Climate Risk Vulnerability Assessment

Province of Agusan del Sur

Message

The global issue of climate change brought a great challenge in Agriculture sector. As the leading industry in the Philippines, we are committed to ensure sustainability of foods amidst these climate variations. Agriculture sector will be greatly affected if these problems can't be mitigated.

The Department of Agriculture accepted the challenge by continuous provision of interventions that will develop adaptation and mitigation skills of our farmers and fishers – helping them battle the effects of climate adversities.

I commend the Research Division for producing a comprehensive and holistic analysis of the Climate Risk Vulnerability Assessment (CRVA) in the region. In this report, the vulnerability index in terms of the adaptive capacity, exposure, and sensitivity are presented in detail, as well as the factors affecting it.

The CRVA is very relevant for it serves two purpose: (1) as basis in the establishment of AMIA Villages where Climate-Resilient Agriculture (CRA) practices are showcased and (2) as guide in implementing programs and interventions of the Department. Similarly, this also serves as reference for policy-makers, farmers, research institutions, academe, organizations, and interested groups.

With this comprehensive output, I hope it will address the crucial role that R&D plays in developing innovations and enhancing the agricultural productivity as well as income of our farmers and fishers in Caraga.

Thank you and Mabuhay! Larga Caraga, Larga!

ENGR. RICARDO M. OÑATE, JR.
Regional Executive Director

Message

As climate change continues to exert pressure on the livelihoods and agricultural productivity of our farmers, the need to understand the vulnerability of the community is very timely and necessary.

Cognizant of the fact that there have been various programs and interventions geared towards adaptation and mitigation initiatives of our farmers and fishers in Caraga, having this comprehensive CRVA report is in the right direction.

This CRVA output will serve as benchmark of future programs and interventions we will be implementing the region. Considering the present situation and the existing resources available, we can make a huge impact in helping our farmers combat the negative effects of climate change in the future.

Through the AMIA project, the Department of Agriculture envisioned of enabling local communities manage climate risks while pursuing sustainable livelihoods. The information presented in this CRVA will help us determine the highly vulnerable municipality where appropriate climate-smart technologies and practices will be introduced.

I commend the Research Division and everyone behind the completion of this CRVA output deserves applause for their extraordinary effort. I am looking forward to seeing a bright R&D future ahead of us.

Congratulations everyone!

NICANDRO M. NAVIA, JR.
Regional Technical Director for
Research, Regulations & ILD/ AMIA Focal Person

Message

I take pride in supporting this printed work, a first of its kind in the area of climate vulnerability assessment. As Project Leader and Chief of the Research Division, it's kind of fulfilling to come-up with this comprehensive CRVA analysis of all the municipalities in Caraga.

Considering all the information presented in this comprehensive CRVA output, we hope that this will be used as reference by our Banner Programs and LGUs in their future interventions, target-setting, and prioritization.

As for the AMIA project, this output will be used as basis in developing and promoting climate-resilient agriculture (CRA) through implementing technologies and practices, introducing institutional and social innovations, and accessing climate-relevant support services.

I am grateful to the Climate Resilient Agriculture Office for initiating projects directed towards increasing climate-change resiliency of our farmers.

To our researchers and collaborating LGUs, thank you very much and congratulations. May this output be an important and significant reference for everyone.

ABEL F. WAGAS
Chief, Research Division
AMIA, Project Leader

Acknowledgement

The AMIA Team would like to express its heartfelt gratitude to those personalities behind the success of this CRVA analysis that provides appropriate strategies to responding to the challenging call of climate change.

This book would not be possible without the contribution and commitment of the following departments and personnel:

We are thankful to the Department of Agriculture-Climate Resilient Agriculture Office for designing and funding this project with enormous budget allocation.

To the Department of Agriculture- Regional Office for the unwavering support in implementing this result-based project.

To our Regional Executive Director, Engr. Ricardo M. Oñate who undeniably stood as pillar of the department.

To the focal person, RTD Nicandro M. Navia Jr. who endlessly provides inputs to this paper.

To the project leader, Chief Abel F. Wagas who consistently monitored the implementation of the project.

To the members of the Technical Working Group (TWG) per Special Order # 11 who untiringly spare their time in attending and supporting AMIA activities.

To the AMIA Technical Staff who perform the data collection, consolidation, and validation to ensure conducive output as a tool for decision-making.

To all the Senior Staff for their continued guidance and supervision in the implementation of all CRVA-related undertakings.

To the concerned LGU's of the Province of Agusan del Sur who undoubtedly provide the data's needed for the creation of CRVA.

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Abstract

This paper provides information on the most vulnerable municipalities to climate change impacts in the Province of Agusan del Sur (ADS) in Caraga region. This assessment was carried out by overlaying climate hazard maps, sensitivity maps, and adaptive capacity maps following the vulnerability assessment framework of the United Nations' Intergovernmental Panel on Climate Change (IPCC). The study used data on the spatial distribution of various climate-related hazards in the province of Agusan del Sur, Caraga region, Philippines. Based on this Climate Risk Vulnerability Assessment (CRVA), San Luis, La Paz and Loreto are among the highly vulnerable municipalities in the province due to its high exposure to climate hazards as well as their low adaptive capacity and the decreasing suitability of crops to climate variability in the aforementioned municipalities. Considering other factors constant, investing for rice, corn, cacao, banana and rubber will be less favourable in the future. However, such potential impacts could be negated if the LGUs will continue investing in climate-change related programs and interventions that will improve farming practices and those that will facilitate agri-related coping mechanisms and strategies. Several climate-resilient farming technologies requires further verification. A Community Participatory Action Research (CPAR) is highly recommended in coming up with location specific climate resilient adaptation options.

Keywords: climate risk vulnerability, sensitivity index, hazard index, adaptive capacity

INTRODUCTION

Impacts of climate change on food production systems depend primarily on the adaptation measures undertaken by local communities (ICCG, 2016). These adaptation strategies will also apply to the complex issues on water use and food production as affected by climate change. The lack of adaptive capacities of the farmers to cope with such climatic variability increases its level of drought vulnerability. Vulnerability to climate change is defined as: "the degree to which a system is susceptible to and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and adaptive capacity (IPCC, 2007).

In the Philippines, due to its geographical and environmental setting, it has become extremely vulnerable to natural disasters, including the effects of climate change (Senate Economic Planning Office (SEPO), 2013). SEPO (2013) quoted that "The Philippines is one of the most hazard-prone countries in the world." The Philippines is now facing the very real impacts of climate change, which threaten to undermine our development prospects and exacerbate the vulnerability of our more impoverished communities. With projected changes in precipitation, temperature, the intensity of tropical cyclones, and the frequency of extreme weather events, considerable efforts would be required to prepare the Philippines to deal with the impacts of climate change on the different climate-sensitive sectors (PAGASA, 2011). In addition, extreme weather events such as typhoons, drought, heavy rains regularly visit the country, and many have led to disasters costing the country billions in pesos every year. The country's agri-fisheries sector is a perennial casualty of these climate-related risks. From 2010 to 2014, loss and damages from climate/weather-induced disasters (FPOPD-DA, 2015) reached a total of Php136 billion or an average of PhP27 billion annually. The increased vulnerability of agri-fisheries communities to climate risks poses a key challenge in enabling them to pursue more resilient and productive livelihoods and ultimately rise out of poverty.

At the regional scale, it has been reported during 2011-2015, the north-eastern Mindanao region (Caraga) was hit by typhoons that caused tremendous agricultural damage. Typhoons Sendong, Agaton, Pablo, and Senyang have been the most publicized ones that brought disasters to the region. In 2012, Typhoon Pablo caused an estimated PHP 3.6 B damaged in agriculture in Regions 4b, 6, 7, 10, 11 12 and Caraga (NDRRMC, 2012).

In response, the Department of Agriculture launched the Adaptation and Mitigation Initiative in Agriculture (AMIA) in 2014, with an overall vision of a Philippine agri-fisheries sector that enables local communities to manage climate risks while pursuing sustainable livelihoods. As its overall approach, AMIA develops and promotes climate-resilient agriculture (CRA) through implementing technologies and practices, introducing institutional and social innovations, and accessing climate-relevant support services.

Climate Risk Vulnerability Assessment (CRVA) of AMIA is conducted to guide the AMIA targeting and planning for building the climate-resilient agri-fisheries communities. It determines the impacts of climate change to have complementary plans and implement strategies to support local communities in managing climate-related risks. It also seeks to introduce complementary activities for building appropriate climate-responsive financial and other key support services.

Outputs of CRVA serve as the basis for developing CRA-related decision-support tools, preliminary models for community action research, and recommended guidelines for providing climate information services.

