Climate Risk Vulnerability Assessment in the Agriculture Sector in the Provinces of Pangasinan, La Union, and Ilocos Norte, Philippines

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INTRODUCTION AND FRAMEWORK

Climate change and variability continue to exert increasing pressure upon the agricultural sector of the Philippines. 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 agricultural sector is recognized as the most vulnerable of all sectors (UNESCAP 2015). A better understanding of major agricultural vulnerabilities to climate risks, thus fundamental to achieving more resilient farming systems, especially among poor rural households. Therefore, it is necessary to identify and prioritize at a higher resolution – 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 (Béné et al. 2015).

Under the umbrella of the Department of Agriculture (DA) project “Adaptation and Mitigation Initiative in Agriculture” (AMIA), a climate risk vulnerability assessment for 3 selected provinces (figure 1) has being conducted to guide DA targeting and planning for building climate-resilient agri-fisheries communities. It also seeks to introduce complementary activities for building appropriate climate responsive financial and other key support services based on adaptive capacity assessment. A key step in the targeting and planning for CRA communities is to assess municipality-level climate-risk vulnerability in the three provinces – Ilocos Norte, La Union, and Pangasinan (figure 1) – and identify key climate risks and adaptive capacity needs to support adaptation. The next step is to assess the profitable climate resilient agricultural (CRA) practices in each of the provinces. Here, we selected two agricultural practices – considered climate smart – that address a particular climate risk and essential to improve farmers’ livelihood. Cost and benefit (CBA) analysis was used to assess the relative profitability of alternative practices compared to conventional practices (or business as usual) (Sain et al., 2017). This ensures that DA investments are cost-effectively channeled to support its overall goals and outcomes.

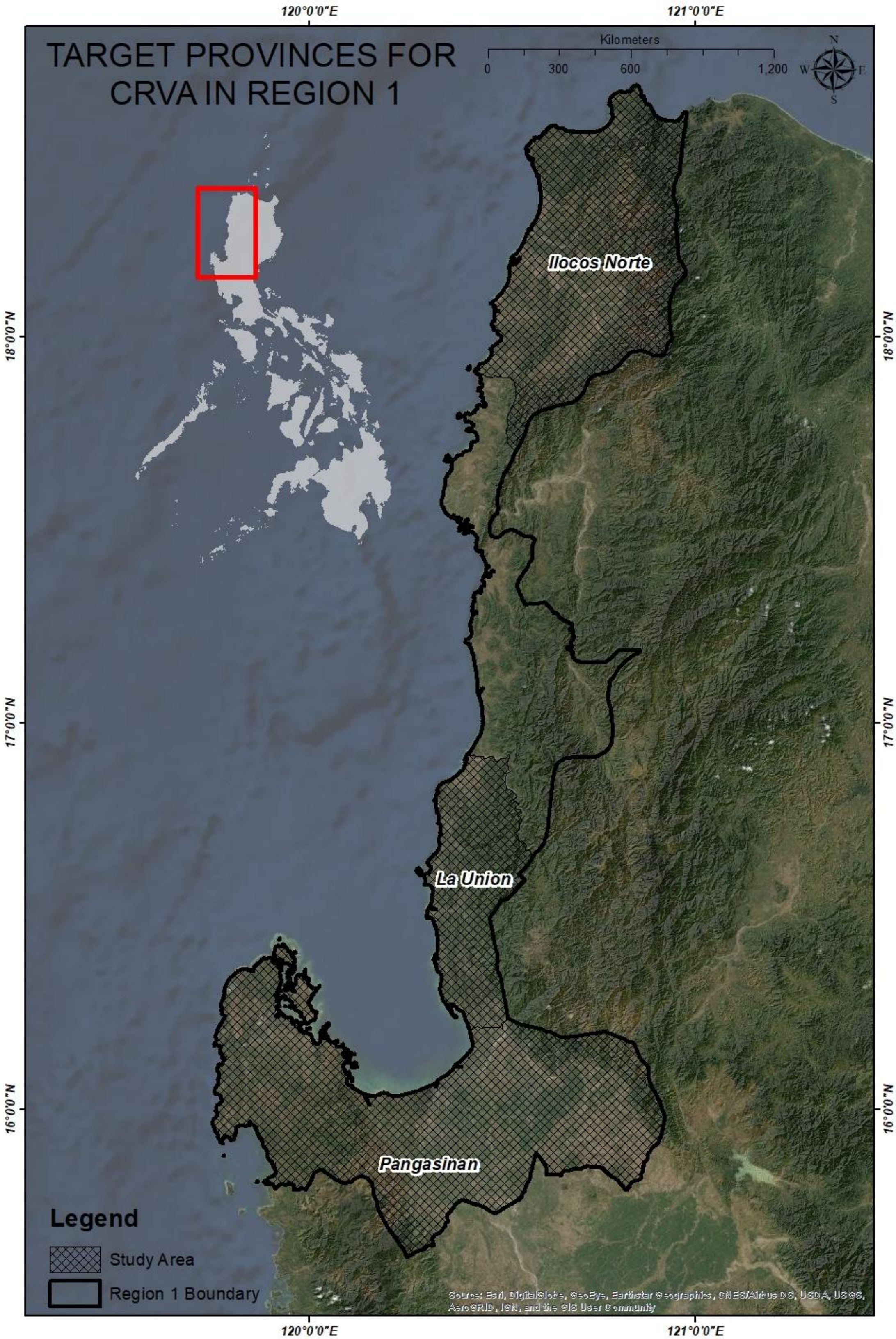
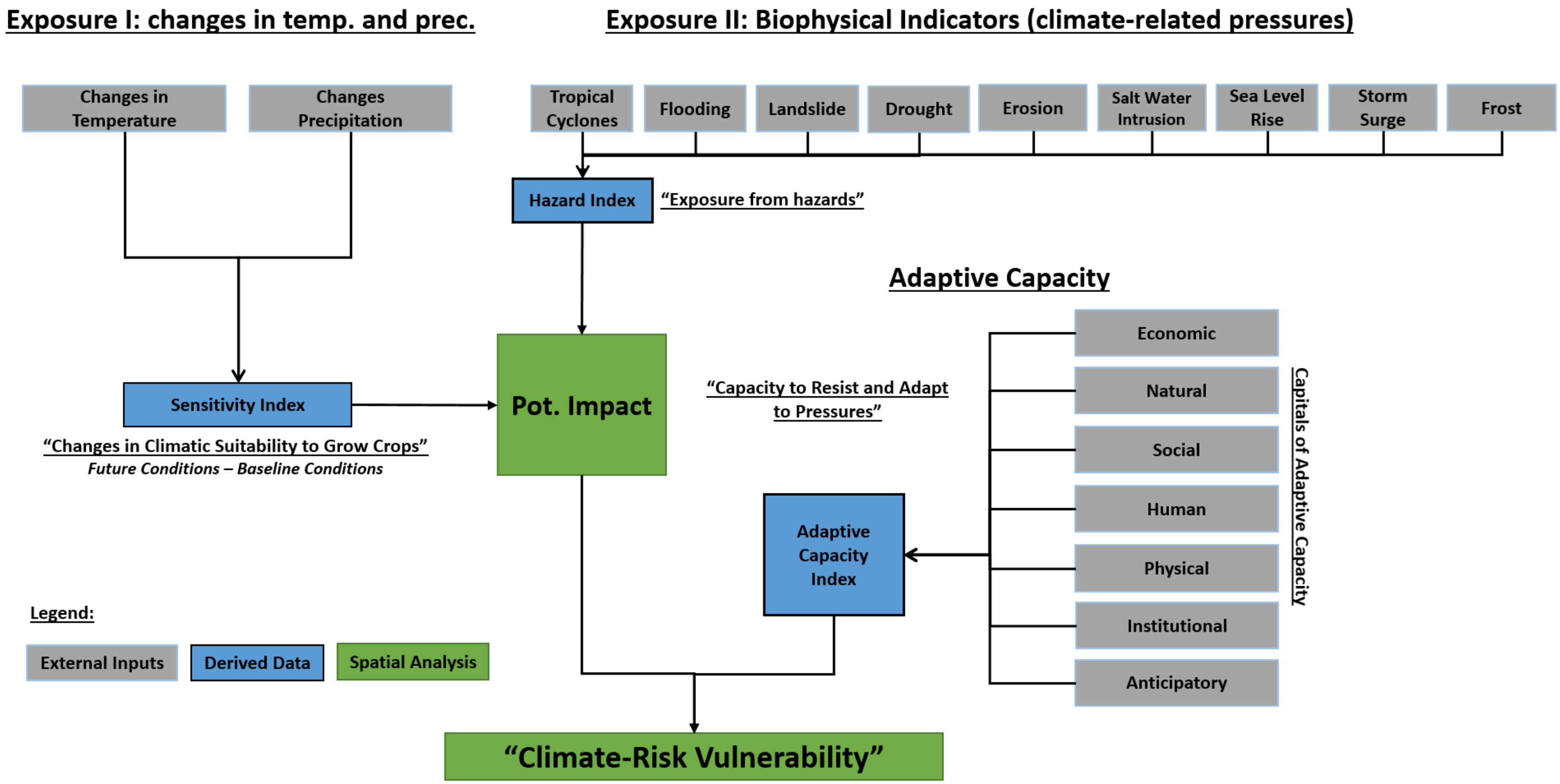


Figure 1. Target provinces in Region 1, Philippines

The following presents an assessment of the three key dimensions of vulnerability for the agricultural sector:

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 (Parker et al., 2019).
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).

Our framework builds on the approach of IPCC that defines climate change vulnerability in terms of exposure to climate change-induced shocks (e.g. increased typhoons, floods, drought, landslides, gradual warming and changes in precipitation patterns); the sensitivity of ecological systems to such shocks; and the adaptive capacity of livelihoods to respond to the climate shocks. The sensitivity analysis is based on the assumption of a high emission scenario (RCP 8.5) by 2050, whereas the adaptive capacity component is derived from the up-to date and validated socio-economic and bio-physical data at the municipality-level in Ilocos Norte, La Union, and Pangasinan. The 2050 time slice was selected to allow for medium term planning for agriculture. Selection of later time slice (2070 and 2090) also present higher climate uncertainty. The detailed composition of each component is shown in figure 2. The resulting vulnerability assessment enables science-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.



$$f(Haz, Sens, AC) = \sum_{n=i}^{n} \left(Haz_{(w_h)} + Sens_{(w_s)}\right) + \left(1 - AC_{(w_a)}\right) \quad \textbf{Eq. 1}$$

Where: *Haz* = hazard index, *Sens* = sensitivity index ($_i$ = crop), and *AC* = adaptive capacity index. W_h = weight given for hazard, W_s = weight given for sensitivity, and W_a = weight given for adaptive capacity.

Figure 2: Climate Risk Vulnerability Assessment Framework

Recent Studies on Climate Change Vulnerability Assessment in the Philippines

Several vulnerability assessments[1] have already been conducted in the Philippines. The summary of the different components (sensitivity, exposure, and adaptive capacity), scale and resolution of already existing climate change vulnerability assessments in the Philippines is available in Annex 1. The climate change vulnerability assessments in the Philippines is characterized by: 1) wide range of indicators used for each component of vulnerability; 2) coverage is very sparse; 3) coverage was broad (Asia) but resolution was too coarse (regional); 4) some study refers climate vulnerability as a single weather event (typhoon); 5) context – some are context specific (agriculture, watersheds) while others are general; 6) limited use of climate projections to forecast climate impacts to species and crops. The studies can be useful for different objectives and institutions, but the variables and analyses are of limited use if impacts of climate change will be understood for the agricultural sector that can be used by the Department of Agriculture in Planning and Designing Climate Resilient Agriculture (CRA). This shows that there is limited initiative that uses a scalable framework to map in high resolution (municipality level) the risks and vulnerability for long term agricultural resilience targeting and prioritization in the Philippines.

Climate Projections in the Philippines

Figure 3 shows the projected precipitation and temperature changes in the Philippines across four time periods (KNMI, 2019). Most of the GCMs suggest that increasing temperature minimum of ~2°C (with an uncertainty of ± 1°C) is expected in most parts of the country under RCP 8.5 scenario. Temperature minimum is one of the highest climatic factor that affects yields for rice (Peng et al., 2004) and maize (Tongson et al., 2017). On the other hand, while majority of the GCMs estimates that precipitation will increase, a few GCMs (25^{th} percentile) suggest that there will be a decrease in precipitation in the Philippines by 2050 until the end of century. The uncertainty of temperature and precipitation shows that a wide range or an ensemble of GCMs should be used in assessing climate change impacts.

[1] Based on limited search over the internet for available articles and reports on VA.

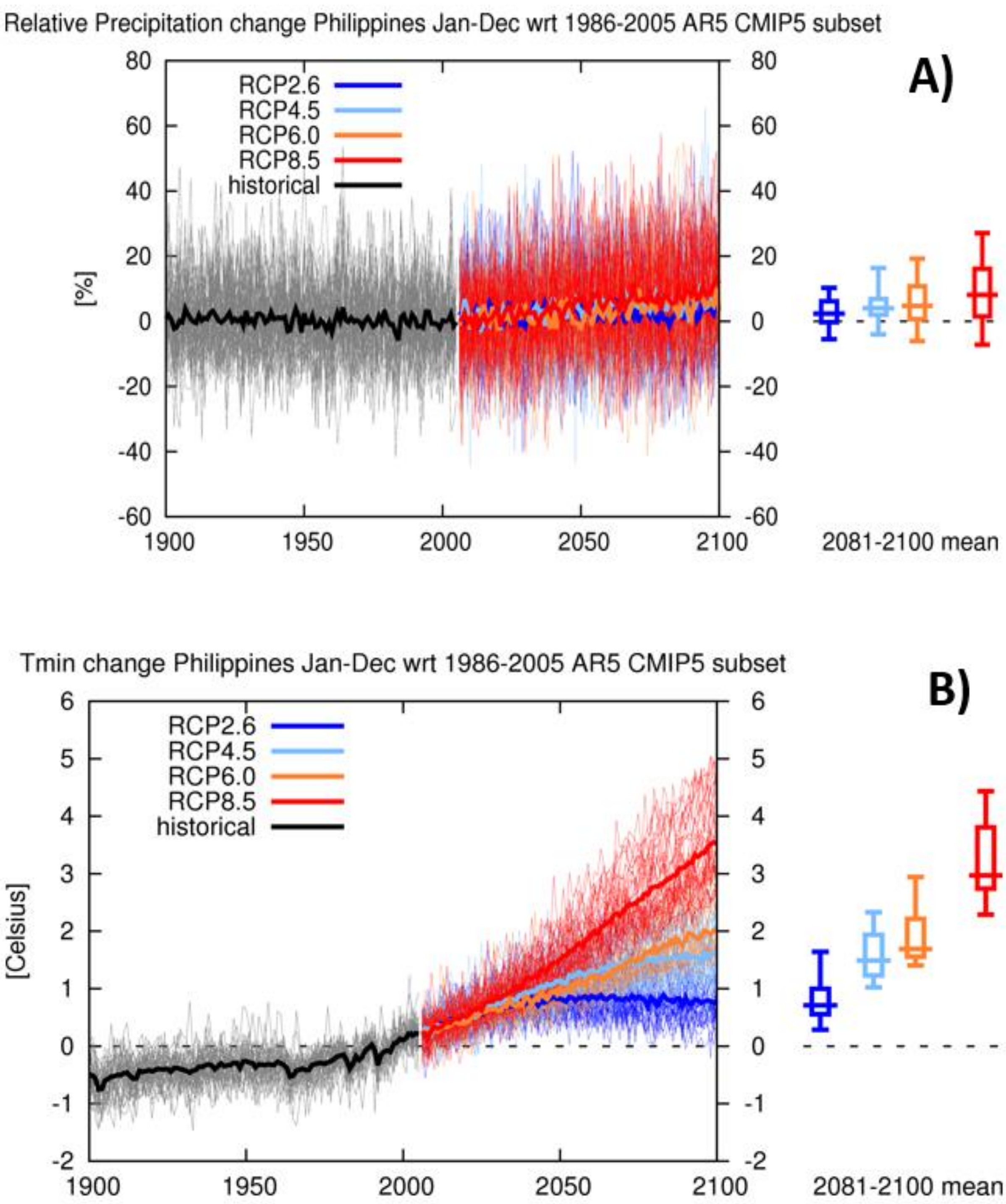


Figure 3. Projected changes in A) precipitation and B) temperature minimum in the Philippines by 2030, 2050, 2070, and 2090.

Background on Philippines' Exposure to Natural Hazards

Typhoons are projected to globally increase its intensity due to progressive climate change over the coming decades (Webster et al. 2005, Emanuel et al. 2008). The vast majority (57%) of global typhoons occur in the Pacific Ocean basin (NOAA 2013): The Philippines is considered the second most exposed country in the world to typhoons after China (NOAA 2010), receiving at least 15 typhoons (aggregate of tropical storms and typhoons) a year (PSA, 2014). Northern Luzon, Southeastern Luzon, and Eastern Visayas are the geographical regions with high incidence of typhoons and tropical storms (Figure 4). With months of higher incidence of typhoon which fall on the major cropping season in the Philippines, farmers are at high risk in terms of crop losses. The economic vulnerability of the agricultural sector to typhoons being the most damaging geophysical hazard was highlighted by FAO (2015) in their recent disaster analysis for the Philippines: *"Most of the production damage and losses [are] caused by typhoons/storms, amounting to USD 3.5 billion or 93 percent [for the agricultural sector]. The majority of the damage and losses in the agriculture sector were in the crop subsector with USD 3.1 billion [for the period 2006-2013]".*

Agricultural production in the Philippines, particularly rice and maize, are exposed to the impact of typhoon since the growing period of these crops coincides when typhoon events are high (Figure 4.A). A single typhoon event can cause billions of pesos in terms of damage to agriculture alone (Figure 4A). In 2015, Typhoon Lando had caused extensive damage to agriculture amounting to almost Php5.9 billion. Among the affected provinces, Nueva Ecija suffered the most damage to agriculture with an estimate amount of Php3.5 billion (Rappler, 2015. Data source from Department of Agriculture).

