consensus which can serve as basis for assigning confidence on projections. It can also be used for assessing climate change at specific locations (e.g., a river basin). Equally important, this method of downscaling enables the correction of biases or errors in the parent GCM. Future climate projections can be modified to better match the statistical properties of the observed local climate conditions, a process known as bias correction.

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Appendix 4
Indicators for Vulnerability Risk Mapping

Risk index maps that were utilized in the vulnerability assessment were obtained from Maplecroft's risk analysis web portal that was accessed by the study team in October 2014 through the Asian Development Bank's account. The portal provides a quantitative assessment of the vulnerability of human population to extreme climate-related events and changes in major climate parameters over the next 30 years. The vulnerability index combines the risk of exposure to climate change and extreme events with the current human sensitivity to that exposure and the capacity of a country to adapt to the potential impacts of climate change.

The indices are presented (and color-coded) on a scale of 0–10, where values closer to 0 represent higher risk and values closer to 10 denote lower risk. Index values are divided into the following risk categories to aid in interpretation: extreme risk (0–2.5), high risk (>2.5–5), medium risk (>5–7.5), and low risk (>7.5–10). Countries are also assigned a rank based on their relative position in the index, where a ranking of 1 represents the highest risk.

The risk indices are made up of several sub-indices which in themselves constitute a discrete risk index. The component sub-indices and weights that were used to derive the vulnerability index are as follows:

- **Exposure index (50%).** Captures the level of potential exposure to extreme climate- related events (e.g., cyclone, drought, flooding, landslide, sea level rise, severe local storm, storm surge, and wildfire) and predicted change to baseline climate parameters (e.g., air temperature, precipitation, and specific humidity).
- **Sensitivity index (25%).** Measures the current human sensitivity to exposure, evaluating economic resources, general health and accessibility of health services, access to knowledge, population pressure, infrastructure, conflict, natural resource pressure, and agricultural dependency
- **Adaptive capacity index (25%).** Measures the ability or potential of a country's economy, institutions, and society to adjust to or to take advantage of existing or anticipated stresses resulting from climatic change.

Exposure Index

The exposure index evaluates the risk of a region that is impacted by extreme climate-related events and the risk posed by the projected changes in baseline climate parameters. While the exposure index is unable to predict the exact location of future extreme events, the user is able to identify broad patterns of potential changes, along with hotspots of extreme events by combining future climate model data with information on past extreme events.

The index map provides a quantitative assessment of the potential for a region to be exposed to future climate change and climate-related extreme events. Indicators and weightings are shown below.

Predicted Climate Change Parameters (30%)

Future climate projections based on representative concentration projection 4.5 (RCP4.5) are taken from the IPCC *Fifth Assessment Report* (2013) to produce the climate change indicators. Data for each indicator were reclassified into 10 risk classes (1–10) based on natural breaks in the data.

- **Predicted change in precipitation (6.67%).** Predicted change in mean annual precipitation (positive or negative) over a 25-year period from 2015 to 2039 relative to the 1980–2005 baseline. Data are generated by the HadGEM2-ES model using RCP 4.5. Changes in precipitation levels can have significant direct impacts on the environment (e.g., extinction, species range shifts), human health (e.g., impacts of extreme events, such as flooding or drought; altered distribution of water-borne disease vectors); and food and commodity supply, with consequential indirect impacts on societies and economies across the globe.
- **Predicted change in air temperature (6.67%).** Predicted change in mean temperature (positive or negative) over a 25-year period from 2015 to 2039 relative to the 1980–2005 baseline. Data are generated by the HadGEM2-ES model using RCP 4.5. Changes in air temperature can have significant direct impacts on the commodity and food supply (e.g., altered crop productivity); the environment (e.g., altered flowering seasons, extinction, species range shifts); human health (e.g. changes in the range and transmission potential of diseases, such as malaria; decreased air quality; heat-stress); and sea level, with consequential indirect impacts on societies and economies across the globe.
- **Predicted change in specific humidity (6.67%).** Predicted change in mean specific humidity (positive or negative) over a 25-year period from 2015 to 2039 relative to the 1980–2005 baseline. Data are generated by the HadGEM2-ES model using RCP 4.5. Changes in humidity levels can have significant impacts on human health. High humidity inhibits evaporation, making cooling by perspiration less effective, leading to higher heat stress and potential mortality. Low humidity levels can also cause heat stress because dryness can enhance the effect of air pollution.
- **Susceptibility to sea level rise (10%).** The risk of coastal inundation due to sea level rise is calculated from a digital elevation model (GTOP030) with relative risk decreasing with increasing height above sea level (up to a maximum of 10 meters).

Climate-related extreme events (70%)

- **Flood risk (10%).** Derived from data on estimates of flood frequency based on 3 sources: observed flood events from 1999 to 2007; statistical estimation of peak-flow magnitude combined with a hydrological model to estimate river stage for the calculated discharge value; the frequency was set using the United Nations Environment Program (UNEP)-Global Resource Information Database (Europe) Preview flood dataset, where information is not available. It was set to an annual rate of 0.02 (i.e., on average one such flood occurrence every 50 years).

- **Drought risk (10%).** Two data sets were utilized to capture the varying hazards associated with different drought time scales due to the complexity in assessing the potential risk related to meteorological drought. Both data sets were calculated using the standardized precipitation index (SPI) which measures the difference between the observed value and a historical mean, but differ in the moving time interval in which their calculations are based. A 3-month SPI data set was selected to identify the risk of deficient rainfall over a time period that is likely to cause a significant reduction in crop yield, whereas a 6-month data set provides a better indication of the probable impact on available groundwater. The data sets used are: drought frequency measurement based on the SPI of a moving 6-month interval (1951–2004) at 0.5° resolution and drought frequency measurement based on the SPI for a moving 3-month interval (1980–2000) at 2.5° resolution.
- **Tropical storm and cyclone risk (10%).** Tropical storm and cyclone risk is calculated using information on the frequency and intensity of cyclones. Intensity is measured based on five categories of cyclone on the *Saffir-Simpson* intensity scale with a further category for sub-cyclone level storms. The data set is based on observations of cyclone events from 1975 to 2007 and includes:
    - **Cyclones.** A compilation of best track data from the World Meteorological Organization and Tropical Cyclone Warning Centers and was modelled to take into consideration the movement of cyclones over time, resulting in an expected frequency for each category of cyclone.
    - **Storms.** Sub-cyclone level sections of cyclone tracks were isolated and buffered by a 50-kilometer radius to approximate the spatial extent of each storm. A frequency score was then obtained by summing the cumulative exposure at 1° resolution.
- **Precipitation-related landslide risk (10%).** Information is derived from data on global landslide and snow avalanche hazards that were compiled by the Norwegian Geotechnical Institute. The institute classifies each grid cell according to relative landslide risk utilizing data on elevation, precipitation, seismicity, slope, soil, soil moisture, and temperature.
- **Severe storm risk (10%).** Information is derived from the annual flash rate of lightning per unit area as a proxy for the associated severe storm risks. It is based on satellite observations from the Global Hydrology Resource Center, National Aeronautics and Space Administration.
- **Wildfire risk (10%).** This assesses the risks posed by wildfires using information on the frequency of wildfires based on a modified product of the World Fire Atlas dataset from UNEP.
- **Storm surge risk (10%).** Derived from UNEP-Global Resource Information Database data on the frequency and intensity of cyclones as well as the likely penetration of surges inland.

Sensitivity Index

The sensitivity index examines the current relative human sensitivity to exposure to extreme climate-related events and predicted climate change. Sensitivity is a measure of the population's susceptibility to the impacts of climate change, which is a function of their existing livelihood, physical, and social circumstances. The index examines aspects of sensitivity related to agriculture, conflict, health, infrastructure, knowledge, population, poverty, and resource pressure by utilizing a combination of subnational and national data. The map provides a quantitative assessment of the relative human sensitivity to exposure to future climate change and climate-related extreme events. The index is comprised of 21 key indicators, which collectively form eight subcategories. Indicators and weightings are detailed below.

Economic resources (15.4%)

While wealth does not ensure protection against climate events, poorer communities are more likely to be affected by exposure to climate change. This is because in many areas they are more likely to inhabit in marginal and exposed lands, they lack the ability to mitigate and recover from the impacts of exposure to climate-related events, and they have insecure or climate sensitive employment conditions that make them very susceptible to both long- and short-term impacts of climate change. Given that wealth tends be unevenly distributed within a country, the first indicator below is designed to capture subnational poverty. Where data was missing for one of the layers, the other indicator carried the appropriate combined weighting.

- **Poverty density index, 2013 (12.3%).** This is a subnational index that estimates the number of people living in poverty. This index divides population count by the brightness of satellite-observed lights with the assumption that areas with high population and relatively low light levels indicate an area of poverty. This in comparison with an area with low population and high light levels that indicates wealth. These poverty estimates were then calibrated using infant mortality data which is a widely adopted proxy for poverty. The resulting subnational map reflects the density of people living in poverty across the globe.
- **Livelihood assets index, 2013 (3.1%).** This index measures where the activities, assets, and capabilities by which households can sustain their immediate and long-term survival are at greatest risk, hence, where livelihoods are most vulnerable to external factors. External factors, such as extreme weather events are elements that could affect the livelihoods of a country's population, thereby, reducing the adaptive capacity of individuals, households, and communities.

General Health and Accessibility of Health Services (15.4%)

People that are in poor health or are undernourished are less likely to have good access to sufficient healthcare and will be more sensitive to the direct and indirect effects of short- and long-term climate change impacts. This is due to their vulnerability to both physical injury and increased sensitivity to more complex impacts (e.g., water or food shortage), increasingly frequent heat waves and epidemics. In addition, populations with poor access to health services are unlikely to be able to access assistance in times of heightened crisis.

The following indicators have been selected as proxies for assessing the overall health of the populace as well as the ability to access basic healthcare.

- **Maternal mortality rate, 2010 (5.1%).** This indicator measures maternal mortality per 100,000 live births.
- **Children under 5 that are underweight, latest 1999–2011 (5.1%).** Prevalence of child malnutrition is the percentage of children under age 5 whose weight for the age is more than two standard deviations below the median for the international reference population ages 0–59 months. The national level data are based on the World Health Organization's child growth standards in 2006 and the subnational level data are from the Centre for International Earth Science Information Network at the Columbia University.
- **Prevalence of undernourishment in total population, average 2010–2012 (5.1%).** This indicator describes the proportion of undernourished in the total population. Where data was missing for one of these malnourishment indicators (children underweight and undernourishment in total population), extant data carried the combined weight (10.3%).

Access to basic knowledge and information (7.7%)

Basic literacy can be critical in the ability to access information and forecast data on the effects of climate change and available adaptation measures. Lack of education can also be connected to disenfranchisement, increased dependency on climate sensitive economic activities (e.g., agriculture), and marginalization. The following indicators are included to assess literacy levels in the entire population. Where data was missing for one of these indicators, extant data carried the combined weight (7.7%).

- **Primary enrolment ratio, latest 2000–2011 (3.9%).** This is the countrywide net primary school enrolment rate.
- **Adult literacy rate, latest 2000–2011 (3.9%).** This indicator is defined as the countrywide adult literacy rate for persons aged 15 and above.

Population pressure (15.4%)

High population density may lead to the location of livelihoods and settlements in exposed, hazard prone areas, and may create greater stress on infrastructure and services. In addition to concentrating casualty risks, there is also an increased risk of disease outbreak in the wake of a disaster event. Rapidly increasing population density can add burden on infrastructure and natural resources and exacerbate existing risks that are present in the environment. The rate of population change can also provide an indication on which regions are likely to experience rapid increase in pressure in the short- and long-term.

- **Population density, 2011 (10.3%).** These data are 2011 estimates for population density. This subnational data was based on the *Landscan* 2011 Global Population Project.
- **Rate of population change, 1990–2015 (5.1%).** This indicator is the rate of population change that is calculated from 1990 and estimated 2015 population density.

Infrastructure and accessibility (15.4%)

Ease of physical and communication access can be crucial in the build up to and aftermath of a disaster event and in the distribution of information to assist with adaptation to climate change (e.g., adaptation and knowledge strategies, community disaster risk reduction initiatives, health recommendations, and livelihoods). Baseline access to basic services also provides an indication of the country's ability to establish and maintain essential infrastructure.

Telephone landline data was used as an adjustment factor for mobile phone subscriptions due to the increasing tendency, especially in developing countries, to choose mobile over landline ownership rather than having both. Where data was available on estimated travel time but was missing for all other indicators, extant data carried the combined weight (15.4%).

- **Estimated travel time to nearest city, 2000 (5.1%).** This indicator details travel time over land or water to the nearest city of 50,000 or more people, estimated in 2000 by the Global Environment Monitoring Unit-Joint Research Centre of the European Commission.
- **Telephone lines and/or subscriptions per 100 population, 2012 (5.1%).** The number of mobile telephone subscriptions per 100 population in 2009 with the number of telephone landlines per 100 population was used as an adjustment factor where landline risks scored 'low'.
- **Access to water and sanitation index, 2014 (5.1%).** This index measures a country's relative accessibility to a clean water supply and improved sanitation.

Extraordinarily vulnerable populace (7.7%)

Vulnerable populations can emerge from a variety of drivers. Civil or international conflict often results in the displacement of populations, and implies that countries are less able to focus resources on climate change adaptation or disaster mitigation. Changes in the climate may increase the number of displaced persons, as water availability, species range shift and temperature variations may affect agriculture, fishing, and other marginal livelihoods, forcing people to move in search of more hospitable conditions.

Displacement increases the burden on services and infrastructure and results in the disruption of livelihoods and traditional coping mechanisms. As a group, elderly people are particularly vulnerable to climate extremes (e.g., extreme cold and heat waves). They are also potentially more vulnerable to natural hazard events as they may have less capacity to respond to warnings (e.g., evacuation notices) and prepare for impacts. Where data was missing for one of the indicators, extant data carried the combined weight (7.7%).

- **Conflict and political violence index, 2013 (2.6%).** This index assesses the relative risk of a country experiencing conflict or political violence.
- **Refugees, 2011–2013 (1.3%).** The number of refugees by country of asylum per 100,000 population.
- **Internally displaced persons, 2011 (1.3%).** The number of internally displaced persons within the country per 100,000 population.
- **Population density for persons over 65 years, 2011 (2.6%).** A subnational indicator of the population density of persons over 65 years of age within a country.

Natural resource pressure (15.4%)

Existing pressure on natural resources provides an indication of areas where as a response to short-term extreme climate events or longer-term climate change pressure is likely to intensify. Ecosystem stress and destruction can increase the physical vulnerability of populations and reduce the potential to exploit alternative food or water resources and livelihoods options. Where data was missing for one or more layer, extant data carried the appropriate combined weight (15.4%).

- **Water stress index, 2013 (4.6%).** This index evaluates total water use relative to renewable water supply. Water stress occurs when demand for water exceeds the available amount or when the quality of water restricts the usable quantity to below demand. Climate change threatens to increase the variability of water supply, shifting and intensifying the extremes, thereby, introducing greater uncertainty in water quantity and quality.
- **Human appropriation of net primary productivity, 1995 (4.6%).** The amount of carbon required to derive food and fiber products that are consumed by the population as a percentage of available net primary productivity.
- **Soil degradation, 1990 (1.5%).** The degree and extent to which the soil has been degraded and the consequential suitability of its use for agriculture.
- **Gross forest cover loss, 2000–2005 (4.6%).** A measure of the total forested cover lost from 2005 to 2010 at the subnational level as assessed by the Geographic Information Science Center of Excellence.

Dependence on agriculture (7.7%)

Populations that are principally engaged in agriculture for subsistence livelihood economy are at particular risk from climate-related events and predicted changes, especially from drought and flooding, since these livelihoods are extremely dependent on meteorological conditions.

- **Agricultural land use, 2005–2006 (7.7%).** This indicator describes the degree to which land is used for agricultural purposes. The land cover classification was derived from Globcover Land Cover product based on ENVISAT MERIS data at 300 meter resolution from January 2005 to June 2006.

Adaptive Capacity Index

The adaptive capacity index evaluates the ability or potential of a country’s institutions, economy, and society to adjust to or to take advantage of existing or anticipated stresses resulting from climatic change. The Intergovernmental Panel on Climate Change defines adaptive capacity as “the ability or potential of a system to respond successfully to climate variability and change.” The ability to cope with and adapt to a changing climate is becoming increasingly important in policymaking as more frequent and severe extreme weather events occur and the gradual changes from rising temperatures become apparent. The Intergovernmental Panel on Climate Change acknowledges that strengthening public health infrastructure is an essential part of adaptation and there are other identified factors that determine how well and how quickly a country’s economy, institutions, and society can adapt to a changing climate. Key factors that influence a country’s adaptive capacity are: strength of the economy, effectiveness and stability of government, level of knowledge transfer and communication to the populace, ability of a country to develop innovative technology or practices, available natural resources, and level of dependence on agriculture or other vulnerable activities to support the economy.

Adaptive capacity can be examined at the individual, community, or national level. The index used by Maplecroft focuses on macro level and structural factors (e.g., economy and governance) to avoid overlap with the community and individual focus of the sensitivity index. This delineation improves the utility of these two dimensions of vulnerability.

The adaptive capacity index has been designed to take account of the current environmental, institutional, political, societal, and technological outlook of each country. The index does not directly address vulnerability to climate change but the adaptive capacity conferred to a country by structures at the macro level. This includes the ability of a country to modify its exposure to risks and to absorb and recover from losses from climate change.

The indicators were selected to evaluate a country's performance in the key areas of economy, education and technology, health, institutions and governance, natural resource security, and reliance on a vulnerable economy. The indicators can be separated into several focus areas. The indicators and their relative weighting within the index are shown below:

Education and Innovation (19.99%)

- **Innovation Pillar, 2012–2013 (5.71%).** This indicator is the innovation pillar of the Global Competitiveness Index published by the World Economic Forum. It assesses the conduciveness of a country's business and educational environment to innovative activity that is supported by the private and public sectors.
- **Expenditure on research and development (R&D), 2006–2011, percentage of gross domestic product (GDP) (5.71%).** High level investment in R&D leads to high levels of technological innovation throughout a country and the ability of businesses to provide new technology and innovation to adapt to a changing operating environment and to move towards a low carbon economy.
- **Gross completion rate, first degree, 2000–2012 (8.57%).** This assesses the rate of completion of tertiary level education. It is a good indicator of the availability of highly skilled workforce in the future which has implications on the economic future of a country as well as its innovation and R&D capabilities.

Strength of Institutions (22.85%)

- **Regime stability index, 2013 (5.71%).** A stable government is vital to the implementation of policies to improve or adapt current systems. Countries with stable government systems will have the ability to develop and to put in place policies and activities that improve on a country's adaptive capacity.
- **Government effectiveness index, 2013 (11.43%).** The effectiveness of a government determines how well policies are rooted, enforced, and the level of compliance with mandates of the government. An effective and stable government are vital for effecting long-term changes to the civic infrastructure or practices within a country.

- **Corruption risk index, 2013 (5.71%).** Adaptation is likely to be influenced by the levels of corruption within a country as this is likely to be linked with the effectiveness of the government and the possibility that financial and technological transfer could be diverted by fraudulent or illegal practices. Countries where corruption is rife are less likely to be able to implement adaptation measures from a financial and governance perspective.

