CLIMATE RISK VULNERABILITY ASSESSMENT (CRVA) OF CAVITE, LAGUNA, BATANGAS AND RIZAL PROVINCES IN REGION 4A

TERMINAL REPORT

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PROJECT INFORMATION

1. Title of the Project:

CLIMATE RISK VULNERABILITY ASSESSMENT (CRVA) OF CAVITE, LAGUNA, BATANGAS AND RIZAL PROVINCES IN REGION 4A

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3. Implementing Agency

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3.2. Collaborating Agency (s)

- Local Government Units in the provinces of Cavite, Batangas, Rizal and Laguna
- DA-RFO 4A
- DA-Southern Tagalog Integrated Agricultural Research Center
- PAGASA/DENR/NAMRIA

4. Project Duration : five (5) months

5. Project Location : Provinces of Cavite, Laguna, Batangas and Rizal Region 4A

6. Budget Allocation from DA-Region 4A : Php 3.836 M

ACKNOWLEDGEMENT

The CRVA Team of Cavite State University would like to express their gratitude to the following persons/institutions that made this project possible;

The Regional Field Office 4A CALABARZON of the Department of Agriculture thru RD Engr. Arnel V. De Mesa and OIC RED Ms. Vilma M. Dimaculangan for entrusting the project to the Cavite State University and for providing the necessary fund;

To the AMIA focal persons of DA RFO4A, Dr. Marie Ella Cecilia M. Obligado and RTD Avelita M. Rosales and technical staff for their unwavering support and cooperation in the conduct of the project;

The different local government units (LGU) thru their MAO and technical staff in the provinces of Cavite, Laguna, Batangas and Rizal in Region 4a for the active participation and generosity in providing data and information needed in the validation and completion of the project;

The Geographic Innovations for Development Solutions, Inc. (GRIDS) for extending technical assistance in the conduct of the several workshops of the project;

The administration of the Cavite State University thru the leadership of Dr. Hernando D. Robles for the support and commitment to the project; and

Above all to Almighty God for providing the team members the wisdom, determination, skills and strength in accomplishing the targets and deliverables of the project.

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INTRODUCTION

The United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as “a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.” Another definition from the Intergovernmental Panel on Climate Change (IPCC) describes it as “any change in climate over time, whether due to natural variability or as a result of human activity.” IPCC is an independent body which produces scientific assessments on climate change that contribute to the work of UNFCCC and support the need of policymakers. Based on their reports, human-induced warming has reached approximately 1℃, likely between 0.8℃ and 1.2℃, above pre-industrial levels in 2017 and it increases at 0.2℃, likely between 0.1℃ and 0.3℃, per decade. Warming of more than 1.5℃ above pre-industrial level has been even experienced in some regions by the decade 2006-2015 (Allen et al., 2018). This warming can be attributed to the increase in greenhouse gas (carbon dioxide, methane, nitrous oxide, chlorofluorocarbons) concentrations in the atmosphere. Globally, economic and population growth continue to be the most important drivers of carbon dioxide increases, mainly from fossil fuel burning (IPCC, 2014). Other sources include transportation, industry, commercial and residential, and agriculture.

In the Philippines, the following are some of the expected changes on seasonal temperature and rainfall according to Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA):

1. All areas will get warmer and more during summer months. Mean temperatures are expected to rise by 0.9℃ to 1.1 ℃ in 2020 and by 1.8 ℃ to 2.2℃ in 2050.
2. There is reduction in rainfall in most parts of the country during summer (March-May). In contrast, rainfall increase is likely during southwest monsoon (June-August) until the transition season (September-November) in most areas of Luzon and Visayas.
3. Wet seasons will become wetter and dry seasons also drier, increasing possible occurrence of floods, dry spells, and droughts.
4. Hot temperature will continue to become more frequent. The number of days with maximum temperature >35℃ is expected to increase in 2020 and 2050.

5. Extreme rainfall is projected to increase in Luzon and Visayas but the number of dry days is expected to increase in all parts of the country in 2020 and 2050.

Climate change and variability continue to exert increasing pressure upon the agricultural sector of the Philippines. Changes in temperature and rainfall patterns can significantly affect crop yields and affect incidence and outbreaks of pests and diseases in both plants and animals. Water stress both in terms of quantity and quality is highly likely. Warmer waters will result to migration of fish species and may negatively affect production of goods and services that are dependent on sea or freshwater bodies. These impacts are tied to the economic status of the country and can cascade into more adverse impacts. Food insecurity can lead to more malnutrition, higher poverty level, and even social unrest and conflicts. Clearly, the impacts of climate and climate-related disasters to the agricultural sector of the country is tremendous and creates a series of other negative impacts to all the other sectors of the society.

The three sectors that record the highest economic damage resulting from geophysical hazards in the Asia Pacific region are transport, housing and agriculture, whereas the agriculture sector is recognized as the most vulnerable of all sectors (UNESCAP, 2015). Philippines ranked 3rd among the most vulnerable countries to climate change and there was Php 290 B total value or production losses in the agriculture sector from 2010-2019 (DA, 2021). A better understanding of major agricultural vulnerabilities to climate risks is therefore fundamental to achieving more resilient farming systems, especially among poor rural areas. It is necessary to identify and prioritize, at a high resolution scale, the municipalities and relevant crops that are most vulnerable to climate risks. In this context, building resilience is not perceived as the ultimate goal, but rather as the intermediate main outcome contributing to the long term goal of improved communities coping capacities to a high degree of climate risks (Bene et al., 2015).

To address this challenge, the Department of Agriculture (DA) mandated the mainstreaming of climate change in the programs, plans, and budget of the department. Under the National Program on Climate Change in Agriculture, the umbrella project “Adaptation and Mitigation Initiative in Agriculture” or AMIA was created, which the Department of Agriculture Systems-wide Climate Change Office (DA-SWCCO) of the Office and Policy and Planning is tasked to oversee. AMIA, as the flagship program of the department for climate adaptation and mitigation, envisions to build climate-resilient livelihood and communities in the Philippine Agri-fisheries sector through Climate Resilient Agri-Fisheries (CRA) approach. AMIA aims to address multiple Sustainable Development

Goals (SDGs): SDG 1 - No Poverty; SDG 2- Zero Hunger; SDG 5 - Gender Equality; SDG 8 - Decent Work and Economic Growth; SDG 10 - Reduced Inequalities; SDG 12 - Responsible Consumption and Production; SDG 13 - Climate Action; SDG 14 - Life Below Water; and SDG 15 - Life on Land (http://amia.da.gov.ph).

Through the AMIA Component 1 project in 2015-2016, DA has undertaken vulnerability assessment focusing on key hotspots for risks and hazards in the country. While this is a useful starting point for vulnerability assessment – representing exposure to climate risks – a combined analysis for sensitivity and adaptive capacity would result in a more comprehensive climate-risk vulnerability assessment.

In 2017, AMIA launched an integrated field-level action for establishing climate-resilient agri-fisheries (CRA) communities. It also introduced complementary activities for building appropriate climate responsive financial and other support services. AMIA aims to invest in the launching of CRA communities – as the initial target sites for action learning, supported by an integrated package of climate services and institutions, within a broader food system/ value chain setting. The program is now geared towards out-scaling CRA to all regions and provinces in the Philippines. A key step in the targeting and planning for CRA communities is to conducting climate risk vulnerability assessment (CRVA) in the provinces. This ensures that AMIA investments are cost-effectively channeled to support its overall goals and outcomes. Furthermore, it addresses the inherent spatial and temporal variabilities within and across sites.

CRVA involves the assessment of the three key dimensions of vulnerability in the agricultural sector. These are as follows:

1. **exposure** - the nature and degree to which a system is exposed to significant climate variations (IPCC, 2014);
2. **sensitivity** - the increase or decrease of climatic suitability of selected crops to changes in temperature and precipitation; and
3. **adaptive capacity** - the ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences (IPCC, 2014).

To support regional targeting and planning for the AMIA, CRVA is necessary to be conducted at the proposed AMIA sites. For the provinces of Cavite, Laguna, Batangas, and Rizal, DA Regional Field Office 4A collaborated with Cavite State University (CvSU), aided with technical assistance from Geographic Innovations for Development Solutions (GrIDS, Inc.) to meet this objective.

The output of the CRVA will show for each municipality of the four provinces the following: (1) different levels of exposure to changes in climate (precipitation and temperature); (2) different levels of hazard risks; and (3) levels of adaptive capacity.

A full CRVA is essential for higher-resolution and longer-term geographic targeting. Vulnerability assessment is a key step in building climate resilient communities. It identifies the geographical areas that are in most need of interventions and the types of interventions appropriate. Recently, the focus of vulnerability has shifted to a wider social and economic driver that affects people's response to climate pressures.

Adaptation prioritization is framed using major vulnerabilities and priority adaptation activities based on the level of exposure to long term climate change and climate hazards. The focus of this vulnerability assessment is to identify key climate risk per municipality as a result of long-term impact to crop suitability and exposure to climate extreme events and variability. The different levels of capacity for adaptation was then assessed using the seven capitals of adaptive capacity (economic, natural, social, human, physical, anticipatory, and institutional).

Objectives

CRVA results are critical to climate change planning and design of further research and development work of DA to build CRA communities. The resulting information would provide DA with necessary information to develop customized strategic action research and development interventions to target key climate risks for each municipality in Region 4A.

The general objective of this project is to assess the climate risk vulnerability of the agriculture sector in key Philippine regions, and to guide DA RFO 4A in targeting and planning of CRA.

Specifically, this project aimed to:

1. identify and prioritize province-specific climate risks that threaten resilience of agriculture communities; and

2. support DA in planning and designing climate-risk responsive development initiatives to build resilience among agriculture communities.

Study Sites

Under the climate change program of the Department of Agriculture (DA), a climate risk vulnerability assessment (CRVA) for four (4) provinces in Region IV-A (Figure 1) was conducted to guide the targeting and planning of climate-resilient agricultural communities to ensure that investments are cost-effectively channeled to support its overall goals and outcomes.

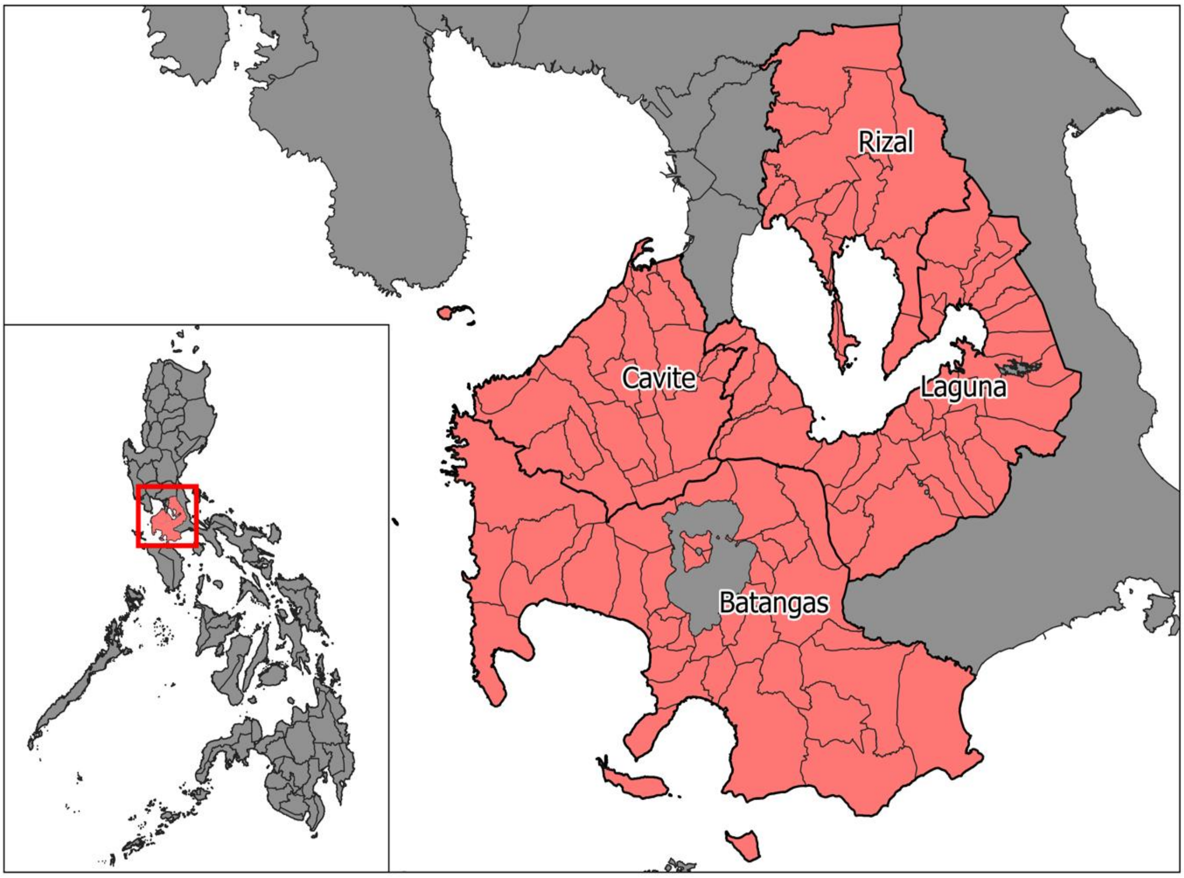


Figure 1. Target provinces in Region 4A, Philippines

Analytical Framework

The strategy and implementation of the vulnerability assessment was based on the developed framework of the International Center for Tropical Agriculture (CIAT) as shown in Figure 2 (Parker et al., 2019, Lan et al., 2016, Baca et al., 2014, Bouroncle, 2016). CRVA in the context of the CIAT framework defined the three key dimensions as follows:

1. Exposure 1 (Sensitivity): The increase or decrease of climatic suitability of selected crops to changes in temperature and precipitation (Parker et al., 2019).
2. Exposure 2 (Hazards): The nature and degree to which a system is exposed to significant climate variations (IPCC, 2014).
3. Adaptive Capacity: The ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences (IPCC, 2014).

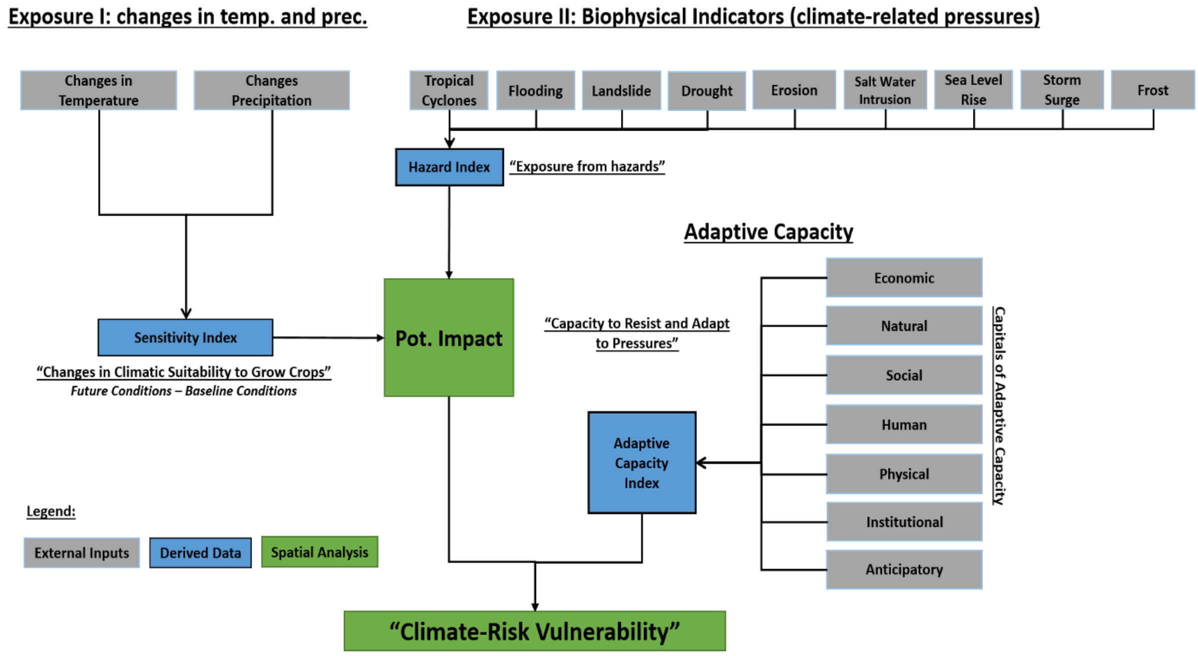


Figure 2. Climate Risk Vulnerability Assessment Framework
(a CRVA framework developed by CIAT customized to the conditions of Philippines)

$$f(Haz, Sens, AC) = \sum_{n=1}^{n}(Haz(wh) + Sens(ws)) + (1 - AC(wa)) \quad \text{Equation 1}$$

where:

Haz = hazard index
Sens = sensitivity index (i = crop)
AC = adaptive capacity index
w_h *= weight given for hazard*
w_s *= weight given for sensitivity*
w_a *= weight given for adaptive capacity*

The sensitivity analysis was based on the assumption of a high emission scenario by 2050 (RCP 8.5) whereas the adaptive capacity component is derived from the up-to-date available data. The detailed composition of each component is shown in Figure 1. The resulting vulnerability assessment enables evidence-based spatial targeting of agricultural extension and financial investment in areas most at risk or tailored to a specific hazard, crop or lack of adaptive capacity.

Beyond the focus on exposure to risks/hazards (in which most of the studies in the Philippines used), the previous study of CIAT recognizes that vulnerability targeting requires understanding the differential impact of these risks on communities depending on degree of sensitivity and their adaptive capacity. Agriculture is a climate-dependent activity and is highly sensitive to climatic changes and climate variability. As reported by Ray et al. (2015), climate controls 33% of global yield variation. In some areas in the Philippines, yield penalty for Maize can decrease by 44% and 35%, by 2020 and 205 respectively (Balderama et. al., 2016). Climate models (and ensembles of climate models) provide insight into future climatology (hotter, drier, wetter, cooler, etc.) and allow understanding of the heterogeneity of future climates and the expected average climatology in any particular region over time. Combined with crop models and climate downscaling approaches, the long-term shocks associated with climate conditions can also be modeled and estimated. Understanding future climate also facilitates understanding of how climate conditions (temperature and precipitation) may affect the niches of crops, pests and disease.

METHODOLOGY

Assessing impacts of climate change to crop suitability (Exposure 1: Sensitivity)

Figure 3 describes the data requirements and information flow for the analysis of potential impact of climate change to crops. The study relies on spatial analysis of climate suitability (precipitation and temperature related) of various important crops in Cavite, Laguna, Batangas, and Rizal and compares baseline and future (year 2050) climatic crop suitability. The change in suitability is estimated by subtracting the current climatic suitability from the future suitability. An ensemble of species distribution models (SDM) provided by Biomod2 (Thuiller et al., 2016 and Thuiller et al., 2009) package in R was used to map climate suitability of crops with a sufficient number of crop occurrences. On the other hand, EcoCrop (Hijman et al., 2001, Ramirez-Villegas, et al., 2013) was used to model crops that have limited occurrence data but are considered important for the livelihoods included in the agricultural sector.

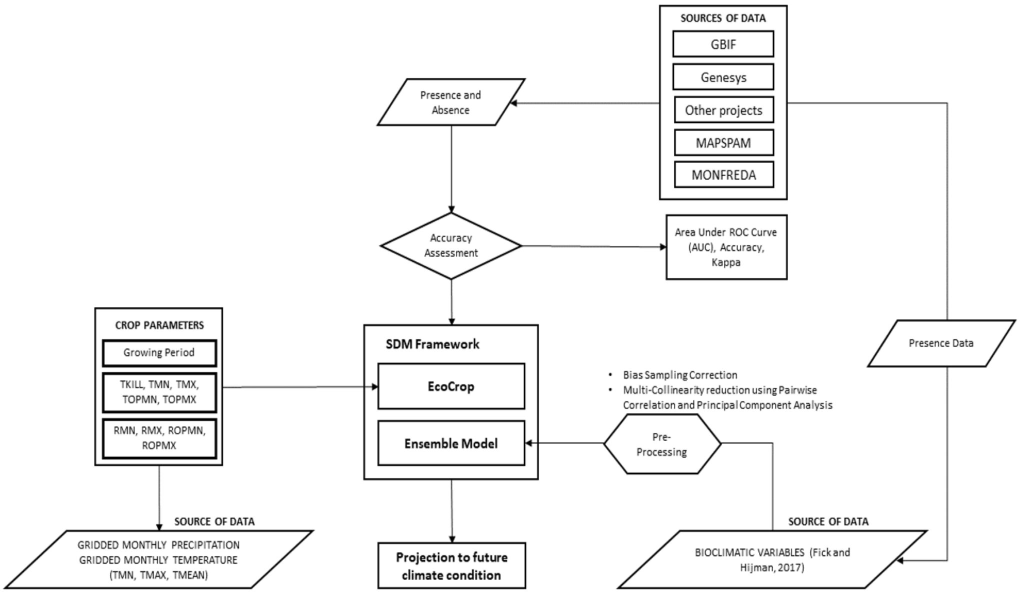


Figure 3. Workflow for assessing climate impacts to crops

Analyzing changes in climate-crop suitability involves a two-step process. The first step is to assess the baseline (current climate condition) climate suitability, and next is to predict the suitability in a later time period.

1. Crop selection and collection of occurrence data

A series of workshops was conducted to identify the priority crops. The list of crops for sensitivity analysis, as suggested by the workshop participants, are shown in Table 1. This was also based on the priority banner crops of DA and on those included in the provincial commodity investment plan.

Table 1. List of crops suggested by stakeholders for sensitivity analysis

PROVINCE	RICE	CORN	COFFEE	CACAO	PINEAPPLE	CASSAVA	COCONUT
Batangas	✓	✓	✓	✓	✓	✓	✓
Cavite	✓	✓	✓	✓	✓		
Laguna	✓	✓	✓	✓	✓		✓
Rizal	✓	✓			✓		
Total presence data	537	326	255	295	180	69	254

Occurrence data were collected using participatory mapping with agricultural technicians and staff from local government units to locate existing crop presence data in each of the municipalities.

The mapping exercise was designed to rapidly collect data from the field. A map was provided with features that can assist in locating the occurrence of crops, such as road and river networks, digital elevation model, municipal and barangay (smallest administrative boundary where decisions and actions are made) boundaries. A fishnet was also included in the map which shows the grids representing the climate resolution. To identify the location of the crops, the experts based their location estimates using the area and production data at the barangay level. For each square polygon, the participants were asked to identify the presence of crops. Additionally, these rules were set during the mapping workshop: Only one count of the same crop per pixel is allowed but multiple crops can be considered per pixel. For instance, if rice is present in multiple locations within the pixel, it can only be marked once. On the other hand, if both rice and maize are present within a pixel, then that pixel can be marked as rice and maize.

2. Baseline Climate Conditions

A total of 20 bioclimatic variables were selected to assess the climate suitability of crops (described in Appendix Table 1) representing annual trends, seasonality, and extreme or limiting environmental factors. For baseline conditions, the Wordclim dataset (available at Worldclim.org) (Hijmans, 2005) was used. Bio 20 (Number of consecutive dry days), a climate variable processed by the International Center for Tropical Agriculture (CIAT), was added to the bioclimatic variables from Worldclim. The bioclimatic variables are derived from monthly temperature and rainfall values and were processed to generate more biologically significant climate variables (Hijmans, 2005). These described bioclimatic factors are relevant in understanding the species response to climate change (O'Donnell and Ignizio, 2012).

3. Future Conditions

Crop distribution was modeled for the present and future conditions to assess the degree of changes in crop suitability under climate change. Thirty-three (33) CMIP5 GCM models (Appendix Table 2) under the representative concentration pathway (RCP) 8.5 scenario (IPCC, 2013 - based on IPCC Assessment Report 5) as basis to assess impact of climate change on climate-crop suitability. RCP 8.5 is characterized as increasing greenhouse gas emissions over time. The data can be downloaded from the Climate Change and Food Security website http://www.ccafs-climate.org/data_spatial_downscaling/.

Suitability change for each crop is obtained as the difference between the projected and baseline suitability values in each pixel (Bouroncle, et al., 2016, Eq. 1). The resulting pixel values may be negative or positive. A negative pixel value indicates that suitability has decreased in the future relative to baseline suitability values. A positive value, on the other hand, indicates that suitability has increased in the future relative to baseline suitability values. For each municipality, the average pixel values of suitability change were derived using zonal statistics. The mean suitability values across municipalities was reclassified following the range of values in Table 2.

$$\text{Suitability change} = \left(\left(\frac{Suitability_{future} - Suitability_{baseline})}{Suitability(baseline)}\right) \div Suitability(baseline\right) \times 100 \quad \text{Eq. 2}$$

where: *future = result of species distribution model for future conditions*
baseline = result of the species distribution model for baseline condition

Table 2. Sensitivity index based on percent change in crop suitability from baseline to future condition (year 2050)

PERCENT CHANGE IN SUITABILITY (Range in %)	INDEX	DESCRIPTION
Less than -50	1.0	Very high loss
> -50 to -25	0.5	High loss
> -25 to -5	0.25	Moderate loss
> -5 to 5	0	No change
> 5 to 25	-0.25	Moderate gain
> 25 to 50	-0.5	High gain
Above 50	-1.0	Very high gain

Assessing hazards and developing a hazard index (Exposure 2: Hazards)

A combination of natural hazard datasets were used to estimate the area in each municipality and province that are under pressure from climate and hydrometeorological risks. The hazard index developed from the datasets collected were also based on official hazard maps of the Department of Environment and Natural Resources (DENR) and DA. The dataset referred to historical databases to evaluate the current potential risk. The analysis of hazards was limited to baseline conditions because many climate hazards can be large-scale singular events and projections of climate hazards to the year 2050 may add layers of uncertainty. However, while it is not possible to attribute singular extreme events to progressing climate change, it is agreed that the likelihood of most extreme events is increasing under progressing climate change (IPCC, 2012).