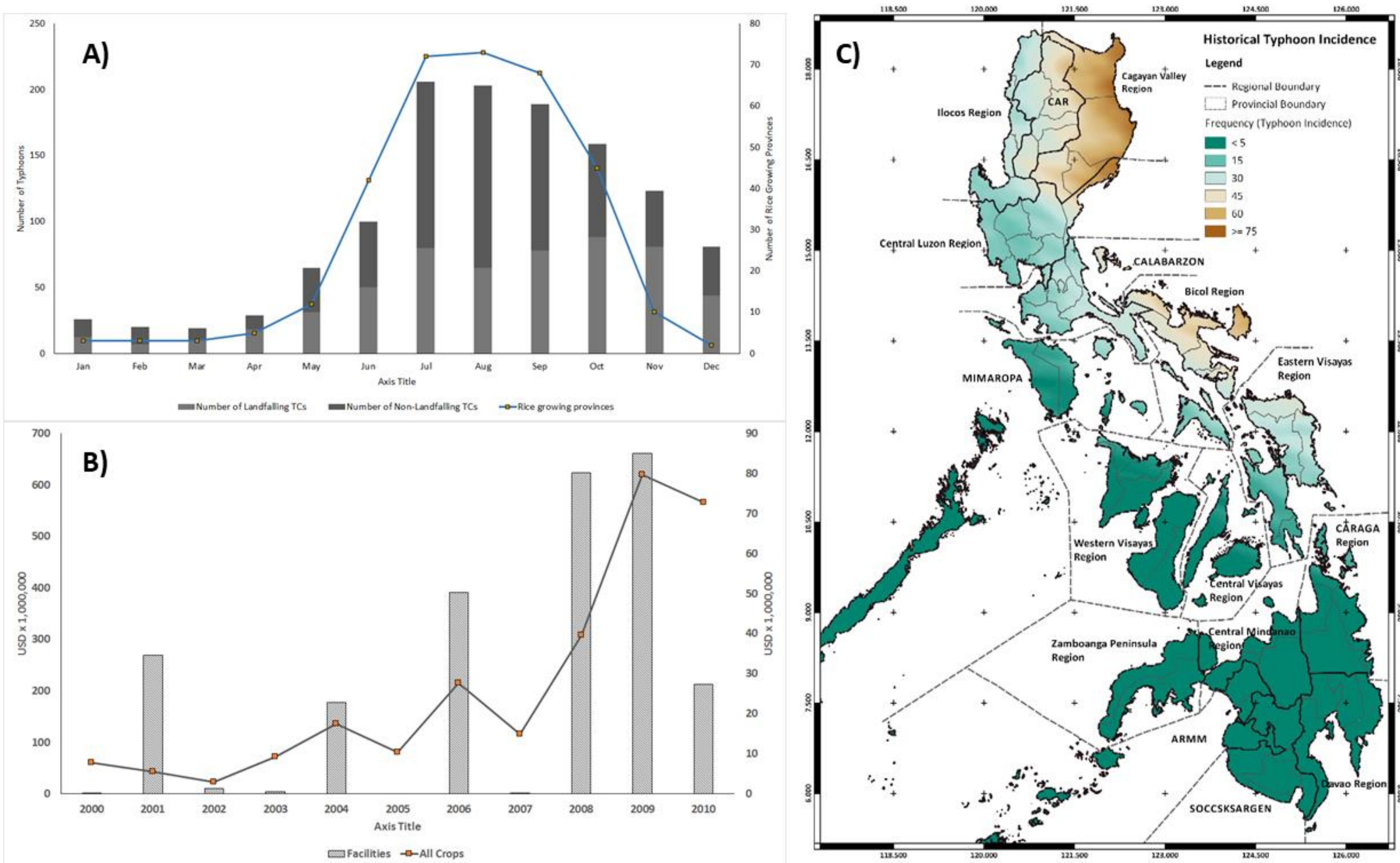


Figure 4. Temporal and spatial risk of typhoon in the Philippines showing A) monthly frequency of tropical cyclones entering the Philippine Area of Responsibility (PAR) from 1951-2013 (Cinco, et al. 2016) and estimated rice growing provinces in the Philippines (Laborte, et al. 2017). The rice growing season, which typically ranges from June to October (based on peak of planting) also coincide with high incidence of typhoons. B) Crop damage trend from year 2000 to 2010. Line graph represent damage to all crops, and bar graph represent damage to agricultural facilities (Israel and Briones, 2013). C) Areas that are most frequently visited by typhoons.

The damage to crops, property, and livelihoods brought about by typhoon, flood, and drought are increasingly becoming greater and costly. As reported by Israel and Briones (2013), the total economic damage of typhoon, flood, and drought from 2000 to 2010 is estimated to be USD 2,234.21 million (figure 5B). The rice sector suffered the most and the damage has an estimated value of USD 1.2 billion, followed by maize (USD 461.50 million) and high value crops (HVC) (USD 244.82 million). Increasing trend in terms of losses to agriculture (Figure 6) were recorded an all-time high in year 2009 brought by two typhoon events (Ketsana and Parma) which severely hit the agricultural areas in regions 1, CAR, 2, 3, NCR, and 4A. These regions are considered the rice bowl of the Philippines causing enormous loses to agricultural sector. Damage to agricultural facilities was found out to be related to crop damage during typhoon, flood, and drought events (Israel and Briones, 2013). The eight climate-related hazards that were considered in this study are briefly described below with an emphasis on its impact within the Philippine context.

Flooding is one of the major problems in the country, primarily during the monsoon season, caused by either typhoon or enhanced southwest monsoon. An enhanced southwest monsoon is a weather system where a typhoon or low pressure area located outside of the mainland Philippines or outside the PAR intensifies the southwest monsoon winds which brings heavy rainfall in Luzon and parts of the Visayas. Flood dataset was acquired from the multi-hazard AMIA dataset in shapefile format.

Drought always has an impact on agricultural, ecological, and socio-economic spheres, causing serious environmental, social, and economic consequences worldwide. Drought is one of the most challenging hazards to monitor since it has a slow onset which is difficult to observe and therefore unlikely to predict. The drought map was acquired from the AMIA 1 dataset, produced using the integration of groundwater potential from NWRB, incidence of drought from the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA), and air temperature.

Erosion is a natural occurring process attributed into different factors such as soil properties, ground slope, vegetation/land cover, and the amount and intensity of rainfall (Montgomery, 2007). It is usually a slow and gradual process which involves movement of rocks and loosened soil on the Earth's surface from one place to another. In the coming years, the soil erosion rate is expected to increase due to more total rainfall and more frequent extreme events brought by climate change. In turn, an increase in erosion rate may lead to poor soil productivity and accelerated siltation of waterways and reservoirs (R.Lal, 2010).

Landslide is one of the hazards which is naturally occurring event that may cause damage to properties, injuries and deaths, and adverse impacts on the environment. In 2011, Jadina stipulated in one of her studies in Southern Leyte that the frequent occurrence of landslide in region is associated with the presence of fault lines and heavy rainfall and not by human activities alone. Although seismicity can be the trigger factor of landslide, other biophysical components such as soil properties, steep slopes and vegetation/land cover are also considered major causal factors.

A **storm surge** is an abnormal rise in the sea water level due to the presence of the storm and tropical cyclones also known as typhoons. Typically, storm surge happens in the coastal regions where water is pushed towards the shore by strong winds which can lead to flooding (Figure 5). In the Philippines, Typhoon Haiyan hits Tacloban in 2013 and was responsible for one among the deadliest storm surge in the last 50 years with an estimate of more than 7000 damaged fatalities recorded by the Philippine government organization known as National Operational Assessment of Hazards (NOAH).

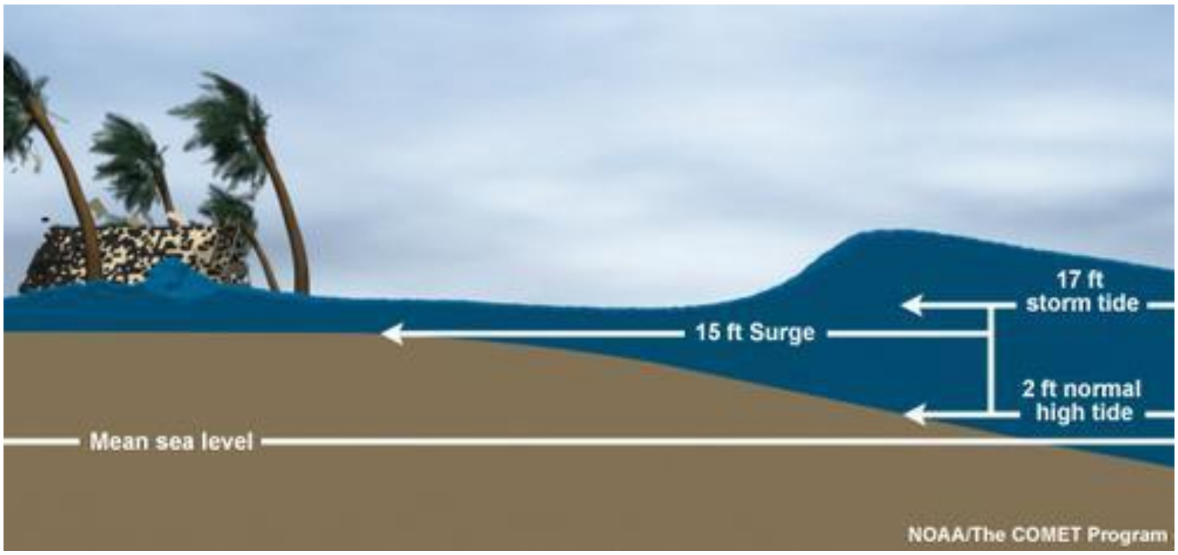


Figure 5. Storm surge vs. storm tide and normal high tide

Sea level rise refers to an increase in the volume of water in the world's ocean caused by global warming. According to the National Aeronautics and Space Administration (NASA), two factors related to global warming identified were the added water from the melting land ice and the expansion of sea water as it warms. There are two types of sea level rise: the global and the local sea level rise. Figure 6 shows the global change in sea level observed by the satellites from 1993 up to present. The global rate of change is at an increasing trend of 3.4 millimeters per year (NASA, 2017). Saxena in 2016 observed that both globally and locally, sea levels are going up. However, she mentioned that there is a big difference among regions in terms of the rate of rising. Because just like the surface of the Earth, the surface of the ocean is not also flat, meaning the sea surface is not changing at the same rate globally.

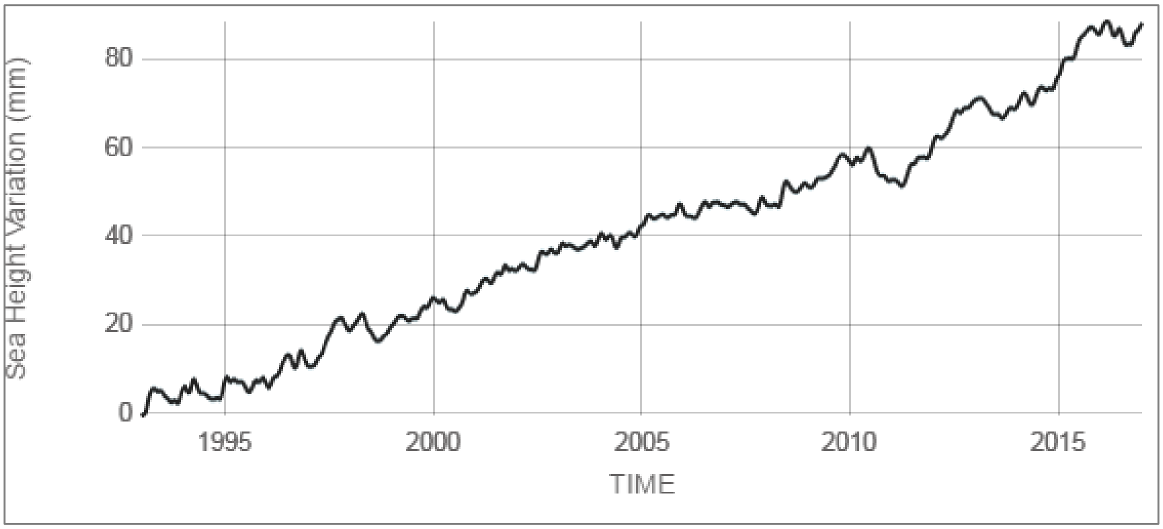


Figure 6. Global sea level observations by satellites showing the rate of change in mm/yr

Source: (climate.nasa.gov)

Saltwater intrusion is defined as the movement of the saline water towards the freshwater aquifers that can lead to contamination of drinking water, as well as decrease in freshwater storage in the aquifers. Along coastal areas, saltwater intrusion naturally occurs and found in the zone of dispersion or transition zone, where the freshwater and saltwater is diffused to keep it at a neutral level (USGS). Common mechanisms which causes saltwater intrusions are groundwater extraction, deepening of canals and drainage networks, and other human activities that lower groundwater levels and reduce freshwater flow to coastal waters.

METHODOLOGY

EXPOSURE 1: Sensitivity (Impact of Climate Change to Crop Suitability)

The crop sensitivity was assessed by changes in climatic suitability of crops by year 2050 in comparison with the baseline suitability. EcoCrop and 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. Analyzing changes in climate-crop suitability involves a two-step process: first step is to assess the baseline (current climate condition) climate-crop suitability which is based on the condition that a species is predicted to occur at a particular location if it approximately matches the environmental condition where it is observed. And second step is to predict the species suitability on a projected time period if it matches the environmental condition where it is observed from the baseline condition.

Crop Selection and Collection of Occurrence Data

An initial workshop and DA consultation was conducted to identify the priority crops (Annex 11) per province. The list of crops for sensitivity analysis are shown in table 1 and is based on the priority banner crops of DA and inclusion to the Provincial Commodity Investment Plan (PCIP). Occurrence data were collected using participatory mapping workshop (Annex 12A) with agricultural technicians and staff from local government units to locate 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, i.e., as road and river networks, digital elevation model, municipal and barangay (smallest administrative boundary where decisions and actions are made) boundaries, that can assist in locating the location of crops. 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 are rules that were set during the mapping workshop: One crop per pixel is allowed. For instance, even if rice is present in multiple locations within the pixel, it can only be marked once; and multiple crops are allowed per pixel. For instance, rice and maize are present within the pixel, then the pixel can be marked as both rice and maize.

Table 1. List of crops suggested by regional partners for sensitivity analysis

Province	Rice	Corn	Mango	Garlic	Tomato	Mungbean	Peanut	Banana	Cassava	Eggplant
Ilocos Norte	x	x	x	x	x	x				
La Union	x	x	x				x	x	x	
Pangasinan	x	x	x		x				x	x

Baseline Climate Conditions

A total of 20 bioclimatic variables were selected to assess the climate suitability of crops (described in Annex 2) representing annual trends, seasonality, and extreme or limiting environmental factors. For baseline conditions, the Wordclim dataset (available at Worldclim.org) (Hijmans, 2005) was used. The bioclimatic variables are derived from monthly temperature and rainfall values and was 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, M and Ignizio, D., 2012).

Future Conditions

Crop distribution was modeled for the present and future conditions to assess the degree of changes in suitability under climate change. Thirty-three (33) CMIP5 GCM models (Annex 3) under Representative concentration pathway (RCP) 8.5 scenario (IPCC, 2013 - based from 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/.

Model Framework and Implementation

Two modeling frameworks were used to generate climate suitability scenarios, namely EcoCrop and Ensemble models. The EcoCrop model was used to generate climate suitability scenarios for crops that are less reliant to irrigation, such as corn, cassava, tomato, eggplant, garlic, mungbean and yam. For rice, which is an irrigation-dependent crop, an empirical model using an ensemble of Random forests (RF), generalized linear model (GLM), and flexible discriminant analysis (FDA) provided by Biomod2 (Thuiller et al., 2016) was used to generate the climate suitability scenarios. The description of the two modeling approaches used to generate the suitability predictions in the future are given below. 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. 2). The resulting pixel values have a range from the negative to positive – negative pixel values which means suitability has decreased 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 per crop was normalized using Table 2 as reference.

$$\textit{Suitability change} = \left(\left(\frac{\textit{Suitability}_{future} - \textit{Suitability}_{baseline}}{\textit{Suitability}_{baseline}}\right) \div \textit{Suitability}_{baseline}\right) x\ 100 \qquad \textbf{Eq. 2}$$

Where: future = result of species distribution model for future conditions, and baseline = result of the species distribution model for baseline condition

EcoCrop is a basic mechanistic model that uses environmental ranges to determine the niche and distribution of a crop and produce a suitability index based on the interaction of the environmental variables (Ramirez-Villegas, et al., 2013). The model was adapted by CIAT based on the original EcoCrop model developed by Hijman et al. (2001). In the model, there are two ecological ranges for a given crop, each one defined by a pair of parameters for each variable for temperature and rainfall. When the conditions over the growing seasons in a particular location are beyond the absolute thresholds, there are no suitable conditions for the crop; when they are between absolute and optimum thresholds there are ranges of suitability conditions (1 to 99), and whenever they are within the optimum conditions there are highly suitable conditions and the suitability score is 100%. The values are shown as an index where values closer to 100 are the areas where the climate is very suitable for a crop to grow.

Ensemble the Biomod2 species distribution model (SDM) was used to map climate suitability of rice. Biomod2 has the ability to run 10 state-of-the-art modeling techniques to describe and model the relationships between a given species and its environment. It attempts to define the ecological niche of a species using a set of environmental variables (precipitation and temperature). It fits an ensemble of forecasts by simulating across more than one set of initial conditions, model classes, model parameters, and boundary conditions (Thuiller et al., 2009). However, SDM models are prone to biases and overfitting where multi-collinearity and high-dimensional spaces of data are present. Therefore, it is necessary to run statistical tests, such as principal component analysis (PCA) and correlation analysis to determine appropriate number of environmental variables that should be retained and used for modeling.