Public Awareness (2.86%)

- **Knowledge on climate change, 2010 (2.86%).** Higher awareness of climate change and its possible impacts on a population can lead to increased pressure on government to enable adaptive policy changes and improve on the uptake of low carbon technology and other adaptation strategies in a country.

Availability of Resources (17.13%)

- **Energy security (short-term) risk index, 2014 (5.71%).** Countries with high energy security are better equipped to recover from external shocks and to cope with the gradual global temperature changes and its resultant impacts. The affordability of power, the extent to which a country depends on energy imports, and the quality of infrastructure all contribute to the sensitivity of supply and reflect the efficacy of energy administration.
- **Water security index, 2014 (5.71%).** Sustainable water resource management is a key issue facing governments as a consequence of climate change. As the severity of droughts in already drought prone regions increases and precipitation becomes less predictable, many countries are likely to experience increased competition between agricultural, commercial, and domestic water users. This index assesses the availability of freshwater supplies, the sustainability of water use, the accessibility of water of sufficient quantity and quality, and the efficacy of the regulatory system.
- **Food security index, 2013 (5.71%).** Food secure countries are less susceptible to external production shocks that may become more likely with changing climatic conditions. Countries with higher food security are less reliant on imported food and have more control on the vulnerability of their food sources to climate change impacts.

Reliance on a Vulnerable Economy (8.57%)

- **Agriculture, value added as a percentage of GDP, 2003–2011 (8.57%).** Severe weather events, droughts, and temperature changes are all likely to have significant impacts on the agricultural productivity of a country. Countries that rely heavily on agriculture are most at risk of the effects of climate change and will find adapting to changing climatic conditions most difficult.

Existing finances and burdens (20%)

- **GDP per capita (constant purchasing power parity), 2007–2011 (11.43%).** The current economic strength and available financial resources are key factors in determining a country's adaptation policies and capacity to develop and implement adaptive measures.
- **External debt as a percentage of GDP, 2010–2011 (2.86%).** This gives a measure of the debt or financial burden of a country as a percentage of its GDP. High level

of debt may limit the resources of a country that are available for funding adaptive capacity measures.

- **Net official development assistance received per capita, 2011 (5.71%).** This represents a country's reliance on aid to support its people. Countries that are not self-sufficient have higher dependence on external resources and will have more difficulty in adapting to climate change without aid from more developed countries. This will be particularly problematic if aid is reduced or withdrawn by donors.

Healthcare Governance (8.57%)

- **Life expectancy, 2012 (8.57%).** Life expectancy is an indication of the general health status of a country and the condition of healthcare provision. Changes in humidity, precipitation, and temperature levels as a result of climate change have health implications on human population and countries. Government with limited ability in delivering adequate healthcare will face the greatest challenge in addressing these impacts.

Reference

Intergovernmental Panel on Climate Change. 2013. *Fifth Assessment Report: Climate Change 2013, The Physical Science Basis* (Contribution of Working Group I *to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*). Retrieved from http://www.ipcc.ch/report/ar5/wg1/.

Appendix 5
Vulnerability Index Mapping

Objective

The vulnerability index mapping that was carried out in the study aims to validate and supplement results that were derived from Maplecroft's climate change risk assessment (Appendix 4). This index mapping has limitations in that it uses fewer indicators compared to Maplecroft. Nevertheless, it is based on a reliable climate change projections database that was obtained from the World Bank climate portal, which was in turn generated from an ensemble of downscaled global climate models as described in Appendix 3. A comparison of the findings from the Maplecroft risk assessment and this study is discussed in this appendix.

In both GIS applications (i.e., Maplecroft and this validation work), the objective is to identify specific regions of the Brunei Darussalam-Indonesia-Malaysia-Philippines East ASEAN Growth Area (BIMP-EAGA) that are most vulnerable to climate change. The resulting maps in this study and the Maplecroft risk maps may be later superimposed on areas of importance to BIMP-EAGA activities as identified in the country level assessments (Appendixes 6–8) and may then be used to identify priority areas for the subregion's decision-makers.

The specific objectives and tasks of this undertaking is to identify and collect data on climate change exposure, sensitivity, and adaptive capacity indicators within BIMP-EAGA and conduct geospatial data analysis to identify hotspots by combining information on vulnerability dimensions (i.e., exposure, sensitivity, and adaptive capacity).

BIMP-EAGA Vulnerability Index Mapping

Relevant climate variables for mid century projections are downloaded from the World Bank Climate Change Data Portal for A1B (in-between pessimistic and optimistic) scenario data sets (in grid/raster format) that are used as exposure indicators. Each grid cell measures 0.5 x 0.5 decimal degree or approximately 50 kilometers (km) x 50 km.

To make the climate variables comparable, the data sets are normalized using the formula:

$$Z_{i,j} = \frac{X_{i,j} - X_{i\ MIN}}{X_{i\ MAX} - X_{i\ MIN}}$$

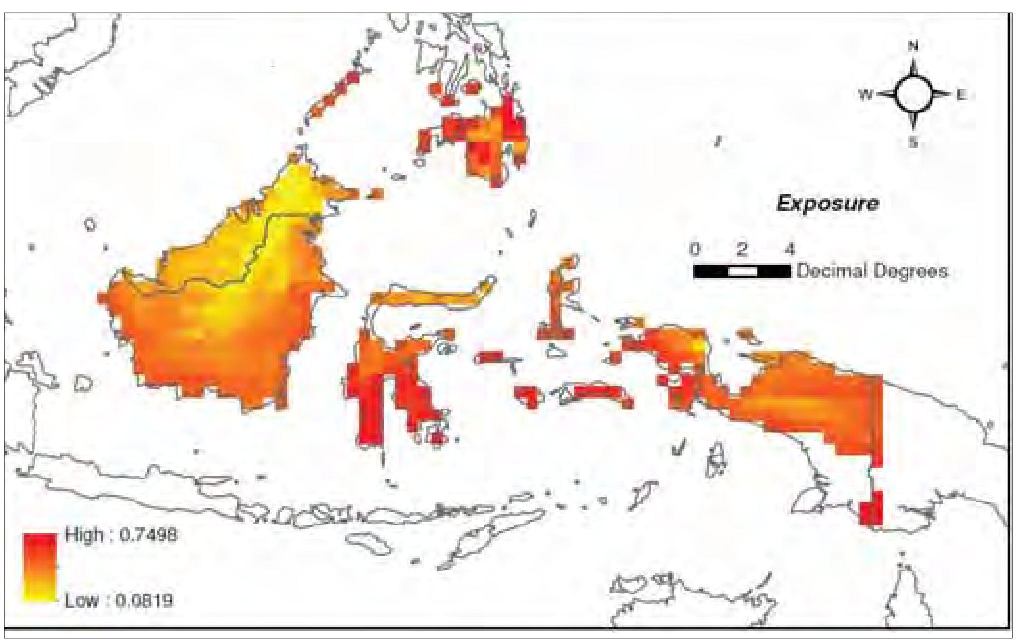
where, Zi, j is the standardized climate variable of type i of region j; $X_{i,j}$ is the unstandardized climate variable of type i of region j; $X_{i\,MAX}$ is the maximum value of the climate variable indicator over region j, and $X_{i\,MIN}$ is the minimum value of the climate variable indicator over region j.

Normalization is done on 8 selected climate variables as follows: average high temperature, consecutive dry days, 5-day rainfall, heat wave duration index, hot days temperature, hottest temperature, number of dry day periods, and wet day rainfall. In the normalization of these exposure variables, the higher the raw value, the higher is the index value (ranging from 0 to 1 after normalization) which also means higher vulnerability threat.

After all the climate variables for exposure vulnerability factor are normalized, the multivariable exposure index map is generated by assuming equal weights (12.5%) or equal degree of importance for all of the variables in each grid cell. This can also be done by obtaining the average normalized variables for each grid cell.

Figure A5-1 shows the multivariable exposure index map. It is a combination of projected climate variables that cause climate-related hazards and hotspot areas in BIMP-EAGA. From the generated exposure index map, hotspot areas include the southern portions of Sulawesi and western portions of Papua in Indonesia, and the eastern and western portions of Mindanao in the Philippines. The lowest index is 0.08 while highest index is 0.75.

Figure A5-1 Multivariable Exposure Index Map of BIMP-EAGA



Source: ADB (2015).

BIMP-EAGA Multivariable Sensitivity Index Mapping

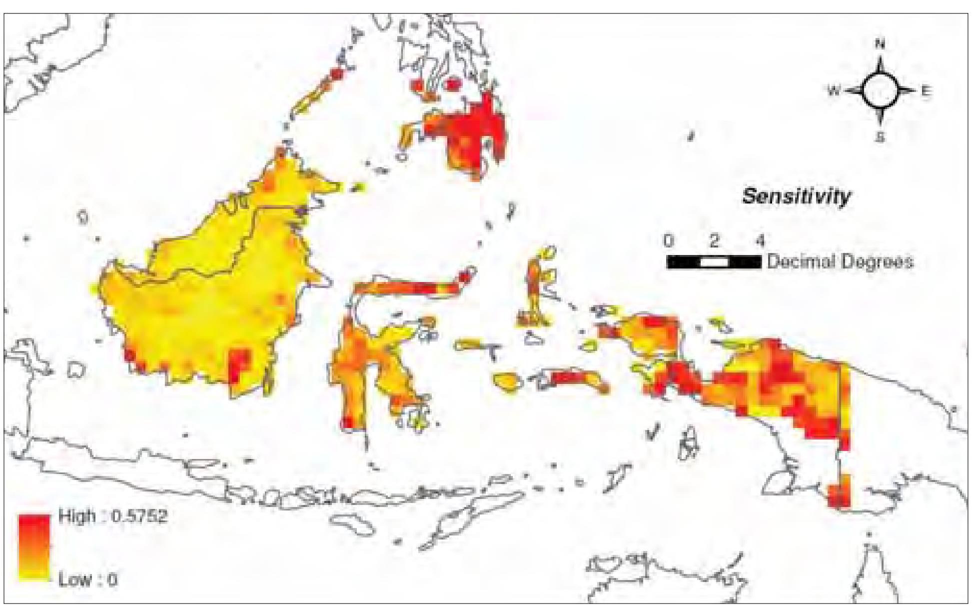
The sensitivity variables or indicators that are used in this study include the following: multihazard economic loss risk, multihazard frequency, percentage flood plain, relative water stress index, and total population. The multihazard economic loss risk variable is obtained from Global Multihazard Total Economic Loss Risk Deciles while the multihazard frequency variable is derived from the Global Multihazard Frequency and Distribution. Both variables originated from the Center for Hazards and Risk Research, Center for International Earth Science Information Network. These data sets were originally obtained in 0.04 x 0.04 decimal degree grid size raster digital data, which are then resized to 0.5 x 0.5 decimal degree grids for consistency with other variables.

The percent floodplain variable indicates the percentage of floodplain area for each grid cell, which is 0.5 x 0.5 decimal degree or approximately 50 km x 50 km. The data set is derived from the Global Lakes and Wetlands Database. Similarly, the relative water stress index variable and the total population variable are obtained in 0.5 x 0.5 decimal degree grids.

Similar to exposure index mapping, normalization is done for all the sensitivity indicators. The index map is generated by assuming equal weights (20%) or equal degree of importance for all the five sensitivity variables for each grid cell. This is done by getting the average value of the normalized variables for each cell.

Figure A5-2 shows the multivariable sensitivity index map of BIMP-EAGA. From the generated map, sensitive areas include a small portion of southern Kalimantan and some

Figure A5-2 Multivariable Sensitivity Index Map of BIMP-EAGA



Source: ADB (2015).

portions Papua and West Papua in Indonesia, and almost the entire Mindanao in the Philippines. The sensitivity indices vary from 0 to 0.58.

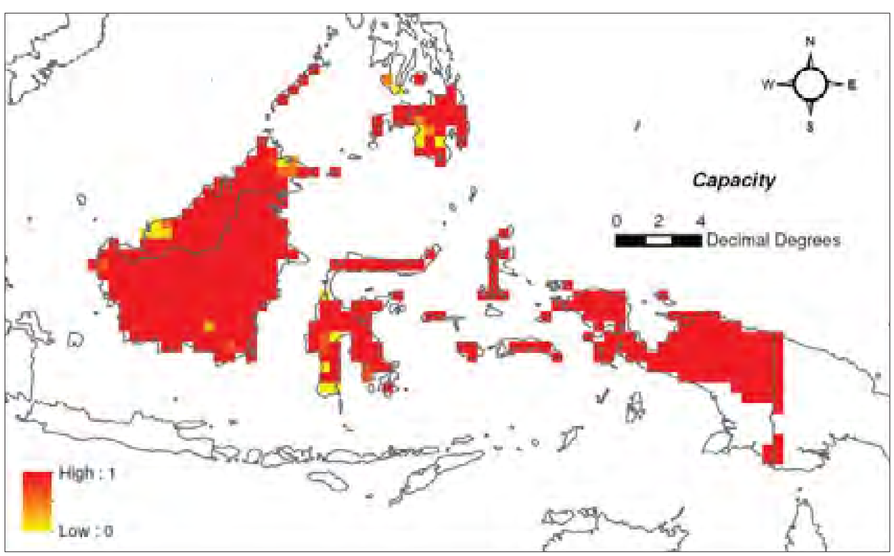
BIMP-EAGA Adaptive Capacity Index Mapping

Adaptive capacity is the degree to which adjustments in practices, processes, or structures can moderate or offset a potential damage. It is a function of infrastructure, socio-economic factors, and technology. Only irrigation equipped area variable is collected as the adaptive capacity indicator. The raw values for the irrigation equipped area variable are in square km per grid cell. The obtained data set is in 0.5 x 0.5 decimal degree grid or approximately 50 km x 50 km.

Similar to exposure and sensitivity index mapping, normalization is done for the adaptive capacity indicator. However, in this case, the higher the capacity, the lower is the vulnerability index. Hence, variables are taken as reliable and the vulnerability values are computed as one minus the normalized values of the capacity indicator to inverse the relationship.

Since only one indicator for adaptive capacity is used in this rapid assessment, 100% weight is given to the irrigation equipped area variable. Figure A5-3 depicts the adaptive capacity index map of BIMP-EAGA. From the generated map, only few areas of the entire region show high adaptive capacity (i.e., southern Sulawesi in Indonesia, western Malaysia, and small portions of southern Mindanao in the Philippines). Since only one indicator is collected and applied for the adaptive capacity factor, most areas have a vulnerability index of 1.

Figure A5-3 **Adaptive Capacity Index Map of BIMP-EAGA**



Source: ADB (2015).

BIMP-EAGA Climate Change Vulnerability Index Mapping

To produce the overall climate change vulnerability index map for BIMP-EAGA, the weighted index of climate change vulnerability is computed for each grid cell for the entire subregion using the normalized and weighted (averaged) indicators for all the 3 vulnerability factors. The resulting climate change vulnerability index for each grid cell is computed using the following formula:

$$V_i = \omega_E * EXP_i + \omega_S * SEN_i + \omega_C * CAP_i$$

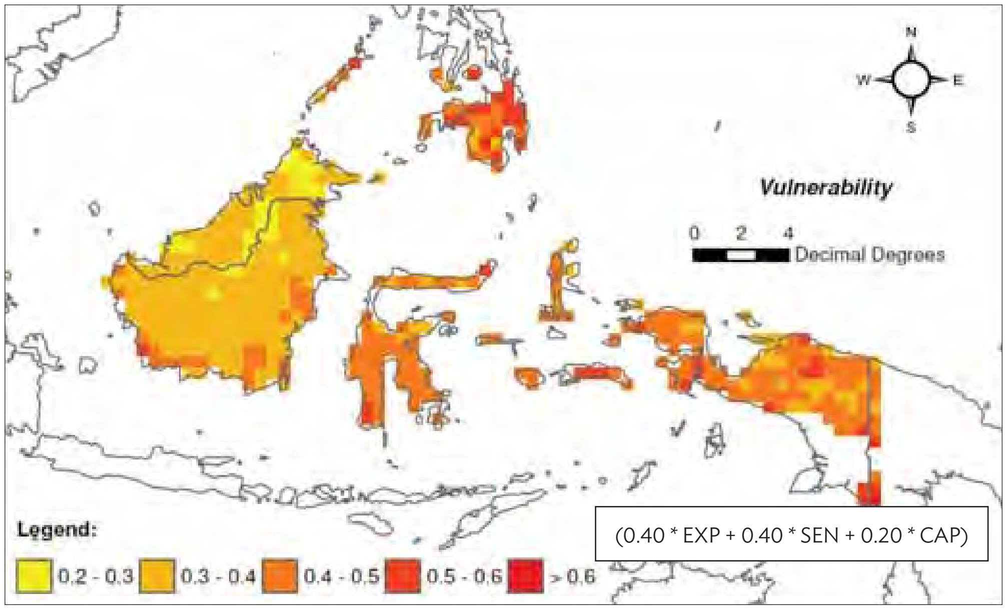
where, *Vi* is the overall weighted climate change vulnerability index; EXP_i, SEN_i, and CAP_i, are the normalized and averaged exposure, sensitivity, and capacity indices respectively; and ω_E, ω_S, and ω_C, are the exposure, sensitivity, and capacity weights applied to the normalized and averaged vulnerability factor indices.

In this study, different weight (ω_E, ω_S, and ω_C) combinations for the vulnerability factors are applied to test the sensitivity of the overall climate change vulnerability indices. The weight combinations applied are:

(1) *0.40 * EXP + 0.40 * SEN + 0.20 * CAP* (Weight Combination 1)
(2) *0.50 * EXP + 0.25 * SEN + 0.25 * CAP* (Weight Combination 2)
(3) *0.40 * EXP + 0.30 * SEN + 0.30 * CAP* (Weight Combination 3)
(4) *0.50 * EXP + 0.30 * SEN + 0.20 * CAP* (Weight Combination 4)

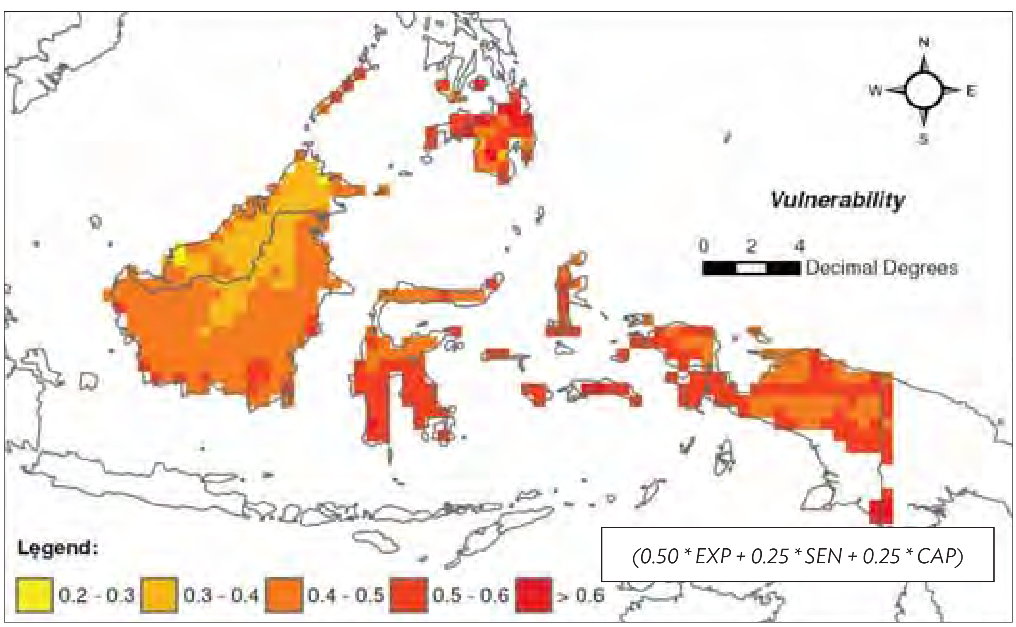
The resulting overall climate change vulnerability index maps for BIMP-EAGA for different weight combinations are shown in Figures A5-4 to A5-7.