Objectives

The general objective of this study is to identify which municipalities in the Province of Agusan del Sur are the most vulnerable to climate change. It is expected that this information will be useful to policy-makers of the province and the region as well as stakeholders in better targeting their support towards climate change efforts. The specific objectives are as follows:

1. To assess exposure, sensitivity, and adaptive capacity of the municipalities to climate risks in the province of Agusan del Sur;

2. To show these vulnerable areas in a map for ease of reference of interested parties; and

3. To plan and design climate-risk responsive research and development interventions to build resilience among agri-fishery communities.

Methodology

Study area

Agusan del Sur (Figure 1) is a province of the Caraga region in Northeastern Mindanao of the Philippines, with a land area of 8,965.50 km2, ranking as the fourth largest in the country and the largest in Caraga region. It has a total population of 609,447 individuals, ranking the highest in Caraga Region and contributing 26.57% of the total 2.293 million population. Agusan del Sur has a tropical climate and is geographically situated below the typhoon belt, with an annual rainfall of 3190-3704 mm. The heavy rainfall starts in either Dec or Jan and slowly abates approaching Feb or Mar (De Guzman 2011). The average temperature is 26.5^{0} C. Agusan del Sur is an elongated basin formation with mountain ranges in the eastern and western sides forming a valley, which occupies the central longitudinal section of the land. The Agusan River, which flows from Compostela Valley in the south towards Agusan del Norte in the north, runs almost in the middle of the valley and empties at Butuan Bay (Chen, 2017).

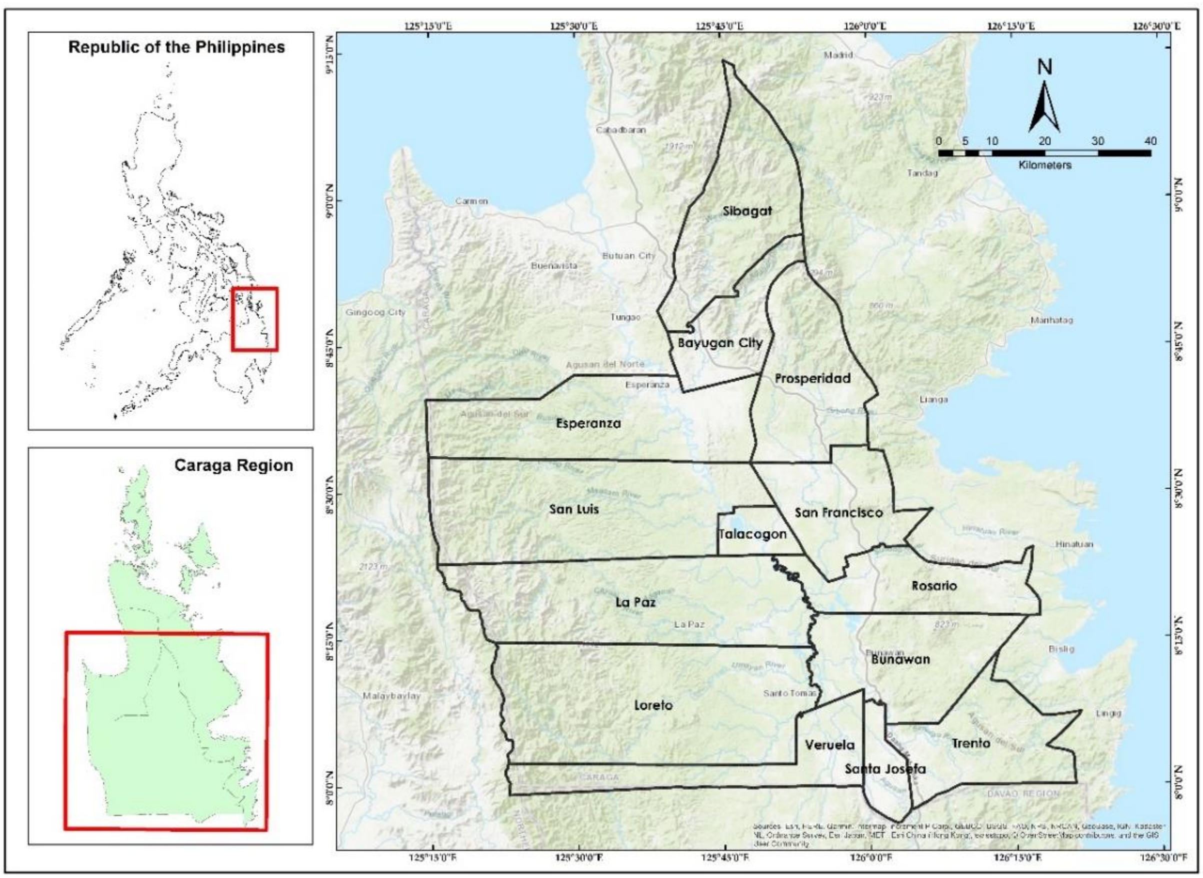

Figure 1. Geographical map of the study area in the province of Agusan del Sur.

The CRVA Framework

Climate risk vulnerability is the degree to which an area is susceptible to the adverse effects of climate change, specifically as manifested in increasing weather variability and projected long-term shift in the occurrence of extreme weather events. Analysis is based on the vulnerability assessment framework from the Intergovernmental Panel on Climate Change (IPCC) which define vulnerability as a function of 3 key dimensions namely, sensitivity, exposure, and adaptive capacity as shown in Figure 2.

Each key dimension has weighted impact factor depending on the importance attributed to the system. The weighted impact factor used in this particular analysis was patterned from that of CIAT which measures CRVA as follows:

Vulnerability*= (*Exposure* * 0.15) + (*Sensitivity* * 0.15) + ((1- *Adaptive Capacity*) * 0.70)** ***Eq (1)

Integrated analysis is done through GIS overlay mapping, which is used to assess spatial patterns and to identify "hotspots" or sensitive areas with significant exposure to climate hazards and low adaptive capacity (Eq 1).

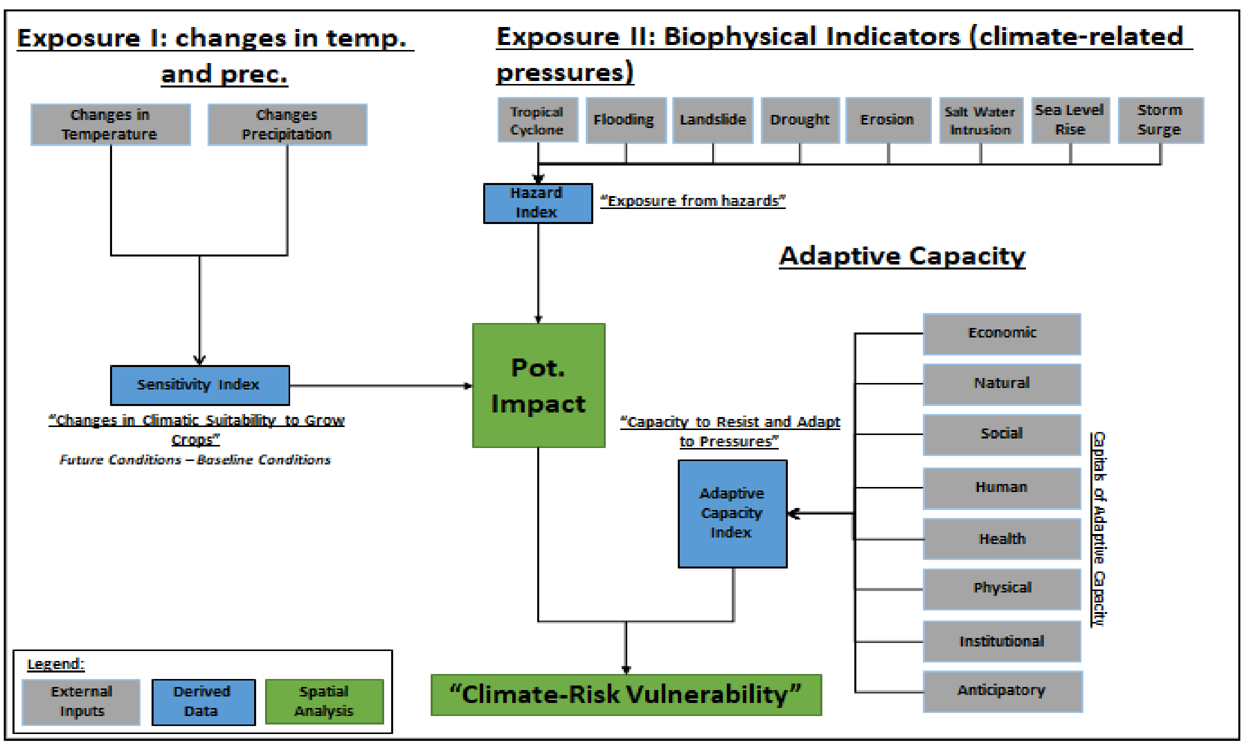

Figure 2. Framework of Climate Risk Vulnerability Assessment

Adaptive Capacity Estimation

The IPCC defined adaptive capacity (AC) as the ability or potential of a system to respond successfully to climate variability and change and includes adjustments in both behavior and in resources and technologies. Literatures provided different versions of adaptive capacity definition however, most of them emphasized on similar idea- "to cope with the consequences". Adaptive capacity focuses on eight capital indicators namely, economic, natural, social, human, health, physical, anticipatory, and institutional. Proxy variables used for each capital were presented in Table 1. Figure 3 displays the stages of adaptive capacity estimation which starts with data standardization or normalization of values to cancel out variability of data using the equation below:

$$Norm = \frac{x - x_{min}}{x_{max} - x_{min}}$$

where:

x = original value
x_{min} = lowest value in the data set
x_{max} = highest value in the data set *Eq (2)*