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

Percent Change in Suitability (Range in %)	Index	Description
<= -50 (Very high loss)	1.0	Loss
>-50 & <= -25 (High loss)	0.5	
> -25 & <= -5 (Moderate loss)	0.25	
> -5 & <= 5 (No change)	0	No Change
> 5 & <= 25 (Moderate gain)	-0.25	Gain
> 25 & <= 50 (High gain)	-0.5	
> 50 (Very high gain)	-1.0	

EXPOSURE 2: Exposure to Hazards

A combination of spatially enabled natural hazard datasets has been used to estimate hydro-meteorological risks of each municipality. Most of the datasets refers to historical databases to evaluate the current potential risk. We limit the analysis of hazards to baseline conditions because many climate hazards can be large scale singular events and projections of climate hazards (e.g. year 2050) would add further layers of uncertainty in the assessment. 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). The succeeding section below discusses the procedure to develop the hazard index, and a brief description of each hazard that was considered in the study.

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 6). Eight (8) hazards were identified in Region 1 that affect crop and livelihoods, these are typhoon, storm surge, flood, drought, erosion, landslide, saltwater intrusion, and sea level rise. Since each hazard has different characteristics (i.e., degree of damage, intensity and frequency) the potential damage also varies. We used the hazard weights developed by the International Center for Tropical Agriculture (CIAT) for Luzon and applied it in Region 1. 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, typhoon (20%), flood (19%), and drought (14.5%) received the larger weights. Each hazard data was aggregated by municipality using zonal statistics. Spatially-weighted sum of all hazards was used to develop the hazards index for each of the municipality. Values were normalized using Eq. 3 to standardize the value from 0 to 1. The results of the hazard analysis were validated by the LGUs thru participatory workshops in the three provinces (Annex 12B).

$$hazidx\_norm = \frac{X - X_{min}}{X_{max} - X_{min}} \qquad \textbf{Eq. 3}$$

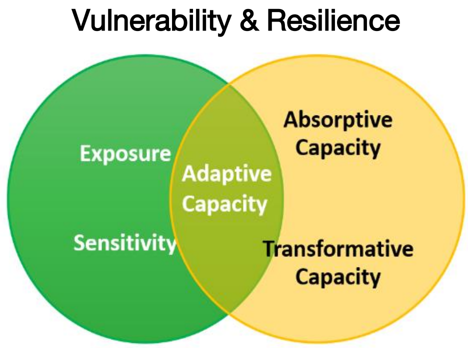
where: hazidx_norm is the normalized values of the hazard index.

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	AMIA multi-hazard map / baseline data from 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	AMIA multi-hazard map / baseline data from Mines and Geosciences Bureau, Department of Environment and Natural Resources (MGB, DENR)	Groundwater potential for the Philippines
Erosion	AMIA multi-hazard map / baseline data from Bureau of Soils and Water Management	1:10,000 scale. Soil erosion classified from low to high susceptibility
Landslide	AMIA multi-hazard maps / baseline data from MGB, DENR	
Storm Surge	AMIA multi-hazard maps / baseline data from 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
Salt Water Intrusion	AMIA multi-hazard map / baseline data from the NWRB	Groundwater potential for the Philippines

ADAPTIVE CAPACITY

Adaptive capacity (AC) 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 when measuring resilience, in addition to absorptive coping capacity and transformative capacity (Figure 7). Both are integrated concepts in a coupled human-environment system (Lei et al. 2014). In this text we define adaptive capacity according to the IPCC (2014): "Adaptive capacity is 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." Due to the country-wide scale, this vulnerability assessment takes, thus, a broader approach to adaptive capacity than more in-depth resilience assessments.



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 7. Concepts of vulnerability and resilience (Source: IPCC 2014).

The adaptive capacity index for this vulnerability assessment is compiled by a set of proxies: none of them alone can give a reliable statement of the current level of adaptive capacity, but as an ensemble considering different capitals they become a more 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 capitals 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 across the three provinces in Region 1. This vulnerability assessment provides high resolution analysis on municipal level as this is where most socio-economic data can be collected. However, often key indicators are only available on national or provincial level. Hence, the list of indicators in Table 7 is not restrictive but supplementary socio-economic data can be added to have a better understanding to what extent is the population will be able to cope with climate change and its related risks.

Indicator Identification Process

The preliminary set of adaptive capacity data were developed by CIAT using official and local datasets. The dataset was analyzed using statistical analysis and integrating feedback from experts to select relevant variables. Country databases from the National Competitiveness Council (NCC), Philippines Statistics Authority, and previous DA projects were used to collect country-wide socio-economic data. Other data sources were derived from the International Water Management Institute (IWMI) and the National Mapping and Resource Information Authority (NAMRIA) to calculate the indicators for the natural capital component. A total of 15 indicators across five (5) capitals were developed. These indicators were validated through workshops participated by LGUs (Annex 13).

The values of the 15 indicators (Annex 4) were converted to a GIS spatial format by linking it to the shapefile municipal units. 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. The process for deriving adaptive capacity is shown in figure 8.

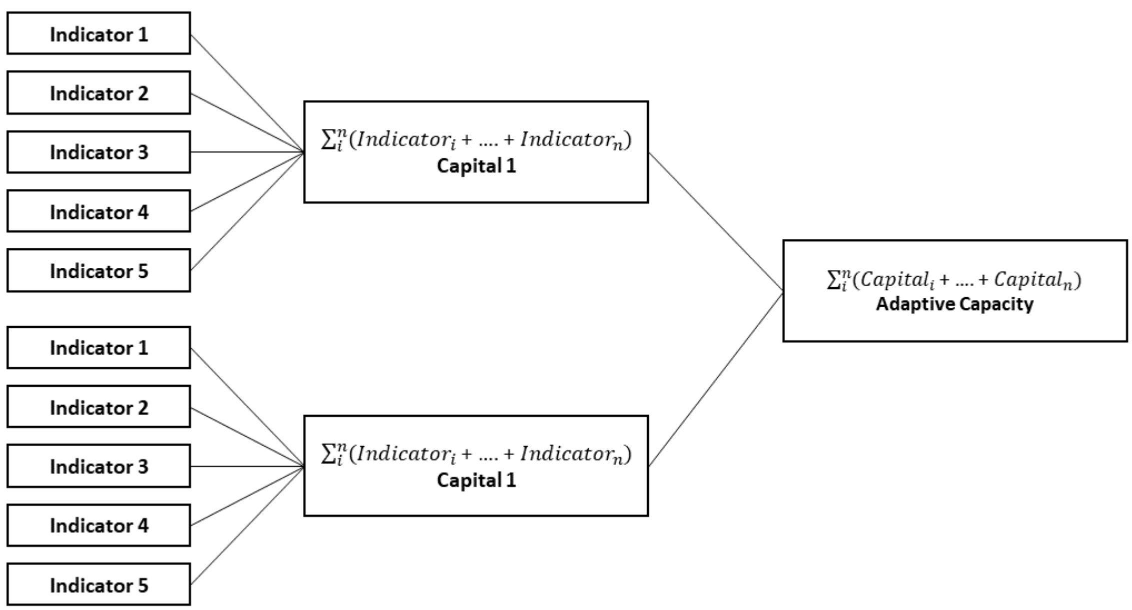


Figure 8. Process flow for deriving the overall adaptive capacity index for each municipality

RESULTS AND DISCUSSION

Exposure 1: Sensitivity

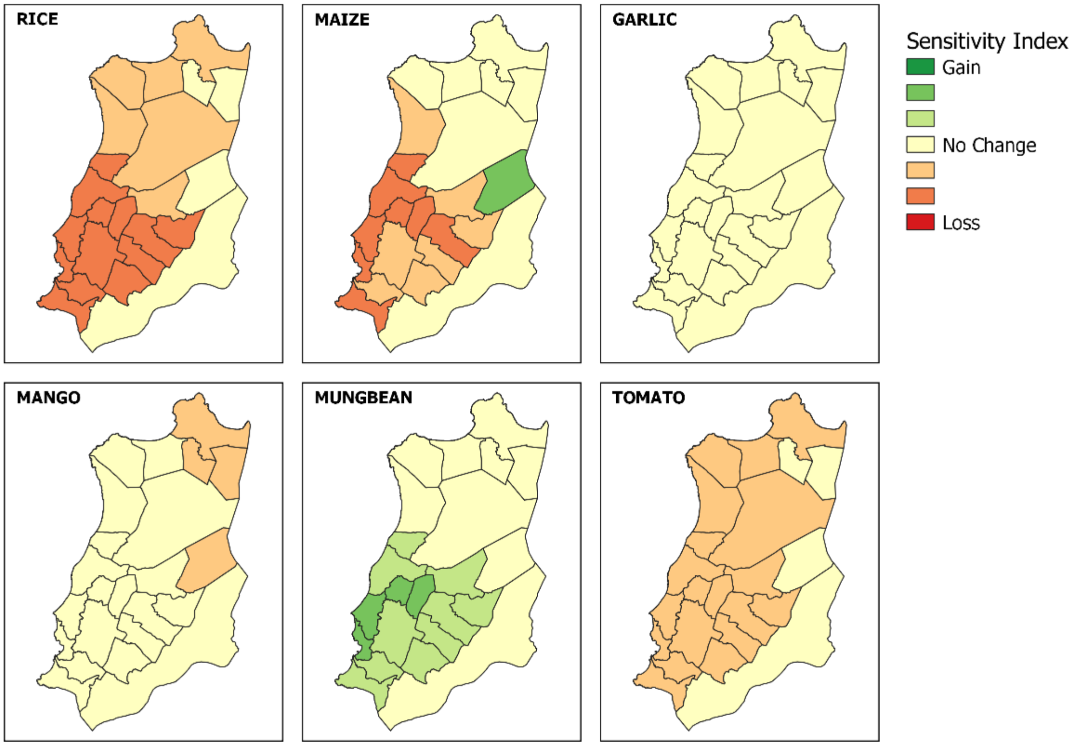
Figure 9A-C shows the changes in climatic suitability of selected crops (rice, corn, tomato, eggplant, garlic, mungbean, cassava, and banana) in the Philippines due to climate change by year 2050. Based on simulation results, trends of suitability changes are:

- Higher losses are shown for rice, maize, tomato and banana in most of the lowland areas due to increasing temperature and precipitation conditions.
- Crops such as cassava and garlic will not have significant change in climatic suitability.
- Crops such as mango, mungbean, and eggplant is expected to increase climate suitability in the future.

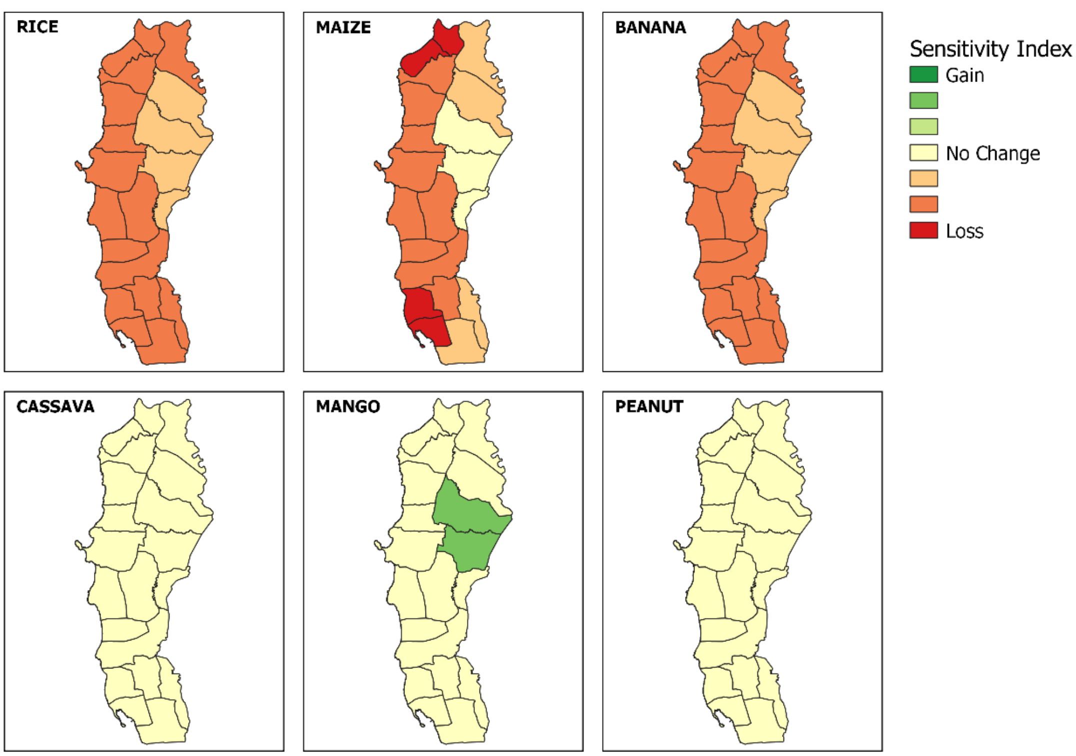
Crops that will experience decrease in climate suitability will benefit from improved crop production (i.e., change in variety) or farming practices system that promotes healthy soil and efficient use of water is vital as a means of climate change adaptation. As reported by Iizumi and Ramankutty (2015), in the absence of fatal weather events, the major variations in crop production would be affected by mean climate conditions. Maize crop simulation in Isabela province under climate change showed 7% to 13% reduction in growing cycles (effect of expansion in dry months) and 17% to 41% reduction in mean yields (water stress and rising temperatures) (Tongson, et al., 2017). 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.

Municipalities in the eastern portion of Pangasinan will considerably gain climate suitability for eggplant. This needs to be carefully examined, since increase in suitability will potentially put more pressure on the forest landscape. This is also similar with Mango, where increase in suitability in the municipalities of San Gabriel and Bagulin might increase deforestation in the future to open new mango production area. Decrease in forest area will affect multiple ecosystem services, e.g. provision for water, regulation of soil erosion, etc. The conservation of ecosystem services also needs to be incorporated in the overall agenda of DA.

A) **ILOCOS NORTE - CROP CLIMATE SENSITIVITY**



B) **LA UNION - CROP CLIMATE SENSITIVITY**



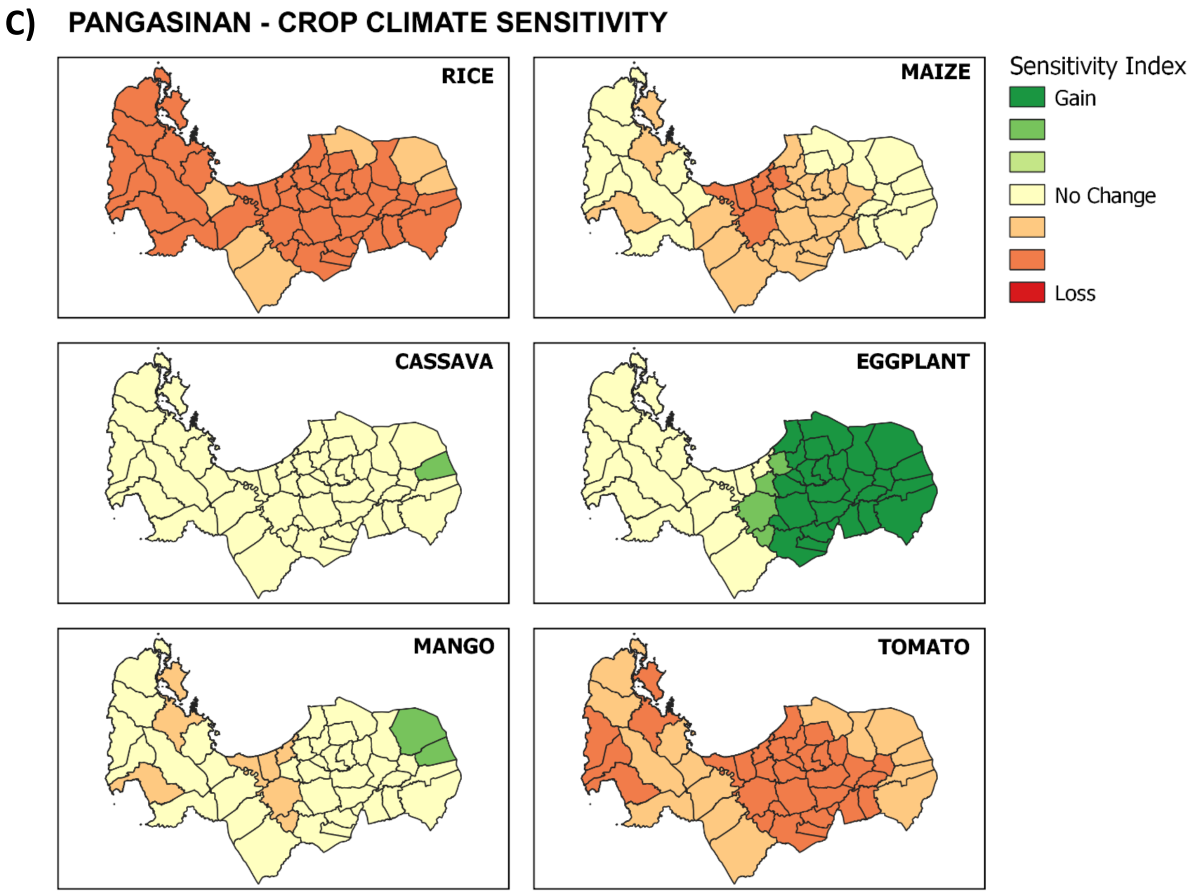


Figure 9. Maps indicating changes in climatic suitability of crops/commodities: A) Ilocos Norte, B) La Union, and C) Pangasinan.

