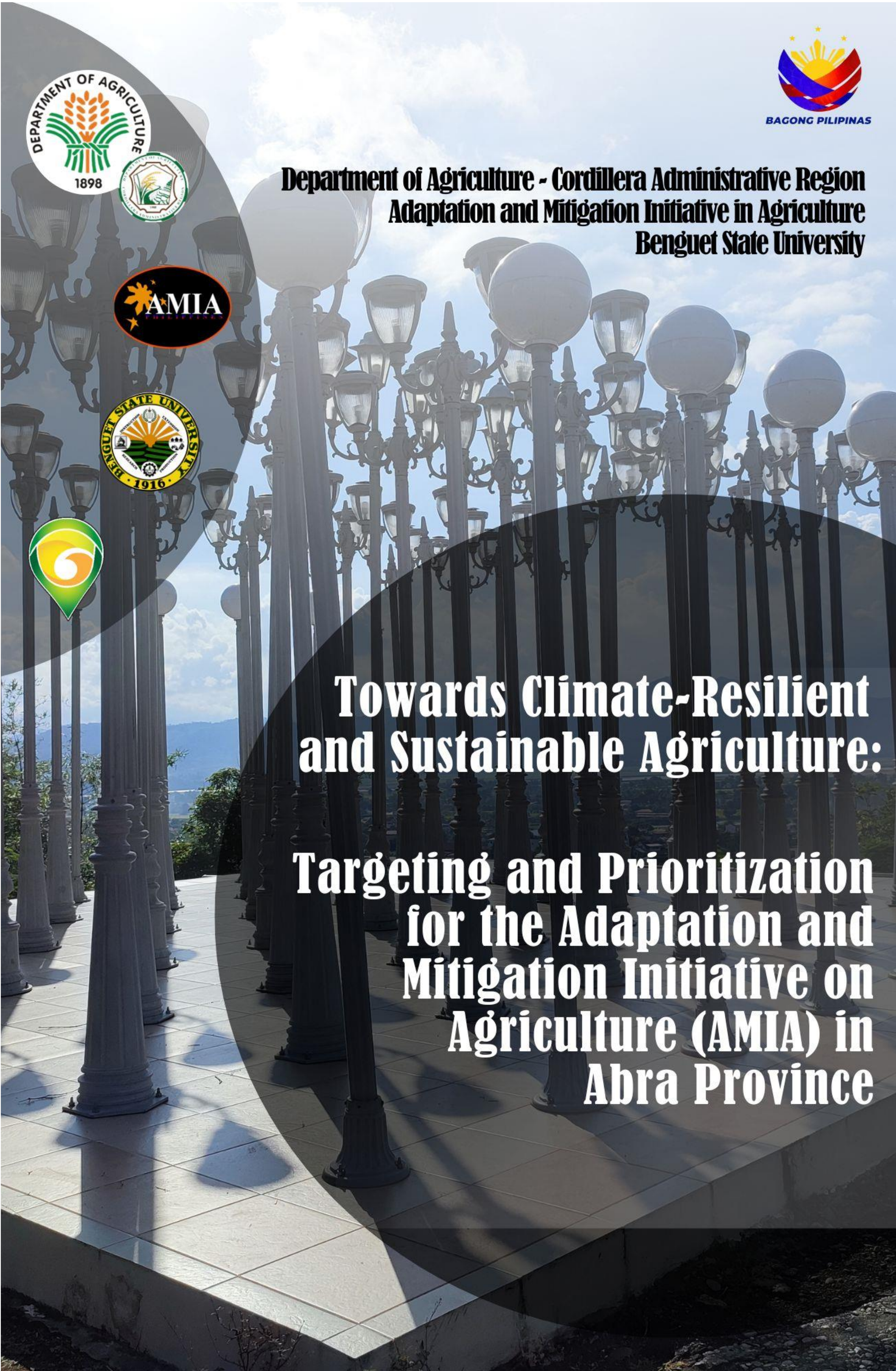


Department of Agriculture - Cordillera Administrative Region
Adaptation and Mitigation Initiative in Agriculture
Benguet State University

Towards Climate-Resilient and Sustainable Agriculture:

Targeting and Prioritization for the Adaptation and Mitigation Initiative on Agriculture (AMIA) in Abra Province

Department of Agriculture – Cordillera Administrative Region
Adaptation and Mitigation Initiative in Agriculture
Benguet State University

Towards Climate-Resilient and Sustainable Agriculture: Targeting and Prioritization for the Adaptation and Mitigation Initiative in Agriculture (AMIA) in Abra Province

CLIMATE RISK VULNERABILITY ASSESSMENT:

Benguet State University

Lynn J. Talkasen
Roscinto Ian C. Lumbres
Quinerlyn A. Godio
Angelica B. Batingal
Mila D. Maguinsay

CLIMATE RESILIENT AGRICULTURE:

Benguet State University

Madeline S. Kingan
Janet P. Pablo
Esther Josephine D. Sagalla
Love Joy B. Gumpod
Nonallee Grail P. Aggalao

COST-BENEFIT ANALYSIS:

Benguet State University

Cheryll C. Launio
Mark B. Bulangen
Rovilyn Tulian
Kacy O. Labon

Table of Contents

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

Globally, climate change continuously threatens the agricultural sector which majority of the population depends on it as their main subsistence. Agriculture strengthens the global economy as it impacts livelihood and trade. However, it is greatly affected by climate change making it vulnerable.

The Adaptation and Mitigation Initiative in Agriculture (AMIA) is a program spearheaded by the Department of Agriculture System-wide Climate Change Office (DA – SWCCO) to mainstream climate change adaptation and mitigation strategies and design complementary activities for building appropriate climate responsive DA support services.

The study, "Towards Climate – Resilient and Sustainable Agriculture: Targeting & Prioritization for the Adaptation and Mitigation Initiative in Agriculture (AMIA) in Abra" was conducted with an objective to assess and develop a climate – resilient agriculture platform as basis for prioritizing climate adaptation and mitigation technological interventions in the municipalities of Abra. Specifically, it aimed to: 1.) assess the climate risk and resilience level of the agricultural communities Abra Province; 2.) document and analyze local CRA practices adapted; 3.) determine and analyze the socio – economic benefit of the technology for adaptation; and 4.) assess climate risks of the agriculture sector through geospatial & climate modeling tools.

The research focused on four priority crops namely, rice, corn, mango and coffee. Rice and corn are main crops distributed throughout the province; coffee is grown in areas with higher elevation while mango is grown in the lower elevation areas.

The assessment of vulnerability of the production of the four crops was assessed by looking into the municipalities' adaptive capacity, sensitivity and exposure to natural hazards as adopted from the framework of the International Center for Tropical Agriculture (CIAT). Climate Risk Vulnerability was assessed to identify municipalities that need implementation of adaptation and mitigation measures to improve the resiliency of agriculture in the province. Maximum Entropy (MaxEnt) software, was used to project the suitability of based on the current occurrences of each crop as indicator of current climate suitability then determining the future climate suitability. Despite the gains in suitability for production of rice, corn and mango in the municipalities of Malibcong, Daguioman, and Boliney, and gain in suitability of coffee in Tubo, generally there are losses in suitability for majority of the municipalities in the province.

Tineg, Licuan-Baay, Sallapadan and Bucay were identified to be the most exposed municipalities to natural hazards. On the otherhand, Bangued, the capital town, is the municipality with the highest adaptive capacity.

The overall CRVA revealed that the municipalities identified as highly vulnerable are due to their high exposure to hazards, adaptive capacity and crop suitability. The results show that by 2050, municipalities must be prioritized in the implementation of interventions on rice production are Sallapadan, Tayum, Manabo, Langiden, Lagangilang, San Isidro and San Juan; San Quintin, San Juan and Langiden for corn production; Lagangilang, Langiden, San

Juan, Sallapadan, San Isidro, and Villaviciosa for mango; and Malibcong, Daguioman, and Boliney for coffee. These municipalities have high to very high vulnerability and have reported moderate to high production for the four crops studied.Climate change poses many diverse challenges to all spheres of human activities especially agriculture. While the scientific community through the years has unfolded several systematic documentation and categorization of the impact of climate change and the adaptation features in different regions of the world, there are yet a lot of specific areas that can be explored. The objectives of this study are to characterize the value chain and identify and assess climate risks and vulnerabilities for major crops in Abra in terms of consequences, underlying factors, adaptation options, farmers' priority adaptations and barriers for adoption. The study used primary data from 56 farmers and secondary data from various documents and reports.

Results showed that the identified major climate hazards in the province are typhoon and drought while the major crops are rice, white corn, mango and coffee. Farmers employed simple adaptation measures to cope with these risks. These include (a) availing of crop insurance, (b) adjustments in farm activities (early planting/early harvesting), (c) planting quality seeds, appropriate varieties or alternate crops, (d) use of wheel or hand tractor to expedite land preparation, (e) use of combine harvester to facilitate harvest, and (f) bagging for mango.

The information on value chain activities, climate-related vulnerabilities and risks for rice, corn, mango and coffee production in Abra may be used by local government units, higher education and research institutions, and private sectors to develop climate smart technologies for the improvement of the production and marketing of these prime commodities. Farmers also need to be capacitated financially, technically and behaviorally to be able to adapt technologies on improved production, processing, and marketing of major crops such as rice, corn, mango and coffee for long term sustainability.

Selected CRA practices, which are not commonly used by farmers were subjected to economic analysis or partial budget analysis. For rice and corn, groundwater solar powered irrigation system is a technology that can increase production via increased cropping intensity and yield. However, the SPIS case evaluated in this project was found not economically viable in its current state, because it was destroyed by typhoon after two years of operation and has not been repaired yet. In addition, the actual area serviced is much less than the expected target service area, rendering the costs outweighing the benefits. On the other hand, the net profit-cost ratio of using electric irrigation pump for corn production during dry season is positive. However, the use of diesel-powered irrigation pump during dry season resulted in negative net profit-cost ratio, even without including the carbon footprints for using diesel fuel. For the SPIS drawing water from rivers in order to support rice-rice cropping pattern, it is economically viable as long as it can irrigate 90% of the planned service area and is not destroyed by typhoon. More techno-economic analysis is needed to ensure optimal irrigation service areas. For mango, fruit bagging is seen to result in better fruit quality and higher selling price. However, this process requires additional labor. Partial budget analysis shows that there is still a positive net benefit when fruit bagging is adopted by mango farmers.

I. RATIONALE

Vulnerability is an important issue in the Philippines when it comes to climate change especially that the country's' main source of sustenance is agriculture which is greatly affected by climate change. Communities are affected brought about by the impacts of climate change on food-security and economy. Smallholder farmers are greatly affected since their livelihood is dependent on growing crops which are dependent on favorable weather. This being the case, the implementation of climate change adaptation and mitigation measures is essential. Apdohan, Varela and Balanay (2021), citing IPCC, stated that the "impacts of climate change on food production depend on the adaptation measures undertaken by local communities". This is true, since climate change adaptation focuses on strengthening resilience and reducing vulnerability according to Food and Agriculture Organization (2018). With proper adaptation and mitigation, production of profitable crops may continue.

The Philippines continues to search for climate change adaptation and mitigation options considering that it is one of the most vulnerable countries to climate change. With its agriculture sector being one of the most important players in the country's economy, yet also the most beset with climate-change-intensified hazards, such as floods, typhoons, landslides, and droughts, it is one of the sectors actively searching for feasible adaptation strategies to promote or implement. Since agriculture also contributes over 30% of the greenhouse gas emissions in the country (UNDP, n.d.), the sector is also always on the lookout for potential mitigation strategies.

Along with various changes in climate, different hazards that hit the Philippines threaten the growth and production of different crops. Thus, the preparation of hazard maps that present the hazard indices of the province are necessary. With these, areas that need consideration based on the risks that natural hazards impose can be identified. With the harsh temperature and precipitation, planting season was also changed in order for the crops to certainly adapt. Improving of even merely maintaining the productivity of crops challenging. This is aggravated by the climate risks or vulnerabilities to which crops are exposed to. A farmer must then practice adaptation and mitigation measures which could pave the way towards achieving resilient farming systems. In addition, this necessitates the need to identify which areas and crops that are most vulnerable to climate risks and prioritize these in the implementation of adaptation and mitigation initiatives (Daipan et al., 2023). Smit and Wandel (2006) stated that vulnerability assessments are used to identify adaptation strategies that are feasible and practical in communities. Moreover, vulnerability assessment is key to understanding the potential climate risks and ultimately in developing a resilient farming system. In addition, Fakhruddin (2019) stated that vulnerability and risk assessment of extreme weather or climate events are essential in informing stakeholders and implementing appropriate prevention, adaptation, and mitigation strategies.

Climatic hazards globally pose significant challenges, impacting ecosystems and human activities. These hazards, including extreme events like hurricanes, droughts, floods, and heatwaves, have intensified, causing disruptions and economic losses. Natural disasters like typhoons, floods, and droughts significantly affect the Philippine economy, particularly agriculture (Esrael and Briones, 2012).

Corn produced in the Philippines encompasses both yellow corn, primarily for feed, and white corn, including glutinous and sweet types, for human consumption. In regions like the Cordillera, especially in Abra, white corn, particularly the glutinous variety, holds significant cultural and economic value. It's a staple in local dishes, boiled as a snack, and processed into 'Cornick.' Additionally, white corn serves as a source of economic opportunities, marketed both retail and wholesale within the province and beyond Cordillera. Monitoring current production data, considering factors like climate and market changes, remains vital for understanding the ongoing impact and trends in this specialized regional corn production (Lucas, 2019).

Mango (*Mangifera indica* L.) is considered one of the oldest fruit trees cultivated in the world. It is also dubbed as “king of fruits” because of its irresistible sweetness, attractive aroma, and beautiful shades of peel and flesh fruit color. Mangoes are of significant importance in the Philippines, serving as a major export product, cultural symbol, and to promote agricultural diversity (Khali and Abobatta, 2023; Phil. Mango roadmap, 2017-2050). In fact, the country is known for its diverse mango varieties and top fruit quality.

Under the Department of Agriculture’s Adaptation and Mitigation Initiative in Agriculture (AMIA), the framework covers the identification of climate-resilient agriculture (CRA) practices that are relevant to address the commodities most vulnerable to the most important hazards as identified in the vulnerability assessment. Climate resiliency in agriculture is a concept that aims to ensure that productivity and food security are enhanced and sustained even with the changing climate and not at the expense of the environment (Labios et al., 2020; CIAT and DA-AMIA, 2017).

However, promoting and implementing CRA practices requires substantial resources, not only on the part of the government–local government unit or line agency but also for the farmers and stakeholders. Adequate funding for the promotion, implementation, and monitoring of adaptation and mitigation options is necessary to effectively address climate change impacts. As mentioned by CIAT and DA-AMIA (2017), even though climate change financing has been integrated into national development planning, a limited number of national financial institutions are available to support CRA activities. It is thus important that preferred and identified CRAs are not only perceived as effective but also proven profitable for society or at least conditions for profitability or efficiency are determined and disseminated to stakeholders and beneficiaries.

II. OBJECTIVES

The main objective of the CRVA component is to assess the climate-risk vulnerability of the production of selected crops as basis for prioritizing climate adaptation and mitigation technological interventions in the municipalities in Abra province.

The specific objectives are:

1. to assess and develop adaptive capacity maps of Abra province using GIS;

2. to generate hazard maps of each municipality in Abra province based on natural hazards identified by the International Center for Tropical Agriculture (CIAT); and
3. to assess the sensitivity of the selected crops in Abra province using GIS and Maximum Entropy (MaxEnt) Software.

For the CRA component, it aimed to assess and develop a climate-resilient agriculture platform as the basis for prioritizing climate adaptation and mitigation technological interventions for rice, corn, mango and coffee production in Abra.

The specific objectives are:

1. Characterize the value chain for major crops in Abra in terms of:
    a. Production profile
    b. Farming system
    c. Value chain key actors and activities
2. Identify and assess climate risks and vulnerabilities for major crops in Abra in terms of:
    a. Consequences
    b. Underlying factors
    c. Adaptation options
    d. Farmers' priority adaptations
    e. Barriers for adoption

The CBA was conducted in order to contribute to the identification of economically feasible climate-resilient agriculture practices for the prioritized hazards for rice, corn, and mango for developing or prioritizing investment plans. Specifically, it aimed to:

1. determine the costs and benefits of selected climate-resilient agriculture practices for rice farming;
2. determine the costs and benefits of selected climate-resilient agriculture practices for corn farming; and
3. determine the costs and benefits of selected climate-resilient agriculture practices for mango farming in Abra.

<u>Limitations of the project</u>. Considering the state of adoption and the intricacies of doing a cost-benefit analysis, only the financial and economic evaluation of using solar-powered irrigation systems for corn and rice production, use of crop insurance, and preliminary analysis for bagging technology for mango were undertaken for the case of Abra. The project was limited to evaluating using the CBA framework the adaptation options that are deemed technically feasible but are not widely adopted or require substantial investment. For the adaptation options that are already almost being used, adopted, or implemented by most farmers in the province, or have no available secondary or primary quantitative data, perceptions or narratives based on the survey and focus group discussions were presented to inform future analysis or investment planning.

III. REVIEW OF LITERATURE

A. Vulnerability and Climate Risk Vulnerability Assessment

The Philippines is reported as one of the most affected countries in terms of climate-related risks and their impact to agriculture whose production is highly dependent on the climate. It was mentioned by Eckstein, Künzel, & Schäfer, (2018) as cited by Badajos (2019) that Philippines ranked as one of the top ten most affected countries in the world with regards to the Long-Term Climate Risk Index from 1997-2016. Tao et. al (2011) also mentioned in their study that Global climate change has become a major problem affecting future survival and mankind development, and that agriculture is one of the sectors most sensitive to climate change.

Vulnerability Assessment (VA) is important in responding to future climate risks, and the process may also help improve the management of current climate risks. (Downing, 2005). Vulnerability is seen as the residual impacts of climate change after adaptation measures have been implemented (Downing, 2005). Thus, there is a need to know the crops' future vulnerability and the suitable adaptation measures that could be implemented. The IPCC Third Assessment Report (TAR) describes vulnerability as "the degree to which a system is susceptible to, or 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 variation to which a system is exposed, its sensitivity, and its adaptive capacity." (IPCC, 2007)

The Philippines is highly prone to natural disasters, with some estimation placing 60% of its land area and 74% of its population to be exposed to numerous hazards, including floods, cyclones, droughts, earthquakes, tsunami and landslides (World Bank Group, 2021). Hazards are one of the causes of the problems around the country as they affect the overall population, economic, health, development and a lot more. Buan (1996) stated that agricultural areas in the Philippines are exposed to climate-related hazards such as high frequency of tropical cyclones and floods, seasonal occurrences of drought and salt water intrusion caused by storm surges.

Adaptive Capacity is the "ability of a system to adjust to climate change, to moderate potential damages, to take advantage of opportunities or to cope with the consequences" as defined by IPCC (2001). However, Peñalba and Elazegui (2013) stated that high adaptive capacity may not necessarily translate to actions that reduce vulnerability. Analysis of adaptive capacity is therefore an important component of CRVA because it enables planners to look at which capitals need improvement to enhance the resiliency of communities (Paquit, 2018). Adaptive capacity is a crucial component for undertaking climate change mitigation and adaptation actions, however, different communities will have different adaptive capacities based on their context (Lang, 2018), . With the climate already changing, and further change in the climate is expected, adaptation is a necessary component of any response to climate change, and therefore investing in enhancing adaptive capacity is necessary (Smith, 2003).

Sensitivity is the "degree to which a system or species is affected, either adversely or beneficially by climate-related stimuli" as defined by IPCC (2001). A climate portal describes sensitivity as how much warmer the planet will get if the amount of greenhouse gases in the atmosphere doubles. While exposure is the nature and degree to which a system is exposed to a significant climate variation. Exposure will depend on where populations choose (or are forced) to live and how they construct their settlements, communities and livelihoods (IPCC, 2014).

Climate change is already impacting the country, threatening to weaken the development prospects and worsen the vulnerability of poorer populations (Apdohan A. G., 2021). 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 (Apdohan et al., 2021). It was also mentioned in the study of Stueker (2018) that "changes in crop yield and production over time are driven by a combination of genetics, agronomics, and climate. Disentangling the role of these various influences helps understand the capacity of agriculture to adapt to change", thus, the conduct of a study on vulnerability is a must. Abra was recorded to have the highest value of production in agriculture and fisheries on the year 2018 having an annual increase of 6.4% (PSA, 2022) but this may be affected in the following years as Ravago (2017) mentioned that there is a likelihood that climate change will increase the probability of flooding, since rainfall is expected to both increase and be more concentrated.

B. Climate Variabilities, Hazards, and Crop Production

Effects of Climate Variabilities and Hazards on Crops Production

Climate hazards profoundly impact crop production in CAR, posing challenges such as flooding from typhoons and heavy rainfall, leading to soil erosion and reduced yields. Prolonged dry seasons and droughts create water scarcity, stunting growth and lowering crop quality. Extreme temperature fluctuations affect flowering and productivity, while increased pests and diseases further harm crops. These challenges worsen food security and livelihoods, emphasizing the need for adaptive farming practices to combat these climate-related adversities in CAR (FAO, 2015).

The vulnerability of major crops to climate hazards in Abra highlights the need for adaptive measures, such as resilient farming practices and the development of climate-smart technologies. Assessing and addressing these impacts are essential to safeguard the production and ensure food security in the region (FAO, 2015).

Crop Production in CAR

Rice

Cordillera Administrative Region (CAR) isn't considered a major rice-producing region compared to areas like Central Luzon and Western Visayas. However, rice cultivation still holds significance in select areas within CAR, particularly in Ifugao and Kalinga.

In 2022, CAR experienced a decrease of 10.36 percent in rice production compared to the previous year, with production totaling 377,133.35 metric tons. Additionally, the production area for rice saw a decrease of 3.93 percent, amounting to 101,555.75 hectares (PSA, 2023). Of the total rice production in CAR in 2022, 85.36 percent came from irrigated areas, while the remaining 14.64 percent came from rainfed areas. Among CAR's provinces, Kalinga remained the top producer, contributing 33.96 percent of the total production. Following Kalinga, Abra accounted for a 22.75 percent share, Apayao for 22.00 percent, with the cumulative share of Ifugao, Benguet, and Mountain Province comprising the remaining 21.28 percent.

Crop Production in CAR Rice In 2023, the palay production in the Cordillera Administrative Region was estimated at 331,470 thousand metric tons – 86% (286,420 MT) from irrigated area and 14% (45,050 MT) from non-irrigated area. The harvested area is around 96,233 hectares with a yield per hectare of 3.44 metric tons and contributing to about 24% share to value of agricultural production. The quantity of palay production and harvested was estimated from the damaged, stolen, given away, consumed, shared and reserved but excludes the produced that are not harvested for other reasons, that may include the effects of the climatic hazards (PhilRice, 2023). Rice had been contributing significantly to food security as this is the primary staple food of more than half of the world's population. Rice, being the largest user of land grown in wide environment is also challenged by the hazards of climate change. Reduction on the yield and yield parameters was observed as an effect of the exposure when rice is grown during the typhoon season from 8.50 to 8.81 tons per hectare to 5.11 tons per hectare observed from five varieties grown in the municipality of Rizal, Kalinga (Odias et al., 2022).

Despite not being a major rice-producing region on a national scale, rice cultivation in CAR plays a significant role in local economies and contributes to food security, particularly in provinces like Ifugao and Kalinga where rice farming holds cultural and agricultural importance.

Corn

The total white corn production in Cordillera Administrative Region (CAR) for 2022 was estimated at 16,471.72 thousand metric tons, harvested from an area of 6,448.72 thousand hectares. This represented an 11.55% decrease in volume production compared to the previous year. Additionally, there was a marginal decrease of 0.008% in the production area. Abra emerged as the largest contributor to white corn production, yielding 15,822 metric tons with an area of 6,138 hectares, which accounted for 96.05% of the region's total. Following Abra, Kalinga contributed 3.22%, and Apayao 0.28% to the regional production. Moreover, Benguet, Mountain Province, and Ifugao also made smaller yet noteworthy contributions of 0.24%, 0.15%, and 0.05%, respectively, to the overall white corn production in the region (PSA, 2023).

Natural disasters like typhoons, floods, and droughts significantly affect the Philippine economy, particularly agriculture. These disasters profoundly impact corn, a vital crop, and with climate change exacerbating this vulnerability, assessing its impact on corn production is critical. Corn faces direct threats from climate change, potentially disrupting both production and various social and economic activities, emphasizing the need to evaluate its impact given its extensive implications for food systems and livelihoods (Esrael and Briones, 2012; Salvacion, 2015).

Mango

In 2022, the Cordillera Administrative Region (CAR) harvested 5,349.84 thousand metric tons of mangoes from an area spanning 1,556 thousand hectares. The province of Abra led the region's mango production contributing 2,074.24 metric tons, closely followed by substantial contributions from Ifugao at 1,842.8 metric tons, Benguet at 696.64 metric tons, Kalinga at 428.26 metric tons, Mountain Province at 272.12 metric tons, and Apayao at 35.78 metric tons (PSA, 2023). However, the mango industry has been confronted with major production challenges and issues, such as declining fruit yield and quality, infestation of pest and diseases, high cost of production, low profit margin, and unstable production (Paguia., et al. 2021). Furthermore, climatic hazards such as typhoons, erratic rainfall, and temperature extremes add to the abovementioned challenges by damaging trees leading to reduced yields and fruit quality. Similarly, floods, droughts, rising temperature, erratic rainfall and windstorm have been observed to negatively affect the survival, growth, establishment and quality of mango seedlings in Ghana (Asare-Nuamah et. al., 2022).

Overcoming these challenges necessitates the application of climate-resilient practices, improved pest and other cultural management practices, better infrastructure and technology, and availability of robust support systems to aid mango farmers in improving their production (Rosegrant and Sombilla, 2018; Ravago, 2016; Adraneda, 2009; Normand et al., 2015). Yet limited resources hinder the effectivity of these adaptation efforts.

The impact of climate hazards on the major crop’s cultivation in Abra, Philippines, has been significant. Increased occurrences of extreme weather events such as typhoons, heavy rainfall, erosion, landslides and droughts have posed substantial challenges to the production. These climatic variations affect crucial growth stages, leading to decreased yields, increased susceptibility to diseases, and low production. Farmers counter these challenges with water conservation, pest control, protective measures, diversifying crops, and soil preservation to mitigate climate risks (DA-BAR, 2022b).

Coffee

In 2021, the Cordillera Administrative Region (CAR) yielded an estimated total coffee production of around 2,229 metric tons (PSA, 2023). While CAR is not yet among the top coffee-producing areas in the Philippines, it has made notable progress and gained recognition for its cultivation of Arabica coffee. The region's high elevation, favorable climate, and soil quality are conducive to the growth of Arabica coffee, renowned for its distinctive flavor profile characterized by mild, slightly fruity, and with hints of chocolate or nutty undertones (DA-BAR, 2022a).

However, various challenges hinder coffee production, including natural disasters, environmental issues, and fluctuating economic conditions. To enhance the sustainability of coffee farming, it's crucial for the government to support local farmers in implementing improvements and innovative techniques in their farming practices and production methods. Such support can significantly contribute to the growth and development of the coffee industry in the Philippines (DA-BAR, 2022a).

C. Adaptation Measures

Use of Solar-Powered Irrigation System

Irrigation is a powerful adaptation for drought in any context. However, current sources of irrigation operate using energy sources such as fuel and electricity, which are not only expensive but use nonrenewable energy. Solar Powered Irrigation System (SPIS) is an irrigation system powered by solar energy, using PV technology, which converts solar energy to electrical energy to run a DC or AC motor-based water pump (BAFS-DA,2021). Solar irrigation systems play a key role in sustainable agriculture, addressing global issues including greenhouse gas emissions, pollution, and sustainable production (Guno & Agaton, 2022). A review paper by Diop et al. (2020) on the technical and economic feasibility of solar irrigation pumping system concluded that solar energy is a promising alternative energy source to fuel and electricity, and it is economically feasible, despite its high investment cost. Similarly, Hartung and Pluschke (2018) also gave a state-of-the-art overview of policies, regulations and incentives for the sustainable use of solar-powered irrigation technologies around the world. They concluded that it offers a reliable source of energy in remote areas and can reduce energy costs for irrigation and enable low emission agriculture. Also, according to IRENA (2015), easy energy supply and enhanced access to water for irrigation, improved yields and enlarged profits, enhanced crop resilience, and food security are some of the benefits for farms and farmers of solar pumping. All these studies, however, have been conducted outside of the Cordillera Administrative Region. To the best of our knowledge based on the literature reviewed, no cost-benefit analysis has been done on the use of SPIS for rice and corn farming in the region. Also, the designs of the SPIS implemented in Abra province differ between the National Irrigation Administration projects with water source from dugwells, and the Department of Agriculture, where the source are rivers.

Use of Crop Insurance

Crop insurance on the other hand mitigates risk by providing an opportunity for farmers to cover production costs for the next season, and maintain their income and consumption even if their crops are destroyed or incur loss due to a disaster (Defiesta & Mediodia, 2016; Reyes, 2019). The country's crop insurance program is administered and implemented by the Philippine Crop Insurance Corporation (PCIC), a government-owned and controlled corporation. The PCIC is mandated to provide insurance protection to farmers against losses arising from natural calamities, plant diseases, and pest infestation of their crops and other agricultural assets.

Use of Pre-harvest Fruit Bagging in Mango Production

Fruit bagging is one of the practices that provide physical protection against pests in mangoes (Ventura et al., 2022) and other fruits and is considered as necessary in areas where there is high fruit fly infestation (Elauria, Manilay, & Abrigo, 2015). The individual fruits or fruit bunches are bagged on the tree for a specific period (Islam et al. 2023). Recycled paper and pages of telephone directories are typically used in the Philippines as materials for the bags while others use specially designed bags (Philippine Mango Industry Roadmap 2017 to 2022) or ready-made bags available at agricultural supply stores. Pre-harvest fruit bagging is one of the most environmentally friendly technique to improve fruit quality by physically protecting the fruit against pathogens, insects, physiological disorders, agrochemical residues, fruit abrasions, sunburn, and bird damage (Buthelezi, Mafeo, & Mathaba, 2020).

Fruit bagging during the early stage of fruit development in mango improves the acceptability of the fruit for export (Bayogan, Esguerra, Campeon, 2006). The experiment conducted by Islam et al. (2023) also showed that pre-harvest fruit bagging using various bagging materials significantly reduced fruit drop, insect infestation, and fruit damage due to birds.

IV. METHODOLOGY

A. Study Site

Abra province, the Philippines' natural dye capital is a landlocked province in the Cordillera Administrative Region (CAR). It is bounded in the north by Apayao in the west by Kalinga and south by Mountain Province. The province's total land area is 397, 555 ha. or 1.3% of the Philippines' land area, with 24.75% ha. of which is alienable and disposable (Moncado, 2019). Abra is subdivided into 27 municipalities and 324 barangays and as of 2020, and has a population of 250,985 as recorded by PSA (2021). Its capital is Bangued located in the western portion of the province. The province is surrounded by tall mountains like the Gran Cordillera Central mountain range and the Malaya mountain range or the Ilocos range. It has 21 mountains with Mount Bangbanglang being the province's highest elevation with 2,467 meter above sea level (masl.) situated in the municipality of Tubo. Abra River is among the longest rivers in the northern Philippines Moreover, agriculture is the main source of living in the province with rice, corn as their major crops. Figure 1 shows the geographic location of the study site as well as the municipal boundaries of the province.

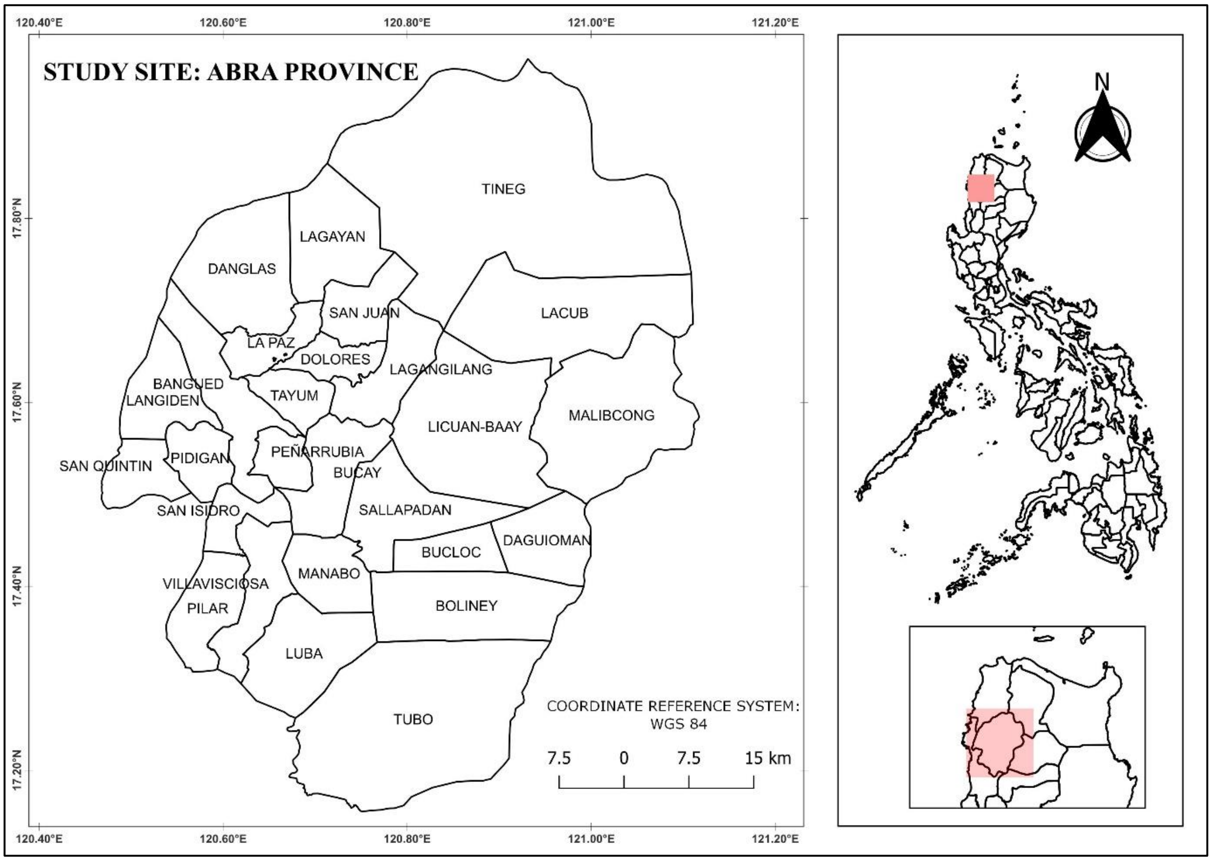


Figure 1. Geographical location of Abra

B. Selected Crops

Rice and corn are main crops distributed throughout the province; coffee is grown in areas with higher elevation while mango is grown in the lower elevation areas.

By the year 2023, 21,796 ha. were planted with rice in the province, of which 14,548.63 ha. were irrigated and 7, 247.36 ha. were rainfed or non-irrigated (PSA, 2023). It was also recorded by PSA that there were 1,253 ha. of corn production areas harvested during the first semester of 2023. For coffee, it was registered that there were 45 ha. production areas harvested and 1,037.12 MT. of mango produced in 2022 (PSA, 2022).

Rice, corn, mango and coffee were selected since these are the crops that are mainly produced in the province. These were selected by the representatives of the Local Government Units (LGU), Office of the Provincial Agriculturists (OPAG) and Municipal Agriculturists (OMAG) that were present during the participatory mapping. The selection was based on the volume of production and in consultation with the Department of Agriculture-Regional Field Office-Cordillera Administrative Region (DA-RFO-CAR).

C. Climate Risk Vulnerability Assessment

Sensitivity Index

Each crop was assessed based on changes in their climatic suitability in the present climatic condition as compared to their suitability to future climatic condition. Maximum Entropy

(MaxEnt) was used to model crop suitability of each crop. The analysis of crop suitability involves two steps namely, determining the current locations of the crops based on the present climatic condition, then predicting the best location of crops based on future climatic changes by the year 2050.