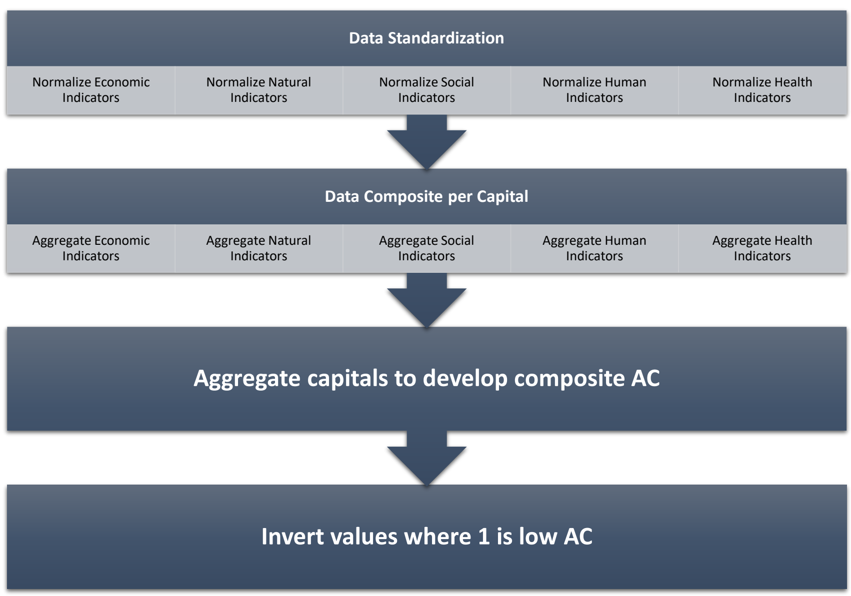

Figure 3. Simplified schematic diagram of AC processing.

Once the values are ready, composite index for each capital is then constructed by getting the average of all indicators. After computing for the composite index, the values were normalized again for consistency. The composite AC is then derived using the sum function of all capital indices. To account for vulnerability, the AC index is then inverted where 1 is considered as low AC.

Table 1. List of indicators used in measuring adaptive capacity

CAPITALS							
Economic	**Natural**	**Human**	**Physical**	**Health**	**Social**	**Anticipatory**	**Institutional**
• Total area planted (top 5 commodities)	• Total service area with irrigation	• Literacy rate	• % of farmers owning agricultural land	• Nutrition rate	• % of women official on government	• No. of MDRRMC registered trainings	• No. of AEW's
• Total volume of production (top 5 commodities)	• Total agricultural land area	• Ratio of school teachers to students	• Average farm size	• Total number of health services	• No. of farmer associations	• % of farmers with access to mobile phones	• % of farmers visited or consulted with AEW's
• Income class		• Total no. of secondary schools	• Total number of livestock owned	• Total number of health professionals	• % of farmers who are members of coops/unions /groups	• % of farmers with access to televisions	• % of farmers visiting or consulting the AEW of MAO
• Total no. of financial institutions		• Total no. of public and private tertiary schools		• % of local citizen with Philhealth		• % of farmers with access to radio	
• Total no. of finance cooperatives		• Total no. of technical vocational schools	• % of agricultural area with irrigation			• % of farmers with access to internet	
• Total no. of ATM's			• Total no. of concrete roads				
• % of farmers covered with insurance			• % of household with water services				
• % of population employed in agriculture			• % of household with electric services				
• Minimum wage rate in agriculture							
• Poverty incidence							

Crop Sensitivity Assessment

Sensitivity index is defined as the increase or decrease of climatic suitability of selected crops to changes in temperature and precipitation (Burgman, 2002). The Climate Change Commission define it as the degree to which a system or species is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea level rise).

Adopting the method suggested by the CIAT, the Maximum entropy (Maxent) model was used to compare crop suitability by the year 2050 vis-à-vis the baseline year. Analyzing changes in crop suitability involves a two-step process: The first step is to assess the baseline (current climate condition) 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. The second step is to predict the location of a species on a particular time slice if it matches the environmental condition where it is observed in the baseline condition. Table 2 presents the 20 bioclimatic variables used to assess climate suitability of crops.

Table 2. Bioclimatic variables used in crop simulation 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 the 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 average span of years (normal).
Bio_6 - Minimum temperature of the 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 the 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.

PARAMETERS	DESCRIPTION
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 rainfall and is expressed as a 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.

Sources*:(O'Donell, M and Ignizio, D., 2012)*

Generating Exposure Index

Exposure index captures the level of potential exposure to extreme climate- related events such as cyclone, drought, flooding, landslide, sea level rise, severe local storm, storm surge, and wildfire (ADB, 2015). The development of an exposure or hazard index relies on spatial analysis of the weighted combination of different historical climate-related natural hazards in the Province of Agusan del Sur. At least eight (8) hazards were identified for the said province, these are tropical cyclone (TC), flood (Fld), landslide (LS), erosion (Ero), saltwater intrusion (SWI), sea level rise (SLR), drought (DRT) and storm surge (SS).

Hazards Weights. The hazard weights used in this study was introduced by the lead partner of CIAT. The weights were identified through focus group discussions conducted and were represented by the different SUCs' experts/focal persons. The qualitative assessment using the following criteria 1) probability 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), and 4) impact to food security of the country, and 5) impact to national economy. Table 3 summarizes the different weights for each island group in the Philippines. The criteria used also reflect the impact of hazards at different scales from local, landscape, and national level. A spatially-weighted sum was used to develop the hazards index for each island group (Luzon, Visayas, and Mindanao). Thus, in the case of the Agusan del Sur province, the weights of the Mindanao cluster were adopted. For each municipality in the province, the value of the hazard index was computed and normalized.

Adopting the framework from CIAT, below is the econometric specification for computing hazard index:

$$Haz_{index} = \sum (TC * 16.95) + (Fld * 15.25) + (LS * 14.41) + (Ero * 12.71) + (Drt * 16.95) + (SWI * 10.17) + (SLR * 5.08) + (SS * 8.48) \qquad \text{Eq (3)}$$

where:

TC= Tropical cyclone LS= Landslide Drt= Drought
Fld= Flood Ero= Erosion SWI= Salt water intrusion
SLR= Sea level rise SS= Storm surge

Five equal breaks were used to geo-visualize the map, and it was classified into 0-0.20 (Very Low), 0.20-0.40 (Low), 0.40-0.60 (Moderate), 0.60-0.80 (High) and 0.80-1.0 (Very High).

Table 3. Hazard weights

Hazards	**ISLAND GROUP**		
	Luzon (%)	Visayas (%)	Mindanao (%)
1 Tropical cyclone	20.00	18.21	16.95
2 Flood	19.05	16.40	15.25
3 Landslide	8.27	10.72	14.41
4 Erosion	11.43	12.57	12.71
5 Drought	14.25	16.17	16.95
6 Saltwater intrusion	11.43	7.21	10.17
7 Sea Level Rise	5.71	8.33	5.08
8 Storm Surge	9.52	10.39	8.48

Source: CIAT

AGRO-EDAPHIC PROFILE

Land Area

In 1976, the province's land area was 8,568 square kilometers, making it the seventh largest in the country. After claiming the disputed boundary between Davao del Norte, Butuan City and with the creation of Sibagat, Agusan del Sur now has an area of 8,966 sq. km.

The municipalities of Loreto, La Paz, Esperanza, and San Luis are the four largest municipalities in land area comprising almost 60% of the province's total land area. Santa Josefa and Talacogon, also river towns, have the smallest land area.