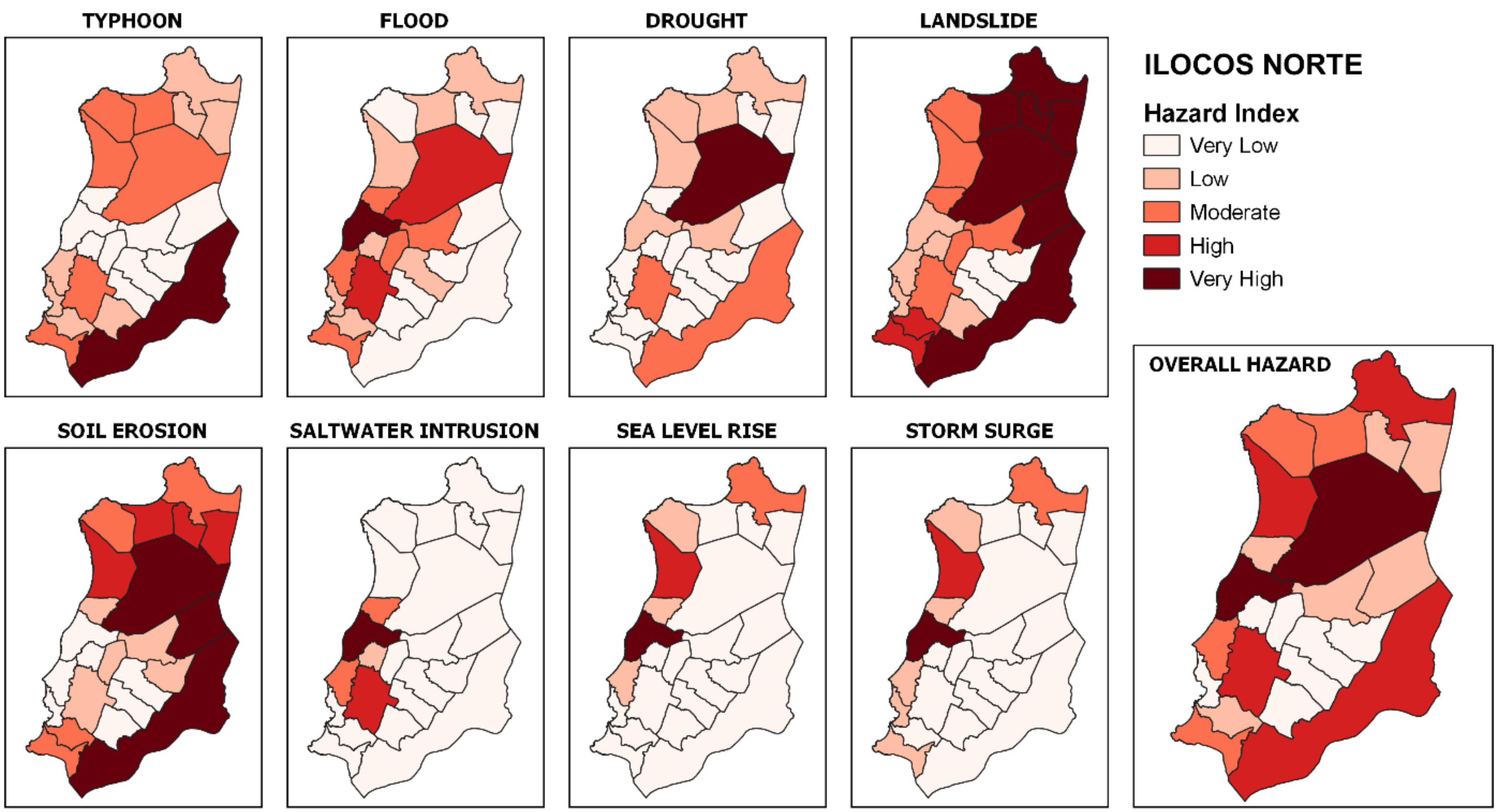
According to Peng in 2004, they observed a decreasing trend by 10% in rice yield during dry season for every 1°C in mean night time temperature. Ramakrishnan et al. (2011) reported varying degree of yield loss along with the different temperature regimes in India. Furthermore, as reported by Iizumi and 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.

According to Martin Parry and Al Gore (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.

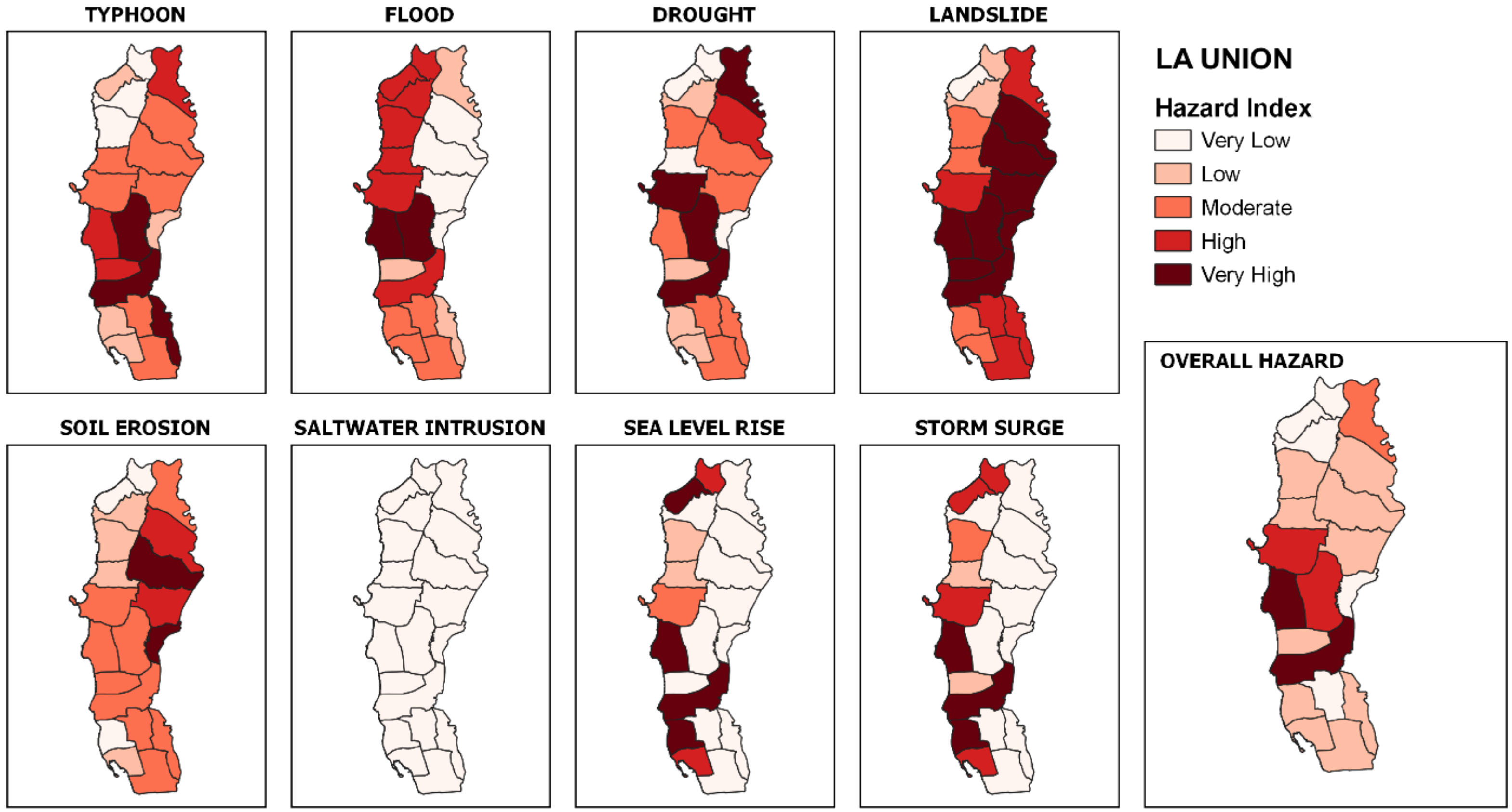
Exposure 2: Hazards

Figure 10A-C shows the degree of exposure to hazard across the 3 provinces. Typhoon, flood, and drought are consistently rated high across the three provinces and are considered the major driving factors of high hazard exposure which leads to high hazard index. Although typhoon have the highest weight among all hazards, its impact was mostly prominent in north Luzon, southeastern Luzon, and eastern Visayas regions in the Philippines. 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.

A)



B)



TYPHOON
FLOOD
DROUGHT
LANDSLIDE
LA UNION
Hazard Index
Very Low
Low
Moderate
High
Very High
SOIL EROSION
SALTWATER INTRUSION
SEA LEVEL RISE
STORM SURGE
OVERALL HAZARD

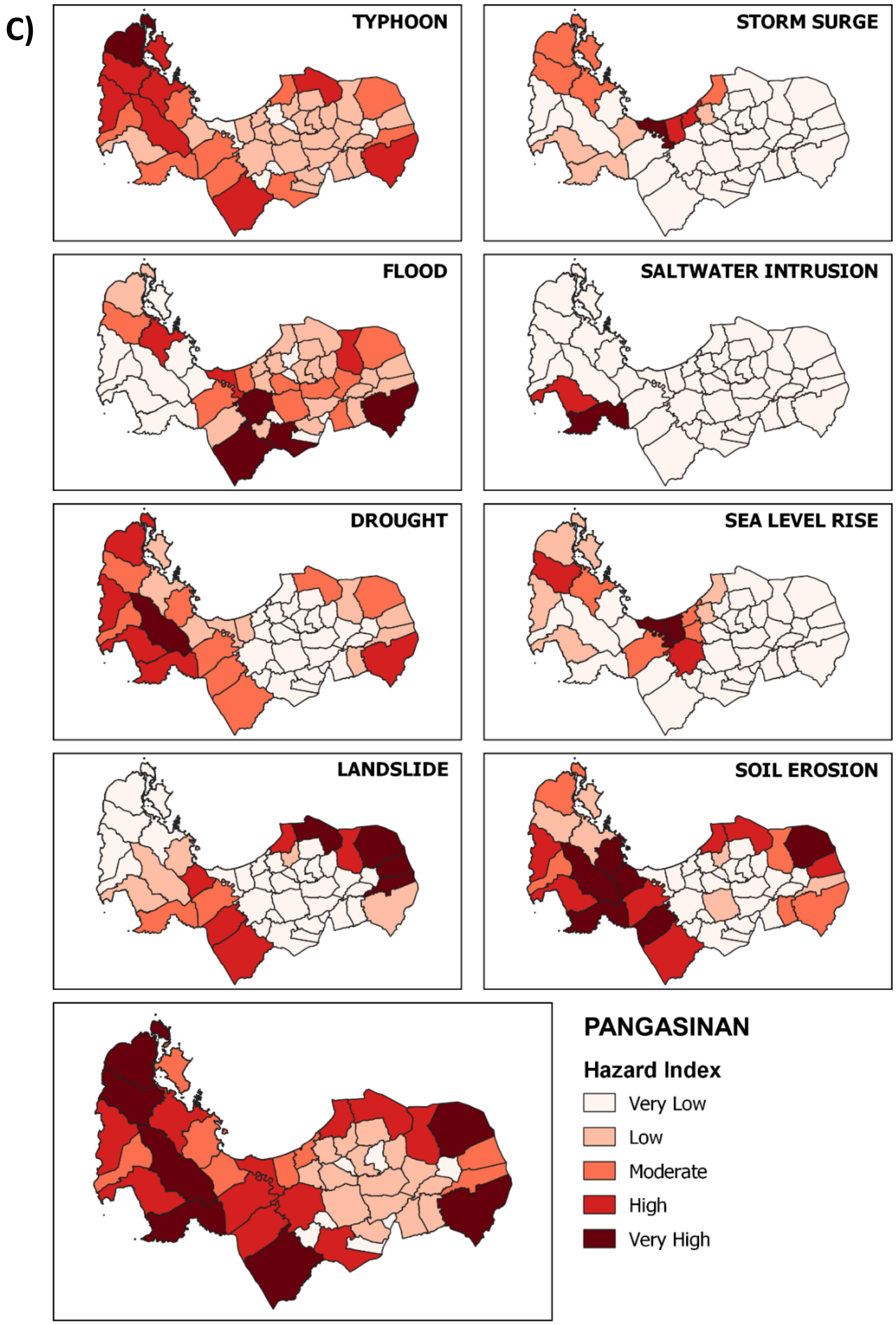


Figure 10. Dominant hazards for each of the municipality in the target provinces A) Ilocos Norte, B) La Union, and C) Pangasinan. Darker colors (hotspots) means higherincidence of hazards and is driven by either extent or overlaps of hazards.

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. Rice, the country's major staple crop, has experienced a decrease in its production potential due to water and heat stress. For instance, as cited by Lansigan et al. (2000), typhoons, floods, and droughts caused 82.4% of the total rice (*Oryza sativa L.*) losses from 1970 to 1990. Unreliable weather patterns such as the onset of the wet season and unpredictable amount of rainfall are already causing losses (Foley et al., 2009). Annex 5 shows the degree of hazard incidence by province and indicates the municipality-level specific climate risk that threatens the resilience of agricultural communities. The level of hazard risk of each municipality can be used to tailor package of climate resilient agricultural packages as demonstrated below:

A. Badoc, Ilocos Norte – Figure 11 shows the various hazards that are threatening agriculture and livelihoods in the municipality. The major hazards are typhoon and flood. With this, the CRA (Climate Resilient Agriculture) option identified by the LGU is Small Water Impounding Project (SWIP) for rice and Small Farm Reservoir (SFR) for corn. Both of these mentioned practices are considered a flood mitigation and effective water resource use strategy which address the flood risk, and – to some extent – drought risk, in the municipality, and the province in general. A cost and benefit analysis was conducted to assess the profitability and benefit of farmers if they adopt the practices. The supplementary material on CBA analysis shows the details of the assessment for SWIP and SFR in Badoc Ilocos (Annex 14). While this is an important consideration in designing the package of agricultural interventions, the CRA design should also not neglect addressing other climate risks, such as drought. Moreover, other CRA practices should be explored that address landslide, erosion, and drought risk.

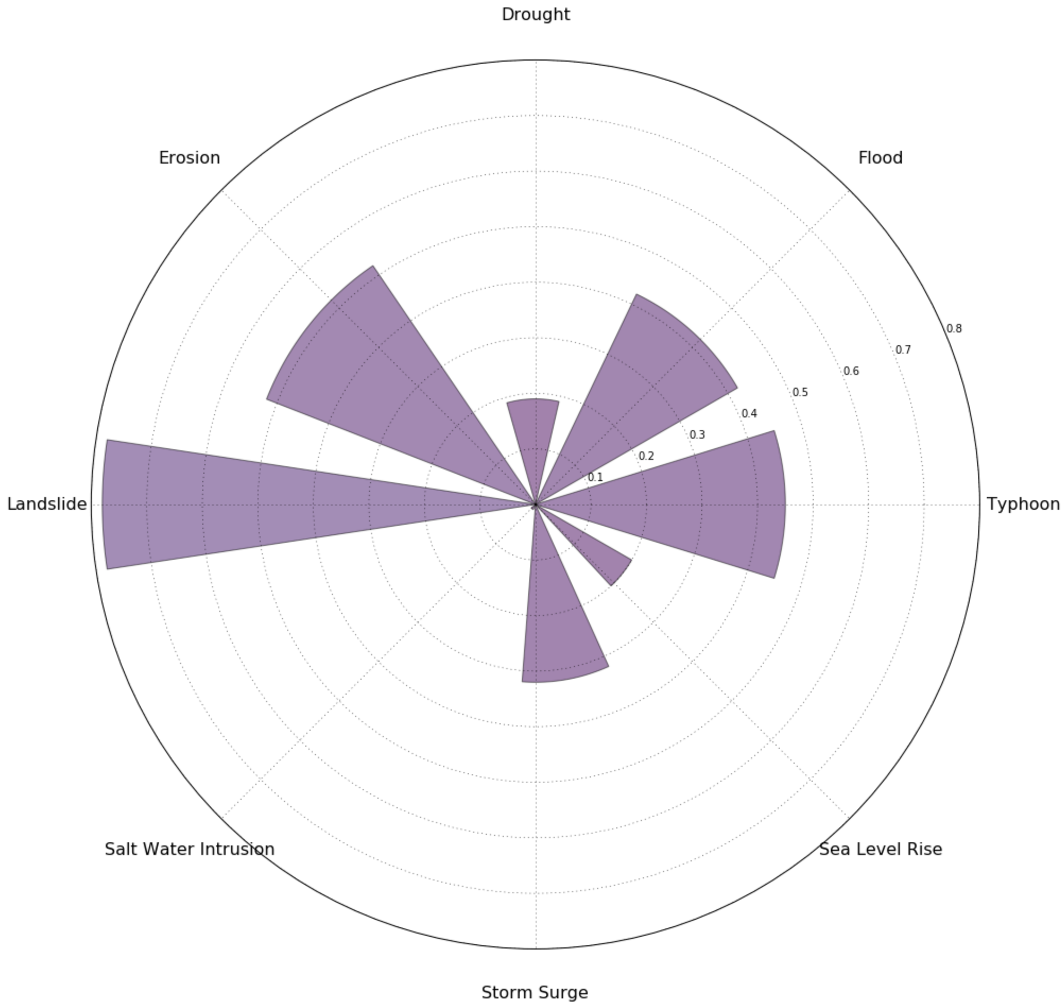


Figure 11. Climate risks of Badoc municipality in Ilocos Norte.

B. Luna, La Union – Figure 12 shows the various hazards risk in the municipality. The dominant hazard is flooding (Figure 12). The Small Farm Reservoir (SFR) for rice and corn was identified as one of the CRA practices in the municipality. The CRA practice is highly essential since it mitigates the impact of excessive rainfall and runoff during the wet season, and provides supplementary water during the dry season. The supplementary material on CBA analysis shows the details of the assessment for SFR in Luna, La Union (Annex 14). While SFR is an important consideration in designing the package of agricultural interventions, other agricultural practices and interventions should be explored that mitigates the impact of typhoon and storm surge that also threatens the agricultural sector and the coastal environment of the municipality.