Figure A5-4 **Climate Change Vulnerability Index Map of BIMP-EAGA *(Weight Combination 1)***



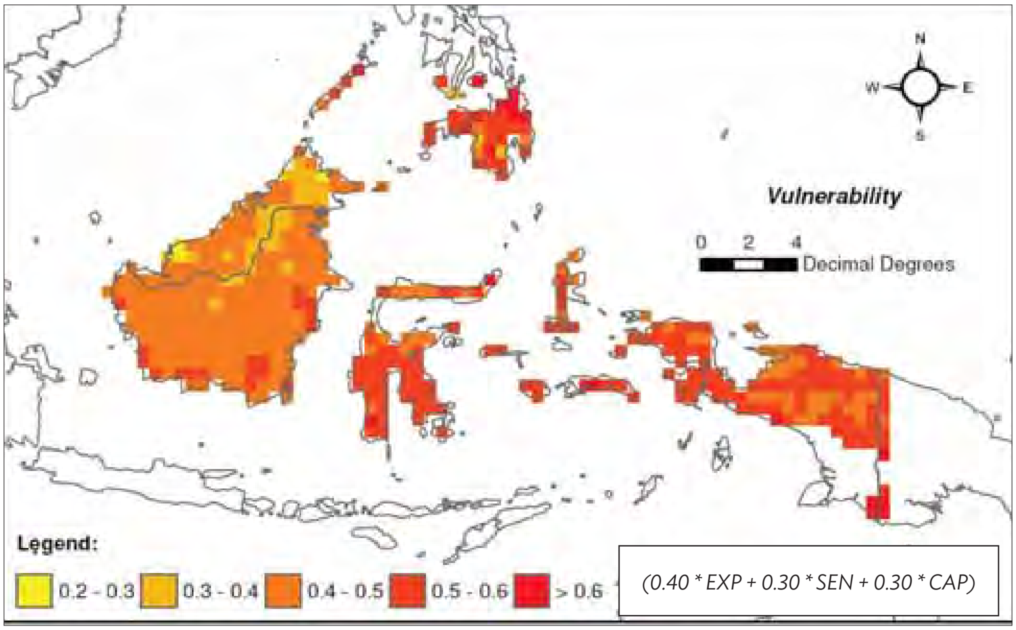
Source: ADB (2015).

Figure A5-5 **Climate Change Vulnerability Index Map of BIMP-EAGA *(Weight Combination 2)***



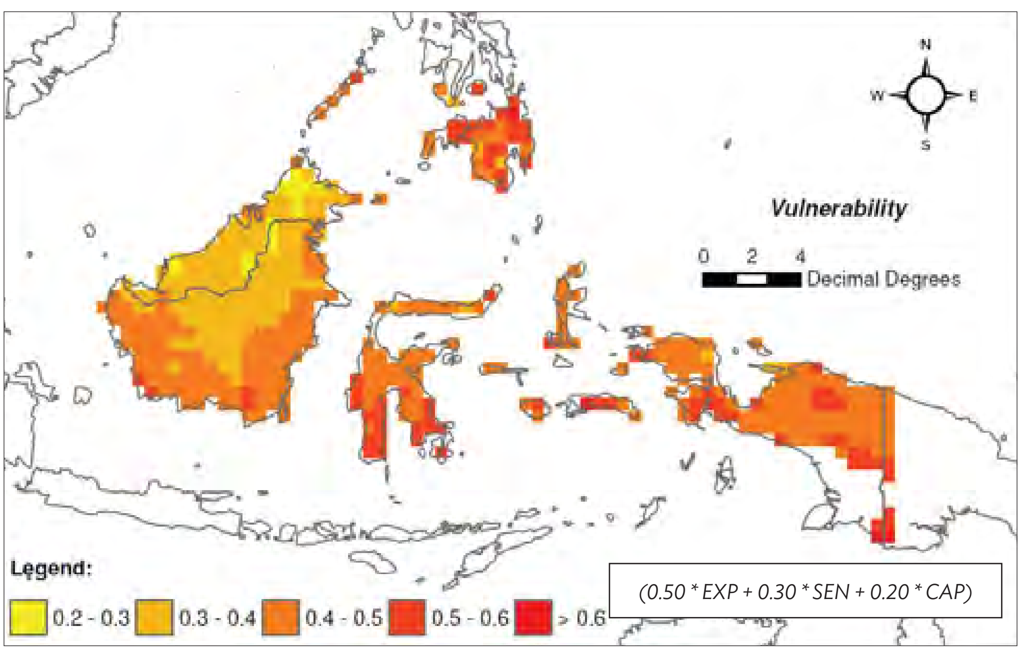
Source: ADB (2015).

Figure A5-6 Climate Change Vulnerability Index Map of BIMP-EAGA *(Weight Combination 3)*



Source: ADB (2015).

Figure A5-7 Climate Change Vulnerability Index Map of BIMP-EAGA *(Weight Combination 4)*



Source: ADB (2015).

Climate Change Vulnerability Assessment and Analysis

Based on the generated climate change vulnerability index maps of BIMP-EAGA, high to extreme vulnerability indices, which are considered as hotspots, are found in most parts of the southern portion of Sulawesi and some areas in Papua and West Papua in Indonesia, and most parts of Mindanao Philippines and Northern Palawan in the Philippines. On the other hand, moderate to high vulnerability indices are found in the coastal areas of Brunei Darussalam, Kalimantan and Maluku in Indonesia, Malaysia, and the remaining portions of Papua, Sulawesi, and West Papua in Indonesia and Mindanao and Palawan in the Philippines. Low to moderate vulnerability indices can be found in the high altitudes of Malaysia and Kalimantan in Indonesia.

The risk analysis web portal of Maplecroft, whose indicators and weighting scheme are described in Appendix 4, also generated a vulnerability index map for BIMP-EAGA. This map provides a quantitative assessment of the vulnerability of human populations to extreme climate-related events and changes in major climate parameters over the next 30 years. The weights given to vulnerability factors are 50% for the exposure index, 25% for the sensitivity index, and 25% for the adaptive capacity index, which are similar to the weighing factors assigned to weight combination 2 for this study.

From the Maplecroft's vulnerability index map of BIMP-EAGA, high to extreme vulnerability indices (hotspot areas) are found in the coastal areas of Indonesia and Malaysia, and the northwest portion of Mindanao in the Philippines, fairly consistent with the climate change vulnerability index maps generated for this study.

From the sensitivity analysis, the resulting climate change vulnerability indices are more sensitive to the exposure index as observed from the climate change vulnerability index maps in Figures A5-4 and A5-5. This is because the exposure index values (ranging from 0.08 to 0.75) are higher than the sensitivity index values (ranging from 0 to 0.58).

On the other hand, since there is only one variable for the adaptive capacity index (irrigation equipped area), which covers only some small areas in BIMP-EAGA, most of the capacity vulnerability indices are assigned the value of 1.0, making the climate change vulnerability indices more sensitive to the adaptive capacity index as observed from Figures A5-5 and A5-7. Hence, lower weight should be assigned to adaptive capacity index or more adaptive capacity indicators should be considered in the vulnerability index mapping.

Reference

Asian Development Bank. 2015. *BIMP-EAGA Climate Change Vulnerability Assessment.* Consultants' report. Manila.

Appendix 6
Brunei Darussalam Country Assessment

Profile

Geography and Biophysical

Brunei Darussalam is situated in the northwestern coast of the island of Borneo at east longitudes 114°04' and 115°23' and north latitudes of 4°00' and 5°05'. It is surrounded on three sides by the eastern Malaysian state of Sarawak and to the north by the South China Sea. It has a total area of 5,765 square kilometres (km^2) with land area of 5,265 km^2, and a small water area of 500 km^2. Its coastline runs 161 kilometers along the South China Sea.

The western part of the country is predominantly hilly lowlands whereas the eastern part consists of mostly rugged mountain terrain. The summit ridge of Bukit Pagon in the western portion contains the highest point in Brunei Darussalam with an elevation of 1,850 meters above sea level; South China Sea is the lowest point. The coast has a wide, tidal, and swampy plain.

Brunei Darussalam is close to vital sea lanes through the South China Sea, linking the Indian and Pacific Oceans and is physically into two parts by Malaysia.

Natural Resources

Brunei Darussalam is well-known for its petroleum and natural gas resources. Oil production reached 170,000 barrels per day and oil exports at 155,315 barrels per day in 2010. Gas production was recorded at 1,208 million standard cubic feet per day and liquefied natural gas exports of 934,860 million British thermal units per day (The Brunei Economic Development Board and The Office of the Prime Minister, 2015).

Another important natural resource of the country is its timber that is supplied by the rich rainforests of Borneo. More than 70% of its land area is covered by primary rainforests. The government has conserved 32,000 hectares as forest reserves and has allocated 50,000 hectares for national parks (Brunei Tourism, 2015). The Ulu Temburong National Park is the first national park that was established in the country and has been protected since 1991. The park is located in the Temburong district in the eastern portion of the country and covers approximately 40% of the district (550 km^2). The park is also known as the "Green Jewel of Brunei" with the Temburong and Belalong Rivers running through the park. It is an important ecotourism center and hosts the Ulu Ulu Resort. The Peradayan Forest Reserve is also located in the district.

Socio-Economic and Demography

Brunei Darussalam is divided into 4 districts, namely: Brunei-Muara, Tutong, Belait and Temburong. Its capital, Bandar Seri Begawan, is located in the Brunei-Muara district and is the center of government and business activities. All of the other major towns are within a two hour driving distance from Bandar Seri Begawan.

As of 2010, the total population of Brunei Darussalam was recorded at 414,400 with an annual population growth rate of 2.0%. The unemployment rate decreased from 3.5% in 2009 to 2.7% in 2010 based on working age population of between 15 to 54 years old (Department of Statistics, 2011).

Economic Growth and Trade

Real gross domestic product grew at 2.6% in 2010 compared to -1.8% in 2009. Its major export partners for crude petroleum include Australia, Indonesia, Republic of Korea, China, India and New Zealand. Natural gas is exported to Japan and the Republic of Korea. In terms of imports, its major products include machinery and transport equipments at BND[11]1,158.8 million followed by manufactured goods valued at BND685.8 million in 2010.

Energy and Water

Brunei Darussalam has installed electricity capacity of 888.0 megawatts with 99.7% coverage in electricity supply. Its production exceeds consumption.

Water supply coverage is reported at 99.9%. Water production is estimated at 160.2 thousand cubic meters (TCM) in 2010 and water consumption at 63.7 TCM in 2010.

Forestry and Production

The country's forestry and fishery industry is small in comparison to its petroleum and natural gas industry. Its forestry products include the following: round timber at 117.8 TCM in 2010; sawn timber at 45.1 TCM; bakau poles at 170,800 pieces; and charcoal at 22,700 kilograms.

In terms of capture fisheries, its production fluctuates between 15,000 metric tons (mt) to 16,000 mt. Capture fisheries production was recorded at 16,317.1 mt in 2010. Its aquaculture industry mainly produces farm prawns followed by fish in cages and fresh water fish. However, the trend is moving towards farming fish in cages as production of farmed prawns decline.

Climate

Brunei Darussalam has an equatorial climate characterized by uniformly high temperature, high humidity, and heavy rainfall. Its temperature ranges from 23°C–32°C while annual rainfall varies from 2,500 millimeters on the coast to 7,500 millimeters in the interior. The wettest months are in November to January during the northeastern monsoon. It is

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[11] Brunei dollar.

occasionally affected by the tropical cyclones track in the South China Sea and Northwest Pacific. It was affected by El Niño in 1972/1973, 1982/1983, and 1997/1998.

Climatic regions

Brunei Darussalam has 4 climatic regions described below:

- **Brunei-Muara district and Bandar Seri Begawan** are humid tropical in the coastal and lower altitude north and humid subtropical in the central Brunei-Muara district (20°–36°);
- **Tutong district** is tropical, hot in the north and warm in the south (22°–32°);
- **Belait district** is tropical, hot in the north and slightly warm in the south. (25°–37°); and
- **Temburong district** is humid subtropical in the higher altitude south and humid tropical in the coastal and lower altitude north (18°–29°).

Natural hazards (e.g., typhoons, earthquakes and severe flooding) are rare. However, it has not been exempt from the impacts of climate change. The incessant and heavy rains during the northeast monsoon season have caused floods in low-lying areas and landslides in several areas. In recent years, the country has also been affected by seasonal smoke/haze resulting from forest fires in neighboring countries.

Its capital city, however, has experienced small earthquakes in the range of 4–5 magnitude, which caused swaying of some high-rise buildings in 1992 and 2005. Consequently, the country established a National Disaster Management Centre in 2006 to promote and implement disaster risk reduction initiatives.

Brunei Darussalam suffered one forest fire disaster in 1998, which caused economic losses of $2 million with no reported casualties. However, in recent years, it has faced a few disasters (e.g., floods and strong winds in 2007; several episodes of landslides, floods, and strong winds in 2008; floods, landslides; and pandemic, serious fire outbreak and haze in 2009).[12]

Sensitivity to Climate Change

Food Security

Concern is on the possibility of substantial losses in rainfed wheat. Agricultural production may be severely affected by the delayed rainy season and extreme climate events due to the El Niño Southern Oscillation as well as increased soil salinity (Asian Development Bank, 2009). Projected sea level rise is likely to result in significant losses to coastal ecosystems that support fisheries.

Water Security

Brunei Darussalam may be affected by decreasing precipitation and an increase in hot days and warm nights (heat stress). Extreme weather events that are associated with El Niño

[12] Retrieved from http:// news.brunei.fm/2009/08/06/country-experiencingworst-disaster-year/.

were reported to be more frequent and intense during the past 20 years. Water resources in marginal areas are likely to be vulnerable to climate change.

State of Preparedness to Climate Change

The government has initiated several programs to reduce and /or mitigate greenhouse gas emissions. These include the following: forest fire prevention and control, forest conservation, improvements in transportation infrastructure to reduce traffic congestion, co-generation power stations to reduce emissions of pollutant gases, full use of unleaded gasoline to reduce air pollution, and the implementation of flood mitigation measures.

In a statement during the 16th Conference of Parties to the United Nations Framework Convention on Climate Change (UNFCCC) and the 6th Meeting of Parties to the Kyoto Protocol, Brunei Darussalam mentioned that it has embarked on an energy efficiency conservation initiative that is aimed towards reducing energy intensity by up to 25% of the 2005 level by 2030. A solar energy pilot project that is capable of producing 1,344 MW hours of electricity per year has started and a commitment was made to reduce carbon emissions by 940 tonnes per year. In terms of sustainable forest management, under the Heart of Borneo Initiative with Malaysia and Indonesia, Brunei Darussalam has designated 58% of its total land area as conservation area under this initiative.

Implementation of climate change related programs are done by several ministries in accordance with their respective areas of responsibilities. These are: the Department of Environment, Parks and Recreation;[13] The Office of the Prime Minister; the Ministry of Energy; the Ministry of Industries and Primary Resources; the Ministry of Communications; the Ministry of Health; and the Ministry of Education.

In addition, the National Council on Climate Change was established to address relevant issues on climate change. Brunei Darussalam is developing a nationally appropriate mitigation action plan but there is no policy document on adaptation (Masli, 2010).

At the international level, Brunei Darussalam signed the Kyoto Protocol on 20 August 2009 and it is assumed that it has conducted several interagency consultations on the accession of the UNFCCC. Other international agreements and treaties signed by Brunei Darussalam include: Plant Protection Agreement for the South East Asia and Pacific Region (1956), Amendment to the Plant Protection Agreement for South East Asia and the Pacific Region (1967), Ramsar Convention on Wetlands of International Importance especially as Waterfowl Habitat (1976), International Convention for the Prevention of Pollution from Ships, Convention on International Trade of Endangered Species, ASEAN Agreement on Nature Conservation, Vienna Convention on the Protection of the Ozone Layer, and the Montreal Protocol on Substances that Deplete the Ozone Layer. However, it has not submitted any national communications reports to UNFCCC.

[13] Focal point for the UNFCCC.

Issues and Challenges

Some of the issues on adaptation and mitigation to climate change across all sectors are: the lack of research on the extent of climate change impacts (e.g., safety of food chain); incomplete and/or insufficient data on the overall impacts of climate change in the country; the lack of baseline information on greenhouse gases; the lack of inventory of industries in the country; minimum level of public awareness and knowledge on climate change and its impact; the need to further strengthen multisectoral cooperation and collaboration and national communication; and the need to promote the use of alternative products (e.g. clean technology through public acceptance and enforcement and/or legislation).

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Appendix 7
Indonesia Country Assessment

Profile

This country level assessment is focused on the provinces of Indonesia that are covered by the Brunei Darussalam-Indonesia-Malaysia-Philippines East ASEAN Growth Area (BIMP-EAGA). This includes 15 provinces within the territory of the following 4 major islands: Kalimantan, Maluku, Papua, and Sulawesi. The island of Kalimantan is one of Indonesia's largest islands with 5 provinces comprised of Central Kalimantan, East Kalimantan, North Kalimantan, South Kalimantan, and West Kalimantan in BIMP-EAGA. Maluku has 1,027 islands of which 2 provinces (i.e., Maluku and North Maluku) are within the subregion. The island of Papua consists of 2 provinces (i.e., Papua and West Papua) while the island of Sulawesi consists of 6 provinces (i.e., Central Sulawesi, Gorontalo, North Sulawesi, South Sulawesi, Southeast Sulawesi, and West Sulawesi) that belong to BIMP-EAGA.

Twenty one percent of the Indonesian export product (based on value) comes from East Kalimantan. These exports depend on natural resources. Agriculture is an important component of the Sulawesi economy, accounting for 33.3% of gross domestic product. Fisheries contributed 0.2% to the national economy of Maluku while mining provided the largest share to the gross domestic product of Papua with 54.3%.

Climate

Pattern of Annual Rainfall and Surface Temperature

The annual rainfall pattern in Indonesia is basically determined by the Asian and Australian monsoon circulation that is characterized by a near surface wind system that changes direction nearly every six months. The annual surface temperature in Indonesia is determined to a large extent by the change in the position of the sun that moves between 23.5° northern latitude and 23.5° southern latitude.

Climate Variability

The climate variability in Indonesia is based on activities of various atmospheric phenomena. The anomaly of sea surface temperature in the Pacific (central and east) and the anomaly of sea surface pressure in the West Pacific cause a decrease (increase) in the seasonal volume in most of the regions in Indonesia.

Maritime Climate

Generally, sea surface temperature in Indonesia waters is above 28°C in January because the western Pacific Ocean winds and the migration of warm surface sea water from the Pacific Ocean increases sea surface temperature. On the other hand, sea surface temperature is lower than 27°C in August due to upwelling from the Indian Ocean to the Java Sea-Banda Sea and the cold air blowing from Australia during the cold monsoon season.

