Climate risk vulnerability assessment on the production of heirloom rice (*Oryza sativa* L.) and Arabica coffee (*Coffea arabica* L.) in Mountain Province, Philippines

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ABSTRACT

Climate change has brought negative and adverse impacts to agricultural production in the Cordillera Administrative Region, including two of the most important agricultural crops, namely, Arabica coffee and heirloom rice. This study was conducted to assess the climate risk vulnerability on the production of these two agricultural products in the municipalities of Mountain Province, Philippines. The climate risk vulnerability was assessed based on the three general and most widely used climate impact factors as recommended by the Intergovernmental Panel on Climate Change (IPCC), namely, exposure to hazard, sensitivity, and adaptive capacity.

The results show, based on the combined indices estimated for each of the three general factors and expected changes in temperature and precipitation as projected by IPCC, that there is high climate risk vulnerability of the two crops in the municipalities particularly in areas where there is high potential exposure to hazards, low climate suitability of key crops in the future, and low adaptive capacity. Findings from the climate risk

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vulnerability analysis (CRVA) developed in the study demonstrate that it, as described in this paper, can serve as a meaningful reference to inform and guide decision-makers from concerned government agencies and the private sector in crafting policies and potential interventions in highly vulnerable areas whose climate risk vulnerability can be estimated and determined using CRVA. It is recommended that the CRVA described in this paper be made part of the tools and potential guides used by the Department of Agriculture to help mainstream climate change adaptation and mitigation strategies.

INTRODUCTION

Over the years, climate change vulnerability assessments that focus on various sectors, including agriculture, have emerged from the scientific literature (Baca et al. 2014; Fritzsche et al. 2014; Jurgilevich et al. 2017). Several studies (Allison et al. 2009; Thiault et al. 2018; Vos et al. 2016) have adopted the Intergovernmental Panel on Climate Change (IPCC) definition of vulnerability which states, "*the extent to which a natural or social system is susceptible to sustaining damage from climate change impacts, and is a function of exposure, sensitivity, and adaptive capacity*" (McCarthy et al. 2001; Vos et al. 2016). Climate change impacts, therefore, can be conceptualized as the aggregation of the impacts of these three components (Fritzsche et al. 2014).

More than 60% or almost 2.2 billion people in Asia and the Pacific rely on agriculture for their livelihood (ADB, 2009). In 2015, the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) reported that the three sectors that record the highest economic damage resulting from geophysical hazards in the Asia Pacific region, including the Philippines, are transport, housing, and agriculture, with agriculture being the most vulnerable. A better understanding of climate risks and vulnerabilities is important in achieving resilient farming systems; thus, it is necessary to identify and prioritize which areas and crops are most vulnerable to climate risks.

The Adaptation and Mitigation Initiative in Agriculture (AMIA) is a program spearheaded by the Department of Agriculture System-Wide Climate Change Office (DA SWCCO) that aims to mainstream climate change adaptation and mitigation strategies and at the same time design appropriate and complementary activities for building appropriate climate responsive support services. One of the projects under the program is the CRVA for the production of agricultural crops.
The Cordillera Administrative Region (CAR) is composed of six provinces and one city namely, Abra, Apayao, Benguet, Kalinga, Ifugao, Mountain Province, and Baguio City. With a mountainous topography and rugged terrain, the region has abundant natural resources and contributes highly in terms of agriculture and mining in the Philippines. About 71 percent of CAR's land area has slopes of 30 degrees and above and about 33 percent of the land lies 1000 mm or more above sea level. It has an agricultural land area of 177,839 ha which is primarily shared by crop lands (PSA-CAR, 2020, Supangco et al. 2022). According to the UNDP (2012), the region is one of the areas in the country that are most vulnerable to climate change.

Recurring extreme weather events result to landslides, erosions, and crop susceptibility to diseases, which greatly affects crop production in the region. Expanding and mainstreaming different climate change adaptations and capacitating local stakeholders in identifying and enhancing their own sustainable agricultural practices would help the country's farmers, especially in CAR, in facing the threats of climate change (Sandoval and Baas, 2014; Supangco et al. 2022).

This study aimed to assess the climate risk vulnerability on the production of heirloom rice and Arabica coffee (*Coffea arabica* L.) as the basis for prioritizing climate adaptation and mitigation measures that are suitable and site-specific. The results of the CRVA can be adopted as one of the bases of the AMIA program in the identification and prioritization of the most vulnerable communities. It can also be used to inform and guide decision-makers from government agencies and private sectors on the areas that are in most need of interventions, and what set of interventions are needed.

MATERIALS AND METHODS

Study Site

Mountain Province is a landlocked province of CAR as shown in Figure 1. The total land area is 2,239.9 km^2, 23% of which are classified as alienable and disposable lands and 77% are forest lands. It has 10 municipalities and 144 barangays. As of 2015, it has a total population of 154,590. Agriculture is the major source of income along with tourism, providing a significant boost to its economy (PSA, 2015). Consistent with the data for CAR, 61 percent of its total land area have a slope of 30 degrees and above. In addition, about 64 percent have an elevation of 1000 m above sea level or higher (PSA-CAR, 2020).