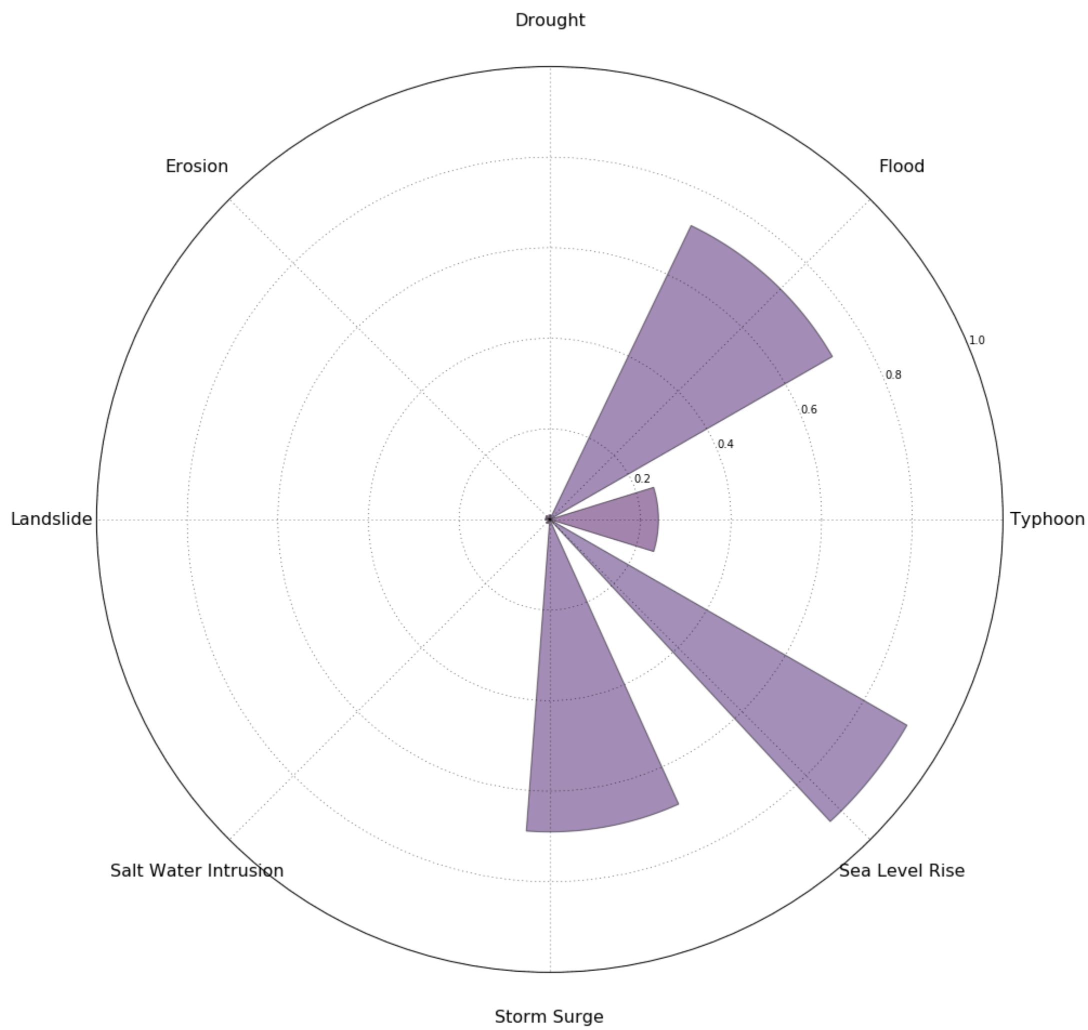


Figure 12. Climate risks of Luna municipality in La Union

C. Sison, Pangasinan – figure 13 shows the main driving factor for exposure is a combination of typhoon, erosion and landslide. Although, drought and flood are also driving high exposure risk in the municipality. The CRA practice identified in the municipality is the adaptive crop calendar for rice and corn. According to Lirag and Estrella (2017), adaptive crop calendar is a CRA practice that address flood and drought during El Niño and La Niña periods. The supplementary material on CBA analysis shows the details of the assessment for adaptive crop calendar in Sison, Pangasinan (Annex 14). The CRA practices relies on reliable and accessible climate information services to provide information on suitable planting and harvesting dates, and this should be considered as priority needs for adaptive capacity. Other CRA options should be explored to address typhoon, erosion, and landslide risks in the municipality.

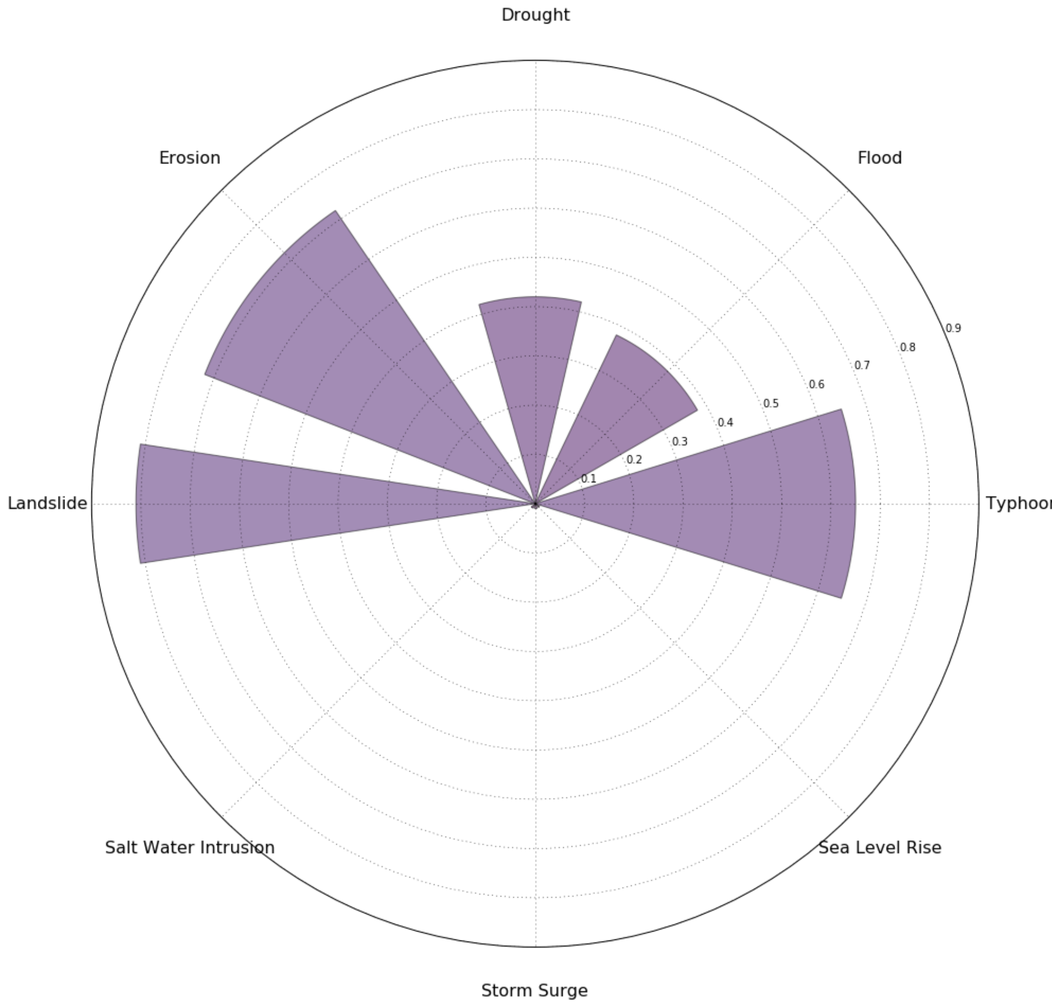
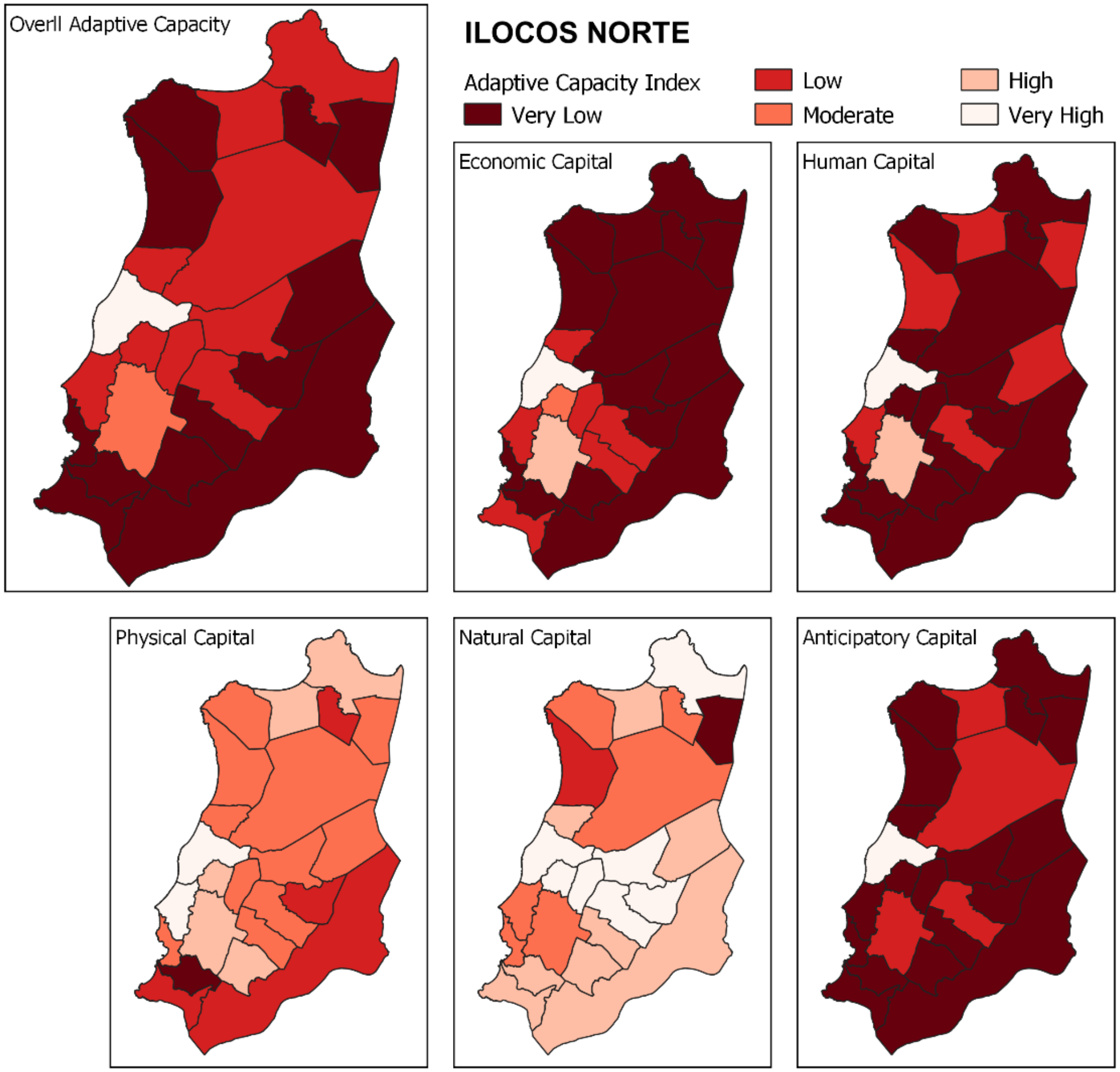


Figure 13. Climate risks in the municipality of Sison in Pangasinan

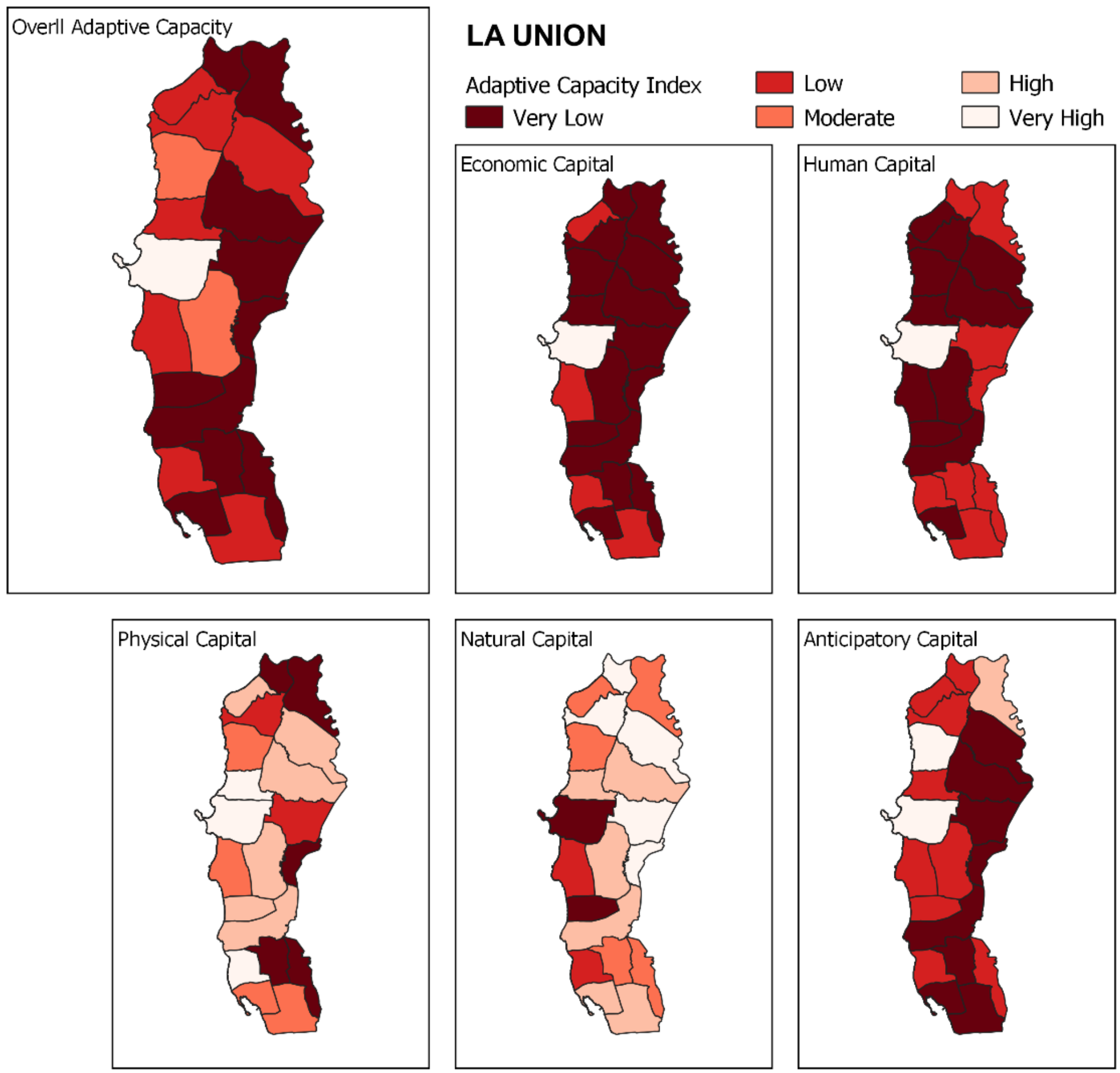
Adaptive Capacity Results

Results are available for each indicator and sub-indicator. One of the strength of this vulnerability assessment is not limited to identification of the areas with a low adaptive capacity as a priority, but also it has the capability to explore, analyze, and target specific capitals and indicators that can increase the resilience of communities to climate change. Figure 13 presents the spatial analysis of the five (5) capitals (figure 14A-C) of adaptive capacity, e.g. A) economic, B) human, C) natural, D) physical, and E) anticipatory, and the adaptive capacity index for the provinces of Ilocos Norte, La Union, and Pangasinan. It can be seen that most cities and municipalities near cities across the study sites have higher adaptive capacity. This is particularly true since cities tend to have higher economic activity and availability of financial services, good access to health and education, and have more provision in terms of support services for agriculture.

A)


ILOCOS NORTE
Adaptive Capacity Index
Very Low
Low
Moderate
High
Very High
Overll Adaptive Capacity
Economic Capital
Human Capital
Physical Capital
Natural Capital
Anticipatory Capital

B)



Overll Adaptive Capacity
LA UNION
Adaptive Capacity Index
Very Low
Low
Moderate
High
Very High
Economic Capital
Human Capital
Physical Capital
Natural Capital
Anticipatory Capital

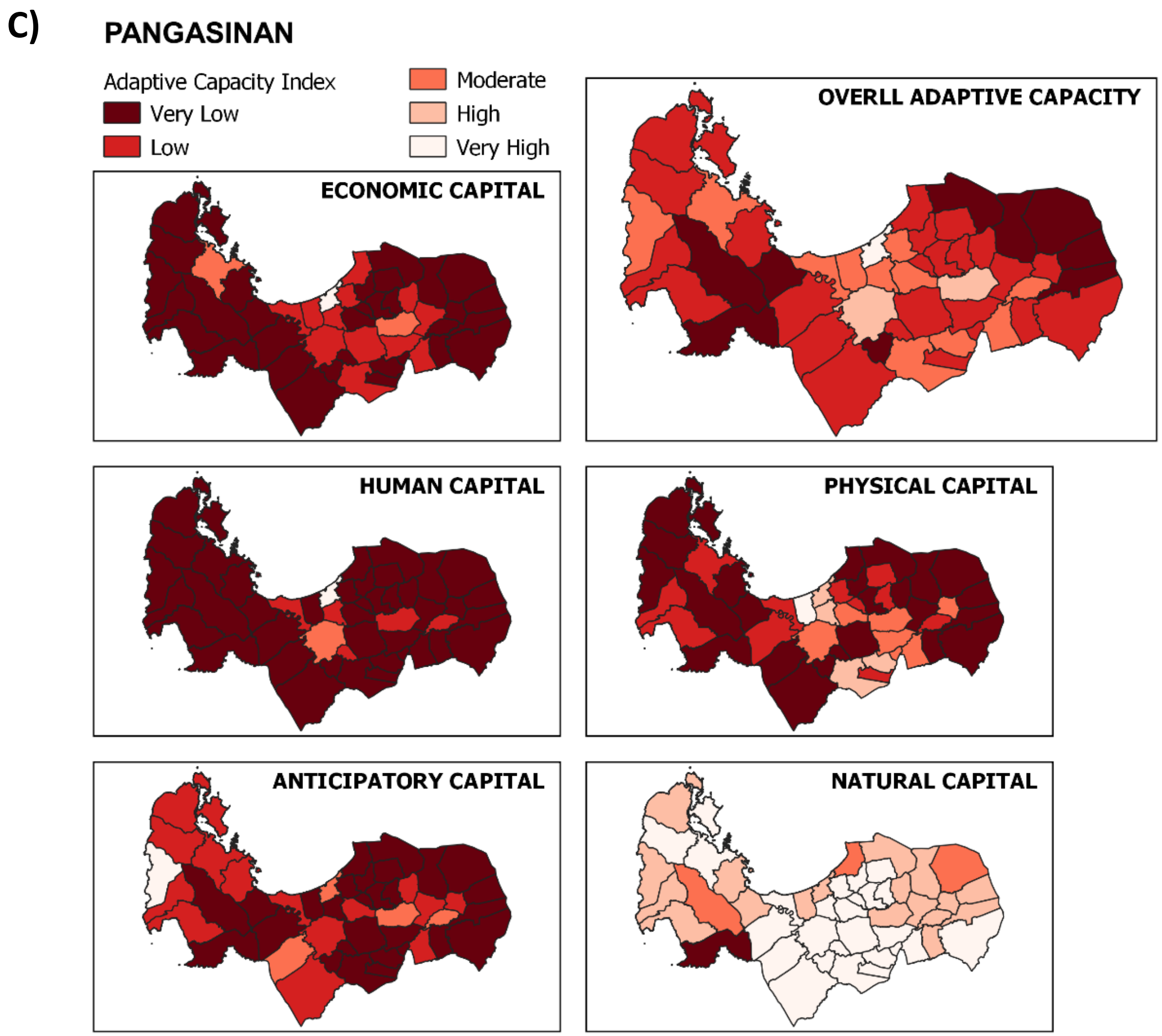


Figure 14. Adaptive capacity capitals such as economic, natural, human, physical, and anticipatory across the province of A) Ilocos Norte, B) La Union, and C) Pangasinan

CLIMATE RISK VULNERABILITY

The final climate risk vulnerability map for rice and corn (Figure 15-A-C) based on the integration of exposure 1 (sensitivity), exposure 2 (hazards), and adaptive capacity components using eq. 1. Other results for crop specific and overall VA are available in Annex 6-8. The weighting of each of the components was adopted from the study of CIAT which indicates 15% (exposure), 15% (sensitivity), and 70% (adaptive capacity). Different classes of vulnerability by municipality (moderate to very high vulnerability) are shown in figure 15-17 indicating the pre-selected municipalities by DA and the adaptive capacity characteristics. The results were validated through a series of workshops with LGUs.