Trend in Climate Change

Surface Temperature Change

According to the Intergovernmental Panel on Climate Change (2007) report, the increase in temperature is around 0.56°C–0.92°C/100 years. On this basis, it can be estimated that the effect of global warming on surface temperature increase in Indonesia is not greater than 1.0°C. However, various studies have shown increasing trends in temperature in Indonesia that are higher than 1.0°C. This may indicate acceleration in global warming. In addition, the trend in local temperature change due to the heat island effect is believed to be quite dominant in urban areas (BAPPENAS, 2010b).

Rainfall Changes

Projections on rainfall changes in Indonesia up to 2020 suggest an increasing trend throughout the country during the months of March to December. For Kalimantan and Sulawesi, rainfall tends to increase in December to April. Conversely, a declining trend in rainfall in July to October has been evident in some of the regions except in Papua.

Sea Surface Temperature/Sea Pressure Level

The increasing trend in sea surface temperature in Indonesia of 0.8°C/100 years is slightly higher than the global average of 0.7°C/100 years. Generally, the increase in sea pressure level in the Pacific Ocean is higher than in the Indian Ocean. In the case of Indonesia, sea pressure level increase is relatively high in the south of Bali, the eastern section of the southern coastline of Java, Lombok, and the islands of Nusa Tenggara due to the transport of warm water from the Pacific Ocean through the Banda Sea, Timor Sea, and Makassar Strait. On the other hand, the lower increase in sea pressure level in the south of Java and Sumatra is caused by the intensity of upwelling of the high frequency of El Niño compared to La Niña from 1982 to the middle of 2000.

Sea Surface Level/Sea Level Rise

The spatial pattern of sea level rise in Indonesia shows the highest occurrence reaching 2.5 centimeters/year in the Banda Sea, Indian Ocean, Java Sea, the north of Papua Island, and a major part of the waters of Indonesia to the east.

Occurrence of Extreme Daily Rainfall

Data from the Tropical Rainfall Measuring Mission satellite shows the probability of extreme daily rainfall in some parts of Indonesia with the exception of several areas in Maluku covering the period 1998–2008. The analysis and projection of extreme values based on changes in the variance of monthly rainfall does not show an increasing trend for the period 2010–2020 with the exception of the months of January to April.

Sensitivity to Climate Change

Food Security

Historically, rice is not the only food source in Indonesia. However, people now depend on rice as the main staple food. National rice production increased from 54 million tons in 2004 to 60 million tons in 2008 (Central Bureau of Statistics, 2009). Indonesia's agricultural sector has succeeded in increasing rice production at a rate of about 5.2% annually. Areas planted to rice rose significantly, particularly in Sulawesi and Kalimantan. In 2013, areas planted to rice in South Sulawesi reached 983,107 hectares (ha) or 60.8% of the total area planted to rice in Sulawesi while South Kalimantan's rice area reached 479,721 ha or 36% of the total planted to rice in Kalimantan.

However, the estimated growth in rice production of 5% in 2004–2008 is not sufficient to meet future demand as the country's population reaches an annual average growth rate of 1.5%. In An estimated 47.6 million or 19.5% of the population in Indonesia experienced high food insecurity in 2012. The government's policy response to this problem during the period 2002–2012 has focused on improved food diversification, suggesting communities to return to local food consumption.

Fishery is one of the marine resources with high potential with production reaching 11.1 million tons in 2012 (KLH, 2012). Sulawesi produces the highest capture fish and aquaculture production at 1.0 million tons and 3.3 million tons, respectively, or around 63% of the combined fish production in Kalimantan, Maluku, and Papua.

The ecosystem of the fishery and marine sector includes coral reefs, mangrove, sea grass, bays, inlets, and estuary. In general, these ecosystems have suffered physical degradation that threaten resource sustainability and welfare.

Indonesia has the largest coral reef area worldwide with 51,000 square kilometers (km^2) or around 18% of the world's coral reef (KKP,[14] 2005). Of the total coral cover, 41.8% is in damaged condition, 28.3% is in moderate condition, 23.7% is in preserved condition, and only 6.2% is in pristine condition.

With a coastline of 81,000 kilometers (km), Indonesia has the world's second largest mangrove forest after Brazil. The Ministry of Forestry recorded mangrove forest cover at 5.5 million ha in 2011 from 7.7 million ha in 2006 (KLH, 2012), of which 7.2% is in damaged condition. Similarly, the country's mangrove area was estimated at 3.1 million ha in 2000, decreasing to 2.9 million ha in 2013 (Ministry of Forestry, 2013). Central and East Kalimantan are among those with the fastest rate of reduction in mangrove area at 13.8% and 8.4%, respectively (KLH, 2013). On the other hand, Papua has the largest mangrove area at 1.0 million ha, of which 95.8% is in good condition (KLH, 2012).

Sea grass area reached 2.0 million ha in 2012 with West Papua having the largest area of sea grass beds at 621,913 ha, of which 95.8% in good condition (KLH, 2013).

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[14] *Kementerian Kelautandan Perikanan* (Ministry of Marine Affairs and Fisheries).

Water Security

According to the Ministry of Public Works[15] (2012), Indonesia has water potential of 3.2 billion cubic meters (m^3)/year and available water of 16.8 m^3/capita/year. The availability of surface and groundwater in Indonesia varies in quantity and quality for each island. Water supply affects the needs of the population and the economy (e.g., agriculture and industry). The availability of water during the rainy season is abundant in Kalimantan and Papua, with 389,689 m^3 and 381,763 m^3, respectively. Water demand in Kalimantan is 2,505 m^3 and 117 m^3 in Papua. Papua has the lowest demand for water due to its low population density of 12.6 persons/km^2 and low demand for water from the agriculture sector, which accounts for 0.5% of Indonesia's total area that is planted to rice. Kalimantan has a population density of 21 persons/km^2 and its share in the total area planted to rice is 6% (KLH, 2012).

Water availability depends on the size of the catchment area (e.g., forests). Papua has the largest expanse of forest area with 42.2 million ha, followed by Kalimantan with 38.3 million ha, Sulawesi with 13.8 million ha, and Maluku with 7.3 million ha. Infrastructure development in Papua remains low compared to other areas in Indonesia, which has led to the preservation of its forest area. In fact, Papua's forest cover area has increased since 2009. On the other hand, exploitation, conversion to oil palm plantation and agriculture, logging mining, infrastructure development, and forest fires are main factors that drive increasing pressure on the forests in Kalimantan (KLH, 2012).

Communities access clean water from taps, boreholes, wells, and protected springs. Data from Indonesia's Central Bureau of Statistics (2010) showed that good quality drinking water meets only 55% of the needs of the Indonesian population. This implies that there is a gap covering about 80 million people, whose need for drinking water is not met.

Energy Security

Indonesia's energy supply will be dominated by coal, followed by oil and gas, although the amount of energy supply from new and renewable energy is increasing. The objective of the national energy development is a reduction in oil consumption and a shift towards non-oil energy consumption.

Renewable energy sources that will have a significant effect on climate change are hydropower and biofuels, which are targeted to contribute around 8% of the national energy demand. Micro hydropower was installed in Sulawesi (138 kilowatts [kW]), Kalimantan (400 kW), and Papua (601 kW). Some of the country's catchment areas have the potential for hydropower. These include Papua with 22,400 megawatts (MW), Kalimantan with 21,600 MW, Sulawesi with 10,200 MW, and Maluku with 430 MW (ESDM,[16] 2013).

[15] *Kementerian Pekerjaan Umum.*

[16] *Energidan Sumberdaya Mineral* (Ministry of Energy and Mineral Resource).

Adaptive Capacity

The adaptive capacity index was constructed as function of socio-economic factors (e.g., human development index and poverty incidence); infrastructure factors (e.g., irrigation and drainage, road density, and electricity coverage); and a technological factor (e.g., communication infrastructure). Each of these contributing factors is explained below.

Socio-economic Factors

Kalimantan has the highest average human development index (HDI) at 74%, followed closely by Sulawesi and Maluku at 73% and 71.7 %, respectively. East Kalimantan has the highest HDI rating in Kalimantan at 77.3% while North Sulawesi has the highest HDI rating in Sulawesi at 77.4%. On the other hand, West Kalimantan and West Sulawesi recorded the lowest HDI in Kalimantan and Sulawesi at 70.9% and 71.7%, respectively. Papua has the lowest average HDI for the entire country at 68.4% and the highest poverty incidence in Indonesia at 2.1%.

Infrastructure Factors

Kalimantan and Sulawesi on average have the most irrigation and drainage units in Indonesia with 74,250 and 74,240, respectively. East Kalimantan with 77,580 units and Central Kalimantan with 76,230 units registered the highest number of irrigation and drainage units in Kalimantan while South Sulawesi recorded the highest number of irrigation and drainage units in Sulawesi with 77,660 units. Sulawesi also has the highest road density at 0.43 km, followed by Maluku at 0.16 km, Kalimantan at 0.10 km, and Papua at 0.05 km. In addition, Sulawesi has the highest percentage of electricity coverage area at 79.9%, followed closely by Kalimantan at 77.6%, Maluku at 71.1%, and Papua at 47.6%. This implies that Sulawesi has high adaptive capacity index in infrastructure.

Technological Factor

Kalimantan has communication infrastructure at 5.0%, followed by Sulawesi at 4.1%, Maluku at 3.5%, and Papua at 3.3%.

Hotspot and Vulnerability Assessment

Kalimantan

The vulnerability rating for most of Kalimantan is medium due to its low population density at 21 persons/km^2 despite having many areas with low coastal slope in Central and South Kalimantan. Only the area near the coastal zone of Banjarmasin in South Kalimantan and Samarinda in East Kalimantan were rated as highly vulnerable due to sea level rise as the coastal areas in this vicinity are characterized with low slope.

South Kalimantan has the highest rate of deforestation, making it sensitive to flood and drought. In East and South Kalimantan, majority of the population live near the watershed, where ecosystems are easily degraded. Also, most of the forest area in East and South Kalimantan has been converted to palm oil plantation or has been exploited for mining.

Sulawesi

In general, the entire coast of Sulawesi has medium to low levels of vulnerability to sea level rise because its coastal slopes are quite high at about 1.5°–3° (BAPPENAS, 2010a). Some of the western coasts of Sulawesi (e.g., the west and southeast area) were rated with medium levels of vulnerability because of its flat coastal zone and moderate population density. For South Sulawesi, although it has a large population compared to other provinces in Sulawesi, it is vulnerable to sea water intrusion and is highly dependent on agriculture and fisheries. However, most of the Sulawesi province has high adaptive capacity in infrastructure, socio-economic, and technological factors. Overall, Sulawesi is less vulnerable to climate change compared to Kalimantan, Maluku, and Papua.

Maluku

Despite the upward trend in sea level of about 0.76 centimeters/year in almost all beaches in Maluku as reported in the *Indonesia Climate Change Sectoral Roadmap* (BAPPENAS, 2010a), the vulnerability index of Maluku is high to extreme although the population density is low (BAPPENAS, 2010c). This is because Maluku has low adaptive capacity owing to poverty and poor infrastructure. In fact, when compared to the rest of the areas in the BIMP-EAGA Indonesia, Maluku ranks the lowest in terms of road, irrigation, and drainage infrastructure.

Papua

Papua has 42.2 million ha of forest covering approximately 65%–75% of the entire province and low population density of about 12.6 person/km^2. The vulnerability index level in Papua is medium to low, especially in the north and west coast, which has high slope. The inundation simulation results by BAPPENAS (2010a) showed that none of the areas in Papua will be affected by coastal inundation even though the south coast has a gently sloping beach. The south coast area is covered with tree canopies. Only the southeast of Papua registered high vulnerability compared to the rest of the province due to its flat coastal area that is susceptible to sea level rise and its degraded coral reefs and coastal ecosystem. The adaptive capacity index of Papua is low due to high poverty incidence and poor infrastructure as measured by road density, electricity coverage area, and telecommunication infrastructure.

State of Preparedness

In accordance with Indonesian Presidential Decree No. 16/2015, the agency known as BP REDD+, along with the National Council on Climate Change, has been absorbed into the newly merged Ministry of the Environment and Forestry as part of a massive government restructuring. Former leaders of BP REDD+ may be kept as advisors of the new Directorate General of Climate Change Oversight.[17]

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[17] One of the nine Directorates General that was established during the restructuring and merging of the Ministry of Environment and Ministry of Forestry.

The National Action Plan for Climate Change Adaptation (*Rencana Aksi Nasional-Adaptasi Perubahan Iklim*) is a planning document that describes the national development strategy and action plan towards resilience to climate change. It is the main input in the formulation of the *government's annual plan* (*Rencana Kerja Pemerintah*) and the National Medium-Term Development Plan (*Rencana Pembangunan Jangka Menengah*) to ensure improved responsiveness to the impacts of climate change.

The Minister of National Development Planning formed the climate change coordination team, comprising of a Steering Committee and six working group to enhance efficiency and effectiveness in realizing the action plans on adaptation and mitigation to climate change.

Government Programs on Climate Change Adaptation and Mitigation in Relation to the Brunei Darussalam-Indonesia-Malaysia-Philippines East ASEAN Growth Area (BIMP-EAGA) Roadmap and Implementation Blueprint

BIMP-EAGA Strategic Pillar No. 1: Enhanced Connectivity

Component 3: Power Interconnection and Development of Renewable Energy

Strategies toward sustainable energy includes the following: (i) the development of micro hydropower energy through the expanded utilization of renewable energy sources to increase climate resilience in Kalimantan, Maluku, Papua, and Sulawesi; (ii) the development of innovative and adaptive technology for the cultivation of energy plantations and the use of agriculture waste in Kalimantan, Papua, and Sulawesi; (iii) the construction of geothermal power plants; (iv) the development of steam power energy, especially in Maluku and Papua; and (v) the development wind energy in Maluku and solar cells in the islands.

BIMP-EAGA Strategic Pillar No. 2: Food Basket Strategy

Strategies on food security include the following: (i) the restoration and development of climate proofed agricultural infrastructure; (ii) the expansion of food agricultural areas; (iii) the development of innovative and adaptive technology; (iv) the development of information and communication system on climate and technology; (v) support system for capacity building of stakeholders, including the development of climate information that is reliable and up-to-date; (vi) the implementation of the Merauke Integrated Food and Energy Estate in Papua; (vii) the implementation of the Masterplan for the Acceleration and Expansion of Indonesia's Economic Development; (viii) adjustments in food production systems to climate change; (ix) the acceleration of food diversification based on Government Decree No. 68/2002; and (x) the implementation of the Minister of Agriculture's Decree No. 19/Permentan/OT.140/3/2011 on the implementation of the Indonesian sustainable palm oil standard.

BIMP-EAGA Strategic Pillar No. 3: Tourism Development

Strategies on tourism development include, among others, the commencement of flights between Pontianak in Indonesia and Kuching in Malaysia by Express Air on 25 October 2013 and Kota Kinabalu in Malaysia and Puerto Princesa in the Philippines on 19 November 2013 by MA Swings. There was a trial run of a new flight route from Davao to Manado in 2013. Airlines are encouraged to explore connections beyond two points to ensure the sustainability of routes. Transport officials also launched the *BIMP-EAGA Airports and Destinations Information* booklet, which provides basic information on designated airports in BIMP-EAGA member countries, the application process for airline operations and airport incentives, and tourism sites in the subregion.

BIMP-EAGA Strategic Pillar No. 4: Environment

Component 1: Sustainable Management of Critical Subregional Ecosystem

Strategies under Component 1 include the following: (i) the restoration and conservation of rainfall catchment areas to increase climate resilience; (ii) the evaluation of peat land in Central Kalimantan to improve land productivity and prevent peat land fire during the dry season; (iii) improvement in watershed management in Kalimantan (i.e., Eastern and Southern Kalimantan), Maluku (Morotai island and Seram island); Papua (i.e., western portion of West Papua and southeastern portion of Papua); Sulawesi (i.e., Central Sulawesi, Gorontalo, North Sulawesi, and South Sulawesi); and (iv) the prevention of deforestation in protected forest and increasing reforested areas.

Component 2: Climate Change Adaptation and Mitigation

Strategies under Component 2 include the following: (i) increasing conservation forest areas: (ii) Presidential Instruction No. 10/2011 regarding the suspension of the granting of new licenses and improvement of governance of natural primary forest and peat land; (iii) the National Movement for Forest and Land Rehabilitation (*Gerakan Nasional Rehabilitasi Hutandan Lahan*); (iv) the Clean River Program (*Program Kali Bersih*); (v) land subsistence and slide mapping; and the reforestation program (involving the planting of five trees each year for each household) combined with a long-term livelihood program for villagers in East Kalimantan; and (vi) Minister Regulation No.1/2007 on the spatial planning of green urban areas to develop urban forests as green open area in Sulawesi.

Component 5: Mainstreaming Environment in Other Strategic Pillars of the BIMP-EAGA Cooperation

One of the strategies under Component 5 is Presidential Decree No.25/2011 on a national task force for preparing the establishment of a REDD+ agency.

Funding of Climate Change Activities

Available funding from the regional and central governments to support climate change efforts is limited. Local funding sources need to be supplemented by funds from international institutions and the private sector to support research and development (R&D), capacity building, and pilot projects.

Gaps and Challenges

The direct impact of climate change occurs at the local scale such that measures should be implemented at the local level to suit local conditions. Regional governments have an important role in implementing climate change adaptation measures in accordance with the conditions that are relevant to the region and in accordance with its level of vulnerability.

The implementation of adaptation measures does not depend on one ministry and/or government agency but involves all sectors, including the government at all levels, the private sector, and the community. The issue of coordination is one of the main challenges in the planning and implementation of adaptation measures in Indonesia. This is more so if linked to the political structure and system of governance that is decentralized. Coordination is crucial not only within the government at the central level but also covers relations among all government levels (i.e., central, provincial, district, and city or village levels).

The vulnerability of communities to the impacts of climate change is generally associated with lack of information on the subject matter.

Resilience Measures

The effectiveness of programs in supporting the implementation of climate resilient development can be enhanced by improving the synergy of adaptation action activities among sectors. Climate change adaptation plans for each sector in the context of food, water, and energy security need to be viewed in terms of the interlinkages of programs among the sectors and their relation with other clusters in the BIMP-EAGA implementation plan.

Proposed activities that link with other clusters include the following: (i) the development of a sea base transportation in the Makassar Port (South Sulawesi), Sorong Port (West Papua), and Halmahera, which connects to south Philippines; (ii) the development of new air links among the cities as tourist destination (e.g.,Kutching-Pontianak-Balikpapan-[Cebu-Davao]-Manado-Wakatobi-Raja Ampat); (iii) the development of cattle production and marketing center in Sulawesi and Papua for export; (iv) the development agro-forestry (e.g., cavendish bananas, cashew, and other commercial timber) in Sulawesi; (v) the development of seaweed processing industry and trade in Sulawesi and a memorandum of understanding on R&D with the Philippines; (vi) coordination to prevent illegal fishing; and (vii) the development of a tourism marketing center in Manado.

The proposed adaptation recommendations were the result of the climate change vulnerability analysis that was conducted for each region. The vulnerability analysis noted the strong and weak points of each region and provided recommendations to support the various goals of BIMP-EAGA (e.g., develop the hydropower energy potential in Sulawesi and Papua, utilize unused land which is many in Papua as agro industry areas [in lieu of forest conversion to the agriculture which happening in Kalimantan, Maluku, and Sulawesi]). An evaluation matrix was also set up to assess and prioritize proposed options based on the following criteria: effectiveness; cost; feasibility; social acceptability; and technical, financial, legal and administrative considerations.