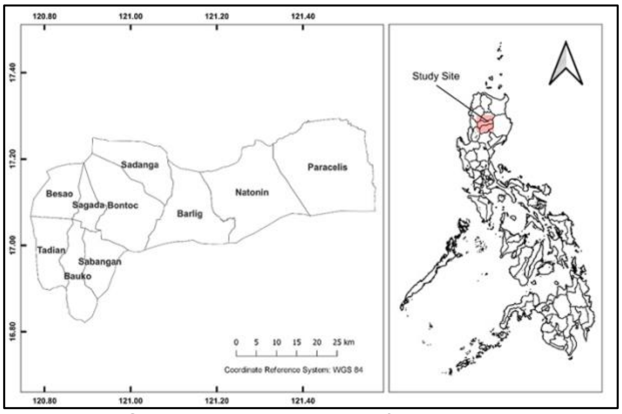

Figure 1: Geographical location of Mountain Province, Philippines

Arabica coffee production areas are located in Mountain Province's western municipalities with elevations of 800-1,800 masl (Batani et al. 2020). Just like in Benguet, it thrives in three agro-ecological zones: high-hills, low-mountain and mid-mountain zones. The high hills zone has elevations from 500-1,000 masl and temperatures ranging from 28.95-32.30^{O}C; areas under low mountain zones has elevations from 1,001 to 1,500 masl with temperature range of 25.43-28.00^{O}C and the mid-mountain zone (1,501-2,000 masl) has temperature range of 18.0-24.00^{O}C (Tad-awan, 2013). Areas above 1000 masl are preferred for the production of coffee with superior quality (Winston et al. 2005) but the upper limit in elevation is 1600 masl (Clarke and Macrae, 1985).

Based on the study of Batani et al. (2020), there are two common production systems of Arabica production in Mountain Province namely, backyard production and the agroforestry or intercropping/multi-cropping practice in small-scale or plantation production. Crop combinations practiced in coffee production areas include: coffee with Alnus (*Alnus japonica* (Thunb.) Steud.), coffee under pine (*Pinus kesiya* Royle ex. Gordon), and coffee with chayote (*Sechium edule* Jacq.) or citrus.

The rice terraces in the Cordillera Administrative Region which were developed by the indigenous peoples of the region is a component of a landscape system that is characterized by multiple land-uses, diversified crop production and traditional governance systems (Camacho et al. 2012, Crisologo-Mendoza & Prill-Brett 2009). The rice terraces continue to evolve in response to biophysical and socio-economic pressures, and as consequence influences farmer's land-use choices (Salazar, 2017). A total of 11,692 ha in the region is planted with heirloom rice in 2014 with a total production of 34,747 metric tons (2.97 mt/ha) (DA, 2016). Salazar (2017), in his study conducted in Ifugao and Mountain Province, mentioned that these terraces are being transformed by various processes of change to include shifts in rice varieties, bio-physical forces like climate change, and cultural transformation.

Data collection and analysis

The methodologies used in this study are based on the procedures used by the DA and the International Center for Tropical Agriculture (CIAT) in conducting CRVA of different crops in various provinces of the Philippines (Paquit et al. 2018; Bito-onon 2020).

As shown in the framework (Figure 2), CRVA is based on three general factors or components, namely: exposure to hazard, sensitivity, and adaptive capacity. Exposure is estimated based on the five climate hazards, which are combined or integrated into a hazard index. The sensitivity index is determined based on the impacts of changes in temperature and precipitation on crops. These two indices reflect, in general, the overall potential climate change impacts. Moreover, adaptive capacity is determined based on five capitals namely, economic, human, physical, institutional and anticipatory that were integrated. Finally, the climate risk vulnerability is estimated based on the effects of the potential impacts combined with the adaptive capacity. Quantum Geographic Information System (QGIS) software was used in spatial analysis and integration of the three components of CRVA.

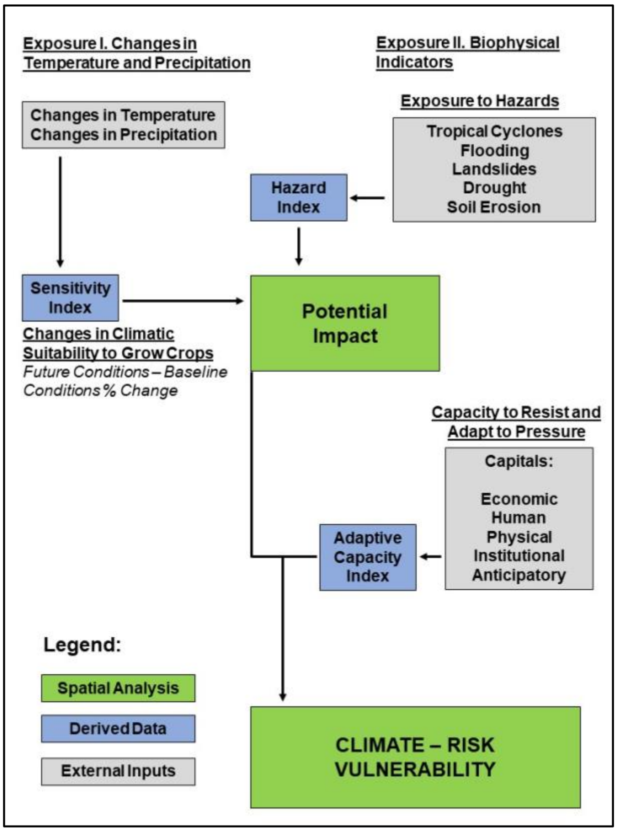

Figure 2: Climate risk vulnerability assessment framework
Source: **(Jurgilevich et al. 2017)**

Exposure to Hazards

Läderach et al. (2011) defined exposure as the character, magnitude, and rate of climate change and variation. Five (5) hazards with different weights were used to assess the exposure to climate impacts and these were tropical cyclones (27.29%), flood (25.99%), drought (19.44%), soil erosion (15.59%), and landslide (11.69%). The spatial data of these hazards were generated by CIAT from various international and national agencies such as the United Nations Environment Programme (UNEP), United Nations International Strategy for Disaster Reduction Secretariat (UNISDR), Department of Science and Technology (DOST), Department of Environment and Natural Resources – Mines and Geosciences Bureau (DENR-MGB). These hazards were weighted based on their impact on agriculture on the national scale which was later downscaled to the provincial level. The weighting process and subsequently the estimation of weights for each hazard involved a systematic analysis of the hazards' impact on the economy, food security, household income, and crop productivity as reported in Paquit et al. (2018).