Forestland constitutes 76% of the total land area or 6,827.5 sq.km while the alienable and disposable constitutes about 24% or 2,137.5 sq.km. Present land use, however showed that settlements and commercial areas already occupy some of the forestlands.

Through the years, the province has lost so much of its forest resources because existing industries are extractive in nature.
(Source:https://agusandelsur.gov.ph/index/about-pgas/2011-11-17-16-33-44/2011-08-15-05-52-37/geography-demography)

Topography

Agusan del Sur is an elongated basin formation with mountain ranges in the eastern and western sides forming a valley, which occupies the central longitudinal section of the land. The Agusan River, which flows from Compostela Valley in the south towards Agusan del Norte in the north, runs almost in the middle of the valley and empties at Butuan Bay. The river has twelve tributaries: Wawa, Gibong and Simulao Rivers in the eastern side and Ojot, Pusilao, Kasilayan, Libang, Maasam, Adgawan, Cawayan, Umayam and Ihaon Rivers in the western side. These tributaries are fed by streams and creeks. The southern half of the province from the municipality of Veruela is an area filled with swamps and lakes, the biggest of which is Talacogon Lake.
(Source:https://agusandelsur.gov.ph/index/about-pgas/2011-11-17-16-33-44/2011-08-15-05-52-37/geography-demography)

Climate

The province is geographically situated below the typhoon belt but is usually affected by depressions forming in the typhoon regions of Visayas and the province of Surigao del Norte. The climate map of the Philippines based on the modified coronas classification shows that the province falls under Type II.

Type II climate has no dry season with very pronounced wet season of heavy precipitation. Maximum rainfall generally occurs from December to January although there is no single dry month. Its average monthly rainfall is 355 mm. and average temperature is 27.15 degree Celsius. Areas characterized by this climate type are generally along or very near the eastern thus are open to the northeast monsoon.
(Source:https://agusandelsur.gov.ph/index/about-pgas/2011-11-17-16-33-44/2011-08-15-05-52-37/geography-demography)

RESULTS AND DISCUSSIONS

Adaptive Capacity

Adaptive Capacity (AC) is the property of a system to adjust its characteristics or behaviour to expand its coping range under existing climate variability or future climate conditions. In practical terms, adaptive capacity is the ability to design and implement effective adaptation strategies or react to evolving hazards and stresses to reduce the likelihood of the occurrence and/or the magnitude of harmful outcomes resulting from climate-related hazards. The adaptation process requires the capacity to learn from previous experiences to cope with current climate and apply these lessons to cope with future climate, including surprises. The AC indicators were clustered into eight (8) capitals such as Economic, Natural, Social, Human, Health, Physical, Anticipatory and Institutional.

Figure 4 presents the results of all capitals as well as the aggregated overall adaptive capacity index. Results showed that Bayugan City is the most adaptive municipality within the province concerning Economic [1.0], Natural [0.38], Social [0.33], Human [0.74], Physical [1.0], Anticipatory [1.0], Institutional [0.75], and Health [0.77]. Bayugan City has high coping mechanisms or strategies to respond to climate-related hazards.

The overall capacity index shows that 6 out of 14 or 40% of the municipalities have a low adaptive capacity index. These are the municipalities of San Luis [0], Loreto [0.15], and La Paz [0.17]. The municipality of San Luis is classified as very low AC index among the 14 municipalities of the said province. The said municipality is a first-class municipality (San Luis); however, the AC indicators considered in this study contradict the municipal class with the available coping variables/indicators. It was observed that there were five capitals in this municipality with very low index; these are Economic [0], Human [0.05], Physical [0.08], Natural [0.12], and Institutional [0.11].

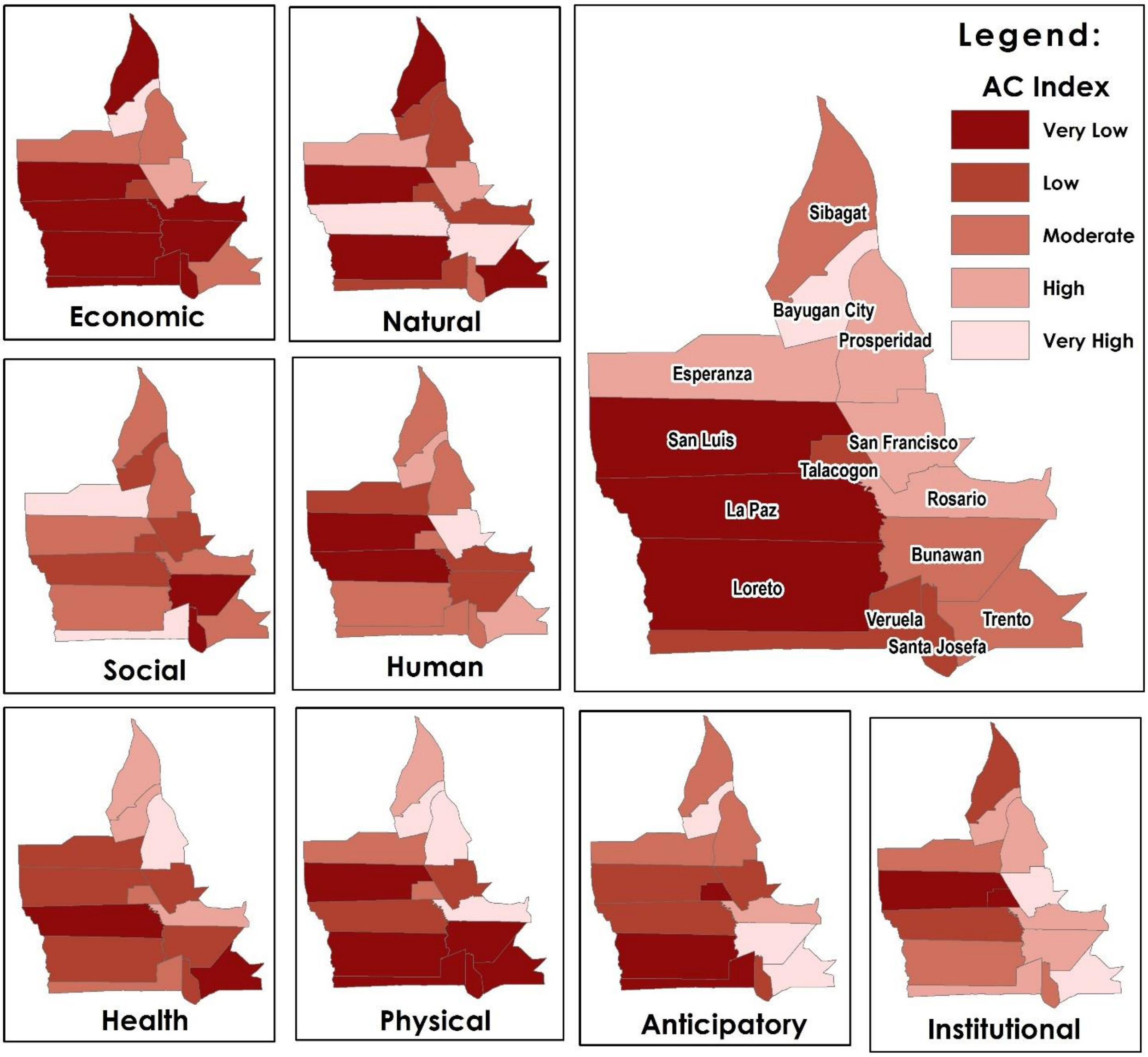

Figure 4. Adaptive Capacity Index in Agusan del Sur

Hazard Index

Hazard is a source or a situation with the potential for harm in terms of human injury or ill-health, damage to property, damage to the environment, or combination of these (dmp.wa.gov.au). Based on the consultation and validation series through online meetings conducted last May-June 2021 with the project partners from the LGU's in the province of Agusan del Sur. At least five hazards were identified in the province of Agusan del Sur, these are tropical cyclone, flood, sea level rise, erosion, and landslide. All hazard data were sourced-out from the International Center for Tropical Agriculture (CIAT), an authorized data provider. The combination of these all-natural hazards had been used to estimate the extent each municipality of the said province by using its hazard weights.

Figure 5 shows the degree of exposure to hazards across the fourteen (14) municipalities of Agusan del Sur. Five (5) hazards were identified in the province: tropical cyclone, flood, sea level rise, erosion, and landslide. The northern part of the province has a high incidence of tropical cyclones compared to other municipalities located in the southern region. Trento and Rosario have high exposure incidence to sea level rise.