- <u>Badoc, Ilocos Norte</u> – The municipality is classified as "very high vulnerability" and this is characterized by high potential impact of climate change to rice, high hazard index driven by high presence of flood, typhoon, landslide, and erosion. The adaptive capacity is rated low to very low across capitals, with a caveat of very low anticipatory and natural capital, which indicates the need for integrated efforts across institutions.

- <u>Luna, La Union</u> - The municipality is classified as high vulnerability and this is characterized by high potential impact of climate change to rice and maize, very low hazard index with presence of flood, storm surge, and high potential impact of sea level rise. The adaptive capacity is rated low to very low across capitals, with a caveat of very low economic, natural, and anticipatory capital, which indicates the need for integrated efforts across institutions.

- <u>Sison, Pangasinan</u> – The municipality is classified as high vulnerability and this is characterized by moderate potential impact of climate change to rice, very high hazard index driven by the presence of typhoon, flood, drought, landslide, and erosion. The adaptive capacity is rated low to very low across capitals, with a caveat of very low economic, anticipatory and human capital, which also indicates the need for integrated efforts across institutions. Since "adaptive crop calendar" is proposed as one of the identified CRA practice, strengthening the anticipatory capital with a provision for bundled package of climate services and insurance is important.

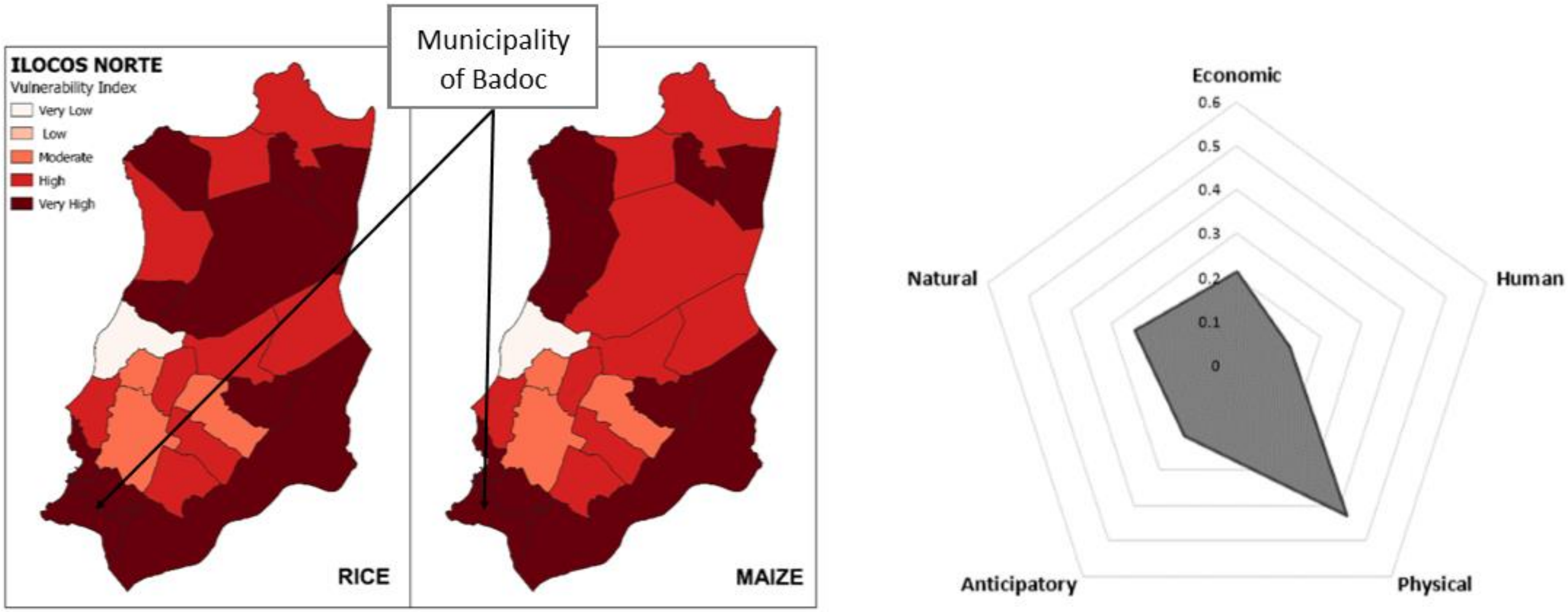


Figure 15A. Vulnerability for rice and corn, and adaptive capacity ratings for the Province of Ilocos Norte

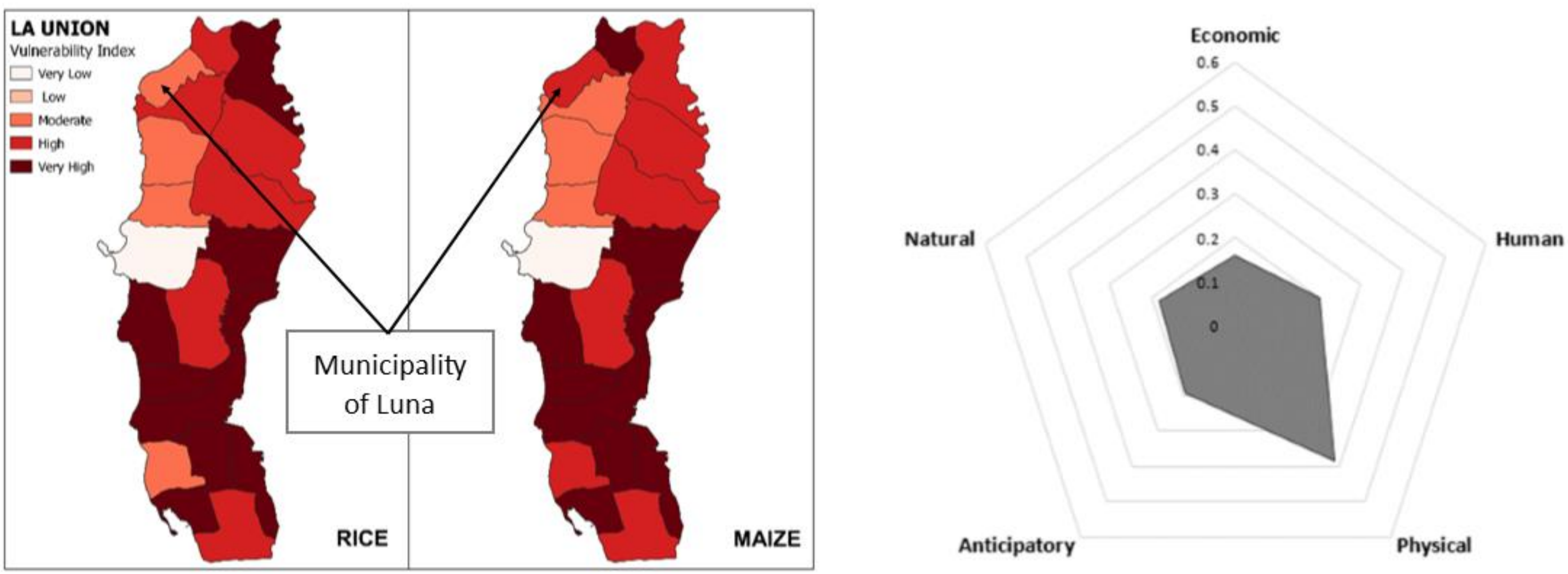


Figure 15B. Vulnerability for rice and corn, and adaptive capacity ratings for the Province of La Union

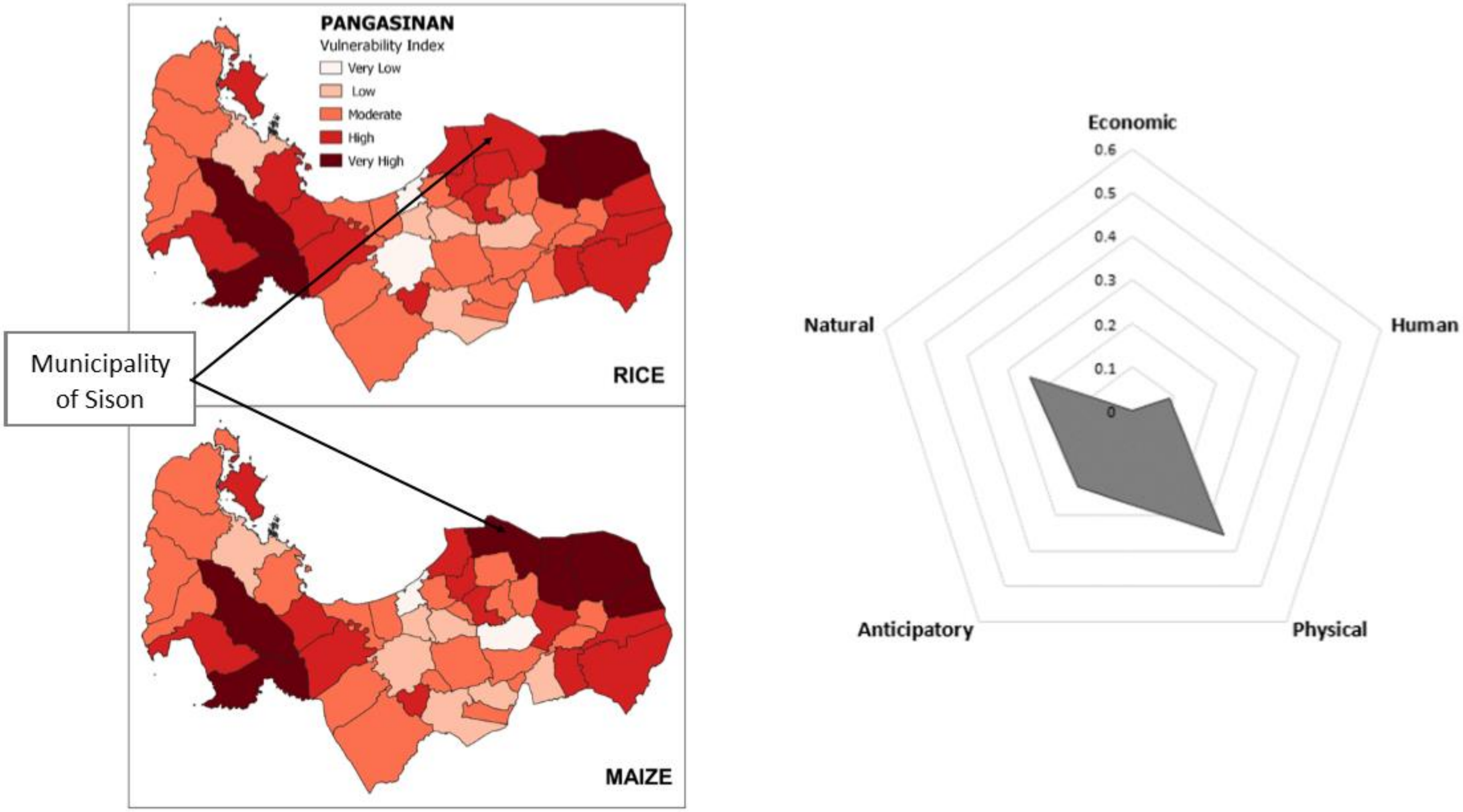


Figure 15C. Vulnerability for rice and corn, and adaptive capacity ratings for the Province of Pangasinan

CONCLUSION

Agricultural vulnerability to climate change was assessed and mapped in three (3) provinces in the Philippines 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, maize/corn, tomato, eggplant, garlic, banana, and mango. In the Philippines, the municipal resolution was used because the authors 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 are in broad agreement with the perception of LGUs and existing literatures on climate change impacts.

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. Impacts of climate change has been quantified using crop distribution models using baseline and future scenarios. These climate crop suitability scenarios are not just an important component of CRVA, but is essential in preparing research interventions in terms of improving agricultural practices and crop management to cope with climate change.

The result of the CRVA study will directly contribute to the DA Regional Field Office 1 in terms of addressing municipality-level climate risk and prioritize needs for adaptive capacity of communities thru designing and planning appropriate interventions and CRA options. We compiled the list of CRA practices (ANNEX 10) identified by LGUs in the region that has the potential for scaling up and contribute to improve livelihoods and resilience of the farming community. These considered CRA practices are important in climate change adaptation, greenhouse gas emission reduction, and food security. Although, cost and benefit analysis should be considered before introducing a CRA practice/technology to make sure that it is profitable and economically viable.

ACKNOWLEDGEMENT

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ANNEXES

ANNEX 1: Recent studies related to climate change vulnerability assessment covering Philippines

Year Published	Scale	Sensitivity	Exposure	Adaptive Capacity	Citation
2017	Abuan Watershed (Flood Vulnerability)	Climate and physical conditions (rainfall rate, slope, river proximity, land cover, elevation, extent of urban, flooding frequency)	Factors at risk (extent of flooded production areas, no. of flooding, duration of flood, yield loss, income loss, dependency on agriculture, extent of damage)	Practice and community management (flood prone maps, historical flood data, access to flood forecast, flood control, average expenditure, access to crop insurance, access to planting calendars)	Balderama et al., 2017
2017	Abuan Watershed (Drought Vulnerability)	Rainfall, no. of continuous dry days, type of river, plant growth, dependence on irrigation, duration of drought, land cover	Extent of production areas, yield losses due to drought, income loss from production, no. of agriculture-dependent families affected	SSIP availability, rainwater harvesting facility, crop diversification practices, drought prone maps, access to crop insurance, access to drought forecast, cloud seeding, livelihood diversification, access to planting calendar, average expenditure for agriculture, use of drought resistance varieties	Balderama et al., 2017
2017	Abuan Watershed (Soil Erosion Vulnerability)	Rainfall, % forest cover, soil texture, slope, land cover, and presence of constriction	Extent of production farm area exposed to different levels of erosion, yield losses from various erosion level, income loss from production, and population dependent on upland agriculture	Average expenditure for agriculture programs for erosion-affected areas for the past 5 years, and % of the total farmers with diversified livelihood practices	Balderama et al., 2017
2016	Mabalacat City, Pampanga	Rainfall volume, Average typhoon wind speed, Plant growth stage	Affected production areas, Affected farmers, Damaged farmer equipment/houses/infrastructure, Frequency of typhoons	Access to crop insurance, Access to typhoon forecasting information, Access to planting calendar bulletins	Mallari, 2016 x
2015	Regional BIMP EAGA	Average high temperature, Hottest temperature, Hot days temperature, Heat wave duration,	Percent floodplain, Multihazard economic loss risk, Multihazard frequency, Relative water stress index, Total population	Irrigation equipped area	ADB, 2015

Year Published	Scale	Sensitivity	Exposure	Adaptive Capacity	Citation
		Consecutive dry days, Number of dry days, Wet day rainfall, 5-day rainfall			
2014	Five barangays in Lian, Batangas[2]	Health of coastal habitats, Coastal integrity vis-à-vis flooding and erosion, and fisheries	Sea surface temperature, Sea surface height, and Relative wave exposure index	Health of coral communities, Health of seagrass meadows, Health of mangrove forests, Water quality, Habitat restoration efforts, Marine protected area, Human settlements, Economy, Education	Licuanan et al., 2015
2008	Sorsogon City, Sorsogon	The authors assumed that Sorsogon will experience stronger tropical cyclones. Increase in rainfall was based from projected rainfall and temperature increase from PAGASA in year 2030 and 2050.		Socio-economic: Poverty incidence, Informality (Tenure), Literacy Rate, PO/CBO,MFI membership; Technology: Access to telecommunications, Access to electricity, Functional DRR Plan; Infrastructure: Household with safe water access, Paved road, Protective infrastructure (sea	Mias-Mamonong and Flores, 2008
ND	Upper Marikina River Basin	Presence of rivers and streams, watershed conditions in terms of forest cover, Dependence on irrigation, Duration of drought	Extent of production areas affected wall, unsafe housing unit)by the last two occurrences of drought (in hectares), Quantity (MT) and value of yield losses (million pesos) due to drought in the last two occurrences, Extent of prime agricultural lands to SAFDZs affected (in hectares)	Small scale irrigation program, Crop diversification practices, Livelihood diversification, cloud seeding program.	Briones, NA x

[2] Barangays San Diego, Lumaniag, Binubusan, Matabungkay, Balibago

ANNEX 2: Bioclimatic variables used in crop distribution modeling

Parameters	Description (O'Donnell, M and Ignizio, D., 2012)
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.