Kalimantan

a. **Food.** This includes the following: (i) peat land rehabilitation in Central Kalimantan; (ii) food production in unused land; (iii) policy implementation that helps landowners increase palm oil production yield focusing on small-scale landowners, expanding capacity, and improving the handling process in the port of Kumai and Quay Bun (for palm oil); (iv) marine fish spawning ground management (based on time calendar and area protection); (v) online harvesting calendar and stock database; and (vi) mangrove management and rehabilitation. Under food security, the evaluation priority matrix proposed the prioritization of online harvesting calendar and stock database as well as mangrove management and rehabilitation.

b. **Water.** This includes the following: (i) rain water harvesting in critical areas, unused land, and peat land; (ii) good watershed management practices (Mahakam, Kapuas, Barito watershed), (iii) management of buffer zones and local communities in the surrounding national parks (e.g., Betung Kerihun National Park, Danau Sentarum National Park, Kayan Mentarang National Park), and protected forest (e.g., forest management units in Kapuas Hulu, Malinau, and Murung Raya); (iv) ensure the availability of and access to water for all by the government; (v) the provision of clean water to include the preservation of water resources to maintain its sustainability; (vi) the continuation and enhancement of reforestation strategies to sustain water catchment areas; (vii) local governments will be required to allocate forest areas as a percentage of the total area (BAPPENAS, 2011). Under water security, the evaluation priority matrix proposed the prioritization of the management of buffer zones and local communities in the surrounding national parks; and ensuring the availability of and access to water for all by the government.

c. **Energy.** This includes the following: (i) the development of hydropower energy in national parks and protected forests (e.g., pico hydro for communities in North Kayong, Ketapang, and Kubu Raya in West Kalimantan); (ii) the development of biogas, biomass power plants, especially biomass from the solid and liquid waste of palm oil; and (iii) the development of geothermal power plants. Under energy security, the evaluation priority matrix proposed the prioritization of increasing biomass energy from the solid and liquid waste of palm oil.

Maluku

a. **Food.** This includes the following: (i) the development of a mega minapolitan in Morotai, which consists of 12 fishing ports, 6 minapolitan regions, and 6 seaweed clusters; (ii) improvement in seaweed processing and the establishment of a seaweed and fisheries marketing depot in North Maluku; (iii) coral reef management, protection, and rehabilitation; the management of marine fish collection (based on size of fish), and the management of marine fish spawning ground (based on time calendar and area protection); (iv) the development of a comprehensive food diversification program (e.g., sago [Metroxylon spp.]); (v) the development of an online harvesting calendar and stock database as well as the development of a technology base fishery resources information center in each fishing village; and (vi) the improvement in the quality of fishery products through training, standardization, and quality control. Under food security, the evaluation priority matrix proposed the prioritization of the development of a mega minapolitan in Morotai.

b. **Water.** This includes the following: (i) rain water harvesting in critical areas (e.g., Seram and Obi islands); (ii) ensure the availability of and access to water for all by the government; (iii) the provision of clean water to include the preservation of water resources to maintain its sustainability; (iv) the continuation and enhancement of reforestation strategies to sustain water catchment areas; and (v) local governments will be required to allocate forest areas as a percentage of the total area (BAPPENAS, 2011). Under water security, the evaluation priority matrix proposed the prioritization of rain water harvesting in critical areas and ensure the availability of and access to water for all by the government.
c. **Energy.** This includes the construction of a steam power plant in Ambon and North Maluku. The evaluation priority matrix proposed the prioritization of this recommendation under energy security.

Papua

a. **Food.** This includes the following: (i) manpower training and capacity building; (ii) the gradual development of food estate land, the acceleration of the process of releasing designated forest land into food estate areas, cattle production and marketing, and food production in unused land; (iii) the development of service and collection-distribution centers for agricultural products; the development of an agribusiness terminal, storage, and export port; the development of an online harvesting calendar and stock database; and the development of a comprehensive food diversification program (e.g., sago [Metroxylon spp.]); (iv) the development of organic and ammonia urea fertilizer; and (v) coral reef management, protection, and rehabilitation; the management of marine fish collection (based on size of fish); and the management of marine fish spawning ground (based on time calendar and area protection). Under food security, the evaluation priority matrix proposed the prioritization of food production in unused land and the development of new growth regions for the production of food in regions with low climate risk and low emission.
b. **Water.** This includes the following: (i) the development and improvement of irrigation facilities; (ii) ensure the availability of and access to water for all by the government; (iii) the provision of clean water to include the preservation of water resources to maintain its sustainability; (iv) the continuation and enhancement of reforestation strategies to sustain water catchment areas; and (v) local governments will be required to allocate forest areas as a percentage of the total area (BAPPENAS, 2011). Under water security, the evaluation priority matrix proposed the prioritization of ensuring the availability of and access to water for all by the government.
c. **Energy.** This includes the following: (i) the construction of steam power plant in Jayapura-Timika; (ii) the development of hydropower; (iii) the development of biomass-based electricity in Merauke and Tanah Miring; and (iv) the development of a geothermal power plant. Under energy security, the evaluation priority matrix proposed the prioritization of the development of steam power, hydropower, and biomass energy.

Sulawesi

a. **Food.** This includes the following: (i) capacity building of farmers, expanding the planting area for corn and rice, and reducing the potential loss of quality and value from post harvest; (ii) the development of a center for cattle production and marketing; (iii) improvement in the implementation of financing schemes for the fermentation of cocoa beans to improve quality, provide one-stop service for investors, and infrastructure (e.g., electricity, water, telecommunication) in all areas of cocoa production and processing industries; (iv) coral reef management, protection, and rehabilitation; the management of marine fish collection (based on size of fish); the management of marine fish spawning grounds (based on area protection and time calendar); increasing aquaculture investment and production; and implement a Marine Stewardship Council standard; (v) the production of seaweed processing, R&D, and marketing; (vi) improving financing access for farmers; and (vii) strengthening institutions to support farmer empowerment and improve their coordination function, online harvesting calendar, and stock database. Under food security, the evaluation priority matrix proposed the prioritization of cattle production and marketing as well as the dissemination of climate change resilient rice varieties.

b. **Water**. This includes the following: (i) rain water harvesting in critical areas; increasing the absorption areas for rainwater in Makassar that are vulnerable to seawater intrusion; good watershed management practices (e.g., Tondano, Sadang and Jeneberang Walanae); and improving irrigation facilities based on simple irrigation that is dependent on rain; (ii) the government ensures the availability and access to water for all; (iii) the provision of clean water to include the preservation of water resources to maintain its sustainability; (iv) the continuation and enhancement of reforestation strategies to sustain water catchment areas; and (v) local governments will be required to allocate forest areas as a percentage of the total areas (BAPPENAS, 2011). Under water security, the evaluation priority matrix proposed the prioritization of improved watershed management and the availability and access to water for all ensured by government.

c. **Energy.** This includes the following: (i) the development of hydropower in Sulawesi; (ii) the development of biogas and/or biomass power plants;[18] and (iii) the development of geothermal power plants. Under energy security, the evaluation priority matrix proposed the prioritization of increasing hydropower and biomass energy from livestock excretion and agriculture waste.

Supporting System (Strengthening Institutional Capacity, Investment, Capacity Building, Technical Assistance, and M&E)

The scope and achievements of the recommendation action plan require support to overcome fragmentation of functions and the main tasks of related line ministries and/ government agencies and to enhance coordination. Details are provided below.

a. **Strengthening Institutional Capacity.** This may consist of the following: (i) ensuring that food security covers food production and consumption with adequate and equitable food supply, product diversification (President Decree

[18] Sulawesi is one of the cattle centers in Indonesia; biomass energy from cattle excretion is preferable.

No. 22/2009 and Ministry of Agriculture No. 43/Permentan/OT 140/2009), targeting rice consumption to decrease by 1.5% capita/year (BAPPENAS, 2013); (ii) good governance management in watershed; (iii) effective regulation and supporting systems for energy development, especially renewable energy (e.g., bio energy, wind, sun, hydropower, and geothermal); (iv) enhancing the capacity of stakeholders in adapting to climate change; (v) developing climate information that is reliable and up-to-date; (vi) encouraging the Environmental Service Indonesia towards green development; and (vii) effectiveness of e-waste management regulation.

b. **Investments.** This may consist of compiling planning documents and laws on vulnerability, risks, and adaptation to climate change towards: (i) improved watershed management and the management of buffer zones and local communities in the surrounding national parks (e.g., Danau Sentarum National Park, Betung Kerihun National Park, Kayan Mentarang National Park) and protected forest (e.g., protected management forests in Kapuas Hulu, Malianu, and Murung Raya); (ii) the development of a program for the rehabilitation of forests and forest reclamation in priority river basin areas; (iii) the development of a program to establish a center for forest seeds and seeds that are resilient to drought and extreme weather; (iv) improving the resilience of agriculture in coastal areas against the threat of climate change; (v) improving sustainable management in critical ecosystems (e.g., watershed areas in Barito, Jeneberang Walanae, Kapuas, Mahakam, Sadang, and Tondano); (vi) improving the sanitation system and micro hydro in Kalimantan, Papua, and Sulawesi; and (vii) restoring and conserving rainfall catchment areas in river basin regions that become the sources of hydropower and geothermal energy stations.

c. **Capacity Building.** This may consist of the following: (i) mainstreaming environment in other strategic pillars of BIMP-EAGA to create awareness among individuals, society, and organizations in the subregion to care for the environment and to implement environmental protection and conservation activities with regard to the other pillars (i.e., food basket, connectivity, and tourism; (ii) improving the balance between socio-economic development objectives and the importance of maintaining quality and sustainable development among stakeholders, the private sector, and communities; (iii) increasing public awareness within BIMP-EAGA communities on the sustainable development of natural resources and the environment and on the phenomenon and impact of climate change; and (iv) promotion of food diversification.

d. **Technical Assistance.** This may consist of the following: (i) developing innovation and technology that are related to climate change and adaptation, and knowledge management; (ii) developing technology for increasing the production of quality seeds from food production plants, forest plants, and energy plantation with high yields and resilient to climate change; (iii) expanding the utilization of pico and micro scale hydropower sources in isolated areas as part of the program on developing energy self-reliant villages that can encourage communities to preserve the environment and the sustainability of environmental services; (iv) supporting activities through scientific studies on the vulnerability of the system of *Pembangkit Listrik Tenaga Air* (hydroelectric power plants) to climate change; (v) developing indigenous technology, including the use of local wisdom; (vi) developing varieties that are resistant to drought and floods, and technology for managing cattle and fish; (vii) developing climate information systems and communication; and (viii) developing the capacity for analysis, prediction and/or estimation of climate and/

or weather, developing networks climate information system, crop calendar, developing a network and institutions of systems for communication.

e. **M&E**. This may consist of the following: (i) designing a system for M&E that will yield information on the progress in attaining program targets on adaptation to climate change; and (ii) implementing M&E of activities on adaptation to climate change.

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Appendix 8
Malaysia Country Assessment

Profile

The country level assessment provided in this section is focused on the states of Sabah and Sarawak, and the Federal Territory of Labuan, which are parts of Malaysia that are covered by the Brunei Darussalam-Indonesia-Malaysia-Philippines East ASEAN Growth Area (BIMP-EAGA).

Malaysia's Sabah state covers an area of about 73,619 square kilometres (km^2), bordering the territory of Kalimantan, Indonesia. Wilayah Persekutuan Labuan covers an area of 92 km^2 is located off the northwestern coast of Borneo Island. Sarawak, also known as the 'Land of the Hornbills' is situated on the northwest of Borneo Island and shares its borders with Brunei Darussalam on the northeast and Kalimantan, Indonesia on the east. It is the largest state in Malaysia with an area coverage of 124,450 km^2 comprising 37.5% of Malaysia's total landmass.

Coral reefs in Malaysia are estimated to cover approximately 4,000 km^2. Most of the coral reefs are found in Sabah, Sarawak, and the east coast of Peninsular Malaysia. Coral diversity is highest in East Malaysia (predominantly in Sabah) with over 550 species. Coral reefs are limited in Sarawak as they are only found in the offshore islands northeast and southeast of Sarawak.

The Department of Statistics Malaysia estimated Sabah's population at 3.5 million in 2013 with an average annual population growth rate of 2.3%. During the same period, gross domestic product growth was at 4.1% and the rate of unemployment was at 5.2% from 5.4% in 2012. Sarawak's total population is estimated at 2.6 million in 2013 with an average annual population growth rate of 2%. Growth in gross domestic product is at 1.5% with the rate of unemployment increasing slightly from 3.5% in 2012 to 3.8% in 2013. The economic structure of Sarawak is largely export-oriented, dominated by primary commodities. Among the 13 states, Sarawak has one of the strongest economies and is the only state with an A-rating from Standard & Poors Ratings Services. Sarawak has maintained steady growth over the past few years with a record of four consecutive years of surpluses despite the global economic crisis,

The Federal Territory of Labuan has a population of 90,000 with annual population growth rate at 0.9%. Labuan's capital, Victoria, is best known as an offshore financial center, offering international financial and business services via the Labuan International Business and Financial Centre since 1990. It is also an offshore support hub for deepwater oil and gas activities in the region. According to the Department of Statistics (2010), the Federal Territory of Labuan's rate of urbanization is high at 82.3% compared to Sabah at 54% and Sarawak at 53.8%.

Current and Indicative Future Climate Conditions and Projections

The average daily temperature throughout Malaysia varies from 21°C to 32°C. The annual average rainfall in Sabah is about 3,000 millimeters (mm) and Sarawak at 3,500 mm. Based on the Malaysian Meteorological Department's surface observation stations data, the west coast of Peninsular Malaysia recorded an increase in rainfall by 6%–10% for 2000–2007 relative to 1990–1999. Central Pahang and the coastal Kelantan showed a decrease in rainfall by 4%–6%. On the other hand, East Malaysia, Sarawak and Sabah recorded an increase in rainfall by 6%–10% and by more than 10%, respectively, during the same period.

The highest rate of sea level rise was recorded between 1993 and 2010 in the offshore areas of Sabah-Brunei-Sarawak, followed by its neighboring coastlines of Sibu, Miri, Brunei, and Labuan. The Malaysian Meteorological Department expects more extreme hydrological conditions to occur. In Sabah, it is expected that the annual mean surface temperature will increase by 2.9°C–3.5°C in Sabah and by 3.0°C–3.3°C in Sarawak by 2100. Meanwhile, the maximum projected monthly rainfall by year 2100 is expected to increase by 9% in Sabah and 32% in Sarawak. The projected climate change impacts in Sabah and Sarawak include extreme changes in the river flow that will cause flooding in Tawau in Sabah and Kemena, Saribas, and Batang Luparin in Sarawak.

Climate Change Impact Analysis

Typically, climate hazards in the region consist of tropical cyclones, floods, droughts and exposure to landslides. In a report by the *Economy and Environment Program for Southeast Asia* (Yusuf and Francisco, 2009), the exposure factor for Malaysia, particularly for Sabah, is more dominant in the determination of the country's vulnerability index than the sensitivity and adaptive capacity factors.

Sensitivity to Climate Change

a. **Food Security.** Malaysia is a major exporter of palm oil and any changes in climate variables will affect palm oil production. It is estimated that palm oil yields could decrease by approximately 30% when temperature increases by 2°C above the optimum levels and decrease in rainfall by 10%. Rice production may fall if the temperature rises above 34°C. In the event of change in climate variability, rubber production will also be significantly affected. An increase in annual temperature above 30°C, coupled with a reduction in mean annual rainfall below 1,500 mm will retard growth and prolong immaturity, and reduce production by 10%.
b. **Coastal and Marine.** Most islands and marine protected areas, particularly in Sabah and Sarawak, are sensitive to climate changes and hazards, especially threats from sea level rise. In recent years, higher than normal water temperature

was identified as one of the factors causing coral bleaching and prolonged events that have resulted in reef degradation and have inadvertently affected coastal economies (e.g., tourism and fishery industries).

c. **Public Health.** The *Malaysian Second National Communication Report to the United Nations Framework Convention on Climate Change* identified the risk of resurgence in vector-borne disease incidence (e.g., dengue, chikungunya, and malaria). With th projected increase in ambient temperature of 1.5°C, malaria cases could increase by 15%. Other disease entities related to food- and water-borne diseases include cholera and typhoid. Flooding occurrence has also been associated with higher incidence of zoonotic diseases, such asleptospirosis. On the other extreme, prolonged drought season reduces the availability of clean water supply and existing water supply may be compromised. Heavy rain and runoff will lead to the contamination of surface water.
d. **Water resources.** It is common for states that are ranked among the top five in terms of sensitivity to climate hazards (i.e., Sabah, Pulau Pinang, Kelantan, Terengganu, and Perlis) to experience extreme drought and flooding. During extreme rainfall and flows, more frequent and severe flooding and more soil erosion incidences are expected. On the other extreme, water shortages from severe droughts (particularly due to the El Niño Southern Oscillation phenomenon) reduce inflows to reservoirs, decreases stream flows, which in turn affect water abstraction and lessens the recharge of groundwater, affecting the quantity of freshwater supply.
e. **Energy.** In 2012, the calculated energy reserve margin for Peninsular Malaysia was 33%, Sabah with 19.6%, and Sarawak with 95% (Energy Commission, 2012). Disruption in transportation includes the use and condition of roads and railways as well as aviation safety.
f. **Forestry and biodiversity.** Increased rainfall translates to waterlogged soils and soil nutrient leaching that lead to tree mortality. Mangrove forests along the low-lying coastlines are vulnerable to sea level rise. This is exacerbated by the projected increase in temperature and changes in rainfall patterns. Low-lying coasts are expected to experience increased levels of inundation, accelerated coastal erosion, and saline intrusion into coastal waterways and water tables.

Adaptive Capacity

Sabah was ranked highest in terms of vulnerability and exposure but lowest in adaptive capacity given its socio-economic conditions, available technology, and current infrastructure. Sarawak was ranked at 9th position.

Coping and Adaptation Analysis

a. **Agriculture.** Several drought tolerant varieties of rice, rubber, and oil palm are under development. Also, research on aerobic rice, which consumes less water has been initiated. Efficient irrigation system to regulate water table depth is being developed for oil palm plantations.
b. **Forestry and biodiversity.** Measures to enhance the National Seed Bank collection have been undertaken to ensure the survival of genetic stock. Additionally, efforts are underway to expand protected forest areas and forest state parks to enhance the natural adaptation processes of forests. Programs for

marine parks management (e.g., Conserving Marine Biodiversity through Enhanced Marine Park Management and Inclusive Sustainable Island Development) have also addressed issues on climate change adaptation.

c. **Coastal and marine.** There were 3 adaptation approaches that were proposed during the 2nd National Communication to United Nations Framework Convention on Climate Change. These include the following: (i) retreat approach (i.e., abandonment of land and structure); (ii) accommodation approach (i.e., continued occupancy and use of vulnerable areas); and (iii) protection approach (i.e., defend vulnerable areas, which includes engineering responses).
d. **Public health.** A Crisis and Preparedness and Response Centre was established to monitor outbreaks and to initiate and coordinate responses.
e. **Water resources.** A Pollution Prevention and Water Quality Improvement program was started to strengthen existing regulatory, preventive, and remedial measures to improve water quality in rivers. Studies that were undertaken formulated integrated action plans toward pollution abatement and water quality improvement. Similar studies are undertaken in Sungai Batang Rejang in Sarawak and Sungai Melaka in Melaka.