For each municipality, the mean value of each hazard was computed using the zonal statistics tool of the QGIS software and was normalized after to make each value more comparable. Based on the hazards' normalized values, the hazard index was calculated as follows:

$$H = \sum w_i h_i \quad (1)$$

where: i corresponds to each hazard,
w_i is the weight of the hazard i, and
h_i is the normalized value of hazard i

Normalization was again employed to generate an index from 0 to 1. Five equal breaks were used to establish the thresholds for the following classes: 0-0.20 (Very Low), 0.20-0.40 (Low), 0.40-0.60 (Moderate), 0.60-0.80 (High), and 0.80-1.00 (Very High).

To determine the overall exposure based on the cumulative or composite effects of these five hazards, a hazard index was formulated which combines or integrates all of the hazards using a weighted sum of the hazard factors. The index that represents the cumulative or combined effects of all factors must reflect the relative 'impact potential' of each factor. This implies or assumes that the different factors have different degrees or levels of potential impacts; hence, the index must reflect the varying impact potential of each hazard factor. Each factor must be assigned or ascribed with a relative weight to reflect its degree of importance.

Sensitivity

The MaxEnt model was based on a software developed by Phillips et al. (2006). It is based on the maximum-entropy approach for modeling species niches and distributions. The model examines a set of environmental factors (e.g., climatic) grids and georeferenced occurrence localities (i.e., presence of species). Based on these georeferenced occurrences, the model expresses a probability distribution where each grid cell has a predicted suitability of conditions for the species. The Presence-Only tool of MaxEnt uses a maximum entropy approach to estimate the probability of the presence of a species or phenomenon. The tool uses collected occurrence or presence points and the set of environmental factors organized in the form of raster to provide an estimate of the probability of presence across a study area. This probability model can then be used to predict the presence of the species or phenomena in other areas if corresponding explanatory variables are known.

In this study, the crop occurrence points were gathered through a participatory mapping approach (Figure 3). This was participated in by representatives from the local agriculture offices including the municipal agriculturists, agricultural technologists, crop coordinators, and staff from the provincial and regional field offices.

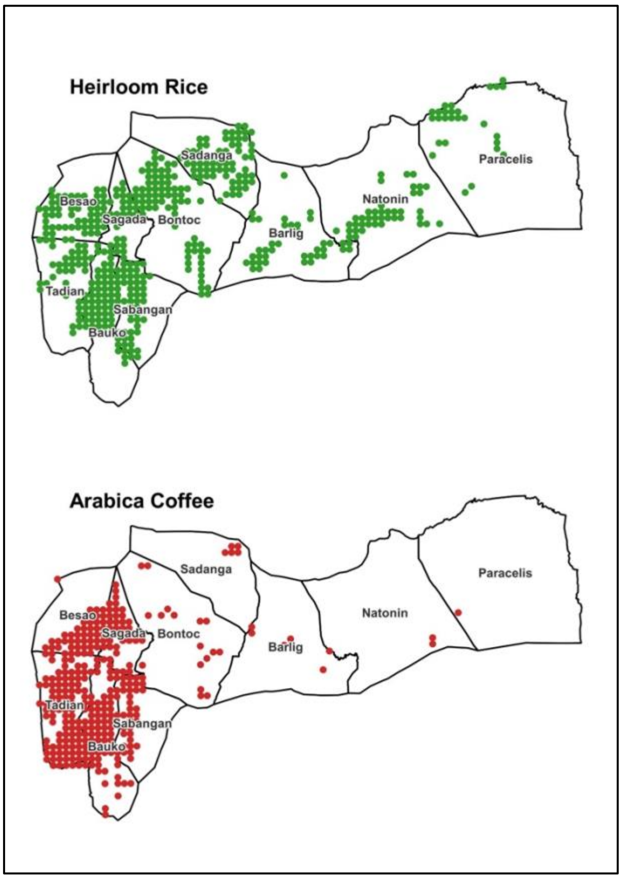

Figure 3: Crop occurrence map of Arabica coffee and Heirloom Rice in Mountain Province

Crop sensitivity was assessed by changes in climatic suitability of the crops by the year 2050 in comparison with the baseline crop suitability. The MaxEnt model was used to model crop suitability under climate change for analyzing species niches and distributions (Phillips et al. 2006; Davis et al. 2012, Läderach et al. 2017). Davis et al. (2012) used MaxEnt to create predictive maps of species occurrences using collected occurrences data and environmental layers or factors. They concluded that MaxEnt gave the best result of all the modelling algorithms they examined using the presence data.

MaxEnt uses environmental data to model the distribution of species (Galletti et al. 2013) and it has been shown to perform better compared to other tools (Leathwick et al. 2006). Analyzing changes in crop suitability involves a two-step process. The first step is to determine the best location for the crop according to a suitability assessment based on the present climatic condition. Predicting the best location for the crop based on future climatic changes is the second step.