1. **Hazard Dataset**

   The development of a hazard index relies on spatial analysis of the weighted combination of different historical climate-related natural hazards in the Philippines using open-sourced and official data (Table 3). Eight (8) hazards were identified in Region 4A that puts pressure on crop production. These are typhoon, storm surge, flood, drought, erosion, landslide, saltwater intrusion, and sea level rise. Since each hazard has a different degree, intensity and frequency, the potential damage also varies. The hazard weights developed by the International Center for Tropical Agriculture (CIAT) for Luzon was used and applied in Region 4A. The weights were derived based on participatory workshops with regional partners and experts using the following criteria: 1) frequency of occurrence, 2) impact of local household income, 3) impact to key natural resources to sustain productivity (refers to how key resources such as water quality and quantity, soil fertility, and biodiversity are affected), 4) impact to food security of the country, and 5) impact to national economy. Among the eight hazards, typhoons (20%), flood (19%), and drought (14.5%) received larger weights. Each hazard data was aggregated by municipality and by using zonal statistics. Spatially weighted sum was used to develop the hazards index for each of the municipality. Values were normalized using Eq. 2 to standardize the value from 0 to 1 using the equation below.

$$\text{hazidx\_norm} = \frac{x - x_{min}}{x_{max} - x_{min}} \qquad \text{Equation 3}$$

where: *hazidx_norm is the normalized values of the hazard index*

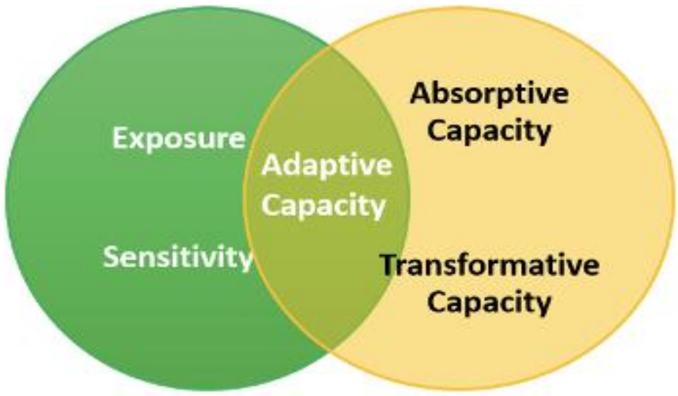
Table 3. Overview of hazard dataset used for exposure component

PARAMETER	SOURCE	UNIT OF MEASUREMENT, SPATIAL AND TEMPORAL RESOLUTION
Typhoon	UNEP / UNISDR, 2013 (https://preview.grid.unep.ch/)	1-kilometer pixel resolution. Estimate of tropical cyclone frequency based on Saffir-Simpson scale category 5 (> 252 km/hr) from year 1970 to 2013.
Flooding	Mines and Geosciences Bureau, Department of Environment and Natural Resources (MGB, DENR)	1:10,000 scale. Susceptibility of flood risk for Philippines from the past 10 years
Drought	DA-AMIA multi-hazard map	Groundwater potential for the Philippines
Erosion	Bureau of Soils and Water Management	1:10,000 scale. Soil erosion classified from low to high susceptibility
Landslide	Mines and Geosciences Bureau, Department of Environment and Natural Resources (MGB, DENR)	
Storm Surge	Disaster Risk and Exposure Assessment for Mitigation, Department of Science and Technology (DREAM, DOST)	
Sea Level Rise	AMIA multi-hazard map	Assumption based on 5m sea level rise
Saltwater Intrusion	National Water Resources Board (NWRB)	Groundwater potential for the Philippines

Adaptive capacity assessment

Adaptive capacity forms one of the three pillars of the vulnerability assessment, in addition to exposure and sensitivity to climate change (Figure 1). At the same time, it is also one of the three components in measuring resilience, in addition to absorptive coping capacity and transformative capacity (Figure 4). Both are integrated concepts in a coupled human-environment system (Lei et al., 2014). Adaptive capacity is defined by IPCC (2014) as the "ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences."

Vulnerability & Resilience



Vulnerability	Resilience
Components: Exposure, Sensitivity, Adaptive Capacity	Components: Absorptive Capacity, Adaptive Capacity, Transformative Capacity
"Passive": What stressors are regions/societies exposed to?	"Active": Capacities to respond to stressors or changing conditions

Figure 4. Concepts of vulnerability and resilience (IPCC, 2014)

The adaptive capacity index for this vulnerability assessment is compiled by a set of proxies: none of them can give a reliable statement of the current level of adaptive capacity when taken singly, but as an ensemble considering different capitals they become a powerful tool in understanding how well a population can cope with climate change and variability with their tangible and intangible assets. This methodology aims to compile information on a set of different factors such as physical, human, social, natural, economic, institutional, and anticipatory capitals. There are many indicators that could form a strong adaptive capacity index, but data availability was a driving factor in establishing the final index in Region 4A. This vulnerability assessment provides high resolution analysis on a regional level as this is where most socio-economic data can be derived. However, key indicators are often available only at the national or provincial level. Hence, the list of indicators in Table 4 is not restrictive but supplementary socio-economic data can be added to have a better understanding of the extent to which the population will be able to cope with climate change and its related risks.

1. **Indicator Identification Process**

   The adaptive capacity indicators were adopted from the preliminary list of indicators developed by CIAT using official and local datasets. A total of 17 indicators across five (5) capitals were developed. These indicators were validated, and if necessary, updated through workshops and secondary data collection with each LGU. Each of the indicators and sub-indicators were aggregated for each capital. The sum of all the AC capitals were used to represent the AC index. The AC index was normalized before calculating the vulnerability.

Table 4. List of selected adaptive capacity indicators and sub-indicators

CAPITAL	INDICATOR	SUB-INDICATOR	SOURCE
Economic	Annual Business Registration		National Competitiveness Council (2015)
	Agricultural wage for plantation and non-plantation		National Competitiveness Council (2015)
	Financial Institutions	Number of Financial Cooperatives	National Competitiveness Council (2015)
		Number of Micro-Finance Institutions	National Competitiveness Council (2015)
		Number of Rural Banks	National Competitiveness Council (2015)
	Poverty		(PSA, 2015)
Human	Health	Number of Public Doctors	National Competitiveness Council (2015)
		Number of Public Nurse	National Competitiveness Council (2015)
		Number of Citizens with Philhealth	National Competitiveness Council (2015)
		Number of Public and Private Health Facilities	National Competitiveness Council (2015)
		Number of Public and Private Clinics	National Competitiveness Council (2015)

	Education	Number of Public Teachers in Secondary Level	National Competitiveness Council (2015)
		Number of Public Teachers in Tertiary Level	National Competitiveness Council (2015)
		Ratio of Teachers to Students	National Competitiveness Council (2015)
		Number of Public Technical Vocational Schools	National Competitiveness Council (2015)
	Ratio of Police to Populations		National Competitiveness Council (2015)
Physical	Infrastructure	Road Network	National Competitiveness Council (2015)
		Road Density	National Competitiveness Council (2015)
	Basic Services	Access to Water	National Competitiveness Council (2015)
		Access to Electricity	National Competitiveness Council (2015)
	Communications	Number of Internet Providers	National Competitiveness Council (2015)
		Number of Telecommunication Providers	National Competitiveness Council (2015)
	Public Transportation	Number of Buses	National Competitiveness Council (2015)
		Number of Vans	National Competitiveness Council (2015)
		Number of Jeepneys	National Competitiveness Council (2015)
	% of crops irrigated		IWMI, 2010
Natural	% of forest cover (including mangrove forest)		NAMRIA 2010 Land Cover
Anticipatory	Presence of Disaster Risk Reduction Management Plan		National Competitiveness Council (2015)

Developing a climate risk vulnerability map integrating the three dimensions of vulnerability

A spatially-weighted overlay analysis was done to integrate the three dimensions of vulnerability. A workshop done by the Department of Agriculture was conducted to determine the weights of each dimension and was adopted (Dikitanan, 2017). A sensitivity analysis of weights was also done to assess the uncertainty of the vulnerability index for each municipality that were covered in the study.

Workshops conducted for the CRVA of Cavite, Laguna, Batangas and Rizal

Table 5 shows the general activities that were conducted for the climate risk vulnerability assessment of Cavite, Laguna, Batangas, and Rizal, as well as the expected outputs of the series of workshops (Table 6) that were conducted with the representatives of Municipal Agriculture Offices of the four provinces and the analysis of primary and secondary datasets.

Table 5. General activities and expected outputs of the project

ACTIVITIES	EXPECTED OUTPUTS
• collect geo-referenced information on crop occurrences across the target sites as inputs to modelling • assess climate change impact to crop suitability using niche-based (species distribution) machine learning models, or mechanistic models • validate the output to crop suitability using participatory or statistical method • collect and organize spatial information on hazards, such as typhoon, flood, drought, soil erosion, landslide, salt water	• climate impact maps on crop suitability (based on crop priorities per province) using machine learning or mechanistic model for four provinces in Cavite, Laguna, Batangas and Rizal. • validated hazard and hazard index maps for the four provinces • validated map of adaptive capacity by capital (economic capital, social capital, etc.) • database of validated adaptive capacity indicators (raw/cleaned data) • GIS-enabled data of crop occurrences and hazards (at

intrusion, sea level rise and storm surge • validate each of the hazard indicator maps through stakeholder consultation or statistical methods • produce composite of hazards to derive the hazard index for each municipality • collect and organize indicators for adaptive capacity • conduct workshop to validate dataset (either collected or generated) and crva maps • conduct workshop with DA-RFO 4A to select targeted sites for establishment of climate resilient village(s)	minimum the typhoon incidence, flood, drought, soil erosion, landslide, saltwater intrusion, sea level rise, and storm surge). • map of potential impact should be developed combining Exposure 1 and Exposure 2 • conduct sensitivity of weights to determine how each of the municipality might change its vulnerability levels with changing weight combinations • report of the project results with recommendations for targeting and establishing climate resilient village (CRVs). • knowledge products for the project outputs, i.e. poster, maps, infographics and manuals, as applicable

Table 6. Workshops and stakeholders' consultations conducted to attain the objectives of the CRVA project

WORKSHOP	OBJECTIVES	DATE	VENUE
Crop Occurrence Mapping Workshop	• introduce the concept of climate risk vulnerability assessment • train participants in using GIS as tool for mapping crop occurrence • digitize actual crop occurrence for each municipality	November 14-15, 2019	Cavite State University, Indang, Cavite

Hazard Mapping and Validation Workshop	• introduce the concept of climate hazards • train participants in using GIS as a tool for deriving hazard index • validate the hazards in each municipality and province	December 5-6, 2019	Cavite State University, Indang, Cavite
Adaptive Capacity Consultation Workshop	• train the participants in using GIS as a tool in deriving adaptive capacity index and in vulnerability mapping	February 18-19, 2020	Cavite State University, Indang, Cavite
Cost Benefit Analysis Workshop	• introduce the use of CBA in determining viable climate-resilient agriculture (CRA) adaptation options • validate the CRA practices of farmers	March 23-24, 2021	Online via Cisco Webex
Output Sharing	• identify and validate most vulnerable areas/municipalities • show/present maps/ graphical outputs for crop suitability, climate and climate-related hazard, adaptive capacity and overall vulnerability of the agricultural sector of different LGUs • guide the participants/ LGUs in determining possible set of intervention for consideration	March 16-18, 2021 April 13-15, 2021	DA RFO 4A CALABARZON, STIARC, Lipa City Online via Cisco Webex

Workshop 1: Crop Occurrence Mapping Workshop

The first workshop was held in Hostel Tropicana, Cavite State University, Indang, Cavite. The workshop was divided into two clusters: the first cluster with participants from Batangas and Cavite was held on November 12-13, 2019 and the second with participants from Laguna and Rizal was held on November 14-15, 2019. The participants are from the Municipal Agricultural Offices (MAO) and Office of the Provincial Agriculture (OPA) of the four provinces.

In preparation for the workshop, the participants were asked to bring data on crops in the municipality (i.e., recent area, production, yield), damage report (i.e., for flood, typhoon, and drought), maps (i.e., administrative maps, crop location maps, land-use/land cover maps, hazard maps), and GPS readings or coordinates of crops, if available. These data sets were necessary to fill in the requirements of the CRVA framework and assess the climate risk and vulnerability of each municipality.

The concept of CRVA was introduced to the participants to familiarize them with how it works and how it can positively impact not just the farmers, but the country in general. CRVA is crucial not just for disaster readiness and risk reduction but also for the sustainability of the country's agriculture. The CRVA framework was also emphasized in the presentation to familiarize the participants with its components and steps.

The participants were introduced to Geographic Information System (GIS) using QGIS. QGIS was the preferred software because it is free and open source. Most of the participants do not know how to use QGIS, hence, it was a good opportunity for them to learn and be familiar with the software as they can also use it in future related projects and tasks in their respective MAOs.

Necessary shapefiles were provided to the participants and they were trained on the features and functions of the software. The participants were taught how to make a shapefile and to put points on the map to indicate location of the major crops present in their municipality or province. These data were necessary to produce the crop occurrence maps.

At the end of the workshop, CRA Prioritization forms were distributed to the participants in preparation for the next workshop. This form was used to identify two priority crops in each municipality, as well as CRA Recommendation for the hazards affecting these crops.

Mr. Milben Bragais of GRIDS, Inc. discussing about climate risk vulnerability assessment

Facilitators and participants of the Crop Occurrence Mapping Workshop for Cavite and Batangas Provinces held on November 12-13, 2019 at Hostel Tropicana, Cavite State University

Facilitators and participants of the Crop Occurrence Mapping Workshop for Laguna and Rizal held on November 14-15, 2019 at Hostel Tropicana, Cavite State University

Workshop 2: Hazard Mapping and Validation Workshop

The second workshop was held in Hostel Tropicana, Cavite State University, Indang, Cavite on December 5-6, 2019 and was attended by representatives from the MAO and OPA of the four provinces. Since there were new participants, a refresher on the CRVA methodology and in using the QGIS software were done. The data on crop occurrence that were created by the participants during the first workshop were also presented.

Hands on exercises were done on data preparation for deriving the hazard index. The participants were grouped according to their province to validate the hazards and the hazard index in their corresponding areas. Additional data on damage reports to agriculture, adaptive capacity, list of climate resilient agricultural practices were also collected from the participants at the end of the workshop.

Ms. Jane Girly Balanza discussing hazard mapping and validation during the Hazard Mapping and Validation Workshop held on December 5-6, 2019 at Hostel Tropicana, Cavite State University

Participants of the Hazard Mapping and Validation Workshop for Cavite, Batangas, Laguna, and Rizal doing the maps for their respective municipalities

Participants of the Hazard Mapping and Validation Workshop held on December 5-6, 2019 at Hostel Tropicana, Cavite State University

Workshop 3: Adaptive Capacity Consultation Workshop

The third workshop was done in Hostel Tropicana, Cavite State University, Indang, Cavite on February 18-19, 2020 and was attended by representatives from the MAO and OPA of the four provinces. A review of the CRVA methodology and of QGIS methods were done at the beginning of the workshop. The collated data on crop occurence and hazard mapping were also presented and additional adaptive capacity data were collected.

The participants were trained on data preparation for deriving adaptive capacity index and vulnerability mapping. Concepts on cost benefit analysis were discussed in preparation for the next workshop, as well as other data requirements from previous workshops that may still be provided by the participants.

GRIDS, Inc. facilitator presenting the Crop Occurrences and Hazard Data from previous workshops

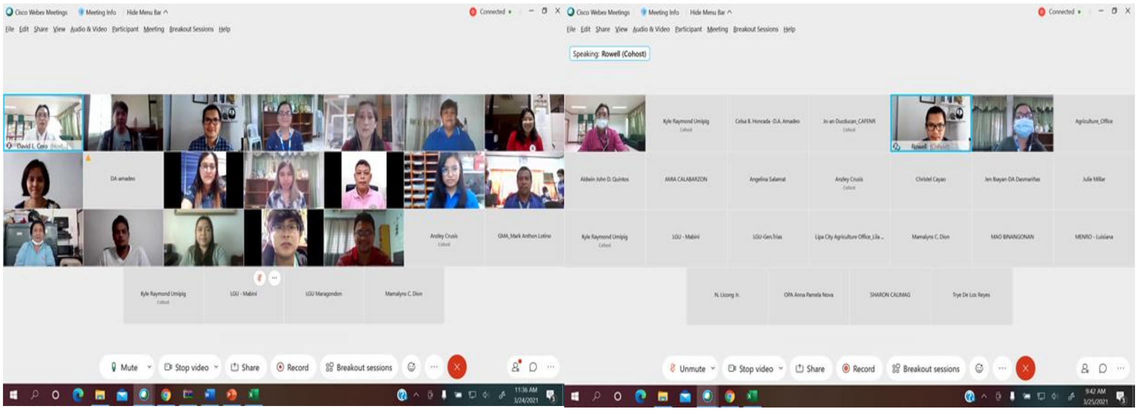
Hands-on Exercise on vector and raster data manipulation during the Adaptive Capacity Consultation Workshop held on February 18-19, 2020 at Hostel Tropicana, Cavite State University

Participants of the Adaptive Capacity Consultation Workshop for Cavite, Batangas, Laguna, and Rizal doing the vulnerability map for their respective municipalities

Participants and Facilitators of the Adaptive Capacity Consultation Workshop held on February 18-19, 2020 at Hostel Tropicana, Cavite State University

Workshop 4: Cost Benefit Analysis and Climate-Resilient Adaptation Practices

An online workshop (via Cisco Webex) on cost benefit analysis was conducted to introduce the use of CBA in determining viable climate-resilient agriculture (CRA) adaptation options and to validate the CRA practices of farmers. The basic concepts of CBA were reviewed and the use of benefit-cost ratio (BCR), net present value (NPV), internal rate of return (IRR), and annuity equity value (AEV) were explored to determine the feasibility of options.



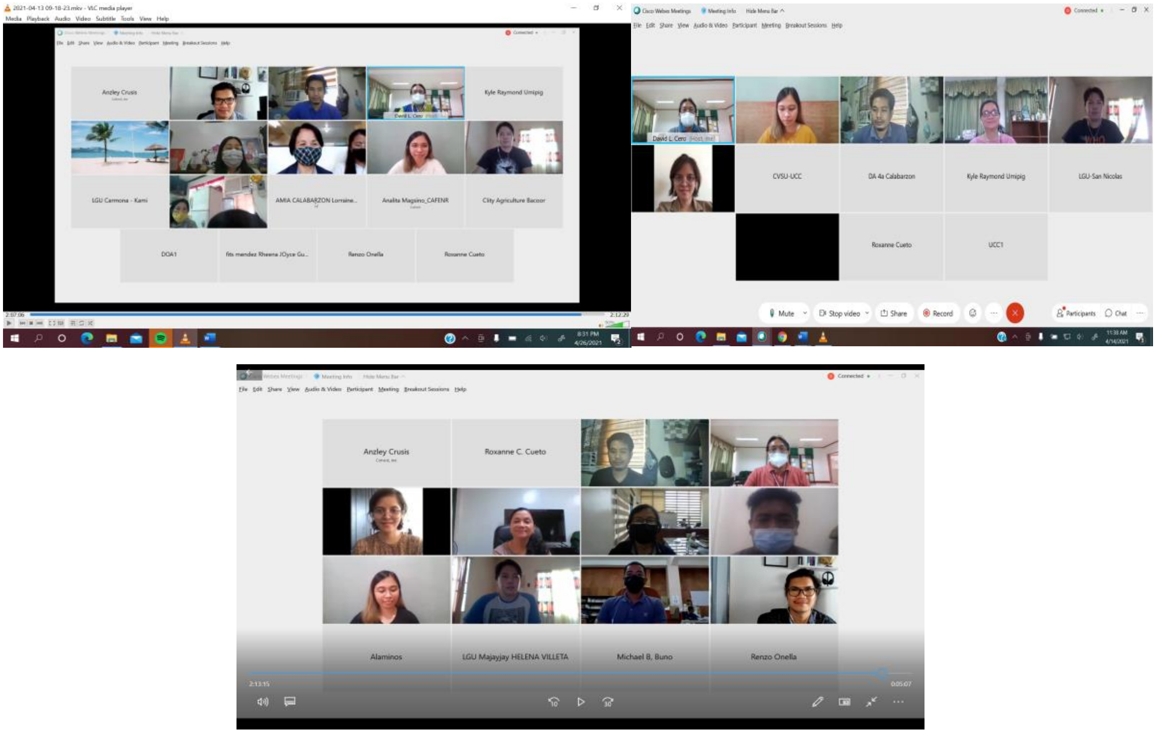
Screenshots of Participants and Facilitators of the Cost-Benefit Analysis Workshop held on March 23-24, 2021 via Cisco Webex online platform

Workshop 5: Output Sharing

Highlights of the results of the project conducted were presented to the stakeholders. Two (2) sessions were conducted in the project output sharing. The first one was a three-day activity on March 16,17, and 18, 2021 held at the DA-RFO 4A at Lipa City participated in by representatives of the agricultural sectors from the four (4) provinces in the region. These were done by batch to ensure adherence to existing health guidelines set by IATF in view of the COVID 19 pandemic limiting the number of participants in this kind of gathering. A total of 87 representatives attended the output sharing activity. An open forum after output presentation highlighted the activity where questions and clarifications were raised and answered.

Pictures of participants in the output sharing activity held on March 16,17 and 18, 2021
at DA RFO 4A CALABARZON, STIARC, Lipa City, Batangas

The second output sharing activity was done virtually using Cisco Webex platform on April 13, 14, and 15, 2021. Similarly, three clustered sessions were conducted – Cavite and Rizal cluster, Batangas cluster, and Laguna cluster. Also, an open forum after output presentation highlighted the activity where questions and clarifications were raised and answered. Issues on the overall vulnerability of their respective provinces based on exposure to climate hazards, sensitivity of major crops grown and adaptive capacity of their area were tackled and resolved.



Screenshots of some of the participants in the virtual sharing of output on April 13,14,and 15, 2021 via Cisco Webex platform

RESULTS AND DISCUSSION

Climate Risk Vulnerability

The final climate risk vulnerability map (Figure 5) is based on the integration of exposure, sensitivity, and adaptive capacity components showing different classes of vulnerability by municipality (low to very high). The weights of each of the components was adopted from the study of CIAT which indicates 30% for impacts (sensitivity + hazards), and 70% for adaptive capacity.

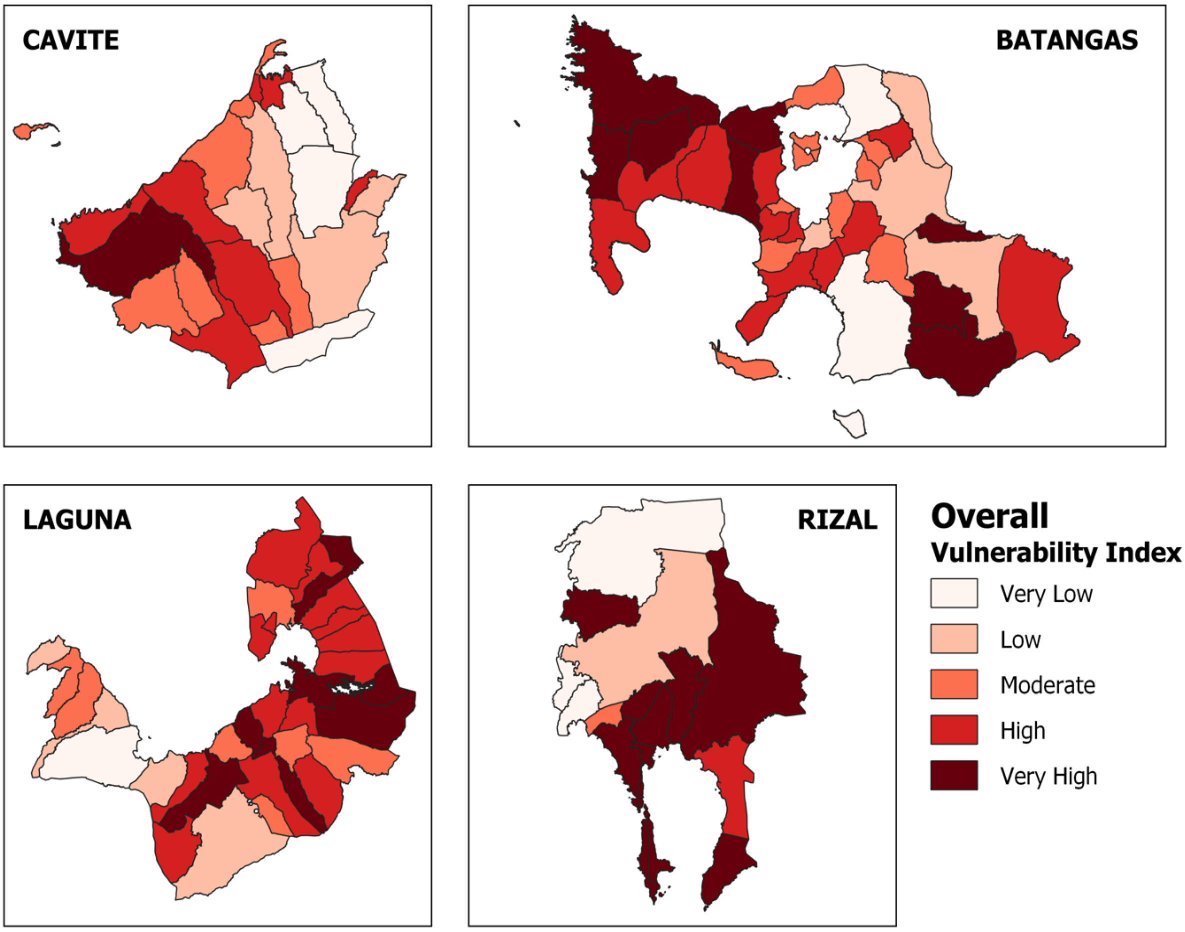


Figure 5. Overall climate risk vulnerability for four provinces in Region 4A – Cavite, Laguna, Batangas and Rizal

Two (2) vulnerable municipalities (Table 7) per province were selected and examined in detail how the various indicators and capitals of the VA explains the vulnerability. The selection of the municipalities is entirely based on the vulnerability rating with no intention to direct the interventions of DA in these municipalities. The following discussion demonstrate how to use the information contained in the database.

Table 7. The three components of vulnerability for each selected municipality

Province and Municipality	Vulnerability	Sensitivity Index	Hazard Index	AC Index
Batangas				
Lobo	Very High (0.8 – 1.0)	High loss for rice, coffee, and cacao	Moderate	Very Low
Nasugbu	Very High (0.8 – 1.0)	High loss for Rice	Very high	Low
Cavite				
Maragondon	Very High (0.8 – 1.0)	High loss for rice, slight loss to maize, coffee, and cacao	Very High	Very Low
Tanza	Very High (0.8 – 1.0)	Very high loss for coffee. Slight loss for rice and maize	High	Very Low
Laguna				
Lumban	Very High (0.8 – 1.0)	High loss for coffee and pineapple. Slight loss for rice and coconut	High	Very Low
Santa Maria	Very High (0.8 – 1.0)	High loss for pineapple, coffee, and cacao	Very High	Low
Rizal				
Binangonan	Very High (0.8 – 1.0)	High loss for coffee, cacao, and pineapple. Slight loss for rice	High	Very Low
Morong	High (0.6 – 0.8)	High loss for coffee, cacao, and pineapple. Slight loss for rice	Low	Very Low

Sensitivity (Exposure 1)

Simulation models show significant changes in the suitability of the study sites to major crops. Figures 6, 7 and 8 show the comparative suitability to coffee, rice and corn in the four provinces in the year 2050 as affected by the changing patterns in temperature and precipitation. Modelling were also run for other major crops for the provinces of Cavite, Laguna, Batangas and Rizal.