Policy Actions

The overarching policy tool for Malaysia on climate change is the National Policy on Climate Change that was approved by the Cabinet in 2009. It provides a framework to mobilize and guide government agencies, industries, communities, and relevant stakeholders in addressing the challenges of climate change in an effective and holistic manner. In addition, the National Green Technology Policy that was launched also in 2009 seeks to promote low carbon technology and ensure sustainable development while conserving the natural environment and resources. Other relevant policies, laws, and regulations that indirectly address climate change issues include the National Policy on the Environment and National Forestry Policy.

Institutional Arrangements

The National Green Technology and Climate Change Council was formed in 2009 and chaired by the Prime Minister of Malaysia. It operates through 5 councils (i.e., Industry Committee, Human Capital Committee, Research and Innovation Committee, Promotion and Public Awareness Committee, and Transportation Committee) to support the development and implementation of the National Policy on Climate Change and the National Green Technology Policy.

Program Implementation

There have been numerous projects and programs that are undertaken by implementing agencies, especially by the National Hydraulic Research Institute Malaysia, particularly in the development of models to project climate change variability. It also acts as a main support agency for other agencies in climate change adaptation and mitigation programs and plans.

Government Programs on Climate Change Adaptation and Mitigation in Relation to the BIMP-EAGA Roadmap and Implementation Blueprint

BIMP-EAGA Strategic Pillar No. 1: Enhanced Connectivity

Component 3: Power Interconnection and Development of Renewable Energy

The strategy of the Ministry of Energy, Green Technology and Water throughout the country is to ensure adequate supply of energy as follows:

(i) **Gas.** Prioritize indigenous resources for local consumption and establish storage for substitute fuels;

(ii) **Renewable energy.** Introduce feed-in tariff to support the growth of renewable energy and prioritize renewable energy to be dispatched into the grid;

(iii) **Coal.** Secure long-term contracts with suppliers and have multiple coal supplier countries;

(iv) **Nuclear.** Study the possibility of introducing nuclear power;

(v) **Hydro.** Develop feasible and viable hydro projects and examine the hydro potential from Sarawak (estimated at more than 20,000 megawatts); and

(vi) **Energy efficiency.** Increase efforts to manage demand and introduce explicit laws on efficient use of energy.

The Rural Electrification Programme (Bekalan Elektrik Luar Bandar) is implemented to provide electricity to houses in traditional villages outside the areas under the operation of local authorities throughout Malaysia. This includes long-houses in the remote areas of Sabah and Sarawak, villages of indigenous people in Peninsular Malaysia, villages in the islands and settlements in small estates that are less than 400 hectares (less than 1,000 acres). By the end of 2012, electrification coverage reached 90.8% out of a total of 369,578 rural houses that were identified in Sabah. Electrification coverage will be further widened to a targeted coverage of 95% by 2015 (Sabah Electricity Supply, 2014).

BIMP-EAGA Strategic Pillar 2: Food Basket Strategy

a. **Agriculture.** Sabah was allocated $152.86 million from the federal government 2013 budget for agriculture. A joint initiative was developed between the state and the federal government to transform Kota Belud into a rice granary. A range of innovative techniques will be introduced under the initiative, including double-cropping and flood mitigation, together with tertiary level water management system. Under the Ministry of Modernisation of Agriculture, Sarawak aims to implement new land development schemes in the utilization of native lands to develop food baskets in Bintangor, near Tanjung Manis. Good agricultural policy is fully embraced by most oil palm companies, such as the Sarawak Oil Palms Berhad.

b. **Fisheries.** Food security is one of the major issues addressed by the Coral Triangle Initiative on Coral Reefs, Fisheries and Food Security (CTI-CFF), especially in relation to fisheries and its surrounding ecosystems. The Sulu Sulawesi Marine Ecoregion, headed by the Sabah Department of Fisheries under the auspices of the CTI-CFF, aims to designate and effectively manage seascapes to ensure sustainable management and utilization of resources. Under the Sarawak Corridor of Renewable Energy economic corridor, the Tanjung Manis Halal hub is expected to develop large-scale aquaculture production of high value species to reduce reliance on wild catch and the risk of low supply due to climate change.

BIMP-EAGA Strategic Pillar 3: Tourism Development

Component 1: Develop Tourism Products and Tourism-Related Infrastructure Focusing on Community-Based Ecotourism as a Flagship Program

Sabah is famous for its extensive coasts, mountain rainforests, and island and coral reef ecosystems, which provide a vast array of plant and animal species. There are currently six parks gazetted under the Parks Enactment (1984). Of these, 3 are terrestrial parks (Mount Kinabalu, a United Nations Educational, Scientific and Cultural Organization world heritage site; Crocker Range; and Tawau Hills) and 3 are marine parks (Turtle Island, Tunku Abdul Rahman, and Pulau Tiga). The Tun Mustapha Park will be the largest protected area with 1.0 million hectares in size. Sarawak ecotourism products offer extensive coastal lowland rainforest, river, and mountain rainforests with rich indigenous cultural heritage. There are 22 protected areas including Mount Mulu National Park, another United Nations Educational, Scientific and Cultural Organization World Heritage site under the protection of Sarawak Forestry Department. Although smaller in size, the Federal Territory of Labuan main island, including its six smaller islands, offers plenty lowland tropical rainforest cover, beaches, and coral formation as ecotourism products.

BIMP-EAGA Strategic Pillar 4: Environment

Component 1: Sustainable Management of Critical Subregional Ecosystems

The trilateral Heart of Borneo Initiative was signed by 3 nations that share the island of Borneo: Indonesia, Malaysia, and Brunei Darussalam. On the coastal realm, the CTI-CFF was launched in 2009 with participation from 6 countries (Indonesia, Malaysia, Papua New Guinea, Philippines, Solomon Islands and Timor-Leste). Within the CTI-CFF program, an ongoing program, the Sulu Sulawesi Marine Ecoregion program focuses on strengthening the management of natural resources by all stakeholders, including local communities, the private sector, and government agencies.

Component 2: Climate Change Adaptation and Mitigation

Most climate change adaptation and mitigation programs are implemented and/or planned at the national level. For example, the National Coastal Zone Physical Plan for East Malaysia has been completed and implemented; and the Integrated Shoreline Management Plan for Malaysian coastlines. The national coastal vulnerability index is currently being expanded nationwide. In forestry, several forest reserves were established and expanded, especially in Sabah and Sarawak (e.g., Deramakot Forest Reserve and Kelawat Forest Reserve). Efforts to enhance the National Seed Bank are also underway aimed to ensure the survival of genetic stocks.

Component 3: Promotion of Clean and Green Production Technologies
A *Green Technology Roadmap Baseline Study for Agriculture and ForestrySectors* (GreenTech Malaysia, 2014) was developed and endorsed in 2013. The baseline study aims to establish data for baseline reference that are specific to the agriculture and forestry sectors by identifying current green technology initiatives, activities and barriers, and establish an enabling environment and framework of action plans for green technology development and applications. In addition, a Green Technology Master Plan was developed and completed in 2011 to translate the National Green Technology Policy into implementable initiatives. Also, GreenTech provides a green technology financing scheme to promote the easy access to the financing of green technology. An initial allocation of RM1.5 billion was offered in 2010–2012. This amount was increased to RM2 billion covering an extended period through 2015. Most of the allocation is for the energy sector with 60%, followed by waste and water sector with 30%, and then the transport and building sector. A proposed *baseline study on green technology-related regulatory framework* was introduced to establish an 'umbrella act' to govern technology and technological development in green technology.

Funding for Climate Change

A study on the *Scoping Assessment on Climate Change Adaptation in Malaysia: Summary* (Solar, 2011) was undertaken by the Economic Planning Unit under The Office of the Prime Minister and funded by United Nations Development Program-Malaysia to assess the economic costs and benefits of adaptation and mitigation measures in specific sectors. In the Tenth Malaysia Plan: 2011–2015 (Economic Planning Unit, 2011), funding of RM5 billion is allocated for flood mitigation programs. This includes the application of an integrated flood management approach through forecasting and warning facilities as well as the development of disaster preparedness and community awareness programs and flood hazard maps. In addition, research and development efforts will be intensified in water resources conservation to support efforts to develop a sustainable water sector for the national economy.

Strategic Resilience Measures

More detailed studies are required on climate change- and sea level rise-related issues (e.g., inundation maps for sea level rise in other critical locations throughout Malaysia, vulnerability index for sensitive areas, assessment of the potential impacts of climate change on other vulnerable sectors, such as agriculture, forestry, biodiversity, water resources, coastal and marine resources, public health and energy).

Within the context of the implementation of the CTI-CFF programs, there are key knowledge gaps and supportive constraints in order to move ahead towards on the ground implementation. These include: (i) support for capacity building, particularly on the collection and analysis of scientific and traditional knowledge and the development of policy and governance to enable effective adaptation to climate change; (ii) understanding the vulnerability of people to improve their capacity to develop effective ecosystem and structural adaptation plans at the local, national, and regional levels; (iii) improving spatial planning, especially in implementing networks of resilient marine protected areas; and (iv) developing a framework to provide early warning of disaster and climate change hazards, and strategies to minimize risk and improve management.

The sustainability of forestry and biodiversity depends on the conservation of genetic resources through gene banks, seed centers and botanical gardens, sanctuaries, captive breeding centers and rehabilitation centers. However, these are restricted by: (i) insufficient funds and funding mechanisms to support research on biodiversity as well as capacity that can be strengthened through training and workshops; (ii) lack of taxonomists for flora and fauna; and (iii) lapse in enforcement and monitoring environmental projects.

To address climate change adaptation in the coastal zone, in-depth knowledge and understanding of storm patterns, intensity, duration, and frequency are required.

In terms of water resources, current climate projection models need further expansion and therefore require emphasis on knowledge building. These models are needed to provide clear parameters and guidance to extend research on the impacts of climate change on water resources, urban and rural drainage systems, catchment management, highway drainage, dam and reservoir safety and integrity, water supply allocation and distribution, irrigation water demand and efficiency, and hydrology analysis for flood risks.

In the area of sustainable agriculture production, the challenge in the agriculture sectors lies in the following: (i) the biological nature of the crops; (ii) the complexity of technical innovation (on and off site); and (iii) the integration of other sectors to support agricultural production (e.g., water and natural resources). Capacity gaps that need attention with respect to 'ecological responsible agriculture' and climate change mitigation and adaptation include: (i) research on adaptation and mitigation options provided by ecological agriculture that take into account context and location specificities (e.g., soil type, crop type, management practices, and climate conditions); (ii) knowledge management arrangements for information and experience sharing, and transfer of and training in good practices that constitute adaptation and mitigation in ecological agriculture, including extension services; (iii) development and implementation of adaptation and mitigation action plans for agriculture, focusing on ecological agriculture; and (iv) institutionalization of financing assistance for adaptation and mitigation measures in the agriculture sector, especially actions that incorporate ecological agriculture practices.

Malaysia, on the whole has fairly adequate legislations, policies and plans in place in relation to climate change adaptation and mitigation. At the institutional capacity front, the country is capable of managing climate change disasters. However, there is still much room for improvement. In relation to governance, national policies must be adopted and implemented at the state authorities' level without amendments (i.e. required enforcement at the operational level). Roles and responsibilities of all stakeholders should be clarified and the participation of industry players enhanced. Particularly for Sabah and Sarawak, perception interviews revealed that there is significant challenge in governance, in part due to the lack of sufficient technical expertise and financial limitations of local authorities.

Efficient climate resiliency practices require cross-sectoral adaptation actions, therefore processes in adaptation policies and governance options cannot be limited to within sectoral initiatives. The following recommendations to support ongoing policy and governance processes to build climate resiliency are as follows: (i) development of a formal vulnerability and adaptation capacity building program to be implemented immediately for all sectors and includes the economic, financial, and social fields; (ii) an integrated vulnerability and adaptation program for all sectors based on a regional and or ecosystem based approach. This program should also include the integration of data and information collected for sharing between all sectors; (iii) within sector vulnerability and adaptation initiatives, including public participation with emphasis on disaster risk reduction and management initiatives; (iv) strategic review of relevant laws, rules, regulations, policies, and plans to strengthen efforts to address climate change issues and encourage adaptation measures; and (v) affirmative climate change adaptation programs for all sectors and integrated into the 5-year development plan of each sector.

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Appendix 9
Philippines Country Assessment

Profile

The country level assessment provided in this section is focused on Palawan and Mindanao, which comprise the Philippine component of the Brunei Darussalam-Indonesia-Malaysia-Philippines East ASEAN Growth Area (BIMP-EAGA). Palawan is the largest province in the Philippines in terms of land area with 16,403 square kilometers (km^2). It is a United Nations Educational, Scientific and Cultural Organization man and biosphere reserve that is known as one of the world's premier tourism destinations and the country's "last frontier" due to its pristine environment. It is the Philippines' southwest frontier with Malaysia and forms a link between the Philippines and the East Indies. Palawan's economy is agriculture based with rice, corn and coconut as its major products. It has rich fishing grounds that teem with tuna, mackerel, lobster, shrimp, and carrageenan. Palawan is the country's top producer of seaweeds. It is the only oil-producing province in the country. Natural gas reserves in the Camago Malampaya gas fields in the northwest are estimated at 3 trillion cubic feet. Palawan is also rich in mineral resources (e.g., chromite, nickel, copper, marble, mercury, iron, saprolite, silica, manganese, limestone, barite, feldspar, talc, sand and gravel, and guano) and has one of the biggest nickel reserves in the country.

Mindanao is the second largest island in the Philippine archipelago with a land area of 102,043 km^2. It is composed of 26 provinces, 33 cities, and 422 municipalities, grouped into 6 regions, namely: Zamboanga Peninsula (Region IX), Northern Mindanao (Region X), Davao, (Region XI), SOCCSKSARGEN[19] (Region XII), Caraga (Region XIII), and the Autonomous Region in Muslim Mindanao (ARMM). Due to its abundant rainfall and few typhoons, numerous river basins and fertile soil, Mindanao is called the Philippines' food basket, with a capacity to feed the whole country and the rest of East ASEAN. It is the country's leading producer of rubber, cacao, banana, coffee, coconut, corn, pineapple, carrageenan, and tuna. Mindanao is also rich in mineral resources, such as gold, nickel, zinc and manganese. Its major exports to the United States, China, Japan and other countries are bananas, tuna, coconut oil, pineapple, fruits, nuts, shrimps and nickel ores and concentrates. It imports petroleum oils, wheat and meslin, milk and cream, and mineral or chemical fertilizers. Indonesia is one of its top five import sources.

[19] Acronym for the region's 4 provinces (i.e., South Cotabato, Cotabato, Sultan Kudarat, and Sarangani) and one of its cities (i.e., General Santos City).

Climate Change Projections

Palawan

Palawan falls under 2 climate types. Type 1 is characterized by six months of dry season and six months of wet season and occurs in the extreme north and south sections and in the entire northwest coast. Type II prevails in the rest of the province and is characterized by a short dry season of one to three months and no pronounced rainy period during the rest of the year. Palawan experiences the northeast monsoon (*amihan*) from November to February and the southwest monsoon (*habagat*) from March to May with favorable months from June to December. The northern and southern extremities and the western portion of the province have annual average rainfall of 2,290 millimeters (mm). The eastern region from Puerto Princesa City to Brooke's Point has an average of 1,672 mm of rainfall annually. The southern portion of the province is practically free from typhoons but the northern part has persistent gales and torrential rains during the months of July and August. Palawan is projected to have significantly increasing temperature changes of 0.9°C–1.1°C in 2020 (2006–2035) and 1.8°C–2.1°C in 2050 (2036–2065).[20] The observed baseline for the seasonal rainfall change of Palawan is 640.6 mm for the period 1971–2000. Under the medium range emission scenario, the projected seasonal rainfall change is 19.6% in 2020 (2006–2035). Projections show that wet months will be more wet (more rainfall) while the dry months will be drier.

A total of 105 tropical cyclones crossed the province of Palawan from 1948–2011 while a total of 124 cyclones crossed within the 100 kilometer (km) rain band of the province. This is a significant climate factor to consider because most of the tropical cyclones have rain band diameters exceeding 100 km and maximum wind speeds that sometimes exceed 180 knots/hour.[21]

The BIMP-EAGA hazards exposure index map provides a quantitative assessment of the potential for a region to be exposed to future climate change and climate-related extreme events. The map shows that Palawan's potential exposure to climate hazards or extreme events ranges from low to medium. Hotspots include the small islands north of the Palawan mainland (i.e., Busuanga, Culion, Coron and Calamian group of islands, Quiniluban and Cuyo group of islands), which have high exposure to climate hazards (e.g., typhoons) since they are within the typhoon belt of the country. Other high exposure areas include Cagayancillo, Balabac islands in the southern tip of the Palawan mainland, and the coastal areas of southern Bataraza, Rizal, Rio-Tuba, Quezon, Espanola, Narra, Sto. Niño-Aborlan boundary, Puerto Princesa, Ulugan Bay, Honda Bay, Babuyan San Rafael, Araceli and Dumaran, San Vicente and Malampaya Sound, and the east coast of El Nido. The Philippine exposure map on climate change shows that Northern Palawan falls under Cluster III of the climate change exposure map (i.e.,

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[20] The medium range emission scenario consists of the global population peaking in mid century and declining thereafter, very rapid economic growth, rapid introduction of new and more efficient technology, and energy generation balanced across all sources.

[21] Government of the Philippines, Climate Change Commission and the Global Green Growth Institute. 2014. *Demonstration of the Eco-town Framework in San Vicente, Palawan, Philippines.* Manila and Seoul. Global Green Growth Institute. Retrieved from http://gggi.org/wp-content/uploads/2014/04/Eco_Town_Framework.pdf.

extreme heating events, disturbed water budget, and sea level rise). The rest of the mainland Palawan falls under Cluster XI (i.e., sea level rise) while its southernmost tip belongs to Cluster V (i.e., extreme rainfall events and sea level rise).[22]

Mindanao

A great portion of Mindanao is characterized with evenly distributed tropical climate types II, III and IV (Corona classification), which makes it ideal for year-round crop production. The regions of SOCCSKARGEN, ARMM, Northern Mindanao, and Zamboanga can be developed as food baskets since they are seldom hit by tropical cyclones. Areas located near the eastern seaboard and areas in Central Mindanao are prone to flooding and landslides. Historically, tropical cyclones visit Mindanao only every 10 years on average.

The projected change in seasonal rainfall across Mindanao varies from -6.8% (SOCCKSARGEN) to +14.8% (Zamboanga Peninsula) by 2020 and -14.4% to +8.9% by 2050. Annual variations in rainfall range from -0.3% in Region XI to +8.1% in Region IX by 2020 and -10.9% in Caraga to 10.8% in Region IX. Regions X, XI, XII, and Caraga will experience a decline in annual rainfall while Regions IX and ARMM will have increased annual rainfall by 2020. All regions in Mindanao, except for Region IX, are projected to experience a decrease in rainfall by 2020. On an annual basis, there will an increase in drier days. Variations in seasonal temperature will range from 0.9%–1.3% by 2020 and 1.7%–2.6% by 2050. This means that Mindanao will experience hotter days in the coming decades.