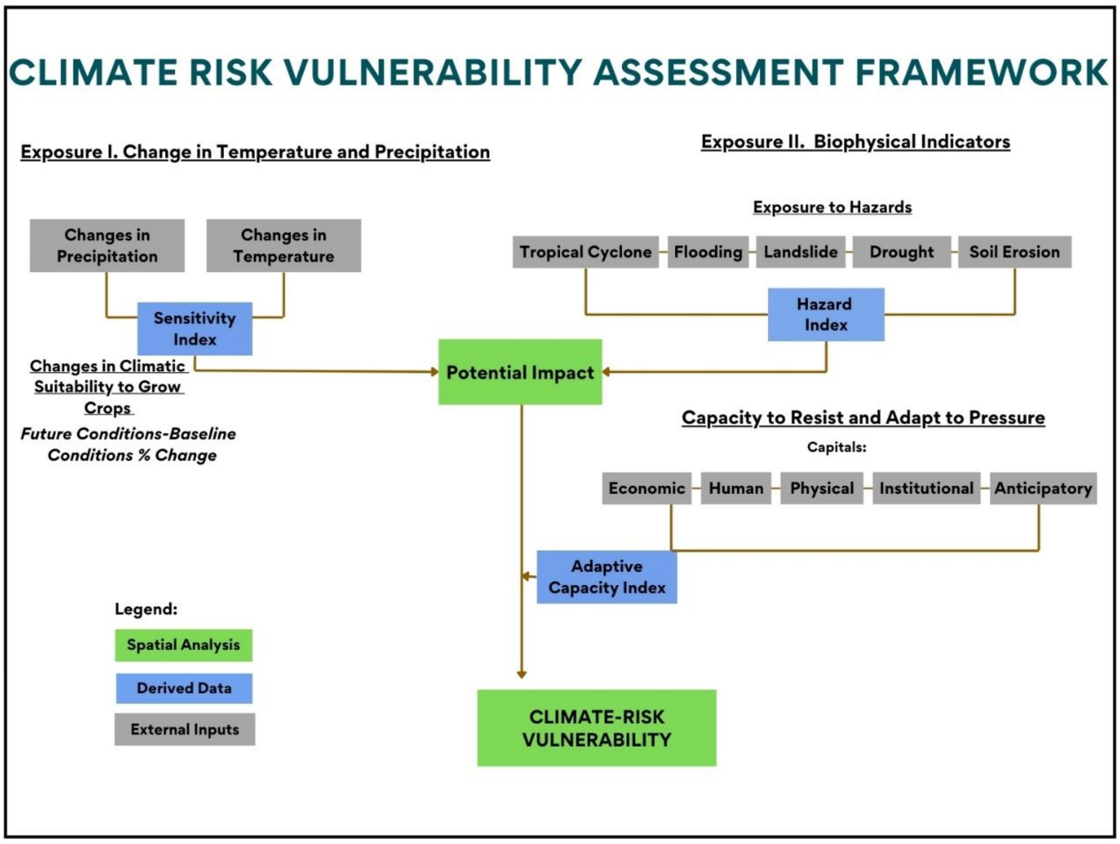


Figure 2. Climate Risk Vulnerability Framework

Source: Palao et. al., 2017

Nineteen (19) bioclimatic variables downloaded from WorldClim, were selected to assess crop suitability. These bioclimatic variables represent annual trends, seasonality and extreme or limiting environment factors.

Crop Occurrence Points

The crop occurrence points were gathered through participatory mapping. This was participated by representatives from the local agriculture offices including the municipal agriculturists, agricultural extension workers, crop coordinators, and staff from the provincial and regional field offices. Participatory mapping is a method used to create a map to incorporate perspectives, recognize alternative ways of knowing, and facilitate cross cultural awareness (Melinda Laituri, 2023). The mapping exercise was facilitated by Benguet State University together with the Department of Agriculture-Cordillera Administrative Region (DA-CAR).

Maps with 1km^2 resolution grids were used by the participants to indicate what crops are produced in each grid. The yield of each crop – rice, corn, mango and coffee were also annotated as high, moderate or low based on existing yield reports. Satellite images of each municipality with features such as road networks, river networks and administrative boundaries were also provided as a guide during the participatory mapping. Crop occurrences were based on their personal knowledge and existing reports of the concerned offices. Georeferenced crop occurrence data were then formatted in comma separated value (.csv) using QGIS software.

Current Conditions

Table 1 shows the 19 bioclimatic variables which were selected to assess the climate suitability of the selected crops in the province. These bioclimatic variables were gathered from WorldClim, a set of global climate layers (gridded climate data in GeoTiff format) that can be used for mapping and spatial modeling (Food and Agriculture Organization of the United Nations, 2023). These variables, representing annual trends, seasonality, and extremes of the environment; accumulated from weather station data from 1961–1990, were derived from monthly temperature and rainfall values to produce biologically relevant variables (Hijman, et al., 2005). These are necessary to understand species' responses to climate change (O'Donnell and Ignizio, 2012). Climatic variables that are related to temperature are Bio 1 to Bio 11 while those related to precipitation are Bio 12 to Bio 19. The data is in raster format with 1km^2 resolution.

Table 1. The Bioclimatic Variables used and their descriptions.

	Code	Climatic variable	Description
Temperature Related	Bio1	Annual Mean Temperature	Annual mean temperature derived from the average monthly temperature.
	Bio2	Mean diurnal range	The mean of the monthly temperature ranges (monthly maximum minus monthly minimum).
	Bio3	Isothermality (Bio2/Bio7)*(100)	Oscillation in day-to-night temperatures.
	Bio4	Temperature seasonality	The amount of temperature variation over a given year based on standard deviation of monthly temperature averages
	Bio5	Maximum temperature of warmest month	The maximum monthly temperature occurrence over a given year (time-series) or averaged span of years (normal).
	Bio6	Maximum 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.
	Bio7	Temperature annual range (Bio5-Bio6)	A measure of temperature
	Bio8	Mean temperature of wettest quarter	This quarterly index approximates mean temperatures that prevail during the wettest season.

	Code	Climatic variable	Description
	Bio9	Mean temperature of driest quarter	This quarterly index approximates mean temperatures that prevail during the driest quarter.
	Bio10	Mean temperature of warmest quarter	This quarterly index approximates mean temperatures that prevail during the warmest quarter.
	Bio11	Mean temperature of coldest quarter	This quarterly index approximates mean temperatures that prevail during the coldest quarter.
Precipitation Related	Bio12	Annual precipitation	This is the sum of all total monthly precipitation values.
	Bio13	Precipitation of wettest month	This index identifies the total precipitation that prevails during the wettest month.
	Bio14	Precipitation of driest month	This index identifies the total precipitation that prevails during the driest month.
	Bio15	Precipitation seasonality (Coefficient of variation)	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.
	Bio16	Precipitation of wettest quarter	This quarterly index approximates total precipitation that prevails during the wettest quarter.
	Bio17	Precipitation of driest quarter	This quarterly index approximates total precipitation that prevails during the driest quarter.
	Bio18	Precipitation of warmest quarter	This quarterly index approximates total precipitation that prevails during the warmest quarter.
	Bio19	Precipitation of coldest quarter	This quarterly index approximates total precipitation that prevails during the coldest quarter.

Source: http://www.WorldClim.org

Future Conditions

Representative Concentration Pathways (Figure 3) illustrates the future of potential carbon dioxide emissions or the possible reduction of atmospheric concentration throughout the current century (Gendre, 2022). The Representative Concentration Pathways (RCP) provide potential trajectories that project future changes in climate by assessing a series of different uncertainties. The RCPs aim at recording the emissions, concentrations, and land-cover change projections (IPCC Data Distribution Center, 2023). Four scenarios were developed that include a stringent mitigation scenario (RCP2.6), two intermediate scenarios (RCP4.5 and RCP6.0), and one with the worst-case scenario with very high greenhouse gas emissions (RCP8.5) (IPCC, 2023).

Crop Distribution Modeling Tool

Maximum Entropy (MaxEnt) species distribution model Ver. 3.3.3k was used to create predictive maps of crop suitability based on the crop occurrence points and environmental layers. The tool is commonly used to estimate most suitable areas for crops based on the probability in geographic areas where the distribution of crops is scarce (Elith, 2002). MaxEnt, compared to other modeling tools produces impressive predictions of crop suitability (Phillips et al., 2008). The tool is based on the connection between species existence and its biophysical environment to predict the current as well as the future distribution of the selected crops (Jayakumar S., 2015). It can also be used to identify new areas for crop production, especially in regions where land use changes or climate changes are adjusting the suitability of certain crops (Nagar, 2023). This model makes use of a correlative model of the climatic conditions that meet the crop’s environmental requirements and predicts the relative suitability of location (Davis et. al, 2012). These environmental requirements were represented by bioclimatic variables (Table 1) which are combined to determine areas most suitable for the particular crop.

Sensitivity Analysis

Sensitivity analysis determines how sensitive the output of a crop model with respect to the elements of the model that are subject to uncertainty or variability. This is serve as a guiding tool when the model is under development, prediction, and for decision support (Monod, 2006). Crop suitability was assessed by changes in climatic suitability of crops by the year 2050 in comparison with the baseline crop suitability. The Maximum entropy (MaxEnt) model was used to model crop suitability under climate change based on the model developed by Phillips et al. (2006). Analyzing changes in crop suitability involves a two-step process. The first step is to determine the best location for crop suitability based on the present climatic condition. The second step is to predict the best location for crop suitability based on future climatic changes. Nineteen variables (Table 1) available at WorldClim.org including the variable processed by CIAT (Bio 20: number of consecutive dry days) were used to assess crop suitability. These were derived from monthly temperature and rainfall values and were processed to generate climate variables (Hijmans, 2005). The described bioclimatic factors are relevant to understand species responses to climate change (O’Donnell and Ignizio, 2012). The bioclimatic factors have become essential for exploring climate changes (Chiou CR., 2015).

Representative concentration pathway (RCP) 8.5 was used as basis for future projection of climate change by year 2050. Representative Concentration Pathways (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 (Figure 4). It is also-called “baseline” scenario that does not include any specific climate mitigation target (Riahi et al. 2011).

The change in climatic suitability of crops between baseline and future predictions was analyzed in QGIS that involved the use of tools such as raster calculation, reclassification and zonal statistics. The difference (expressed as percentage), as shown in an equation below, in projected and current suitability determines the climate change crop suitability, and reflects the degree of crop sensitivity to changing environmental conditions. Higher change in a negative direction reflects higher impact of climate change.

Crop sensitivity formula:

X 100

(Source: (Palao, 2017)

An index (Table 2) was developed from -1.0 to 1.0 for sensitivity where the range from 0.25 to 1.0 indicates a loss in suitability, while -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 condition.

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

Source: (Palao et al., 2017)

Hazard Index

Hazard refers to the possible, future occurrence of natural or human-induced physical events that may have adverse effects on vulnerable and exposed elements (Cardona, 2012) and are identified based on its known potential impact on the agricultural sector and characterized by their extent, magnitude, severity, duration and variability (Bragais et al., 2020 and Parker, 2019). The identification of hazard was based on its potential impacts on the agricultural sector.

Hazard Dataset

Eight (8) climatic hazards were identified by CIAT and other CRVA partner agencies that affect agricultural production in the Philippines. These are tropical cyclone, flood, drought, soil erosion, landslide, storm surge, saltwater intrusion and sea level rise. Hazard datasets refer to the historical databases to evaluate the current susceptibility of a hazard to occur in a geographic area (Bragais et. al., 2020). These datasets were based on the result of workshops and consultations conducted by CIAT with local and national experts - SUC experts/focal persons. Each of these hazards was weighted for each island group of the Philippines because these island groups are unique in terms of exposure to hazards, rainfall pattern, landform, and crop distribution. Also, each hazard has different degree, intensity and frequency, and the potential damage also varies. Since Abra province is a landlocked, sea level rise, saltwater intrusion and storm surge were excluded. The final weights of hazards used are as follows: typhoon (27.29%), flood (25.99%), drought (19.44%), soil erosion (15.59%), and landslide (11.69%).

CIAT provided the raster (tropical cyclone, drought) and vector data (landslide, flood and soil erosion) for the Cordillera region. Processing of these hazards was mostly done in QGIS software. Since the given data were for the whole region, the raw data of each hazard was clipped to get the needed feature for Abra Province (Figure 3). Vector data were rasterized (vector to raster) then normalized to have values that ranges from 0 – 1. Mean values of tropical cyclone, flood, soil erosion, and landslide and sum value for drought were calculated using the zonal statistics function of QGIS. After calculating the mean and sum values, these were normalized using the modified Luzon weights specified above. The overall hazard value was the sum of the normalized values of hazard and the overall hazard index is the normalized hazard value. The formula used is shown below:

$$H = \sum w_i h_i$$

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

The hazard index was classified into five (5) equal breaks – 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).

Normalization formula:

hazidx_norm=

where: hazidx_norm is the normalized values of the hazard index and x is the value of a particular hazard.

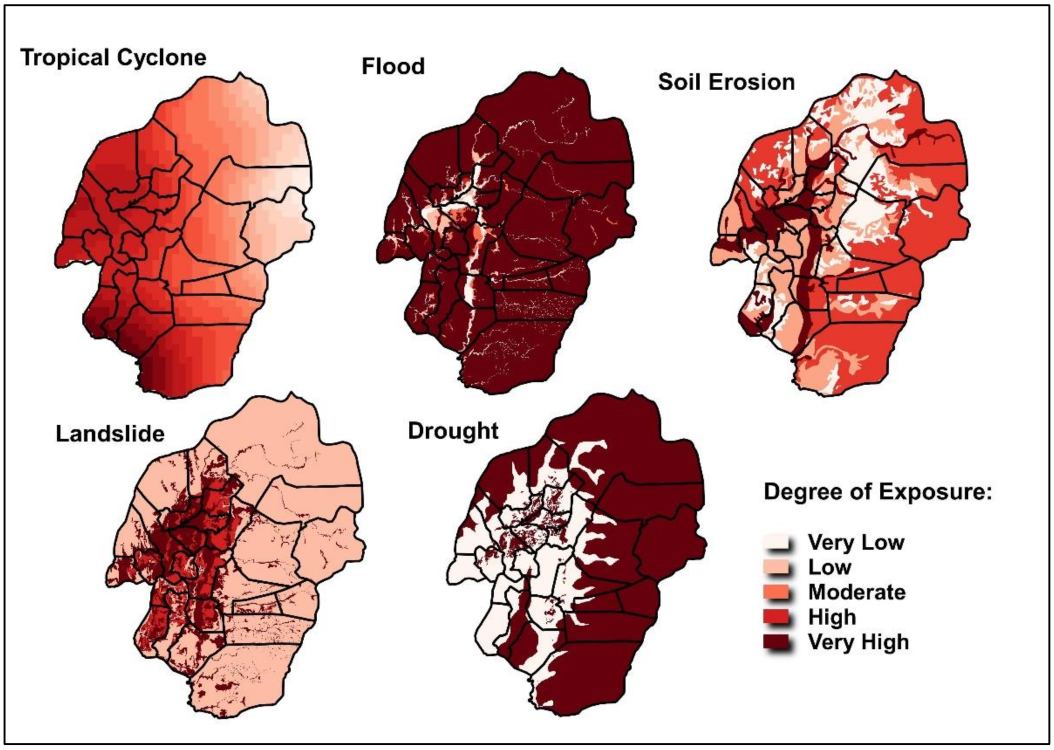


Figure 3. Raster hazard data clipped from the data provided by CIAT

Adaptive Capacity Index

Adaptive capacity is a function of both asset-based components of a community such as wealth and human capital (Margles, 2016) or it is the ability of someone to adjust to changes in the environment. Adaptive capacity is the third component of CRVA in addition to exposure and sensitivity.

This study aims to provide a high-resolution analysis at the municipal level, however, there are limited socio-economic variables available. Hence, Table 3 shows the list of capitals and the collected indicators that were used as bases for the adaptive capacity of the 27 municipalities of Abra. These capitals include economic, human, physical, institutional, anticipatory, and natural. These indicators were derived from the available data (mostly from 2018) from the Cities and Municipalities Competitiveness Index (CMCI) of the Department of Trade and Industry (DTI) and CIAT. Furthermore, the data on natural indicator were extracted from the 2020 Land Use and Land Cover data created by the National Mapping and Resource Information Authority (NAMRIA). Each indicator was normalized and was summed up for each capital. The formula used for computation and normalization is shown below.

$$AC\ indicator\_norm = \frac{X - X_{min}}{X_{max} - X_{min}}$$

where: AC indicator_norm = is the normalized values of the AC indicators

X = is the original value of the indicator of the municipality

X*max* = is the highest value among all the municipalities

X*min* = is the lowest value among all the municipalities

Finally, tabulated normalized values for each capital of the different municipalities were integrated in a spatial data or the Abra shapefile that contains municipal boundaries.

Table 3. List of capitals with their indicators

Capital	Indicator
Economic	Classification
	Gross sales of registered firms
	Total capitalization of new business
	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 and Industrial firms/customers
	Cost of water - Commercial users and Industrial firms/customers
	Price of diesel as of December 31, 2018
	Regional daily minimum wage rate agricultural plantation and non-plantation (amount in Peso) 2015
	Daily minimum wage rate - non-agricultural (Establishments with more than 10 workers)
	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 loan 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 and private health services – Doctors
	Capacity of public and private health services – Nurses
	Capacity of public and private health services – Midwives
	Public and private secondary education - Number of Teachers

Capital	**Indicator**
	Public and 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 and electricity service
	Number of public and private secondary and tertiary schools
	Number of public and private - Clinics
	Number of public and private – Clinic Beds
	Number of public and private – Diagnostic Centers
	Number of public and private - Hospitals
	Number of public and private – Hospital Beds
	Public and private – Infrastructure for Evacuation
	Presence of drainage systems in LGU Center
	Presence of water and power source
	Presence of a sanitary landfill
	Practice of Waste Segregation
Institutional	Presence of comprehensive development plan
	Presence of the local investment incentives code
	Presence of the equivalent of an investment promotions unit
	Getting building and occupancy permits – Minutes
	Getting building and occupancy permits – Steps
	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
Anticipatory	Presence of the CLUP and DRRMP
	Presence of an office that implements the CLUP and DRRMP
	Presence of staff manning the office
	Presence of local E.O or ordinance that mandates the implementation of the CLUP and DRRMP
	Conduct of LGU-wide disaster drill
	Date of latest LGU-wide disaster drill
	Presence of an 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
Natural	Total area of open forest in hectare
	Total area of closed forest in hectare

Capital	Indicator
	Total area of brushland and shrub land in hectare
	Total number of protected area

Source: CMCI of DTI and CIAT.

Vulnerability Assessment

After the assessment of the three components of vulnerability – sensitivity index, exposure to hazard index, and adaptive capacity index - for the different municipalities, the climate risk vulnerability of each crop were determined using the weights provided by the CIAT.

The vulnerability formula is shown below:

$$f = +1-A)$$

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.*

The weights used in this study was based on the previous CRVA projects. These weights were determined during the consultations and workshops of local and national experts. The weight given for adaptive capacity was 70% and 15% for both sensitivity and hazard. Various scenarios were also created using different percentages as shown in Table 4 since the analysis of weights for each component of vulnerability are highly subjective. These weights were based on literatures to explore the impact on different vulnerability classes.

There are five (5) classifications for vulnerability (very low to very high vulnerability) for each municipality. The overall vulnerability was determined using the QGIS software. The CRV maps of rice, corn, mango and coffee were produced using the different weights or versions. Lastly, the crop occurrence data were overlaid to the CRV maps to easily identify the areas for prioritization of intervention.

Table 4. Weights used to assess vulnerability assessment.

Version	Sensitivity (%)	Hazard (%)	Adaptive Capacity (%)
Version 1	15	15	70
Version 2	33	33	33
Version 3	25	25	50
Version 4	20	20	60
Version 5	30	30	40

D. Climate Resilient Agriculture

The study used both primary and secondary data. Desk reviews were done to gather secondary data and information regarding the identification of target crops and study sites. Primary data were gathered through focus group discussions (FGDs), key informant interviews (KIIs), field observation and photo documentation.

The crops chosen for the study were those identified as priority crops by the Department of Agriculture - Regional Field Office - Cordillera Administrative Region (DA-RFO-CAR), and of which is based on the volume and area of production. The study sites were selected based on their crop production, gathered from the Philippine Statistics Authority (PSA), DA-RFO-CAR, and the provincial and municipal agricultural offices. During the field activities, the priority crops identified were verified in the study sites based on their crop production.

Courtesy calls and reconnaissance meetings were first conducted with the Office of the Provincial Agriculturist (OPAG), the Offices of the Municipal Agriculturist (OMAG) and some barangay officials then followed by the focus group discussions and key informant interviews with farmers and local officials. Structured workshop templates and questionnaires were used. The respondents came from the 10 municipalities of Abra. The respondents were selected through convenience sampling from each municipality.

The tool used for the climate risk assessment for agriculture was adapted from the methodology developed by the International Center for Tropical Agriculture (CIAT) (Figure 4). Structured workshop template and questionnaires were used that includes the following indicators and parameters collected through desk reviews, FGD and KII:

1. Agriculture context
    a. People and livelihoods (gender-specific variables): demographics (current and trend; specific emphasis on rural populations); economic and social prosperity (poverty, access to basic needs - water and electricity, education, etc.); food security and nutrition
    b. Agriculture activities: land use, farm size and title deeds; agriculture jobs and incomes; agricultural input use (water/irrigation, fertilizer, pesticides)
    c. Key value chain commodities: identification and description of key value chain commodities relevant for food security and national and country economy
    d. Challenges for the agriculture sector: outlining the key challenges for the agricultural sector in the county
2. Climate vulnerabilities
    a. Past Climate Change and variability of the agricultural sector
    b. Farmers´ perceptions of Climate Change and related risks
    c. Future projected changes (with some discussion on uncertainty)
    d. Climate vulnerabilities per commodity (across major value chains)
3. Adaptation options/interventions
    a. Current interventions, programs and policies
    b. Gaps in current adaptation options and needed interventions, programs and policies (conceptually mapped to specific vulnerabilities in the major commodities)
4. Institutional resources and capacity to implement adaptation strategies
    a. Types of institutions engaged in facilitating the implementation of adaptation strategies
    b. Resources and capacity to tackle climate change aspects, to deliver services (extension, insurance, financial services, etc.) and to execute (staffing, planning, implementation, financial management)

c. Intra- and inter-institutional coordination for effective management
d. Gaps in institutional management and governance to support the implementation of adaptation strategies

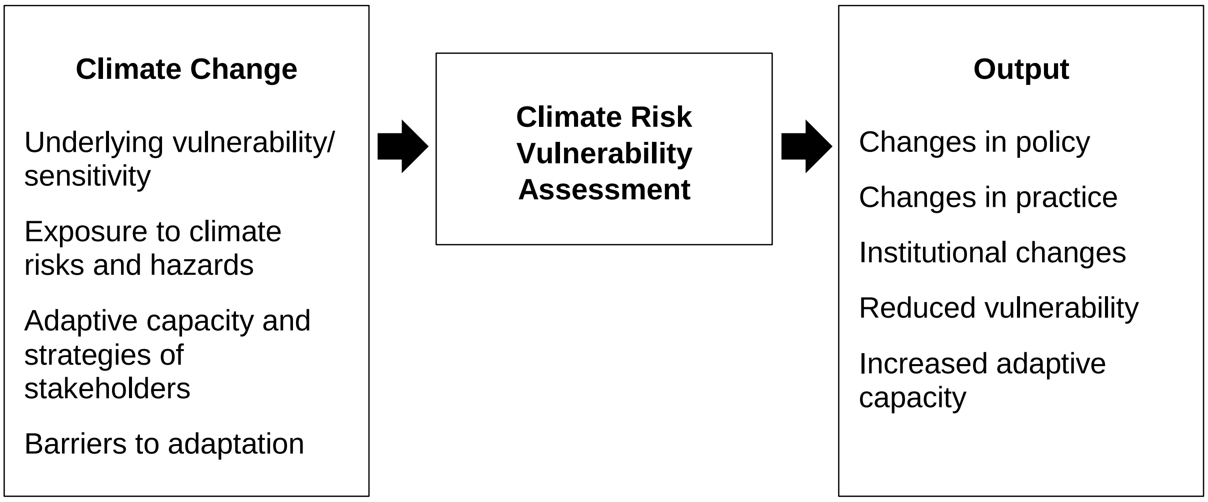


Figure 4. Conceptual framework of the study.

E. Cost Benefit Analysis

The study used survey data of beneficiaries or users and non-beneficiaries or counterfactual farmer practices. The quantitative data was supplemented by qualitative data based on open-ended questions in the survey with probing, focus group discussions (FGDs), and key informant interviews with groups or individuals relevant to the identified adaptation practices. FGDs were conducted with user groups, and key informants are the farmer or irrigations association presidents and LGU personnel.

Population and Sampling

Since the major corn areas in Abra are also located in rice-producing areas, the sampling for rice and corn farmers was done based on the adaptation practices used in the major rice and corn farming barangays (Table 1). For the evaluation of the adaptation practices for rice farming, farmer-beneficiaries of solar power irrigation systems (SPIS) from river water sources, rainfed farmers, and farmers with irrigated rice farms were purposively sampled. The inclusion criteria for the respondents are: 1) the farmers is planting rice in at least one farm parcel; 2) their rice farm is located in the top three rice-producing barangays in the municipality; and 3) at least one of their parcels was supported with SPIS or water pump in the reference cropping seasons 2022 wet and dry seasons. For the counterfactual sample, purely rainfed farmers whose farms are purely rain-dependent in the said cropping calendar. The final number of respondents interviewed is: 75 from the municipality of Bangued (59 rainfed farmers, and 16 with irrigated rice fields), 15 from Bucay (3 rainfed farmers, 3 farmers with irrigated rice fields, and 9 SPIS beneficiaries), 6 from La Paz (5 rainfed farmers and 1 SPIS beneficiary) 3 rainfed farmers from Pidigan, and 15 farmers from Tayum (4 rainfed farmers, and 11 SPIS farmer beneficiaries).

In the case of corn farming, at least 63 farmers were interviewed using an interview schedule. Most of the respondents' cropping pattern is rice-corn wherein the adaptations were applied during the dry season only since their rice parcels are rainfed during wet season. The inclusion criteria for the respondents are: 1) their farm is located in the top corn-producing areas in the municipality; 2) at least one of their parcels was supported with a solar-powered irrigation system during the reference cropping season of 2022 dry season. For the counterfactual sample, corn farmers with parcels that are purely rainfed and supported with water pumps (diesel/electric) in the said cropping season. The final number of respondents interviewed is: 61 from the municipality of Bangued (9 solar SPIS users, 15 rainfed farmers, 17 electric pump users, and 20 diesel pump users) and 2 from Pidigan (1 electric pump user and 1 rainfed).

In the case of mango farming, 20 mango farmers were interviewed from the top three-mango producing municipalities. The inclusion criteria for the respondents are: 1) their farm is located in the top mango-producing areas in the municipality; 2) they have at least tried to practice fruit bagging.

Table 5. Study Municipalities and Survey Barangays Covered

Commodity	Survey Municipality	Survey Barangays	No. of Survey Respondents	Adaptation Practice
Rice and Corn	Bangued	Brgy. Cabuloan, Brgy. Lipcan, Brgy. San Antonio, Brgy. Sta. Rosa	46	9 SPIS-Dugwell; 17 Electric Pump; 20 Diesel Pump
	Pidigan	Brgy. Poblacion West, Brgy. Suyo	1	Electric Pump
Rice	Tayum	Brgy. Bagalay	11	SPIS-River
	Bucay	Brgy. Bangbangcag	9	SPIS-River
	La Paz	Brgy. Malabbaga	1	SPIS-River
Mango	Bucay	Brgy. Bangcagan and Bugbog	3	
	Peñarrubia	Brgy. Malamsit	7	
	Lagangilang	Brgy. Paganao, Brgy. Nagtupacan, Brgy. Tagodtod	10	

Profile of Rice and Corn Farmer Respondents

The average age of rice and corn respondents is 52 years old, they have more than 20 years of farming experience, and almost 27% are senior citizens (Table 2). All of the farmers have some form of formal education, although most of them are elementary graduates and 20% are high school graduates implying that most farmers in the area are functionally literate. Most of them are members of a farmer association. However, 16% are not members of any kind of organization. These results imply that there is still room for social preparation among the respondents in terms of encouraging the remaining non-members to join associations. Government benefits, such as production support, including the deployment of potential smart-agricultural practices, can only be accessed via farmers/irrigators associations or cooperatives. According to Araullo (2006) & Deriada (2005), cooperatives and associations act as a means by which farmers can access services from government institutions such as extension services, formal credit, and insurance program

Profile of Mango Farmers, Abra

Most of the mango farmers respondents are male and above 41 years old (Table 7). All have reached high school level meaning they are functionally literate. Most of them are members of a farmer association.

Data Collection

The interview was done face-to-face using an interview schedule, which was pretested in a previous study under the same program area by the same researchers (see Launio et al., 2022) and modified and supplemented based on the identified adaptation practices. Respondents were informed about the project and consent through signature was sought before the interview. Validation of the survey data was done through recall to survey respondents by phone, and through focus group discussion with crop stakeholders in the study areas. Invited participants during the validation are farmer leaders in the relevant municipalities, agricultural extension workers, and other key stakeholders and informants in relation to the adaptation being evaluated.

Data Analysis

Depending on the type and the adoption status of the climate resilient adaptation practices identified in Pablo et al. (2023) for the identified priority hazards for the province in Lumbres et al. (2023), cost and return analysis, and cost-benefit analysis (CBA) were used to analyse the financial economic feasibility of the climate resilient adaptation practice relative to farmer practice or to the counterfactuals. ANOVA and T-test (parametric or non-parametric) were used to analyze whether differences between adopters and non-adopters or between adaptation and counterfactual were significant.

For rice and corn adaptation practices, CBA and CRA were used to determine the economic feasibility of using Solar Powered Irrigation System. Net effects were calculated to determine the financial gain or loss from adopting wherein a positive change in income indicates a net financial gain to farmer-adopter. The CBA assumptions were based on the actual data generated from the survey and data and information from key informant interviews. Also coding and recoding were done to arrive at the most common farmer’s perceptions of the advantages and disadvantages of the adaptation strategies.

Table 6. Respondents Profile, Rice and Corn Farmers, Abra, 2023

Item	Rainfed (n=26)		Diesel Pump (n=20)		Electric Pump (n=18)		SPIS dugwell users (n=9)		SPIS River (n=21)		Irrigated (n=19)	
	n	%	n	%	n	%	n	%	n	%	n	%
Sex												
Male	19	73.08	13	65.00	15	83.33	8.00	88.89	15	71.43	15	78.95
Female	7	26.92	7	35.00	3	16.67	1.00	11.11	6	28.57	4	21.05
Age (mean)		**55**		**49**		**50**		**53**		**54**		**53**
20-30	1	3.85	1	5.00	-	-	-	-	-	-	1	5.26
31-40	3	11.54	4	20.00	4	22.22	-	-	1	4.76	1	5.26
41-50	5	19.23	6	30.00	6	33.33	3.00	33.33	6	28.57	6	31.58
51-60	5	19.23	6	30.00	4	22.22	5.00	55.56	9	42.86	6	31.58
61 and above	12	46.15	3	15.00	4	22.22	1.00	11.11	5	23.81	5	26.32
Farming Experience		**29**		**27**		**27**		**24**		**31**		**25**
10 years and below	4	15.38	3	15.00	1	5.56	2.00	22.22	2	9.52	3	15.79
11 - 20	3	11.54	4	20.00	6	33.33	3.00	33.33	5	23.81	6	31.58
21-30	8	30.77	6	30.00	5	27.78	1.00	11.11	2	9.52	3	15.79
31-40	4	15.38	6	30.00	5	27.78	2.00	22.22	8	38.10	4	21.05
41 years and above	7	26.92	1	5.00	1	5.56	1.00	11.11	4	19.05	3	15.79
Educational Attainment												
Elementary Undergraduate	3	11.54	3	15.00	-	-	1.00	11.11	4	20	4	21.05
Elementary Graduate	5	19.23	4	20.00	6	33.33	3.00	33.33	4	20	7	36.84
HS Undergraduate	4	15.38	6	30.00	-	-	-	-	2	10	-	-
HS Graduate	6	23.08	3	15.00	2	11.11	1.00	11.11	6	30	5	26.32
College Undergraduate	2	7.69	2	10.00	6	33.33	3.00	33.33	1	5	-	-
College Graduate	1	3.85	1	5.00	3	16.67	1.00	11.11	2	10	1	5.26
Vocational Graduate	5	19.23	1	5.00	1	5.56	-	-	1	5	2	10.53
Organization Membership												
Irrigators Association	1	3.85	-	-	-	-	-	-	-	-	-	-
Farmers Association	25	96.15	9	45.00	16	88.89	8.00	88.89	21	100	16	84.21
Cooperatives	3	11.54	-	-	-	-	-	-	-	-	-	-
Others	-	-	-	-	-	-	-	-	-	-	-	-
None	-	-	11	55.00	2	11.11	1.00	11.11	-	-	3	15.79

Table 7. Respondents Profile, Mango Farmers, Abra

Item (N-20)	Frequency	Percentage (%)
Sex		
Male	16	80
Female	4	20
Age		
20-30	1	5
31-40	1	5
41-50	7	35
51-60	5	25
61 and above	6	30
Farming Experience		
10 years and below	5	25
11-20	7	35
21-30	8	40
31-40	-	-
41 years and above	-	-
Educational Attainment		
Elementary Undergraduate	-	-
Elementary Graduate	-	-
High School Undergraduate	7	35
High School Graduate	6	30
College Undergraduate	1	5
College Graduate	5	25
Vocational Graduate	1	5
Organizational Membership		
Irrigators Association	1	5
Farmers Association	14	70
Cooperatives	1	5
Others	-	-
None	5	25

For the cost-benefit analysis, net present value (NPV), benefit-cost ratio (BCR), internal rate of return (IRR), and payback period (PP) were used as economic indicators. The. NPV is the value of the discounted future net benefits. In this study, the net benefits of intervention were computed as the difference or change in the net benefits when using the climate-resilient adaptation (e.g., rice production with water pump) compared to the counterfactual (rain-dependent rice production). If the resulting NPV of the adaptation practice considering the assumed project duration is greater than zero, it is viable and would be profitable for the farmers to use. Otherwise, an intervention with an NPV<0 should not be promoted. BCR is calculated by dividing the total discounted benefits by the total discounted costs, while the internal rate of return (IRR) is the discount rate that makes the NPV=0. The intervention is deemed worthwhile to invest in if the BCR>1. For the IRR, the decision rule is that the adaptation practice is worth implementing if the calculated IRR is greater than the acceptable discount rate. The discount rate used in this study is 10%, which is the NEDA-ICC recommended rate. While the evaluation framework is largely using the “with and without”, this was not possible for some of the prioritized adaptation practices, so only qualitative perceptions were gathered. For those with substantial data, coding and recoding were done to arrive at the most common farmer’s perceptions of the advantages and disadvantages of the adaptation strategies.

One benefit of the SPIS is the carbon saving from the evaded use of diesel fuel to support corn farming during the dry season. To calculate the GHG emission for diesel-powered irrigation pumps, the average annual fuel consumption (FC) was multiplied by the emission factor (EF) described in the equation:

$$GHG = FC \times EF \times GWP$$

wherein: GHG= GHG emissions from fuel used by the machinery, kg CO_2

FC = amount of diesel used by the machinery, liters

EF = emission factor of diesel

GWP - Global Warming Potential of CO_2, CH4 and NO_2

For diesel pump use, the assumed emission factor for CO_2 is 2.71 kg GHG; 0.00127 for methane (CH_4) and 0.00107 for NO_2 (EPA, 2023). The assumed carbon price was Php278.15/kg CO_2-eq converted from US$5 per ton CO_2 (Duggal, 2021; Singapore Ministry of Sustainability and the Environment, 2024).

V. RESULTS AND DISCUSSION

A. Climate Risk Vulnerability Assessment

Sensitivity Index

Current crop occurrence

The crop occurrence maps of corn, rice, mango and coffee are the results of the participatory mapping that was based on the personal knowledge and existing reports/ data from their respective municipality. Based on Figure 5(A), majority of the rice production areas are found in municipalities found on the western side of the province. Most of the high production (=/> 2.5 tons/ha) areas are found in the municipalities of Pidigan, San Quintin, Tubo, and Tayum while most of the moderate production (2.6-4.4 tons/ha) areas are in Bangued, Dolores, Lapaz, Luba, San Isidro, Tayum, and Villaviciosa. These municipalities are found in low elevation areas with flat to rolling topography. Sparce rice production areas with moderate or low (</= 2.5 tons/ha) production are found on the eastern side of the province which are of high elevation. According to PhilRice, average rice production in 2023 in Abra is 3.41 tons/ha which ranges from 2.86 tons/ha in non-irrigated areas to 3.69 tons/ha in irrigated areas. The municipalities with the highest production are Tubo (3.5 tons/ha), Pidigan (3.47 tons/ha), and Bangued (3.42 tons/ha) (PhilRice, 2022).

Just like in rice, large corn production areas are found on the western side of the province as shown in Fig 5 (B). San Quintin, Pidigan and some areas of Tubo have high (>2.5 tons/ha) corn production. Langiden, Bangued, La Paz, San Juan, Peñarrubia, Sallapadan, Manabo, Lagangilang, parts of Tubo and Tineg have moderate production (2.3-2.5 tons/ha) while the rest of the municipalities have low (<2.3 tons/ha) production.