Nineteen bioclimatic variables (Table 1) available at WorldClim.org were utilized to assess crop sensitivity. These were derived from monthly temperature and rainfall values and were processed to generate climate variables (Hijmans et al. 2005). These bioclimatic factors are relevant to understanding species' responses to climate change (O'Donnell and Ignizio 2012). Eleven of the bioclimatic variables are temperature related and eight are precipitation related.

Table 1: Bioclimatic variables used in sensitivity modelling

Parameters	Description*
Temperature Related	
Bio 1. Annual mean temperature	Annual mean temperature derived from the average monthly temperature.
Bio 2. Mean diurnal range	The mean of the monthly temperature ranges (monthly maximum minus monthly minimum).
Bio 3 - Isothermality	Oscillation in day-to-night temperatures.
Bio 4 - Temperature seasonality	The amount of temperature variation over a given year based on standard deviation of monthly temperature averages
Bio 5 - Maximum temperature of warmest month	The maximum monthly temperature occurrence over a given year (time-series) or averaged span of years (normal).
Bio 6 - Minimum temperature of coldest month	The minimum monthly temperature occurrence over a given year (time-series) or averaged span of years (normal). Variation over a given period.
Bio 7 - Temperature annual range	A measure of temperature
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.
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 the 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.

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

The IPCC's Representative concentration pathway (RCP) 8.5 was used as the basis for future projection of climate change by the year 2050. RCPs form a set of greenhouse gas concentration and emissions pathways designed to support research on impacts and potential policy responses to climate change (Moss et al. 2010). RCP 8.5 corresponds to a high greenhouse gas emissions pathway and is the upper bound of the RCPs. It is also called a 'baseline' scenario that does not include any specific climate mitigation target (Riahi et al. 2011).

The sensitivity of the crops to climate change for both the current and future predictions was analyzed in QGIS using spatial modeling tools such as raster calculation, reclassification, and zonal statistics. The difference (expressed as a percentage) in the projected and current suitability, as shown in the equation below, reflects the impacts of climate change on crop suitability. It also reveals the degree of crop sensitivity to changing environmental conditions. Higher change in either direction reflects higher impacts of climate change. Positive change implies improvement in the suitability and negative change implies a reduction in crop suitability relative to the current crop suitability.

$$\text{Percent Change in Crop Suitability} = \frac{\text{Projected Conditions- Current Conditions}}{\text{Current conditions}} \times 100 \quad (2)$$

CIAT developed a sensitivity index showing the percent change in crop suitability (expressed in a range) and the corresponding sensitivity index for each range (Table 2). The index ranges from -1.0 to 1.0. The sensitivity index reflects the climate risk vulnerability of the crop where the range from 0.25 to 1.0 indicates a loss in suitability, 0 indicates no change, and -0.25 to -1.0 indicates a gain in suitability.

Table 2: Sensitivity index based on percent change in crop suitability from baseline to future conditions

Percent Change in Suitability (Range in %)	Sensitivity 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	

Source: CIAT

Adaptive Capacity

Adaptive capacity is the ability of a system to adjust to climate change (Läderach et al. 2011) and is directly correlated with resilience (Paquit et al. 2018). In this study, adaptive capacity was based on a set of factors or capitals identified and developed by experts from the DA, National Economic Development Authority (NEDA), United Nations Food and Agriculture Organization (UN-FAO), Non-Government Organizations (NGOs), and the academe. These capitals include economic, human, physical, anticipatory, and institutional. Each capital has indicators that were used as bases for each municipality's adaptive capacity. Data were collected from the Cities and Municipalities Competitive Index (CMCI) of the Department of Trade and Industry (DTI) and CIAT (Table 3).

Table 3: List of capital factors with their indicators

Factors	Indicators
Economic	- Local Government Unit (LGU) class - gross sales of registered firms - total capitalization of new businesses - number of approved business permits for new business applications - number of approved business renewals, - number of occupancy permits approved, - number of approved fire safety inspection, - number of declared employees for new business applications, - number of declared employees for business renewals, local inflation rate, - cost of electricity-commercial users, - cost of electricity-industrial firms/customers, - cost of water- commercial users, - cost of water- industrial firms/customers, - price of diesel as of December 31 2018,

	- regional daily minimum wage rate agricultural plantation (in Php) 2015, - regional daily minimum wage rate agricultural non-plantation (in Php) 2015, - daily minimum wage rate - non-agricultural (establishments with more than 10 workers), - daily minimum wage rate - non-agricultural (establishments with 10 workers or below), - cost of land in a central business district - cost of rent - number of universal/commercial banks - number of thrift and savings banks - number of rural banks - number of finance cooperatives - number of savings and loans associations with quasi-banking functions - number of pawnshops - number of money changers/foreign exchange dealers - number of remittance centers - number of microfinance institutions - total number of LGU recognized / registered business groups - total number of other business groups - business tax collected by the LGU (in Php) - real property tax collected by the LGU (in Php) - total revenues of the LGU (in Php) - total LGU budget
Human	- capacity of public health services – doctors - capacity of public health services – nurses - capacity of public health services – midwives - capacity of private health services – doctors - capacity of private health services – nurses - capacity of private health services – midwives - public secondary education - number of teachers - public secondary education - number of students - private secondary education - number of teachers - private secondary education - number of students - number of local citizens with PhilHealth registration
Physical	- existing road network - asphalt (in km.) - total land area - percentage of households with water service - percentage of households with electricity service - number of public and private secondary schools - number of public and private tertiary schools - number of public and private health - clinics - number of public and private health - clinic beds - number of public and private health - diagnostic centers - number of public and private health - hospitals - number of public and private health - hospital beds - infrastructure for evacuation – public and private - presence of drainage systems in LGU center - presence of water source - presence of power source - presence of a sanitary landfill - practice of waste segregation
Anticipatory	- presence of an office that implements the DRRMP - presence of staff manning the office - presence of local executive order or ordinance that mandates the implementation of the DRRMP - conduct of LGU-wide disaster drill - date of latest LGU-wide disaster drill - presence of early warning system that integrates professional responders and grassroots organization - total budget for DRRMP - availability of local geohazard maps from DENR - availability of LGU risk profile from DSWD
Institutional	- presence of comprehensive development plan - presence of the local investment incentives code - presence of the equivalent of an investment promotions unit (physical office) - getting building permits - minutes - getting building permits – steps - getting occupancy permits – minutes - getting occupancy permits – steps - number of DILG recognized awards