On the other hand, some municipalities located within the Agusan Marsh sanctuary, particularly in Loreto, La Paz, Prosperidad, and Esperanza, are classified as the most exposed areas to flooding (very high), while some areas are classified as moderate to high flood exposure. The presence of the Agusan River basin in these areas causing flooding incidence across the province during the rainy season. Elevated areas have high exposure to landslides and erosion. Overall exposure results show a very high incidence of hazards in the municipality of Sibagat, followed by high hazard classification incidence in Bayugan City, Esperanza, Prosperidad, La Paz, and Loreto.

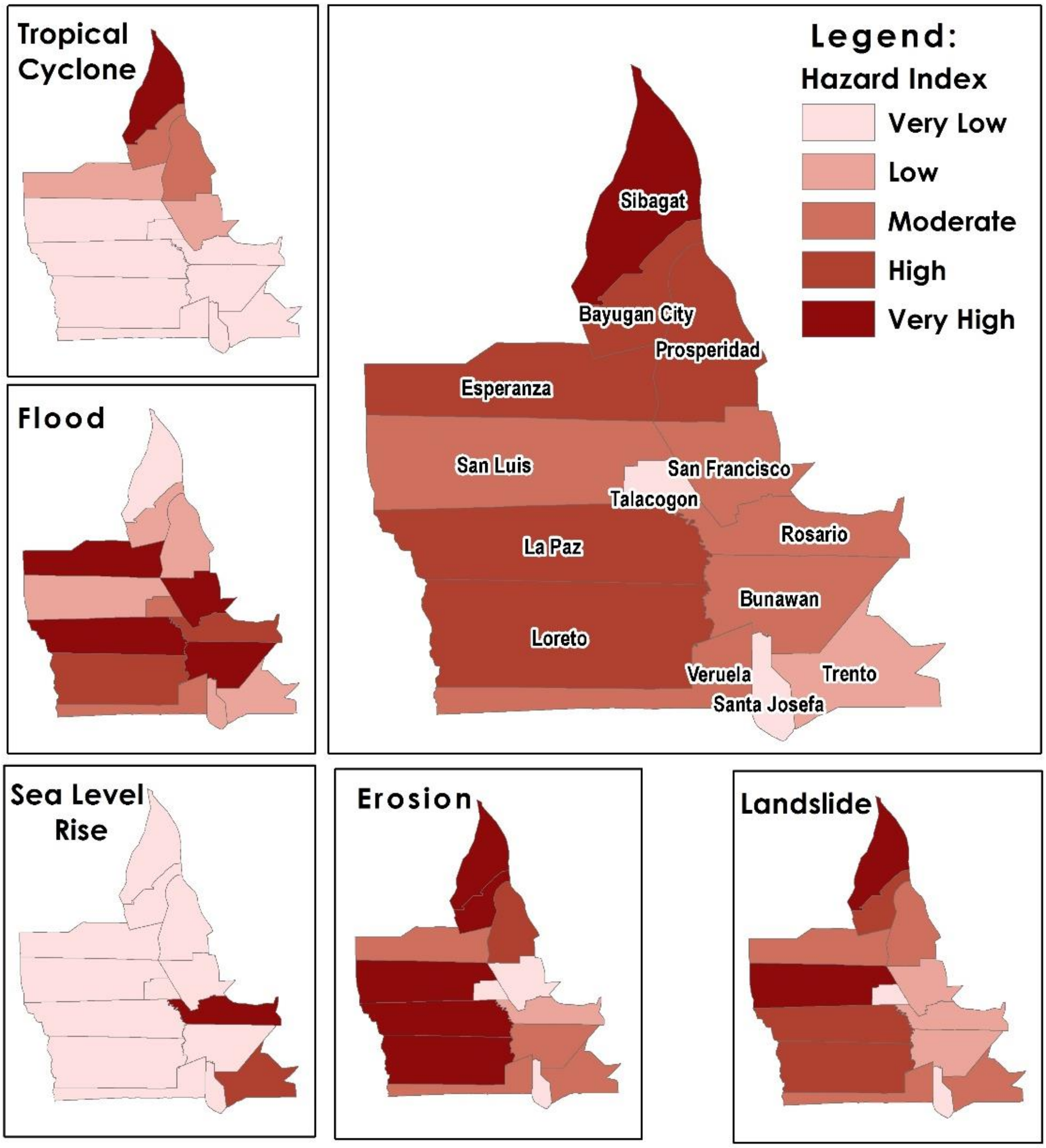

Figure 5. Hazard index map in Agusan del Sur.

Sensitivity Index

In the province of Agusan del Sur, the results revealed that each crop varies its suitability on its adverse effect due to climate variability. For this province, the municipalities of Sibagat and Esperanza showed greater losses its suitability for banana, corn, and rubber, while other crops of these municipalities have maintained its suitability in the year 2050. In contrast, some municipalities of the said province have gained or maintained its suitability in the upcoming years. The changing climate in the year 2050 has to do with the suitability effect of the crops in the said province.

Banana. The suitability of bananas in the northern and southwestern part of Agusan del Sur (Figure 6a), particularly in the municipalities of Sibagat, Loreto, and Veruela, showed a great influence on sensitivity (loss in suitability) in the year 2050. The unfavorable climate conditions and a reduction in yield for the banana industry in these municipalities are expected. On the other hand, other municipalities showed less sensitivity with a positive suitability outcome (no change or gain). San Luis, La Paz, and Rosario Municipalities have gained climatic suitability for bananas, while the rest have maintained its suitability. The modeled future climate condition in the said municipalities are favorable for the banana crop.

Corn. Corn is another important cereal in the country. It is one of the primary commodities of Agusan del Sur Province and other provinces of Caraga. The overall suitability map of corn crop showed a remarkable high impact to sensitivity where 7 out of 14 (50%) municities in the said province, particularly in the municities of Sibagat, Bayugan City, Esperanza, Prosperidad, Loreto, Veruela, and Bunawan, are losing its suitability in the coming years. However, the central part of the province has gained or maintained corn suitability in the year 2050 (Figure 6b). The climate variation in the predicted model by the year 2050 covered 50% of the municipalities in the province showed high sensitivity (not suitable).

Rice. The western part of Agusan del Norte has adversely affected climate variability, particularly in Esperanza, Loreto, and Veruela. As a whole, it implies the favorable suitability of rice crop in the municipalities of Sibagat, Bayugan City, Prosperidad, San Francisco, Rosario, Bunawan, and Trento as manifested in the map (Figure 6c).

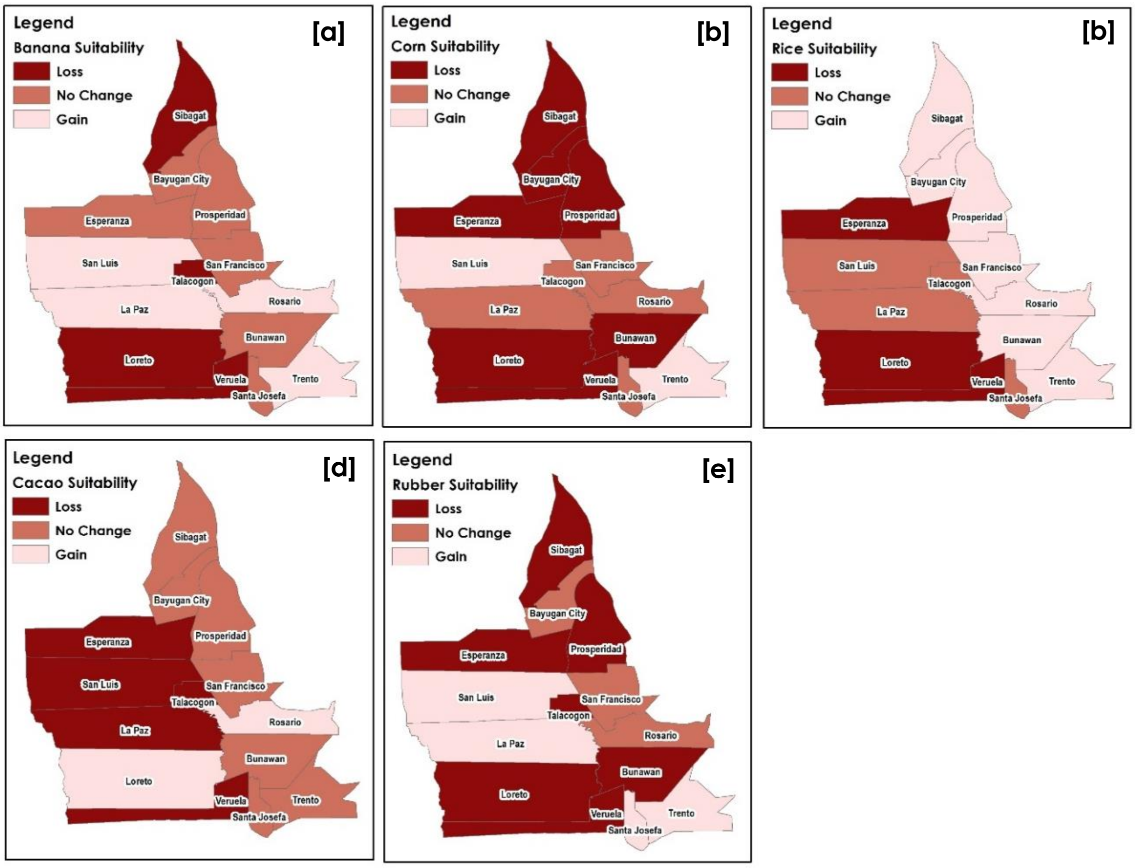

Figure 6. Sensitivity (Suitability) index of banana [a], corn [b], rice [c], cacao [d], and rubber [e] in Agusan del Sur province