Mango is mostly produced in areas of low elevation which includes the top producing (high production: >6.9 tons/ha) municipalities of Tubo, San Juan, western portion of Bangued and northern portion of San Isidro (Figure 5C). Langiden, portions of Bangued, San Isidro, Sallapadan, eastern portion of Bucloc, northern portion of Peñarrubia, Lagangilang, La Paz, and portion of Danglas have moderate production (4.1-6.9 tons/ha). Low production (<4.1 tons/ha) is found in Lagayan, Lacub, Malibcong, Daguioman, Boliney, western portion of Bucloc, Manabo, Bucay, Pidigan, and San Quintin.

Finally, coffee is produced in municipalities on the eastern side of the province with high elevation (Figure 5D). Coffee production areas are sparse and can be found in the municipalities of Boliney, Bucloc, Daguioman, and Malibcong with moderate (0.6-1.4 tons/ha) to low (<0.6 tons/ha) production.

Crop Sensitivity

The results of sensitivity analysis show the changes in climatic suitability of selected crops in Abra due to climate change by year 2050 through climate modeling and use of species distribution model or the Maximum Entropy. Crop production is inherently sensitive to variability in climate. Some of the early studies of the impacts of climate change on crops highlighted the importance of changes in crop development at warmer temperatures in determining the impact change on crop yield (Craurd, 2009).

Rice

Historically, rice is one of the major crop in Abra and it continues until the present. Over the years, farmers of rice often change the variety of rice they grow . Either wet or drought tolerant varieties are grown to adapt to the changing climate. Some of the varieties produced are Rc 118 and Rc160 because of greater yield and theire acclimatization to temperature and climate. Palanog (2015) mentioned that the use of adaptable and high-yielding varieties is one of the key factors in achieving rice sufficiency in the country.

The raster data shown in Figure 6 indicate the change in the current and future crop suitability of rice in all municipalities. Areas that have lighter color tend to have high crop suitability as compared to areas with darker color. Currently, rice has very high suitability in San Juan, La Paz, Dolores, Lagangilang and Bucay. However, it is projected that these municipalities will be the least suitable for rice production by 2050. The result of the sensitivity analysis (Figure 8A) show that in 2050 rice have very high suitability in the municipalities of Boliney, Daguioman, and Tubo followed by Malibcong compared to the rest of the municipalities where there are losses in suitability.

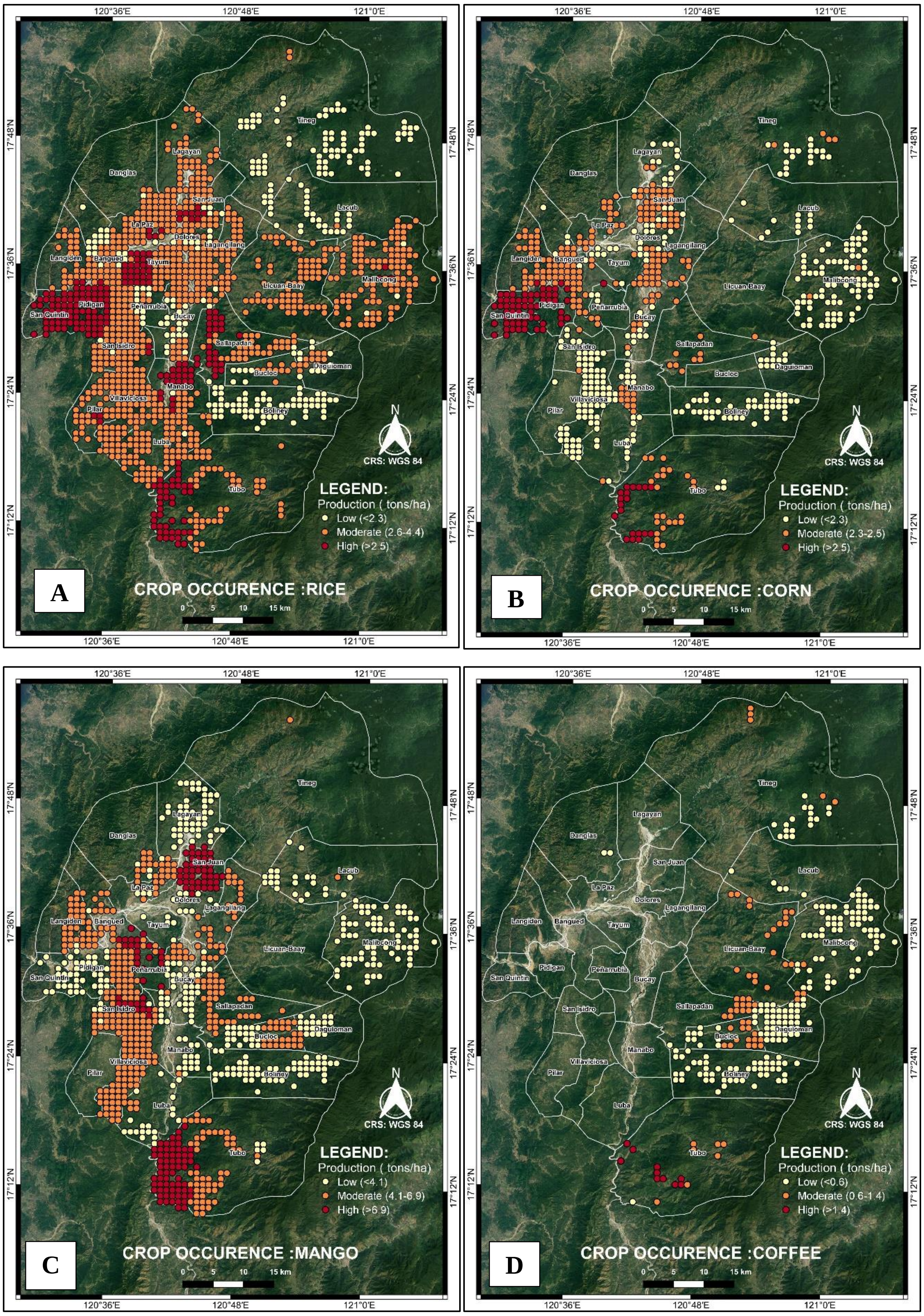


Figure 5. Crop occurrence or rice (A), corn (B), mango (C), and coffee (D) in Abra province.

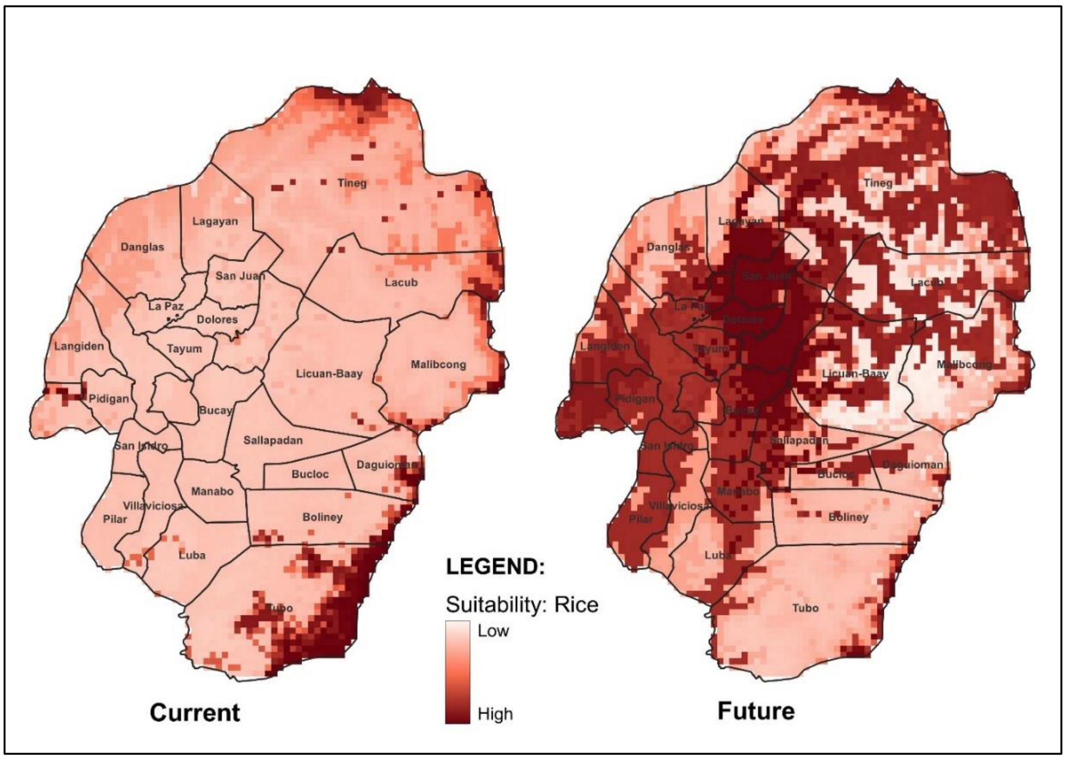


Figure 6. Baseline and projected crop suitability of rice in Abra.

<u>Corn</u>

Figure 7 shows the raster data on the current and future suitability of corn in all the municipalities in Abra. Areas that have lighter color tend to have high crop suitability compared to areas with darker color. The result of the sensitivity analysis (Figure 8B) shows that it is projected that Malibcong, Daguioman, Boliney and Tubo have very high crop suitability whereas the rest of the municipalities will have a loss in crop suitability. Corn is one of the most important staple crops in the Philippines which is ranked second to rice in the utilization of agricultural resources (Exconde, 1975).

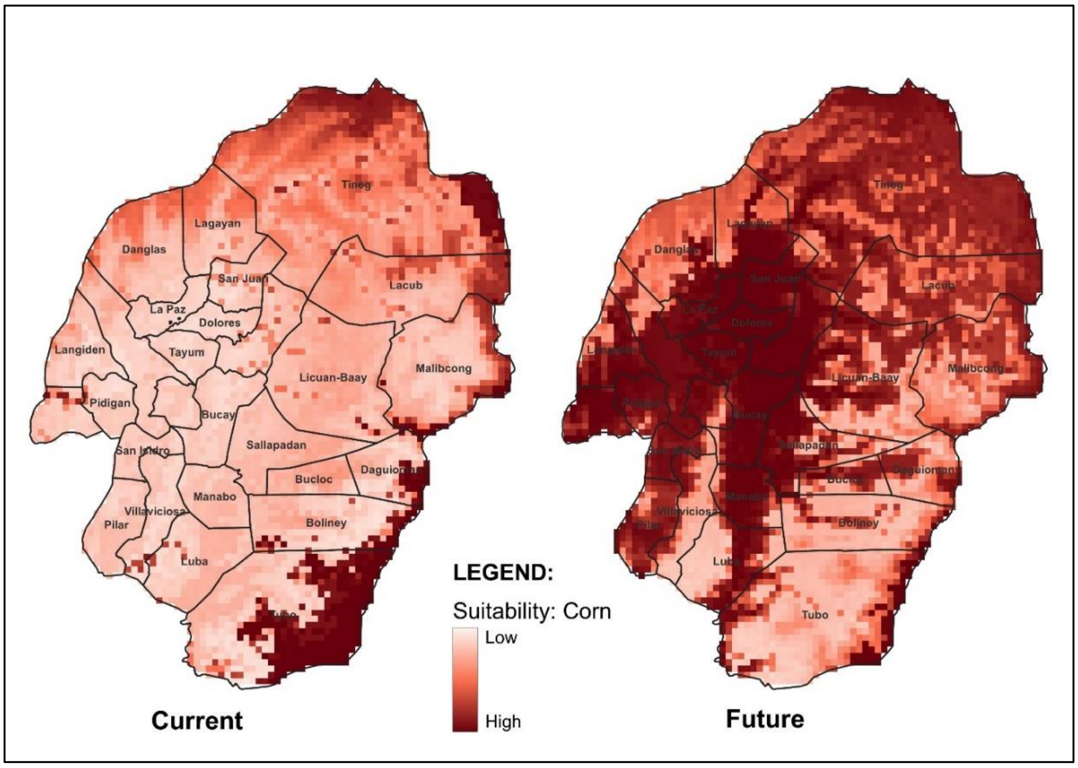


Figure 7. Baseline and projected suitability of corn in Abra.

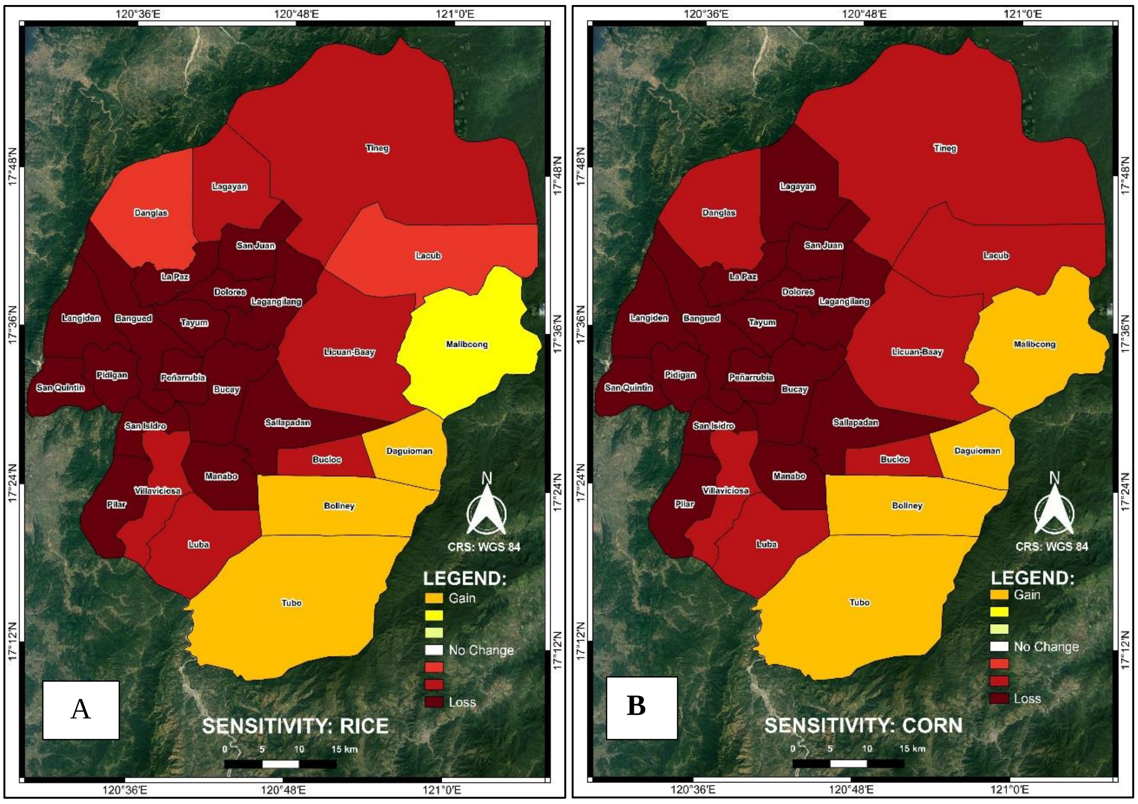


Figure 8. Sensitivity maps of Rice (A), and Corn (B) in Abra province.

Coffee

Climate change and variability already had and will continue to harm coffee production throughout the world. Between 80% and 90% of the world's coffee is produced by smallholder farmers who depend on nature (Ayal, 2023). Coffee has become one of the popular hot beverages in the Philippines and become a normal thing to do. The raster data of the current and future suitability of the crop in Abra is shown in Figure 9 while the suitability is in Figure 11 B.

Mango

Mango is the national fruit and is a high value crop in the Philippines that boost to the rural and national economy. The raster data of the current and future suitability of the crop in Abra is shown in Figure 10. At present, majority of the municipalites are suitable for the production of mango. However, it is projected that by 2050 (Figure 11 B), mango will gain suitability in the municipalities of Malibcong, Daguioman, Boliney, and Tubo and will loss suitability in the rest of the province.

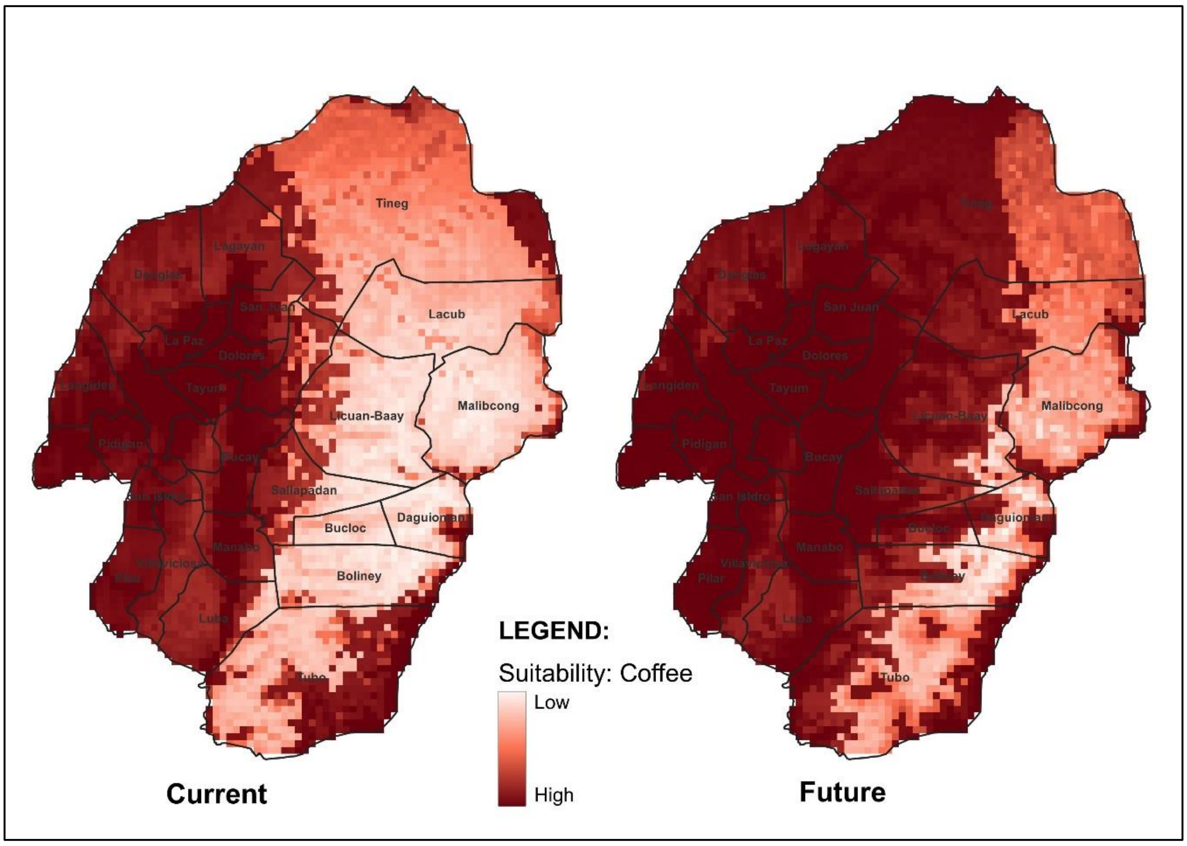


Figure 9. Baseline and projected crop suitability of coffee in Abra.

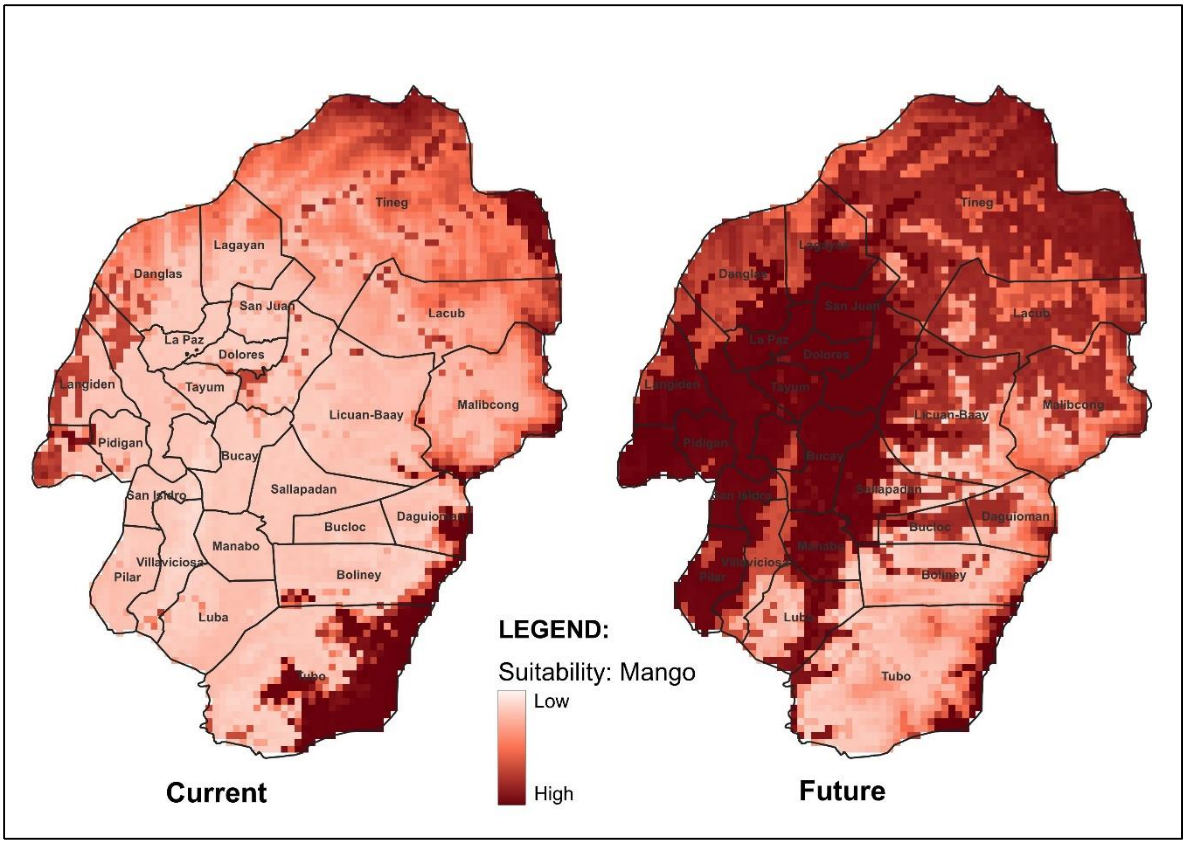


Figure 10. Baseline and projected crop suitability of mango in Abra.

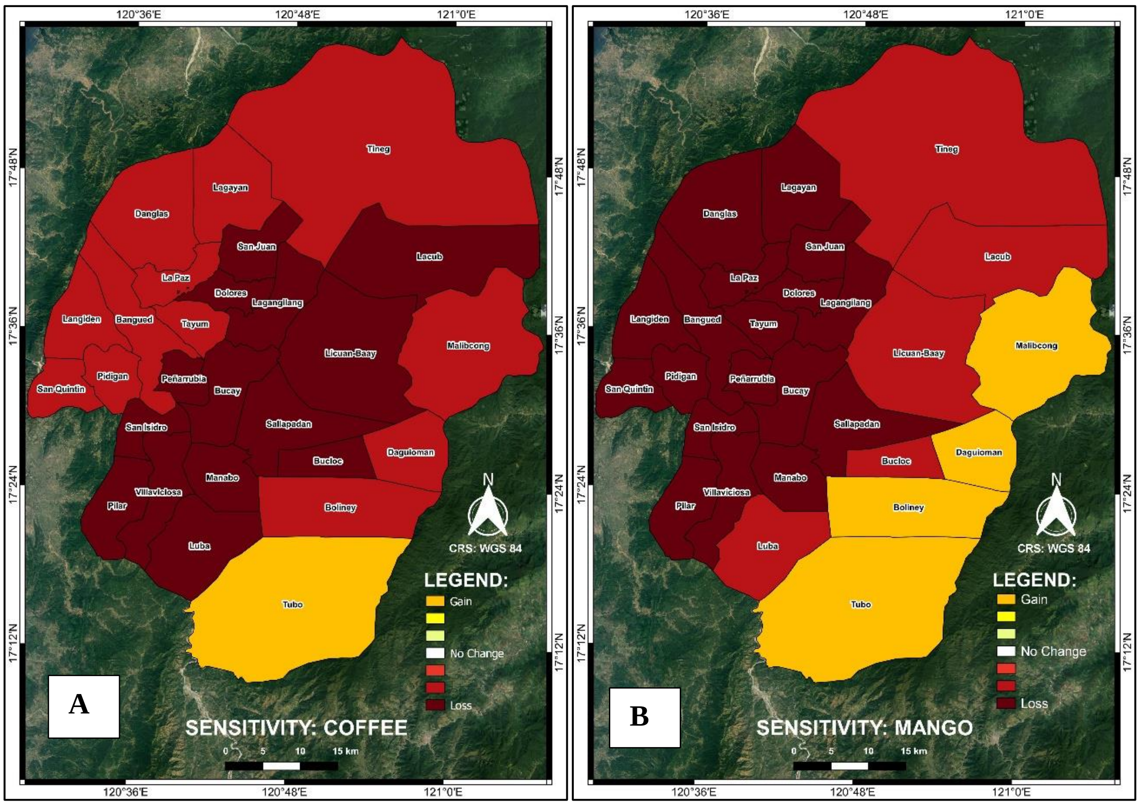


Figure 11. Sensitivity map of Coffee (A) and Mango (B).

Hazard index

The Philippines is highly vulnerable to the impacts of climate change due to its high exposure to natural hazards-dependence on climate-sensitive natural resources, and vast coastlines where all major cities and the majority of the population reside as stated by the World Bank

Group (2017). Five (5) hazards were used to come up with the hazard index. These include tropical cyclone, flood, drought, soil erosion, and landslide. These hazard maps were provided by CIAT. The values for each hazard were normalized to give uniform weights and classifications.

Tropical Cyclone

Climatically, the Philippines have been classified as one of the most disaster-prone countries in the world (World Bank, 2023). Tropical Cyclone as defined by PAG-ASA is a warm-core low pressure system associated with a spiral inflow of mass at the bottom level and spiral outflow at the top level. It is one of the most experienced hazards in the Philippines due to the country's geographical location. It generally produces heavy rains and destroys crops and properties (DOST, 2023). The Philippines lies in the world's most cyclone-prone region, averaging 19–20 cyclones each year, 7–9 of which make landfall (Herrera, 2013). For the past 5 years, Philippines have experienced 95 Tropical Cyclones. Typhoon and flash-flood, as mentioned by Balahadia (2019), reduce farm productivity by damaging farm input.

Based on the results shown in Figure 12(A), Malibcong and Lacub have the highest exposure to Tropical Cyclone among all the municipalities of Abra which are followed by Tineg, Licuan-Baay, and Daguioman. These municipalities are located in in areas with high elevation within the Central Cordillera Range. The municipalities of Sallapadan, Bucloc and Boliney fall under moderate exposure while the rest fall under low to very exposure.

Flood

Floods depend on precipitation intensity, volume, timing, antecedent conditions of rivers and their drainage basins (e.g., presence of snow and ice, soil character, wetness, urbanization, and existence of dikes, dams, or reservoirs) (IPCC, 2007). This is an overflow water onto normally dry land as defined by National Weather Service in Morristown, Tennessee. Threat of flood has been increasing because of land degradation that contributes to surface runoff. Abra is listed as one of the flood prone areas in the Philippines. The overall topography of the province is the main reason why it is constantly flooded especially the municipalities located near the Abra River and in lower elevation areas such as Manabo, Tayum, Bangued, Dolores, La Paz and Pidigan.

Figure 12 (B) show that Tayum and Dolores has the highest exposure to flood followed by Bangued (capital) and La Paz since they are located in a lower elevation and near the Abra River. Moderately exposed municipalities are San Juan, Bucay and Manabo while the rest of the municipalities of Abrahave low exposure to very low exposure to flood.

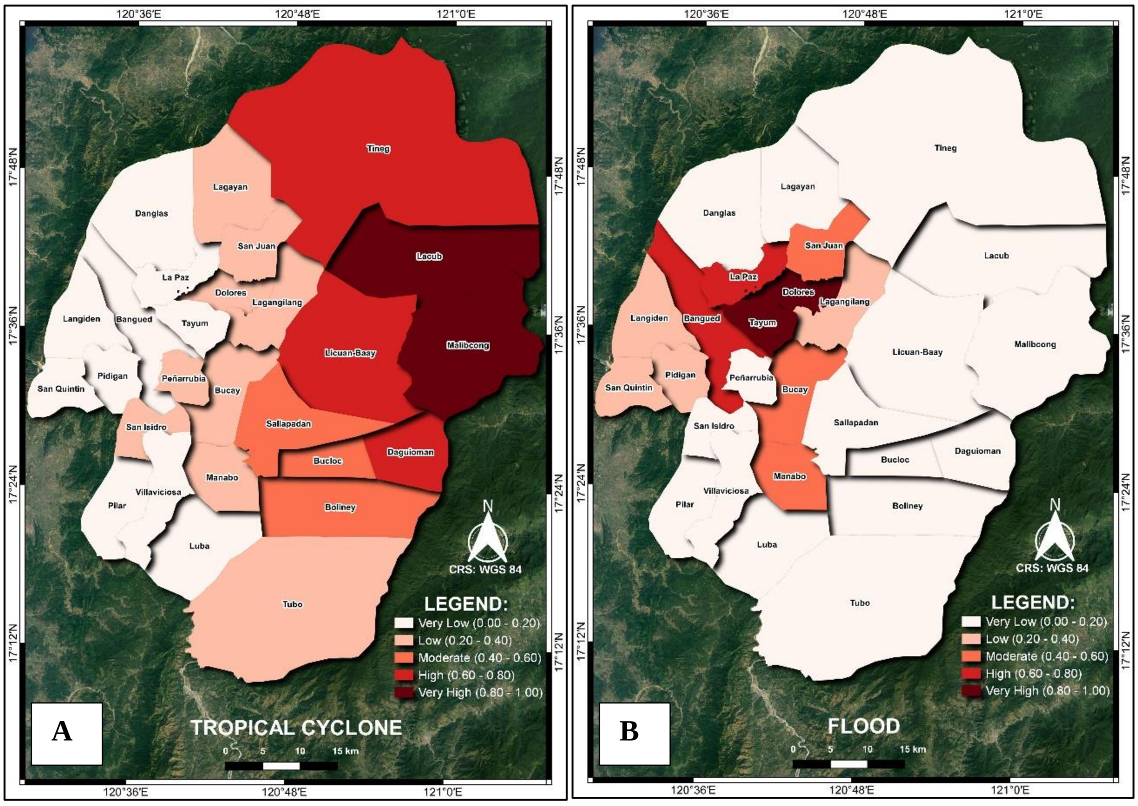


Figure 12. Abra Hazard: Tropical Cyclone (A), Flood (B).

Landslide

Landslide, according to PHIVOLCS is the mass movement of rock, soil, and debris down a slope due to gravity. It is a natural process that occurs in steep slopes. The number of landslide disasters fluctuated and peaked in 1999. In 2022, the number increased compared to the previous year when the country recorded 30 recorded landslides (Statista, 2023) . CAR is a mountainous region exposed to landslide which has the highest risk to this hazard. In the year 2022, the province of Abra has experienced an earthquake that triggered numerous landslides throughout the province having 58 landslides reported. As Paderes et. al (2021) mentioned, upland areas in Abrahave high landslide susceptibility rating.

Results show (Figure 13A) that eight (8) municipalities are highly exposed to landslide. These are the municipalities of Danglas, Tineg, Lacub, Licuan-Baay, Malibcong, Daguioman, Boliney and Tubo. Municipalities under high exposure are Lagayan, Langiden, Sallapadan, Bucloc, and Luba. All of the earlier mentioned municipalities are found in mid to high elevation areas with mountainous terrains. Under low exposure are San Quintin, San Isidro, Pillar, Manabo, Peñarrubia, Bangued, and Lagangilang while the rest of the municipalities have very low exposure.

Soil Erosion

Soil erosion is a serious threat to the sustainability of agricultural systems in the Philippines (Olabisi, 2011) and considered one of the worst environmental issues in the country (Salvacion, 2022). It is a major agricultural and environmental problem in the Philippines primarily caused by rainfall under upland, subsistence rain-fed farming. Philippine Forest cover has been depleting since 1934-2010 up until the recent year 2023. Humans continuously degrade vegetation that covers the soil like land conversion into agricultural lands, shifting cultivation or "kaingin” system and other anthropogenic activities that causes soil erosion. Alt (1989) also mentioned that agricultural soil productivity is decreased by lowering crop yield. The province of Abra is included in the areas that are heavily eroded (Medina, 2019). Almost all of the agricultural land areas with steep terrain suffer from moderate to severe soil erosion (Tababa, 2023) and the slope in Abra province ranges from 0 to more than 50 percent.

Result show that only Licuan-Baay and San Isidro have the highest exposure to soil erosion followed by Tineg, Lacub, Lagangilang, Peñarrubia and Villaviciosa (Figure 13B). Municipalities which are exposed to soil erosion are those that are either found in mountainous areas or those that Municipalities with moderate soil erosion are Lagayan, Danglas, Langiden, Sallapadan, Boliney, Pilar, Luba, and Tubo. Eight municipalities are under low exposure, and four have very low exposure to soil erosion.

Drought

The term drought may refer to meteorological drought (precipitation well below average), hydrological drought (low river flows and water levels in rivers, lakes and groundwater), agricultural drought (low soil moisture), and environmental drought (a combination of the above) (IPCC, 2007). Sathyan et al. (2018) mentioned in their research that one billion people in Asia could face water shortage which may lead to drought and land degradation by the 2050s. Philippines is highly vulnerable to drought, resulting in severe impacts to crop productivity, water availability, and food security (Porio, 2019).

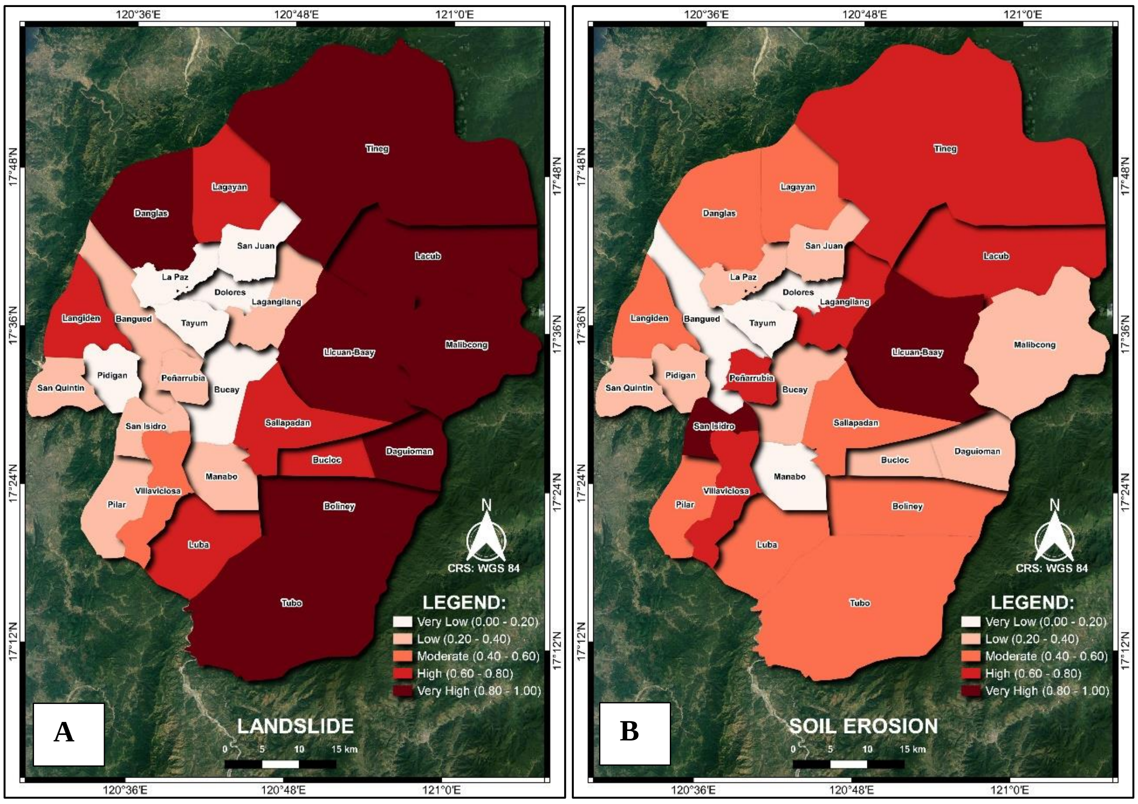


Figure 13. Abra Hazard: Landslide (A) and Soil Erosion (B).

In another study conducted, it was foreseen that most of the western part of Luzon will be drier as rainfall is expected to be lesser (Israel, 2012) thus occurrence of drought is more likely. In Abra, drought is observed mostly in the months of April-May. Drought highly affects farmers due to lack of water supply for their farms that can lead to low productivity of crops especially rice and corn. It was also mentioned by Paderes et. al (2021) that low harvest is sometimes attributed to the decrease or sometimes the absence of rainfall. On the other hand, drought can significantly affect other crops like rice, corn and mango that mostly thrive during summer.