	- getting mayor’s permit for new business applications – minutes - getting mayor’s permit for new business applications – steps - getting business renewal permits- minutes - getting business renewal permits - steps

Normalization was employed to transform the values of each indicator to a common range from 0 to 1. Indicators that are binary (yes or no) were either 1 (yes) or 0 (no). The normalized values of the indicators for each capital were summed, after which the values of each capital were summed and normalized. Furthermore, the normalized values of each factor were integrated into the spatial data for Mountain Province. Five equal breaks were used to classify the adaptive capacity of each municipality: 0-0.20 (Very Low), 0.20-0.40 (Low), 0.40-0.60 (Moderate), 0.60-0.80 (High), and 0.80-1.00 (Very High).

Climate Risk Vulnerability Assessment
Climate risk vulnerability index (CRVI) is the integration of the municipalities’ degree of exposure to hazard, sensitivity, and adaptive capacity components. The weight for exposure to hazard and sensitivity was 15% each and 70% for adaptive capacity (Paquit et al. 2018). A workshop was conducted by CIAT with national experts to determine the relative importance or significance of the three factors relative to CRVI and equation used in this study is shown below:

$$\text{CRVI} = \sum_{i=i}^{n}\left(\left(\text{Haz}_{(w_h)} + \text{Sens}_{(w_s)}\right) + 1 - \text{AC}_{w_a}\right) \qquad (3)$$

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

RESULTS AND DISCUSSION

Exposure to Hazards

Tropical cyclone, landslide, and soil erosion are considered the major driving factors of the overall hazard index. Results showed that flood and drought are more prevalent in Paracelis since the municipality has a lower elevation compared to other municipalities (Figure 4). When it comes to tropical cyclone, Cardenas et al. (2015) reported that the Philippines is centered within the hot spot for sea level rise and increasing tropical cyclone intensity. It has the highest weight percentage (27.29%) that contributes to the overall hazard index. Studies show that the tropical cyclones and their epiphenomena such as floods, storm surges, landslides and others cause some of the largest losses of life and damages to property and the economy (Huigen and Jens 2006; Bankoff 2007; Camargo et al. 2007; Cheong et al. 2011; Yumul et al. 2011). The occurrence of landslides, on the other hand, is more prevalent in the municipalities of Besao, Sagada, Sabangan, Sadanga, Barlig, and Natonin. These municipalities are located on higher elevations and sloping areas. Soil erosion is also one of the major factors that affect hazard index. It is a complex process that depends on soil properties, ground slope, vegetation, and rainfall amount and intensity (Selby, 1993). In the past decades, increasing population in the province has brought higher demand of resources resulting to deforestation and adoption of intensive agricultural practices. According to Lantican et al. (2003), these developments have resulted in high rates of soil erosion and degradation of soil and water resources not only in the sloping lands, but also in the plains. Based on Figure 4, the municipalities of Sagada, Bontoc, Sadanga, and Barlig are most exposed to soil erosion. Overall, the municipality of Paracelis is the most exposed to climate change induced hazards (Figure 5).

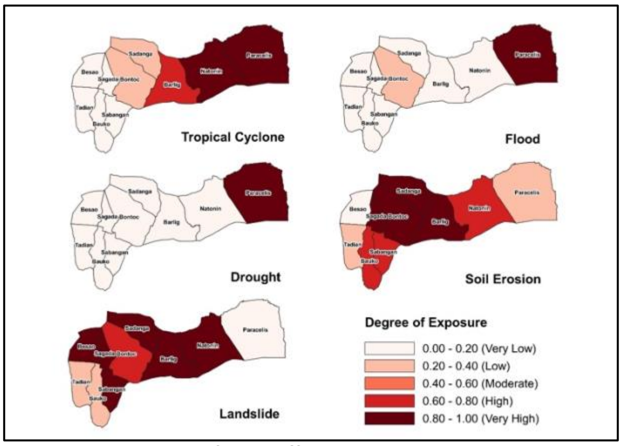

Figure 4: Exposure of the different local government units in Mountain Province to five hazards

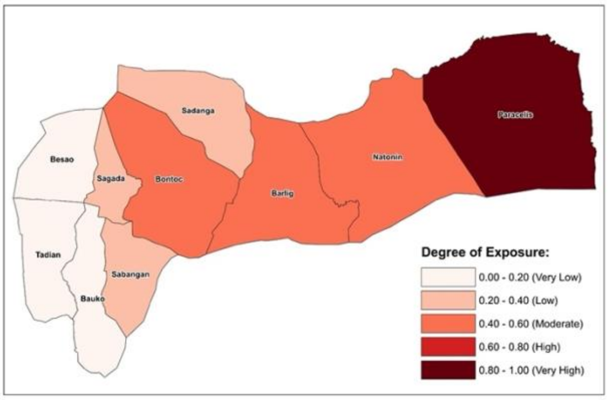

Figure 5: Overall hazard index of the different local government units in Mountain Province