Cacao. A decreasing suitability result has been shown in the western part of Agusan del Sur province. In contrast, most of the municipalities of the said province have maintained the suitability (no change) for cacao crop (Figure 6d). LGUs under the classification (loss suitability) may opt to have a better planning preparation to cope with adverse impacts in the future. An overall suitability map showed that the province of Agusan del Sur is gaining or maintaining its suitability for cacao crop outnumbered the negative impact (loss) based on the number of municipalities.

Rubber. Rubber is one of the most popular agro-industrial crops in the world. This crop is also one of the identified priority crops in Agusan del Sur. Based on the suitability map, the result revealed that a high adverse impact on climate change suitability in the future is manifested in the northern and southern parts of the province (Figure 6e). However, a favorable outcome in some municipalities such as San Luis, La Paz, Santa Josefa, and Veruala have gained its suitability while the remaining three municipalities (i.e., Bayugan City, San Francisco, and Rosario) maintained their suitability for rubber crop (no change).

The sensitivity results in Agusan del Sur emphasize the need for improvement in crop management, better provision and optimize the utilization of the water for irrigation and increase adaptation strategies to cope up such increasing climatic pressures that might affect the agricultural productivity.

Vulnerability Index

The vulnerability model was constructed using the GIS platform to pre-process the spatial and a spatial data sets for the three components: sensitivity, exposure, and adaptive capacity to come with the total climate risk vulnerability assessment (CRVA). Figure 7 to Figure 11 showed the index level maps in the provinces of Agusan del Sur. The potential impact (sensitivity + exposure) in the respective municipalities showed the variations on how the commodities in these areas are exposed and adversely affected by climate change and hazards pressures in the coming years. The total CRV index for banana, cacao, corn, rice, and rubber in the province of Agusan del Sur showed that municipalities that were identified as highly vulnerable were San Luis, Loreto, and La Paz (Figure 7 to Figure 11).

The exposure and adaptive capacity component indexes in measuring the vulnerability are common to all commodities in the province of Agusan del Sur. The vulnerability result only varies to the sensitivity status of the commodity. Hence, each commodity has different impact characteristics to handle such adverse effects to climate variability. The radar graph showed in Figure 7b to Figure 11b indicates the impact of the three component drivers (sensitivity, exposure, and adaptive capacity) in measuring the vulnerability status of the five prime commodities in the said province. As observed in Figure 7a to Figure 11a, Bayugan City is the only area identified as less vulnerable due to its high adaptive capacity across the five commodities. Several areas of the province are highly exposed to hazards, such as Sibagat [1.0], Bayugan City [0.77], Loreto [0.72], La Paz [0.70], Prosperidad [0.69], and Esperanza [0.66].

Banana. Figure 11a showed the total derived vulnerability of banana commodity in Agusan del Sur where municipalities of San Luis [0.75], Loreto [0.74], and La Paz [0.65] are the most vulnerable areas due to high potential impact (sensitivity + exposure) with lower adaptive capacity. It is also shown that Bayugan City is less vulnerable among the municipalities in the said province due to its high coping mechanisms. The radar graph showed in Figure 7b indicates that banana crops in several municipalities are highly exposed to different hazards, sensitive to climate variability, and less adaptive are vulnerable.

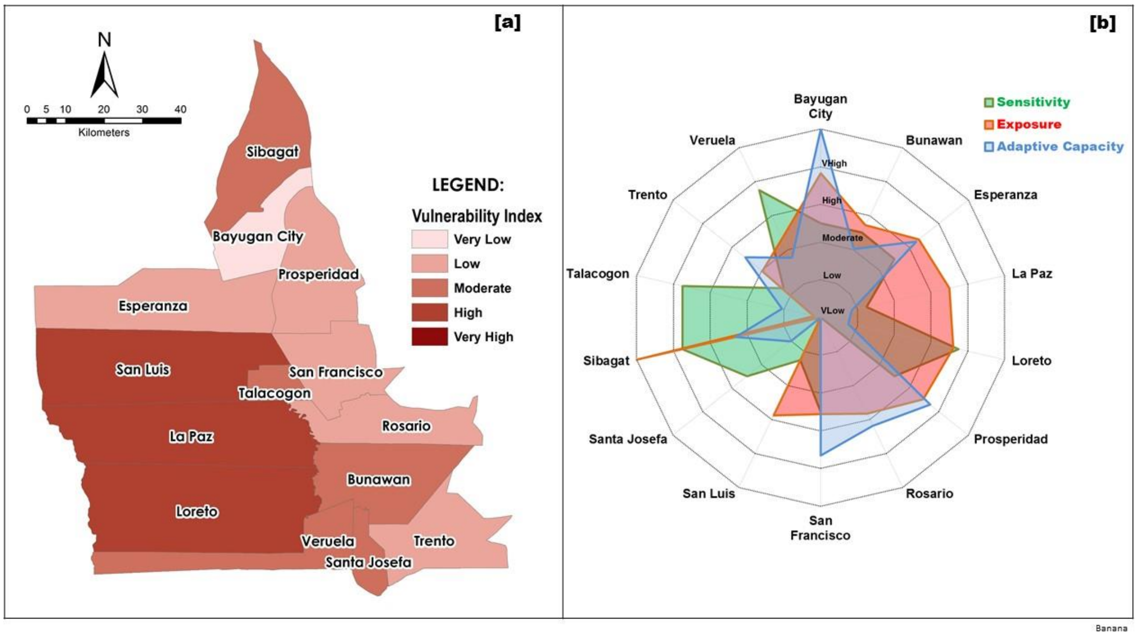

Figure 7. Vulnerability Index Map [a] and Radar Graph [b] for Banana crop in Agusan del Sur

Cacao. The vulnerability map of Cacao commodity (Figure 8a) also showed that the municipality of San Luis [0.82] is considered the most vulnerable area across Agusan del Sur province with very low adaptive capacity. High adaptive capacity index is also observed in Bayugan City [1.0], Prosperidad [0.74], San Francisco [0.73], and Esperanza [0.65]. The radar graph (Figure 8b) indicates that the municipalities Loreto and Rosario are decreasing its suitability for cacao production.

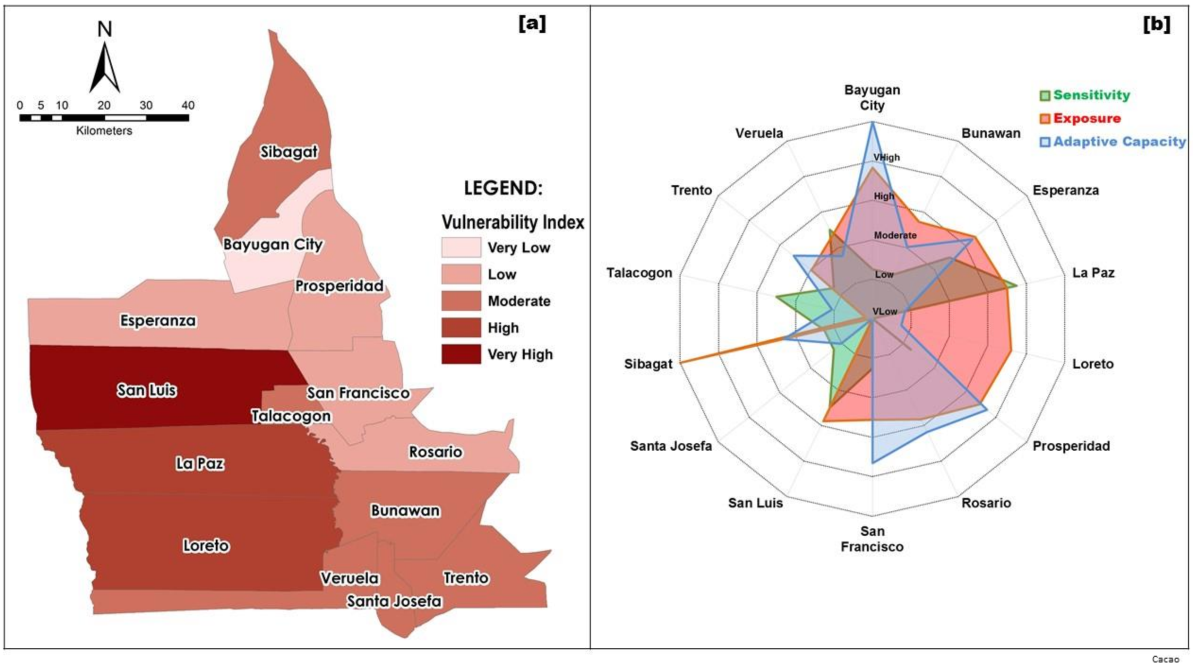

Figure 8. Vulnerability Index Map [a] and Radar Graph [b] for Cacao crop in Agusan del Sur.