In Abra, municipalities of Bucay, Sallapadan, and Pillar have the highest exposure to drought followed by municipalities of Bangued, Langiden, Lagangilang, Manabo and Luba. Most of these municipalities are rice and corn producing areas. On the other hand, themunicipalities of San Quintin, Pidigan, San Isidro, Tubo, Danglas, San Juan, Lagayan, Licuan-Baay and Tineg have moderate exposure while La Paz, Tayum, Dolores, Peñarrubia and Villaviciosa have low exposure. It is observed in the result that drought is experienced mostly in the lowland areas in the province whereas, drought does not significantly affect most of the upland areas (Figure 14A).

Overall Hazard Index

The normalized values of the eight (5) hazards were summed to come up with the overall hazard index of Abra province which is shown in Figure 14 (B). The municipalities of Tineg, Licuan-Baay, Sallapadan and Bucay have the highest exposure to hazard as these are classified to have a high to very high exposure to landslide, drought, soil erosion, and flood. These were followed by Lacub, and Malibcong with high exposure to tropical cyclone and landslide, moreover, Lacub and Lagangilang have high exposure to soil erosion, and Lagangilang with high exposure to drought. The rest of the municipalities have very low to moderate exposure.

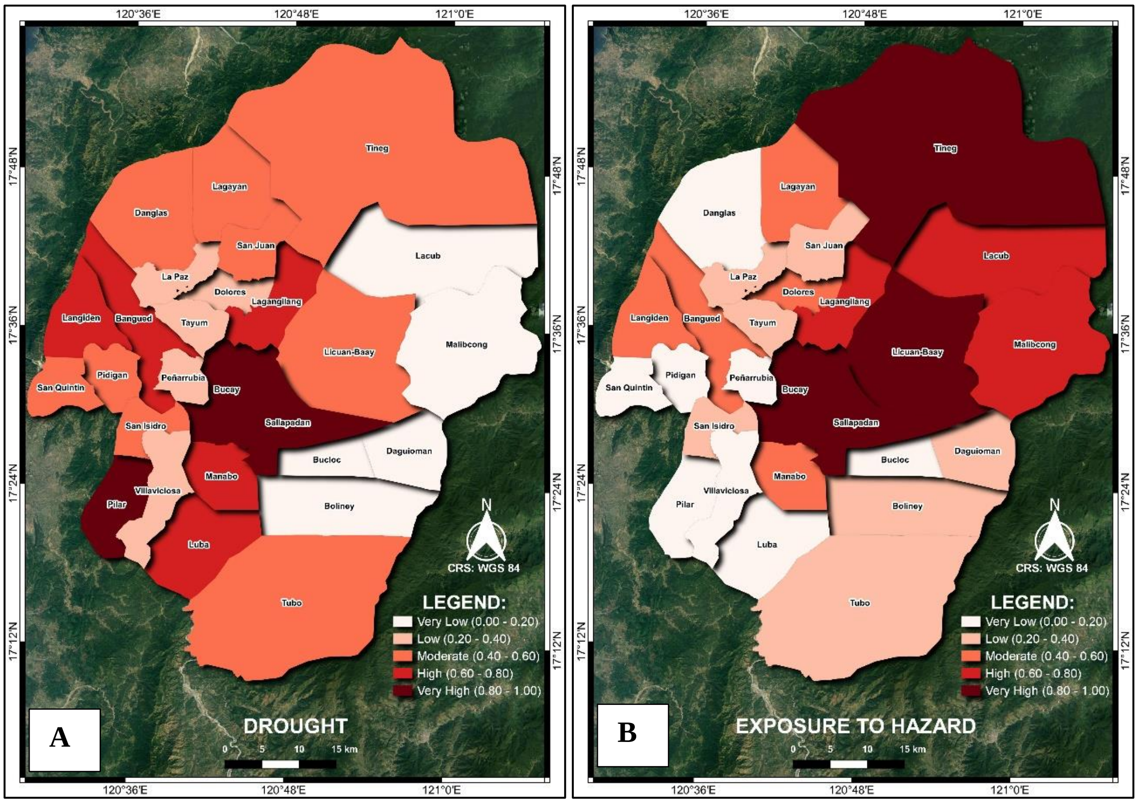


Figure 14. Abra Hazard: Drought (A), Overall Hazard (B).

Adaptive Capacity Index

The following presents the spatial analysis of all 6 capitals as well as the aggregated overall adaptive capacity index. Each indicator for a particular capital was normalized for easier comparison and analysis of data due to the large difference between the values of these indicator. Data were classified as Very Low (0 – 0.20), Low (0.20 – 0.40), Moderate (0.40 – 0.60), High (0.60 – 0.80), and Very High (0.80 – 1.00) adaptive capacity.

Abra posted an economic growth of 10.0 % in 2021, the fastest growth among economies in the Cordillera region during the period (PSA, 2022). Result shows that the municipality of Bangued has very high adaptive capacity in terms of the economic capital (Figure 15A). Bangued, being the capital of the province, is the center of trading, establishments, health centers and education thus it has more economic activities. Bucay have moderate adaptive while La Paz, Lagangilang, Lagayan, Licuan-Baay, Manabo, Peñarrubia, Pidigan, Pilar, San Juan, San Quintin, Tayum, and Villaviciosa have low while the rest of the municipalities have very low adaptive capacity namely Boliney, Daguioman, Danglas, Dolores, Lacub, Langiden, Luba, Malibcong, Sallapadan, San Isidro, Tineg, and Tubo. The municipalities that were considered to have very low adaptability have low revenue, few banks or financial institutions and, and low LGU budget.

The municipality of Bangued have very high adaptive capacity when it comes to physical capital (Figure 15B). The presence of significant number of facilities such as public utility vehicles (PUVs), schools, clinics and hospitals, automated teller machines (ATMs), ambulances, firetrucks, evacuation centers, pharmacies, and gas stations contribute to the high index of the said municipality. It is followed by eight (8) municipalities with low adaptive capacity namely Lagayan, Danglas, Tayum, Bucay, Pidigan, San Quintin, Villaviciosa, and Malibcong. Whereas the rest of the municipalities are under very low adaptive capacity.

Figure 16 (A) shows that Bangued and Peñarrubia have very high adaptive capacity in terms of the institutional capital which is followed by seven (7) municipalities with high adaptive capacity, namely; Tayum, Pidigan, Bucay, Pilar, Dolores, Lagangilang, and Malibcong. While municipalities that have moderate adaptive capacity are Danglas, Lagayan, La Paz, San Juan, Lacub, Licuan-Baay, Sallapadan, Manabo, Luba, Tubo, and San Quintin. Compared to the other capitals, the adaptive capacity for this capital is high since the municipalities have comprehensive development plans and investment incentive codes, and the processing of business application and permits are fast.

In human capital (Figure 16B), only Bangued has very high adaptive capacity while the rest of the municipalities have very low adaptive capacity. This because Bangued has the highest number of public and private health workers such as doctors, nurses, and midwives, has the most number of teachers and students for both public and private secondary education and lastly has the most number of citizens with PhilHealth registration.

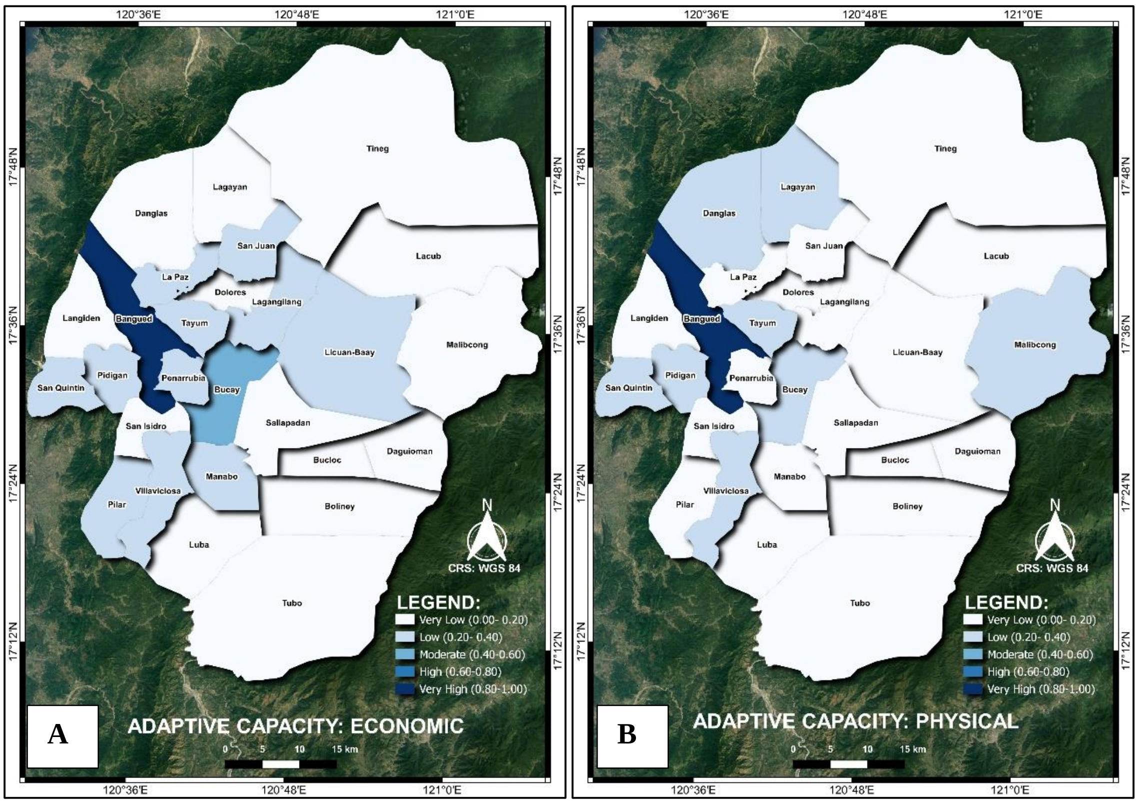


Figure 15. Economic (A) and Physical (B) capital.

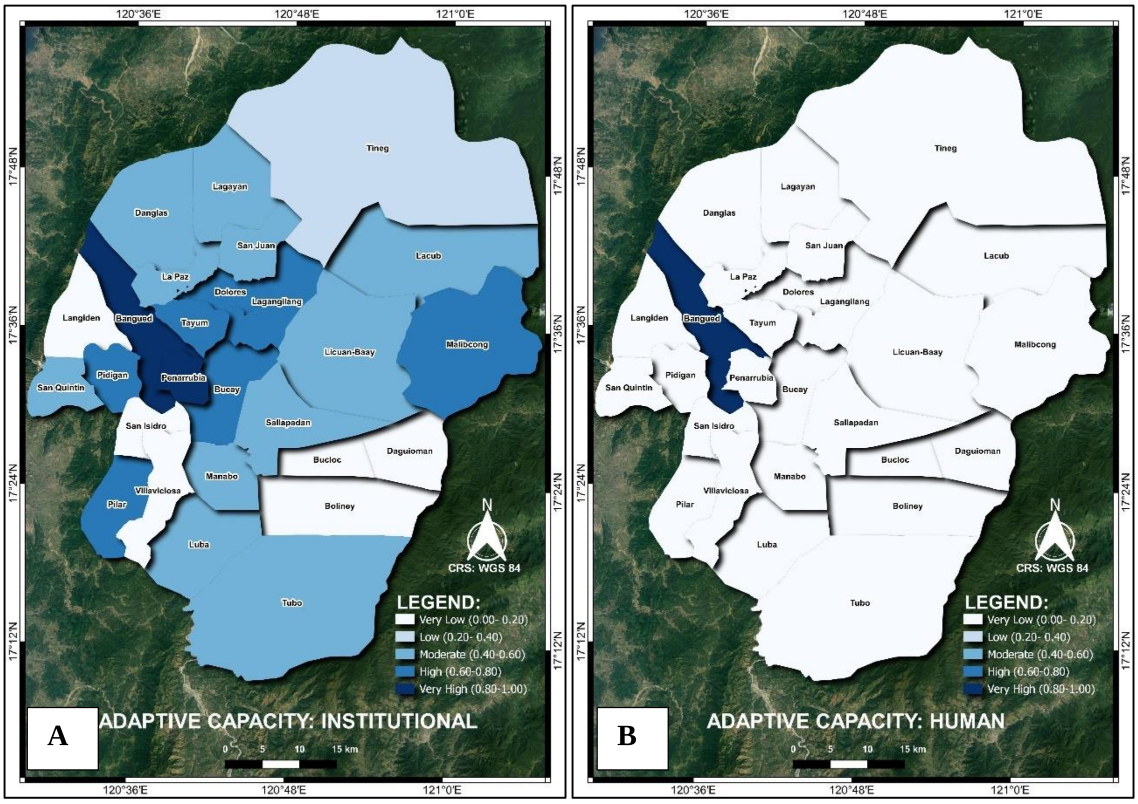


Figure 16. Institutional (A) and Human (B) capital.

Majority of Abra (11 municipalities) have very high adaptive capacity for the anticipatory capital as shown in Figure 17. These are Tineg, Lacub, Danglas, San Juan, Bangued, Peñarrubia, Tayum, Pidigan, San Quintin, Daguioman, Luba, and Tubo. Dolores and Bucay have high adaptive capacity followed by Bucloc, and Bucay with moderate adaptive capacity. Municipalities with low are Licuan-Baay, Malibcong, Sallapadan, and Lagangilang while the rest have very low adaptive capacity. Majority of the municipalities have high to very high adaptive capacity for this capital because of the presence of CLUP and DRRMP including offices and local ordinances that ensure the implementation of these plans. In addition, these municipalities have allotted a relatively high budget for DRRM.

In 2021, the total forest cover of Cordillera Administrative Region was approximately 804.8 thousand ha. (Statistica, 2023). Out of this, the province of Abra had 146,700 ha. of forest cover (DENR-FMB, 2010). Figure 17B shows that Tineg and Tubo have very high indices in terms of natural capital followed by Licuan-Baay and Malibcong with high indices. This is because of the presence of large areas in these municipalities that are still covered with closed and open forest and brushlands. Daguioman and Boliney have moderate, San Quintin, Langiden, Bangued and Lacub have low indices while the rest of the municipalities have very low indices. Parts of land located in the municipalities of San Quintin, Langiden, Pidigan, Bangued, La Paz, Tayum, Lagangilang, Bucay, Manabo, Luba, and Tubo forms the Abra River Basin stated as a Candidate Key Biodiversity Areas (Critical Ecosystem Partnership Fund, 2019) while the Cassamata (Victoria) Hill Protected Landscape is located in Bangued which was declared through Proclamation No. 1305, s. 1974.

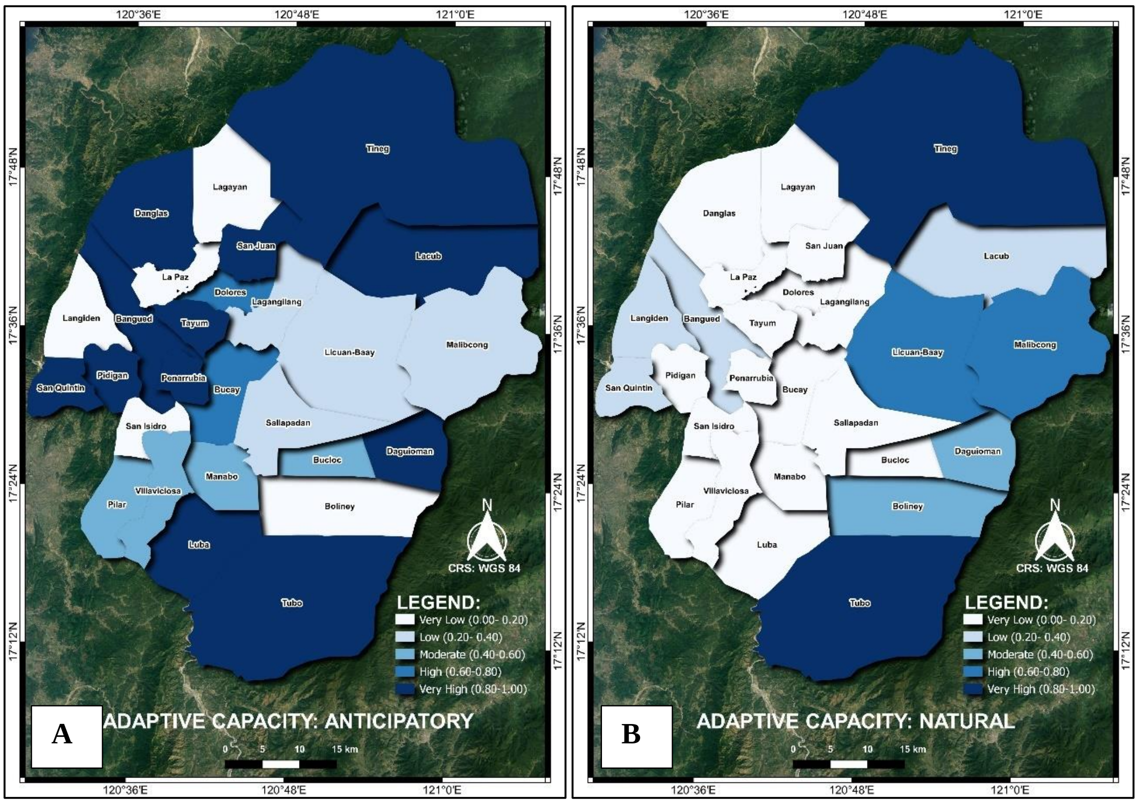


Figure 17. Anticipatory (A) and Natural (B) capital.

Adaptive capacity index is the aggregation of the six capitals as shown in Figure 18 (left). The capital of the province was classified the most adaptive (080-1.00) since it is consistent in 5 capitals except for Natural capital. Tineg, Tubo, and Bucay (0.40-0.60) follows then Danglas, San Juan, Dolores, Tayum, Lacub, Licuan-baay, Malibcong, Daguioman, Peñarrubia, Manabo, Luba, Pilar, Pidigan and San Quintin (0.20-0.40) while the rest of the municipalities have very low adaptive capacity (0-0.20). The inverted adaptive capacity index (Figure 17 right) shows the municipalities with the highest vulnerability (darkest color) in terms of their adaptive capacity. Bangued show the lowest since it already has the highest adaptive capacity for the overall result whereas shown also are Lagayan, La Paz, Langiden, San Isidro, Villaviciosa, Sallapadan, Bucloc, and Boliney with very high which means that these municipalities have low over all adaptive capacity. Lang (2018) mentioned that low adaptive capacity generally leads to increased vulnerability. This mainly supports the result since the most resilient municipality in the province have the highest adaptive capacity.

Overall Adaptive Capacity Index

Adaptive capacity index is the aggregation of the six capitals. Bangued is the most adaptive (0.80-1.00) since it consistently has high indices in 5 capitals except for natural capital. Tineg, Tubo, and Bucay (0.40-0.60) follows then Danglas, San Juan, Dolores, Tayum, Lacub, Licuan-baay, Malibcong, Daguioman, Peñarrubia, Manabo, Luba, Pilar, Pidigan and San Quintin (0.20-0.40) while the rest of the municipalities have very low adaptive capacity (0-0.20). The inverted adaptive capacity index (Figure 18 right) shows the municipalities that are most vulnerable (darkest color) due to low adaptive capacity. Bangued is the least vulnerable since it has the highest adaptive capacity for the overall result Figure 18 left-Lagayan, La Paz, Langiden, San Isidro, Villaviciosa, Sallapadan, Bucloc, and Boliney due to their limited adaptive capacity.

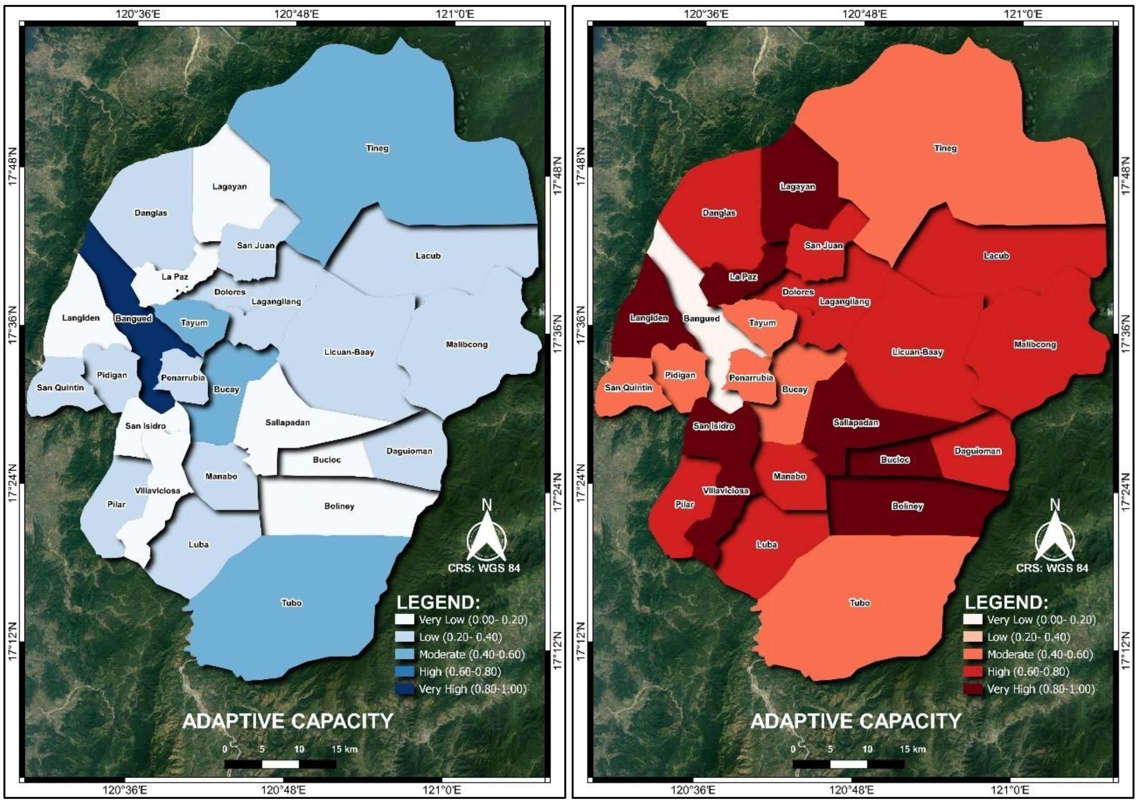


Figure 18. Over all adaptive capacity (left) and inverted adaptive capacity (right).

Climate Risk Vulnerability

The climate risk vulnerability map of each crop is an integration of the municipalities' exposure to hazard (15%), sensitivity (15%) and adaptive capacity components (70%). Different weights, as presented in Table 4, were used in assessing the vulnerability of each crop whereas the results showed consistency in detection of highly vulnerable municipalities. This shows that the characteristic of vulnerability, in terms of its component and respective indicators are not too sensitive to varying weight proportions. The weights used in this study was based on the previous study conducted by CIAT and the 70-15-15 weight was used as a reference.

*Rice*Rice, being the country's staple food, is a priority crop. Philippines belongs to the top producers of rice in the world as reported by the Department of Agriculture (2022). The province of Abra produced 76,921 MTS based on PSA (2023) data. The municipalities of Langiden, Sallpadan, La Paz, San Isidro and Lagangilang (Figure 19) have very high vulnerability in rice production despite the varying weights for the three components. But among these municipalities, only Sallapadan reported to have high rice production while the rest have moderate production (Figure 20).

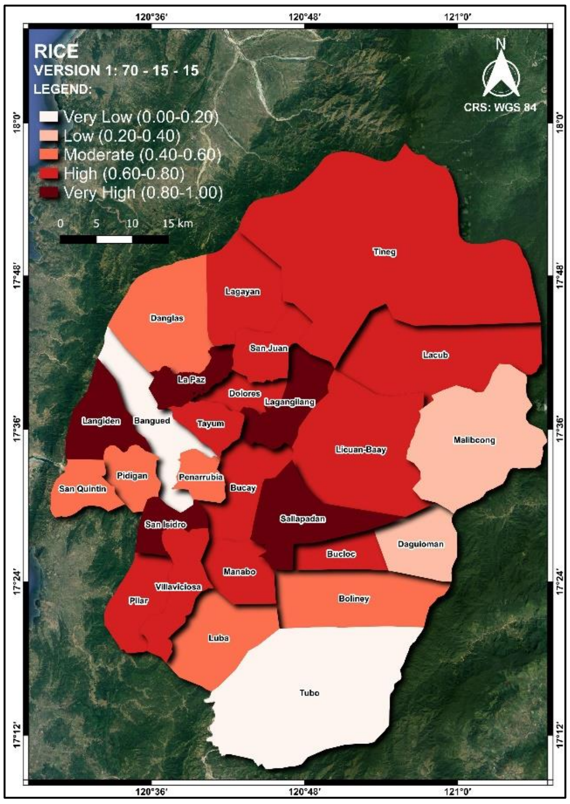


Figure 19. Rice CRVA result for versions one to five (B).

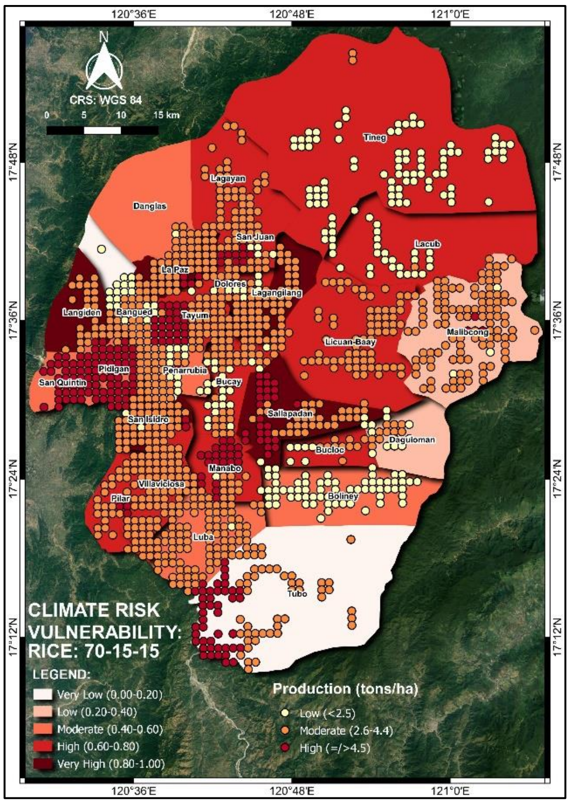


Figure 20. Rice CRVA with overlaid crop occurrence.

Rice is a highly vulnerable crop to climate change because of its critical dependence on water supply (Peñalba, 2013). On the other hand, Tubo and Bangued have very low vulnerability with, Tubo consistently having very low vulnerability using the different weights. Sallapadan, Tayum, Manabo, Langiden, Lagangilang, San Isidro and San Juan have moderate to high production and at the same time have high to very high vulnerability, thus, this indicates the need for interventions in these municipalities.

Corn

Corn is the second most important crop in the Philippines next to rice. Corn is produced throughout the province but generally, they produce white and glutinous corn. Although the corn production in CAR is estimated at 99,103.68 MTS (PSA, 2023) the province of Abra ranked third among the provinces in CAR with 13,610 metric tons or 14% of the total corn production in the region (PSA, 2023).

Based on the results of corn (Figure 21), the municipalities of Lagayan, La Paz, Langiden, Lagangilang, Sallapadan, Manabo, BUcloc,and San Isidro consistently have very high vulnerability despite the varying weights assigned for the three components (exposure, sensitivity, adaptive capacity). On the other hand, the municipalities of Malibcong and Tubo consistently have very low vulnerability. Municipalities that showed consistency as being highly vulnerable are Lacub, Licuan-Baay and Pilar. With the distribution of 70-15-15 as basis, Lagayan, La Paz, Langiden, San Isidro, Manabo, Sallapadan, Bucloc and Lagangilang have very high vulnerability while Tubo, Malibcong and Bangued that have very low vulnerability. As shown in Figure 22, the corn growing areas with reported high production are found in the municipalities of Pidigan, San Quintin and Tubo. However, corn production was determined have high vulnerability in San Quintin among the three mentioned above. Some municipalities with moderate corn production and the same time have high to very high corn production vulnerability are San Juan, La Paz, Langiden, and Lagangilang (Figure 22). Taking into consideration the vulnerability and crop occurrence and production, San Quintin, San Juan, and Langiden may be prioritized for implementation of mitigation or adaptation strategies.

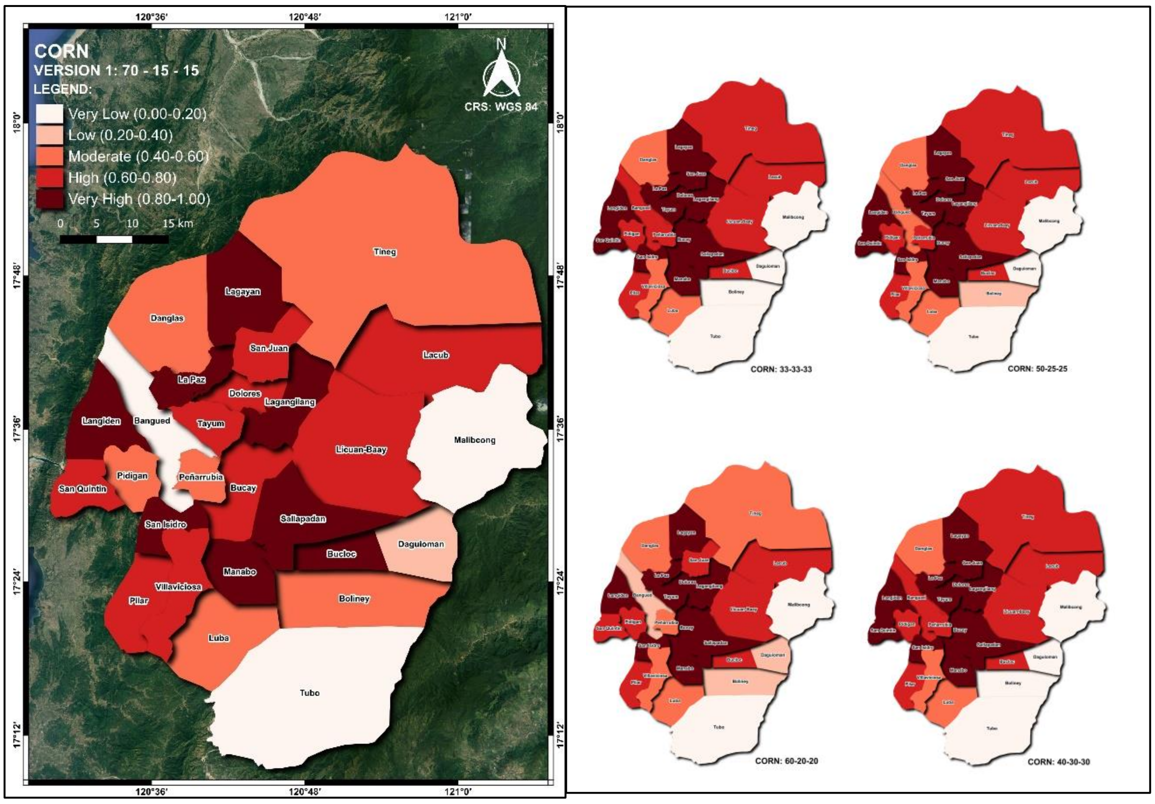


Figure 21. Corn CRVA result for and versions one to five.

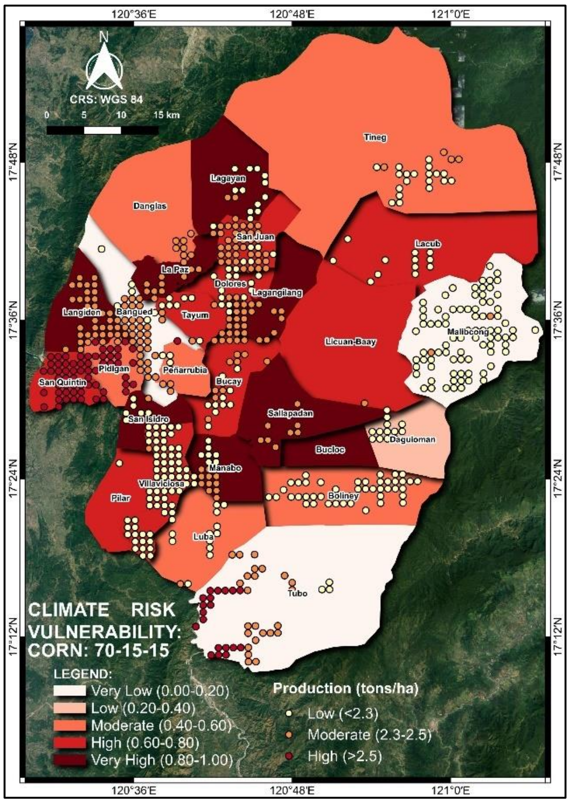


Figure 22. Corn CRVA with overlaid crop occurrence.

Mango

Aside from being the national fruit of the Philippines, mango is considered the third most important fruit crop in the country. Philippines is favored with a suitable climate that best suit one of the best mango variety, the carabao mango (HVCDP, 2022) including the province of Abra.

It is shown in Figure 23 that the municipalities of Lagayan, La Paz, Langiden, San Isidro, Manabo, Sallapadan, Bucloc and Lagangilang have very high vulnerability for its mango production despite the different weights, while the municipalities of Bangued, Malibcong and Tubo are the least vulnerable. Based on the crop occurrence and volume of production, together with the high to very high vulnerability of mango production. The municipalities of Lagangilang, Langiden, San Juan, Sallapadan, San Isidro, and Villaviciosa may be prioritized for climate change interventions (Figure 24).

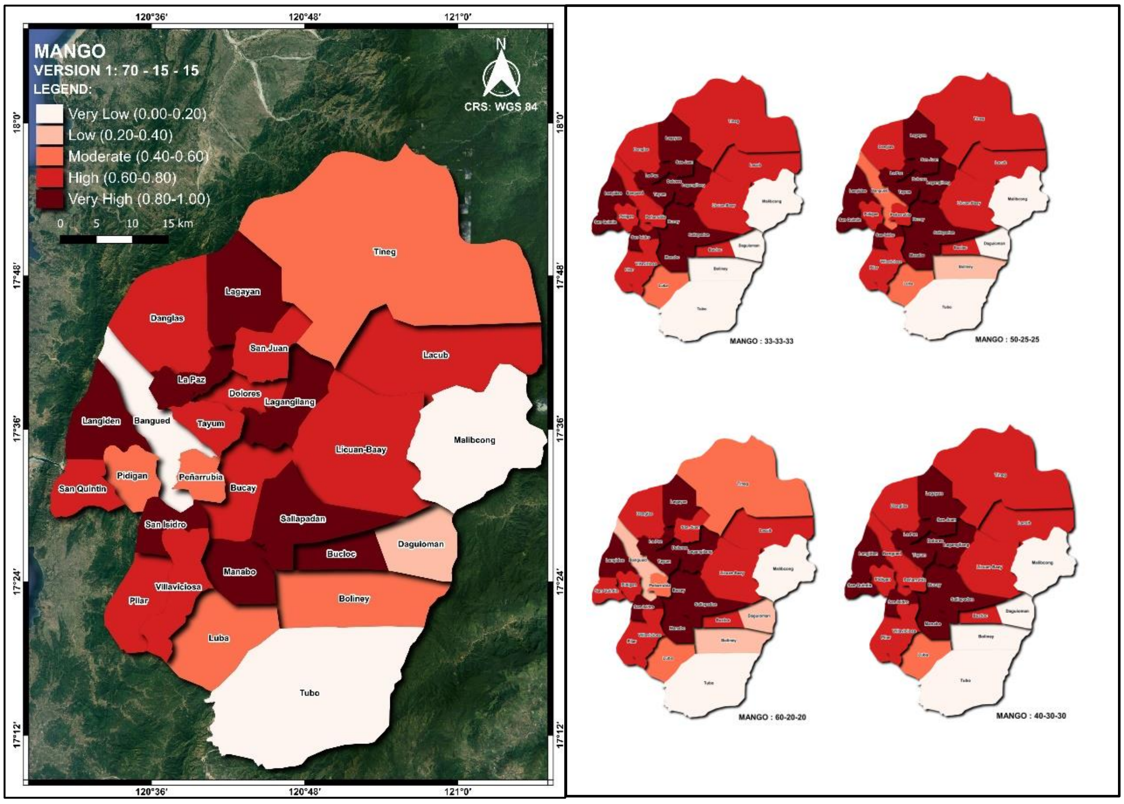


Figure 23. Mango CRVA result and versions one to five.