Sensitivity

Heirloom Rice
Over 500 heirloom or locally-adapted rice varieties grown in the terraces of Cordilleras have been passed down from one generation to another for several centuries together with traditional knowledge well adapted to the local ecosystem (Nozawa et al. 2008). The people and their culture are considered as “living gene banks” for highland rice varieties. However, according to Sekine (2021), this traditional agricultural system has been threatened by climate change, overuse of natural resources, modernization of IP communities, and the lack of successors. The current and projected crop suitability are shown in Figure 6 where the areas with lighter red color are the areas where heirloom rice are suitable in contrast with the areas with darker red color where crops are least suitable. Recall that projected crop suitability was estimated using the IPCC RCP data for 2050 under the 8.5 climate scenario while current crop suitability was estimated using current climate data. Figure 7 shows that the municipality of Bauko will gain crop suitability compared with all other municipalities where losses in crop suitability are expected due to projected changes in climatic conditions in 2050.

Arabica Coffee
Arabica coffee is grown in the higher elevation of the province where the temperature is low. The current crop suitability as well as the projected crop suitability of Arabica coffee are shown in Figure 8. Based on the results, all of the municipalities are projected to lose crop suitability for Arabica coffee (Figure 7).

According to Bunn (2015), coffee has proven to be highly sensitive to climate change. Several studies also show that the productivity of Arabica coffee will be reduced due to climate change (Gay et al. 2006; Zullo et al. 2011; Schroth et al. 2009; Bunn et al. 2015). Davis et al. (2012) reported that the stated optimum mean annual temperature range for Arabica coffee is 18°C – 21°C or up to 24°C. At temperatures above 23°C, the development and ripening of fruits are accelerated, often leading to the loss of beverage quality.

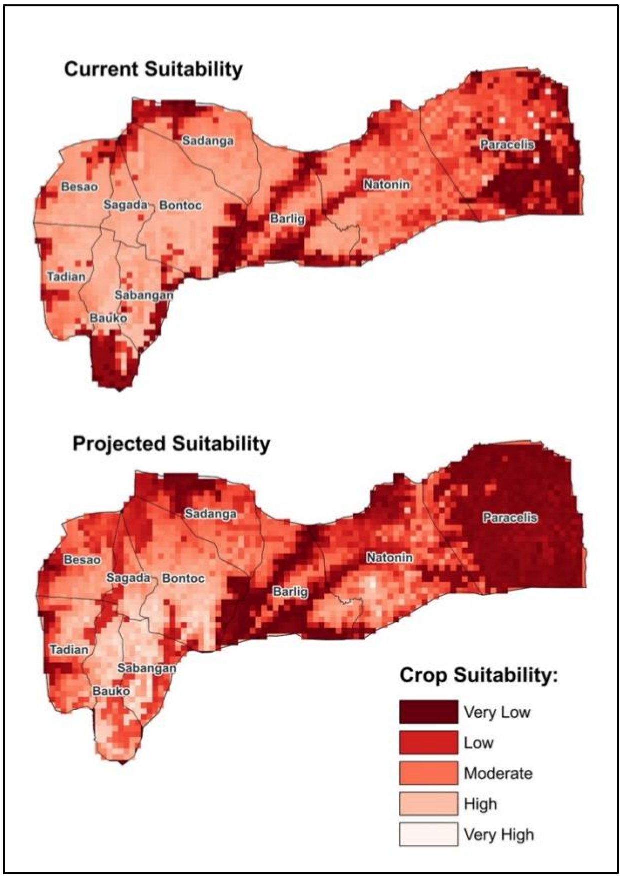

Figure 6: Current and projected crop suitability of heirloom rice in Mountain Province

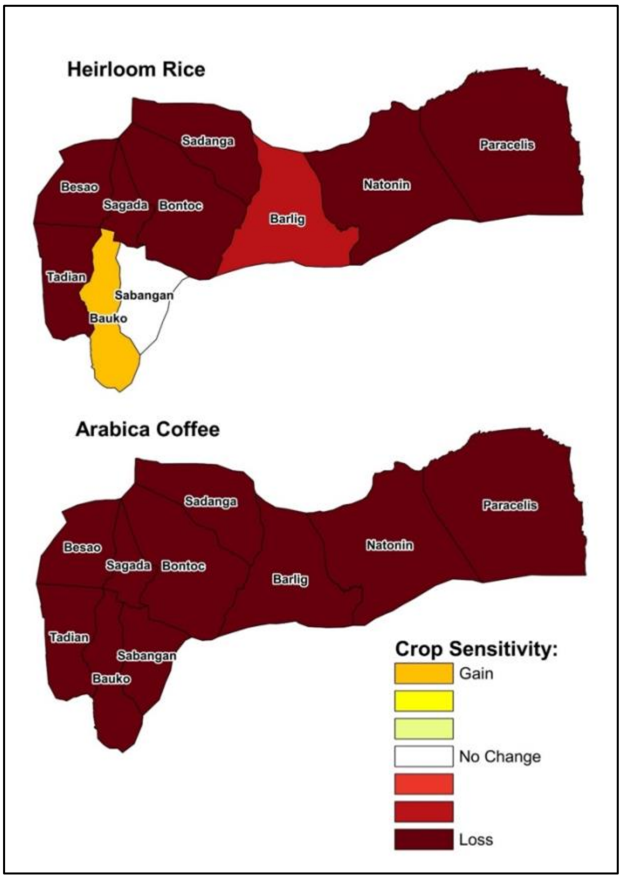

Figure 7: Sensitivity index map of heirloom rice and Arabica coffee in Mountain Province