ANNEX 3: 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

Model	Modeling Center	Institution
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

ANNEX 4: Selected list of indicators and sub-indicators

Attribute Capital	Indicator	Sub-indicator	Source
Economic Capital	1. Poverty		Philippine Statistics Authority (2012)
	2.Inflation Rate		National Competitiveness Council (2015)
	3.Minimum wage (agriculture)	3.1 Ag. minimum wage non-plantation, and 3.2 ag minimum wage plantation	National Competitiveness Council (2015)
	4.Financial Institutions and Cooperative	4.1 Total banks & financial institutions, and 4.2 Number of finance cooperatives	National Competitiveness Council (2015)
Natural Capital	5.% of area irrigated		International Water Management Institute (IWMI)
	6.% of closed forest and mangrove forest		National Mapping and Resource Information Authority
Human Capital	7.Health	Ratio to population: 7.1 Public health services, 7.2 Private doctors, 7.3 Private health services, 7.4 Health services manpower, 7.5 Public doctors, and 7.6 Local citizens with PhilHealth	National Competitiveness Council (2015)
	8.Education	8.1 Number of secondary schools (public and private), and 8.2 ratio of public school teachers to students	National Competitiveness Council (2015)
Physical Capital	9.Infrastructure investment		National Competitiveness Council (2015)
	10.Infrastructure Network		National Competitiveness Council (2015)
	11.Access to services	11.1 % of households with access to electricity services, and 11.2 % of households with access to water services	National Competitiveness Council (2015)
	12. Number of Public Transport		National Competitiveness Council (2015)
	13.Telephone Companies and Mobile Services		National Competitiveness Council (2015)
Anticipatory Capital	14. Number of trainings held relating to climate change		Municipal/City Agricultural Office
	15. Access to communication technology i.e., cellphone, internet		Municipal/City Agricultural Office

ANNEX 5. Municipality-level hazard risks for selected municipalities of A) Ilocos Norte, B) La Union, and C) Pangasinan. Box shows the target municipality of DA for the establishment of climate resilient villages.

(A)

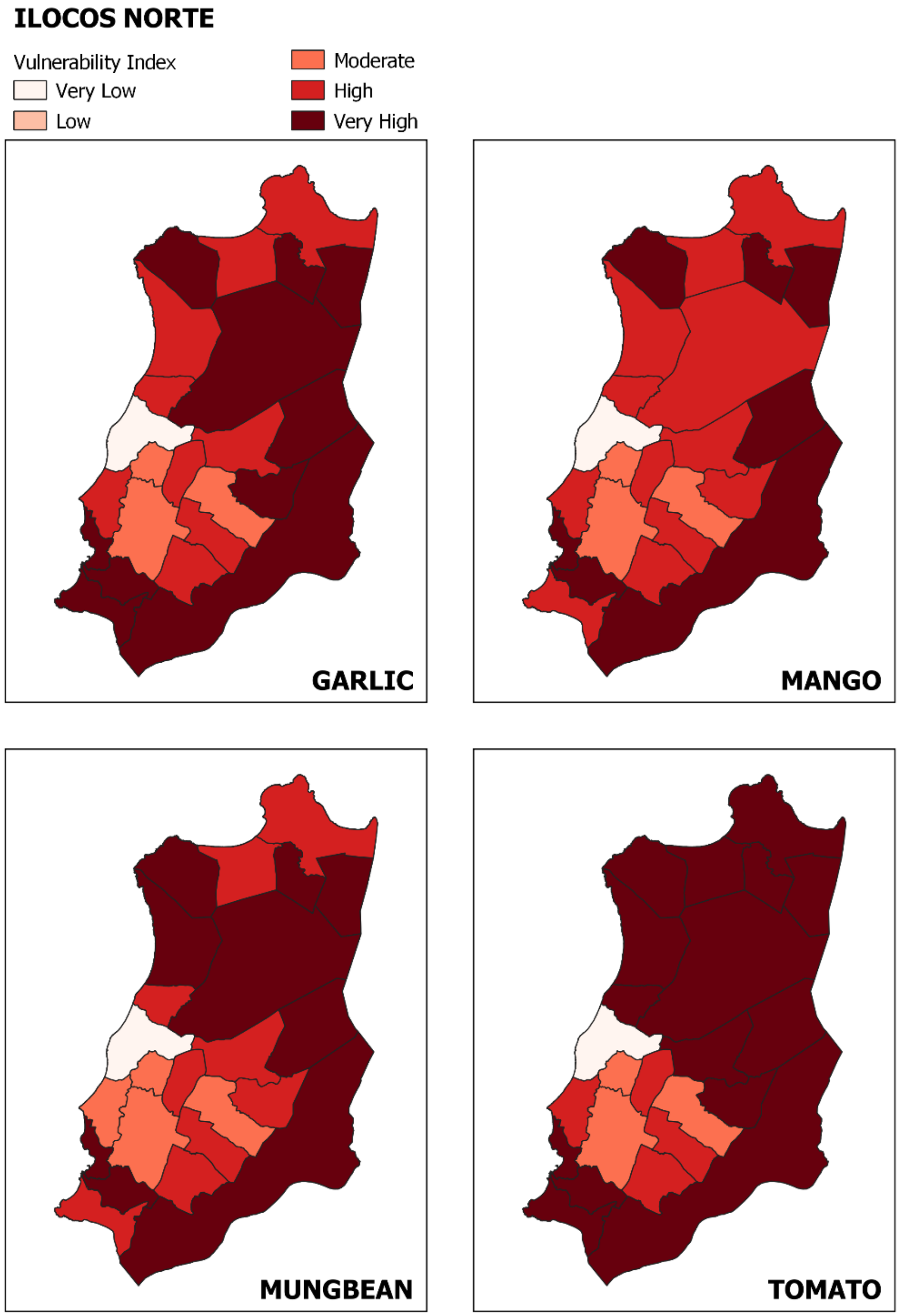

Hazards
Typhoon
Flood
Drought
Erosion
Landslide
SWI
Storm.Surge
SLR
Hazard.Index
MUNI_CITY
Tubao
Sudipen
Santol
Santo Tomas
San Juan
San Gabriel
Rosario
Pugo
Naguilian
Luna
City of San Fernando
Caba
Burgos
Bauang
Bangar
Balaoan
Bagulin
Bacnotan
Aringay
Agoo
0.00 0.25 0.50 0.75 1.00
value

(B)

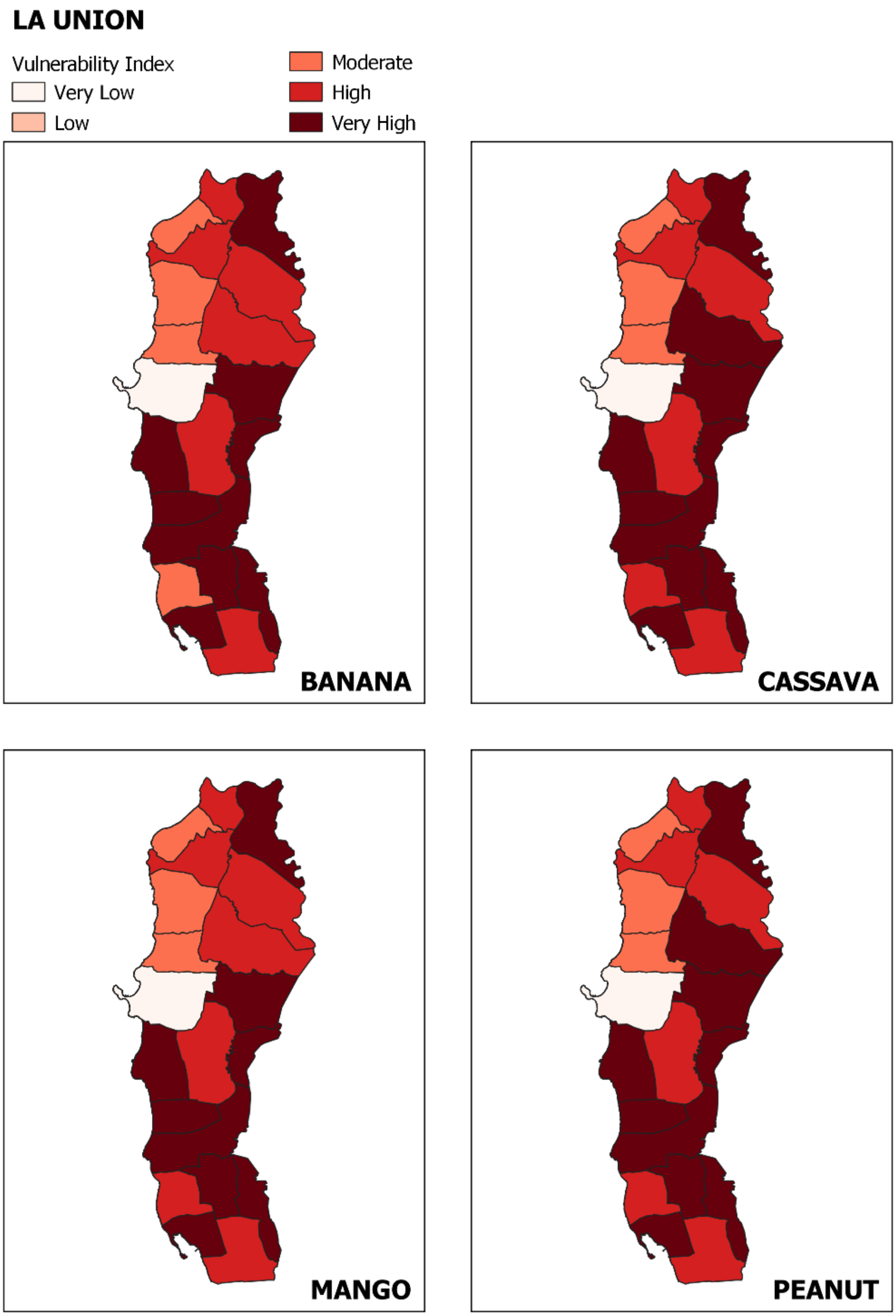

Hazards
Typhoon
Flood
Drought
Erosion
Landslide
SWI
Storm.Surge
SLR
Hazard.Index
MUNI_CITY
Villasis
Urbiztondo
Umingan
Tayug
Sual
Sison
Santo Tomas
Santa Maria
Santa Barbara
San Quintin
San Nicolas
San Manuel
San Jacinto
San Fabian
San Carlos City
Rosales
Pozorrubio
Natividad
Mapandan
Mangatarem
Mangaldan
Manaoag
Malasiqui
Mabini
Lingayen
Laoac
Labrador
Infanta
Dasol
Dagupan City
City of Urdaneta
City of Alaminos
Calasiao
Burgos
Bugallon
Bolinao
Binmaley
Binalonan
Bayambang
Bautista
Basista
Bani
Balungao
Asingan
Anda
Alcala
Aguilar
Agno
0.00 0.25 0.50 0.75 1.00
value

(C)

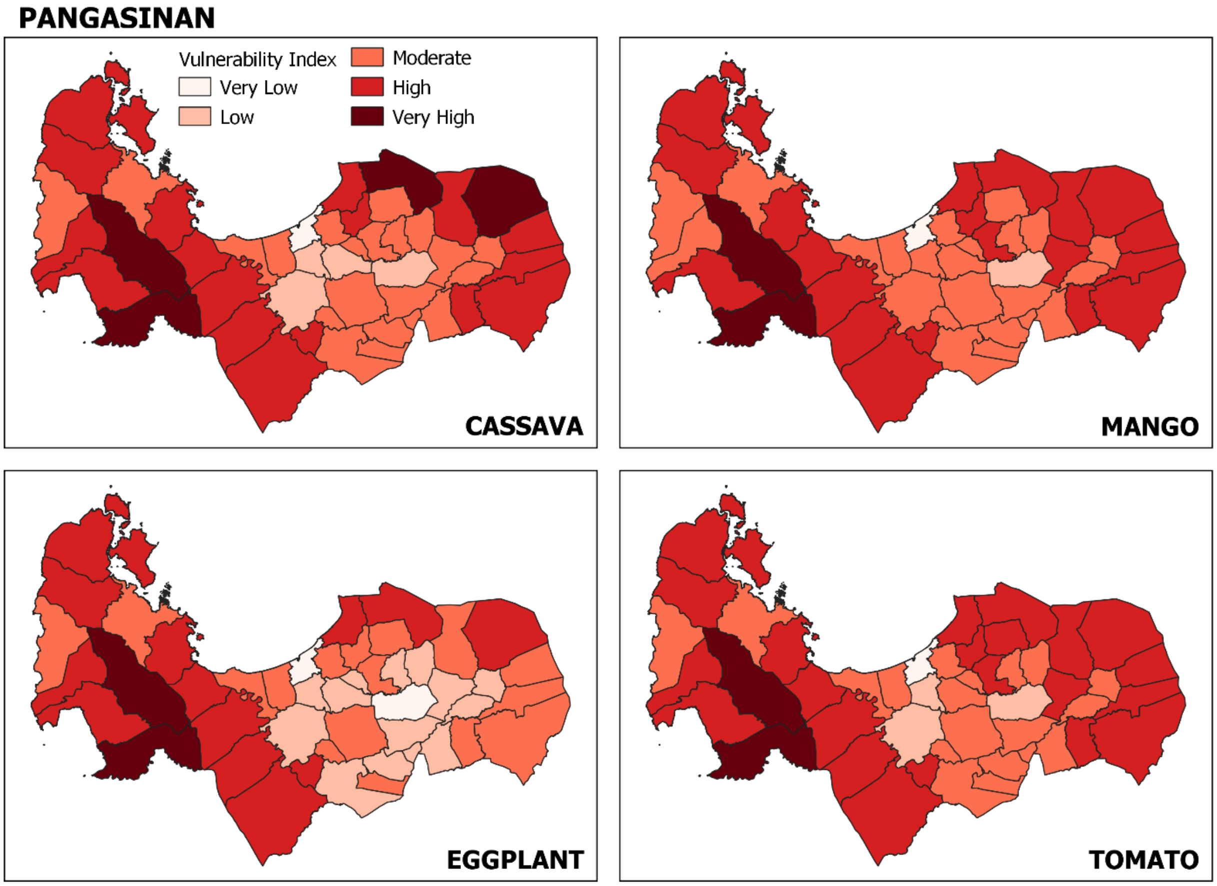
ANNEX 6: Municipality-level vulnerability maps for garlic, mango, mungbean, and tomato in the Province of Ilocos Norte



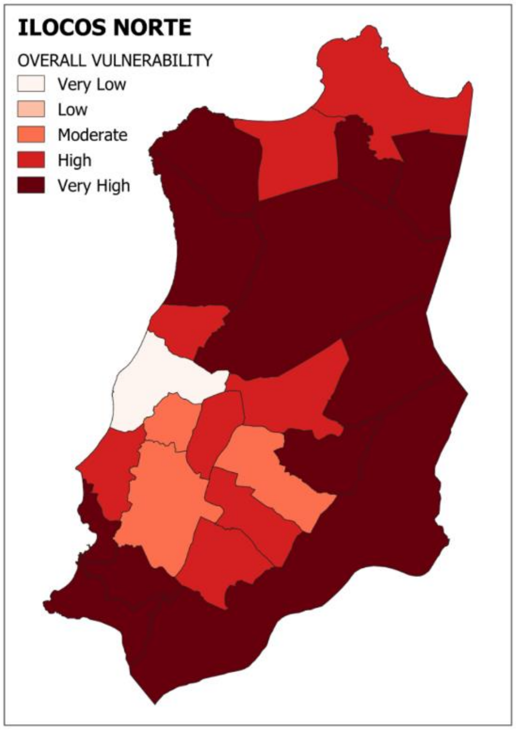
ANNEX 7: Municipality-level vulnerability maps for banana, cassava, mango, and peanut in the Province of La Union

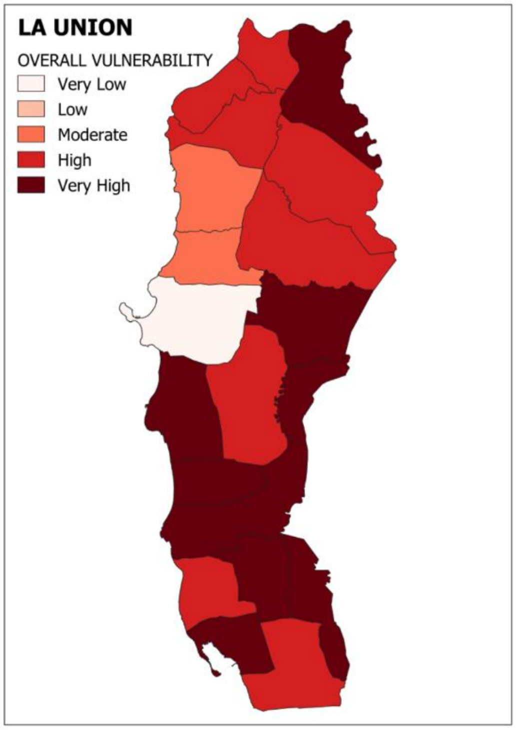


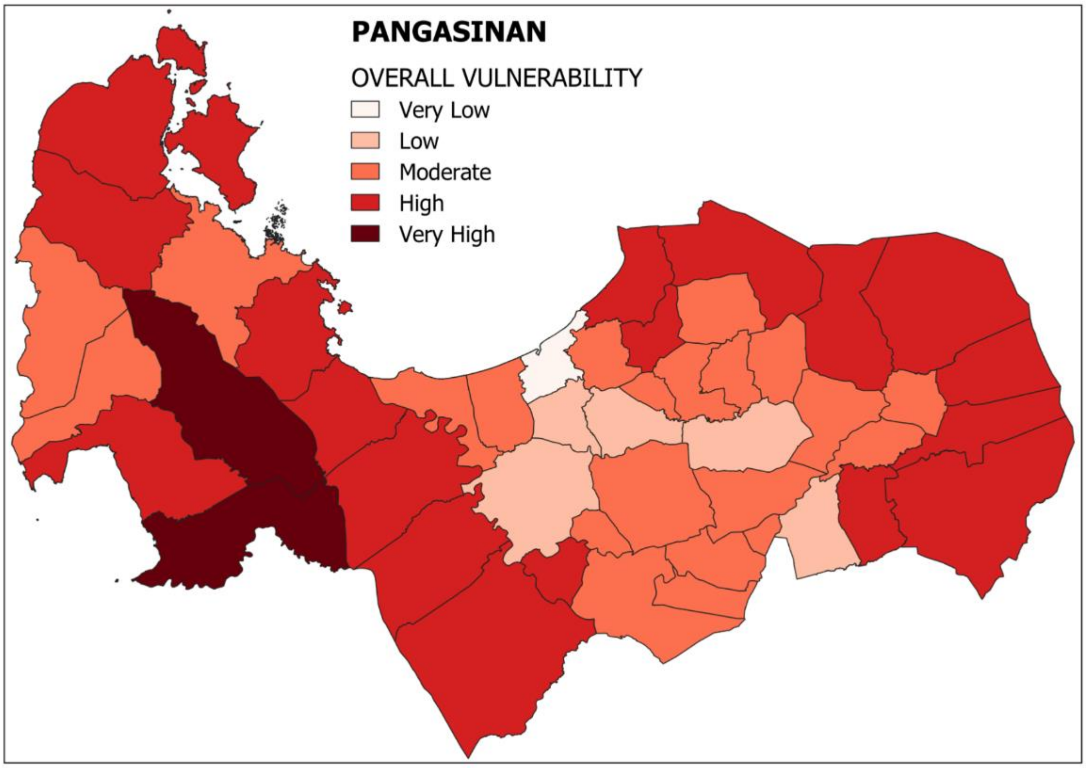
ANNEX 8: Municipality-level vulnerability maps for cassava, mango, eggplant, and tomato in the Province of Pangasinan



ANNEX 9: Overall municipality-level vulnerability maps for Ilocos Norte, La Union, and Pangasinan







ANNEX 10: List of recommended CRA practices in the region.