The BIMP-EAGA hazards exposure index map shows that compared to the islands of Luzon and Visayas, which have extreme exposure to climate change extreme events on average, the island of Mindanao's exposure ranges from low to medium. There are only a few hotspots with fairly high exposure (i.e., Dinagat and Siargao Islands in Surigao del Norte in the northern tip of Mindanao, and a small portion of the northeastern coasts of Surigao del Sur, Davao Oriental and Compostela Valley). Some portions of the Zamboanga Peninsula, Maguindanao, Sultan Kudarat, Sarangani, Bukidnon and North Cotabato and the small islands of Basilan, Jolo and Tawi-Tawi in the southernmost tip of Mindanao, near Sabah in Malaysia also have a fairly high exposure. This is because Maguindanao, North Cotabato, Sultan Kudarat and the Compostela Valley are included in the list of the Mines and Geosciences Bureau's top 20 provinces that are susceptible to floods. Bukidnon, Davao Oriental, and Saragani are included in the list of top 20 provinces that are susceptible to landslides.

The Philippine climate change exposure map shows that Northeast Mindanao falls under Cluster VIII (i.e., extreme heating events, increasing ocean temperature, extreme rainfall events, and sea level rise). Southeast Mindanao belongs to Cluster VII (i.e., extreme heating events, increasing ocean temperature, and sea level rise). Southwest and Northwest Mindanao belong to Clusters VI and XI (i.e., sea level rise).

[22] Human Development Network. 2012. *Philippine Human Development Report 2012/2013: Geography and Human Development*. Manila. Retrieved from http://hdn.org.ph/20122013-philippine-human-development-report/.

Sensitivity to Climate Change

Palawan

The BIMP-EAGA sensitivity map provides a quantitative assessment of the relative human sensitivity to exposure to future climate change and climate-related extreme events. The sensitivity index indicates the population's susceptibility to the impacts of climate change, which is a function of existing physical, social, and livelihood circumstances that are related to health, poverty, knowledge, infrastructure, conflict, agriculture, population and resource pressure. The map shows that Palawan falls between the medium to high sensitivity range. Hotspots are found in the Culion, Coron, and Busuanga islands, north of the Palawan mainland, the southeastern portion of the Palawan mainland including Narra, Española and Brooke's Point, and the eastern seaboard of Southern Palawan, including Bugsuk island. These are areas with lesser infrastructure and social services facilities and are farther from the provincial capital.

a. **Food security.** Palawan's rice production decreased by 3.97% from 329,689 metric tons (mt) in 2011 to 316,599 mt in 2012. Hence, the rice sufficiency level declined by 8% from 160% in 2011 to 152% in 2012. In 2011, the total irrigated area was 19,217 hectares (ha) or only 30% of the total potential irrigable area. Around 26,504 households stated that they experienced decrease in crops harvested in 2011–2012 due to drought, typhoons, floods, pests, and decrease in supply of water for irrigation. In terms of livestock production, 14,204 households or 41% of the total households surveyed stated that they experienced reduction in livestock production due to typhoons, floods, and extreme hot weather conditions.

   The province experienced a decline in the average annual increase in fish production from 21.3% in 2000–2007 to 9.8% in 2011. This decline was affirmed by 13,156 fishing households, who stated that they experienced decreased fish catch in 2011–2012 due to increased competition, fewer fishes, and coral bleaching. Studies by the Palawan Council for Sustainable Development showed that only 13.4% (109.2 km^2) of Palawan's reefs are in excellent to good condition and the remaining 86.6% are in fair to poor condition.[23] In San Vicente, 59,071 ha are highly vulnerable to drought. Around 218 or 4% of the total population are farming households living below the poverty line with 90% of them engaged in monocropping (Balangue, 2013b).

   In the forestry sector, San Vicente's forests are relatively young, fragile, unstable, and consist mostly of hardword species. The opening stock of forest resources was estimated at 25.6 million cubic meters (MCM) valued at P20.6 billion. Under a one-year business as usual scenario, it was projected that forest resources will increase to 26.2 MCM valued at P21.4 billion, even with forest losses. Under a worst case climate change scenario, considering that San Vicente lies in the typhoon belt, the opening stock of forest resources will be reduced to 20.1 MCM valued at P19.6 billion. Hence, climate change extreme events (e.g., typhoons)

[23] Palawan Council for Sustainable Development Report 2011, as cited by the Asian Development Bank. 2014. *State of the Coral Triangle Philippines*. Mandaluyong City, Philippines: ADB.

resulting in rain-induced landslides are projected to cause losses to forest resources of 2.1 MCM valued at P1.7 billion in one year [24]

b. **Water security.** Around 84.4% of the total households in Palawan have access to safe drinking water. This figure is lower than the national average of 88.9%. Households access their drinking water through piped water, drilled or closed well water systems. In San Vicente, the present aggregate water production capacity of the existing water system is 1.9 million MCM yearly, of which 15% is consumed by households and businesses connected to the water system (Balangue, 2013b). Projections on total water demand for domestic, irrigation, ecotourism, and physical and economic development are as follows: 16.2 MCM in 2013, 17.6 MCM 2020, and 36.1 MCM in 2050. These projections are expected to result in a deficit in water supply deficit of 14.3 MCM in 2013, 15.7 MCM in 2020, and 34.2 MCM in 2050. The vulnerability assessment of water system facilities showed that the highest vulnerability rating was given to old water distribution pipes that are installed in residential areas and industrial centers that are affected by flooding in low-lying areas.
c. **Energy security.** Only 106,434 households have access to electricity or 58% of the total potential households. The provincial government of Palawan through its energy program "*Barangay* Electrification Project-Solar Home System Electrification Project," has provided 10,716 solar energy home system units and solar battery charging stations in 105 *barangays* covering 20 municipalities. According to the Department of Energy, the combined rated capacity of power plants in Palawan is 82.5 megawatts (MW) and their dependable capacity is 71.7 MW. The main grid in Puerto-Narra-Brooke's Point consists of three power plants that run on bunker and diesel fuel. The main island of Palawan has 10 diesel-run micro grids. Power plants, refineries and depots, power transmission and distribution systems, fuel distribution systems, oil, gas and geothermal rigs, solar photovoltaic systems, and wind power systems are subject to climate trends (e.g., sea level rise, increasing rainfall, strong typhoons, increasing temperature and drought). The direct impact of these climate trends are coastal inundation, flooding, soil erosion, landslides, toppling of infrastructure, and water supply reduction. These in turn will cause forced power outages, interruption in the operation of power plants and other energy systems, and fuel supply and power interruption. The consequences would be economic slowdown (Department of Energy, 2014a).

Mindanao

The BIMP-EAGA sensitivity map shows that provinces in Mindanao that are in the bottom rank of the human development index (0.499 and below) and with greater poverty indices are highly sensitivite to climate change extreme events. These include the provinces of Agusan del Sur, Basilan, Bukidnon, Compostela Valley, Davao Oriental, Lanao del Sur, Maguindanao, Misamis Occidental, North Cotabato, Sarangani, Sultan Kudarat, Sulu, Surigao del Norte, Surigao del Sur, Tawi-Tawi, Zamboanga del Norte and Zamboanga Sibugay. Most of these provinces are in the ARMM.

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[24] Government of the Philippines, Climate Change Commission (CCC) and Global Green Growth Institute. 2014. *Demonstration of the Eco-town Framework in San Vicente, Palawan, Philippines.* Manila and Seoul.

a. **Food security, agriculture, and natural resources.** Mindanao has 3 agro-ecological zones (i.e., the wet, moist and dry zone). These provide the generalized physical conditions and ecological information that are needed to determine crop suitability and hence, the sensitivity of the agricultural sector to climate change extreme events. In Opol, Misamis Oriental, a pilot site for the Climate Change Commission (CCC) and the Housing and Land Use Regulatory Board project on Mainstreaming Climate and Disaster Risks in the Comprehensive Land Use Plan, certain crop production areas are at risk to flooding and are vulnerable to reduced seasonal rainfall, increased number of dry days, and extreme temperature events, which potentially affect productivity. In addition, the Bonbon-Luyong, Bonbon Poblacion Coastal Area in Opol is in high risk to flooding due to the poor quality of structure along the coast while fishpond areas are moderately at risk given their location and design. In Surigao City, 8.6 km^2 (49%) of the total agricultural land of 17.8 km^2 are highly sensitive to extreme climate events. Estimates of the risks of fatality and property damage to agricultural lands and built-up areas in Surigao City are shown in the main report.
b. **Water security.** The largest watersheds in the country are in Mindanao, (i.e., Lake Lanao Watershed Reservation, in Marawi City, Lanao del Sur and the Kabulnan River Watershed Forest Reserve spanning the provinces of Sultan Kudarat, Maguindanao, and South Cotabato). Regions X, IX, XII and XI in Mindanao are among the top 5 regions with the highest water resources potential, most of which are from surface water. Nonetheless, increasing water demand, especially from industrial users, has resulted in a number of cities experiencing water stress (i.e., Davao, Cagayan de Oro, and Zamboanga). These highly urbanized cities rely mostly on groundwater for water supply, resulting in uncontrolled withdrawal from groundwater aquifers in recent years. In Opol, Misamis Oriental, the local water supply is further threatened by saltwater intrusion from coastal flooding and the projected reduction in seasonal rainfall and the increase in temperature due to climate change.
c. **Energy security.** More than half of Mindanao's power supply comes from hydropower. Northern Mindanao has almost 680 MW of potential hydropower capacity, followed by Caraga with 280 MW. For geothermal energy, Mindanao has a 50 MW Mindanao III geothermal project in Mt. Apo, the country's highest mountain. Around 100 MW of geothermal resources are in Region XII (General Santos, Cotabato and South Cotabato). Region X has the second largest potential at 80 MW located in Misamis Occidental, Misamis Oriental and Lanao del Norte. In the event of El Niño (drought) and the declining dependable capacities from hydropower plants, the island needs to establish additional power generation capacities to support its growing economy and to address the immediate need for sufficient power supply.[25] Mindanao power plants have a combined installed capacity of 2,087 MW and a dependable capacity of 1,749 MW. Sea level rise, increasing rainfall, strong typhoons, increasing temperature and drought will cause coastal inundation, flooding, soil erosion, landslides, damage to energy infrastructure, and reduced water supply (in cases of drought). These will result

[25] Government of the Philippines, Department of Energy. 2014b. Mindanao Energy Plan, 2013–2030. Powerpoint presentation for the stakeholders consultation. Zamboanga City. February.

in forced power outages, interrupted operation of power plants and other energy systems, and fuel and power supply interruption. These will adversely affect economic activities in the province and in the country.

Adaptive Capacity

Palawan

The Palawan Provincial Planning and Development Office staff has produced provincial hazard profiles with hazard maps as inputs in mainstreaming disaster risk reduction and climate change adaptation into their provincial development and physical framework plans. This is under the Integrating Disaster Risk Reduction and Climate Change Adaptation in Local Development and Decision-making Processes project of the National Economic and Development Authority with assistance from the United Nations Development Program, the Australian Agency for International Development, and the New Zealand Aid Programme. The project aims to (i) enhance local awareness and understanding of climate change and its effect on existing natural hazards, (ii) develop tools to integrate climate risks in disaster risk reduction enhanced planning, (iii) demonstrate practical integrated disaster risk reduction and/or climate change adaptation approaches at the community level, (iv) develop policy instruments to enhance multi-stakeholder cooperation to address climate change, and (v) strengthen national and local multi-stakeholder coordinating mechanisms on climate change. The provincial government is also implementing the Department of Interior and Local Government's (DILG) community-based monitoring system, which uses household surveys to obtain climate change related-data (e.g., number of agricultural households with decreased harvests due to extreme climate events like typhoons and floods).

In Puerto Princesa City, a study site of the WWF-Bank of the Philippine Island's Business Risk Assessment and the Management of Climate Change Impacts (2014), included adaptive capacity variables that reflect a city's ability to implement climate adaptation strategies. These include: labor/work force, family savings, functional literacy, city revenue, expenditures, reserves, banking data and the city's scores for the local governance performance monitoring system, crime statistics, and the human development index. With these, a city-specific score was given for each of the six parameters. These scores were then averaged to generate an inverse adaptive capacity rating. A self-rating of 5.0 is the perfect score. The Puerto Princesa City government gave itself "excellent" ratings in 17 out of 20 criteria that comprise the local governance performance monitoring system score sheet or an average score of 4.9 for 2011.

The Eco-town Demonstration Project in San Vicente ranked its *barangays* from 1 to 10 based on their adaptive capacity with 1 having highest adaptive capacity and 10 the lowest. *Barangays* with the highest adaptive capacity scores per category are as follows: Binga in natural disaster; Caruray in biodiversity, living conditions and poverty, and industry; New Agutaya in water resources and energy; Port Barton in natural resources; and San Isidro in health. On the other hand, the lowest adaptive capacity scores were observed in the following: Binga in biodiversity; Caruray in water resources and natural disaster; Poblacion in living conditions and poverty; Port Barton in health; and Sto. Niño in natural resources and energy. The adaptive capacity for San Vicente's coastal and marine sector is characterized by the following: 93% of fishing households use motorized boats, 10 for specialized officials in the fisheries office, presence of fish processing facilities (i.e., freezer, fish drying facilities), P 4.12 million fund for the municipal disaster risk reduction and management plan, presence of municipal fishery regulatory boards, presence of at least five *bantay dagat* (sea guards) per *barangay* with an annual budget of P900,000, availability of loans and other assistance from the national government, existence of other livelihood activities (i.e., seaweed farming and sardines making), and the presence of established fish sanctuaries and marine parks.

Mindanao

The National Economic and Development Authority project, Integrating Disaster Risk Reduction and Climate Change Adaptation in Local Development and Decision-making Processes, is building the capacity of the provincial planning and development staff in the provinces of Zamboanga del Norte, Zamboanga del Sur, Zamboanga Sibugay, Camiguin, Davao Oriental, Compostela Valley, Bukidnon, Sarangani, South Cotabato, Agusan del Norte, Agusan del Sur, Surigao del Norte, and Surigao del Sur in the preparation of hazard profiles and maps based on the geohazard maps of the Mines and Geosciences Bureau and climatic data from Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA). Surigao City in the province of Surigao del Norte is also a pilot area for mainstreaming disaster risk reduction and/or climate change adaptation in its comprehensive land use plan.

In the WWF and Bank of the Philippine Islands study (2014), the following local governments in Mindanao rated their own adaptive capacity as follows (with 5 as the perfect score): Butuan City with 4.8; Davao City with 4.8; Zamboanga City with 4.7; Cagayan de Oro City with 4.6; and General Santos City with 4.3. A Social Weather Stations survey (2013) on basic knowledge on the impacts of climate change involving 900 respondents from Mindanao, showed that only 5% of respondents stated that they have extensive knowledge, 27% had partial but sufficient knowledge, 44% had only a little knowledge, and 24% did not know anything about the impacts of climate change.[26]

Vulnerability and Hotspots

Palawan

The BIMP-EAGA vulnerability map combines the (i) risk of exposure to climate change and extreme events, with the (ii) current human sensitivity to that exposure and the (iii) capacity of a country to adapt to, or take advantage of, the potential impacts of climate change. The map shows that Palawan borders between the low to the medium categories. This is because its geographical location and climatic types have lower risks for the population to be exposed to climate change extreme events. Vulnerability assessments in San Vicente reveal that in terms of agriculture under a business as usual situation, Palawan will experience a decline in rice productivity and assorted crops production in the next 25 years. This condition is attributed to the rising demand for food, which estimated to

[26] Social Weather Stations. 2013. *First Quarter 2013 Social Weather Survey: 85% of Filipino Adults Personally Experienced the Impacts Of Climate Change*. Quezon City. Retrieved from http://www.sws.org.ph/.

growth at a conservative increment of 4% per annum with potential impacts from farm management deficiencies (11.7%); climate-related impacts (8.3%); insect infestation (7.2%); and wastage in harvesting, transporting, processing, and wasteful consumption of food products (6.4%).

In San Vicente, without the development of additional areas, the capacity of existing rice production areas will decline within the first 4 years and will continue up to the 25th year. In the forestry sector, forest areas that are vulnerable to landslides due to extreme rainfall events were identified by *barangay*. Vulnerability is a function of exposure represented by slopes. Forests located in 0%–18% slope have low vulnerability to landslides, those located in 18%–30% slopes have medium vulnerability, and those located in 30%–50% and up are highly vulnerable to landslides. Around 16,160 ha of forest areas were classified as highly vulnerable, 12,817 ha with medium vulnerability, and 121 ha have low vulnerability. In terms of sensitivity to landslides, smaller trees, due to their smaller diameters, are more sensitive than the medium and bigger trees. Around 2.3 million trees are highly vulnerable to landslides due to high rainfall brought by climate-related rain-induced landslides.

In the water sector, vulnerability of the water system facilities is defined by exposure as a function of effect factors (i.e., flash floods, siltation, drying of streams, and knocking down of trees in streams); sensitivity is a function of impacts of climate-related events; and adaptive capacity is a function of existing deterring factors or mitigating factors. In San Vicente, streams, water intake and piping, close type water reservoirs, and distribution pipes to houses were highly vulnerable with the distribution pipes having the highest vulnerability rating (Balangue, 2013a).

Mindanao

In the BIMP-EAGA vulnerability map, most of the areas in Mindanao are within the medium vulnerability range. However, some portions of the northern and coastal provinces in the Zamboanga Peninsula, Northern Mindanao, Caraga, and ARMM are highly vulnerable to extreme climate-related events such as flooding. The vulnerability of some interior provinces in Region XI (Davao) and SOCCKSARGEN (Region XII) border between the high and extreme range.

The provinces of Maguindanao (ARMM), North Cotabato (Region XI), Sultan Kudarat, Davao del Norte/Compostela Valley are among the top 20 provinces in the country that are susceptible to floods. Except for Davao del Norte, these are also the provinces with human development index ranking that are much lower than half of the other provinces in the Philippines. They also have high poverty incidence. On the other hand, Bukidnon, Davao Oriental, and Saragani are among the top 20 provinces that are susceptible to landslides.

The impacts on the agriculture, forestry, and natural resources, water and energy situation in various provinces of Mindanao were also studied. For Surigao del Norte, projections on rice production for 2020–2050 show that there will be a 5% probability of exceeding the minimum yield of 1.8 mt/ha during normal years and a 7% and a 5% probability of exceeding the minimum yield of 1.3 mt/ha during La Niña and El Niño years, respectively. Coastal inundation in Surigao due to a 1-meter sea level rise brought about by typhoons will result to in total land loss of 1.4 million square meters of land. Doubling the sea level rise (worst case scenario) will increase total land loss to 2.0 million square meters. Extreme sea level changes will occur during intense tropical storms and typhoon occurrences as sea level rise will add up to the storm surges.[27]

State of Preparedness

The Philippines established a CCC in 2009. It is tasked to coordinate, monitor, and evaluate the government's plans and programs on climate change. The Commission spearheaded the formulation of the National Framework Strategy on Climate Change in 2010 and the National Climate Change Action Plan in 2011. The framework strategy was reinforced by the enactment of the Philippine Disaster Risk Reduction and Management Act of 2010 and the strengthening of the National Disaster Risk Reduction Management Council and the local disaster risk reduction management councils. A cabinet cluster on Climate Change Adaptation and Mitigation was also established in 2011. The cluster prepared a roadmap with components on policy services, vulnerability assessment and/or risk mapping, modelling and forecasting, capacity building and sector-specific adaptation and mitigation actions. The cluster aims to ensure the adoption of climate change adaptation and mitigation measures by local government units (LGUs), the national government change mitigation agencies, and the general public; and to ensure that these are incorporated in their respective annual work plans and budgets. The cluster is composed of the Department of Environment and Natural Resources (DENR) Secretary as chair, the National CCC as secretariat, and several government agencies as members.