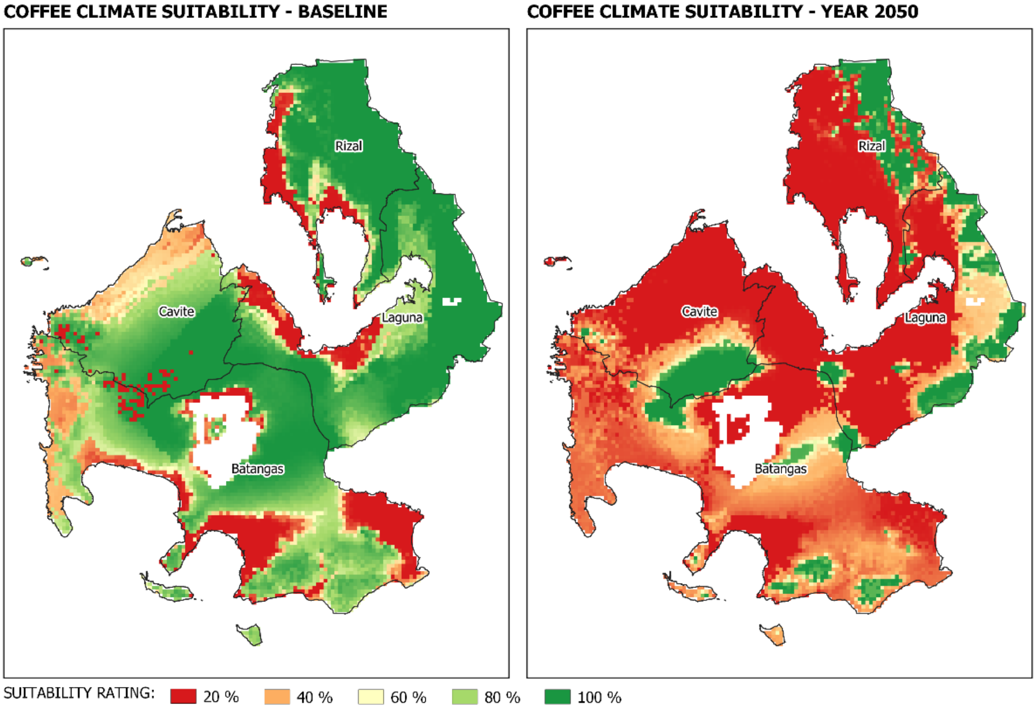


Figure 6. Comparative climatic suitability to coffee of the of the provinces of Cavite, Laguna, Batangas and Rizal in the year 2050 vs. baseline

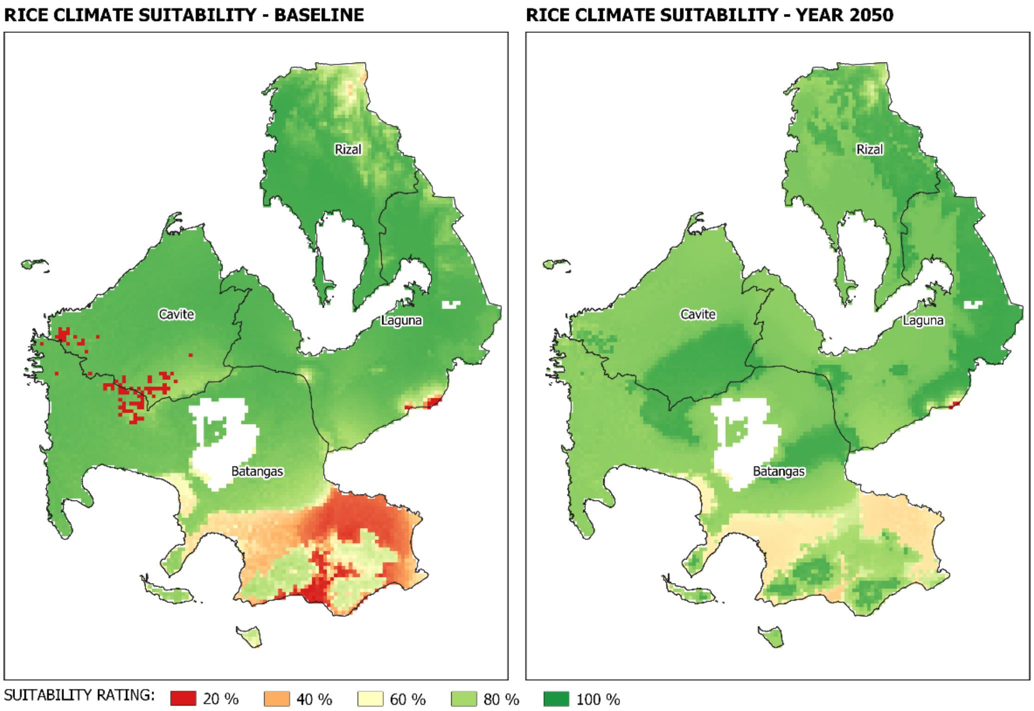


Figure 7. Comparative climatic suitability to rice of the of the provinces of Cavite, Laguna, Batangas and Rizal in the year 2050 vs. baseline

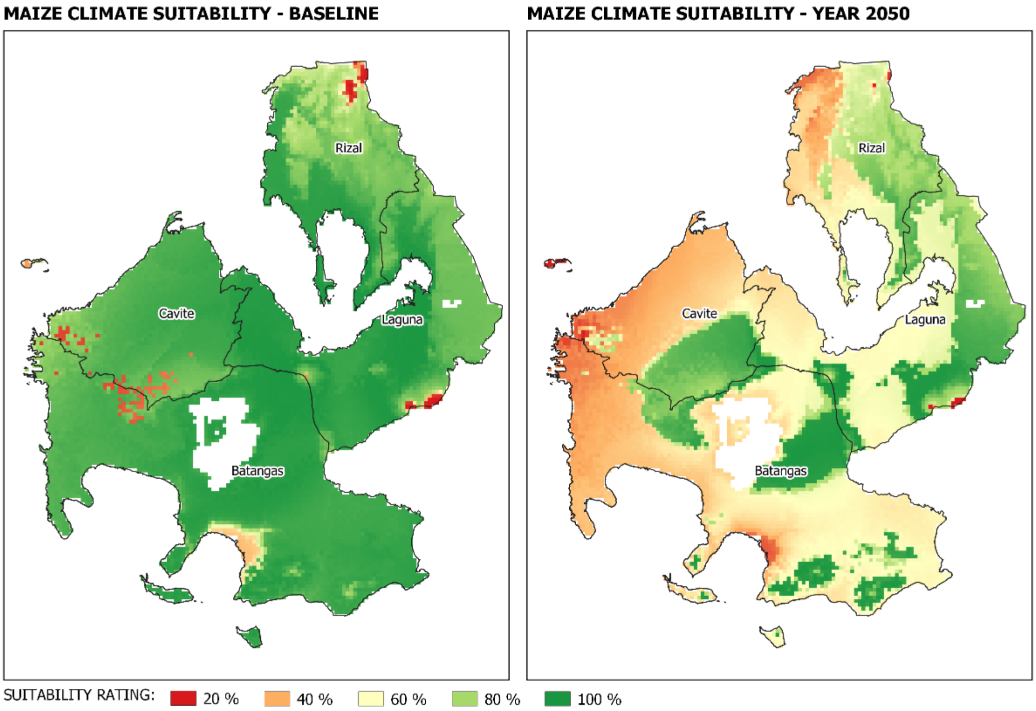


Figure 8. Comparative climatic suitability to corn of the of the provinces of Cavite, Laguna, Batangas and Rizal in the year 2050 vs. baseline

The following figures (Figures 9-12) show the changes in climatic suitability of selected crops (rice, corn, pineapple, cassava, coffee, cacao, and coconut) in the four (4) provinces of Region 4A due to climate change by year 2050. Based on simulation results, trends of suitability change by 2050 are:

- Overall, high climate change impacts are simulated for coffee and cacao
- Overall, slight to high climate change impacts are simulated for rice
    - Although there is only slight decrease for rice.
    - Eastern portion of Batangas, i.e., Lobo, Rosario, San Juan, and Taysan, will have more suitability losses
    - Western portion of Cavite, i.e., Ternate and Maragondon, will have higher suitability losses
- Overall there is no change in suitability for cassava and coconut
- Overall there is slight decrease in climate suitability for pineapple
- There are no crops that are simulated to increase in suitability
- Lowland areas are simulated to slightly decrease the suitability of maize

Crops that will experience decrease in climate suitability will benefit from improved crop production (i.e., change in variety). Farming system practices that promote healthy soil and efficient use of water is vital as a means of climate change adaptation. This emphasizes the need for improved crop management, responsive research and development initiatives, and better provision for infrastructure (irrigation) and technology to cope with the increasing pressures of climate change to agricultural productivity. Moreover, the analysis of change in climatic suitability provides information on the potential impact of climate change and allows decision makers to prepare adaptation measures for each geographic location.

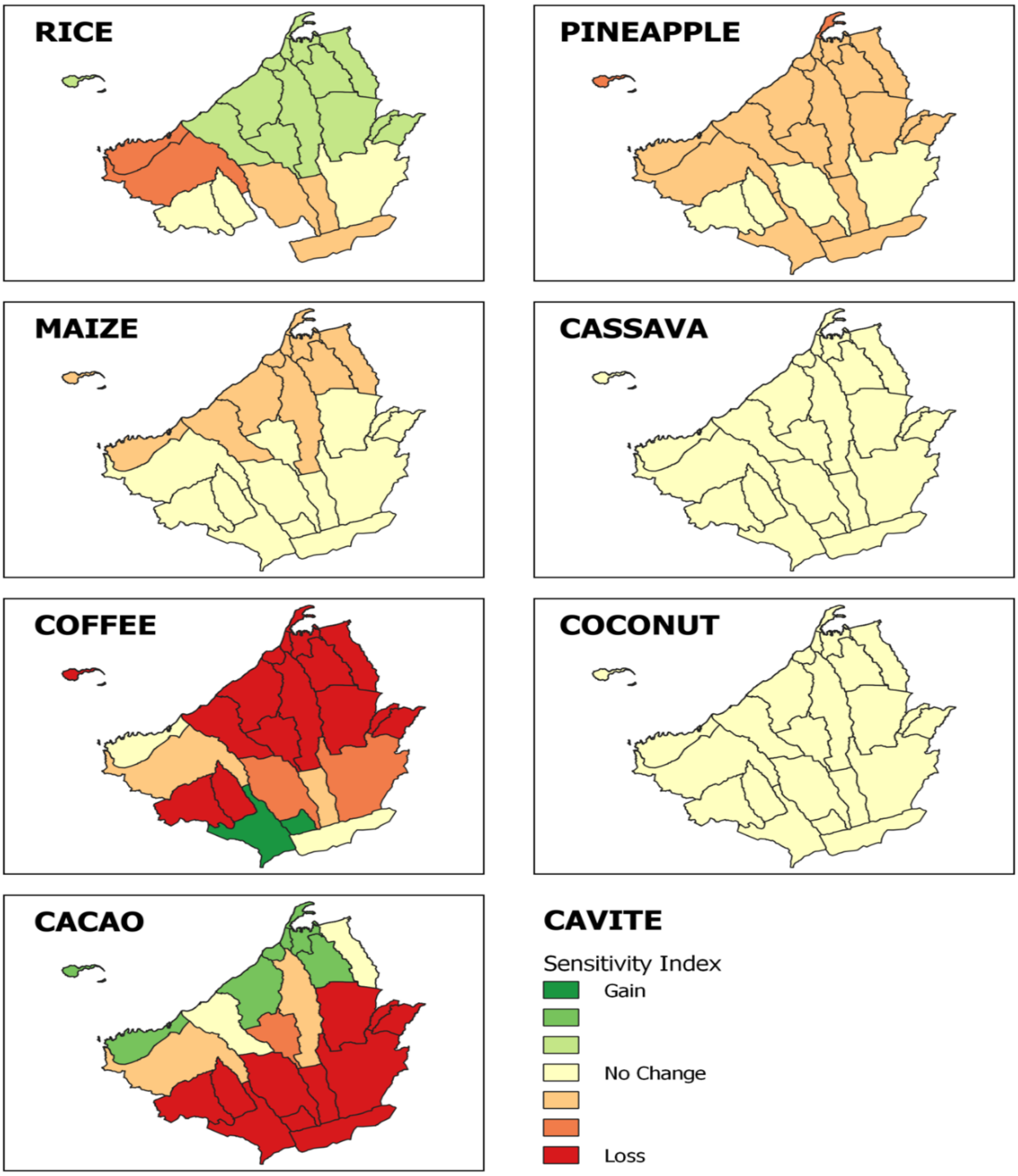


Figure 9. Maps indicating changes in climatic suitability of crops/commodities in Cavite

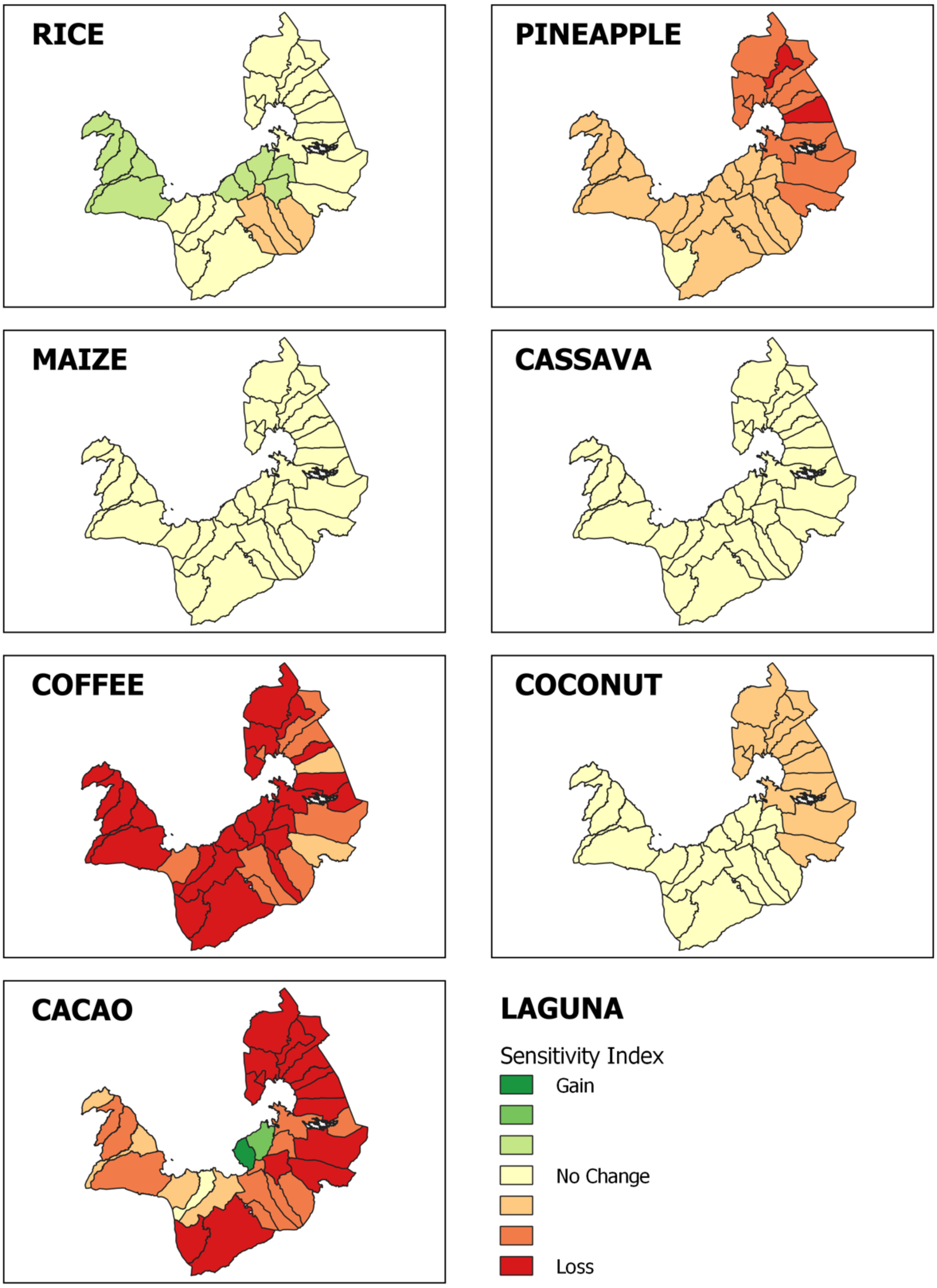


Figure 10. Maps indicating changes in climatic suitability of crops/commodities in Laguna

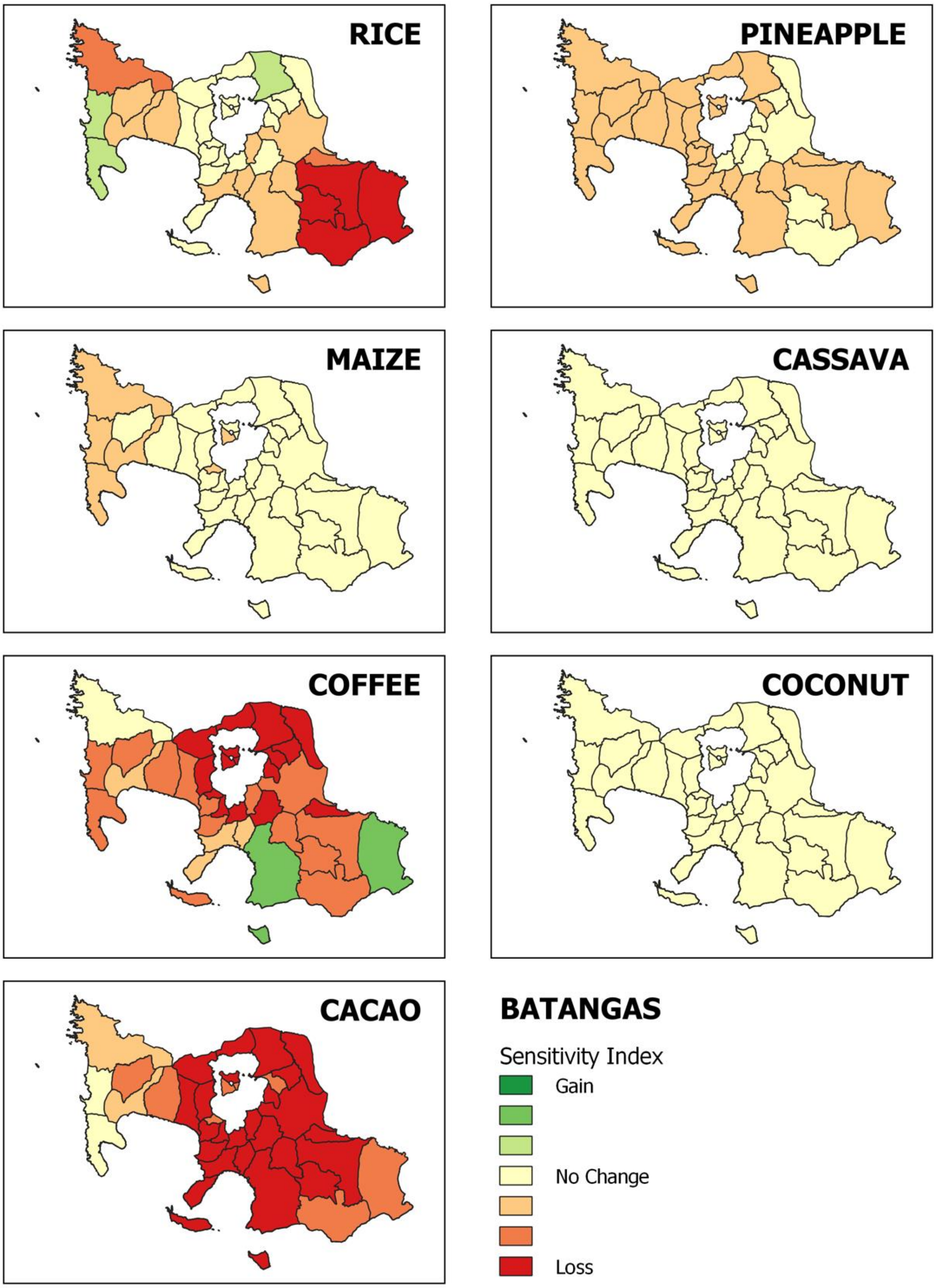


Figure 11. Maps indicating changes in climatic suitability of crops/commodities in Batangas

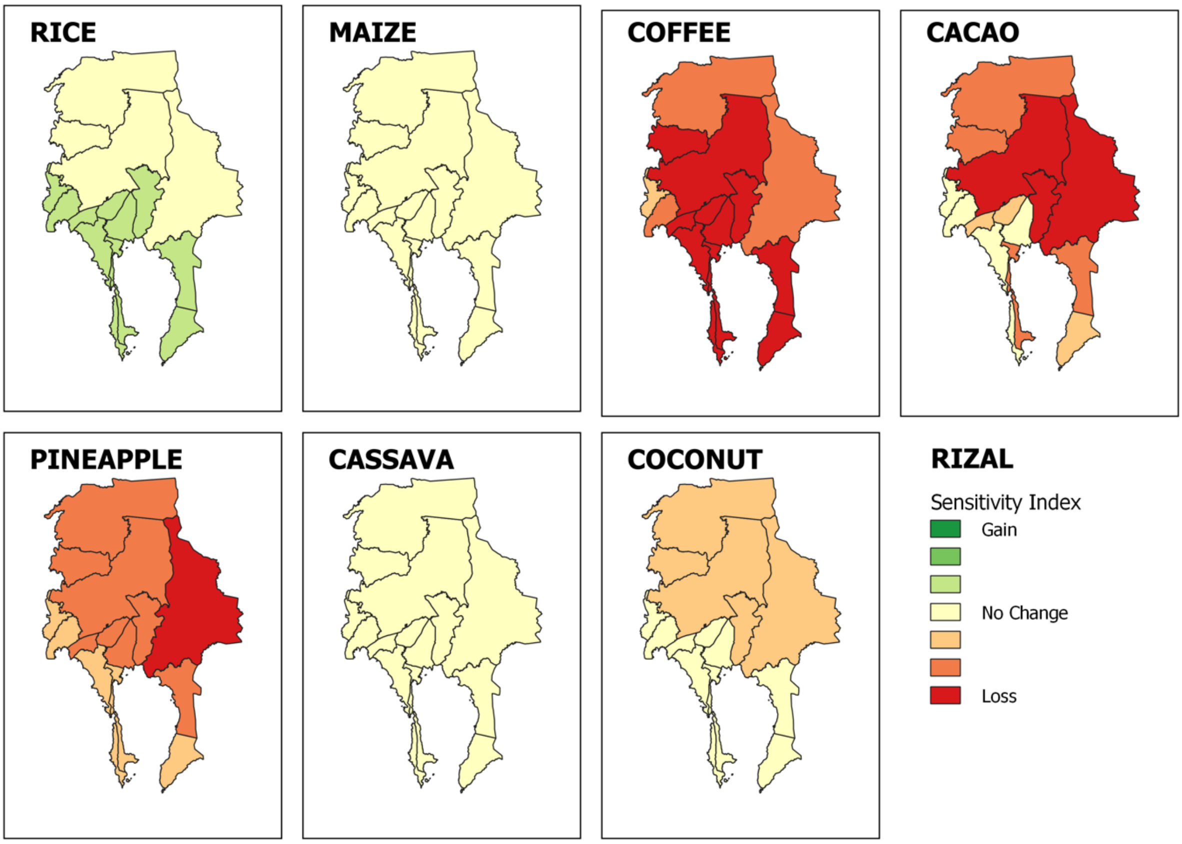


Figure 12. Maps indicating changes in climatic suitability of crops/commodities in Rizal

According to Peng (2004), a decreasing trend by 10% in rice yield during dry season for every 1°C increase in mean nighttime temperature is observed. Ramakrishnan et al. (2011) reported varying degree of yield loss along with the different temperature regimes in India. Furthermore, as reported by Iizumi and Ramankutty (2015), the accumulated rainfall during the crop duration has high correlation with planted area. Hence, availability of precipitation during dry season (driest quarter) and temperature regimes have a strong negative effect on crop distribution and growth. In the case of coffee, Bunn et al (2015) indicates that there could be an altitudinal migration of coffee similar to the predicted pattern in Indonesia and South America. This will have an impact on the forest cover of the Philippines, since suitability of coffee will be shifting to higher elevations where most of the remaining forest lands are located. On the other hand, cassava is a highly resilient crop and will be likely to remain suitable in the future.

According to IPCC (2007), “Climate change will generally reduce production potential and increase the risk of hunger. Where crops are grown near their maximum threshold temperatures and where dry land, non-irrigated agriculture predominates, the challenge of climate change could be overwhelming especially for subsistence farmers.

Hazard Risk (Exposure 2)

The hazard component captures the short term and recurrent extreme climate events that impacts agricultural livelihoods. While ‘sensitivity’ is useful in longer term planning, the ‘hazard’ assessment is more focused on immediate needs for interventions. Since the hazard index is a composite of multiple hazards, higher hazard index (red and dark red colors on the map) reflect several geographical overlaps of hazards (overlap of typhoon, flood, and drought), and wider geographical extent of hazards.

Climate and climate-related hazards assessment of Cavite

The overall hazard index for the province of Cavite is presented in Figures 13 and 14 showing the varying degree of exposure of the different municipality/city in the province.