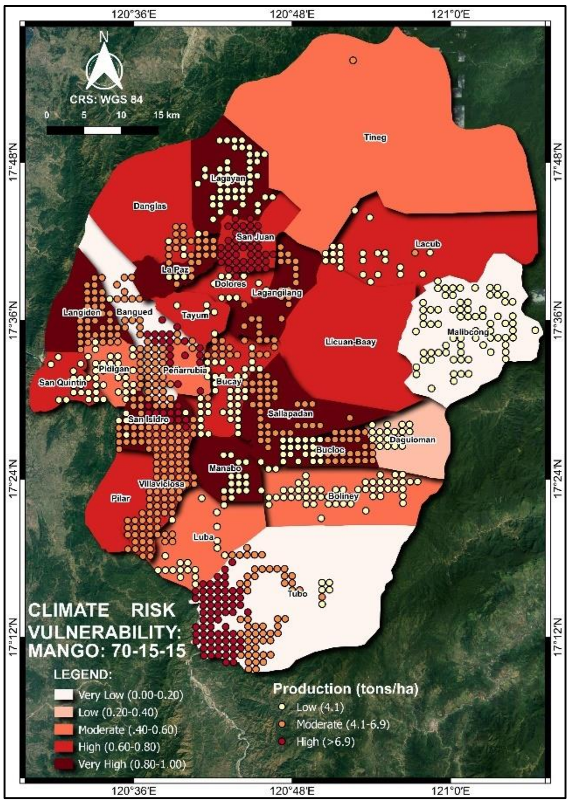


Figure 24. Mango version one with the overlaid crop occurrence.

Coffee

Coffee is the world's second most heavily sold commodity next to oil (Cordillera Mountain Coffee, 2019) and this contributes to the country's productivity especially in the agricultural sectors (Luat, 2022). It is part of the Filipino culture and one of the source of incomes for farmers in coffee producing regions in the country (Santa Barbara, 2022). It has also become one of the famous hot beverages in the Philippine. In 2022, the value of coffee produced amounted around 3.37 billion Philippine pesos and the total consumed by Filipinos amounted to 3.31 milion 60 kilogram bags (Statistica, 2022).

In the province of Abra, major production comes from the upland since the crop suits the climatic conditions in those areas. Results of CRVA shows that San Isidro, Lagangilang, Licuan-Baay, Sallapadan, and Lacub consistently have very high vulnerability in all the different versions used (Figure 25). With version 70-15-15 as reference, Figure 26 shows that almost all of the municipalities are vulnerable except for Bangued and Tubo. In addition, the figure shows that the eastern part of the province mostly produces coffee but with low to moderate production. Despite having low production, majority of the production areas located in the municipalities of Malibcong, Daguioman, and Boliney and at the same time have high to very high vulnerability of coffee production which could enhance adaptability and production in these areas are needed.

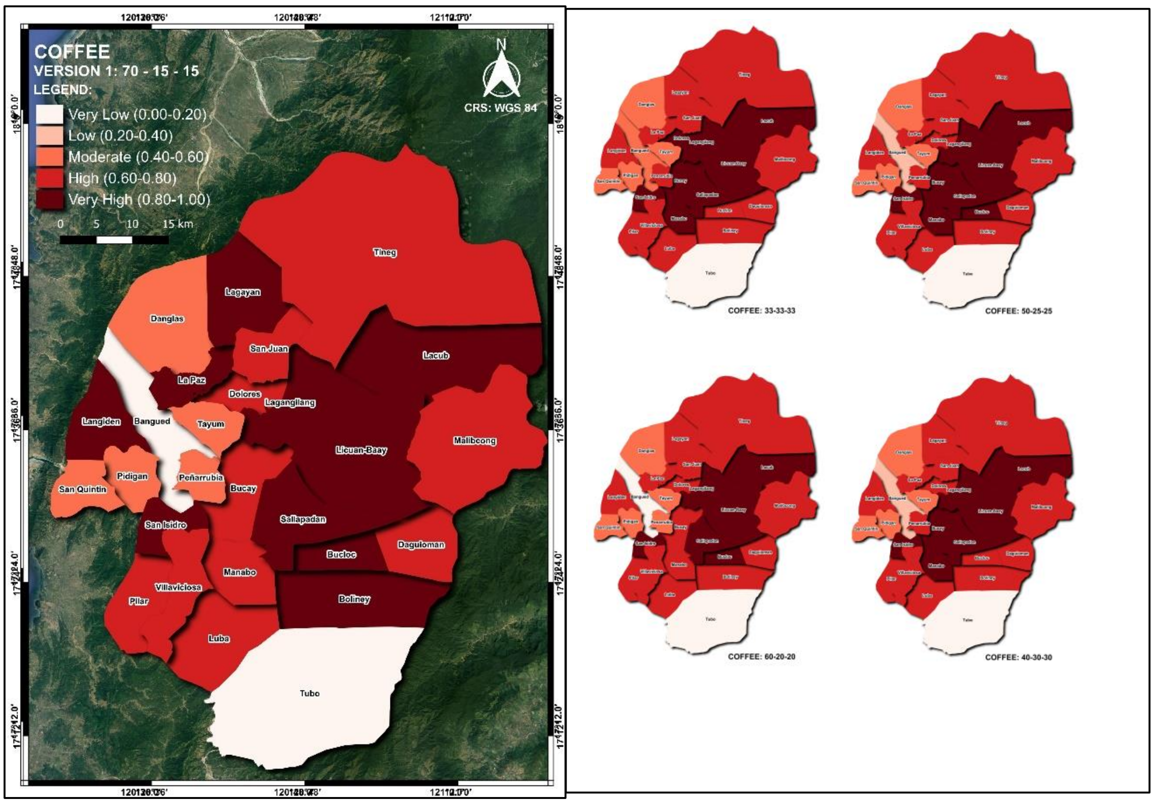


Figure 25. Coffee CRVA result and versions one to five.

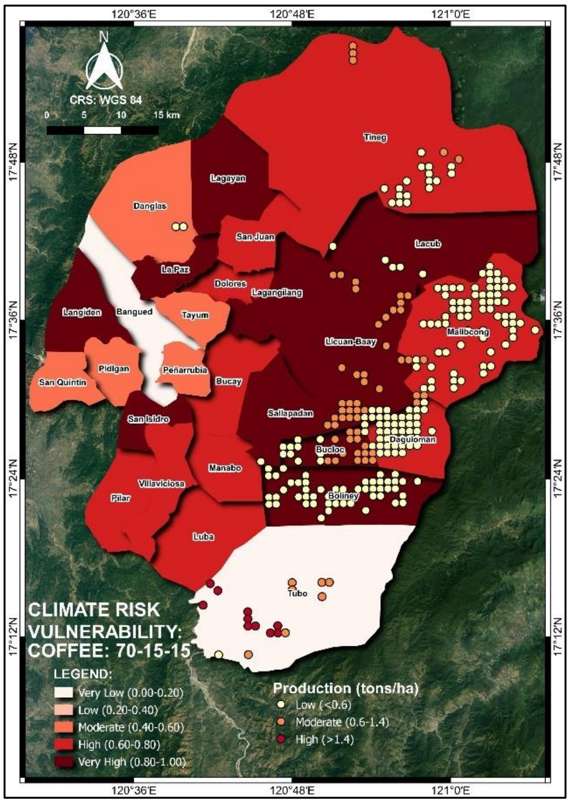


Figure 26. Coffee CRVA with the overlaid crop occurrence.

B. Climate-Resilient Agriculture

Characterization of the Value Chain for Rice, Corn, Mango and Coffee

Production Profile

Rice

Abra experienced a notable decrease of 3.18% in rice production, falling from 79,444.00 metric tons in 2013 to 76,921.00 metric tons in 2022 (PSA, 2023) (Figure 27). This decline can be attributed to several factors, including adverse weather conditions and natural calamities.

In 2016, the decline in the volume of production was primarily caused by the impact of drought, particularly during the first quarter, and the occurrence of typhoon "Lawin" in the fourth quarter. Moreover, heavy and prolonged monsoon rains in recent years have exacerbated the reduction in crop yield. The southwest monsoon (Habagat) in the third quarter of 2018, intensified by typhoons "Henry," "Inday," and "Jose," resulted in substantial damages and losses in rice production, as reported by the NDRRMC in 2018. This was followed by further damage inflicted by typhoon "Ompong" in the fourth quarter of the same year.

The adverse effects of El Niño persisted into 2019, affecting production from the first to the third quarter. El Niño typically resulted in delayed onset and premature termination of the rainy season, weak monsoon events characterized by brief, isolated heavy rainfall, and decreased tropical cyclone activity within the Philippine Area of Responsibility (PAR), as noted by Lansigan et al. in 2000.

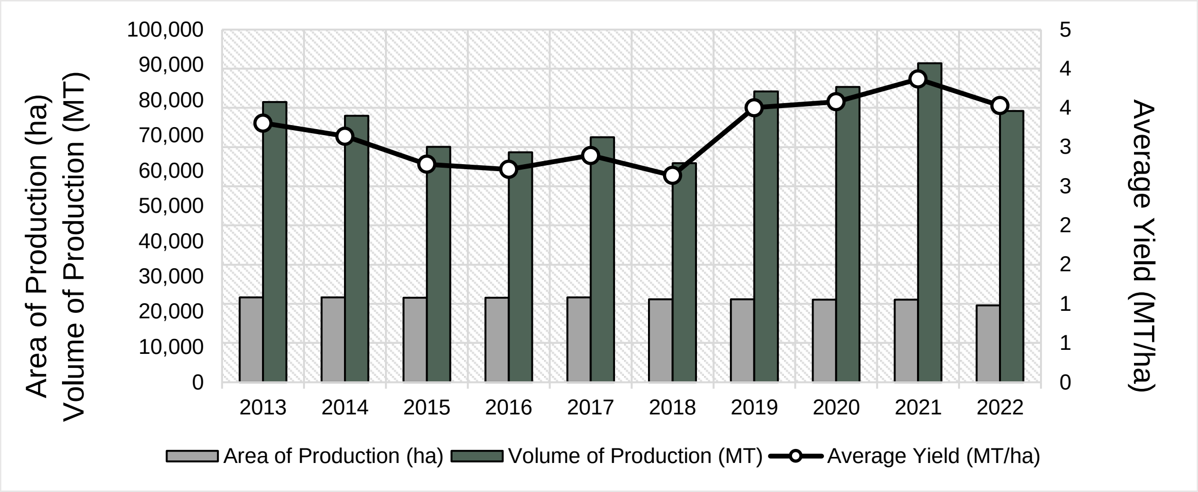


Figure 27. Annual production and harvested area of rice in Abra.

White Corn

Figure 28 illustrates the harvested area and yield data in the past ten years. It shows that white corn (glut 4 or 7) production in Abra from 2012 to 2019 was consistently at an average of 15,316 metric tons with an average of 6,177 hectares planted. A notable increase occurred in 2020 and 2021, reaching 17,533 metric tons and 6,138 hectares (PSA, 2023). This suggested conducive weather conditions or improved farming methods. However, in 2022, the production decreased by 10% with the same area planted. As disclosed by Lucas (2023), various factors contributed to this decline, including unpredictable weather patterns, pests and diseases, inadequate soil management, limited access to modern agricultural technologies, market fluctuations, and insufficient government support. Addressing these issues through improved farming practices, technology, education, and better policies could help stabilize and potentially increase white corn production in the region.

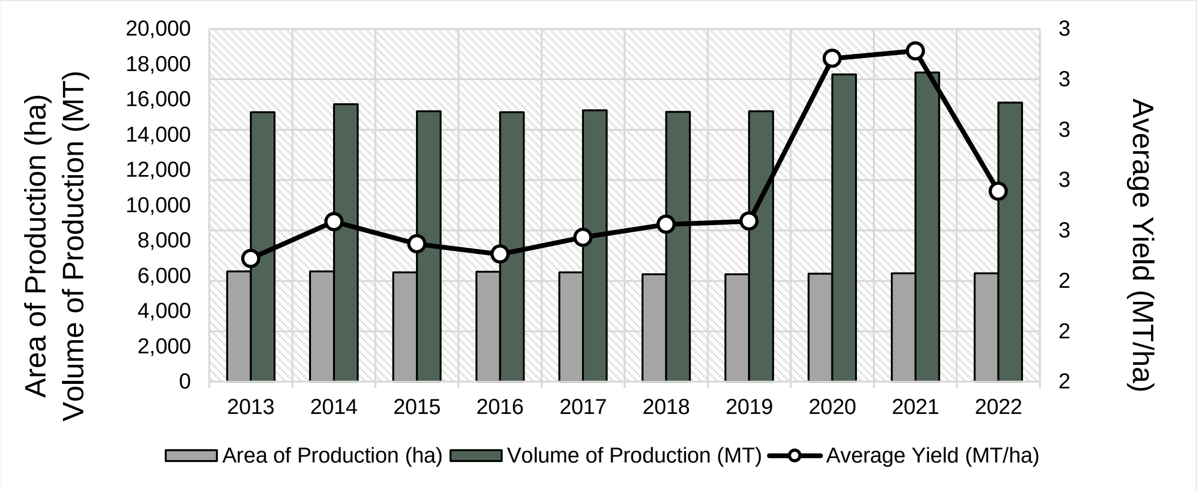


Figure 28. Annual production and harvested area of white corn in Abra.

Mango

Between 2012 and 2016, the area of production for mangoes in Abra was at 110 hectares before expanding to 125 hectares in 2017 (PSA, 2023). Initially, there was a consistent rise in volume of production from 2012 to 2017, however, production eventually fluctuated and peaked at 1,037 metric tons in 2022 (Figure 29). This surge in mango production may be attributed to improved farming practices, favorable weather conditions, and specific techniques like use of potassium nitrate to induce flowering.

The decline in mango production can be attributed to various factors, including skin diseases and pests such as the 'kurikong' and 'tarakitik,' which affect flowering and fruiting stages. Additionally, rainfall during flower and fruit development can increase disease incidence (Khalifa and Abobatta, 2023). The farmers' limited knowledge on appropriate pest control methods may further impact yield loss and fruit quality (Paguia, et al., 2021).

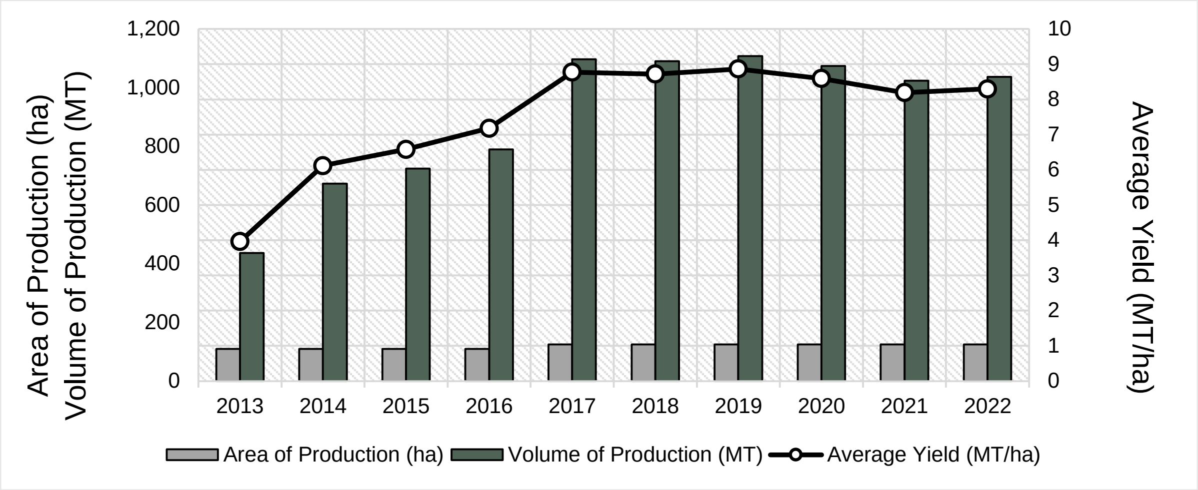


Figure 29. Annual production and harvested area of mango in Abra.

Coffee

The demand for coffee is consistently rising, yet production is steadily declining. However, in Abra, coffee production has remained relatively stable for the past 10 years (Figure 30). In fact, in spite of the slight decline in area of production, volume of production remained at above 50 metric tons for the last 5 years (PSA, 2023).

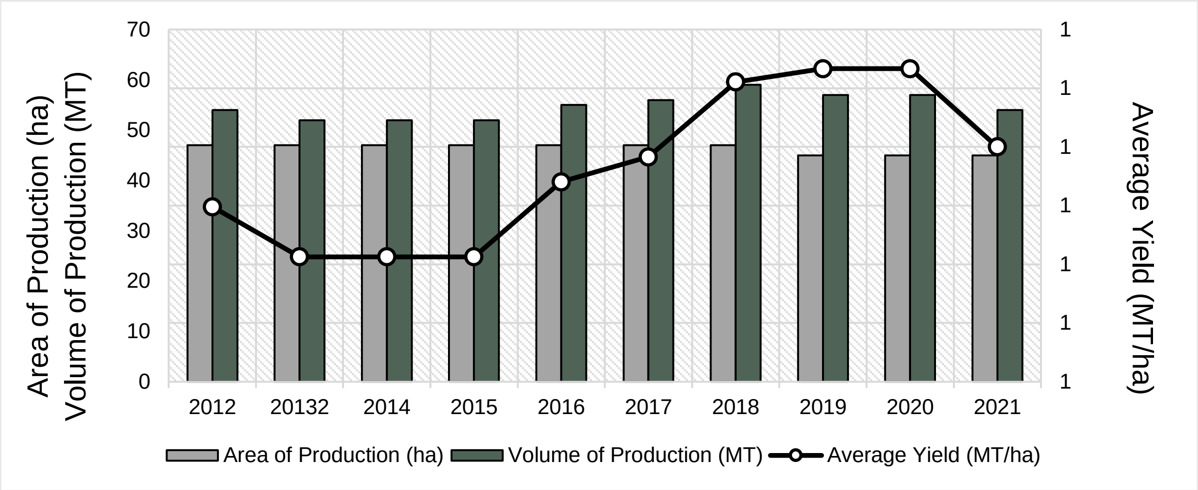


Figure 30. Annual production and harvested area of coffee in Abra.

Farming System and Planting Calendar

Rice

In Abra, the rice farming system is predominantly monocropping (Figure 31), with farmers typically planting once or twice a year. Some farmers engage in crop rotation, wherein rice is cultivated only once a year. During the wet season, rice serves as the primary crop, while during the dry season, farmers alternate it with corn and various vegetables like mung beans and yard-long beans. Additionally, some farmers opt for monocropping with border crops like taro or gabi. The bulk of the rice produced by these farmers is primarily utilized for household consumption.

The wet season rice cropping usually starts in June and is harvested around October, whereas the dry season cropping begins in December and harvested in April. However, in certain areas, planting may start a month earlier.

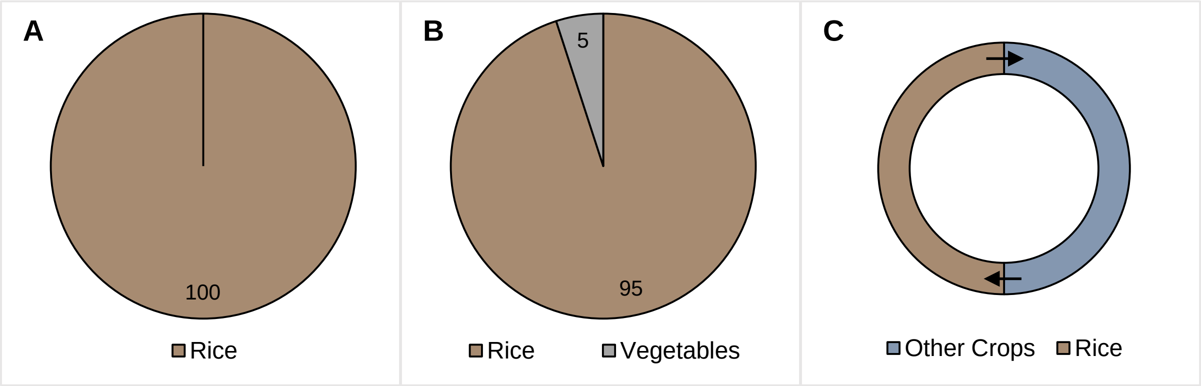


Figure 31. Proportion of rice in a (A) monocropping system; (B) monocropping system+ border crops; and (C) crop rotation scheme in Abra.

<u>White Corn</u>

White corn cultivation in Abra is heavily rainfed, with farmers utilizing natural rainfall as the primary irrigation source before resorting to water pumps. Corn in the province is grown in various farming systems, including monocropping, strip-cropping with vegetables, and crop rotation with rice (Figure 32). A common practice involves growing white corn alongside vegetables, or occasionally strip-cropping with squash, string beans, and peanuts for home consumption, marketing, and pest control (as alternate hosts).

Preparatory activities such as cleaning and harrowing preceded planting, with traditional techniques emphasizing manual labor and basic tools. Hand planting, minimal fertilizer use, and chemical pest control is prevalent. Some farmers adopted crop rotation and strip cropping to optimize land use and maintain soil fertility. Planting is generally done in May, September, and January, with corresponding harvests in August, December, and April. Farming practices are shaped by financial constraints, limited mechanization, need for new pest-resistant varieties, and reliance on water pump-fed irrigation. Conventional methods, including synthetic chemicals, are commonly used for pest management to have higher yield.

After harvest, white corn is often sold in local markets or through middlemen due to restricted access to the formal market. Selling through middlemen can negatively impact the farmers' incomes. Nonetheless, there are ongoing efforts aimed to ultimately bolster white corn production in the region such as facilitating access to quality inputs, providing modern agricultural training focusing on sustainable practices to address climate and soil health challenges, distribution of improved seeds, and establishment of market connections (Lucas, 2023).

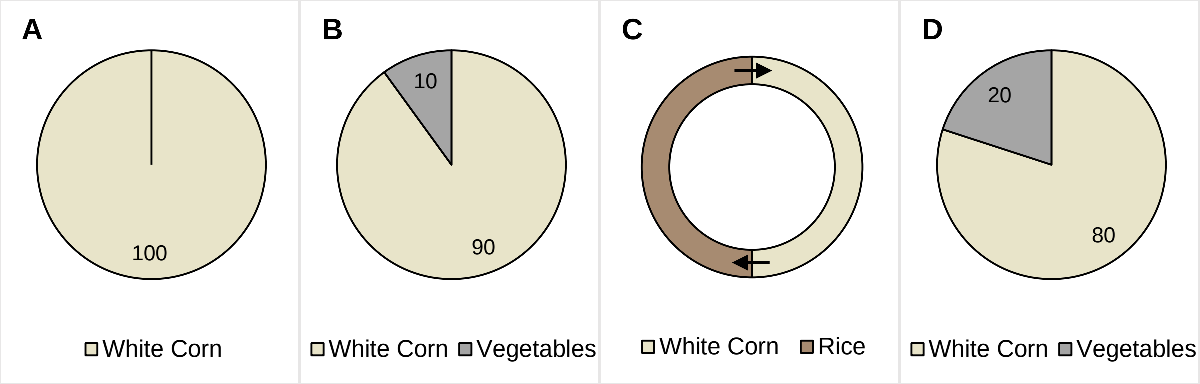


Figure 32. Proportion of white corn in a (A) monocropping system; (B) monocropping system+ border crops; (C) crop rotation scheme; and (D) strip cropping system in Abra.

Mango

In Abra, farmers employ monocropping, mixed cropping, and integrated farming, cultivating mangoes alongside bananas, pineapples, and various vegetables (Figure 33). Fruit and non-fruit trees are also planted for furniture, complemented by strategically built housing or fencing for livestock.

The preference for the Carabao mango variety is due to its taste and resilience to local conditions. Land preparation and planting of grafted mango seedlings starts from June to August depending on environmental factors and farmer’s practice. Flower induction using potassium nitrate is done after 3 years from grafting during the months of September to February. Mango fruits are usually ready for harvest at 105 to 130 days depending on when flower induction was done. Harvesting is usually done from March to May.

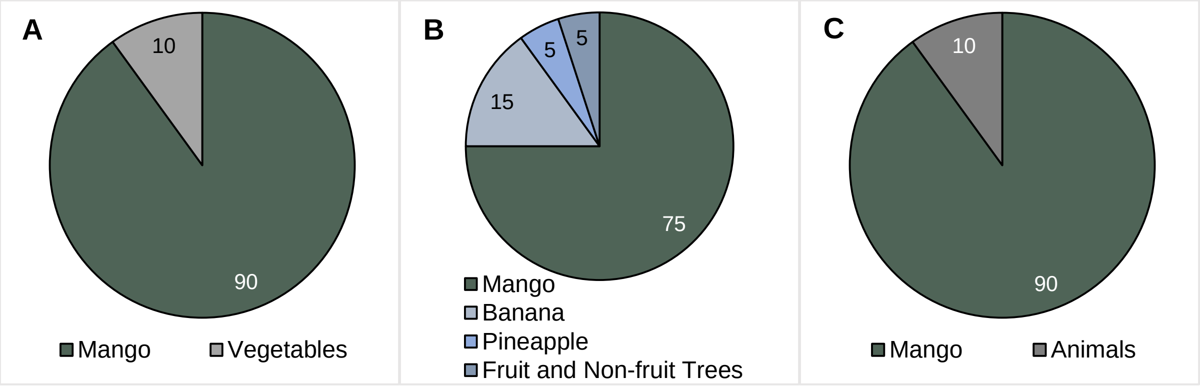


Figure 33. Proportion of mango in a (A) monocropping system+ border crops; (B) mixed cropping; and (C) integrated farming system in Abra.

Coffee

Coffee in Abra is predominantly planted within a mixed cropping system in smallholder areas (Figure 34), with Robusta being the primary coffee species grown. However, there is a small portion allocated to Liberica, Excelsa and Arabica species. Alongside coffee trees, various trees such as narra, acacia and gmelina, as well as fruit-bearing trees like star apple, pomelo, and mango, are planted. These additional trees serve as windbreakers and provide shade for the coffee trees, while their fruits can be harvested for household consumption or sold for additional income. Farmers typically plant coffee at the onset of wet season, between May and July, and it usually takes approximately 3-4 years for the coffee trees to bear fruit, depending on the species. Harvesting of coffee berries occurs from December to March, approximately 8-10 months after flowering.

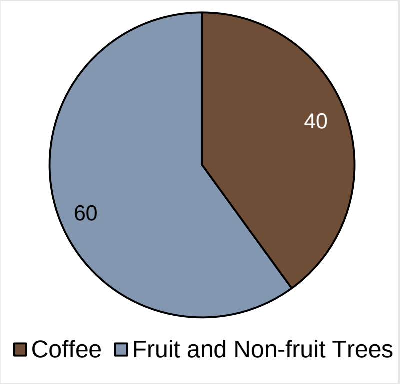
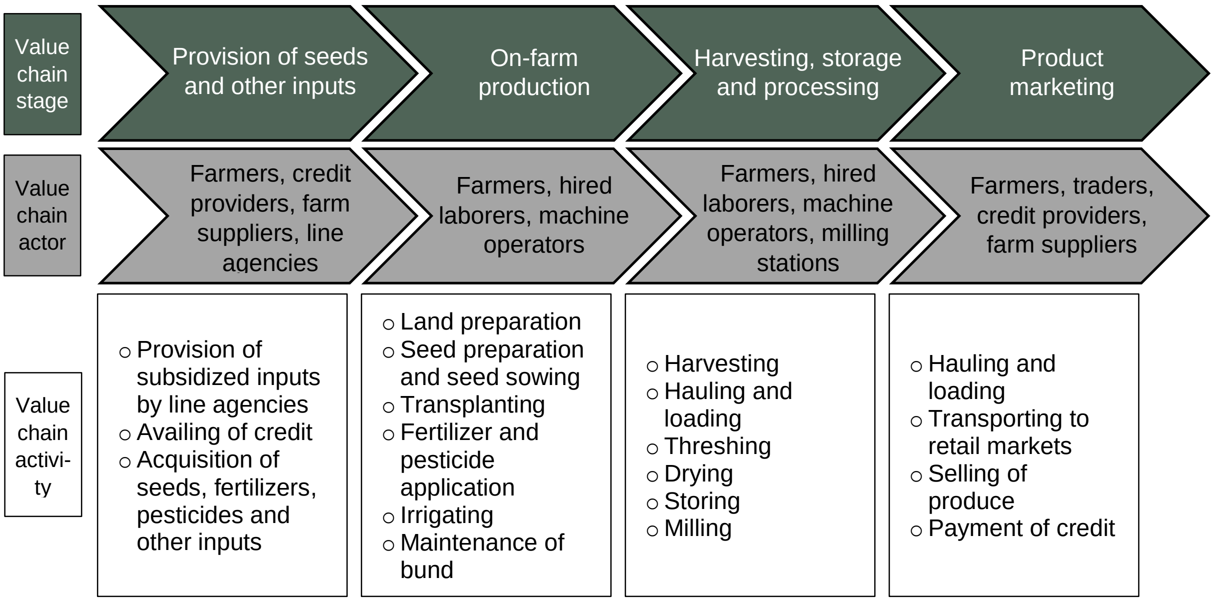


Figure 34. Proportion of coffee in a mixed cropping system in Abra.

Value Chain Key Actors and Activities

<u>Rice</u>

The different activities involved in the production and marketing of rice in Abra are as follows (Figure 35):



Value chain stage	Provision of seeds and other inputs	On-farm production	Harvesting, storage and processing	Product marketing
Value chain actor	Farmers, credit providers, farm suppliers, line agencies	Farmers, hired laborers, machine operators	Farmers, hired laborers, machine operators, milling stations	Farmers, traders, credit providers, farm suppliers
Value chain activi-ty	○ Provision of subsidized inputs by line agencies ○ Availing of credit ○ Acquisition of seeds, fertilizers, pesticides and other inputs	○ Land preparation ○ Seed preparation and seed sowing ○ Transplanting ○ Fertilizer and pesticide application ○ Irrigating ○ Maintenance of bund	○ Harvesting ○ Hauling and loading ○ Threshing ○ Drying ○ Storing ○ Milling	○ Hauling and loading ○ Transporting to retail markets ○ Selling of produce ○ Payment of credit

Figure 35. Value chain stages, actors and activities of rice production in Abra.

a. Provision of seeds and other inputs

Majority of rice farmers in Abra plant seeds harvested from their previous cropping, while a smaller proportion acquire seeds from agricultural farm supply stores. Farmers registered in the Registry System for Basic Sectors in Agriculture (RSBSA) also receive seeds and other inputs, such as fertilizers, provided by the Department of Agriculture. Additionally, some farmers with limited financial resources seek loans from banks, cooperatives and private individuals to acquire seeds and other necessary farm inputs like fertilizers and pesticides. Alternatively, they may obtain necessary farm inputs on credit from agricultural supply stores.

b. On-farm production

The process of seedbed preparation and land preparation starts with land clearing, followed by primary and secondary tillage operations once irrigation water is introduced on the farm. It is mostly done with the use of hired rotavator, tractors (hand tractors or four-wheeled drive tractors), and animal-droned farm implements.

Most farmers employ seed sowing rather than direct seeding, and they often hire laborers during transplanting. Fertilizers are applied twice every cropping: first, during the seedling stage, approximately 7 days after sowing, and second, during the early vegetative stage, around 30 days after transplanting. Regular maintenance and clearing of bunds are carried out mostly through manual weeding to ensure continuous water flow and sanitation. Irrigation is typically conducted on a weekly basis or as required, particularly during the booting stage for irrigated areas, to ensure optimal crop growth. In terms of pest management, farmers apply insecticides, fungicides and molluscicides as needed.

c. Harvesting, storage and processing

Harvesting is done when rice is fully matured, employing either a combine harvester or, in some areas, hired laborers for manual harvesting followed by threshing. Subsequently, farmers commonly dry their rice grains on roadsides or multi-purpose drying pavements (MPDP), if accessible. Once dried, the produce is stored, and milling is done only as needed for subsequent food consumption.

d. Product marketing

Rice grains are primarily sold based on dried weight, with straight buying by traders being a common practice. In this method, buyers directly purchase rice from the farmer’s area. These activities are managed by the farmers themselves, who negotiate a fair price and handle logistics with their buyers.

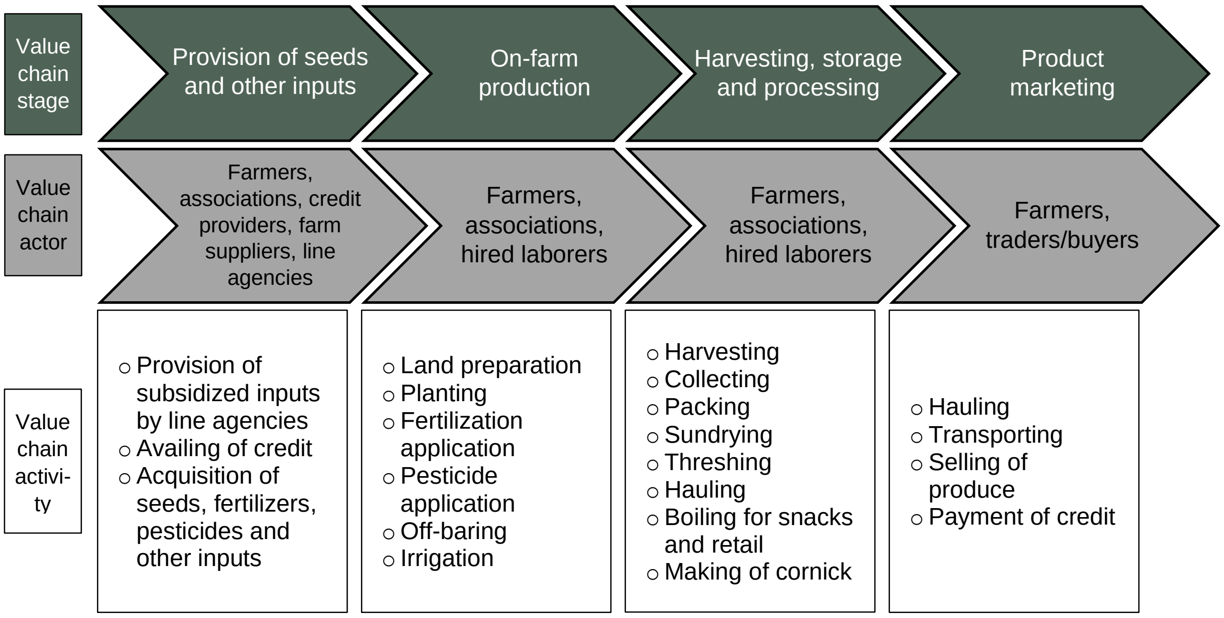
<u>White Corn</u>

The different activities involved in the production and marketing of white corn production in Abra (Figure 36):

a. Provision of seeds and other inputs

Abra white corn farmers commonly depend on saved seeds from previous harvests, supplemented by seeds from the local Department of Agriculture. Agricultural stores in central towns serve as comprehensive supply hubs, offering seeds, fertilizers, pesticides, and fungicides. Loans provided by private firms and cooperatives like the Bangued Multipurpose Cooperative and farmers’ cooperative are accessible to both men and women. A subset of farmers can secure credit for farm inputs with a 3% interest rate within the cropping season.

Insights from focus group discussions and key informant interviews underscored the collaborative relationship between farmers and credit providers, emphasizing the role of external support in overcoming financial challenges. Furthermore, the central town agricultural stores played a pivotal role in enhancing the accessibility of resources, contributing to the dynamics of white corn farming in Abra.



Value chain stage	Provision of seeds and other inputs	On-farm production	Harvesting, storage and processing	Product marketing
Value chain actor	Farmers, associations, credit providers, farm suppliers, line agencies	Farmers, associations, hired laborers	Farmers, associations, hired laborers	Farmers, traders/buyers
Value chain activi-ty	○ Provision of subsidized inputs by line agencies ○ Availing of credit ○ Acquisition of seeds, fertilizers, pesticides and other inputs	○ Land preparation ○ Planting ○ Fertilization application ○ Pesticide application ○ Off-baring ○ Irrigation	○ Harvesting ○ Collecting ○ Packing ○ Sundrying ○ Threshing ○ Hauling ○ Boiling for snacks and retail ○ Making of cornick	○ Hauling ○ Transporting ○ Selling of produce ○ Payment of credit

Figure 36. Value chain stages, actors and activities of white corn production in Abra.

b. On-farm production

Farmers in Abra follow a systematic process of production activities on-farm. It begins with meticulous land preparation, involving clearing and plowing before seed sowing, following recommended practices. During land preparation, the pulled-out weeds are piled, dried then burned over the area before cultivation, plowing ash back into the soil. Primary and secondary tillage operations using hand or wheel tractors follow. Off-barring, a vital step to ready the land for planting and for irrigation, is executed using animal-drawn implements or hand tractors.

Many farmers in the region adopted a three-cropping cycle, with experts' advice, enabling harvest within a 90-day (green corn) timeframe. Manual planting, often done by family members and hired laborers, remain a prevalent practice. Fertilizer is applied thrice in a cropping season with the assistance of laborers, following a ratio of 2 bags urea (46-0-0) and 2 bags complete fertilizer (14-14-14) per hectare.