Corn. The same with Banana commodity, the vulnerability index (Figure 9a) produced in Corn commodity showed that the municipalities of San Luis [0.75], Loreto [0.74], and La Paz [0.69] are highly vulnerable areas with lower adaptive capacity in the said province. Radar graph (Figure 9b) showed a yield reduction is expected in corn production, particularly in San Luis and Trento municipalities due to the unfavorable climate condition (low suitability) in the future years.

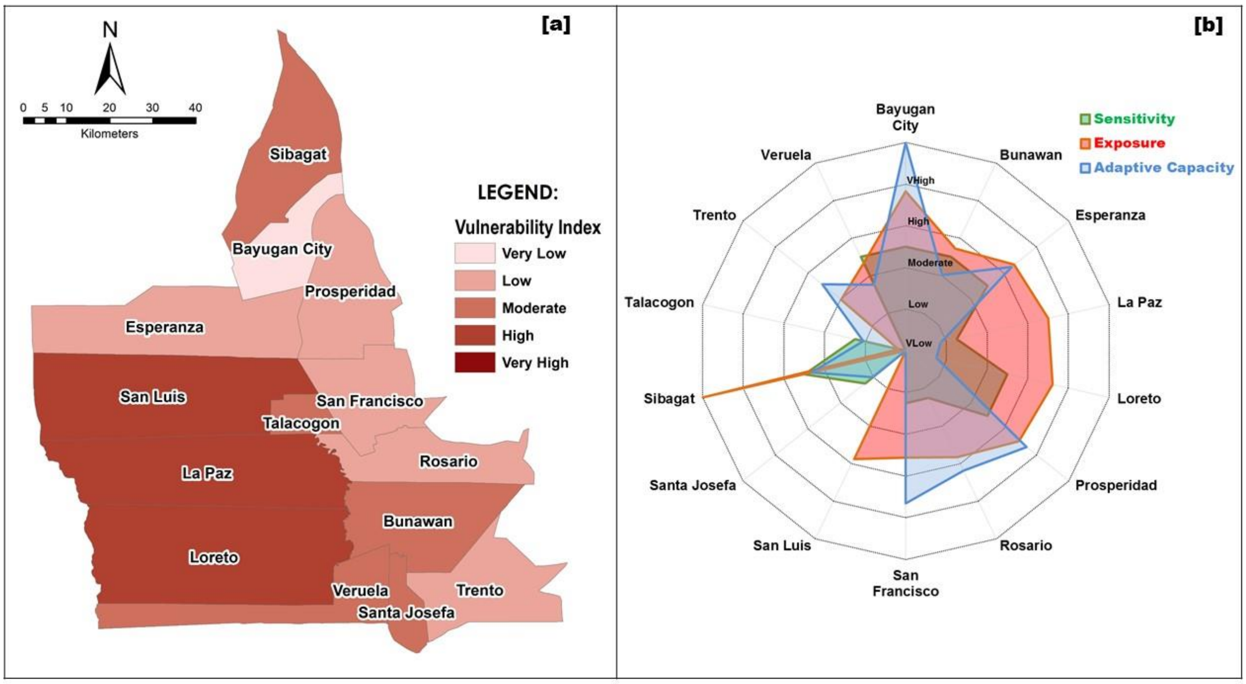

Figure 9. Vulnerability Index Map [a] and Radar Graph [b] for Corn crop in Agusan del Sur

Rice. Figure 10a showed the vulnerability status of the rice commodity in the province. Still, municipalities of San Luis [0.79], Loreto [0.74], and La Paz [0.69] have a high vulnerability index. The local government units under this vulnerability index classification may improve the farming communities' coping mechanisms or strategies to respond to climate-related hazards. The radar graph (Figure 10b) indicates that the municipality of Rosario is highly sensitive (low suitability) to climate change.

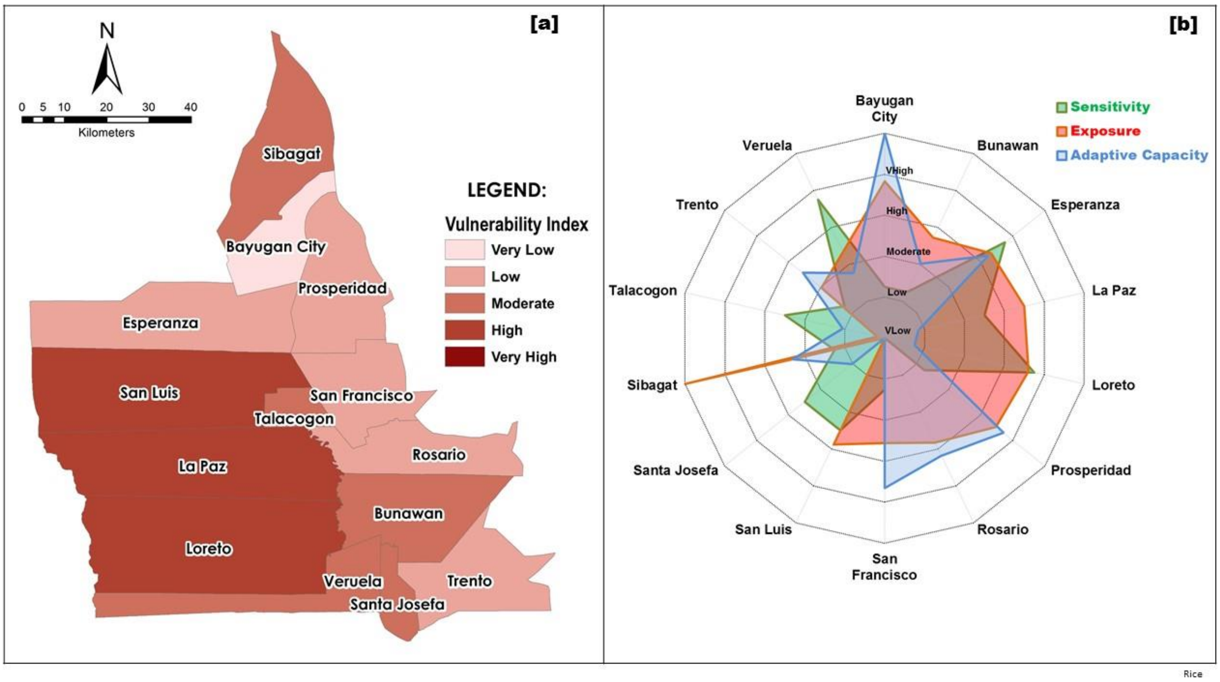

Figure 10. Vulnerability Index Map [a] and Radar Graph [b] for Rice crop in Agusan del Sur

Rubber. The vulnerability index map for the Rubber commodity shown in Figure 11a is notably similar to the previous commodities except the Coffee crop. Rubber production (Figure 11b) in the province is generally suitable except in the municipality of Trento (very low).