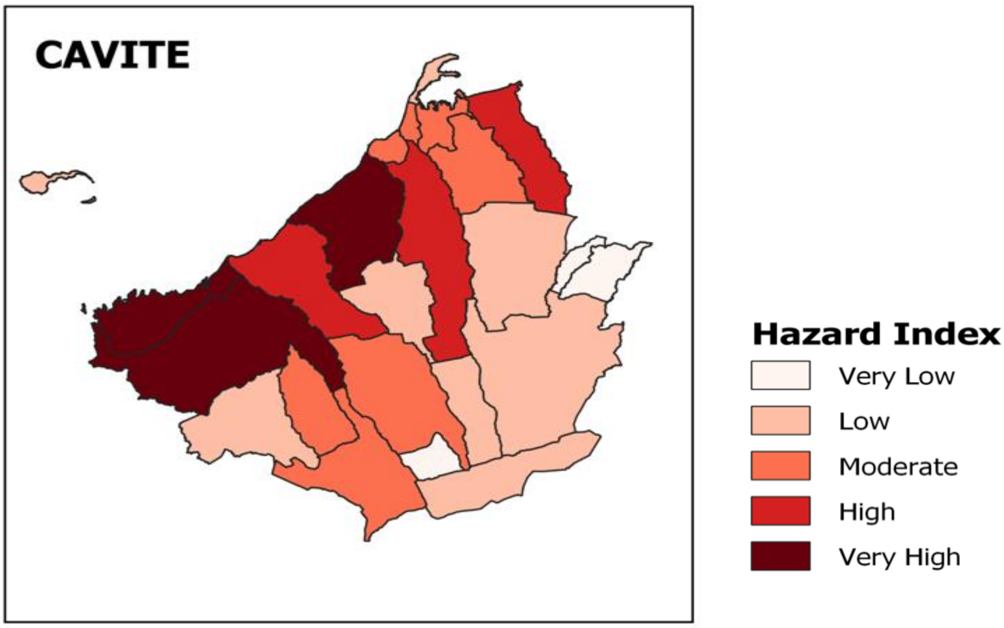


Figure 13. Overall hazards index for each of the municipality in the province of Cavite showing darker colors (hotspots) to mean higher incidence of hazards driven by either extent or overlaps of climate and climate-related hazards

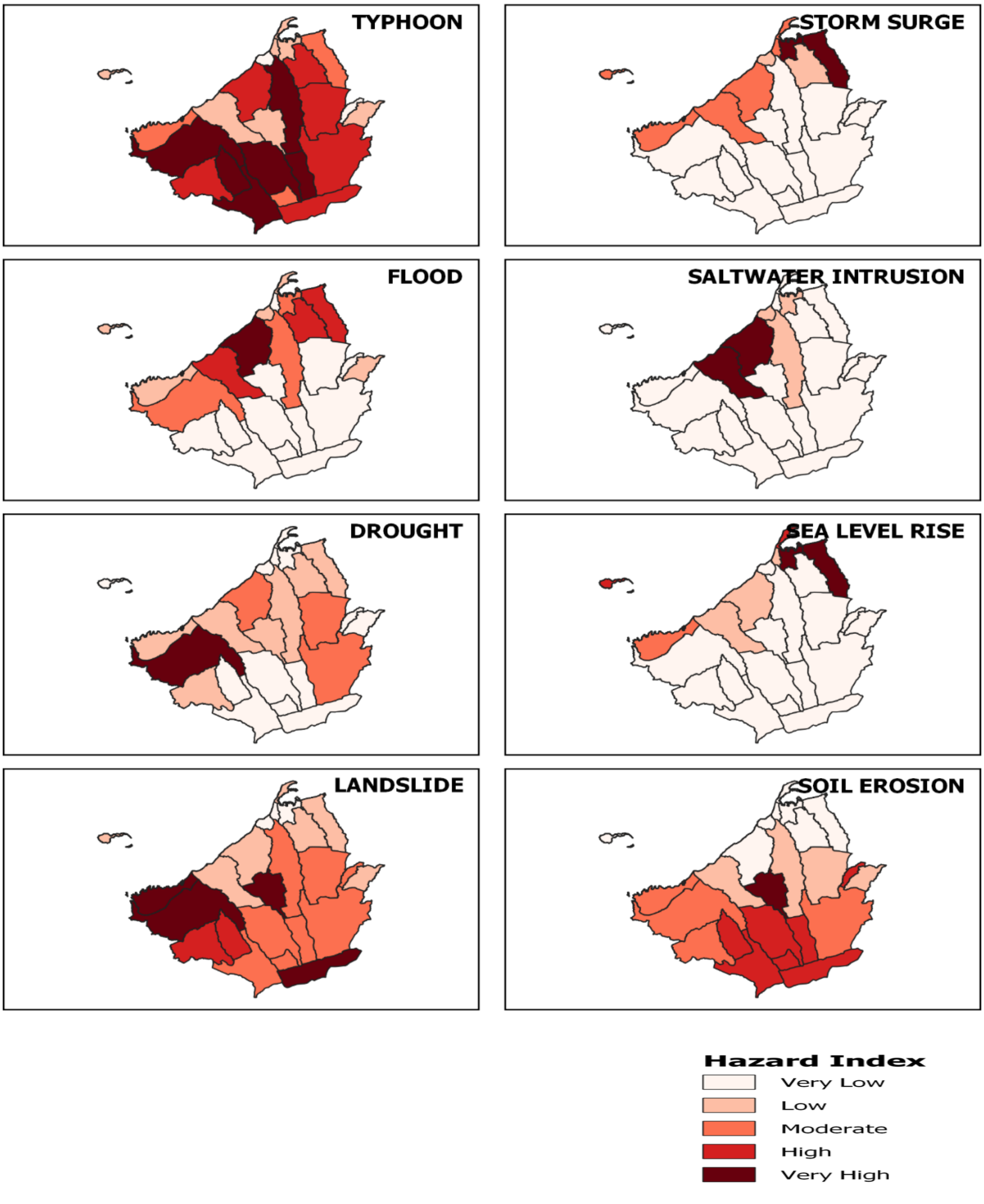


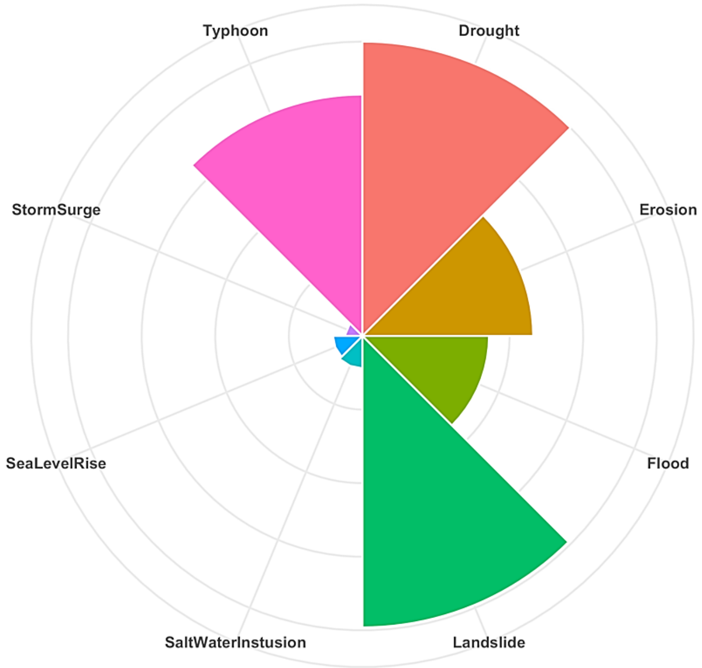
Figure 14. Exposure of the province of Cavite to different climate and climate-related hazards

The impacts of global climate change are already felt in the Philippines particularly in the inland valleys and upland ecosystems. Frequent occurrences of devastating droughts and floods, warming temperatures, and increasing weather variability were among the local manifestations. Unreliable weather patterns such as the onset of the wet season and unpredictable amount of rainfall are already causing losses (Foley et al., 2009). We demonstrate how to use the information of hazard risk level of each municipality to tailor livelihood packages that supports climate resilience. The municipalities identified for each province were selected because of their high hazard risk score. But this does not mean that low hazard risk should not be given attention, because some hazards present in those municipalities still pose threat to agri-fisheries livelihood.

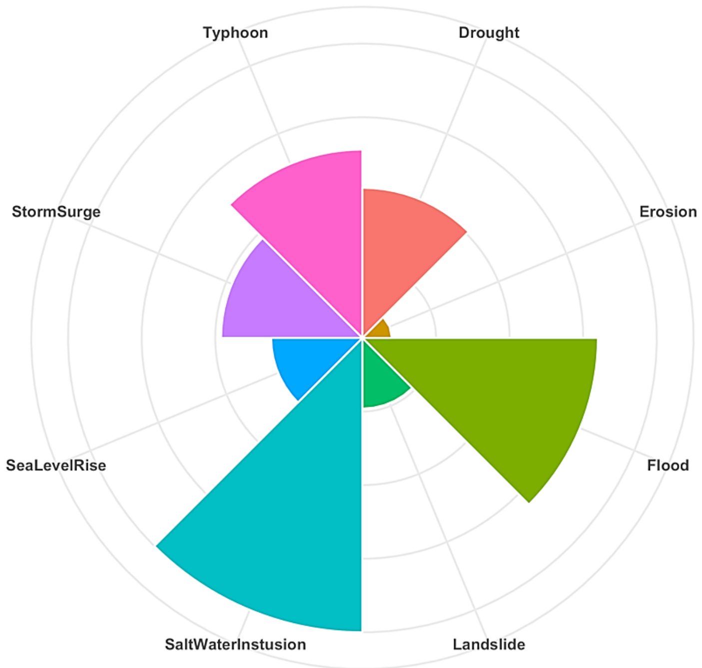
In the province of Cavite, for instance, two sample municipalities – Maragondon and Ternate, can be identified for detailed assessment as follows:

a. Maragondon (Figure 15a) – the dominant climate hazards are typhoon, drought and landslide. Since landslide is a main threat, proper zoning and mapping should be done to promote sustainable agricultural practices and minimal activities in high risk zones. Improved services on forecasting and early warning should be in place to prepare communities to mitigate impact of typhoon and drought.

b. Tanza (Figure 15b) – the dominant climate hazards are flood and saltwater intrusion, since the municipality has a longer coastal area compared to Maragondon. Since salinity is a big problem, the agriculture sector should monitor the seasonality to promote diverse livelihoods in areas that are highly affected by saltwater intrusion. In flood-prone areas, establishment of irrigation may control the amount of water entering the agricultural fields, while stored water can be used during the dry season for another cropping.



(A -Municipality of Maragondon**)**



(B – Municipality of Tanza**)**

Figure 15. Climate risks of Maragondon (A) and Tanza (B) in the province of Cavite

Climate and climate-related hazards assessment of Laguna

The overall hazard index for the province of Laguna is presented in Figures 16 and 17 showing the varying degree of exposure of the different municipality/city in the province. The climate and climate-related included typhoon, flooding, rain-induced landslide, drought, erosion, storm surge and saltwater intrusion.

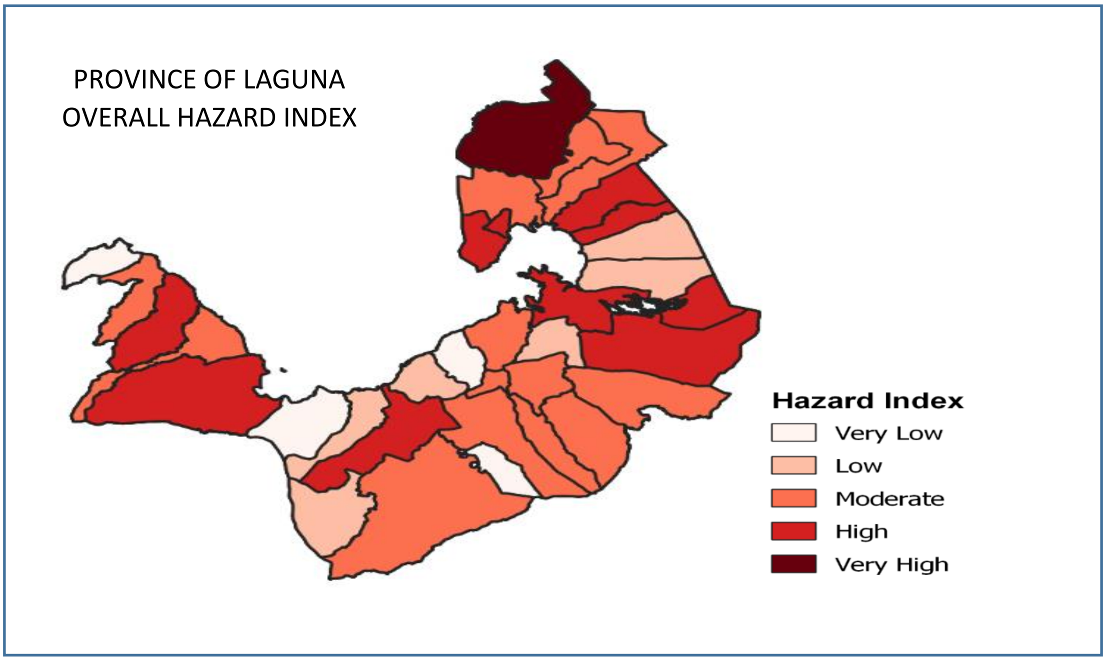


Figure 16. Overall hazards index for each of the municipality in the province of Laguna showing darker colors (hotspots) to mean higher incidence of hazards driven by either extent or overlaps of climate and climate-related hazards

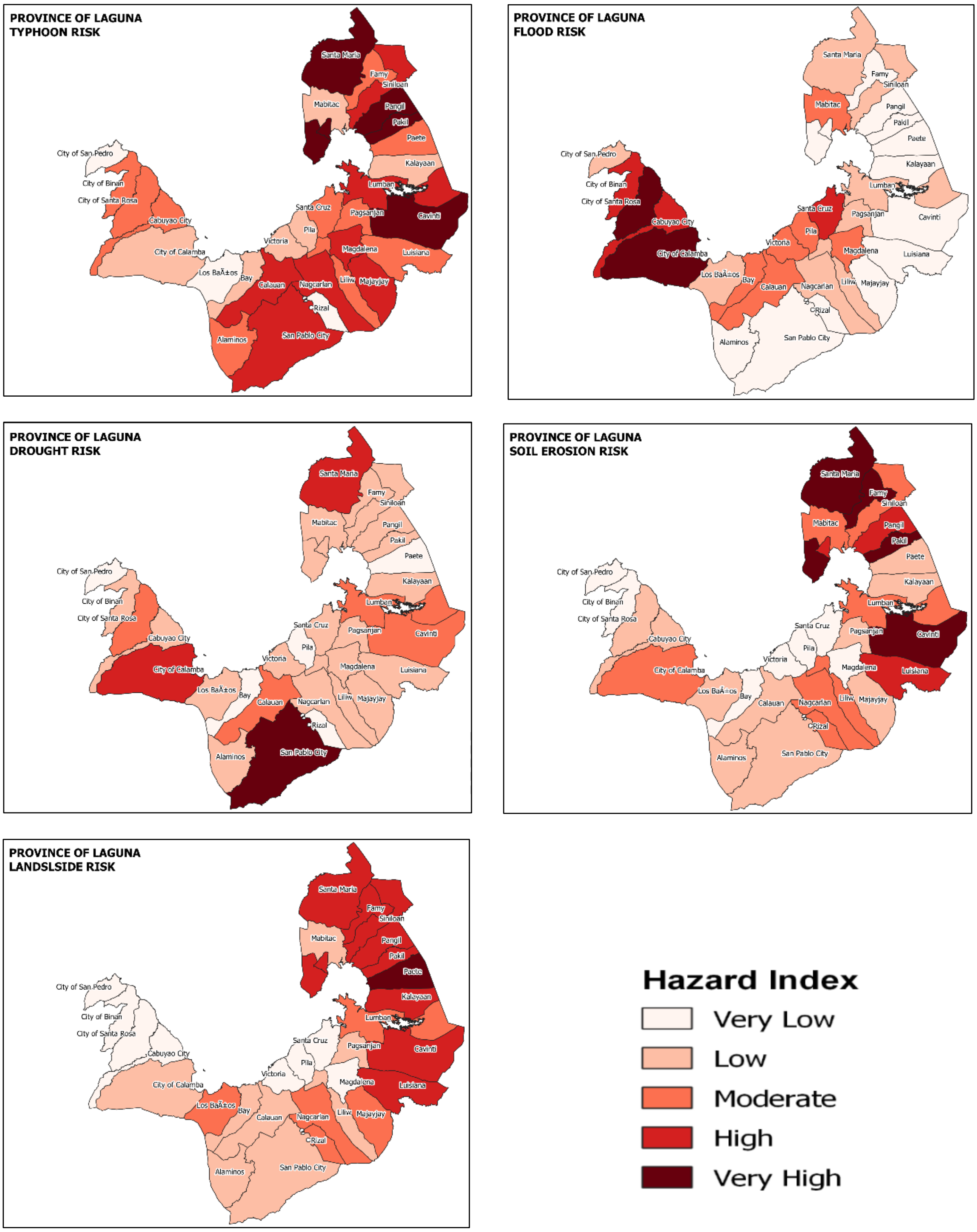


Figure 17a. Exposure of the province of Laguna to different climate and climate-related hazards

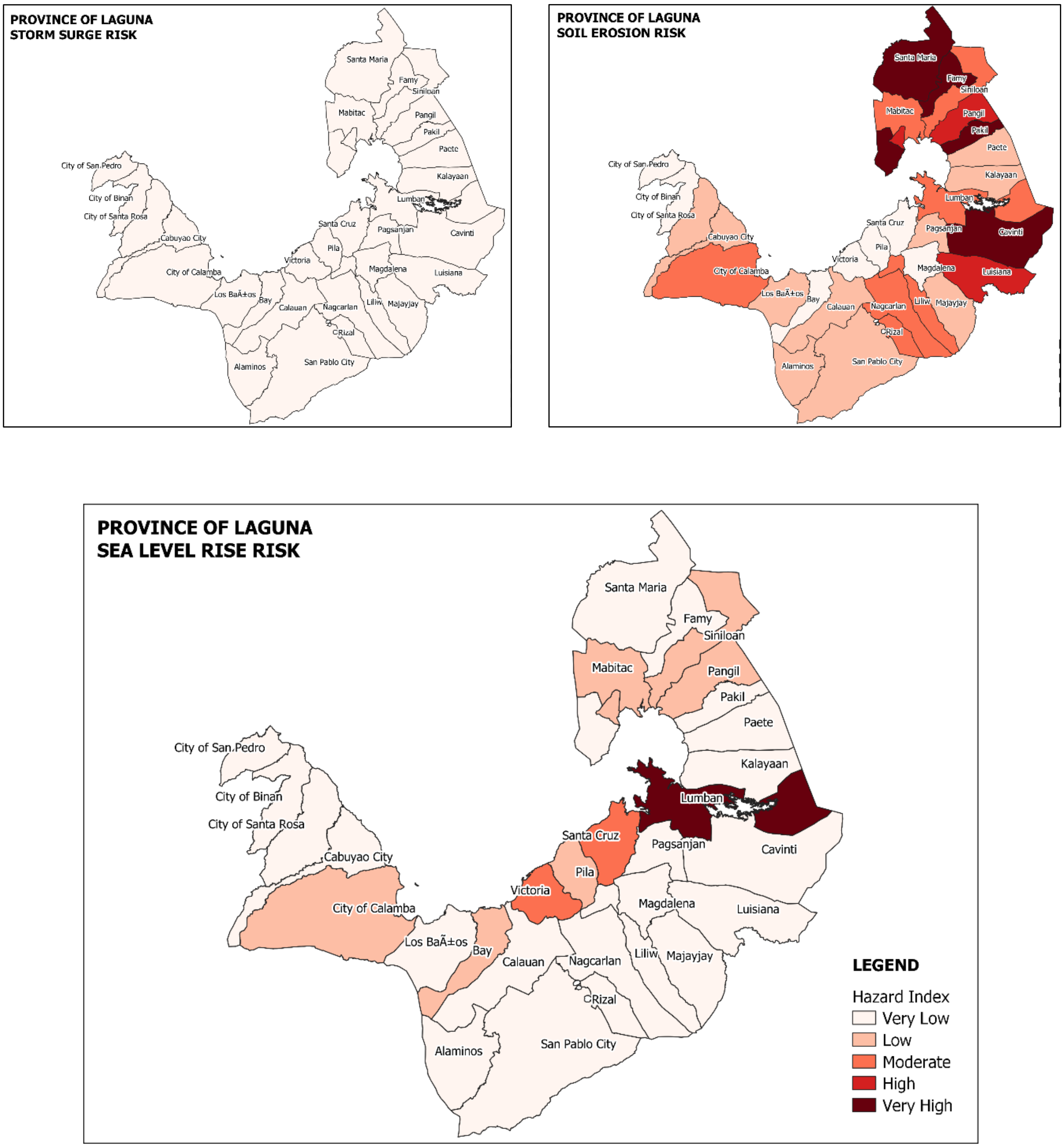
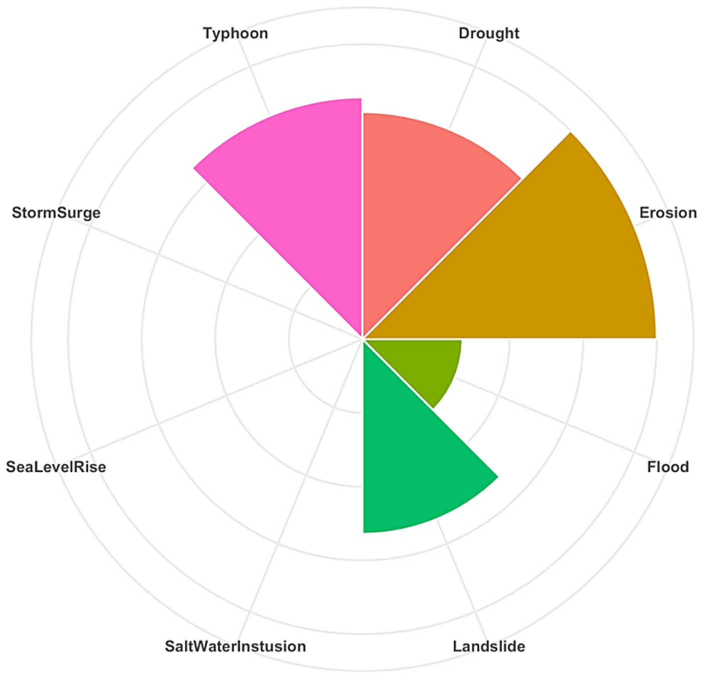


Figure 17b. Exposure of the province of Laguna to different climate and climate-related hazards (storm surge, sea level rise and soil erosion)

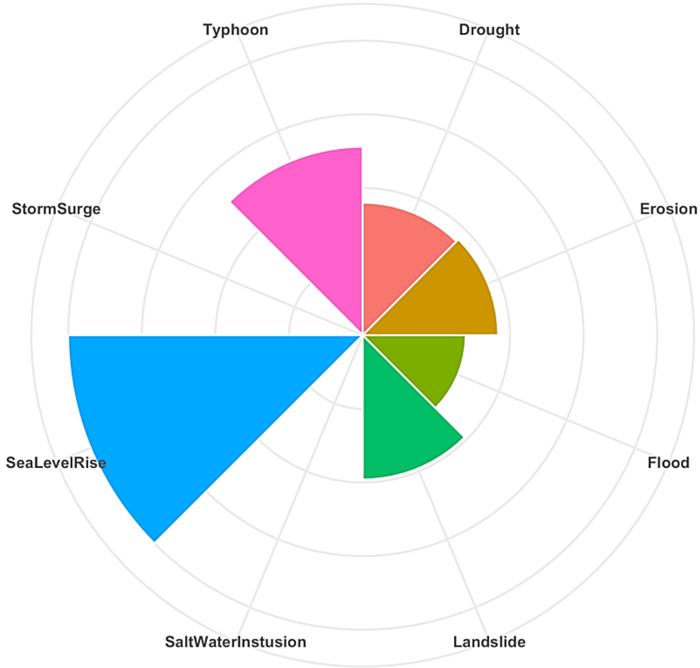
The two (2) municipalities selected in the province of Laguna for detailed analysis were Sta. Maria and Lumban.

a. Santa Maria (Figure 18a) - the dominant climate hazards are typhoon, drought, and soil erosion. The terrain is hilly with mean elevation and slope of 211 meters and 22 degrees. Reduction of soil loss through the promotion of sustainable agricultural practices should is deemed. Additionally, drought and typhoon mitigating measures should be practiced to reduce damage to agricultural livelihoods.

b. Lumban (Figure 18b) – sea level rise (more of swelling of the water from the lake) is the main climate risk in the near future, with additional risk of typhoon. Increase in the water level from the lake can bring more flooding and inundation in the municipality. Proper zoning of these area is recommended. Establishment of irrigation system may help in controlling the amount of water going in the field.



(A – Municipality of Santa Maria)



(B – Municipality of Lumban**)**

Figure 18. Climate risks of Santa Maria (A) and Lumban (B) in the province of Laguna

Climate and climate-related hazards assessment of Batangas

The overall hazard index for the province of Batangas is presented in Figures 19 and 20 showing the varying degree of exposure of the different municipality/city in the province.