Weeding is primarily managed by women, and done manually. Meanwhile pesticide application is typically executed by men using knapsack or power sprayers twice in a cropping season to control pests. Irrigation is crucial in corn farming, with most farmers watering every 10 days, starting around 15 days after planting. This strategic approach ensured optimal crop growth and development throughout the season.

c. Harvesting, storage and processing

Harvest of white corn can be done within three months (90 days) after planting or as determined by buyers' demands, especially if they seek green corn for specific processing purposes. The farmers are careful to gather sufficiently mature kernels, preferably at the dent stage, for sale, processing or family consumption. Farmers sort the cobs according to quality and segregate those for family consumption and those for the retail or wholesale market. Precise timing of harvest is necessary to ensure high-quality yield.

According to insights gathered from focus group discussions and key informant interviews, harvesting to processing activities is done mostly by hired laborers. Buyers, within the province and from the neighboring Ilocos region, often set the market price. They buy kernels directly from the farmers or sometimes undertake the harvesting, collection, and packing themselves. Some farmers hire laborers for various tasks, including harvesting, bagging, collection, and threshing. Retailing or 'tingi-tingi' (selling small quantities), is managed by local sellers within the barangay for immediate consumption.

Post-harvest handling involves sorting, cleaning, and storage to ensure product quality. Farmers engage in direct marketing or collaborate with intermediaries, negotiating prices and finalizing sales. Subsequently, they reinvest in inputs like seeds and fertilizers for the next cropping cycle, to ensure a continuous production flow.

d. Product marketing

In Abra, white corn is sold in both dried and fresh forms, either in retail and wholesale. The marketing activities associated with white corn involved not only farmers but also hired laborers and contracted workers, illustrating a variety of approaches within the province.

Wholesale buyers played a pivotal role in collecting and packaging the product for transportation to various destinations. After the production and harvest phase, farmers actively participate in key marketing steps, thoroughly preparing their harvest and accessing markets through avenues such as direct referrals or partnerships.

According to Lucas (2023), this engagement allowed farmers to negotiate fair prices, manage logistics effectively, and establish robust communication with buyers, placing a strong emphasis on secure transactions and feedback mechanisms for quality enhancement. The success of these marketing endeavors relied on collaborative efforts that revolved around market understanding, quality maintenance, efficient logistics, fair pricing strategies, and a commitment to continuous improvements. In addition, collaboration among farmers, extension services, suppliers, and buyers remained strong throughout the value chain stages, emphasizing that best practices, quality inputs, market connections, and efficient post-harvest handling, all contribute to the success of value chain activities in Abra's on-farm production.

Mango

The different activities involved in the production and marketing of mango production in Abra (Figure 37):

a. Provision of seeds and other inputs

In Abra, mango cultivation involves a systematic process where farmers primarily acquire grafted seedlings from Batangas sellers who visit their locality. To secure their farming supplies, they turn to the agricultural supply center within the town, obtaining necessary inputs, typically fertilizers and pesticides, for their mango cultivation.

Notably, some farmers negotiate with owners of extensive mango plantations from other municipalities. In these agreements, caretakers or farmers typically receive a 70% share, while the plantation owner retains a 30% share from the gross income.

According to farmers who participated in focus group discussions (FGDs) and key informant interviews (KIIs), they independently manage their mango cultivation by utilizing personal capital and establishing relationships with agents or buyers who facilitate the provision of farm inputs. These inputs may include potassium nitrate, fertilizers, pesticides, and other essentials, which are sometimes obtained through credit arrangements with suppliers.

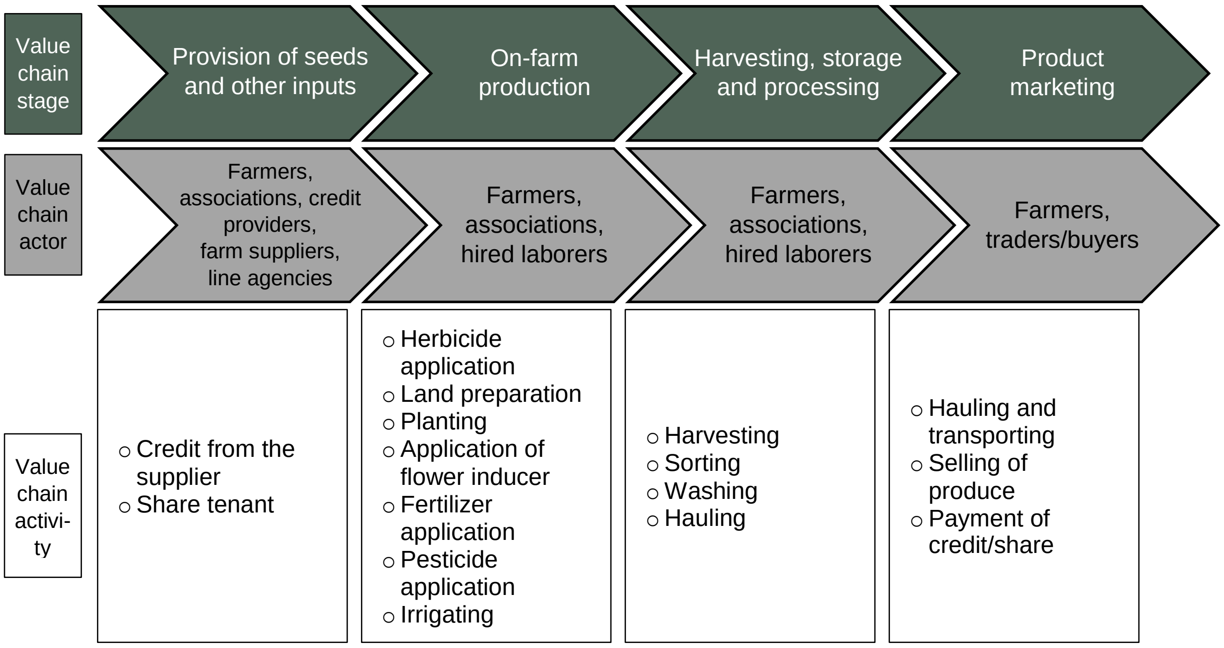
b. On-farm production

Land preparation involves clearing using herbicides and cultivation. Three days prior to planting the mango seedlings, irrigation is done to loosen the soil. Planting responsibilities are divided, with family members handling the mango seedlings and laborers tending to other crops like pineapple, banana, legumes, and various vegetables. When planting grafted mango trees, a mixture of urea (46-0-0) and complete fertilizer (14-14-14) at a ratio of 1:1 is used. This mixture is sufficient for 12-15 century seedlings, which are planted 18 inches deep, for optimal growth and development. The majority of century mango trees are 'tawid' or inherited from the farmers' parents or relatives.

A specific regimen for applying potassium nitrate, with a 2Kg:16L ratio of potassium to water suitable for 3 century mango trees or 5-7 grafted mango trees, encourages flower induction. The potassium nitrate mixture is applied on the 3rd year from planting during the months of September to October at a frequency of 2 to 3 times a month. Pesticide application begins in November and continues until February to mitigate insect pests. Bi-monthly irrigation is sustained from January to February, and pesticides are applied from flowering until the fruits are matured. Weeding is done bi-monthly or monthly based on plantation size.

Fertilizer and pesticide application pose challenges for some farmers due to difficulties with water availability, lack of electric sprayers and laborers, and limited access to resources.

In addition to mango and vegetable production, some farmers are involved in livestock and poultry production.



Value chain stage	Provision of seeds and other inputs	On-farm production	Harvesting, storage and processing	Product marketing
Value chain actor	Farmers, associations, credit providers, farm suppliers, line agencies	Farmers, associations, hired laborers	Farmers, associations, hired laborers	Farmers, traders/buyers
Value chain activi-ty	○ Credit from the supplier ○ Share tenant	○ Herbicide application ○ Land preparation ○ Planting ○ Application of flower inducer ○ Fertilizer application ○ Pesticide application ○ Irrigating	○ Harvesting ○ Sorting ○ Washing ○ Hauling	○ Hauling and transporting ○ Selling of produce ○ Payment of credit/share

Figure 37. Value chain stages, actors and activities for mango production in Abra.

c. Harvesting, storage and processing

A week before harvesting, farmers proactively remove all weaver ants to prevent accidents during climbing of trees. Harvesting takes place between March to May at 105 to 130 days from flower induction. Harvesting involves a manual process conducted by a dedicated team of laborers, comprising 3-5 climbers, 2 collectors, and 2 packers. Some farmers opt for a single harvest, particularly those selling to other municipalities, while others, including caretakers, harvest two to three times based on buyer demands.

Farmers harvest grafted mango plants twice a year while century mango plants are harvested once a year if flowering inducers are used. Applying flower inducers have the advantage of yielding a significant quantity of fruit with reduced insect damage.

The postharvest activities include sorting, washing, and hauling, completing the sequence of activities in mango production.

d. Product marketing

In the marketing of mangoes, the fruits are typically sold through two primary channels: either directly by the farmer at buyer stations or through the buyer who purchases the products from the farm. Buyers who opt to go to the farm are typically contacted by the farmers before harvesting. Some farmers, on the other hand, take on the responsibility of transporting and selling their produce at designated buying stations. The specific approach varies based on agreements between the farmer and the buyer. Additionally, the payment of credit, a crucial step in the marketing process, ensures a fair and timely transaction between the farmer and the buyer.

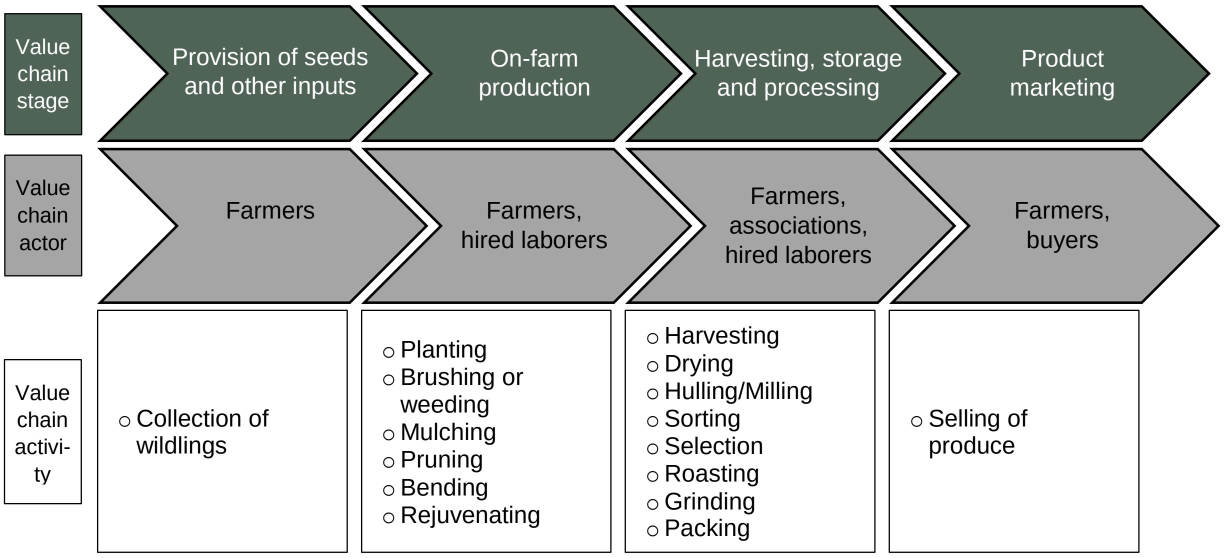
The quality of the mangoes also plays a crucial role in the selling process. Buyers are inclined to purchase mangoes with clean skins and normal-sized fruits. However, concerns about mango spoilage due to lack of buyers were raised by farmers during focus group discussions and key informant interviews.

Coffee

The different activities involved in the production and marketing of coffee production in Abra (Figure 38):

a. Provision of seeds and other inputs

In Abra, the majority of coffee farmers carefully select wildlings from productive coffee trees in their own areas or from neighboring farms. Additionally, some farmers and their associations have received coffee seedlings and nursery facilities from government line agencies. This assistance has enabled them to obtain higher-quality seedlings, generate additional income through seedling production and sales, and reduce production expenses.



Value chain stage	Provision of seeds and other inputs	On-farm production	Harvesting, storage and processing	Product marketing
Value chain actor	Farmers	Farmers, hired laborers	Farmers, associations, hired laborers	Farmers, buyers
Value chain activity	○ Collection of wildlings	○ Planting ○ Brushing or weeding ○ Mulching ○ Pruning ○ Bending ○ Rejuvenating	○ Harvesting ○ Drying ○ Hulling/Milling ○ Sorting ○ Selection ○ Roasting ○ Grinding ○ Packing	○ Selling of produce

Figure 38. Value chain stages, actors and activities for coffee production in Abra.

b. On-farm production

Farmers may hire laborers to assist with land preparation if they have the budget and need to prepare more land. Farmers dig holes to accommodate root development and directly plant coffee seedlings or wildlings using spacing typically ranging from 3 meters x 4 meters to 4 meters x 5 meters. Fertilizers are not commonly applied. Manual weeding or brushing, cutting of weeds under the canopy of the coffee trees, is conducted once a year. Mulch, comprising of dried leaves found in the area, is spread under the canopy to minimize competition for nutrients and water, maintain soil moisture, and suppress weed growth.

Field monitoring, pruning, and mulching are typically carried out simultaneously with weeding or brushing. During pruning, excess branches are removed to enhance aeration and light penetration throughout the coffee tree canopy. Some farmers also employ propagation techniques such as bending down the main stem and staking it on the ground, then cutting off the bent stem after desirable vertical sprouts emerge. Additionally, a few farmers attempt to rejuvenate underperforming old coffee trees by cutting their vertical stems to stimulate the growth of new sprouts. However, the majority of coffee farmers refrain from this practice due to the lengthy time required before the trees bear coffee berries.

c. Harvesting, storage and processing

During the harvesting period, majority of farmers in Abra practice strip picking, where they remove all coffee berries at once. Subsequently, they utilize the dry method of processing. The harvested coffee berries are spread out on a cemented floor with a net under to facilitate immediate drying, reducing moisture content to approximately 12-14%. Depending on weather condition, it typically takes about 2 to 3 weeks for the coffee berries to dry properly.

Once dried, the berries undergo hulling or milling to remove the dried fruit covering. Undesirable materials or broken pieces are removed, and defective beans are separated from good beans. The coffee beans are then roasted and ground to the farmers' desired roast level and grind size before being packed and stored.

d. Product marketing

If farmers produce more coffee than they require or need for household consumption, they sell the surplus. Some farmers opt to sell their coffee directly to customers, particularly if they have pre-existing orders. Buyers are typically located within their municipality or elsewhere in Abra.

Assessment of Hazard and Climate Change Sensitivity

Identification of Climate Hazards

Rice

Rice farmers perceive that the typhoons nowadays are stronger in intensity compared to those in the past. They often encounter three to four typhoons a year, typically occurring between July and October, along with an extended monsoon season (habagat), bringing strong winds, heavy rainfall, flooding, soil erosion, and landslides. Rice production suffers adversely during and after such occurrences because farmers are often unprepared and lack effective strategies to mitigate such hazards (Table 5).

This impacts the growth and development of the rice crops, leading to reduced farm productivity and delaying farm activities, which also affects the source of income of farm laborers. Furthermore, these weather events cause damage to farm inputs, equipment, machinery, and infrastructure, and may even result in the death of animals. Soil erosion and landslides are also observed on roads and mountainsides.

Moreover, farmers have observed an increase in temperature, prolonged summers, and the occurrence of droughts, which have adverse effects on crops, animal production and aquaculture.

Table 8. Perception of farmers on climate hazards and impact on rice production.

Climate Hazard	Perception of Farmer on Climate Hazards and its Impacts
Typhoon/Habagat	Typhoons nowadays are stronger in intensity compared to past typhoons. Flooding and erosion or landslides are expected particularly during the occurrence of typhoons and persistent rainfall. Destruction and/or loss of farm inputs, equipments, machineries, and infrastructures, and death of animals occur. Continuous rain and prolong submergence of rice crop significantly affect the growth, development and grain yield. Rice grains become underdeveloped or easily vulnerable to blackening and discoloration.
Drought	Drought negatively affects rice growth and development. Rice crop is stunted, and reduction of panicle exertion and spikelet fertility is experienced. Pest occurrence become more severe.

White Corn

Climate hazards, manifesting as excessive rainfall, typhoons, irregular rainfall, prolonged dry season, and droughts, pose a substantial threat to white corn production in Abra (Table 6). These natural hazards affect planting schedules, crop growth, and result in reduced yields. Unpredictable weather occurrences such as typhoons cause floods and landslides, disrupting farming operations and affecting production schedules. Monsoon or persistent rains contribute to crop losses, exacerbated by rising temperatures and erratic rainfall patterns. On the other hand, during prolonged dry season and droughts, water supply become difficult, resulting to income loss from stunted plant growth and crop wilting.

These observations confirm previous reports that droughts induce water stress leading to stunted growth or crop failure, while excessive rainfall can cause waterlogging and promote diseases. Extreme temperatures, especially heatwaves, negatively affect pollination and grain formation, reducing both yield and quality. Additionally, climate hazards increase pest and disease risks, further threatening crop health and production.

Essential adaptation strategies are crucial for white corn farmers in Abra to address these challenges. These strategies include cultivating resilient crop varieties, implementing efficient water management practices, and adopting robust measures for pest and disease control.

These initiatives play a vital role in mitigating the adverse effects of climate hazards on white corn production in Abra.

Lucas (2023) reported insights into how corn farmers globally are adapting to climate change by utilizing advanced techniques like early planting, resilient crop varieties, efficient water management practices, and pest control measures to maintain yields despite worsening climate conditions.

Table 9. Perception of farmers on climate hazards and impact on white corn production.

Climate Hazard	Perception of Farmer on Climate Hazards and its Impacts
Typhoon, flood and landslide	Typhoons have a detrimental effect on agricultural productivity, destroying farm inputs and giving rise to problems such as pest infestation in flooded fields, small and scanty cobs, and difficulties in the marketing of kernels. Additionally, continuous rainfall and prolonged lodging of corn plants have a considerable impact on both plant growth and grain yield. Farmers in sloping areas, especially during critical crop stages, face challenges associated with soil erosion, particularly when subjected to persistent rainfall or the occurrence of typhoons.
Drought	Drought has detrimental effects on the various growth stages, development, and yield of white corn. Much like typhoons, lack of water increases the chances of small and scanty cobs and susceptibility of plants to pests and diseases. Additionally, the unpredictable weather patterns have caused prolonged alternation between rainy and dry seasons.

Mango

The constant threat of typhoons, coupled with strong winds, inflict severe damage on mango trees such as broken branches, uprooted trees, and, in severe cases, the destruction of entire orchards (Table 7). In addition, high wind speed disrupt crucial stages like flowering and fruit setting, significantly impacting the overall productivity of mango trees. Orchards situated on slopes are vulnerable to landslides during continuous rain, contributing to yield and financial losses.

Likewise, prolonged dry seasons and drought induce water stress in mango trees, detrimentally affecting their growth, flowering, and fruit development. Farmers may observe numerous blooms on the plants, but the fruits do not grow in proportion to the number of blooms, thereby resulting in low fruit yield. Since the fruiting period is considered to be the most sensitive period of water stress, water supply is the most critical during the first six weeks of the fruit developing process. If growers could not supply water within the correct time period, water stress will induce late stage fruit drop and reduce fruit mass via decreased cell size and number (Rathnayaka, 2021).

Moderate winds with light rain may also occur from November to December, which results in the blackening of flowers and eventually flower abortion or drop. The reduction in the number of flowers impacts fruit yield and income.

The collective impact of these climate hazards significantly undermines mango production in Abra. Farmers grapple with reduced yields, compromised fruit quality, and, at times, complete crop loss due to the detrimental effects of these climatic events (Adraneda, 2009).

Table 10. Perception of farmers on climate hazards and impact on mango production.

Climate Hazard	Perception of Farmer on Climate Hazards and its Impacts
Typhoon	Strong typhoons and winds may result in broken branches and uprooted trees. High wind speed can also disrupt flowering, fruit setting, and the overall health of the mango trees. Orchards situated on slopes are susceptible to soil erosion and potential landslides during continuous rain.
Moderate Winds with Light Rain	The occurrence of moderate winds coupled with light rain during the last quarter of the year are closely associated with black color impact on flowers and eventually flower abortion.
Drought	Drought and prolonged dry spells can result in water stress for mango trees, affecting their growth, flowering, and fruit development.

Coffee

The climatic hazards identified were drought and typhoon (Table 8). Drought can affect old coffee trees, particularly if it coincides with the flowering and bearing stages. During this critical period, flowers and young berries may prematurely dry due to insufficient moisture. Additionally, young coffee trees are also susceptible to the effects of drought, exhibiting symptoms such as wilting leaves and stunted growth, which result from limited moisture or water availability.

Typhoons pose a significant threat to coffee farmers. They can uproot trees, break branches, topple shade trees, which in turn damages coffee trees, and increase flower and fruit drop, particularly during bearing and flowering stages. Typhoons also contribute to erosion and landslides, ultimately causing destruction to farms, footpaths, and farm-to-market roads.

Table 11. Perception of farmers on climate hazards and impact on coffee production.

Climate Hazard	Perception of Farmer on Climate Hazards and its Impacts
Typhoon	Branches and stems of coffee trees break due to strong wind and toppling of other trees. Increase flower and fruit drop when typhoon hits during the flowering and bearing stages. Erosion or landslides are expected particularly during the occurrence of typhoons and persistent rainfall.
Drought	Young coffee trees are more vulnerable to wilting and stunting. Young berries may dry early.

Assessment of Climate Hazard Consequences

Rice

The major climatic events that the agricultural community experiences are typhoons and monsoon rains (habagat) that occur from July to October while drought or prolonged dry season occur from November to April. Farmers often experience significant losses, with more than 50 percent of their produce being affected when typhoon occurrence coincides with the vegetative stage up to the harvesting time (Figure 39). Direct effects of typhoons include flooding of the fields, lodging of crops, and shattering of rice grains leading to delayed harvesting and vivipary, where rice grains germinate while still attached to the panicle, further delaying drying activities. Additionally, erosion and landslides affect farms, roads, bridges, houses, and irrigation systems, hindering agricultural activities and transportation of produce. The extended summer season and drought significantly affects water supply and the rice growth stages and development. These effects include stunting, reduced spikelet fertility and panicle exertion, attack of pest become more severe, and crop wilting and drying, ultimately leading to decreased yield. Additionally, an increased on-farm water consumption necessitating additional expenses for fuel to operate water pumps for irrigation (Table 9).

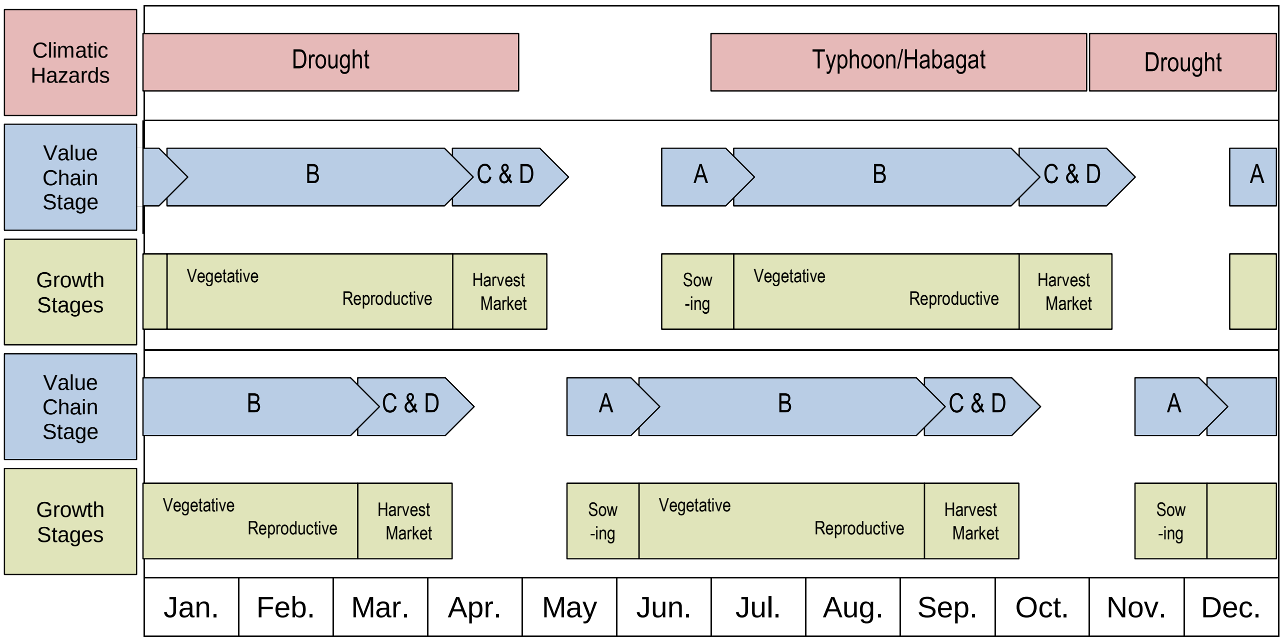


Figure 39. Climatic hazards on time, growth and value chain stages of rice production in Abra.

Table 12. Type of hazard, consequences and severity of impact on rice production.

Type of Hazard	Affected Value Chain Stage*	Consequence	Severity
Typhoon/ Habagat	A	Delay in acquisition of inputs	Minor
	B	Delay in seedbed preparation	Minor
		Delay in seeds sowing	Minor
		Destruction of rice seedlings	Moderate-Severe
		Delay in land preparation	Minor
		Delay in transplanting	Minor
		Delay in application of fertilizers and pesticides	Minor
		Damage to irrigation systems	Moderate-Major
		Destruction of bunds	Minor
		Erosion and landslide	Moderate
		Flooding of rice fields	Major-Severe
		Lodging of rice plants	Moderate-Severe
		Shattering of rice grains	Moderate-Major
	C	Delay in harvesting	Major-Severe
		Difficulty in using combine harvester during harvesting	Moderate
		Difficulty in drying the rice grains	Moderate-Major
		Low quantity and quality of produce	Major
	D	No traders	Minor
		Delays in transporting of produce	Minor
		Low price for the produce	Major
		Low to negative income of farmers	Major
Drought	B	Scarcity of water	Major-Severe

Note: *A- Provision of seeds and other inputs; B- On-farm production; C- Harvesting, storage and processing; D- Product marketing

White Corn

Climatic events in the province present multifaceted challenges to agriculture, impacting critical aspects of farming. As shown in Figure 40, white corn is grown in three cropping seasons whole year round. Planting is done in May, September, and January, with corresponding harvests in August, December, and April respectively. Typhoons frequently occur in Abra from July to October and drought can happen anytime from November to April. These significantly affect all activities across the value chain, but on-farm production and marketing activities are the most affected. Typhoon or drought that occur particularly during crucial growth stages can result to significant income loss due to crop damages. The flowering stage is most vulnerable because the resistance or tolerance of white corn to environmental changes is typically at its lowest during this stage.

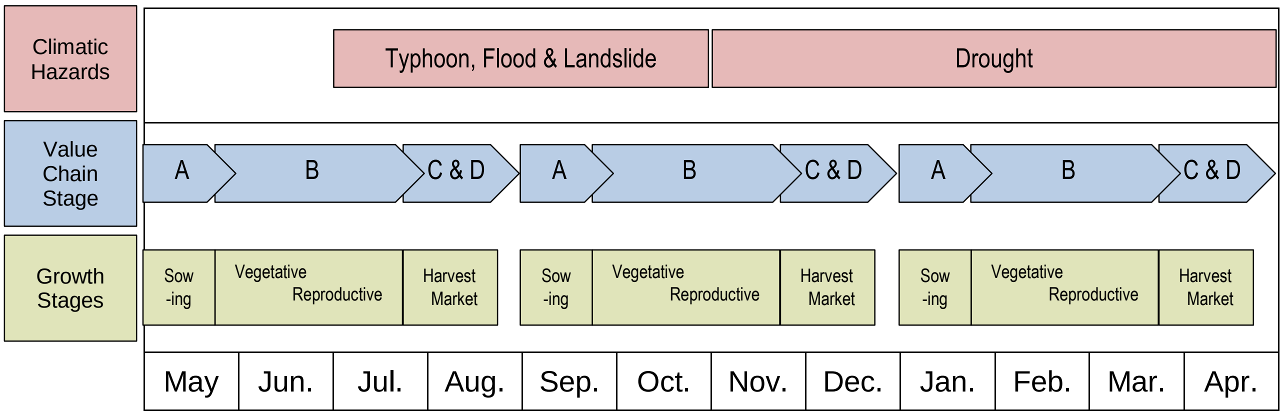


Figure 40. Climatic hazards on time, growth and value chain stages of white corn production in Abra.

Based on the FGD and KII, farmers related that corn farming faces hazards from erratic weather like typhoons, droughts, landslides and floods. These adverse conditions introduce additional complexities for farmers along with the absence of a price regulation system which further compounds the negative impact on farmers' income.

Typhoon-induced problems include limited availability of labor, disrupted activities, severe crop damage, a major occurrence of pests and diseases particularly affecting open-pollinated crops, and reduced yields. Excessive rainfall results in waterlogging, both impacting root health and crop yield. Persistent rain and floods result in lodging of plants, and a higher incidence of pests post-typhoon leading to low productivity. Heavy rains from the reproductive to harvest stage result to reduced pollination, significantly reducing yield and quality of kernels. Continuous rainfall likewise poses a threat to seed quality, where sun-drying is necessary for optimal seed conditions. The recruitment of laborers, especially men, after a calamity becomes difficult as they would be busy restoring their own farms. Rivers and waterways may overflow and become hard or life-threatening to navigate. Field repairs after flooding and landslides cause significant delays in the planting process. Market inaccessibility due to landslides and road closures and limited access to credit sources not only affects farmers but also credit lenders, bank branches, and agricultural suppliers, leading to temporary closures or delays. Farmers face substantial barriers when seeking financial assistance, primarily due to high service charges, insurance fees, and related expenses.

According to Rezaei et al. (2018) and Asseng et al. (2018), typhoons themselves damage crops, resulting in reduced yields and hindering flower growth. Flooding exacerbates these issues, further diminishing yield and quality. Pests and diseases threaten crops and their increased prevalence necessitates the use of pesticides. Rising temperatures and variability in rainfall negatively impact crop growth and development.

On the other hand, drought not only diminishes crop yield and quality but can also result to crop failure due to high temperatures and water stress especially if it coincides with the reproductive stage. The land becomes hard, cracked and dry or overgrown with weeds during long dry season, delaying land preparation and imposing additional expenditure for irrigation and weeding. Lack of irrigation from planting to vegetative growth results to drying of seedlings, weak stunted plants, and delayed flowering. The overall result is low yield and financial loss to farmers. Farmers also observe an increase in pest population and disease incidence when dry season is prolonged.

The impact of adverse weather conditions like typhoons, floods, landslides, prolonged dry season and drought (Table 10) on agricultural activities, is experienced with varying degrees of severity along the value chain. Much like the rest of Luzon, tropical cyclones (typhoons) and droughts are the key climate hazards affecting Abra.

Typhoons cause moderate consequences such as delay in credit acquisition, limited credit sources, labor shortage, small scanty cobs (possibly due to decreased pollination activities), and weak stunted plants. Temporary inaccessibility of market during these events also poses a moderate level of disruption. Meanwhile, high incidence of pests and diseases and damaged irrigation systems are a major challenge. On the severe level, typhoons cause extensive crop damage from flooding and lodging of plants and failure to preserve good seeds for the next planting season due to poor drying. All these effects boil down to low productivity and hence low income for the farmers.

ABI, et. al. in 2021 reported that heavy rains and floods associated with strong typhoons disrupt the activities of most lowland rice farmers, while highland vegetable and upland corn growers are vulnerable to soil erosion, landslides, and strong winds. Droughts have detrimental effects on upland corn and rain-fed production.

The moderate impacts of drought include delayed land preparation, limited labor (most of the men prefer non-farming livelihood activities during dry season) and stunting of plants due to lack of irrigation. Furthermore, drought can lead to major impacts such as high incidence of pest and diseases and small scanty cobs produced. At the extreme without supplemental irrigation, crop damage can be severe with prolonged drought.

A common major concern is the absence of a price regulation system for corn which puts farmers at a disadvantage.

Table 13. Type of hazard, consequences and severity of impact on white corn production.

Type of Hazard	Affected Value Chain Stage*	Consequence	Severity
Typhoon, flood and landslide	A	Delayed credit/loan acquisition	Moderate
		Limited credit sources	Moderate
	B	Limited laborers	Moderate
		Failure to preserve good seeds	Severe
		Crop damage	Severe
		Delayed land preparation	Moderate
		Damage to irrigation system	Major
	C	High incidence of pests and diseases	Major
		Small and scanty cobs	Moderate
		Stunted and weak plants	Moderate
	D	Inaccessible to market	Moderate
		No price regulation	Major
Drought	B	Delayed in land preparation	Moderate
		Limited laborer	Moderate
		Damage crop due to lack of irrigation (wilting)	Severe
		High incidence of pest and diseases	Major
		Small scanty cons produced	Major
		Stunted and weak plant	Moderate
		No price regulation	Major

Note: *A- Provision of seeds and other inputs; B- On-farm production; C- Harvesting, storage and processing; D- Product marketing

Mango

Typhoons, drought, and moderate winds with light rain are prominent threats that detrimentally affect mango cultivation in Abra.

The typhoon season, which occurs from July to October, coincides with critical stages in the value chain such as buying of inputs, land preparation, and planting on the 1st year of growth (Figure 41). Difficulties and delay in land preparation, fertilizer and pesticide application coupled with flooding and soil erosion may be experienced, especially for the first 3 years of growth (Table 11).

Moreover, critical growth stages of the plant, namely, seedling, vegetative, and reproductive stages especially flower induction and fruit setting on the 3rd year of growth may be impacted by the occurrence of typhoons and strong winds. Consequently, small-sized fruits and blackening of the fruit peel can be exacerbated by high incidence of pest and diseases leading to low yield and income.

Drought or prolonged dry season, which may occur from November to April, induces water stress in mango trees, negatively impacting its growth and fruit quality. Water for irrigation is usually lacking during this period especially from November to February. Production practices such as pesticide and fertilizer application may be delayed in the face of high incidence of pest and diseases. The time for flower induction and fruit setting also coincides with drought or prolonged dry season thereby leading to poor fruit quality and low yield.

Likewise moderate winds with light rains may be experienced from November to December, which as mentioned earlier coincides with flower induction and fruit setting. High incidence of pest ultimately leading to reduced income are some of the challenges faced by the farmers.

Similar observations were made by Normand et al. (2015) where different climatic variables impacted key processes for mango production such as photosynthesis, vegetative and reproductive development, and fruit quality. These consequences may be exacerbated by the lack of strategic and long-term research and development efforts leading to the development of innovative technology that can enhance competitiveness of the mango industry in local and export markets (DA-BAR, 2022b).

Mitigating these challenges requires the implementation of resilient practices and fortification of orchards. Collaborative efforts involving farmers, experts, and government support are essential to develop and implement strategies that can withstand and adapt to the adverse effects of climate change. This proactive approach is crucial to sustaining mango production in Abra and ensuring the resilience of the region's mango industry in the face of evolving climate patterns (Normand et al., 2015).

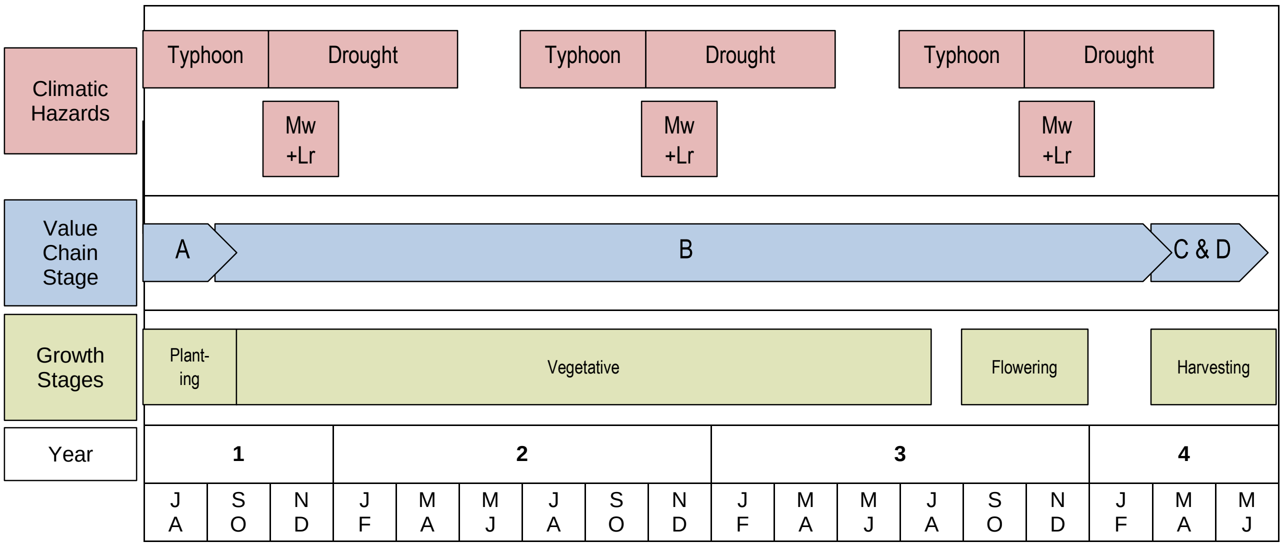


Figure 41. Climatic hazards on time, growth and value chain stages of mango production in Abra.