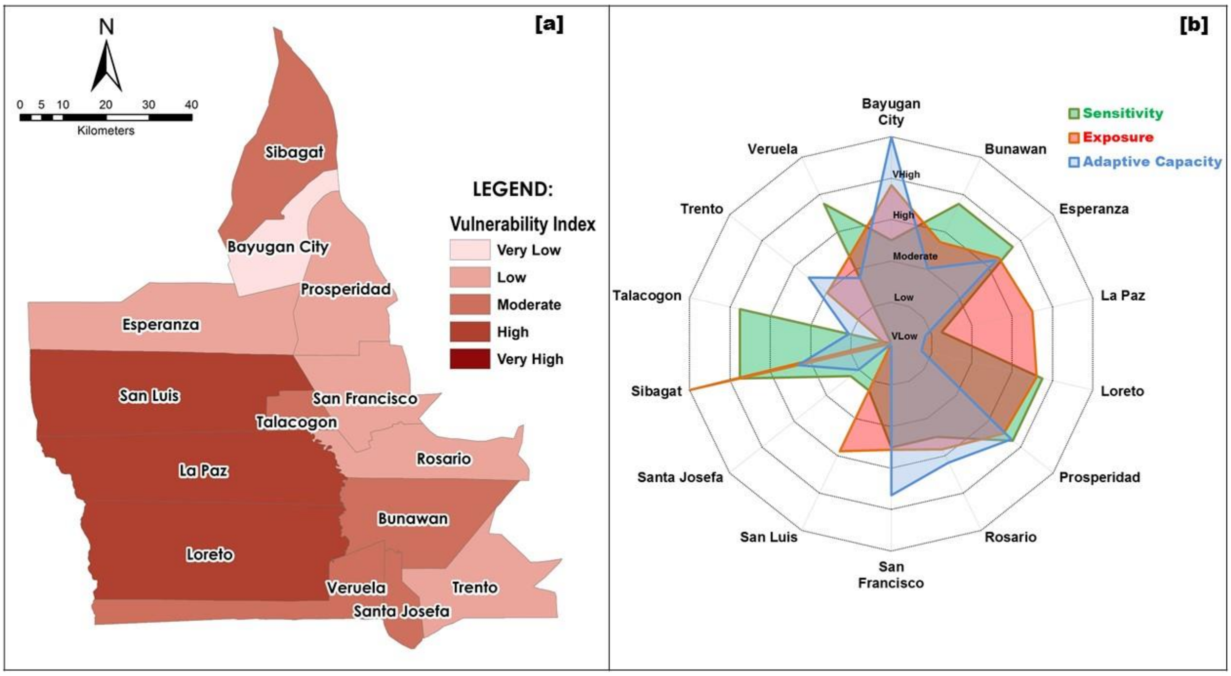

Figure 11. Vulnerability Index Map [a] and Radar Graph [b] for Rubber crop in Agusan del Sur

CONLCUSION AND RECOMMENDATION

The identification of the area's most vulnerable to climate change risks in Caraga region is among the extensive work to do. This assessment responds to the need by identifying which municipalities in the province of Agusan del Sur are the most vulnerable to climate change and producing a map to show climate change vulnerability in the province. Gathered data at regional, provincial and municipal levels from various sources were integrated in a consistent and meaningful manner to produce a map indicating the area's most vulnerable to climate change. Despite data limitations, it is expected that the output of this analysis will be useful to policy-makers and stakeholders in better targeting programs and interventions towards adaptation measures undertaken in the region particularly in Agusan del Sur.

Based on this CRVA, the municipality of San Luis, La Paz and Loreto were among the highly vulnerable municipalities in the province due to its high exposure to climate hazards particularly low adaptive capacity and the decreasing suitability of crops to climate variability in the aforementioned municipalities. Considering other factors constant, investing for rice, corn, banana, cacao and rubber will be less favorable in the future. However, such potential impacts could be negated if the LGUs and other government institutions will continue investing in climate-change related programs and interventions that will improve farming practices and those that will facilitate agri-related coping mechanisms and strategies.

Climate Resilient practices are recommended for these municipalities. These practices will be adapted in AMIA Villages that will be established after this CRVA. Several practices such as alternate wetting and drying (i.e., controlled irrigation rather than standard continuous flooding of rice fields), adoption of water-saving technologies (e.g. drainage, drip irrigation), use of traditional and new varieties, plowing techniques, compost application, moderate fertilizer application and planting at moderate density can be applied. According to the article published by Chandra, A. et al. (2017) adaptation of organic farming such as use of rice hull as soil cover improved water use, soil moisture and soil infiltration during dry seasons. Vegetables survived the long drought seasons because grass cover in the topsoil retains moisture. Mitigation and adaptation options were also influenced by farmer knowledge of growing seasons and local climate conditions. By scheduling planting with real-time climate information via seasonal calendars, smallholder farmers were able to coincide with the early or late rainy seasons or avoid disasters. Farmers also reported seasonal calendar better tools for planting under organic agriculture compared to relying on fertilizers and chemicals to mitigate drought effects on high value crops. Use of Site-Specific Nutrient Management (SSNM), Integrated Pest Management (IPM) and use of early maturing and stress-tolerant varieties are best practices for Corn. To further validate these farming practices, Community Participatory Action Research (CPAR) is recommended.

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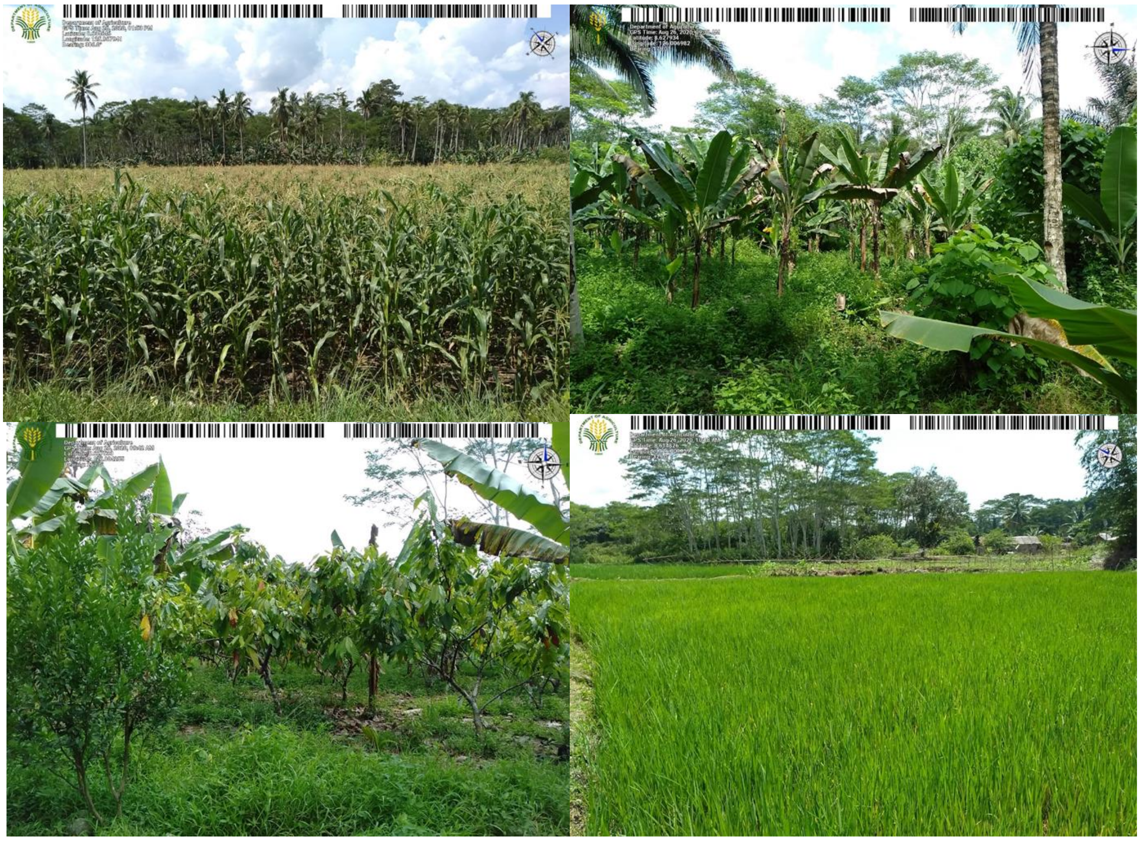
Appendices

Appendix Figure 1. Crop occurrence validation in Bayugan City, Agusan del Sur.

Appendix Figure 2. Crop occurrence validation Bunawan, Agusan del Sur.

Appendix Figure 3. Crop occurrence validation in La Paz, Agusan del Sur.

Appendix Figure 4. Crop occurrence markings in Loreto, Agusan del Sur.



Appendix Figure 5. Crop occurrence markings in Prosperidad, Agusan del Sur.

Appendix Figure 6. Crop occurrence markings in San Luis, Agusan del Sur.

Appendix Figure 7. Crop occurrence markings in Sta. Josefa, Agusan del Sur.

Appendix Figure 8. Crop occurrence markings in Talacogon, Agusan del Sur.

Appendix Figure 9. Crop occurrence markings in Trento, Agusan del Sur.

Department of Agriculture-Caraga

ADAPTATION AND MITIGATION INITIATIVES IN AGRICULTURE

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