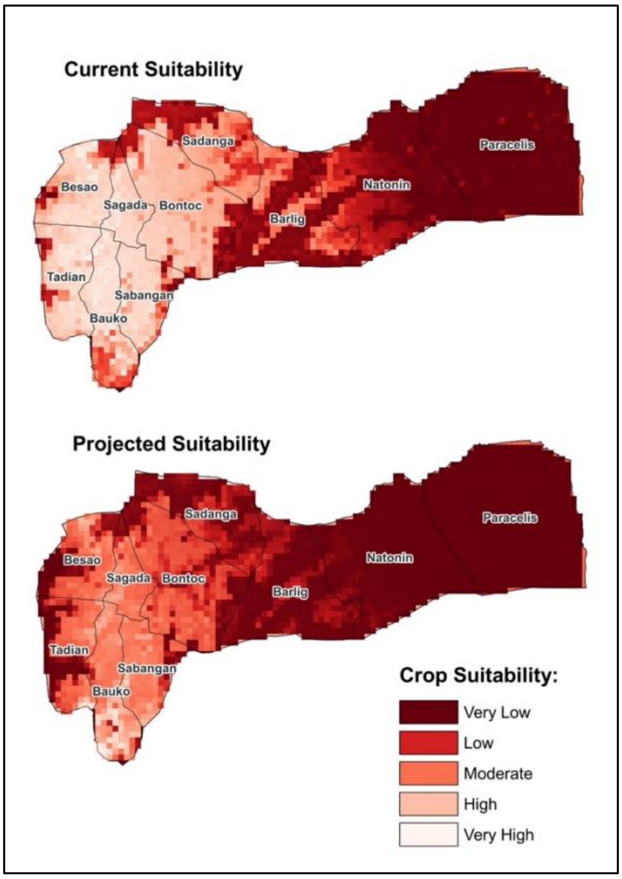

Figure 8: Current and projected crop suitability of Arabica coffee in Mountain Province

Adaptive Capacity

There are a number of indicators that could form a strong adaptive capacity index but data availability was a constraining factor in establishing the final index. Hence, the five factors and indicators described in Table 3 were adopted in the study. Figure 9 shows the adaptive capacity of each municipality based on each capital. Also, based on the results shown in Figure 10, the municipalities of Bontoc and Bauko are the most adaptive in the province. Paracelis has moderate adaptive capacity, Besao, Sagada, Sabangan, Tadian, and Natonin have low adaptive capacity while Barlig and Sadanga have the lowest adaptive capacity.

Climate Risk Vulnerability Assessment

This study has adopted the assumption that vulnerability is estimated as: 30% potential impact (exposure and sensitivity) and 70% adaptive capacity. However, it is possible to change the relative importance of these major factors through more intensive multi-criteria analysis procedures such as those described in Mendoza and Martins (2006). Based on the results, almost all of the municipalities are vulnerable to climate change except Bauko and Bontoc which show low vulnerabilities as compared to other municipalities in Mountain Province in terms of heirloom rice and Arabica coffee production (Figure 11). The high adaptive capacities of these two municipalities also

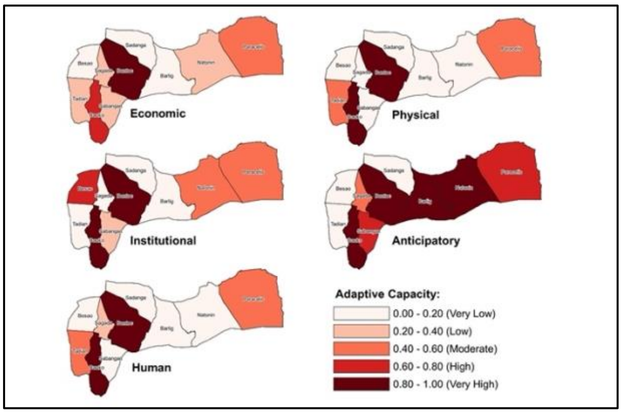

Figure 9: Adaptive capacity of the different Local Government Units in Mountain Province based on economic, institutional, human, physical and anticipatory capital factors

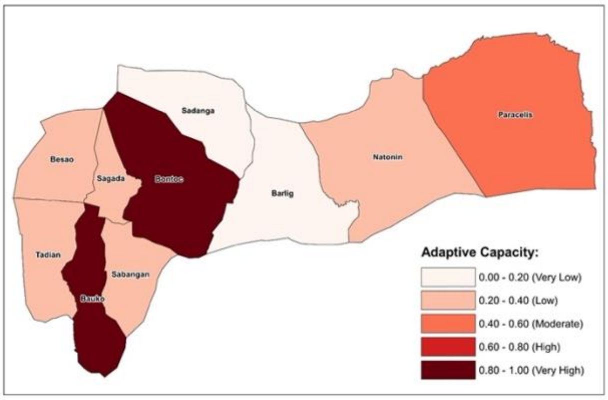

Figure 10: Overall adaptive capacity index of the different Local Government Units in Mountain Province