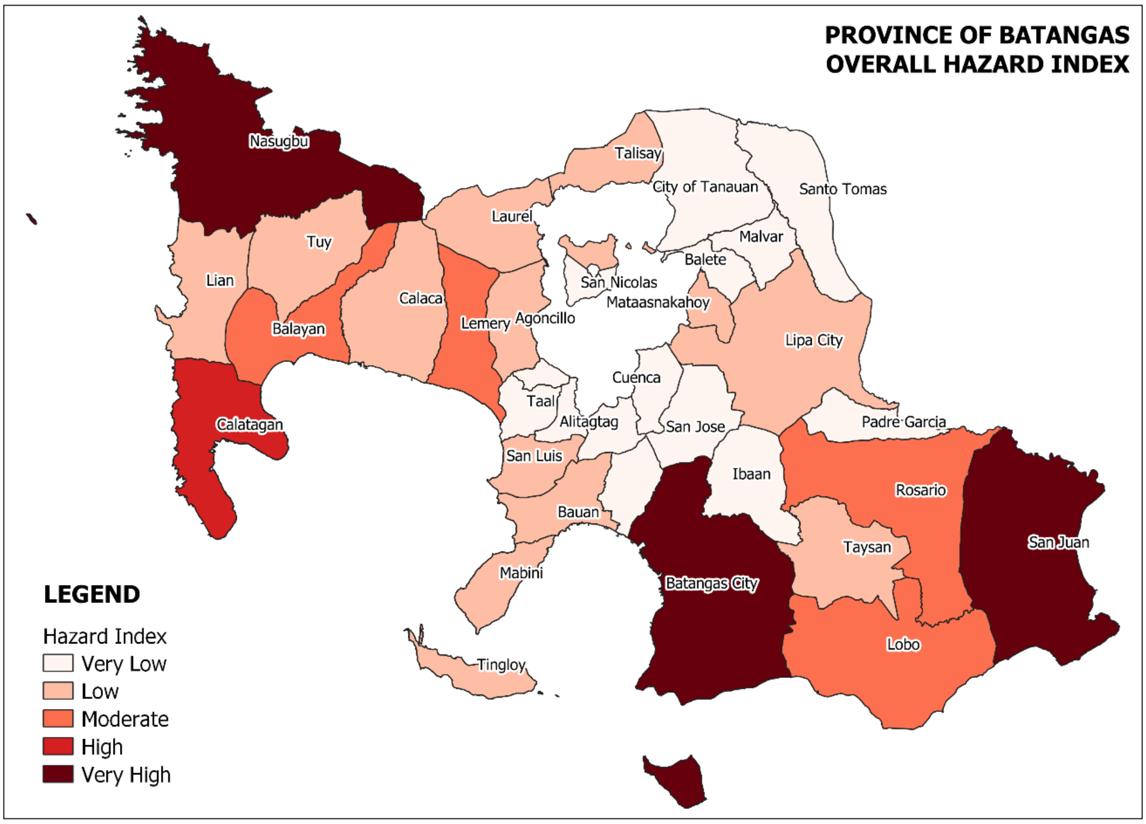


Figure 19. Overall hazards index for each of the municipality in the province of Batangas showing darker colors (hotspots) to mean higher incidence of hazards driven by either extent or overlaps of climate and climate-related hazards

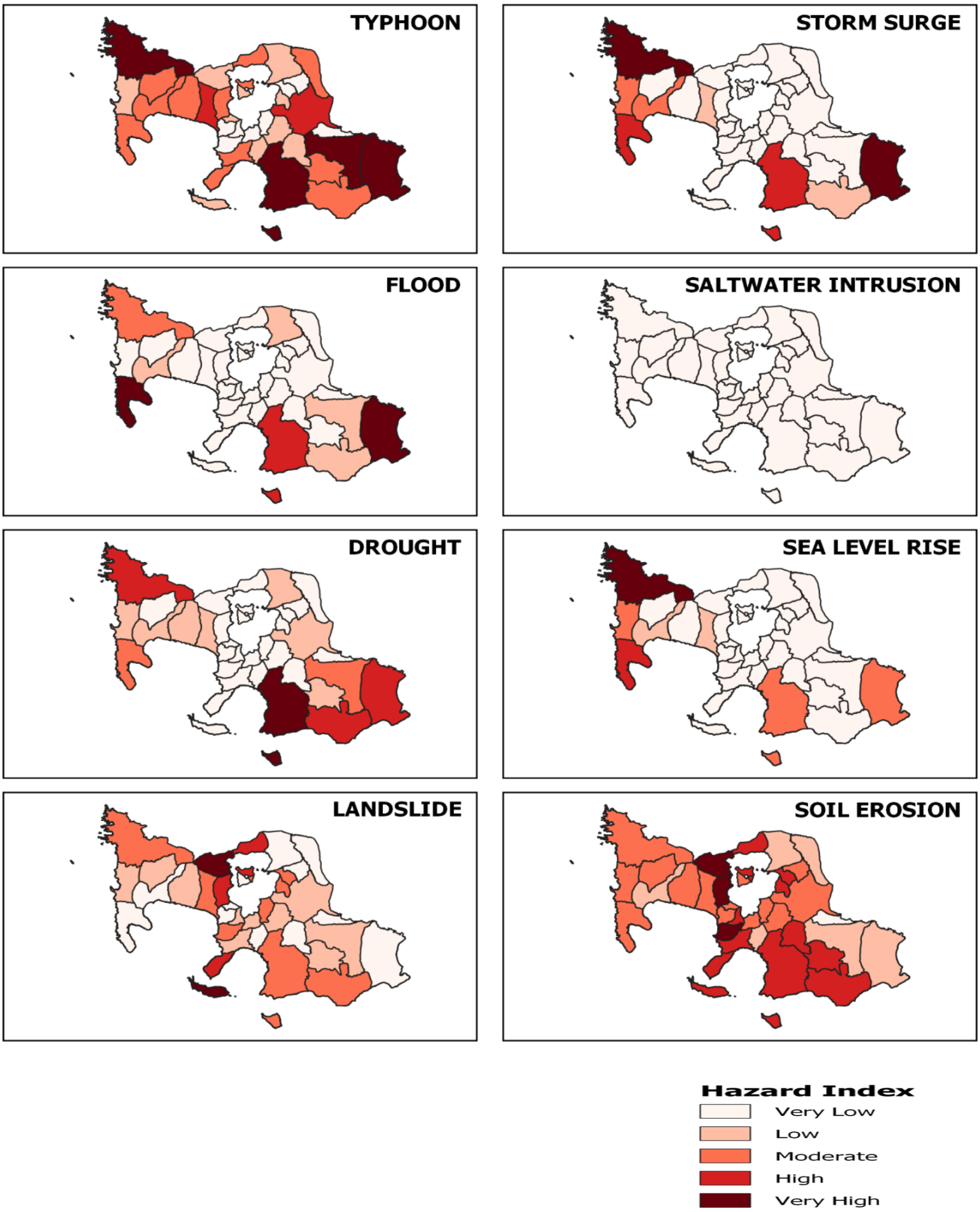
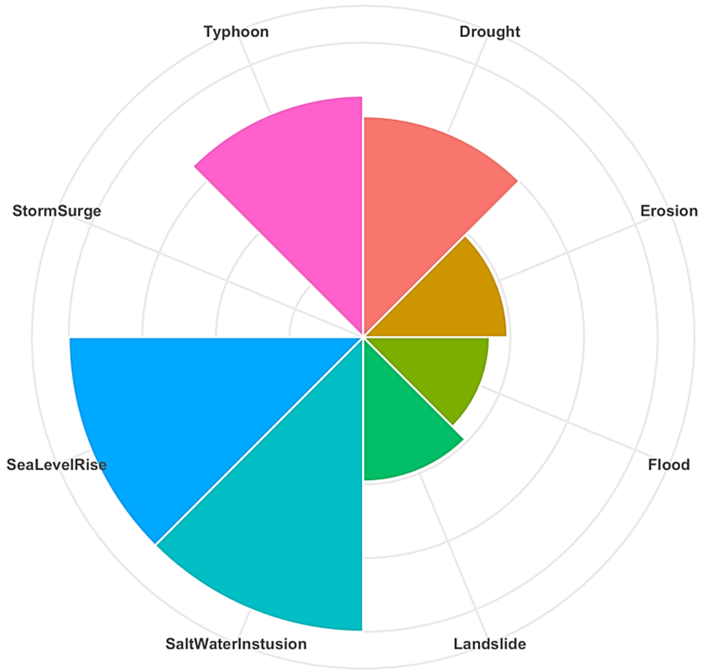


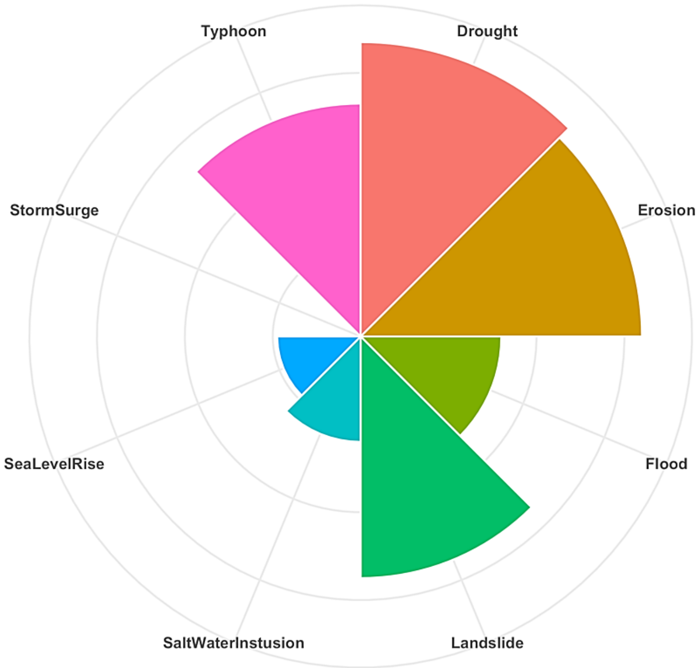
Figure 20. Exposure of the province of Batangas to different climate and climate-related hazards

In the province of Batangas, two sample municipalities – Lobo and Nasugbu, were identified for detailed assessment as follows:

For the municipality of Lobo (Figure 21a) – the dominant climate hazards are typhoon, drought, and soil erosion, with some additional risk for storm surge and sea level rise. The design of agricultural livelihood packages should consider planting typhoon- and drought-resilient crops (i.e., root crops) to ensure provision of food, or adjusting the crop calendar not to coincide with months that are at high risk to typhoon. Agroforestry should also be promoted because of high risk to erosion. Additionally, proper zoning to limit agricultural activities in high landslide risk areas. On the other hand, for the municipality of Nasugbu (Figure 21b) – typhoon and drought, with additional caveat of very high risk to saltwater intrusion and sea level rise. The same recommendations with the municipality of Lobo for drought and flood. Proper zoning of saline intrusion should be conducted to ensure that suitable agricultural (or fisheries) are practiced in these areas.



(A - Municipality of Lobo**)**



(B – Municipality of Nasugbu)

Figure 21 Climate risks of Lobo (A) and Nasugbu (B) in the province of Batangas

Climate and climate-related hazards assessment of Rizal

The overall hazard index for the province of Rizal is presented in Figures 22 and 23 showing the varying degree of exposure of the different municipality/city in the province.

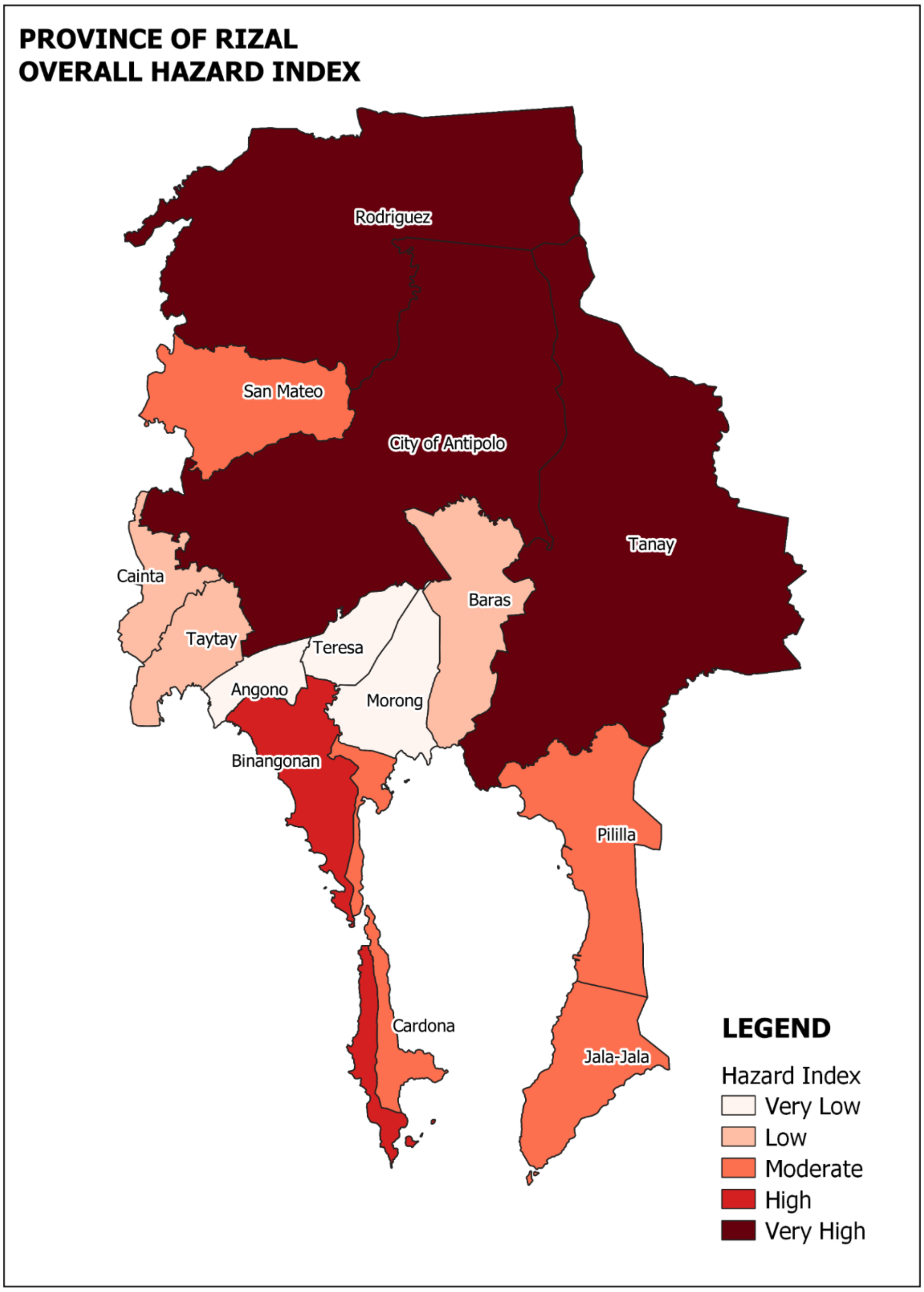


Figure 22. Overall hazards index for each of the municipality in the province of Rizal showing darker colors (hotspots) to mean higher incidence of hazards driven by either extent or overlaps of climate and climate-related hazards

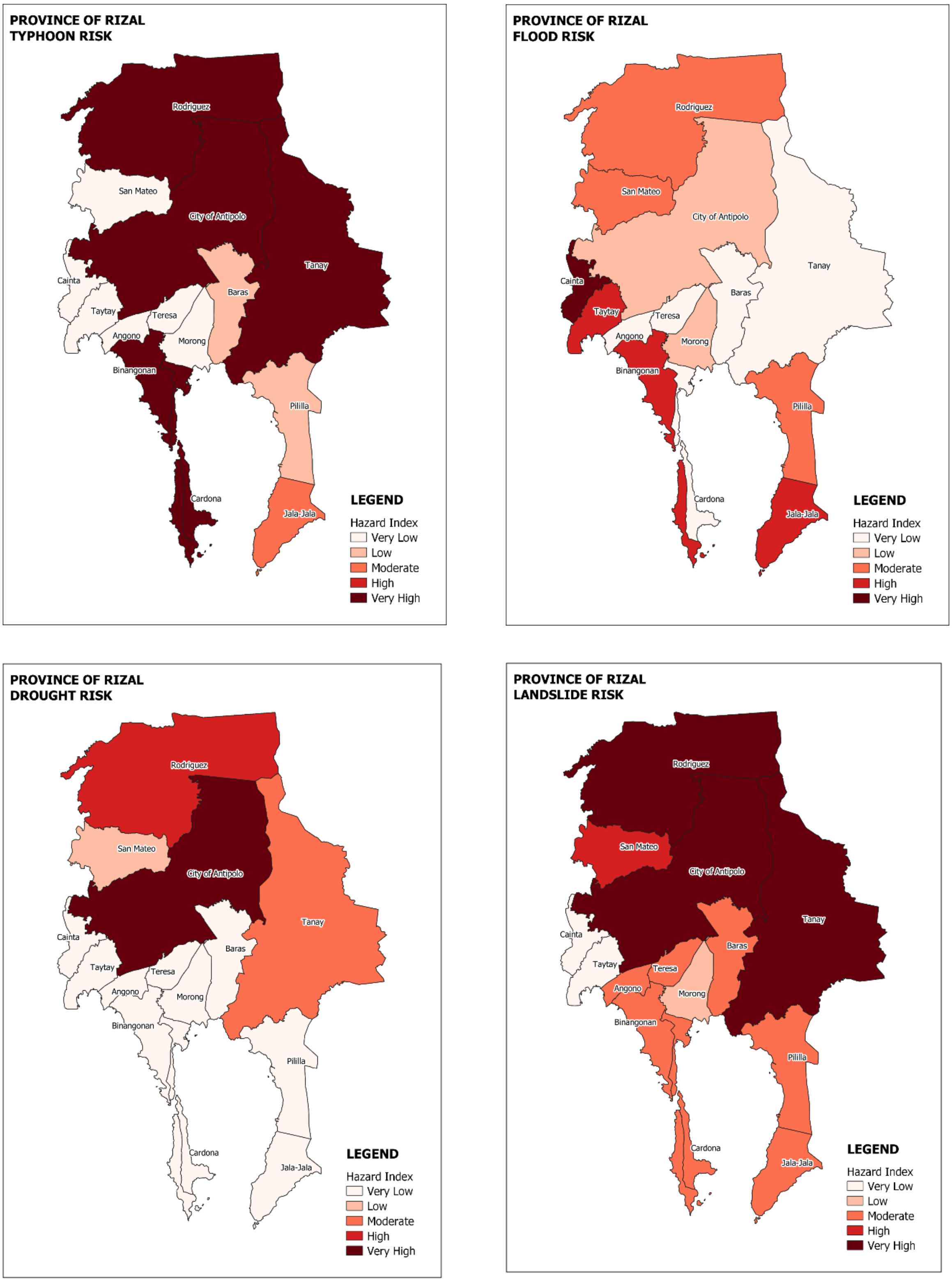
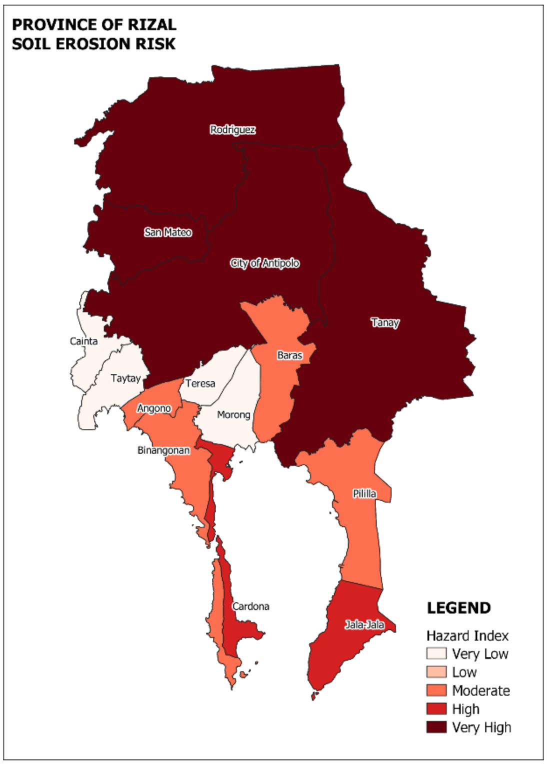
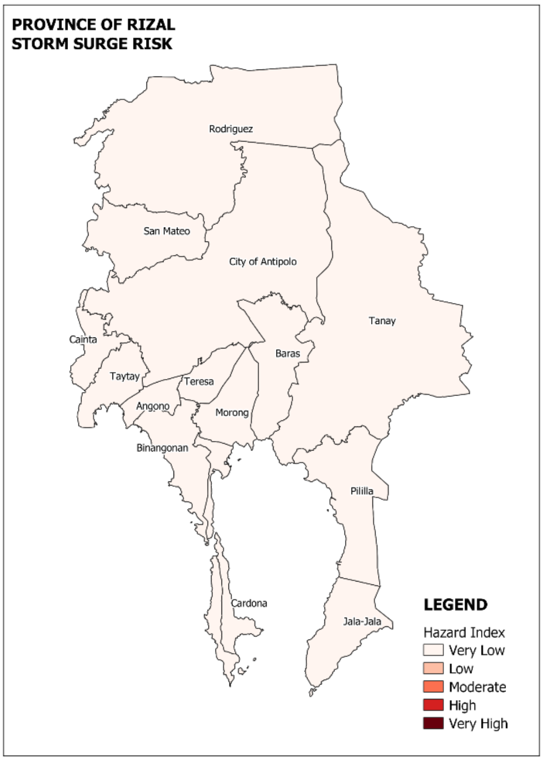


Figure 23a. Exposure of the province of Rizal to different climate and climate-related hazards (typhoon, flooding, drought and landslide)





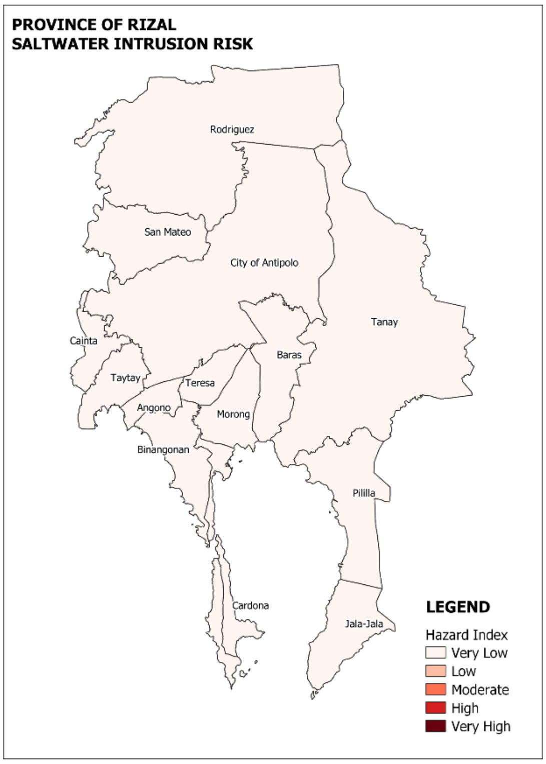
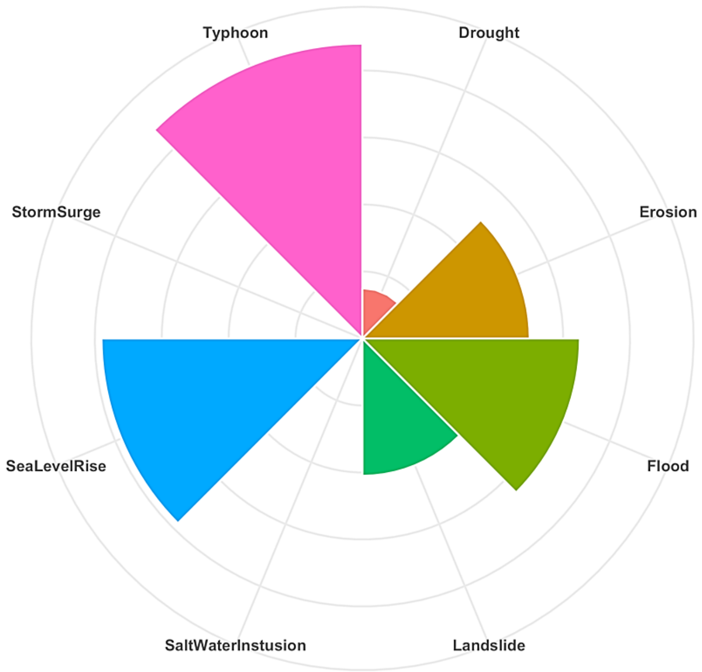


Figure 23b. Exposure of the province of Rizal to different climate and climate-related hazards (erosion, storm surge, and saltwater instrusion)

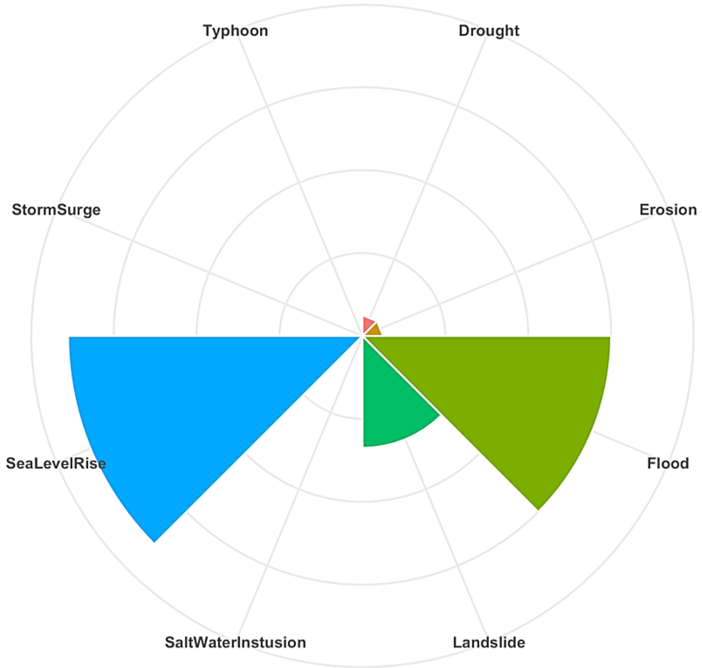
In the province of Batangas, two sample municipalities – Lobo and Nasugbu, were identified for detailed assessment as follows:

Binangonan (Figure 24a) – the main climate risks are typhoon and sea level rise (increased in water level from the lake). Improved communication channels for typhoon early warning should be in place. Areas that might be inundated because of increased water level from the lake should be identified to plan for other types of land uses in those areas.

Morong (Figure 24b) – the main climate risks are sea level rise and flood. Increased water level from the lake can lead to inundation and flooding. Improved early warning should be in place to reduce damage from flood.



(A – Municipality of Binangonan**)**



(B – Municipality of Morong**)**

Figure 24. Climate risks of Binangonan (A) and Morong (B) in the province of Rizal

Adaptive Capacity Assessment

Results are available for each indicator and sub-indicator. One of the strengths of this vulnerability assessment is that it is not limited only to identification of the areas with low adaptive capacity. It has the capability to explore, analyze, and target specific capitals and indicators that can increase the resilience of communities. The adaptive capacity index is a composite value of the five capitals (economic, human, physical, natural, and anticipatory) which represents the resources available for adaptation. Most cities and municipalities adjacent to cities across the study sites have higher adaptive capacity. This is particularly true since cities tend to have higher economic activity, availability of financial services, good access to health and education, and have more provision in terms of support services for agriculture.

Adaptive capacity for the province of Cavite

For the province of Cavite, Figure 25 shows the overall adaptive capacity index based on the composite scores from the determinants used. The parameters included factors from economic, human, physical, natural and anticipatory capitals. A total of 17 parameters were utilized to come with the adaptive capacity index for a given municipality.