*Mw+Lr means moderate winds with light rain

Table 14. Type of hazard, consequences and severity of impact on mango production.

Type of Hazard	Affected Value Chain Stage*	Consequence	Severity
Typhoon	A	Delayed in acquiring farm inputs	Minor
	B	Difficulty in land preparation	Moderate
		Limited farm machineries	Major
		Limited laborers	Moderate
		Floods and landslides	Major
		Delayed in fertilizer and pesticides application	Major
	C	High incidence of pests and diseases	Major
		Poor quality of product (blackening of the skin and small fruits)	Major
		Low productivity	Major
	D	Inaccessible of farm-to-market road	Major
		No price regulation	Major
Drought and Moderate wind with light rain	B	Difficulty in land preparation	Moderate
		Limited farm machineries	Major
		Limited laborer	Moderate
		Scarcity of water irrigation	Major
		Delayed in fertilizer and pesticides application	Major
	C	High incidence of pest and diseases	Major
		Poor quality of fruits	Major
		Low productivity	Major
	D	Inaccessibility of farm-to-market road	Major
		No price regulation	Major

Note: *A- Provision of seeds and other inputs; B- On-farm production; C- Harvesting, storage and processing; D- Product marketing

Coffee

The occurrence of drought on November to April (Figure 42) affects the old coffee trees moderately during flowering and bearing stages where premature drying may be observed. Additionally, young coffee trees are also moderately affected by drought, with leaves wilting and growth stunted due to limited moisture or water (Table 12).

During typhoon occurrences, the collection of wildlings and planting activities may be delayed. Typhoons can cause uprooting of trees, breaking of branches, and toppling of shade trees, leading to damage. Additionally, severe flower and fruit drop, especially during bearing and flowering stages, may be observed. Furthermore, typhoons contribute to erosion and landslides, causing moderate destruction to farms, footpaths, and farm-to-market roads.

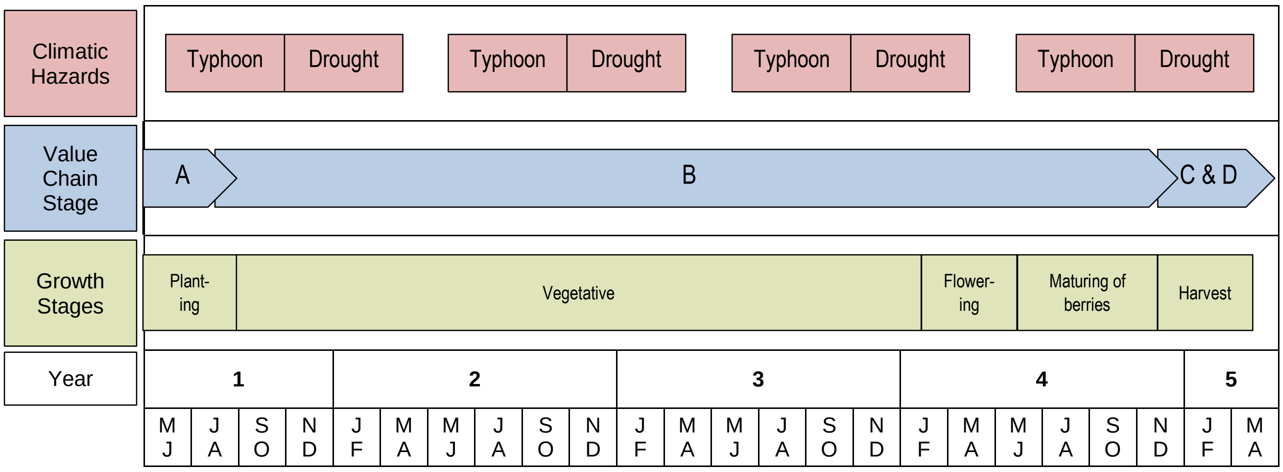


Figure 42. Climatic hazards on time, growth and value chain stages of coffee production in Abra.

Table 15. Type of hazard, consequences and severity of impact on coffee production.

Type of Hazard	Affected Value Chain Stage*	Consequence	Severity
Typhoon	A	Delay in collecting wildlings	Minor
	B	Delay in planting	Minor
		Increase in flower and fruit drop	Severe
		Breakage of stem and branches	Moderate
	A, B, C, D	Soil erosion/landslides	Moderate
Drought	B	Weak and stunted plants	Moderate
		Drying of berries	Moderate
		Wilting of leaves	Moderate

Note: *A- Provision of seeds and other inputs; B- On-farm production; C- Harvesting, storage and processing; D- Product marketing

Underlying Factors

Rice

Factors that further contribute to the damages caused by climatic hazards are diverse and can be classified as biological, infrastructure, institutional, policy and socio-economic in nature (Table 13). Some areas are prone to flooding, erosion and landslides. The majority of the rice farms are located in low-lying areas and near a sloping area where they are prone to flooding and landslides, which limit transport and marketing activities due to the near impassibility of roads. Additionally, poor condition of farm-to-market roads pose challenges in procuring and transporting farm inputs. Too many requirements and short application time to avail loans from lending agencies also contribute to the difficulties faced by farmers. Furthermore, limited manpower or labor available during crucial activities exacerbate the situation.

Table 16. Underlying factors and stage of value chain affected in rice production.

Underlying Factor	Type of Factor	Affected Value Chain Stage*
Flood prone areas Landslide or soil erosion prone areas	Biophysical	A, B, C, D
Limited MPDPs/ drying facilities No farm to market roads	Infrastructure	A, C, D
Too many requirements and limited time of application when availing credit/loan	Institutional	A
Low buying price	Policy	D
Conflict on land ownership/ management Limited transportation and high cost of transportation Limited laborers for manual harvesting (rainfed areas)	Socio-economic	A, B, C, D

Note: *A- Provision of seeds and other inputs; B- On-farm production; C- Harvesting, storage and processing; D- Product marketing

White Corn

Limited funds pose a hindrance to farmers in buying small farm machines for land preparation and irrigation which ultimately reduces labor productivity during climate hazards, while the absence of modern farming methods adversely affects efficiency and resilience (Table 14). Geographical challenges, which is especially faced by farmers in remote areas, result in difficulties accessing farm vehicles and public transport, disqualifying them from government lending programs. Additionally, infrastructure and sustainability issues in areas with limited access to irrigation and inadequate infrastructure create significant challenges in dealing with the aftermath of climate hazards. Farmers' lack of understanding and training on effective pest management contributes to high damage rates of pests and diseases.

Baas et al. (2023) revealed that fluctuations in markets and restricted access to formal markets contribute to income instability for farmers, and inadequate policy support becomes a constraint impacting overall growth and resilience in white corn farming. Socio-economic challenges, including high interest rates and stringent requirements for government lending programs, affect financial stability.

To enhance the resilience of white corn farmers in Abra, address these underlying factors through improved resource access, technology adoption, policy reforms, and socio-economic empowerment is crucial. Furthermore, measures such as increased availability of farm equipment, establishment of processing facilities after typhoons, and improvements in marketing facilities are essential for mitigating the impact of climate hazards on white corn production (Doe, 2020).

Table 17. Underlying factors and stage of value chain affected in white corn production.

Underlying Factor	Type of Factor	Affected Value Chain Stage*
Flood or drought prone farm areas Erosion or landslide prone areas High incidence of pest and diseases	Biophysical	B, C, D
Poor road conditions Insufficient/poor irrigation system Lack of farm facilities and processing facilities Lack of farm equipment/machineries	Infrastructure/Institutional	A, B, C, D
No established price regulation Limited manpower or labor available Insufficient knowledge on insect pest and disease management Difficulty in getting credit or loans	Infrastructure/Institutional/ Socio-cultural	A, C
High interest on lending agencies Increase of price on inputs	Socio-economic	A

Note: *A- Provision of seeds and other inputs; B- On-farm production; C- Harvesting, storage and processing; D- Product marketing

Mango

Challenges such as poor road conditions, insufficient irrigation systems, lack of farm and processing facilities, and a deficit in farm equipment and machinery are evident in all the value chain stages. Biophysical factors, including high incidence of pest and diseases, flood-prone areas, and erosion- or landslide-prone regions, impact on-farm production (B) and harvesting (C) stages. Additionally, socio-economic factors such as the absence of established price regulation, limited labor availability, insufficient knowledge on pest management, and difficulties in obtaining credit or loans affect provision of inputs (A), harvesting (C), and marketing (D) stages. These factors aggravate the consequences experienced by mango farmers from climate hazards. These challenges emphasize the need to address both agricultural and socio-economic aspects for the sustained production of mango in Abra (Table 15).

Table 18. Underlying factors and stage of value chain affected in mango production.

Underlying Factor	Type of Factor	Affected Value Chain Stage*
Flood or drought prone farm areas Erosion or landslide prone areas High incidence of pest and diseases	Biophysical	B, C, D
Poor road conditions Insufficient/poor irrigation system Lack of farm facilities and processing facilities Lack of farm equipment/machineries	Infrastructure/Institutional	A, B, C, D
No established price regulation Limited manpower or labor available Insufficient knowledge on insect pest and disease management Difficulty in getting credit or loans	Infrastructure/Institutional/ Socio-cultural	A, C
High interest on lending agencies Increase of price on inputs	Socio-economic	A

Note: *A- Provision of seeds and other inputs; B- On-farm production; C- Harvesting, storage and processing; D- Product marketing

Coffee

The severity of the impact of typhoons and drought on coffee trees and farms depends on the underlying factors such as elevation of the farm, lack of farm-to-market roads, etc. (Table 16). Usually, coffee farms are situated in mountainous and steep or sloping areas which are prone to soil erosion and landslides during typhoons. In areas where farm-to-market roads are non-existent or unimproved, transportation of inputs and marketing of produce becomes especially challenging.

Most farmers are elderly and often engage in other farming activities thus also need additional labor in doing farm maintenance and harvesting. However, the majority of the younger generation prefer urban employment opportunities over farming, further exacerbating labor shortages in agricultural activities.

Table 19. Underlying factors and stage of value chain affected in coffee production.

Underlying Factor	Type of Factor	Affected Value Chain Stage*
Erosion or landslide prone areas	Biophysical	A, B, C, D
Poor road conditions	Infrastructure	A, B, C, D
Limited manpower or labor available	Socio-cultural	B, C

Note: *A- Provision of seeds and other inputs; B- On-farm production; C- Harvesting, storage and processing; D- Product marketing

Climate Impacts on Gender

Rice

Men, women, youth, and children, as all integral components of farm operations. In rice production, men typically exhibit a very high degree of involvement (Table 17). Men are predominantly engaged in productive activities, particularly in physically demanding farm production management tasks, which often expose them to harsh weather conditions such as strong winds and heavy rains.

On the other hand, women's have high involvement across various value chains. They actively participate in less physically strenuous agricultural activities and are often responsible for household tasks such as childcare, food preparation, and meeting other basic needs. Additionally, women engage in non-farm income-generating activities.

Youth involvement in farming activities varies from low to high levels, depending on individual circumstances. Conversely, children typically have little to no involvement in farming activities. The youth have low to high involvement in the farming activities while children have normally no to low involvement in farming activities.

Table 20. Degree of involvement of each gender in the value chain stages for rice production.

Value Chain Stage	Gender	Degree of Involvement	
		Rating	Description
Provision of seeds and other inputs	Men	5	Very High
	Women	4	High
	Youth (15-30 y/o)	3	Medium
	Children (<15 y/o)	0	No Involvement
On-farm production	Men	5	Very High
	Women	4	High
	Youth (15-30 y/o)	3	Medium
	Children (<15 y/o)	1	Very Low
Harvesting, storage and processing	Men	5	Very High
	Women	4	High
	Youth (15-30 y/o)	4	High
	Children (<15 y/o)	2	Low
Product marketing	Men	4	High
	Women	5	Very High
	Youth (15-30 y/o)	2	Low
	Children (<15 y/o)	0	No Involvement

White Corn

In the first stage of the value chain – provision of seeds and other inputs - men have a very high involvement while women are highly involved. Youth and children are usually not involved in this stage (Table 18). Men are more knowledgeable on what inputs to buy and are capable of hauling and transporting these items to the farm. Women, on the other hand are engaged in other tasks such as household chores and other farm activities.

The second stage of the value chain is on-farm production where the degree of involvement is very high for men, and high for women and youth. Children are not engaged especially if they are schooling. Men are principally in charge of land preparation, planting, irrigation, fertilizer application and pest management with occasional help from women and youth. Other less tedious farm activities like weeding are handled by women and youth.

In the harvesting, processing and storage of products, men, women and youth are highly involved. In this stage of the value chain, all genders have the same level of involvement because they are all capable of the work entailed like pulling of ears, collecting, packing and hauling.

In the marketing of products, women take the lead while men take the supporting role. Women haggle with middlemen to get the best price for their products but men are likewise involved in price negotiation. Youth and children are seldom involved except for occasional help with hauling.

Table 21. Degree of involvement of each gender in the value chain stages for white corn production.

Value Chain Stage	Gender	Degree of Involvement	
		Rating	Description
Provision of seeds and other inputs	Men	5	Very High
	Women	4	High
	Youth (15-30 y/o)	0	No Involvement
	Children (<15 y/o)	0	No Involvement
On-farm production	Men	5	Very High
	Women	4	High
	Youth (15-30 y/o)	4	High
	Children (<15 y/o)	0	No Involvement
Harvesting, storage and processing	Men	4	High
	Women	4	High
	Youth (15-30 y/o)	4	High
	Children (<15 y/o)	0	No Involvement
Product marketing	Men	4	High
	Women	5	Very High
	Youth (15-30 y/o)	0	No Involvement
	Children (<15 y/o)	0	No Involvement

During climate hazards, men are frequently involved in physically demanding tasks such as farm restoration, making them more vulnerable to the challenges posed by adverse weather conditions. Their responsibilities may include assisting machine operators, transporting produce, and participating in road clearance activities. Meanwhile, women stay at home, managing household responsibilities and caring for children.

In the aftermath of climate hazards, men continue to play a crucial role in farm restoration, contributing to the recovery and preparation of the farm for future activities. Women also engage in various post-hazard activities such as cleaning up the surroundings, organizing stored produce, and actively participating in the overall recovery process. Collaborative efforts between men and women are evident both during and after hazards, as they work together to ensure recovery from damages and the sustainability of their livelihood. This is crucial for the overall resilience of the farming household.

This collaborative approach is essential, considering that farming is the primary source of income for many households. The impact on men and women during and after climate hazards is directly related to their distinct roles, with men typically handling physically demanding tasks and women often managing household responsibilities.

Mango

Traditionally, there is a division of labor, with men often involved in activities such as land preparation, planting, and pesticide application, while women are more involved in tasks like fruit picking, sorting, and processing (Table 19). This division in labor can impact access to income and decision-making power within households.

Men and women jointly procure farm inputs, including fertilizers and pesticides provided by government agencies. Men typically handle the physically demanding task of farm restoration after typhoons, exposing themselves to higher vulnerability during these climate-related hazards. During typhoons, men are more involved in assisting machine operators in lifting of produce and road clearance, while women, typically remaining at home, manage household responsibilities and care for children. Farmers, laborers, and buyers collaborate across the agricultural cycle, from harvesting to product marketing. This cooperative approach is integral to family farming, the primary income source for most households in Abra.

Table 22. Degree of involvement of each gender in the value chain stages for mango production.

Value Chain Stage	Gender	Degree of Involvement	
		Rating	Description
Provision of seeds and other inputs	Men	5	Very High
	Women	4	High
	Youth (15-30 y/o)	1	Very low
	Children (<15 y/o)	0	No Involvement
On-farm production	Men	5	Very High
	Women	4	High
	Youth (15-30 y/o)	3	Medium
	Children (<15 y/o)	0	No Involvement
Harvesting, storage and processing	Men	5	Very High
	Women	4	High
	Youth (15-30 y/o)	5	Very High
	Children (<15 y/o)	0	No Involvement
Product marketing	Men	4	High
	Women	4	High
	Youth (15-30 y/o)	3	Medium
	Children (<15 y/o)	0	No Involvement

Coffee

In coffee production, men are found to be more vulnerable to climate hazards (Table 20). Particularly during typhoons, men typically take on the responsibility of checking the farm as it can be perilous due to strong winds, heavy rains, and thunderstorms, with potential risks ahead. The farmers are also responsible in restoring eroded farms and clearing roadblocks caused by toppled trees and other structures after the typhoon and continuous rain. This work requires intense physical labor, such as carrying stones and clearing debris to repair the affected areas.

In contrast, women's involvement in coffee production ranges from low to high, with their primary tasks revolving weeding, harvesting, processing, and marketing. Additionally, women typically handle household chores, including caring for children.

The involvement of youth and children in coffee production is minimal to nonexistent, as the location of the farms is often distant, on steep slopes, and considered more dangerous.

Table 23. Degree of involvement of each gender in the value chain stages for coffee production.

Value Chain Stage	Gender	Degree of Involvement	
		Rating	Description
Provision of seeds and other inputs	Men	2	Low
	Women	0	No Involvement
	Youth (15-30 y/o)	0	No Involvement
	Children (<15 y/o)	0	No Involvement
On-farm production	Men	3	Medium
	Women	2	Low
	Youth (15-30 y/o)	1	Very Low
	Children (<15 y/o)	0	No Involvement
Harvesting, storage and processing	Men	4	High
	Women	3	Medium
	Youth (15-30 y/o)	2	Low
	Children (<15 y/o)	1	Very Low
Product marketing	Men	4	High
	Women	4	High
	Youth (15-30 y/o)	0	No Involvement
	Children (<15 y/o)	0	No Involvement

Identification and Prioritization of Adaptation Options

Rice

Adaptation to climate hazards is essential in crop production to mitigate the impacts of climate change. In Abra, over 61% of farmers opt for crop insurance to protect them against financial losses caused by natural disasters, adverse weather conditions, and other perils that could damage their crops and reduce their yields (Figure 43). Additionally, farmers select varieties suited to specific planting season including early maturing and drought-tolerant options like NSIC Rc222 and NSIC Rc216. The farmers also express appreciation for government support in providing seeds.

In their farming practices, farmers make use of tractors, whether hand-operated or four-wheeled drive, to expedite land preparation while reducing labor costs. They also take proactive measures by cleaning, repairing, and maintaining bunds, canals, and drainages ahead of impending typhoons or heavy rainfall to ensure effective water flow, thus minimizing potential crop damage and flooding. During typhoon events, farmers resort to early harvesting using combine harvesters to preempt losses and safeguard their rice fields.

Furthermore, during periods of drought, farmers capitalize on water pumps and solar-powered irrigation systems to sustain agricultural output, and fortify resilience against water scarcity. For farmers lacking access to such, they opt for planting alternative crops like mungbean during the dry season, diversifying their income sources. These adaptive measures underscore the proactive approach adopted by Abra's farmers in addressing climate challenges and maintaining crop productivity.

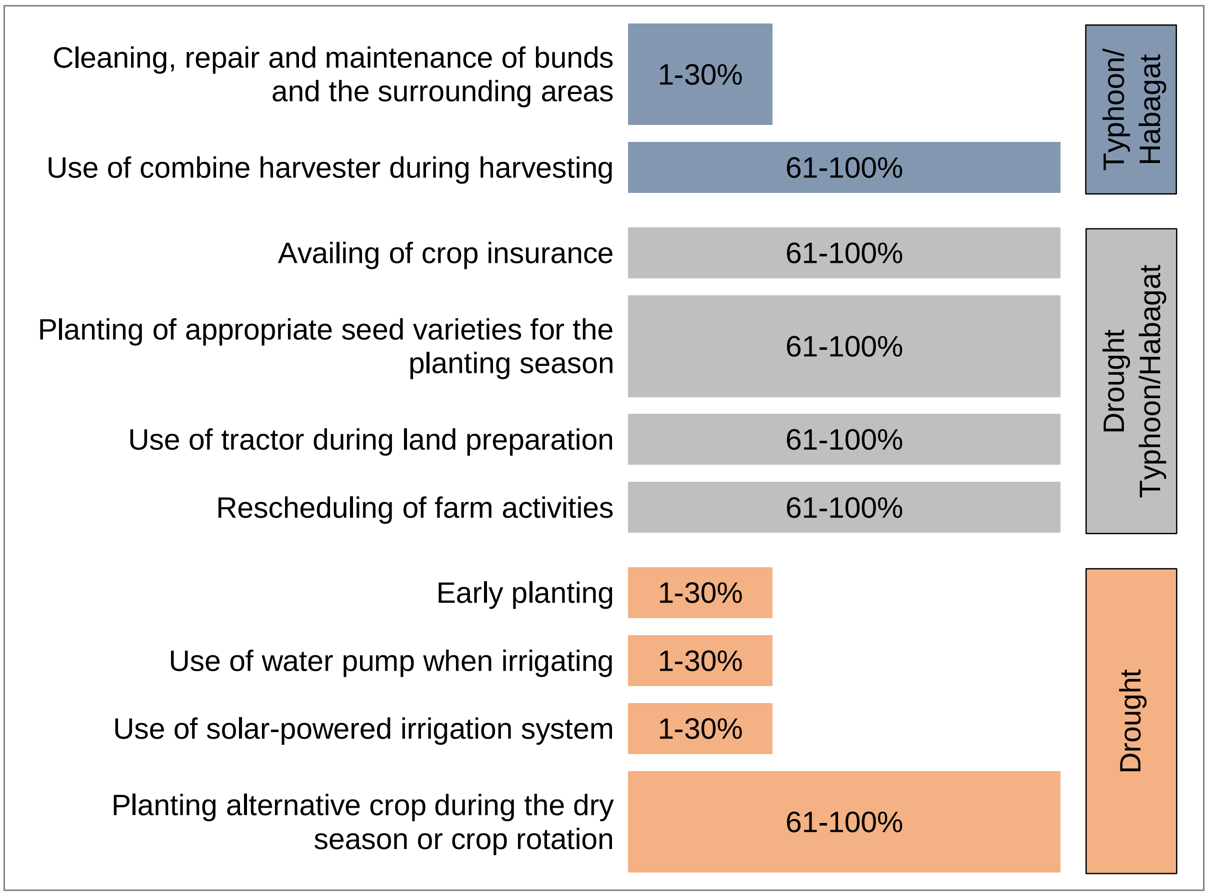


Figure 43. Adaptation options and degree of adoption by rice farmers.

<u>White Corn</u>

Farmers strategically employ measures to cope with devastating effects of climate hazards (Figure 44). In more recent years, farmers are encouraged to enroll their crops for financial assistance 15 days after planting as safeguard against potential drought or typhoon. The Department of Agriculture, in collaboration with RSBSA, provides complimentary seeds and fertilizers after these calamities, leading to reduced agricultural expenditures for many farmers.

During dry seasons, farmers use water pumps for irrigation. Hand or wheel tractors are also employed to efficiently complete tasks in fewer working days and reduce labor costs. Farmers also select good seeds from their previous harvest as seedstock for the next planting season. The farmers also enumerated coping mechanisms during rainy season. Temporary flood control structures are built especially near riversides during typhoons to prevent inundation and crop devastation. Farmers adjust their planting schedules based on typhoon forecasts and use hand or wheel tractors to facilitate land preparation. The use of quality seeds was also mentioned as a strategy.

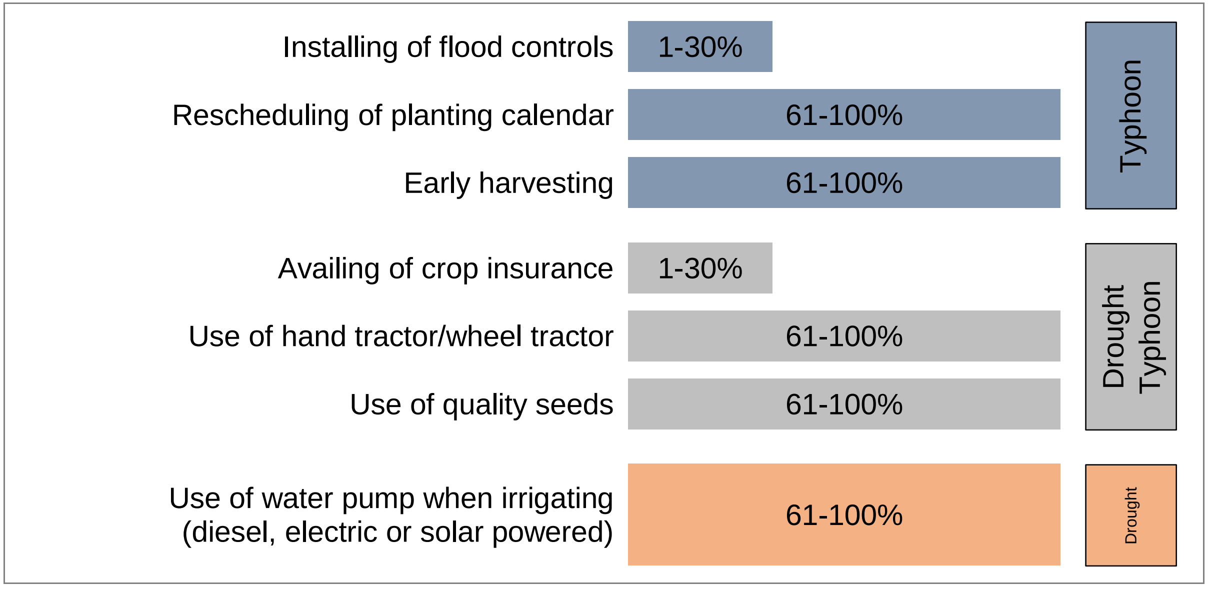


Figure 44. Adaptation options and degree of adoption by white corn farmers.

Mango

A few mango famers have implemented adaptation strategies to offset or minimize the impact of climate hazards (Table 21). For typhoons, the planting of windbreaks has an adoption rate of 1 to 30%. In the case of moderate winds with light rain and drought, the adoption rate for fruit bagging is within the 1 to 30% range. The low adoption rate of these strategies may be due to some roadblocks such as lack of financial benefits.

Similarly, mango farmers in Ghana have practiced adaptation strategies, such as creating gutters, applying agrochemicals, grafting and improved seed varieties, planting of trees as shades, irrigation and soil improvement techniques including mulching, to mitigate climate variability and change effects (Asare-Nuamah et al., 2022).

Table 24. Adaptation options and degree of adoption by mango farmers.

Hazards	Adaptations	Degree of Adoption
Drought/Moderate wind with light rain	Bagging of fruits	1-30%
Typhoon	Use of windbreaks (planting of trees)	1-30%

Coffee

Unfortunately, there are no specific adaptation options or mitigation strategies mentioned for the identified climatic hazards. Although certain practices were discussed, coffee farmers primarily engage in these practices to increase production and manage their farms, rather than specifically addressing climate-related risks such as typhoons and droughts.

Farmers emphasize that they do not implement extensive measures because their coffee trees are surrounded by shade trees like narra, acacia, and gmelina, as well as fruit-bearing trees like star apple, pomelo, and mango. During typhoons and droughts, these shade trees serve as protection against high temperatures and act as buffer trees against strong winds and heavy rains.

The majority of the farmers' coffee produce is used for home consumption, and any surplus is sold for additional income. However, farmers note that the volume of harvest has significantly decreased due to climate change. The reduced harvest has led some coffee farmers to convert or shift their coffee farms into other types of farming where they can potentially earn higher income.

Barriers to Adoption

Rice

The adaptation options identified and accessible to farmers present certain barriers to adoption (Table 22). Despite the availability of options, some farmers still opt to plant traditional varieties. Moreover, farmers refrain from availing loans from banks due to the numerous requirements and the short application window.

Institutional barriers further hinder adoption. Low institutional support is noted, alongside a lack of technical capacity and equipment among rice farmers. In certain areas, accessibility remains an issue as combine harvesters cannot reach all fields, and there is a scarcity of such equipment relative to the number of farmers.

Table 25. Barriers in technology adoption for climate hazards affecting rice production.

Barrier Type	Description	Affected Value Chain Stage*	Rank
Institutional	Low institutional support	A	1
Technical	Lack of technical capacity Access to technical equipment	C	2
Financial	Access to credit	A	3
Behavioral	Conflicts with traditional methods	B	4

Note: *A- Provision of seeds and other inputs; B- On-farm production; C- Harvesting, storage and processing; D- Product marketing

White Corn

The adoption of practices aimed at mitigating losses caused by climate hazards is hindered by significant barriers, particularly the lack of support, especially from government institutions. These recognized barriers encompass financial challenges arising from a perceived lack of financial benefits, technical limitations due to insufficient technical and human capacity, informational gaps characterized by low awareness of climate-smart techniques, and institutional challenges rooted in low institutional support.

These barriers collectively impede various stages of the value chain (Tables 23). Notably, low institutional support ranks as the most formidable obstacle, affecting stages B, C, and D. The lack of perceived financial benefits poses a significant barrier across stages A, B, C, and D, while technical limitations impact stages A, C, and D. Informational gaps, leading to low awareness of climate-smart techniques, affect stages A, B, C, and D. Overcoming these barriers is crucial for successful adoption, emphasizing the need for comprehensive support, awareness campaigns, and capacity-building initiatives to enhance resilience in the face of climate-related challenges in corn production.

Table 26. Barriers in technology adoption for climate hazards affecting white corn production.

Barrier Type	Description	Affected Value Chain Stage*	Rank
Institutional	Low institutional support	B, C, D	1
Financial	Lack of financial benefits	A, B, C, D	2
Technical	Lack of technical capacity Lack of human capacity	A, C, D	3
Informational	Low awareness of climate smart techniques	A, B, C, D	4

Note: *A- Provision of seeds and other inputs; B- On-farm production; C- Harvesting, storage and processing; D- Product marketing

Mango

Technical barriers, such as lack of technical and human capacity, impact on-farm production, harvesting and marketing stages of the value chain. The lack of laborers-for-hire at critical stages in the value chain is usually due to other out-of-town job opportunities. Institutional barriers, such as low support and a regulatory gap, affect all stages of the value chain. Low institutional support in terms of seedling distribution, information drive on climate change impacts and adaptation techniques, etc. may contribute to low yield and income. Lack of regulatory frameworks for mango production especially on establishment of a stable market price, may lead to costly breaks in the value chain, low fruit quality, reduced profit and overall global competitiveness (USAID, 2015). Financial hurdles, especially a perceived lack of benefits, impact purchase of inputs, on-farm production and marketing practices. Informational barriers, like low awareness of climate smart techniques and inadequate services, pose challenges across all stages of the value chain. Similarly, behavioral obstacles, such as short-term thinking and conflicts with traditional methods, affect all stages of the value chain and influence decision-making. Short-term thinking refers to perceived lack of immediate financial benefit if a particular climate change adaptation technique is practiced. Overcoming these barriers necessitates targeted interventions to enhance capacity, emphasize financial benefits, raise awareness, and address behavioral factors for widespread adoption of climate-smart techniques in mango production (Table 24).

Table 27. Barriers in technology adoption for climate hazards affecting mango production.

Barrier Type	Description	Affected Value Chain Stage*	Rank
Technical	Lack of technical capacity Lack of human capacity	B, C, D	1
Institutional	Low institutional support Lack of regulatory framework	A, B, C, D	2
Financial	Lack of financial benefits	A, C, D	3
Informational	Low awareness of climate smart techniques Lack of information services	A, B, C, D	4
Behavioral	Short term thinking Conflict with traditional methods	A, B, C, D	5

Note: *A- Provision of seeds and other inputs; B- On-farm production; C- Harvesting, storage and processing; D- Product marketing

Coffee

Low or limited support, particularly from government institutions, can present a barrier to the adoption of practices aimed at reducing losses caused by climate hazards (Table 25). The provision of government subsidies could assist farmers in mitigating these losses and implementing preventive measures.

Furthermore, the majority of coffee farmers are now elderly, and the younger generation tends to prefer urban employment opportunities, exacerbating labor shortages and resulting in decreased engagement in coffee production. This trend further emphasize the need for support and incentives to encourage younger individuals to participate in agricultural activities such as coffee farming.

Table 28. Barriers in technology adoption for climate hazards affecting coffee production.

Barrier Type	Description	Affected Value Chain Stage*	Rank
Institutional	Low institutional support	A, B, C, D	1
Technical	Lack of human capacity	B, C	2

Note: *A- Provision of seeds and other inputs; B- On-farm production; C- Harvesting, storage and processing; D- Product marketing

Support Granted to Farmers

Rice

Government and non-government organizations in Abra are actively involved in providing support to rice farmers to enhance rice productivity, food security, and rural livelihoods. Some of the key initiatives include subsidies and grants in the form of seeds, fertilizers, and other inputs, credit facilities, crop insurance, infrastructure, and market support (Table 26).

To address the risks associated with crop failure due to natural disasters or other unforeseen events, the government offers crop insurance schemes like those provided by the Philippine Crop Insurance Corporation. This serves to safeguard farmers' investments and provide a safety net in the event of calamities.

Financial aid programs like the Rice Farmers Financial Assistance (RFFA), amounting to Php 5,000.00 per farmer registered in the Registry System for Basic Sectors in Agriculture (RSBSA), are extended to farmers. These funds assist farmers in procuring agricultural inputs, investing in farm infrastructure, and covering operational expenses.

Moreover, the government prioritizes rural infrastructure development, including irrigation systems and farm-to-market roads, to sustain productivity and enhance transportation efficiency.

Efforts are also made to facilitate market linkages for farmers, ensuring access to markets with fair prices for their produce. Initiatives such as the National Food Authority (NFA) play a role in maintaining stable rice prices through procurement and distribution mechanisms.

Overall, these collaborative efforts aim to empower farmers in Abra, enabling them to improve their agricultural practices, secure their livelihoods, and contribute to the region's economic development.

Table 29. Some of the supports received by the rice farmers

Assistance/Support	Agency
Rice seeds and fertilizers	Department of Agriculture (DA) Local Government Units (LGUs)
Rice Farmers Financial Assistance (RFFA) (Php 5,000.00)	Department of Agriculture (DA)
Brush cutters	Department of Agriculture (DA) Department of Labor and Employment (DOLE) Local Government Units (LGUs)
Solar-powered irrigation system (SPIS) Water pumps and rolls of hose Power sprayers	Department of Agriculture (DA) National Irrigation Administration (NIA) Local Government Units (LGUs)
Knapsack sprayers and rechargeable sprayers	Department of Agriculture (DA) Local Government Units (LGUs)
Combine harvesters Threshers	Department of Agriculture (DA) Department of Social Welfare and Development (DSWD) Local Government Units (LGUs)
Fuel subsidy	Department of Agriculture (DA)
Multi-purpose drying pavements (MPDP)	Department of Agriculture (DA) Local Government Units (LGUs)
Indemnity payments	Philippine Crop Insurance Corporation (PCIC)

White Corn

The Department of Agriculture-Regional Office plays a crucial role in supporting Local Government Units by providing essential equipment and resources to aid farmers in their agricultural activities (Table 27). These include hand tractors, power sprayers, water pumps (diesel), corn shellers, drums (16L), corn seeds and fertilizers, and Multi-Purpose Drying Pavement (MPDP) to aid farmers in their agricultural activities. Additionally, the agency collaborates with the Department of Agrarian Reform, Department of Trade and Industry, and Department of Labor and Employment to establish food processing centers like the Cornick processing center. These center aims to empower women by enabling them to generate additional income through cooperative efforts. Indemnity payments, managed by the PCIC, are facilitated to assist farmers in cases where climate hazards impact their farms, while brass cutters (diesel) and fuel subsidies are also provided by the Department of Agriculture-Regional Office and Provincial and Local Government Units, respectively, to further support agricultural development and ensure sustainability.