contribute to their low vulnerabilities. Additionally, in terms of forest ecosystem, the area of closed forest of Bauko and Bontoc are 140.22 ha and 3,897.48 ha, respectively while the area of open forest of Bauko and Bontoc are 4,429.59 ha and 15,581.31 ha, respectively based on the 2020 land cover map (National Mapping and Resource Information Authority 2022). On the other hand, the municipality of Sadanga, shows a very high vulnerability both in heirloom rice and Arabica coffee production, while Barlig has a very high vulnerability for Arabica coffee production. The vulnerability of the production system for heirloom rice will be exacerbated if current concerns, particularly environmental concerns, of farmers are not addressed. The farmer respondents in the study by Salazar (2017), for instance, stated that there were no activities by the Heirloom Rice Project that addressed climate vulnerabilities, i.e. infrastructural damage due to storms and flooding, which are their greatest concern. These CRVA maps provide information at a municipal level that is essential for planning and prioritization. For example, in terms of Arabica coffee production, it is recommended to prioritize the municipalities of Sagada, Besao, and Tadian since these municipalities have high vulnerabilities and at the same time high production of coffee as shown in Figure 12. Although Sadanga has the highest vulnerability, the occurrence of Arabica coffee in the municipality is low.

CONCLUSION

The vulnerability of the productivity of heirloom rice and Arabica coffee to climate change was assessed and mapped in the 10 municipalities of Mountain Province using spatial modeling and statistical analysis of climate impacts, climate variability, and socio-economic variables.

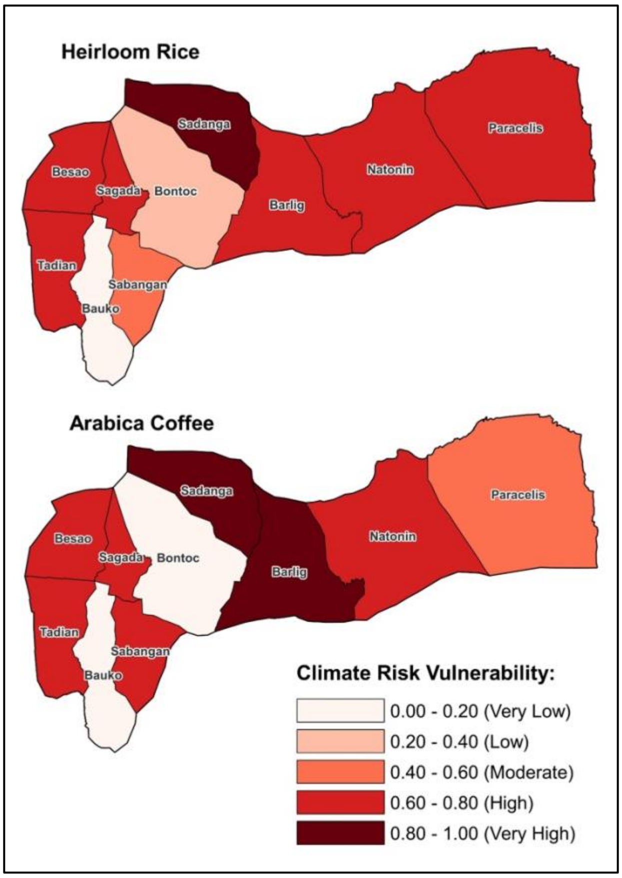

Figure 11: Climate risk vulnerability map of heirloom rice and Arabica coffee production in Mountain Province

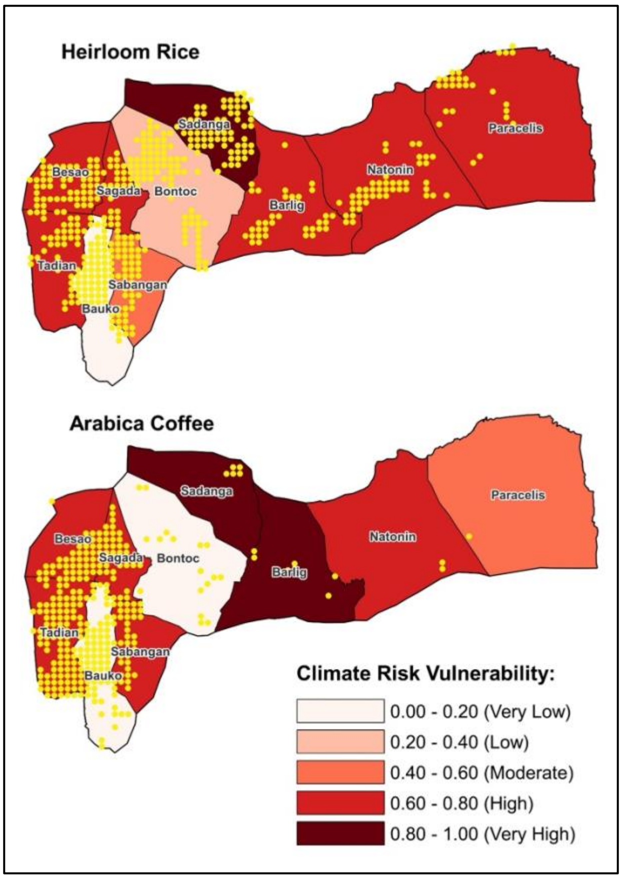

Figure 12: Climate risk vulnerability maps of Mountain Province overlaid with the crop occurrences of heirloom rice and Arabica coffee

The results are also based on modeling results which have inherent uncertainties and limitations. Given that the adaptive capacity has higher weights, it constitutes a significant factor in the overall vulnerability. A high vulnerability was observed in municipalities where there is a divergence of high exposure to hazards, lower climate suitability of key crops in the future, and low adaptive capacity. The results from CRVA described in this paper can serve as a reference to inform and guide decision-makers from concerned government agencies as well as private sectors on areas that are in most need of interventions and what interventions are needed.

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