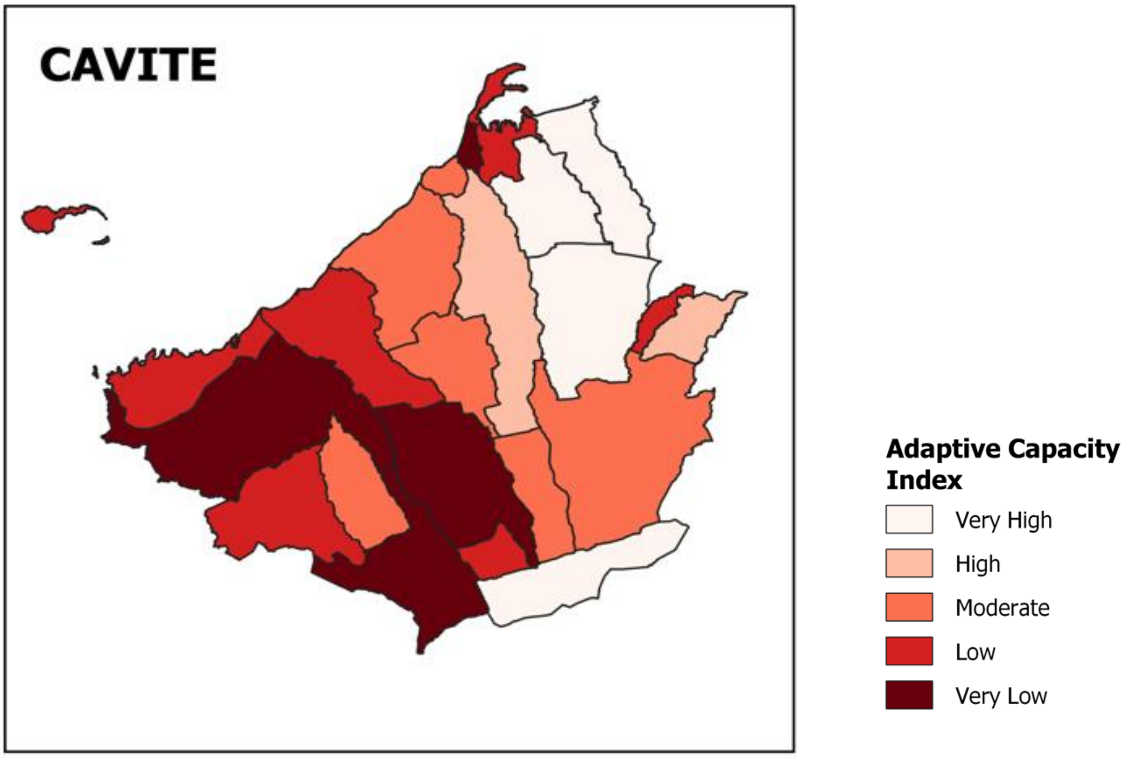
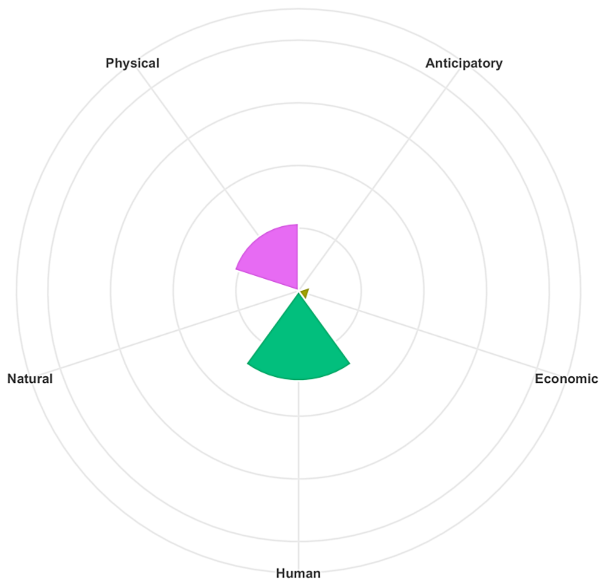


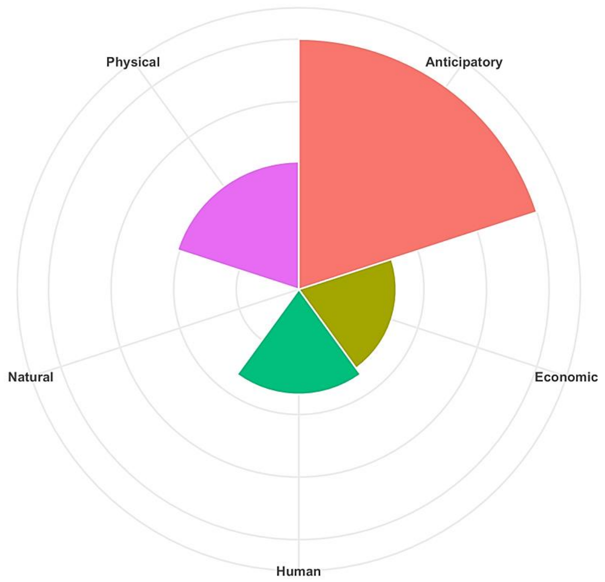
Figure 25. Overall adaptive capacity index of the province of Cavite as determined across economic, natural, human, physical, and anticipatory capitals

A detail assessment of the adaptive capacity based on existing capitals was done to two (2) selected municipalities in the province of Cavite, namely, Maragondon and Tanza as shown in Figures 26a and 26b. For the municipality of Maragondon, it has a very low rating across adaptive capacity capitals which requires a lot of effort from various sectors to increase their adaptive capacity. On the other hand, the municipality of Tanza (Figure 25b) has shown better ratings across adaptive capacity compared to Maragondon, although the rating is still classified as low except for anticipatory capital. Tanza has already developed the Disaster Risk Reduction

Management Plan which means that they have taken the initial necessary step to better prepare for climate change, hazards, and extreme events. However, the municipality should improve their natural capital through provision of more green spaces, by reforestation to reduce incidence of flooding. To mitigate the impact of sea level rise and storm surge, the municipality should also encourage/promote mangrove rehabilitation.



(A – Municipality of Maragondon**)**



(B – Municipality of Tanza**)**

Figure 261. Adaptive capacity rating for the municipalities of (A) Maragondon and (B) Tanza, province of Cavite.

Adaptive capacity for the province of Laguna

For the province of Laguna, Figure 27 shows the overall adaptive capacity index based on the composite scores from the determinants used. The parameters included factors from economic, human, physical, natural and anticipatory capitals. A total of 17 parameters were utilized to come with the adaptive capacity index for a given municipality.

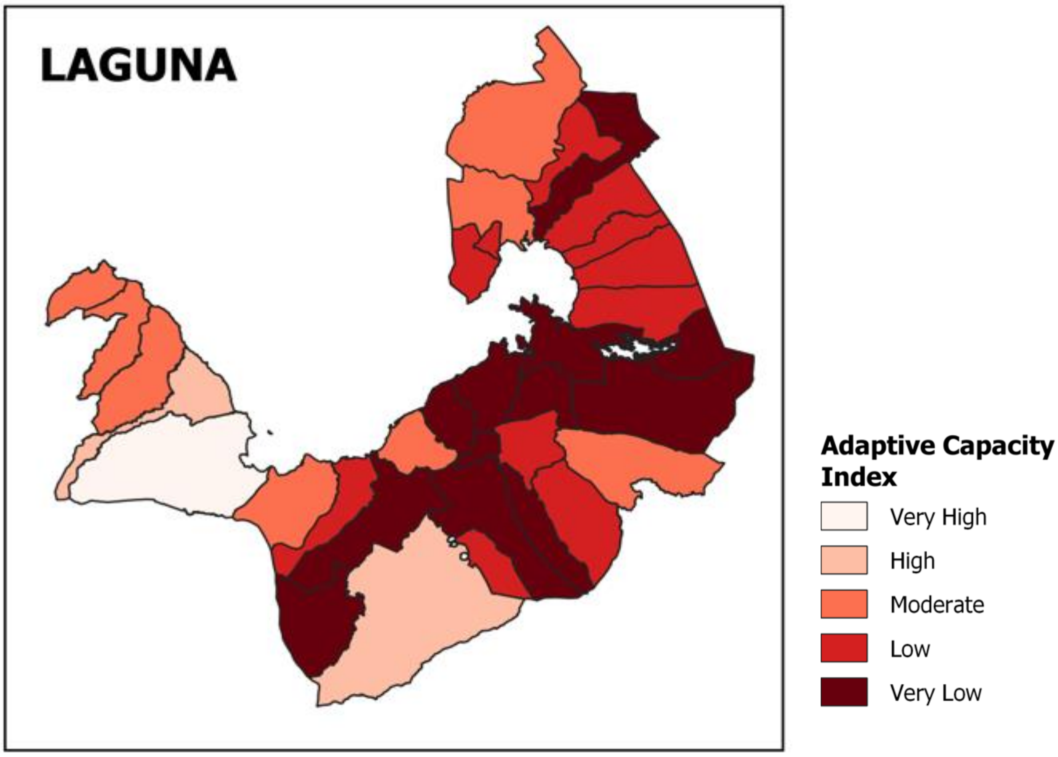
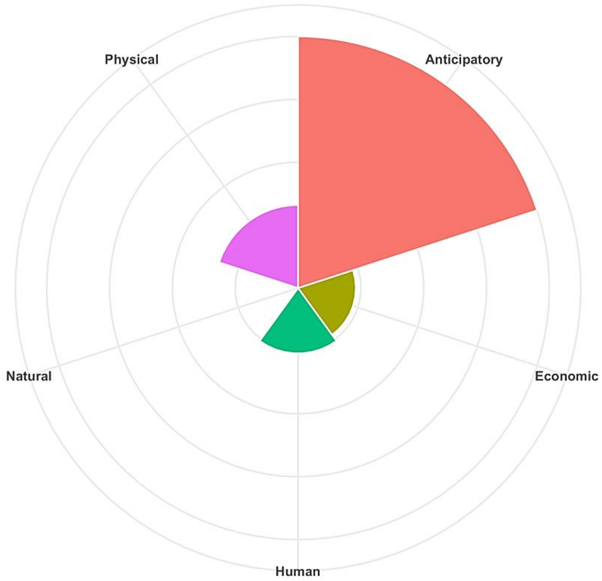
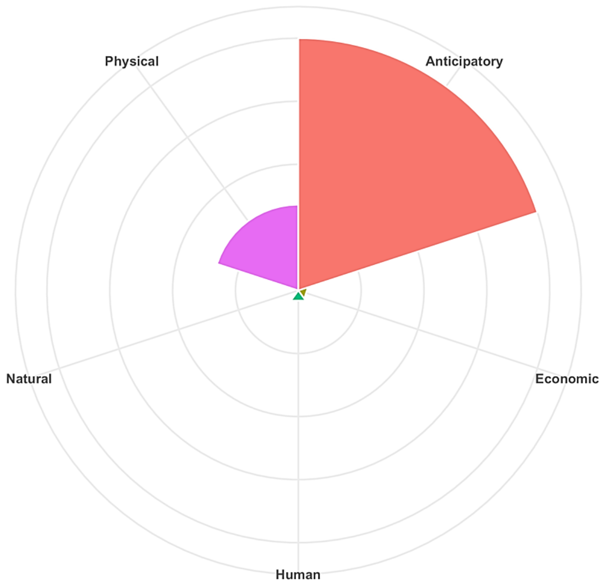


Figure 27. Overall adaptive capacity index of the province of Laguna as determined across economic, natural, human, physical, and anticipatory capitals

Analysis of the selected two (2) municipalities of the province of Laguna, Sta. Maria (Figure 28a) and Lumban (Figure 28b) showed that both municipalities have very low to low ratings across capitals for adaptive capacity except for anticipatory capital, with an additional caveat of very low natural capital. High anticipatory capital is due to the presence of Disaster Risk Reduction Management Plan (DRRMP). The municipality will benefit from improved natural capital to reduce hazard and climate change risks, such as risk erosion and landslide. More focus should be done to improve the four very low capitals. Also translating the DRRMP into actions will contribute to community resilience.



(A – Municipality of Santa Maria**)**



(B – Municipality of Lumban**)**

Figure 282. Adaptive capacity rating for the municipalities of (A) Santa Maria and (B) Lumban, province of Laguna.

Adaptive capacity for the province of Batangas

For the province of Batangas, Figure 29 shows the overall adaptive capacity index based on the composite scores from the determinants used. The parameters included factors from economic, human, physical, natural and anticipatory capitals. A total of 17 parameters were utilized to come with the adaptive capacity index for a given municipality.

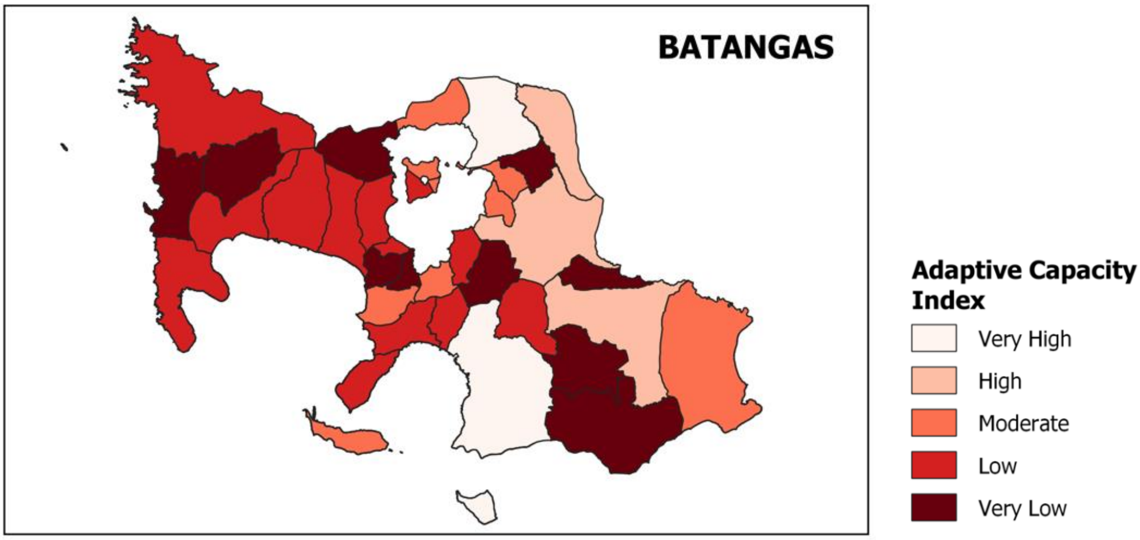
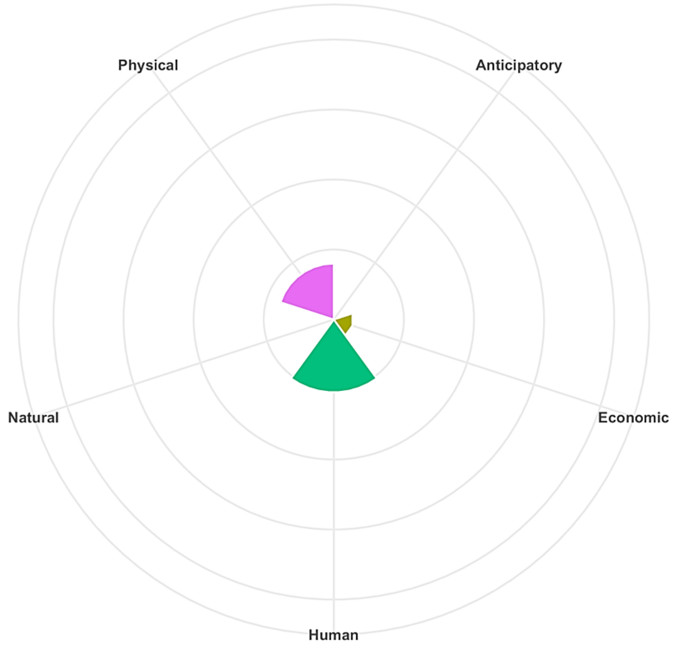
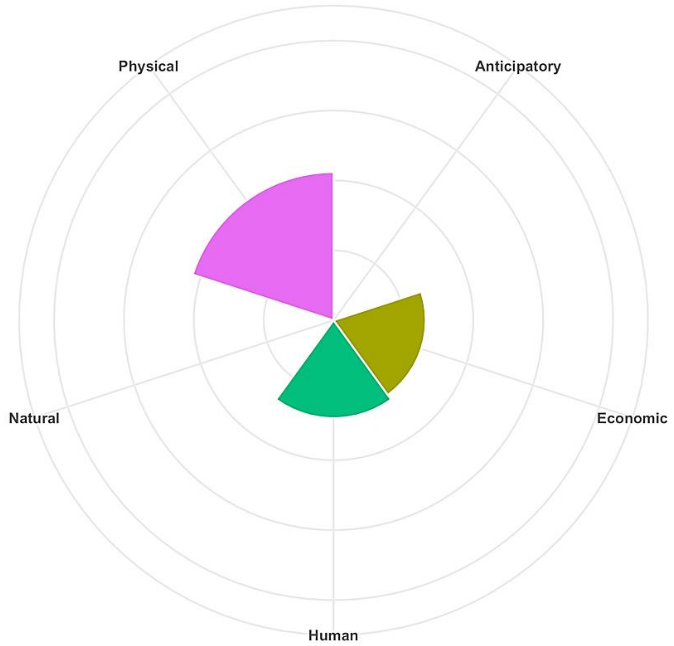


Figure 29. Overall adaptive capacity index of the province of Batangas as determined across economic, natural, human, physical, and anticipatory capitals

Two municipalities of the province of Batangas were selected for detailed analysis of their adaptive capacity, namely, Lobo (Figure 30a) and Nasugbu (Figure 39b). The municipality of Lobo was assessed to have low to very low ratings of the five adaptive capacity capitals. This means that there is a need for an integrated approach from different sectors to improve the adaptive capacity of the municipality. The other municipality of Nasugbu was noted to have the same condition with the municipality of Lobo, although with a slightly higher rating for economic capital due to tourism-related activities.



(A – Municipality of Lobo**)**



(B – Municipality of Nasugbu**)**

Figure 30. Adaptive capacity rating for the municipalities of (A) Lobo and (B) Nasugbu, Province of Batangas

Adaptive capacity for the province of Rizal

For the province of Rizal, Figure 31 shows the overall adaptive capacity index based on the composite scores from the determinants used. The parameters included factors from economic, human, physical, natural and anticipatory capitals. A total of 17 parameters were utilized to come with the adaptive capacity index for a given municipality.

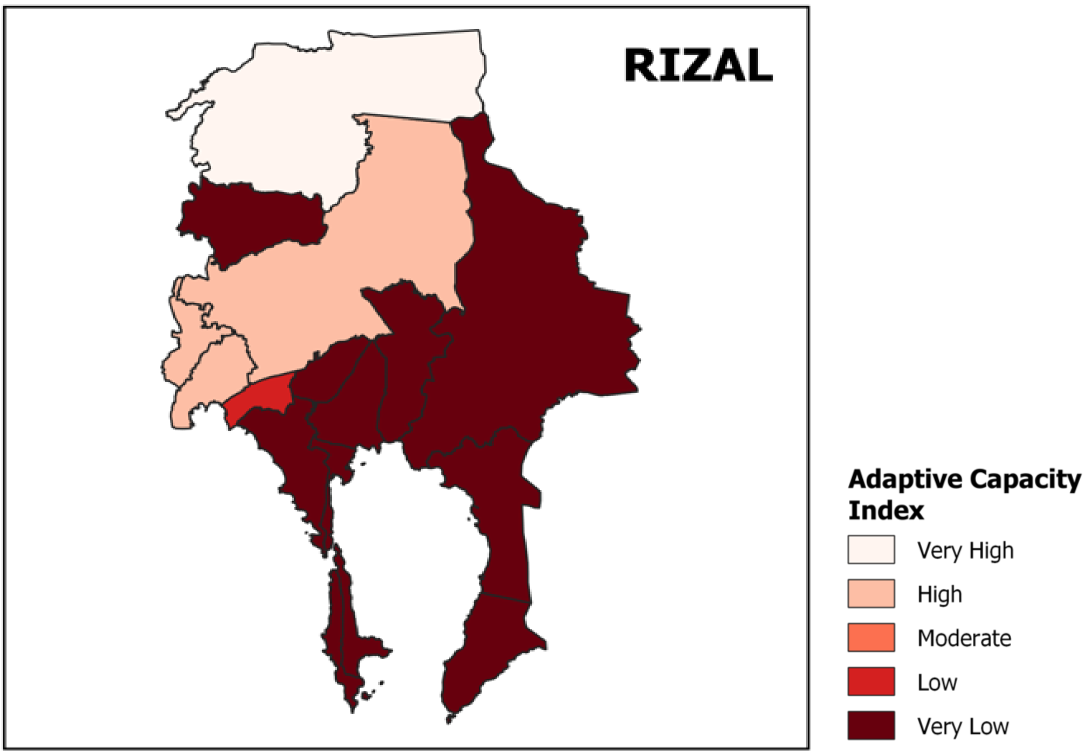
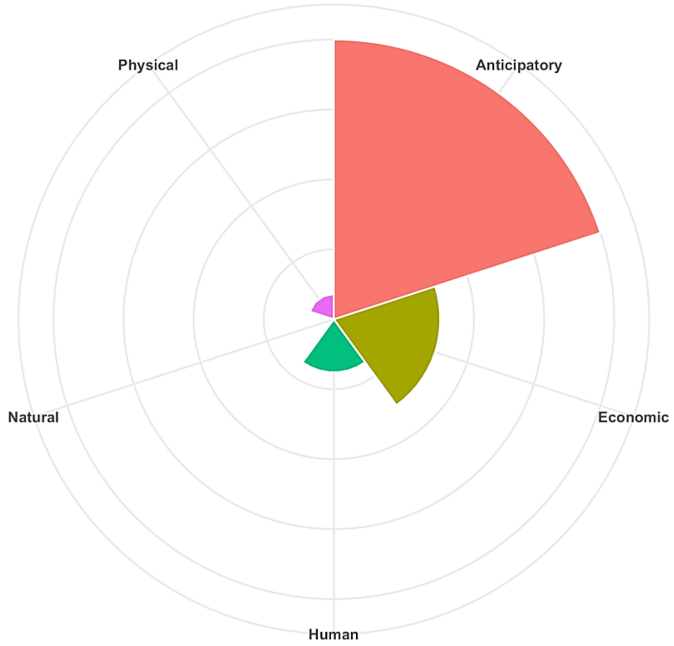
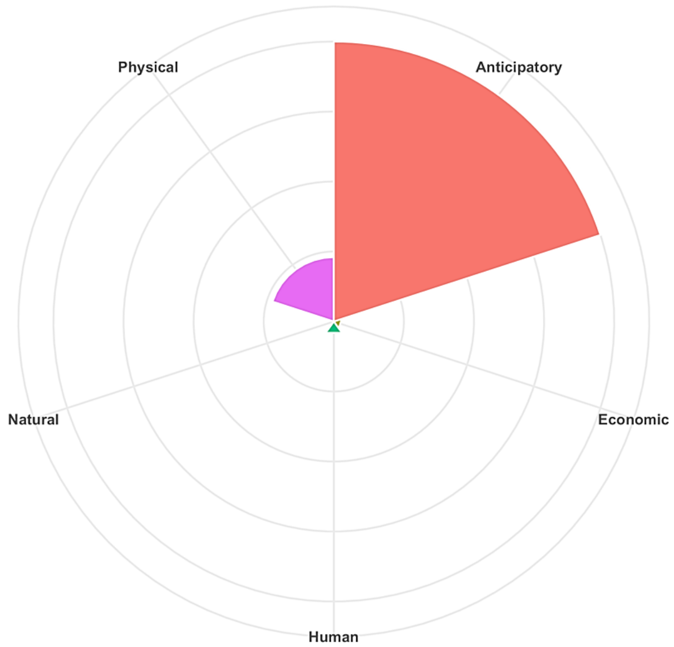


Figure 31. Overall adaptive capacity index of the province of Rizal as determined across economic, natural, human, physical, and anticipatory capitals

Analysis of the two (2) municipalities of Rizal, Binangonan (Figure 32a) and Morong (Figure 32b) have shown that both municipalities have very low ratings for the four (4) adaptive capacity capitals, such as economic, physical, human, and natural. High anticipatory capital is due to the presence of Disaster Risk Reduction Management Plan (DRRMP). The municipality will benefit from improved natural capital to reduce hazard and climate change risks. More focus should be done to improve the four very low capitals. Also, translating the DRRMP into actions will contribute to community resilience.



(A – Municipality of Binangonan**)**



(B – Municipality of Morong**)**

Figure 32. Adaptive capacity rating for the municipalities of (A) Binangonan and (B) Morong, province of Rizal.

SUMMARY, CONCLUSION AND RECOMMENDATIONS

Agricultural vulnerability to climate change was assessed and mapped in the four (4) provinces in Region 4A, Philippines – Cavite, Laguna, Batangas, and Rizal - using modeling and statistical analysis of climate impacts, climate variability, and socio-economic variables. The analyses focused on key commodities in the region, such as rice, corn, coffee, cacao, pineapple, cassava, and coconut. In the Philippines, the municipal resolution was used because it is believed this is where significant decision making and planning takes place, especially in the agricultural sector. With inherent uncertainties, any planning and development initiative using the output of this research should be made with consideration of local conditions. However, with all these limitations, the results presented in this report are in broad agreement based on "stakeholder consultations". A series of consultation and validation workshops were conducted to confirm the adaptive capacity indicators and result of hazard analysis. These workshops are important to ensure the accuracy of the results. The crops identified in the sensitivity analysis were based on importance to farmers and priorities of the Department of Agriculture. The analysis of the three components provides valuable information at municipality level to better understand challenges and opportunities that can be used to tailor-fit interventions based on local needs and risks.

The CRVA output can be used to inform and guide decision makers from government agencies, extension staff, and private sectors on geographic areas that are in most need of interventions, and what package of interventions are needed for each geographical area. It also opens door for cross-sectoral collaboration between different government agencies and private sectors, particularly in municipalities where adaptive capacity ratings are low to very low across capitals. Impacts of climate change has been quantified using crop distribution models using baseline and future scenarios.

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ANNEX

Ex-Ante Cost-Benefit Analysis of Selected Climate-Resilient Agriculture Practices in the provinces of Cavite, Laguna, Batangas, and Rizal of Region 4A

Rationale

Given the adverse impacts of climate shocks and stresses, promoting Climate-Resilient Agriculture (CRA) practices is one of the strategies of the Government of the Philippines to manage risks associated with climate change and to pursue sustainable livelihoods among farming communities. Many approaches fall under the heading of CRA. Robust prioritization framework and data on cost-effectiveness of these approaches are needed for decision-support and investment planning. Many prioritization approaches including the use of simulation models, expert judgement, CBA, participatory appraisal and hybrid methods are used for investment planning [Mwongera et al., 2014; Claessens et al., 2012].