The National Framework Strategy on Climate Change was formulated in 2010 to ensure and strengthen the adaptation of the country's natural ecosystems and human communities to climate change, charting a cleaner development path for the country in the process. This is reinforced by the enactment of Republic Act 10121, the Philippine Disaster Risk Reduction and Management Act of 2010, and the creation of the National Disaster Risk Reduction and Management Council with counterparts at the provincial, municipal and/or city, and *barangay* levels.

The National Climate Change Action Plan, 2011–2028 contains the following strategic priorities: (i) food security, (ii) water sufficiency, (iii) ecosystems and environmental stability, (iv) human security, (v) climate smart industries and services, (vi) sustainable energy; and (vii) knowledge and capacity development. The Philippine Development Plan, 2011–2016 also identified climate change issues and policy direction to address these challenges.

The Palawan Council for Sustainable Development is a multisectoral and interdisciplinary body, created under *Republic Act 7611* or the Strategic Environmental Plan for Palawan *Act*. It is responsible for the governance, implementation and policy direction of the Strategic

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[27] Second National Communication on Climate Change: Philippine SNC Project (Project ID #0037339). The Philippines: Enabling Activities for the Preparation of the Second National Communication on Climate Change to the United Nations Framework Convention on Climate Change is a project of the Government of the Philippines and the Global Environment Facility through the United Nations Development Programme. DENR serves as implementing partner and national executing agency. This project is administered by the Inter-Agency Committee on Climate Change through the Environment Management Bureau as its secretariat.

Environmental Plan. The Mindanao Development Authority (MinDA) was created by virtue of Republic Act 9996 in 2010. Its purpose is ensure a coordinated and integrated approach in the formulation and implementation of various Mindanaowide interregional development plans, programs, and projects, including efforts to promote the active participation of Mindanao and Palawan in BIMP-EAGA. It covers all the provinces and cities in Regions IX, X, XI, XII, Caraga, and ARMM. Palawan will be included in the coverage of the MinDA only as it pertains to its involvement in BIMP-EAGA. It has an advisory board in BIMP-EAGA.

Government Programs on Climate Change Adaptation and Mitigation in Relation to the BIMP-EAGA Roadmap and Implementation Blueprint

BIMP-EAGA Strategic Pillar No. 1: Enhanced Connectivity

Component 3: Power Interconnection and Development of Renewable Energy

Mindanao has 14 diesel power plants, 1 coal-fired plant and 16 renewable energy projects, namely, 12 hydroelectric power plants, 2 geothermal plants, 1 solar photovoltaic project, and 1 biomass project, with a total installed capacity of 2,087 MW. Palawan has 11 hydroelectric power plant projects totalling around 127 MW. It has 3 bunker fuel power plants and 14 diesel power plants with a rated capacity of 82.46 MW.[28] The provincial government has a solar home system electrification project, where it provided 20 municipalities with solar energy home system units and solar battery charging stations.[29] As a climate change adaptation and mitigation measure, the DENR proposed the use of geothermal areas as air sheds. The Mindanao Power Monitoring Committee of MinDA tracks the energy capacity and performance of these power plants and studies potential renewable energy sources.

BIMP-EAGA Strategic Pillar No. 2: Food Basket Strategy

The programs of the Department of Agriculture include: Mainstreaming Climate Change Adaptation and Mitigation Initiatives in Agriculture, Climate Information System, Philippine Adaptation and Mitigation in Agriculture Knowledge Toolbox, Climate Smart Agriculture Infrastructure, Financing and Risk Transfer Instruments on Climate Change, Climate Smart Agriculture and Fisheries Regulations and Climate Smart Agriculture Extension System. Programs under Component 2 (Optimize the Potential of Agriculture, Livestock, and Fisheries Products for Exports) include the Department of Science and Technology's (DOST) project on Agriculture Reinvigorated through Integrating Crop Science with Weather Outlook and Data from Remote Sensing. The following projects of DOST are under Component 3 (Promote Sustainable Livelihoods of Farmers and Fisherfolk): Fishing Maps Generated using Space Technology and Sensors Developed and Deployed for Agricultural and Fishery Ecosystems for Food Safety and Better Yield.

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28 Government of the Philippines Department of Energy. 2014a. Powerpoint presentation during the *Cabinet Cluster on Climate Change meeting*. Quezon City. 5 August.

29 Government of the Philippines, Palawan Provincial Planning and Development Office. 2013. *Palawan Socio-economic Profile. Puerto Princesa.*

BIMP-EAGA Strategic Pillar No. 3: Tourism Development

The following sites of the community-based ecotourism development program are under Component 1 (Develop Tourism Products and Tourism-Related Infrastructure Focusing on Community-Based Ecotourism as a Flagship Program): Puerto Princesa in Palawan, Lake Sebu in South Cotabato and Tibolo in Davao del Sur.

BIMP-EAGA Strategic Pillar No. 4: Environment

Component 1: Sustainable Management of Critical Subregional Ecosystems

This component has several multi-country projects involving the Philippines (e.g., Coastal and Marine Resources Management in the Coral Triangle-Southeast Asia supported by the Asian Development Bank and the Global Environment Facility, and Developing Sustainable Alternative Livelihoods in Coastal Fishing Communities in the Coral Triangle (Indonesia and the Philippines supported by the Asian Development Bank). In addition, the Philippines has about 11 projects in support of this component, such as the Restrospective Analyses of Climate Change from Coastal Erosion Trends and Uplifted Coral Reef Assemblages-Vulnerability of Coastal Villages in Davao and Iloilo and Monitoring of Potentially Vulnerable Coastal Fisheries in Northwestern Mindanao.

Component 2: Climate Change Adaptation and Mitigation

The Philippines has about 39 projects addressing climate change adaptation and mitigation. Notable among these are the Climate Change Adaptation Program supported by the World Bank; the Climate Forecast Applications for Disaster Mitigation; Strengthening Capacities for Climate Risk Management and Disaster Preparedness supported by the Food and Agriculture Organization; and Adaptation to Climate Change and Conservation of Biodiversity supported by GTZ. DENR launched a number of programs, including the National Greening Program (P18 billion, 2014–2015), National Geohazards Assessment and Mapping, Watershed Characterization and Vulnerability Assessment, anti-illegal logging, air quality monitoring, and cadastral surveys.

The Department of Agrarian Reform's programs include the following: Pilot-testing of Climate Proofed Community and Community-Managed Potable Water Supply, Sanitation and Hygiene project in Agrarian Reform Areas. The National CCC is implementing Project READY (Hazards Mapping and Assessment for Effective Community-based Disaster Risk Management), Multihazard Mapping of Major River Basins, Eco-town Pilot Projects, and the Climate Twin Phoenix Project. The Department of Public Works has a flood control program that entails the upgrading of engineering design standards for flood control, drainage and slope protection works, and the construction of rainwater collection systems and slope protection works. The Department of Energy's mitigation strategies include renewable energy projects and programs on energy efficiency and conservation. The National Economic and Development Authority and the DILG are building the capacity of local governments through the project, Integrating Disaster Risk Reduction and Climate Change Adaptation in Local Development and Decision-making Processes. The Palawan Council for Sustainable Development and the European Union's Center for Appropriate Technology are implementing the Zero Carbon Resorts Project.

MinDA, in coordination with DENR has MindaNOW!–Nurturing Our Water Program, as a complementing initiative to the economic corridors in the context of balancing economic development and ecological integrity. This program has initiated the adoption of the payment for ecosystem services in the management of Mindanao's water sources (e.g., Mindanao river basin, Cagayan de Oro river basin, and Lake Lanao). In addition, it started the River Basin Management Information System for Mindanao. MinDA has a pipeline project on the massive rehabilitation of mangroves along the Eastern Seaboard of Mindanao. It also has a proposed Low Emissions Project that involves the updating of local emission factors, greenhouse gas inventory, the computation of carbon credits, and a study on renewable energy resources. As its contribution to the National Greening Program, MinDA is coordinating the "Treevolution" (massive tree planting) covering all the six regions in Mindanao. MinDA has a spatial development strategy called "Mindanao Development Corridors" aimed at achieving physical integration among key economic clusters in Mindanao and preparing the island for greater economic cooperation with the BIMP-EAGA and other ASEAN countries in anticipation of ASEAN integration by 2015. This includes the provision of common service facilities to Mindanao's industries and the establishment of biodiversity corridors as a climate change mitigation measure.

As the national authority for clean development mechanism (CDM), the DENR has given letters of approval for 112 CDM projects, with an estimated 8.6 million tonnes of carbon dioxide equivalent.[30] The Department of Agrarian Reform's project is on Pilot testing of Climate Proofed Community. The DOST-PAGASA-Advanced Science and Technology projects are: Light Detection and Ranging, Flood Modeling for Early Warning and Remote Sensing Satellite Images for Soil Moisture Mapping, Rapid Damage, Radar Images for Ground Subsidence and Crop Yield and Project NOAH (Nationwide Operational Assessment of Hazards).

The CCC's interagency projects are: Project READY (Hazards Mapping and Assessment for Effective Community-based Disaster Risk Management) Project- Multihazard Mapping of Major River Basins, Eco-town Projects, and Climate Twin Phoenix Project. The Department of Public Works and Highways has a flood control program that entails the upgrading of engineering design standards for flood control, drainage, and slope protection works, construction of rainwater collection systems and use of coconets and geosynthetic materials in slope protection works, identification of public facilities as safe shelter evacuation centers, and the removal of informal settlers and structures on waterways and no build zones.

Component 5: Mainstreaming Environment in Other Strategic Pillars of the BIMP-EAGA Cooperation

The CCC and the Office of Civil Defense of the DILG Capacity Building Project for Local Governments, entails the creation of a local government climate and disaster exposure database, contingency and climate and disaster risk-based planning, and the upscaling of the ecotown framework. The CCC, UNDP, the Australian government, and LGUs of the cities of Cagayan de Oro and Iligan and the provinces of Compostela Valley and Davao Oriental in Mindanao are implementing Project Climate Twin Phoenix to assess the vulnerability of areas and prioritize climate and/or disaster risk mitigation actions,

30 As of September 2012, the Philippines ranked 10th globally in terms of the number of registered CDM projects, which then numbered 58 (Government of the Philippines, CCC. 2014. *Draft 2nd National Communication to the United Nations Framework Convention on Climate Change*).

mainstream climate change and disaster risk reduction in local plans, and raise awareness and competency of local stakeholders.

DOST's projects on Water Resource Assessment Management involves the study on the effect of projected rainfall due to climate change on the hydrology cycle of our river systems, development of tools and know-how to monitor the health of our river systems, and the study of the natural defense system to protect the health and integrity of river systems against human and natural stressors. The Department of Agrarian Reform's water-related project is the Community-managed Potable Water Supply, Sanitation and Hygiene project in Agrarian Reform Areas. DENR has various watershed characterization, vulnerability assessment, and watershed rehabilitation projects. The DILG provides incentives and awards, such as the "*Galing Pook*" (Excellent Place) on governance innovations, including climate change measures.

Funding for Climate Change

The Philippine government appropriations for climate change adaptation and mitigation, estimated at around P30 billion in 2013 has increased by 2.5 times in real terms and 26% annually from 2008–2013, higher than the 6% growth in the national budget. While this funding is about 0.3% of gross domestic product, it still falls short of the recommended 2% of gross domestic product for climate actions by the *Stern Review* in 2006.[31] Hence, the Philippine government introduced the People's Survival Fund that will be used to finance climate change adaptation and mitigation projects of local governments, in accordance with the Climate Change National Strategic Framework.

Resilience Measures

An analysis of gaps and needs on climate change adaptation and mitigation was done, followed by an evaluation of a long list of options using the following criteria: effectiveness, costs, technical, financial, legal and administrative feasibility, political, social and cultural acceptability and required time.

For Palawan, the top climate change adaptation and/or mitigation options for food security, agriculture, and natural resources are: (i) improved watershed management; (ii) mapping of vulnerable agricultural areas; (iii) National Greening Program (nationwide reforestation); (iv) improved forest fire protection and control; (v) the development of a comprehensive system for monitoring (and modeling) natural resources, watersheds, and ecosystems under changing climatic and environmental conditions; (vi) biodiversity corridors; (vii) educational and outreach activities to improve natural resource management practices; (viii) enhanced monitoring systems for floods, droughts, storm surges, and other adverse impacts of climate change; (xi) research on indigenous climate resilient crop species; (xii) assessment of and program

[31] Government of the Philippines, CCC. 2014b. Powerpoint presentation to the Cabinet Cluster on Climate Change. Quezon City. 5 August.

implementation for priority areas for habitat protection and restoration; and (xiii) crop mixing for climate resilient, sustainable farming, and optimization of production in highly vulnerable agricultural areas.

For water security, the top options from the ranking of stakeholders in Palawan are: (i) comprehensive watershed management; (ii) water augmentation, including rain harvesting, surface runoff collection, stream flow diversion, and ponding; (iii) studies on how upstream water use impact on coastal estuaries and bays; (iv) improved monitoring and forecasting systems for floods, storm surges, and droughts; (iv) regular maintenance of irrigation systems to increase their efficiency; (vii) introduction of crops with lesser water requirements; and (viii) proper water allocation procedures and pricing. The proposed projects in San Vicente, Palawan espoused by Balangue (2013b) include the following: (i) the establishment of vegetative soil erosion control along stream banks; (ii) the construction of check dams and small water impounding structures; (iii) the construction of additional water reservoirs; (iv) the replacement of old, rusty water distribution pipes; and (v) water treatment in the reservoir, followig the Philippine standards for drinking water before distribution to consumers.

For energy security, the following options received high priority among the Palawan stakeholders: (i) the promotion of renewable energy resources, energy efficiency and conservation; (ii) updating of country and/or local emission factors and greenhouse gas inventory; (iii) study on potential installed and production capacity, investment requirements, operating costs, and projected revenues from sale of electricity per energy source, with focus on renewable energy sources.

For Mindanao's food security, agriculture, and natural resources in Siargao Island, Surigao del Norte, the proposed climate change adaptation and/or mitigation projects that were submitted to the CCC were: (i) the improvement of stream flow capacity project and riverbank stabilization in San Isidro; (ii) the establishment of protected areas; (iii) watershed rehabilitation; (iv) enhanced environmental protection (terrestrial, coastal, and marine); and (v) mangrove plantations. In the San Vicente municipality in Palawan, the study of Balangue (2013b) proposed the following: (i) increase water volume capacity of irrigation canals and drain out water from canals in rice paddies during rains to prevent flooding; (ii) green manure composting; (iii) seed banks; (iv) soil amelioration to address acidic soils; (v) coral reef rehabilitation and protection; (vi) establishment of sustainable forest and fuelwood plantations; (vii) enrichment planting of dipterocarpus tree species endemic to the area (e.g., kalantas and Dalingdingan); and (viii) training of households in low smoke and carbon emission charcoal production.

For water security, the proposed climate change adaptation and/or mitigation projects in Opol, Misamis Oriental in Mindanao include: (i) the identification and development of feasible local potable water sources, (ii) the establishment of a local water district with water treatment and recycling facilities, and (iii) the implementation of rainwater harvesting and/or storage systems. In Siargao del Norte province, the municipal government of del Carmen proposed a "Potable Water Supply and Micro Watershed Rehabilitation Project" while the municipal government of Pilar proposed a project on "Reducing Vulnerability to Climate Change through Improved Access to Safe Water and Sanitation."

Policies on Climate Change Adaptation and Mitigation

These include the following: (i) creation of a policy environment conducive for private investments in climate smart agriculture, (ii) integrated information tools and system technology for natural resources management and information sharing among sectors, and (iii) economic valuation of land resources to guide land use decisions, (iv) policy environment for sustainable development of future expansion areas for agriculture (e.g., those in higher elevation ecosystems coupled with sustainable management of forestlands), (v) joint policy on climate change data sharing for development planning and program implementation among BIMP-EAGA countries. (vi) incentives for local governments and the private sector for climate change resilience initiatives (e.g., payment for environmental services), and (vii) water allocation and pricing policies.

Supporting System (Strengthening Investment, Capacity Building, Technical Assistance, and Monitoring and Evaluation

Investments

Items for fund sourcing and investments include: (i) integrated watershed management based on vulnerability assessments; (ii) technical modernization of the PAGASA weather station networks, specialized facilities, tools and databases and calibration of observations for remotely sensed data application and improvement of data recovery, processing, storage and dissemination; (iii) the establishment of river basin gauging stations and buoys and automated stations in remote areas; (iv) regular maintenance of irrigation facilities to reduce water losses; (v) a comprehensive system for monitoring natural resources, watersheds, and ecosystems under changing environmental conditions; (vi) renewable energy sector investments as follows: hydropower (1,025.1 MW, P114.8 billion), geothermal (580 MW, P61.6 billion), wind (556 MW, P62.3 billion), and biomass (183.9 MW, P19.6 billion); and (vii) construction or upgrading of sewerage systems in major BIMP-EAGA cities as flood control measures.

Capacity Building

Capacity building in the following areas are needed: (i) integrated vulnerability assessment at the local level to formulate appropriate adaptation options; (ii) climate fit crop programming to support the food basket strategy of BIMP-EAGA; (iii) climate-based cropping mix, especially in highly vulnerable areas; (iv) how to access and use geospatial, social science data, sea level rise predictions, nearshore currents, circulation patterns, coastal upwelling effects on natural systems and productivity, potential impacts of storm surge, and event-related inland flooding to develop ridge to reef atmospheric or ocean-atmosphere-watershed modeling and inundation maps; and (v) methodologies on how to engage stakeholders in the development and implementation of strategic adaptation plans, including local and/or regional priorities for habitat protection and restoration (e.g., biodiversity corridors). MinDA also proposed a low emissions project, coupled with capacity building on computation of carbon credits. The staff of PAGASA also need enhanced training on climate monitoring and forecasting (i.e., meteorological, hydrological, aerological, upper-air, and remotely sensed observations and those of tidal and ocean currents).

Technical Assistance

Technical assistance is needed in the following: (i) generation of data on energy investment requirements, costs, potential installed capacity and actual production data for renewable energy sources, per energy resource; (ii) studies on local emission factors, downscaling of climate models to provinces and municipalities; (iii) tools for improved land use selection, assessment of watershed and ecosystem services under future climate and socioeconomic scenarios; (iv) technology for integrated natural resources information systems to guide stakeholders in the adoption of climate smart silvicultural practices, (v) assessment of the long-term effects of climate change (e.g., pressure of human resource use in the coastal areas and risks to communities); (vi) studies on the impacts of water policies on upstream and downstream environments; and (vi) the generation of updated data on water resources availability and crop-soil suitability. MinDA also requested for assistance on the establishment of an interface of its River Basin Management Information System with PAGASA's Nationwide Operational Assessment of Hazards or Project NOAH.

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