CRA Practice	Aqua-culture	Corn	Livestock	Mango	Rice	Root crops	Sugarcane	Tobacco	Vegetables	Total
Alternate Wetting and Drying	0	2	0	0	10	1	0	1	0	14
Adaptive Crop Calendar	0	16	0	1	23	5	0	3	16	64
Agroforestry	0	0	0	1	0	0	0	0	0	1
Alternative Feeds (e.g., forages)	0	0	2	0	0	0	0	0	0	2
Aquaponics	1	0	0	0	0	0	0	0	1	2
Aquasilviculture	1	0	0	0	0	0	0	0	0	1
Biogas Digester	0	0	1	0	0	0	0	0	0	1
Climate Information System	0	1	0	0	1	0	0	0	1	3
Climate Resilient Housing	0	0	5	0	0	0	0	0	0	5
Crop Insurance	0	2	0	1	3	0	0	0	0	6
Direct Seeding	0	0	0	0	1	0	0	0	0	1
Drip irrigation	0	0	0	0	0	0	1	0	1	2
Early Maturing Variety	0	7	0	0	7	0	0	0	2	16
Floating Fish Cages	2	0	0	0	0	0	0	0	0	2
Floating Feed Areas	1	0	0	0	0	0	0	0	0	1
Flower Induction	0	0	0	1	0	0	0	0	0	1
Integrated Pest Management	0	10	0	3	13	5	1	1	11	44
Intercropping	0	0	0	0	2	3	0	0	2	7
Organic	1	7	1	1	5	4	0	0	11	30

CRA Practice	Aqua-culture	Corn	Livestock	Mango	Rice	Root crops	Sugarcane	Tobacco	Vegetables	Total
Pest Tolerant Variety	0	4	0	1	2	1	0	0	0	8
Adjust Planting Density	0	1	0	0	0	0	0	0	1	2
Postharvest (e.g., drying, storage)	0	0	0	1	3	2	0	0	3	9
SCoPSA	0	1	0	0	0	0	0	0	0	1
Site-specific Nutrient Management	0	10	0	1	8	3	1	0	2	25
Small-scale Irrigation (e.g., SWIP, STW)	0	20	0	0	22	4	0	3	8	57
Solar Irrigation	0	2	0	0	1	2	0	0	1	6
Adjusted Stocking Density	1	0	0	0	0	0	0	0	0	1
Stress Tolerant Variety	0	18	0	0	27	2	1	0	10	58
Vermicomposting	0	0	1	0	0	0	0	0	0	1
Windbreak	0	0	0	0	1	0	0	0	1	2
Total	7	101	10	11	129	32	4	8	71	373

ANNEX 11: Workshop for Priority Crop Identification with CRVA overview and basic GIS training held at Dagupan Village Hotel, Dagupan City, Pangasinan last July 23-25, 2019.

ANNEX 12: Workshop for Crop Occurrence Mapping (A) and Hazard Validation (B) held at OPAg, Laoag City, Ilocos Norte, OPAg, San Fernando City, and DA-PREC, Santa Barbara, Pangasinan last September 23-25, 2019.

ANNEX 13: Cost-Benefit Analysis of Selected Climate-Resilient Agriculture Practices and Adaptive Capacity Validation Workshop held at Hotel Linda, Vigan City, Ilocus Sur last October 17-18, 2019 and Calasiao Regency Hotel, Calasiao, Pangasinan last October 21-22, 2019.





ANNEX 14: Ex-Ante Cost-Benefit Analysis of Selected Climate-Resilient Agriculture Practices in Region 1 by Rowell C. Dikitanan

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. Participatory workshop was conducted in Dagupan, Pangasinan last 24 July 2019 with DA's regional field office and Local Government Units (LGUs) to select at least two best-bet CRA practices[3] based on the results of the CRA profiles [Dikitanan et al., 2017] and the following criteria:

    - Local relevance (Does it address the main climate risk/hazard? Does it affect the priority crop?)

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

- CRA scope (Does it enhance food security/productivity, adaptation, mitigation?)
- Scaling potential (Is it likely to be adopted by farmers? Is there a support service [financial, technical, community/LGUs]?)

The objectives of the workshop were to: 1) provide an overview of the CRA prioritization framework and 2) long listing of CRA practices and ranking of CRA practices. A total of 32 municipalities and one city from Ilocos Norte, La Union, and Pangasinan are represented in the workshop.

2. Production cost and returns report from LGUs was used as the main input data for CBA. Literature review and focus group discussions (FGDs) were conducted to fill data gaps. Data collected include production costs and yields for farms both with and without CRA practices, installation and maintenance costs of CRA practices, and prices received by farmers.

   Data were collected for the following municipalities:

   - Badoc (and Solsona), Ilocos Norte

   Badoc, Ilocos Norte is a 3rd class municipality with 31 barangays and 31,616 (as of 2015 census) people. The major crops are rice onion, tobacco, corn, and garlic.

   - Sison (and Sual), Pangasinan

   Sison, Pangasinan is a 3rd class municipality with 28 barangays and 47,518 (as of 2015 census) people. The major crops are rice, corn, and tobacco.

   - Luna, La Union is a 3rd class municipality with 40 barangays and 35,802 (as of 2015 census) people.

3. Data was summarized in a spreadsheet and the best-bet practices were assessed based on potential profitability using a spreadsheet program. The CBA online tool developed with funding from the International Fund for Agricultural Development and the CGIAR Research Program on Climate Change, Agriculture and Food Security led by CIAT is currently under maintenance.

4. CBA capacities of LGUs were enhanced through back-to-back trainings in Vigan, Ilocos Sur (17-18 October 2019) and Calasiao, Pangasinan (21-22 October 2019):

   The objectives of the training were to: 1) strengthen capacities in conducting CBA based on the recommended methodological guidelines/tool and 2) present progress on CBA work and collect additional CBA data. A total of XX participants from Ilocos Norte and Ilocos Sur are present in Vigan, Ilocos Sur and XX participants from La Union and Pangasinan are present in Calasiao, Pangasinan.

   A spreadsheet-based CBA tool was developed and distributed during the training. Formulae are embedded in the tool so users only need input cost and returns data as well as some key assumptions. Participants find this helpful and useful for their future analysis.

Based from the answers of the participants in the pre- and post-training evaluation, their level of familiarity with the concept of CRA and CBA increased after the training in Vigan, Ilocos Sur by 54% and 59%, respectively (Table 1). Level of familiarity with the concept of CRA and CBA increased after the training in Calasiao, Pangasinan by 50% and 62%, respectively (Table 2). The average rating of the trainings is "good" (Table 3).

Table 1. Participants' level of familiarity with CRA and CBA concept in Vigan, Ilocos Sur.

Level of familiarity	Before	After	Difference
CRA	1.69	4.03	2.34 (139%)
CBA	1.73	4.00	2.27 (131%)

Table 2. Participants' level of familiarity with CRA and CBA concept in Calasiao, Pangasinan

Level of familiarity	Before	After	Difference
CRA	2.08	3.62	1.54 (74%)
CBA	1.64	3.56	1.92 (117%)

Table 3. Participants' average satisfaction rating.

Criteria	Average Rating	
	Vigan, Ilocos Sur	Calasiao, Pangasinan
1. How well did the training achieve its objectives?	4.34 (Good)	4.14 (Good)
2. How useful was the materials being provided?	4.27 (Good)	4.28 (Good)
3. Was the length of the training sufficient?	4.06 (Good)	4.00 (Good)
4. Was the content of the training well organized?	4.19 (Good)	4.23 (Good)
5. Was the flow of the training properly executed?	4.12 (Good)	4.26 (Good)
6. How clear and understandable were the discussions?	4.24 (Good)	4.05 (Good)
7. How well the training met your expectations?	4.12 (Good)	4.12 (Good)
8. How effective were the presenters?	4.36 (Good)	4.44 (Good)
9. How readable and clear were the presentations?	4.03 (Good)	3.63 (Good)
10. How comfortable was the venue for you?	4.24 (Good)	3.77 (Good)
Average	4.20 (Good)	4.09 (Good)

5. Validation of results was also conducted during the back-to-back trainings and additional data were collected.

Results

Long-list of CRA Practices from 32 municipalities and 1 city

Priority commodities in the region include aquaculture, corn, livestock, mango, rice, rootcrops, sugarcane, tobacco, and vegetables. More than 30 CRA practices were identified by participants (Table 4).

Table 4. List of recommended CRA practices in the region.

CRA Practice	Commodity									Total
	Aquaculture	Corn	Live-stock	Mango	Rice	Root crops	Sugarcane	Tobacco	Vegetables	
Alternate Wetting and Drying	0	2	0	0	10	1	0	1	0	14
Adaptive Crop Calendar	0	16	0	1	23	5	0	3	16	64
Agroforestry	0	0	0	1	0	0	0	0	0	1
Alternative Feeds (e.g., forages)	0	0	2	0	0	0	0	0	0	2
Aquaponics	1	0	0	0	0	0	0	0	1	2
Aqua silviculture	1	0	0	0	0	0	0	0	0	1
Biogas Digester	0	0	1	0	0	0	0	0	0	1
Climate Information System	0	1	0	0	1	0	0	0	1	3
Climate Resilient Housing	0	0	5	0	0	0	0	0	0	5
Crop Insurance	0	2	0	1	3	0	0	0	0	6
Direct Seeding	0	0	0	0	1	0	0	0	0	1
Drip irrigation	0	0	0	0	0	0	1	0	1	2
Early Maturing Variety	0	7	0	0	7	0	0	0	2	16
Floating Fish Cages	2	0	0	0	0	0	0	0	0	2
Floating Feed Areas	1	0	0	0	0	0	0	0	0	1
Flower Induction	0	0	0	1	0	0	0	0	0	1
Integrated Pest Management	0	10	0	3	13	5	1	1	11	44
Intercropping	0	0	0	0	2	3	0	0	2	7
Organic	1	7	1	1	5	4	0	0	11	30
Pest Tolerant Variety	0	4	0	1	2	1	0	0	0	8
Adjust Planting Density	0	1	0	0	0	0	0	0	1	2
Postharvest (e.g., drying, storage)	0	0	0	1	3	2	0	0	3	9
SCoPSA	0	1	0	0	0	0	0	0	0	1
Site-specific Nutrient Management	0	10	0	1	8	3	1	0	2	25

CRA Practice	Commodity									Total
	Aquaculture	Corn	Live-stock	Mango	Rice	Root crops	Sugarcane	Tobacco	Vegetables	
Small-scale Irrigation (e.g., SWIP, STW)	0	20	0	0	22	4	0	3	8	57
Solar Irrigation	0	2	0	0	1	2	0	0	1	6
Adjusted Stocking Density	1	0	0	0	0	0	0	0	0	1
Stress Tolerant Variety	0	18	0	0	27	2	1	0	10	58
Vermicomposting	0	0	1	0	0	0	0	0	0	1
Windbreak	0	0	0	0	1	0	0	0	1	2
Total	7	101	10	11	129	32	4	8	71	373

<u>Prioritized CRA Practices</u>

The prioritized CRA practices in the region (Table 5) are:

1. Small Water Impounding Project (SWIP) – "An earth-filled structure with a height of 5-15 meters constructed across narrow valleys or depression to create a reservoir that will harvest and store rainfall and runoff for immediate or future use. Has a minimum service area of 15 hectares (DA, 2017)."

2. Small Farm Reservoir (SFR) – "Impounding and storage facility with concrete or plastic as lining and protection of embankment. These are used to collect rainfall and runoff for immediate and future agricultural use. Has a minimum production area of 0.5 hectare per unit *DA, 2017)."

3. Adaptive Crop Calendar (ACC) – Adjusting planting date based on rainfall availability or climate hazard (e.g., typhoon).

Table 5. Prioritized CRA practices in the region.

Municipality, Province (Commodity)	CRA Practice
Badoc, Ilocos Norte (Rice)	SWIP
Badoc, Ilocos Norte (Corn), Luna, La Union (Rice and Corn)	SFR
Sison, Pangasinan (Rice and Corn)	Adaptive Crop Calendar

<u>CBA Results</u>

Key assumptions based on literature review and FGDs:

- Average farm area: 0.5 ha
- Discount rate: 15%
- Project cycle: 10 yrs

SWIP

Benefits	Costs
• Increase in yield by 10% • Possibility of additional cropping season, agri-fishery, and agri-tourism • Decrease in external irrigation and fuel cost: 100%	• Construction: PhP 300,000 per ha of service area (excluding canal lining) • Lifespan: 25 years • Construction cost per farmer w/ 1 ha farm: [PhP 300,000 / 25 yrs] x 10 yrs = PhP 120,000 • Maintenance: 1% per year = PhP 1,200 • Increase in harvesting (+sacks) and postharvest cost brought by increase in yield (10%)

SFR

Benefits	Costs
• Increase in yield by 10% • Possibility of additional cropping season • Decrease in external irrigation and fuel cost: 50% (supplement only)	• Construction: PhP 50,000 per unit/0.5 ha of coverage area • Lifespan: 5 years • Construction cost per farmer w/ 1 ha farm: [PhP 50,000 / 0.5 ha] = PhP 100,000 • Maintenance: 1% per year = PhP 1,000 • Increase in harvesting (+sacks) and postharvest cost brought by increase in yield

Adaptive Crop Calendar

Benefits	Costs
• Increase in yield by 5% • Reduction in irrigation and fuel cost: 10% (rainfall availability)	• Increase in harvesting (+sacks) and postharvest cost brought by increase in yield

All of the prioritized CRA practices are more financially profitable compared to conventional practice except for SWIP and SFR in Badoc, Ilocos Norte. It is recommended that agri-fisher and/or agri-tourism be implemented in SWIP to further increase the benefits. The Benefit-Cost Ratio of corn production in Badoc, Ilocos Norte is low even without SFR. Thus, high yielding varieties and cost-reduction practices should be combined with SFR. Both SWIP and SFR entail large investment cost compared to ACC.

Badoc, Ilocos Norte	Rice*		Corn**	
	without SWIP	with SWIP	without SFR	with SFR (2-cropping)
Net Present Value (PhP)	259,951	236,256 (↓)	26,069	8,172 (↓)
Benefit-Cost Ratio	1.46	1.35	1.09	1.01
Internal Rate of Return (%)	63.98	38.31	24.79	15.95
Annuity Equivalent Value (PhP)	51,796	47,074	5,194	1,628
Initial Investment (PhP)	122,639	252,879	62,080	229,113
Payback Period (years)	5.19	11.77	26.20	308.40

**Hybrid Seed (Wet Season) + Certified Seed (Dry Season) Commercialization ** Yellow Corn*

Luna, La Union	Rice*		Corn**	
	without SFR	with SFR (2-cropping)	without SFR	with SFR (2-cropping)
Net Present Value (PhP)	122,436	189,964 (↑)	70,434	106,272 (↑)
Benefit-Cost Ratio	1.41	1.26	1.24	1.15
Internal Rate of Return (%)	59.15	35.28	40.73	26.94
Annuity Equivalent Value (PhP)	24,396	37,851	14,034	21,175
Initial Investment (PhP)	64,119	240,108	63,523	232,179
Payback Period (years)	5.76	13.90	9.92	24.03

**1 Cropping Only (Wet Season) **Yellow Corn*

Sison, Pangasinan	Rice*		Corn**	
	without ACC	with ACC	without ACC	with ACC
Net Present Value (PhP)	302,306	335,481 (↑)	351,630	381,418 (↑)
Benefit-Cost Ratio	1.63	1.69	2.27	2.37
Internal Rate of Return (%)	82.30	88.73	150.55	161.14
Annuity Equivalent Value (PhP)	60,235	66,845	70,063	75,998
Initial Investment (PhP)	103,594	104,883	59,637	59,989
Payback Period (years)	3.77	3.44	1.87	1.73

**Hybrid (Wet Season) + Inbred (Dry Season) Production **Yellow Corn (Seed)*

Additional	Solsona, Ilocos Norte		Sual, Pangasinan
	Rice*	Corn**	Rice***
Net Present Value (PhP)	379,520	39,280	85,822
Benefit-Cost Ratio	1.67	1.17	1.41
Internal Rate of Return (%)	87.11	32.91	59.12
Annuity Equivalent Value (PhP)	75,620	7,827	17,100
Initial Investment (PhP)	121,325	51,007	44,976
Payback Period (years)	3.52	14.28	5.76

**Wet Season + Dry Season **Yellow Corn ***1 Cropping Only (Wet Season); Does Not Plant Corn*

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