Methods

We applied CBA in prioritizing CRA practices. CBA determines the relative profitability of alternative practices compared to conventional practice or business as usual (BAU) [Sain et al., 2017]. It is an essential economic tool that is used for guiding the economic agents to make appropriate decisions in investments for a project or policy options. The decision criterion depends on the sum of the net present value of all the future flows of costs and benefits associated with the investment. CBA compares two scenarios: BAU scenario and after implementation of the practice scenario. BAU represents the flow of costs and benefits before the implementation while the after implementation represents the flow of costs and benefits after a new practice or project has been implemented. CBA can be challenging in cases where the economic agents want to compare the BAU and after the implementation scenario if benefits and costs have not been realized yet. Moreover, attaching the value of the tradable and non-tradable services, such as externalities, can be difficult. Nevertheless, CBA is an economic tool of choice that has proved to be very useful in evaluating investment decisions [Van Wee, 2012].

Activities

1. CRA concept and prioritization framework (see Dikitanan et al, 2017) were discussed during a workshop last 19 February 2020 in CvSU. Further, a CRA form (Attachment 1) was distributed to the participants (including those from earlier workshops) to gather a long list of recommended CRA practices[1] in the region.
2. Production cost and returns report from RFO, PRDP, and PSA were used as the main input data for CBA. Literature review and key informant interviews were conducted to fill data gaps. Data collected include production costs and yields for

[1] Practices are considered CRA if they enhance productivity as well as at least one of the other objectives of CRA (adaptation and/or mitigation).

farms both with and without CRA practices, installation and maintenance costs of CRA practices, and prices received by farmers.

3. Data was summarized in a spreadsheet and the best-bet practices were assessed based on potential profitability using a spreadsheet program.
4. Field validation of results was deferred due to COVID-19 but was done thru online/virtual consultation with stakeholders.

CBA Assessment Results

Long-list of CRA Practices

Priority commodities in the region include banana, black pepper, cacao, coconut, coffee, corn, lanzones, mango, rambutan, rice, sugarcane, and vegetables. More than 20 CRA practices were identified by the LGUs (Attachment 2).

Prioritized CRA Practices

Selection process is site-specific so ideally this activity should be conducted once the CRA villages were already chosen. Given this limitation, we relied on primary and secondary to select CRA practices to evaluate. Priority crops (Annex Table 1) per province were selected based on latest volume of production data from Philippine Statistics Office (% share to regional production). Agriculture in Rizal is less intense compared to other provinces, so selection was based on LGU's advice. Further, RFO advised to include lowland vegetables in the prioritization.

Annex Table 1. Priority crops in the four (4) provinces in Region 4A.

Province	Priority crops	
	Major crops	Major lowland vegetables
Batangas	1. Mango 2. Banana 3. Corn*	1. String beans* 2. Ampalaya 3. Okra
Cavite	1. Coffee 2. Cacao* 3. Banana	1. Okra* 2. Ampalaya 3. String beans
Laguna	1. Rice* 2. Banana 3. Corn	1. Okra 2. String beans 3. Squash
Rizal	1. Rice 2. Banana 3. Mango*	1. String beans 2. Okra 3. Eggplant

*selected

Priority CRA practices: Alternate Wetting and Drying (AWD), adaptive crop calendar, contour farming (e.g., Sustainable Corn Production in Sloping Areas (SCoPSA), floating garden, integrated farming (e.g., intercropping, multi-storey cropping) (Annex Tables 2 and 3) per selected crop were selected based on the aggregated hazards data from CRVA and number of times it was recommended by LGUs. Description of these practices can be found in Labios, et al. Compendium of Climate-Resilient Agriculture Technologies & Approaches in the Philippines.

Annex Table 2. Selected CRA practices in the four (4) provinces in Region 4A.

Province	Major Hazard 1	CRA practice 1	Major Hazard 2	CRA practice 2
Batangas	Erosion	SCoPSA (Corn)	Landslide	Intercropping (String beans)
Cavite	Typhoon	Multi-storey cropping (Cacao)	Landslide	Adaptive crop calendar (Okra)
Laguna	Drought	AWD (Rice)	Typhoon	Adaptive crop calendar (Squash)
Rizal	Landslide	Contour farming (Mango)	Flood	Floating garden (Eggplant)

Annex Table 3. List of CRA practices in the provinces of Cavite, Laguna, Batangas and Rizal in Region 4A

CRA	COMMODITY												TOTAL
	Banana	Black pepper	Cacao	Coconut	Coffee	Corn	Lanzones	Mango	Rambutan	Rice	Sugarcane	Vegetable	
Alternate Wetting and Drying	0	0	0	0	0	0	0	0	0	6	0	0	6
Adaptive Crop Calendar	1	0	0	0	0	3	0	0	0	10	0	4	18
Contour Farming	1	0	0	0	0	0	0	0	0	0	0	0	1
Crop Insurance	1	0	0	0	1	0	0	0	0	2	0	1	5
Crop Rotation	0	0	0	0	0	1	0	0	0	1	0	4	6
Drainage System	0	0	0	0	1	0	0	0	0	2	0	0	3
Drip Irrigation	0	0	0	0	0	0	0	0	0	0	0	1	1
Early Maturing Variety	2	0	0	1	1	0	1	0	1	4	0	3	13
Greenhouse	0	0	0	0	0	0	0	0	0	0	0	1	1
Hydroponics	0	0	0	0	0	0	0	0	0	0	0	1	1
Integrated Pest Management	4	1	0	0	3	2	1	1	1	3	0	1	17
Intercropping	3	0	1	0	1	1	1	0	0	0	0	2	9
Leveling	0	0	0	0	0	0	0	0	0	1	0	0	1
Organic	1	0	2	0	2	1	1	1	1	3	0	2	14
Plastic Mulching	0	0	0	0	0	0	0	0	0	0	0	2	2
Postharvest (e.g. drying, storage)	4	1	1	0	3	0	0	1	0	2	0	0	12
Pruning	1	0	0	1	0	0	0	0	0	0	0	0	2
Site-specific Nutrient Management	2	0	0	0	4	0	1	1	1	2	0	0	11
Small-scale Irrigation (e.g. SWIP, STW)	3	0	0	0	3	1	0	0	0	6	1	7	21
Seed Banking	0	0	0	0	0	0	0	0	0	1	0	1	2
Solar Irrigation	0	0	0	0	0	1	0	0	0	0	0	1	2
Stress Tolerant Variety	5	1	1	1	1	4	2	0	1	15	1	6	38
Windbreak	3	0	1	0	0	0	0	0	0	0	0	2	6
Total	**31**	**3**	**6**	**3**	**20**	**14**	**7**	**4**	**5**	**60**	**2**	**39**	**194**

Results of Cost-Benefit Analysis

Key assumptions based on literature review include:

- Discount rate: 15%
- Project cycle: 10 years
- Medium yield
- Existing trees

Further, CRA practice-specific, which needs further validation is shown in Annex Table 4 below.

Annex Table 4. List of CRA practice-specific in the provinces of Cavite, Laguna, Batangas and Rizal in Region 4A

Benefits	Costs
AWD	
• Increase in yield by at least 2% • Reduction in irrigation (38%) and fuel cost (40%)	• Increase in harvesting (+sacks) and postharvest cost brought by increase in yield • Minimal installation cost (e.g., pani pipe)
Adaptive Crop Calendar	
• Less hazard damage by 10%-30% (less soil erosion, additional windbreaks)	• none
Contour Farming	
• Less soil erosion by at least 10% (erosion of the topsoil affects productivity)	• Minimal installation cost (e.g., A-frame, erosion pins)
Floating Garden	
• Less hazard damage by at least 10%	• Installation cost (e.g., raft, additional labor) of around PhP 7,500 / ha
Integrated Farming	
• Less hazard damage by 10%-30% (less soil erosion, additional windbreaks)	• Depends on the type of land especially the slope. Average of PhP 7,500 / ha

Summary of results are presented in following tables (Annex Table 5.1 – 5.4). All of the prioritized CRA practices are more financially profitable compared to conventional practice. Further, these practices likely contribute to reduced greenhouse gas emissions, increased agricultural productivity, enhanced food security, improved welfare of the poor, and additional environmental benefits. Note that the net present values calculated may be lower bound estimates given some "hard-to-quantify" benefits are not yet included in the calculations including integrated crops/trees.

Annex Table 5.1. Summary of CBA indicators for selected CRA practices in Batangas.

Indicator	Corn*		String beans**	
	without SCoPSA	with SCoPSA	without intercropping	with intercropping
Net Present Value (PhP)	53,196	62,624 (↑)	1,292,395	1,536,051 (↑)
Benefit-Cost Ratio	2.32	2.52	2.34	2.58
Annuity Equivalent Value (PhP)	10,599	12,478	257,512	306,061
Initial Investment (PhP)	8,675	9,775	207,919	216,169
Payback Period (years)	1.79	1.72	1.77	1.55

*White corn (Regional data from PSA, 2018) **Regional data from PRDP, 2019

Annex Table 5.2. Summary of CBA indicators for selected CRA practices in Cavite.

Indicator	Cacao*		Okra**	
	Without multi-storey cropping	With multi-storey cropping	Without adaptive crop calendar	With adaptive crop calendar
Net Present Value (PhP)	626,512	1,068,178 (↑)	968,101	1,174,254 (↑)
Benefit-Cost Ratio	2.49	3.50	2.09	2.32
Annuity Equivalent Value (PhP)	124,834	212,837	192,896	233,973
Initial Investment (PhP)	90,655	98,905	191,158	191,158
Payback Period (years)	1.59	1.02	2.17	1.79

*600 trees per ha (Regional data from PRDP, 2019) ** Regional data from PRDP, 2019

Annex Table 5.3. Summary of CBA indicators for selected CRA practices in Laguna.

Indicator	Rice*		Squash**	
	Without AWD	With AWD	Without adaptive crop calendar	With adaptive crop calendar
Net Present Value (PhP)	82,509	90,852 (↑)	40,477	261,621 (↑)
Benefit-Cost Ratio	1.30	1.33	1.09	1.55
Annuity Equivalent Value (PhP)	16,440	18,103	8,065	52,129
Initial Investment (PhP)	59,096	59,060	102,450	102,450
Payback Period (years)	7.88	7.15	27.84	4.31

*Irrigated rice, wet season (Regional data from PSA, 2018) **Regional data from PRDP, 2019

Annex Table 5.4. Summary of CBA indicators for selected CRA practices in Rizal.

Indicators	Mango*		Eggplant**	
	without contour farming	with contour farming	without floating garden	with floating garden
Net Present Value (PhP)	1,185,149	1,376,768 (↑)	1,140,399	1,400,796 (↑)
Benefit-Cost Ratio	2.96	3.25	1.90	2.10
Annuity Equivalent Value (PhP)	236,143	274,324	227,227	279,112
Initial Investment (PhP)	130,127	138,377	273,127	281,377
Payback Period (years)	1.21	1.11	2.63	2.21

*Provincial data from PRDP, 2019 ** Regional data from PRDP, 2019

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Attachment 1
CRA prioritization form

Province:
Priority crops (top 2 only):
1.
2.
Major climate hazards (top 2 only):
1.
2.

Name:
Designation:
Mobile number:
Email:

Priority crop 1: _______________
Major climate hazard: ___________________

Recommended CRA Practice[1]	Ranking[2*]
1.	
2.	
3.	
4.	
5.	

Priority crop 2: _______________
Major climate hazard: ___________________

Recommended CRA Practice[1]	Ranking[2*]
1.	
2.	
3.	
4.	
5.	

[1]CRA Practice Definition:
Practices are considered CRA if they enhance productivity **AND** at least one of the other objectives of CRA (climate risk adaptation and/or GHG mitigation)

[2]Criteria for Ranking:
1. Is it likely to be adopted by farmers?
2. Is there a service (e.g., financial, technical, community) that can support adoption/scaling?
3. Does it enhance food security/productivity?
4. Does it address the major climate hazard?

*Scale from 1-5 (1 high priority and 5 low priority)

APPENDICES

Appendix Table 1. Bioclimatic variables used in crop distribution modeling

PARAMETERS	DESCRIPTION
Temperature Related	
Bio_1 - Annual mean temperature	Annual mean temperature derived from the average monthly temperature.
Bio_2 - Mean diurnal range	The mean of the monthly temperature ranges (monthly maximum minus monthly minimum).
Bio_3 - Isothermality	Oscillation in day-to-night temperatures.
Bio_4 - Temperature seasonality	The amount of temperature variation over a given year based on standard deviation of monthly temperature averages.
Bio_5 - Maximum temperature of warmest month	The maximum monthly temperature occurrence over a given year (time-series) or averaged span of years (normal).
Bio_6 - Minimum temperature of coldest month	The minimum monthly temperature occurrence over a given year (time-series) or averaged span of years (normal).
Bio_7 - Temperature annual range	A measure of temperature variation over a given period.
Bio_8 - Mean temperature of wettest quarter	This quarterly index approximates mean temperatures that prevail during the wettest season.
Bio_9 - Mean temperature of driest quarter	This quarterly index approximates mean temperatures that prevail during the driest quarter.
Bio_10 - Mean temperature of warmest quarter	This quarterly index approximates mean temperatures that prevail during the warmest quarter.

Bio_11 - Mean temperature of coldest quarter	This quarterly index approximates mean temperatures that prevail during the coldest quarter.
Precipitation Related	
Bio_12 - Annual precipitation	This is the sum of all total monthly precipitation values.
Bio_13 - Precipitation of wettest month	This index identifies the total precipitation that prevails during the wettest month.
Bio_14 - Precipitation of driest month	This index identifies the total precipitation that prevails during the driest month.
Bio_15 - Precipitation seasonality	This is a measure of the variation in monthly precipitation totals over the course of the year. This index is the ratio of the standard deviation of the monthly total precipitation to the mean monthly total precipitation and is expressed as percentage.
Bio_16 - Precipitation of wettest quarter	This quarterly index approximates total precipitation that prevails during the wettest quarter.
Bio_17 - Precipitation of driest quarter	This quarterly index approximates total precipitation that prevails during the driest quarter.
Bio_18 - Precipitation of warmest quarter	This quarterly index approximates total precipitation that prevails during the warmest quarter.
Bio_19 - Precipitation of coldest quarter	This quarterly index approximates total precipitation that prevails during the coldest quarter.
Bio_20 - Number of consecutive dry days	Consistent number considered as dry days.

Source: O'Donnell, M. and Ignizio, D., 2012

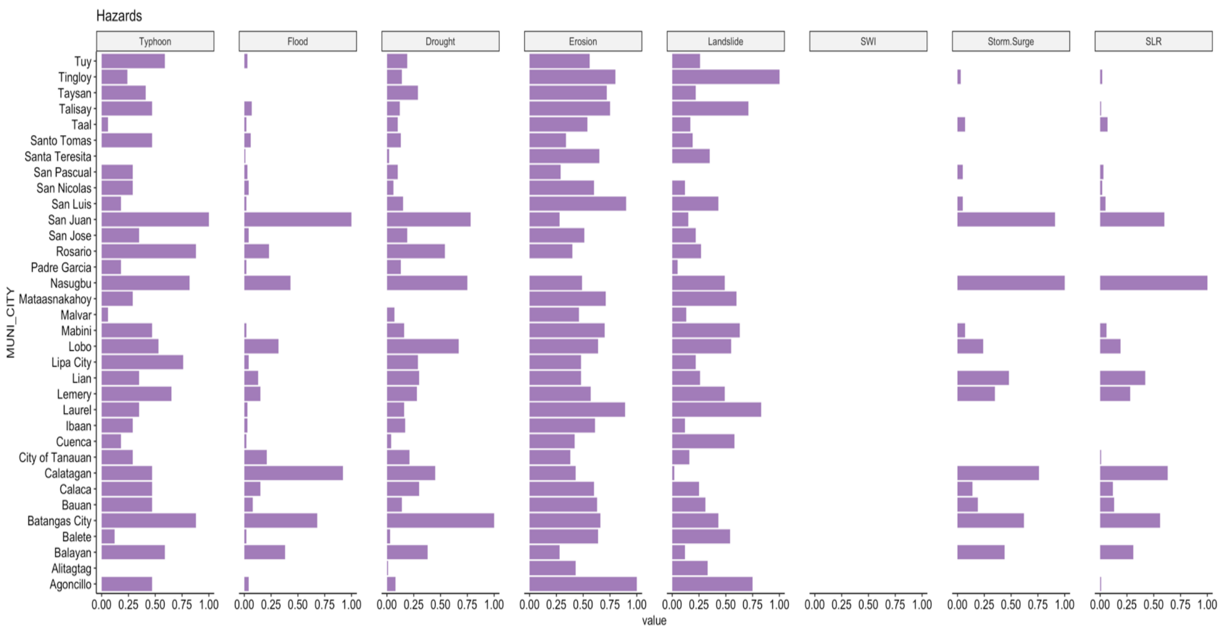
Appendix Table 2. Global Circulation Models used in the study to assess future climate suitability

MODEL	MODELING CENTER	INSTITUTION
bcc_csm1_1	BCC	Beijing Climate Center, China Meteorological Administration
bcc_csm1_1_m	BCC	Beijing Climate Center, China Meteorological Administration
bnu_esm	GCESS	College of Global Change and Earth System Science, Beijing Normal University
cccma_canesm2	CCCMA	Canadian Centre for Climate Modelling and Analysis
cesm1_bgc	NSF-DOE-NCAR	National Science Foundation, Department of Energy, National Center for Atmospheric Research
cesm1_cam5	NCAR	National Center for Atmospheric Research
cnrm_cm5	CNRM-CERFACS	Centre National de Recherches Meteorologiques / Centre Europeen de Recherche et Formation Avancees en Calcul Scientifique
csiro_access1_0	CSIRO-BOM	CSIRO (Commonwealth Scientific and Industrial Research Organisation, Australia), and BOM (Bureau of Meteorology, Australia)
csiro_access1_3	CSIRO-BOM	CSIRO (Commonwealth Scientific and Industrial Research Organisation, Australia), and BOM (Bureau of Meteorology, Australia)
csiro_mk3_6_0	CSIRO-QCCCE	Commonwealth Scientific and Industrial Research Organization in Collaboration with the Queensland Climate Change Centre of Excellence
ec_earth	EC-EARTH	EC-EARTH Consortium
fio_esm	FIO	The First Institute of Oceanography, SOA, China
gfdl_cm3	NOAA GFDL	Geophysical Fluid Dynamics Laboratory
gfdl_esm2g	NOAA GFDL	Geophysical Fluid Dynamics Laboratory
gfdl_esm2m	NOAA GFDL	Geophysical Fluid Dynamics Laboratory
giss_e2_h	NASA GISS	NASA Goddard Institute for Space Studies

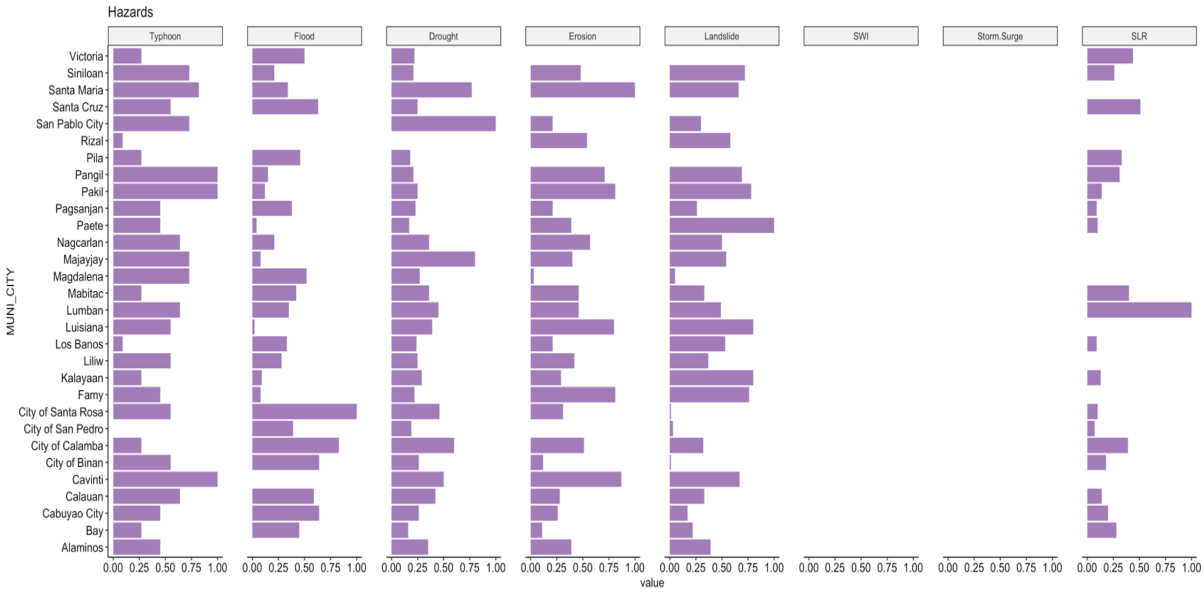
giss_e2_r	NASA GISS	NASA Goddard Institute for Space Studies
inm_cm4	INM	Institute for Numerical Mathematics
ipsl_cm5a_lr	IPSL	Institut Pierre-Simon Laplace
ipsl_cm5a_mr	IPSL	Institut Pierre-Simon Laplace
ipsl_cm5b_lr	IPSL	Institut Pierre-Simon Laplace
lasg_fgoals_g2	LASG-CESS	LASG, Institute of Atmospheric Physics, Chinese Academy of Sciences; and CESS, Tsinghua University
miroc_esm	MIROC	Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies
miroc_esm_chem	MIROC	Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies
miroc_miroc5	MIROC	Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology
mohc_hadgem2_cc	MOHC (additional realizations by INPE)	Met Office Hadley Centre (additional HadGEM2-ES realizations contributed by Instituto Nacional de Pesquisas Espaciais)
mohc_hadgem2_es	MOHC (additional realizations by INPE)	Met Office Hadley Centre (additional HadGEM2-ES realizations contributed by Instituto Nacional de Pesquisas Espaciais)
mpi_esm_lr	MPI-M	Max Planck Institute for Meteorology (MPI-M)
mpi_esm_mr	MPI-M	Max Planck Institute for Meteorology (MPI-M)
mri_cgcm3	MRI	Meteorological Research Institute
ncar_ccsm4	NCAR	National Center for Atmospheric Research
ncc_noresm1_m	NCC	Norwegian Climate Centre
nimr_hadgem2_ao	NIMR/KMA	National Institute of Meteorological Research/Korea Meteorological Administration

Appendix Table 3. Index scores for the different climate and climate-related hazards in the province of Cavite.

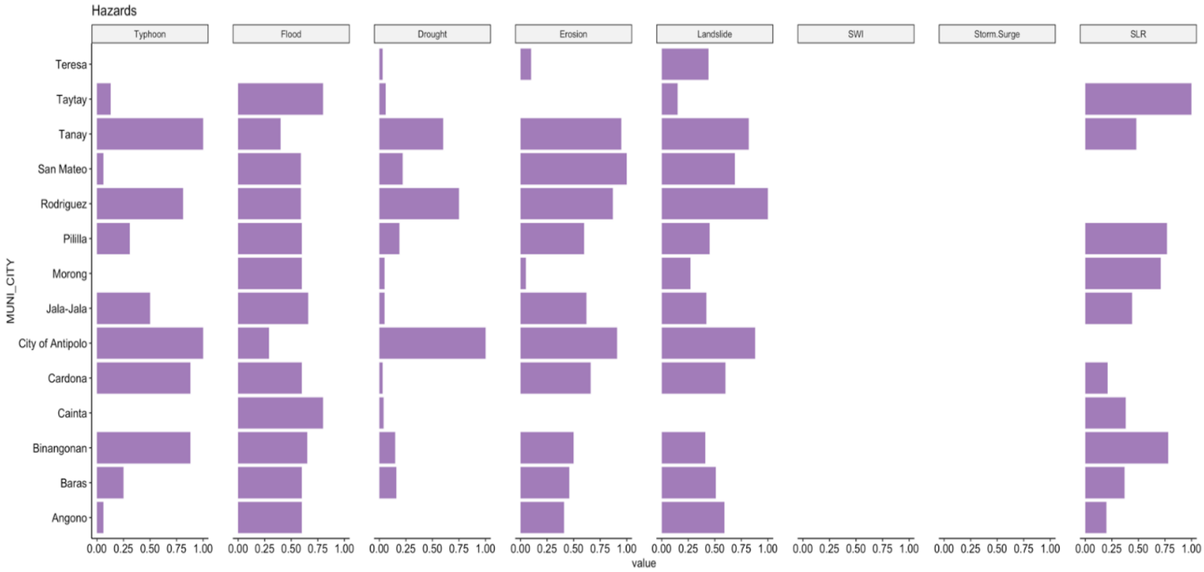
Appendix Table 4. Index scores for the different climate and climate-related hazards in the province of Batangas.



Appendix Table 5. Index scores for the different climate and climate-related hazards in the province of Laguna



Appendix Table 6. Index scores for the different climate and climate-related hazards in the province of Rizal



Appendix Table 7. Adaptive capacity (AC) scores for the municipalities of Batangas

LGU	ECONOMIC	HUMAN	PHYSICAL	NATURAL	ANTICIPATORY	AC SCORE	AC_NORM
Agoncillo	0.15	0	0.42	0	1	1.57	0.33
Alitagtag	0.2	0	0.41	0	1	2.09	0.49
Balayan	0.47	0	0.53	0	0	1.36	0.26
Balete (BS)	0.22	0	0.28	0	1	1.89	0.43
Batangas	0.93	1	0.86	0	1	3.72	1
Bauan	0.78	0	0.67	0	0	1.56	0.32
Calaca	0.24	0	0.38	0	0	1.22	0.22
Calatagan	0.22	0	0	0	1	1.43	0.28
Cuenca	0.23	0	0.18	0	1	1.55	0.32
Ibaan	0.24	0	0.4	0	1	1.73	0.38
Laurel	0.03	0	0.38	0	0	0.67	0.04
Lemery (BS)	0.33	0	0.47	0	0	1.21	0.21
Lian	0.13	0	0.43	0	0	0.73	0.06
Lipa	1	1	1	0	0	3	0.77
Lobo	0.07	0	0.2	0	0	0.53	0
Mabini (BS)	0.38	0	0.78	0	0	1.28	0.24
Malvar	0.26	0	0.23	0	0	0.86	0.1
Mataasnakahoy	0.26	0	0.42	0	1	2.13	0.5
Nasugbu	0.33	0	0.53	0	0	1.2	0.21
Padre Garcia	0.21	0	0.23	0	0	0.66	0.04
Rosario (BS)	0.47	0	0.63	0	1	2.55	0.63
San Jose (BS)	0.43	0	0.23	0	0	0.96	0.14
San Juan (BS)	0.58	0	0.67	0	0	1.91	0.43
San Luis (BS)	0.21	0	0.53	0	1	1.91	0.43
San Nicolas (BS)	0.12	0	0.25	0	1	1.77	0.39

Appendix Table 8. Adaptive capacity (AC) scores for the municipalities of Cavite

LGU	ECONOMIC	HUMAN	PHYSICAL	NATURAL	ANTICIPATORY	AC SCORE	AC_NORM
Alfonso	0.19	0.38	0.65	0	0	1.22	0.17
Amadeo	0.2	0.4	0.47	0	1	2.07	0.44
Bacoor	0.99	0.84	1	0	1	3.87	1
Carmona	0.52	0.46	0.65	0	1	2.63	0.61
Cavite	0.46	0.41	0.78	0	0	1.78	0.34
Dasmarinas	0.82	1	0.84	0	1	3.66	0.93
Gen. Emilio Aguinaldo	0.1	0.64	0.47	0	1	2.21	0.48
General Trias	0.63	0.42	0.77	0	1	2.83	0.67
Imus	1	0.91	0.75	0	1	3.67	0.94
Indang	0.2	0.3	0.62	0	0	1.12	0.14
Kawit	0.43	0.59	0.21	0	0	1.61	0.29
Magallanes	0	0.55	0.22	0	1	1.77	0.34
Maragondon	0.05	0.36	0.27	0	0	0.68	0
Mendez	0.22	0.24	0.3	0	1	1.76	0.34
Naic	0.14	0.34	0.25	0	1	1.73	0.33
Noveleta	0.14	0	0.01	1	0	1.15	0.15
Rosario	0.64	0.36	0.02	0	1	2.03	0.42
Silang	0.54	0.99	0.93	0	0	2.47	0.56
Tagaytay	0.69	0.9	0.77	0	1	3.36	0.84
Tanza	0.39	0.42	0.51	0	1	2.32	0.51
Ternate	0.01	0.48	0	0	1	1.61	0.29
Trece Martires	0.52	0.18	0.81	0	1	2.51	0.58
Gen. Mariano Alvarez	0.4	0.38	0.69	0	0	1.47	0.25

Appendix Table 9. Adaptive capacity (AC) scores for the municipalities of Laguna

LGU	ECONOMIC	HUMAN	PHYSICAL	NATURAL	ANTICIPATORY	AC SCORE	AC_NORM
Alaminos	0.00	0.23	0.46	0.00	0.00	0.69	0.08
Bay	0.04	0.52	0.55	0.00	0.00	1.10	0.20
Binan	0.81	0.17	1.00	0.00	0.00	1.98	0.47
Cabuyao	0.60	0.12	0.78	0.00	1.00	2.50	0.62
Calamba	1.00	1.00	0.63	0.00	1.00	3.75	1.00
Calauan	0.15	0.11	0.41	0.00	0.00	0.67	0.07
Cavinti	0.09	0.40	0.29	0.00	0.00	0.77	0.10
Famy	0.11	0.42	0.00	0.00	1.00	1.53	0.33
Kalayaan	0.10	0.30	0.06	0.00	1.00	1.46	0.31
Liliw	0.04	0.00	0.39	0.00	0.00	0.43	0.00
Los Banos	0.36	0.44	0.39	1.00	0.00	2.19	0.53
Luisiana	0.07	0.20	0.53	0.00	1.00	1.80	0.42
Lumban	0.04	0.05	0.34	0.00	0.00	0.44	0.00
Mabitac	0.25	0.37	0.16	0.00	1.00	1.78	0.41
Magdalena	0.22	0.13	0.22	0.00	1.00	1.57	0.35
Majayjay	0.08	0.26	0.05	0.00	1.00	1.40	0.29
Nagcarlan	0.19	0.25	0.45	0.00	0.00	0.88	0.14
Paete	0.08	0.09	0.32	0.00	1.00	1.50	0.32
Pagsanjan	0.02	0.24	0.53	0.00	0.00	0.80	0.11
Pakil	0.12	0.08	0.12	0.00	1.00	1.32	0.27
Pangil	0.06	0.28	0.33	0.00	1.00	1.68	0.38
Pila	0.07	0.02	0.47	0.00	0.00	0.57	0.04
Rizal	0.00	0.35	0.02	0.00	1.00	1.37	0.29
San Pablo	0.82	0.94	0.74	0.00	0.00	2.49	0.62
San Pedro	0.67	0.75	0.88	0.00	0.00	2.30	0.56

Appendix Table 10. Adaptive capacity (AC) scores for the municipalities of Rizal

LGU	ECONOMIC	HUMAN	PHYSICAL	NATURAL	ANTICIPATORY	AC	AC_NORM
Angono	0.18	0.15	0.6	0	0	0.93	0.28
Antipolo	1	0.66	0.37	0	0	2.03	0.65
Baras	0.02	0.37	0.17	0	0	0.55	0.15
Binangonan	0.38	0.19	0.09	0	0	0.66	0.18
Cainta	0.69	1	0.58	0	0	2.26	0.73
Cardona	0.05	0.05	0.11	0	0	0.22	0.03
Jalajala	0.19	0.17	0.07	0	0	0.43	0.11
Rodriguez	0.34	0.54	0.17	1	1	3.05	1.00
Morong	0.03	0.05	0.23	0	0	0.31	0.06
Pililla	0.06	0.01	0.34	0	0	0.41	0.10
San Mateo	0.27	0.2	0.09	0	0	0.56	0.15
Tanay	0.54	0.1	0	0	0	0.64	0.18
Taytay	0.71	0.49	1	0	0	2.19	0.71
Teresa	0	0	0.12	0	0	0.12	0.00

PHOTO-DOCUMENTATION

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APPENDICES

Appendix Table 1. Bioclimatic variables used in crop distribution modeling

PARAMETERS	DESCRIPTION
Temperature Related	
Bio_1 - Annual mean temperature	Annual mean temperature derived from the average monthly temperature.
Bio_2 - Mean diurnal range	The mean of the monthly temperature ranges (monthly maximum minus monthly minimum).
Bio_3 - Isothermality	Oscillation in day-to-night temperatures.
Bio_4 - Temperature seasonality	The amount of temperature variation over a given year based on standard deviation of monthly temperature averages.
Bio_5 - Maximum temperature of warmest month	The maximum monthly temperature occurrence over a given year (time-series) or averaged span of years (normal).
Bio_6 - Minimum temperature of coldest month	The minimum monthly temperature occurrence over a given year (time-series) or averaged span of years (normal).
Bio_7 - Temperature annual range	A measure of temperature variation over a given period.
Bio_8 - Mean temperature of wettest quarter	This quarterly index approximates mean temperatures that prevail during the wettest season.
Bio_9 - Mean temperature of driest quarter	This quarterly index approximates mean temperatures that prevail during the driest quarter.
Bio_10 - Mean temperature of warmest quarter	This quarterly index approximates mean temperatures that prevail during the warmest quarter.
Bio_11 - Mean temperature of coldest quarter	This quarterly index approximates mean temperatures that prevail during the coldest quarter.
Precipitation Related	

Bio_12 - Annual precipitation	This is the sum of all total monthly precipitation values.
Bio_13 - Precipitation of wettest month	This index identifies the total precipitation that prevails during the wettest month.
Bio_14 - Precipitation of driest month	This index identifies the total precipitation that prevails during the driest month.
Bio_15 - Precipitation seasonality	This is a measure of the variation in monthly precipitation totals over the course of the year. This index is the ratio of the standard deviation of the monthly total precipitation to the mean monthly total precipitation and is expressed as percentage.
Bio_16 - Precipitation of wettest quarter	This quarterly index approximates total precipitation that prevails during the wettest quarter.
Bio_17 - Precipitation of driest quarter	This quarterly index approximates total precipitation that prevails during the driest quarter.
Bio_18 - Precipitation of warmest quarter	This quarterly index approximates total precipitation that prevails during the warmest quarter.
Bio_19 - Precipitation of coldest quarter	This quarterly index approximates total precipitation that prevails during the coldest quarter.
Bio_20 - Number of consecutive dry days	Consistent number considered as dry days.

Source: O'Donnell, M. and Ignizio, D., 2012

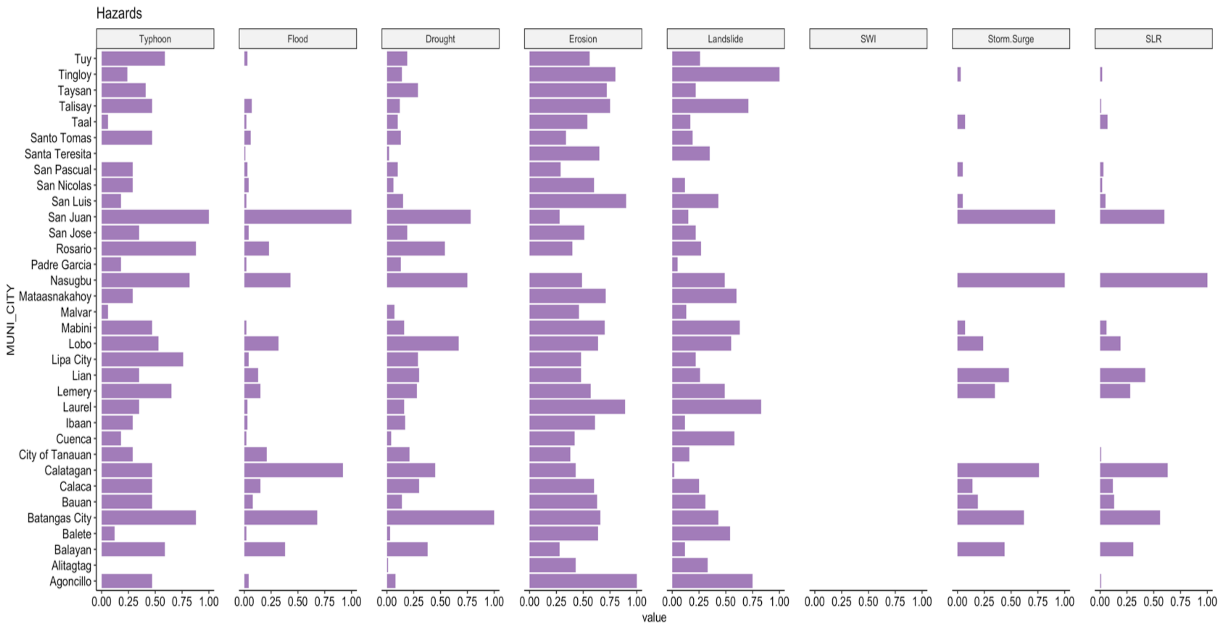
Appendix Table 2. Global Circulation Models used in the study to assess future climate suitability

MODEL	MODELING CENTER	INSTITUTION
bcc_csm1_1	BCC	Beijing Climate Center, China Meteorological Administration
bcc_csm1_1_m	BCC	Beijing Climate Center, China Meteorological Administration
bnu_esm	GCESS	College of Global Change and Earth System Science, Beijing Normal University
cccma_canesm2	CCCMA	Canadian Centre for Climate Modelling and Analysis
cesm1_bgc	NSF-DOE-NCAR	National Science Foundation, Department of Energy, National Center for Atmospheric Research
cesm1_cam5	NCAR	National Center for Atmospheric Research
cnrm_cm5	CNRM-CERFACS	Centre National de Recherches Meteorologiques / Centre Europeen de Recherche et Formation Avancees en Calcul Scientifique
csiro_access1_0	CSIRO-BOM	CSIRO (Commonwealth Scientific and Industrial Research Organisation, Australia), and BOM (Bureau of Meteorology, Australia)
csiro_access1_3	CSIRO-BOM	CSIRO (Commonwealth Scientific and Industrial Research Organisation, Australia), and BOM (Bureau of Meteorology, Australia)
csiro_mk3_6_0	CSIRO-QCCCE	Commonwealth Scientific and Industrial Research Organization in Collaboration with the Queensland Climate Change Centre of Excellence
ec_earth	EC-EARTH	EC-EARTH Consortium
fio_esm	FIO	The First Institute of Oceanography, SOA, China
gfdl_cm3	NOAA GFDL	Geophysical Fluid Dynamics Laboratory
gfdl_esm2g	NOAA GFDL	Geophysical Fluid Dynamics Laboratory
gfdl_esm2m	NOAA GFDL	Geophysical Fluid Dynamics Laboratory
giss_e2_h	NASA GISS	NASA Goddard Institute for Space Studies

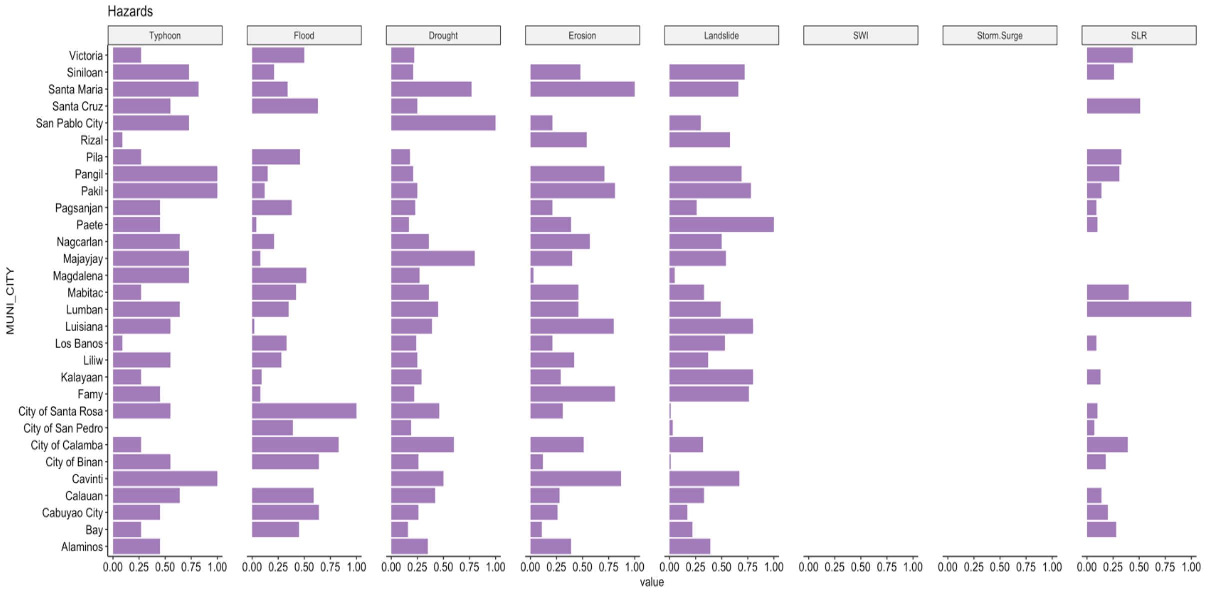
giss_e2_r	NASA GISS	NASA Goddard Institute for Space Studies
inm_cm4	INM	Institute for Numerical Mathematics
ipsl_cm5a_lr	IPSL	Institut Pierre-Simon Laplace
ipsl_cm5a_mr	IPSL	Institut Pierre-Simon Laplace
ipsl_cm5b_lr	IPSL	Institut Pierre-Simon Laplace
lasg_fgoals_g2	LASG-CESS	LASG, Institute of Atmospheric Physics, Chinese Academy of Sciences; and CESS, Tsinghua University
miroc_esm	MIROC	Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies
miroc_esm_chem	MIROC	Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies
miroc_miroc5	MIROC	Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology
mohc_hadgem2_cc	MOHC (additional realizations by INPE)	Met Office Hadley Centre (additional HadGEM2-ES realizations contributed by Instituto Nacional de Pesquisas Espaciais)
mohc_hadgem2_es	MOHC (additional realizations by INPE)	Met Office Hadley Centre (additional HadGEM2-ES realizations contributed by Instituto Nacional de Pesquisas Espaciais)
mpi_esm_lr	MPI-M	Max Planck Institute for Meteorology (MPI-M)
mpi_esm_mr	MPI-M	Max Planck Institute for Meteorology (MPI-M)
mri_cgcm3	MRI	Meteorological Research Institute
ncar_ccsm4	NCAR	National Center for Atmospheric Research
ncc_noresm1_m	NCC	Norwegian Climate Centre
nimr_hadgem2_ao	NIMR/KMA	National Institute of Meteorological Research/Korea Meteorological Administration

Appendix Table 3. Index scores for the different climate and climate-related hazards in the province of Cavite.

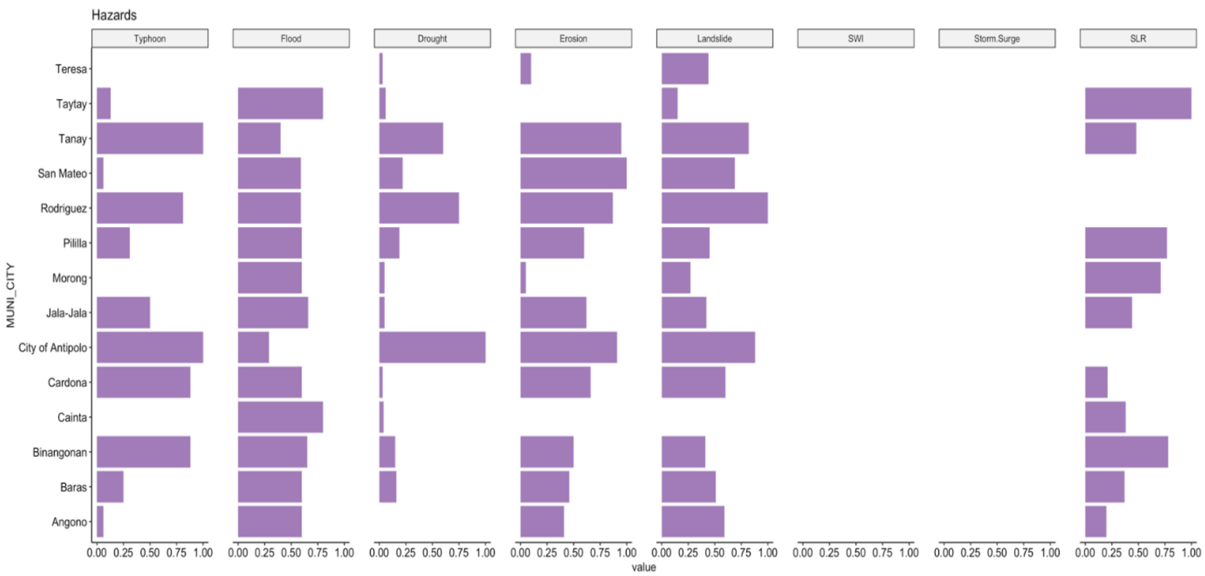
Appendix Table 4. Index scores for the different climate and climate-related hazards in the province of Batangas.



Appendix Table 5. Index scores for the different climate and climate-related hazards in the province of Laguna



Appendix Table 6. Index scores for the different climate and climate-related hazards in the province of Rizal



Appendix Table 7. Adaptive capacity (AC) scores for the municipalities of Batangas

LGU	ECONOMIC	HUMAN	PHYSICAL	NATURAL	ANTICIPATORY	AC SCORE	AC_NORM
Agoncillo	0.15	0	0.42	0	1	1.57	0.33
Alitagtag	0.2	0	0.41	0	1	2.09	0.49
Balayan	0.47	0	0.53	0	0	1.36	0.26
Balete (BS)	0.22	0	0.28	0	1	1.89	0.43
Batangas	0.93	1	0.86	0	1	3.72	1
Bauan	0.78	0	0.67	0	0	1.56	0.32
Calaca	0.24	0	0.38	0	0	1.22	0.22
Calatagan	0.22	0	0	0	1	1.43	0.28
Cuenca	0.23	0	0.18	0	1	1.55	0.32
Ibaan	0.24	0	0.4	0	1	1.73	0.38
Laurel	0.03	0	0.38	0	0	0.67	0.04
Lemery (BS)	0.33	0	0.47	0	0	1.21	0.21
Lian	0.13	0	0.43	0	0	0.73	0.06
Lipa	1	1	1	0	0	3	0.77
Lobo	0.07	0	0.2	0	0	0.53	0
Mabini (BS)	0.38	0	0.78	0	0	1.28	0.24
Malvar	0.26	0	0.23	0	0	0.86	0.1
Mataasnakahoy	0.26	0	0.42	0	1	2.13	0.5
Nasugbu	0.33	0	0.53	0	0	1.2	0.21
Padre Garcia	0.21	0	0.23	0	0	0.66	0.04
Rosario (BS)	0.47	0	0.63	0	1	2.55	0.63
San Jose (BS)	0.43	0	0.23	0	0	0.96	0.14
San Juan (BS)	0.58	0	0.67	0	0	1.91	0.43
San Luis (BS)	0.21	0	0.53	0	1	1.91	0.43
San Nicolas (BS)	0.12	0	0.25	0	1	1.77	0.39

Appendix Table 8. Adaptive capacity (AC) scores for the municipalities of Cavite

LGU	ECONOMIC	HUMAN	PHYSICAL	NATURAL	ANTICIPATORY	AC SCORE	AC_NORM
Alfonso	0.19	0.38	0.65	0	0	1.22	0.17
Amadeo	0.2	0.4	0.47	0	1	2.07	0.44
Bacoor	0.99	0.84	1	0	1	3.87	1
Carmona	0.52	0.46	0.65	0	1	2.63	0.61
Cavite	0.46	0.41	0.78	0	0	1.78	0.34
Dasmarinas	0.82	1	0.84	0	1	3.66	0.93
Gen. Emilio Aguinaldo	0.1	0.64	0.47	0	1	2.21	0.48
General Trias	0.63	0.42	0.77	0	1	2.83	0.67
Imus	1	0.91	0.75	0	1	3.67	0.94
Indang	0.2	0.3	0.62	0	0	1.12	0.14
Kawit	0.43	0.59	0.21	0	0	1.61	0.29
Magallanes	0	0.55	0.22	0	1	1.77	0.34
Maragondon	0.05	0.36	0.27	0	0	0.68	0
Mendez	0.22	0.24	0.3	0	1	1.76	0.34
Naic	0.14	0.34	0.25	0	1	1.73	0.33
Noveleta	0.14	0	0.01	1	0	1.15	0.15
Rosario	0.64	0.36	0.02	0	1	2.03	0.42
Silang	0.54	0.99	0.93	0	0	2.47	0.56
Tagaytay	0.69	0.9	0.77	0	1	3.36	0.84
Tanza	0.39	0.42	0.51	0	1	2.32	0.51
Ternate	0.01	0.48	0	0	1	1.61	0.29
Trece Martires	0.52	0.18	0.81	0	1	2.51	0.58
Gen. Mariano Alvarez	0.4	0.38	0.69	0	0	1.47	0.25

Appendix Table 9. Adaptive capacity (AC) scores for the municipalities of Laguna

LGU	ECONOMIC	HUMAN	PHYSICAL	NATURAL	ANTICIPATORY	AC SCORE	AC_NORM
Alaminos	0.00	0.23	0.46	0.00	0.00	0.69	0.08
Bay	0.04	0.52	0.55	0.00	0.00	1.10	0.20
Binan	0.81	0.17	1.00	0.00	0.00	1.98	0.47
Cabuyao	0.60	0.12	0.78	0.00	1.00	2.50	0.62
Calamba	1.00	1.00	0.63	0.00	1.00	3.75	1.00
Calauan	0.15	0.11	0.41	0.00	0.00	0.67	0.07
Cavinti	0.09	0.40	0.29	0.00	0.00	0.77	0.10
Famy	0.11	0.42	0.00	0.00	1.00	1.53	0.33
Kalayaan	0.10	0.30	0.06	0.00	1.00	1.46	0.31
Liliw	0.04	0.00	0.39	0.00	0.00	0.43	0.00
Los Banos	0.36	0.44	0.39	1.00	0.00	2.19	0.53
Luisiana	0.07	0.20	0.53	0.00	1.00	1.80	0.42
Lumban	0.04	0.05	0.34	0.00	0.00	0.44	0.00
Mabitac	0.25	0.37	0.16	0.00	1.00	1.78	0.41
Magdalena	0.22	0.13	0.22	0.00	1.00	1.57	0.35
Majayjay	0.08	0.26	0.05	0.00	1.00	1.40	0.29
Nagcarlan	0.19	0.25	0.45	0.00	0.00	0.88	0.14
Paete	0.08	0.09	0.32	0.00	1.00	1.50	0.32
Pagsanjan	0.02	0.24	0.53	0.00	0.00	0.80	0.11
Pakil	0.12	0.08	0.12	0.00	1.00	1.32	0.27
Pangil	0.06	0.28	0.33	0.00	1.00	1.68	0.38
Pila	0.07	0.02	0.47	0.00	0.00	0.57	0.04
Rizal	0.00	0.35	0.02	0.00	1.00	1.37	0.29
San Pablo	0.82	0.94	0.74	0.00	0.00	2.49	0.62
San Pedro	0.67	0.75	0.88	0.00	0.00	2.30	0.56

Appendix Table 10. Adaptive capacity (AC) scores for the municipalities of Rizal

LGU	ECONOMIC	HUMAN	PHYSICAL	NATURAL	ANTICIPATORY	AC	AC_NORM
Angono	0.18	0.15	0.6	0	0	0.93	0.28
Antipolo	1	0.66	0.37	0	0	2.03	0.65
Baras	0.02	0.37	0.17	0	0	0.55	0.15
Binangonan	0.38	0.19	0.09	0	0	0.66	0.18
Cainta	0.69	1	0.58	0	0	2.26	0.73
Cardona	0.05	0.05	0.11	0	0	0.22	0.03
Jalajala	0.19	0.17	0.07	0	0	0.43	0.11
Rodriguez	0.34	0.54	0.17	1	1	3.05	1.00
Morong	0.03	0.05	0.23	0	0	0.31	0.06
Pililla	0.06	0.01	0.34	0	0	0.41	0.10
San Mateo	0.27	0.2	0.09	0	0	0.56	0.15
Tanay	0.54	0.1	0	0	0	0.64	0.18
Taytay	0.71	0.49	1	0	0	2.19	0.71
Teresa	0	0	0.12	0	0	0.12	0.00