Table 30. Some of the supports received by the corn farmers

Assistance/Support	Agency
Corn seeds and fertilizers	Department of Agriculture (DA)
Hand tractors	Department of Agriculture (DA)
Brush cutters	Department of Agriculture (DA) Local Government Unit (LGU's)
Fuel subsidy	Department of Agriculture (DA) Local Government Unit (LGU's)
Power sprayers Water pumps (diesel)	Department of Agriculture (DA)
Drums (16L)	Department of Agriculture (DA) Local Government Unit (LGU's)
Corn shellers	Department of Agriculture (DA)
Multi-purpose drying pavements (MPDP)	Department of Agriculture (DA)
Food processing center (Cornick)	Department of Agriculture (DA) Department of Agrarian Reform (DAR) Department of Trade Industry (DTI) Department of Labor and Employment (DOLE)
Indemnity payments	Philippine Crop Insurance Corporation (PCIC)

Mango

The Department of Agriculture-Regional Office extends vital assistance and support to farmers through a variety of means (Table 28). This includes providing diesel power sprayers, mini chainsaws, and grass cutters to boost agricultural productivity. Furthermore, fertilizers, potassium nitrate, and grafted mango seedlings, along with other necessary farm inputs are provided as a result of collaboration between the Department of Agriculture-Regional Office and Local Government Units. Local Government Units also conduct training programs on different aspects of agriculture, equipping farmers with essential technical knowledge and skills. Additionally, they distributed plastic crates, which aid in the efficient handling and transportation of agricultural produce. This collaborative endeavor is aimed at strengthening the agricultural sector and fostering sustainable farming practices for the mutual benefit of farmers and communities.

Table 31. Some of the supports received by the mango farmers

Assistance/Support	Agency
Grafted mango seedlings	Department of Agriculture (DA) Local Government Units (LGUs)
Fertilizers Potassium nitrate	Department of Agriculture (DA) Local Government Units (LGUs)
Mini chainsaws Grasscutters	Department of Agriculture (DA)
Power sprayers (diesel)	Department of Agriculture (DA)
Plastic crates	Local Government Units (LGUs)
Trainings (on agricultural farming)	Local Government Units (LGUs)

Coffee

Government and non-government organizations in Abra are actively engaged in supporting coffee farmers to enhance coffee productivity, competitiveness, and livelihoods. Some of the key initiatives include coffee seedling distribution, and training and capacity building (Table 29).

The distribution of coffee seedlings to farmers encourages the expansion of coffee cultivation. These seedlings are often sourced from nurseries that produce high-quality planting materials. Training sessions and capacity-building endeavors are conducted to equip coffee farmers with essential knowledge and skills to improve their farming practices, increase productivity, and enhance the quality of their coffee beans.

These endeavors contribute to broader strategies aimed at revitalizing the coffee industry, which confronts challenges such as aging trees, low productivity, and competition from imported coffee. By extending support to coffee farmers, the objective is to amplify production, enhance quality, and fortify the competitiveness of Philippine coffee both domestically and globally.

Table 32. Some of the supports received by the coffee farmers

Assistance/Support	Agency
Training/demonstration on coffee harvesting and processing	Department of Trade and Industry (DTI)
Coffee seedlings	Department of Environment and Natural Resources (DENR)
Coffee processing machines Coffee depulper Coffee roaster Coffee grinder	Department of Agrarian Reform (DAR) Department of Trade and Industry (DTI) Department of Environment and Natural Resources (DENR) Local Government Units (LGUs)
Coffee processing building	Department of Agrarian Reform (DAR)
Knapsack sprayer	Local Government Units (LGUs)
Nursery facility	Department of Trade and Industry (DTI)

C. Cost-Benefit Analysis

Economic Viability of the Prioritized Adaptation Practices for Corn Production during Dry Season in Abra

Solar Powered Irrigation System (SPIS)

Based on the database of the National Irrigation Administration NIA), there are 21 Groundwater Solar Pump Irrigation Systems SPIS) established in Abra from 2021 to 2024 amounting to Php122.17 million with target service area of 370 hectares.

Comparative Farm Profile

The use of SPIS was compared to the use of diesel-pump and electric-pump-powered pump, which are counterfactual as mentioned by farmers. The average area cultivated by rainfed farmers, diesel pump users, electric pump users, and solar-powered irrigation system users are shown in Table 30. The most common cropping pattern in Abra is rice-corn, with the SPIS used only during the dry season. The dry season corn cropping usually occurs between October to November and harvesting happens between January to February.

Table 33. Farm Profile and Farming Characteristics of Corn Farmers, Dry Season Abra

Item	**Rainfed**		**Diesel Pump**		**Electric Pump**		**SPIS Dugwell**	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Area (ha)	1.33 (0.94)	0.26-5	1.62 (0.86)	0.5-3	1.14 (0.65)	0.30-2.50	0.64 (0.25)	0.4-1
Distance of Parcel to water source (km)	-	-	0.39 (1.25)	0.001-5	3.85 (14.98)	0.005-60	0.08 (0.08)	0.001-0.24
Distance of Parcel to water source (mins)	-	-	3.35 (3.53)	0.5-10	8.28 (9.80)	0.50-30	(20.02)	1-50
Distance from parcel to house (mins)	16.98 (12.88)	1-55	14.17 (8.73)	3-30	9.18 (7.69)	2-30	12.22 (10.86)	2-30

Item	Rainfed		Diesel Pump		Electric Pump		SPIS Dugwell	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Distance from parcel to nearest market (mins)	24.44 (10.74)	10-45	10.00 (0.00)	10-10	21.67 (14.43)	5-30	10.33 (5.72)	2-15
Cropping Patterns								
Rice-Fallow	7	26.92						
Rice-Rice	1	3.85						
Rice-Corn	16	61.54	19	95.00	14	77.78	3	33.33
Rice-corn-corn	0	0	1	5.00	4	22.22	6	66.67
Rice-Vegetables	2	7.69	-	-	-	-	-	-

Perceived Changes as a Result of Using SPIS

Table 31 itemizes the farmers' perceptions of changes in corn farming and the advantages as a result of using SPIS for their corn production. One of the top perceived impacts is that it increases their yield during the dry season. As stated by some of the respondents, *"inmado ti apit ti mais ta makapaminduwa kami makamula ti mais ta idi ket maminsan lang"*. According to a case study by Magrath (2015), the transformational impact of solar irrigation resulted in increased farm yields of Zimbabwe farmers to an average of 4 to 5 tons of maize per hectare. This Ruti irrigation scheme by Oxfam also enabled the farmers to grow three crops per annum and rotate crops to grow a diversity of nutritious and cash crops. Moreover, the project evaluation of this scheme shows that household incomes increased. Another advantage of the SPIS project is it is cost-saving on electricity and fuel. According to some respondents, *"nabawasan ti gastos ta haan gumatang ti krudo", "haan masapol nga gumatang krudo wennu agusar ti kuryente"*. This result can be supported by the study of Rana et al., (2021) who found that the advantages of solar pumping systems include low operating cost and maintenance compared to the high fuel and maintenance costs of diesel-powered generators. In addition, high fuel and maintenance costs have been long-standing problems with diesel engines (Aligah, 2011). Sattar and Rahman (2004) stated that while the initial capital cost of a solar pump may be far greater than a generator because of low maintenance and zero fuel cost, solar-powered systems can be a cheaper option in the long run.

Table 34. Perceived changes and advantages of using Solar Powered Irrigation System

Item	**Frequency***	**%**
Increase in yield	6	66.67
Cost saving (electricity, fuel)	6	66.67
For agricultural use	2	22.22
Sufficient irrigation	2	22.22
For domestic and animal use	2	22.22
Change of crop due to availability of irrigation	1	11.11
Utilization of unused land area for agricultural purposes due to availability of irrigation.	1	11.11
Two cropping of maize	1	11.11
Less labor since don't need to pull/drag hoses to the parcel	1	11.11

*multiple answers

On the other hand, one disadvantage mentioned by the farmers is that the scheduling of irrigation for farmers is not being followed. They also stated that *"haan na kami masupplyan amin nga agsasabay ta haan nga mabalin nga aggigiddan kami ta agkurang ti danum"* (the SPIS cannot supply our irrigation needs simultaneously because water is not enough). This perception is confirmed in the observed data based on the before and after data of SPIS users interviewed for this project.

Observed Changes in Cropping Pattern, Cropping Intensity, Yield, and Income as a Result of Using Water Pumps for Dugwell

Cropping Pattern and Intensity. The common cropping pattern in the survey areas where the SPIS for dugwells were established is rice-corn or a cropping intensity of 200%. Some farmers supported by water pumps such as diesel and electric pumps can plant rice and then corn twice a year while the majority of rainfed farmers can only plant one rice and then one corn in a year (Table 32). For the majority of farmers who use solar-powered irrigation systems (SPIS), they can have a third cropping of corn or a cropping intensity of 300%. The establishment of SPIS in the surveyed areas, thus, resulted in an increase in cropping intensity by 67%, while using diesel and electric pumps increased cropping intensity by 5% and 22%, respectively. This result is similar to a study in Gutu in which the solar irrigation scheme of Oxfam enabled them to obtain three harvests a year and rotate between food crops and cash crops. This result confirms the conclusion of many studies on the influence of improvement of irrigation on land productivity, particularly on cropping intensity (Karunakaran and Palanisami, 1998; Mondal and Sarkar, 2021; Launio and Abyado, 2022).

Table 35. Comparative Cropping Pattern of Corn Farmers, by Irrigation Source, Abra

Cropping Pattern/ Crop Intensity	**Rainfed (n=16)**		**Diesel Pump (n=20)**		**Electric Pump (n=18)**		**SPIS (n=9)**	
	n	%	n	%	n	%	n	%
Cropping Pattern								
Rice-corn	16	100	19	95.00	14	77.78	3	33.33
Rice-corn-corn	-	-	1	5.00	4	22.22	6	66.67
Cropping Intensity	200%		205%		222%		267%	

Change in Average Input-Use. Average input use often differs between rainfed and irrigated corn ecosystems. In the case of corn farming during the dry season in Abra, the application of urea and complete (14-14-14) fertilizers was found higher for irrigated farms with SPIS users having the highest value (Table 33). As stated by the respondents, *"idi awan pump uno padanum, haan kami unay agbugaso ta awan sirbi na, tumangken lang ijay rabaw ti daga"* (When there was no irrigation pump, we limit our fertilizer application because it will just dry on top of the soil.) As explained by Manalili et al. (2016), weather conditions during the dry season are usually more favorable, and solar radiation is more abundant, so N fertilizer should be higher. However, for average herbicide use in corn, the application is lower for SPIS and electric-pump irrigation-supported farmers. This corroborates the result for conventional rice farming in Ifugao, where the herbicide use in rainfed farms was higher than in water pump and CIS-irrigated-supported rice production (Launio et al., 2022).

Table 36. Average Input-Use in Corn Production in Abra, 2022 Dry Season

Item	**Rainfed**	**Diesel Pump User**	**Electric Pump User**	**SPIS User**	**Pooled**
Urea (kg/ha)	46.15	82.41	80.12	110.49	76.56
Triple 14 (kg/ha)	0	4.52	0	6.94	2.43
Ammonium Phosphate (kg/ha)	52.60	22.68	82.85	40.28	49.99
Foliar (L/ha)	0.08	0.15	0	0.25	0.1
Herbicides (L/ha)	0.42	0.52	0.01	0.22	0.3
Pesticides (L/ha)	1.65	1.53	2.75	1.66	1.93

Change in Annual Labor Use. While the use of SPIS is not in itself labor increasing or reducing, more than 30% of SPIS users claimed that there is an increase in labor use since they stated *"inmado ti trabaho ta maminduwa nga agmula ti corn ngem maminduwa metlang makaapit"* (there is an increase in labor employed since we can plant corn twice a year). This increase in labor use is associated with the increase in cropping intensity as a result of using SPIS as seen in Table 32.

Increase in Yield. Figure 45 roughly shows the difference in the yield distribution of rainfed corn farmers and farmers with water pumps during the dry season. Most of the rainfed farmers' and diesel pump users' yields ranged from 0-1 tons/ha while farmers supported with electric pumps had yields ranging from 1.1-2 tons. For corn farmers using the solar-powered irrigation system with water coming from dugwell, the majority of them had yields ranging from 2.1-3 tons which is higher than the others. Moreover, 11% of the SPIS users also had yields ranging from 4.1 to 5 tons showing the yield-increasing impact of SPIS. Similar results were also obtained in the case of Ifugao in 2021 where yields of farmers supported by water pumps were higher than rainfed (Launio et al., 2022). Similar results were also obtained from the Ruti irrigation scheme in Zimbabwe wherein with the use of a solar pumping irrigation project, the farmers produced an average of 4 to 5 tons of maize per hectare thus increasing yield and income (Magrath, 2015).

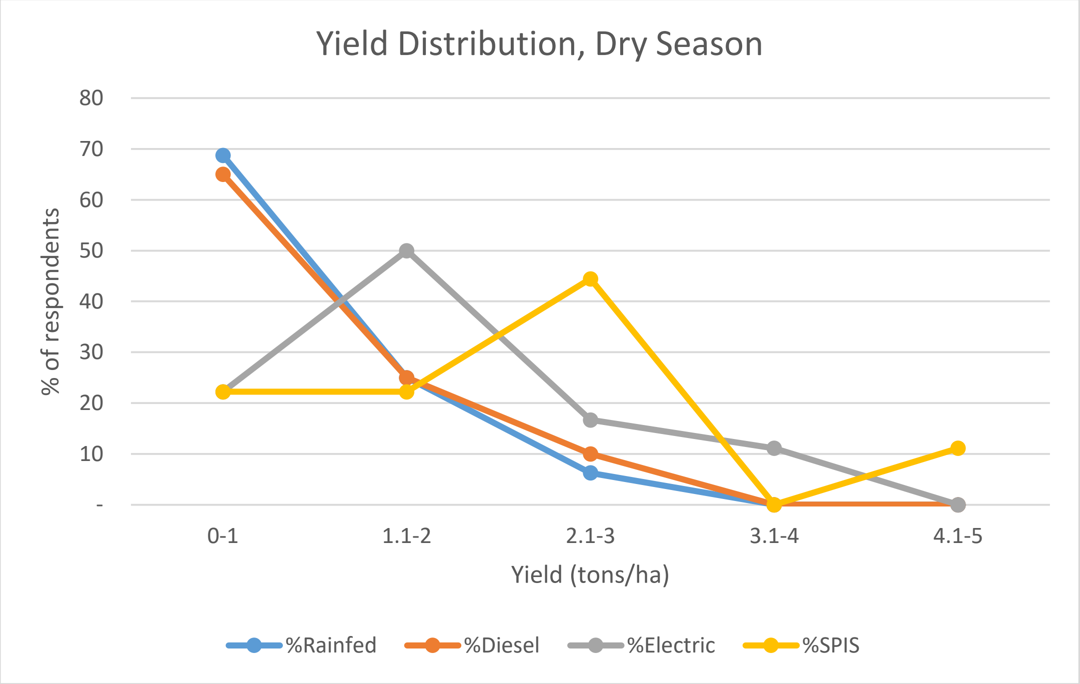


Figure 45. Yield Distribution of Abra Corn Farmers, 2022 Dry season

Change in Annual Income. Table 34 presents the profitability analyses of wet-season rice farming for samples using diesel and SPIS for corn farming during the dry season. In general, according to the farmers, rainfall was enough to support the wet-season rice crop, the harvest of which is also largely consumed by the household. The water pumps were only used for the second crop corn farming. Table 35 presents the detailed cost and return analysis of corn production during the dry season comparing farmers who are rain-dependent and farmers with irrigation facilities like diesel-powered, electric-powered, and solar-powered irrigation pumps. Because of the difficulty in interviewing three crops' input-output data and the claim of respondents that the production and costs for the second cropping for corn were similar to the first corn crop in the dry season, the same costs and income were used in deriving the annual income. The counterfactual for the farmers who are beneficiaries of SPIS who get their irrigation from dug wells is the corn production using diesel and electric pumps. On the other hand, the counterfactual for those who use diesel-powered and electric-powered water pumps is purely rainfed farms. Table 35 shows that the net profit-cost ratio from corn farming for SPIS users is much higher at 0.28 centavos profit for every peso invested than the farms supported by diesel-powered and electric pumps. In terms of mean yield, the difference between corn production supported with SPIS and electric pump is not significant but is quite substantial at around 800-900 kg/ha when compared with rain-dependent farms. The fuel cost for diesel-powered water pump users is Php1,359/ha, similar to the average electric cost per hectare for electric-powered pumps at Php1,423/ha.

Table 37. Cost and Return Analysis of Rice Farming in Abra, 2022 Wet Season

Item	**Diesel-Pump Users (n=20)**	**SPIS dugwell Users (n=7)**	**Pooled (n=27)**
Average Area Cultivated (ha)	1.55	0.80	1.35
Returns			
Total harvest (kg ha-1)	**1,507.71**	**1,916.07**	**1,613.58**
Price (P kg^{-1})	17.61	17.61	17.61
Gross Returns (P/ha)	**26,550.69**	**33,742.02**	**28,415.11**
Costs (P/ha)			
CASH COSTS			
Seed/Planting Material	1,548.47	4,351.43	2,275.16
Fertilizer	8,222.74	10,805.36	8,892.31
Herbicides	1,795.23	2,229.85	1,907.91
Pesticides	1,545.64	2,143.88	1,700.74
Labor			
Preharvest Labor	4,862.46	4,369.39	4,734.62
Hauling	402.38	252.55	363.54
Food Cost	1,593.90	3,627.55	2,121.14
Fuel cost	208.33	-	154.32
Electric cost	-	-	-
Transportation Cost	118.93	126.11	120.79
Repair and Maintenance cost	65.74	53.57	62.59
Other Production Cost	350.07	444.18	374.47
Total Cash Costs	**20,713.89**	**28,403.86**	**22,707.58**

Item	Diesel-Pump Users (n=20)	SPIS dugwell Users (n=7)	Pooled (n=27)
NON-CASH COSTS			
Labor			
Preharvest Labor	3,132.88	9,595.66	4,808.42
Harvesting	3,499.14	5,004.52	234.46
Land Rental	8,513.91	6,752.14	8,057.15
Depreciation Cost	16.79	38.15	22.33
Total Non-Cash Costs	**15,162.72**	**21,390.47**	**13,122.36**
Total Production Costs	**35,876.61**	**49,794.33**	**35,829.94**
Net Profit P/ha	**(9,325.92)**	**(16,052.31)**	**(7,414.83)**
Net Profit Cost-Ratio	**(0.26)**	**(0.32)**	**(0.21)**
Net Returns to Land & Management	**5,820.01**	**5,300.01**	**5,685.20**

Table 38. Cost and Returns Analysis of Corn Production in Abra, 2022 Dry Season

	Rainfed (n=16)	Diesel Pump (n=20)	Electric Pump (n=18)	SPIS (n=9)
Average Area Cultivated (ha)	1.16	1.62	1.14	0.64
Returns				
Total harvest (kg ha-1)	**1,046.25**	**1,133.21**	**1,830.97**	**1,949.46**
Price (Php kg^{-1})	26.68	26.68	26.68	26.68
Gross Returns (Php/ha)	**27,913.87**	**30,234.16**	**48,850.23**	**52,011.53**
Costs (Php/ha)				
CASH COSTS				
Seed/Planting Material	995.00	1,688.75	1,927.22	1,144.44
Fertilizer	3,171.70	3,841.10	4,396.28	4,797.22
Herbicides	194.58	288.50	27.78	133.33
Pesticides	1,848.16	1,539.71	1,937.16	2,564.81
Labor				
Preharvest Labor	5,149.07	5,218.87	4,634.52	4,654.94
Harvesting	2,493.56	3,505.97	3,133.02	5,524.20
Land Rental	9,804.98	11,111.23	18,736.64	11,208.33
Food Cost	1,946.55	1,361.19	2,534.34	3,435.19
Fuel cost	295.83	1,358.82	166.67	348.15
Electric cost	-	-	1,422.50	-
Transportation Cost	86.90	111.67	107.50	230.63
Repair and Maintenance cost	352.98	548.04	359.26	1,385.03
Other Production Cost	281.82	361.76	283.24	1,158.89
Total Cash Costs	**26,621.13**	**30,935.61**	**39,666.13**	**36,585.16**
NON-CASH COSTS				
Labor				
Preharvest Labor	3,851.18	2,492.50	4,831.97	3,404.17
Harvesting	911.48	414.17	1,183.33	551.39
Depreciation Cost	20.34	16.79	47.71	64.49
Total Non-Cash Costs	**4,782.99**	**2,923.46**	**6,063.01**	**4,020.04**
Total Production Costs	**31,404.12**	**33,859.06**	**45,729.14**	**40,605.21**
Net Profit P/ha	**(3,490.25)**	**(3,624.91)**	**3,121.09**	**11,406.33**
Net Profit Cost-Ratio	**(0.11)**	**(0.11)**	**0.07**	**0.28**
Returns to land & management	**1,272.41**	**(718.24)**	**9,136.38**	**15,361.88**

Cost-Benefit Analysis of Solar Powered Irrigation System (SPIS) from Dugwell

The following assumptions were considered in the baseline analysis:

a. The investment cost for SPIS is Php 1,805,323.24 based on the actual cost per unit provided by the National Irrigation Administration, which is comprised of 4 – 6 panels with 12-14 meters deep of dugwell
b. The maintenance cost of Php 500 per hectare per season given by beneficiaries to the Association;
c. Solar Powered Irrigation System actual lifespan of 2 years and an actual service area of 2.5 hectares;
d. The identified benefits were based on the survey and validated during focus group discussions, namely: increase in yield during dry season, increase in cropping intensity wherein the cropping pattern for diesel pump user is rice-corn while rice-corn-corn for SPIS users, saved fuel use of 35L/season, saved repair and maintenance cost from using diesel pump, and estimated environmental benefit in terms of reduced carbon emission from combustion of diesel;
e. For the carbon emission calculation, the emission factors used are from EPA (2023) (Table 36), while Php278.15/ton CO_2-eq was used for carbon pricing based on actual carbon market in Singapore (Duggal, 2021; Singapore Ministry of Sustainability and the Environment, 2024).
f. The discount rate is 10% based on NEDA-ICC recommendation.

Table 39. Assumed Emission Factor and Global Warming Potential of Diesel per GHG

Diesel	Carbon Dioxide (kg CO2/gallon)	Methane (kg CH4/gallon)	Nitrous Oxide (kg N2O/gallon)
Emission Factor	10.21	0.00127	0.00107
Global Warming Potential (GWP)	1.00	28.00	265.00

Source: Federal Register EPA; 40 CFR Part 98; e-CFR, (https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-98) & EPA (2023) Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021 (Annexes); Intergovernmental Panel on Climate Change (IPCC), Fifth Assessment Report (AR5), 2013

Given the above assumptions, the estimated NPV is negative Php 1,437,665.55 with a BCR of 0.13 (Table 37). This result is because the SPIS established in 2022 was destroyed when Typhoon Egay hit Abra in 2023 and was not repaired until the time of data collection. Moreover, only 3 beneficiaries with an actual area covered of 2.5 hectares benefited since according to the respondents, the water cannot accommodate all the areas of the supposedly six beneficiaries with a total of 7 hectares per SPIS unit. They stated *"nu nalawa ti lapogem, narigat na masupplyan jay adu nga tao ta agkurang ti danum".*

Table 40. Cost and Benefit Analysis of NIA-funded Solar Powered Irrigation System for Dugwell Water Source, Abra

Item	NPV (Php)	BCR	IRR (%)	Payback period
SPIS	(1,437,665.55)	0.13	-94%	17.53

Assuming that the supposed service area of 7 hectares was covered by the SPIS, it will be economically viable (Table 38). Further sensitivity analysis shows that if the actual service area of 2.5 hectares was covered, it would still not be an economically viable investment even if it is functioning for 20 years. On the other hand, assuming the SPIS was repaired every five years but still supplied the actual service area of 2.5 hectares, it would still not be an economically viable project, implying the importance of yield advantage as a source of incremental benefits. These results indicate that with the substantial investment cost of establishing a solar-powered irrigation system, it is important that the estimated service area can be supported, and the risks from extreme weather events like typhoons, be considered in the design. Further technical evaluation of design is also recommended for the SPIS established in Abra to understand why the target service area was not met. It should be noted that in contrast to our results, previous studies have shown that the use of Photovoltaic energy for water pumping systems is feasible and more profitable than diesel pump-supported farming (Dahdic and Shrivastava, 2017; Raza et al., 2022; Campana et al., 2016; Nowar, 2009).

Table 41. Results of Sensitivity Analysis on CBA assumptions of SPIS Dugwell, Abra

Item	NPV (Php)	BCR	IRR (%)	PP
Scenario 1 Service area of 7 ha with 20 years life span (based on design)	162,498.59	1.10	3%	8.52
Scenario 2 Actual service area of 2.5 ha supported, with 20 years life span	(747,565.86)	0.55	-11%	17.53
Scenario 3 Actual service area of 2.5 ha with 20 years lifespan with assumed repair every 5 years	(1,251,070.62)	0.42	-8%	17.53
Scenario 4 Actual service area of 2.5 hectares with 20 years lifespan and carbon pricing increased to 25$ per ton CO2-e	(745,260.51)	0.55	-11%	17.48

Environmental Impact

Based on the values used in carbon emission calculation and assuming zero emission from solar-powered irrigation systems, an average GHG emissions of 0.10 tons of CO2 annually was reduced by replacing diesel-powered irrigation with solar-powered irrigation systems in this study. This result is less than the result of the study of Ghosal et al. (2020) wherein a 4.34 ton of CO_2/ha emission reduction was recorded in the case of Odisha, India. The main reason for this is the actual service area of 2.5 hectares considered in this study. Solar-powered irrigation systems are pollution-free and can be used to mitigate CO2 emissions (Rana et al., 2021b).

Crop Insurance

The understanding of farmers about crop insurance is shown in Table 39. Both beneficiaries and non-beneficiaries have a similar understanding of crop insurance. Majority of the beneficiaries claimed that it helps farmers. They stated *"makatulong ti mannalon nu mapirdyan ka"*. On the other hand, a higher percentage of non-beneficiaries are not aware and have no idea about crop insurance which may have influenced their decision not to avail crop insurance.However, some of the non-beneficiaries also claimed that crop insurance provides financial assistance or help to farmers.

Table 40 itemizes the perception of corn farmers in terms of availing crop insurance. While some of them understand that crop insurance provides some kind of assistance during calamities, the experience of the majority of the farmers of not being able to receive indemnity during calamities may have influenced their perception of the actual benefits of crop insurance. Furthermore, the perceptions of the non-beneficiaries were consistent with their understanding of crop insurance. The majority of them have no idea about crop insurance hence they were unable to discuss any benefits.

Table 42. Farmer's Perceived Understanding about Crop Insurance

Item	Frequency	Percentage
Beneficiaries		
It will help farmers in case of crop damage	12	30.00
"Sukat ti gastos nu mapirdyan ka ti mula"	10	25.00
None/No Answer	9	22.50
They give financial assistance in case of crop damage	7	17.50
Insurance of crops	2	5.00
Total	40	
Non-beneficiaries		
No answer/Not aware	9	52.94
If insured, they give financial assistance or help to farmers with damaged crops	8	47.06
Total	17	

Table 43. Perceived Benefits of Availing Crop Insurance

Item	Frequency	Percentage
Beneficiaries		
None	17	42.50
Insurance of crops that in case of damaged crops, there will be assistance given	16	40.00
Can help farmers with damaged their crops	7	17.50
Total	40	
Non-beneficiaries		
No answer/no idea	12	70.59
If crops are damaged, there will be help given that can substitute losses	5	29.41
Total	17	

The perceived constraints of availing crop insurance are enumerated in Table 41. Majority of the beneficiaries stated that they haven't encountered any constraints in availing of crop insurance which means they have complied with the requirements and have received indemnity payment for their damaged crop. However, some claimed that the indemnity payment takes a long time to receive. During the validation of findings, the LGU stated that there is a shortage of staff that validates or processes the indemnity, which is why it takes a long time to process the indemnity payment. In addition, they also stated that some farmers submit their report of crop damage late or some information do not tally thus affecting the processing of the indemnity payments.

Table 44. Perceived Constraints on Crop Insurance (Beneficiaries)

Item	Frequency	Percentage
None	25	62.50
Long time before indemnity will be received	7	17.50
A lot of requirements	3	7.50
Not enough indemnity	2	5.00
Long time processing	3	7.50
No indemnity payment received	1	2.50
Long-time monitoring and validating the area damaged	1	2.50

*multiple answers

Table 42 shows why non-beneficiaries of crop insurance never availed of this program. A higher number stated that they had no idea or were not aware of this program thus they never availed of it. Aside from this, some non-beneficiaries never avail of crop insurance because it is time-consuming and has lots of requirements. As stated by some of the farmers, *“taktak gamin, masikuranak ta nagadu dawdawaten da nga documento”* (It requires much time, they are requiring a lot of documents).

Table 45. Why non-beneficiaries never availed crop insurance

Item	Frequency	Percentage
No idea/ Not aware	8	47.06
Time time-consuming and lot of requirements	7	41.18
Small area	1	5.88
Late application	1	5.88
Total	17	113.33

Use of Tractor for Land Preparation

The use of a tractor for land preparation was identified as one adaptation strategy for both drought and typhoon. Majority of the farmers answered that the advantage of using tractor in land preparation is the faster land preparation which also saves labor and time and therefore less labor cost (Table 43). According to them, *“napaspaspas ti panakatrabaho na ket nadardaras ka metlng makamula”, “nagasgastos ti agpaarado mano-mano ta nabaybayag ti trabaho tapos pakanem pay isuda”.* This claim is supported by the comparison study of Sutjana & Adipura (2012) in using a plow, tractor, and cultivator which showed that it only takes 22.07 hours to complete the land preparation of a hectare when using a tractor compared to more than 3 weeks with 4-5 hours a day for manual land preparation since carabao needs to rest. Another claimed advantage of using this machinery is the better soil quality wherein the farmers stated *“napinpino ti panakabungkal ti daga na”.* Based on the comparative study of Maranan (1985), farmers adapted tractors for land preparation because the machine provided a better quality of tillage and the tractor was faster and easier although in this case, they were evaluating the machine in the rice farm.

Table 46. Perceived Advantages of Using Tractor

Advantages	Frequency	Percentage
Faster land preparation	58	92.06
Better soil quality	5	7.94
Saves labor and time	5	7.94
Less labor cost	1	1.59
Total	69	

*multiple answers

Table 44 shows that the majority of the farmer respondents encountered no problem when using tractors for land preparation of their corn farms implying that they make effective use of the farm machinery. However, 23% claimed that it is costly. In the case of Abra, the service rate for tractors is on a per-hour basis unlike in some other provinces such as Apayao which is on a per-hectare contract basis. Thus, having a larger area to be prepared results in longer hours of operation and higher cost.

Table 47. Perceived Disadvantages of Using Tractor

Disadvantages	Frequency	Percentage
None	34	53.97
Costly	15	23.81
Shallow plow	11	17.46
"Haan na maala ti igid"	3	4.76
Displaced labor ("ammuyo")	1	1.59
Total	64	101.59

*multiple answers

Early Harvesting

Table 45 presents the reasons why some farmers practice early harvesting while Table 46 indicates its perceived consequences. The top reason was to to save some corn and income as they stated *“tapnu haan unay masayang jay apit ken isu pay day pagalaan pang bin-i ken isupay nga maincome”*. Moreover, according to them, once the farmers are informed that a typhoon or strong rain will landfall in their area, they will harvest corn that can be harvested beforehand. They stated *“nu mabalitaan mi nga aglandfall day typhoon ijay lugar mi, burasen min dagijay mabalin maburasen”*. According to Kumar et al., (2017), early harvesting as a risk mitigation measure improves crop resilience and has the potential to enhance a crop’s overall economic viability. On the other hand, this practice also has consequences as the farmers stated that it is difficult to sell as some cobs are not yet matured (Table 46).

Table 48. Why respondents practice early harvesting

Item	Frequency	Percentage
To save some corn and income	3	75
"Isu pay day maala nga pang bin-i"	1	25
To save some financial losses	1	25

Total	5

Table 49. Perceived Consequences of practicing early harvesting

Consequences	Frequency	Percentage
"Nu haan paylang as in mabalin, kumbet day bukel na"	2	50
Difficult to sell	2	50
Lower price	1	25
None	1	25

*multiple answers

Economic Viability of the Prioritized Adaptation Practices for Rice Production in Abra

Use of Solar Power Irrigation Systems as an Adaptation for Drought

Comparative Farm Profile

Rain-dependent rice farmers cultivate an average area of 0.93 hectares, while farmers with irrigated rice fields cultivate an average of 1.23 hectares and SPIS farmer beneficiaries cultivate an average area of 0.74 hectares (Table 47). This average area cultivated for rice by respondents is very similar to the average area holding of farmers in Abra based on the Census of Agriculture 2012 (PSA, 2024).

Table 50. Respondents Profile, Rice Farmers, Abra

Item	**Rainfed (n=26)**		**SPIS River (n=21)**		**Irrigated (n=19)**	
	n	%	n	%	n	%
Sex						
Male	19	73.08	15	71.43	15	78.95
Female	7	26.92	6	28.57	4	21.05
Age (mean)		**55**		**54**		**53**
20-30	1	3.85	-	-	1	5.26
31-40	3	11.54	1	4.76	1	5.26
41-50	5	19.23	6	28.57	6	31.58
51-60	5	19.23	9	42.86	6	31.58
61 and above	12	46.15	5	23.81	5	26.32
Farming Experience		**29**		**31**		**25**
10 years and below	4	15.38	2	9.52	3	15.79
11 - 20	3	11.54	5	23.81	6	31.58
21-30	8	30.77	2	9.52	3	15.79
31-40	4	15.38	8	38.10	4	21.05
41 years and above	7	26.92	4	19.05	3	15.79
Educational Attainment						
Elementary Undergraduate	3	11.54	4	20	4	21.05
Elementary Graduate	5	19.23	4	20	7	36.84
HS Undergraduate	4	15.38	2	10	-	-
HS Graduate	6	23.08	6	30	5	26.32
College Undergraduate	2	7.69	1	5	-	-
College Graduate	1	3.85	2	10	1	5.26
Vocational Graduate	5	19.23	1	5	2	10.53
Organization Membership						
Irrigators Association	1	3.85	-	-	-	-
Farmers Association	25	96.15	21	100	16	84.21
Cooperatives	3	11.54	-	-	-	-
Others	-	-	-	-	-	-
None	-	-	-	-	3	15.79

Perceived Changes as a Result of Using SPIS

Table 48 itemizes the farmers' perceptions of changes in rice farming and the advantages as a result of using SPIS for their rice production, secured water source for irrigation and that they can plant for 2nd crop are the two top perceived impacts.

Table 51. Perceived changes and advantages of using Solar Powered Irrigation System

Item (n-18)	**Frequency**	**Percentage**
Secure Water Source for irrigation no need to wait for rain	10	55.56
We can have 2nd cropping	10	55.56
Hanen matikag ti mula	4	22.22
We can now schedule our planting no need to wait for the rain	2	11.11

Observed Changes in Cropping Intensity, Yield, and Income

Cropping Intensity. SPIS farmer beneficiaries and farmers with irrigated rice farms usually plant rice-rice cropping system, while the majority of rainfed farmers plant rice only once during the wet season and corn during the dry season (Table 49). The wet-season rice is usually planted from June to July and harvested from September to October, while dry-season rice is planted from January and harvested from April to May, while dry season corn is usually planted from October to November and harvested in January. This result confirms the conclusion of many studies on the influence of improvement of irrigation on land productivity, particularly on cropping intensity (Karunakaran and Palanisami, 1998; Mondal and Sarkar, 2021; Launio and Abyado, 2022). Thapa and Scott (2019) also underscored the benefits of structural adaptation practices, such as expanding water sources in highly water-stressed rice areas with farmer-managed irrigation systems. They found that a cropping intensity of around 2.8 is maintained in systems that implemented some form of adaptation actions.

Table 52. Cropping Intensity of Rice Farmers

Cropping Pattern	**Rainfed**		**Irrigated**		**SPIS**	
	n	%	n	%	n	%
Rice-Fallow	7	26.92	-	-	2	9.52
Rice-Rice	1	3.85	17	89.47	18	85.71
Rice-Corn	16	61.54	2	10.53	-	-
Rice-Corn-Corn	0	-	-	-	-	-
Rice-Vegetables	2	7.69	-	-	1	4.76
Cropping Intensity	173%		200%		190%	

Change in Input Use. Application of urea and complete (14-14-14) fertilizers were found higher for irrigated rice farms and SPIS-supported rice farms compared with rainfed farms (Tables 50 and 51). In addition, herbicide use was also higher for rainfed farmers during the wet season This is contrary to the result of Beltran et al. (2013) in which herbicide use is significantly higher in irrigated rice arguing that the application of herbicides is more effective if water is controlled. However, during the dry season irrigated and SPIS-supported rice farms have a higher herbicide used per hectare which is the same as the report of Donayre et al. (2022) whose experiments in dry-seeded-drip-irrigated rice showed that the effect of season and weed control technique treatments was significant on weed density and biomass, where higher weed density was observed during the dry season.

Table 53. Average Input Use for Conventional Rice Farming, Abra, 2021 Wet Season

Item	Rainfed Farmers	Irrigated	SPIS	Pooled
Urea (kg/ha)	110.95	175.55	163.63	131.24
Triple 14 (kg/ha)	18.89	7.24	25.13	18.11
Ammonium Phosphate (kg/ha)	89.49	78.61	73.95	84.85
Foliar (li/ha)	0.47	0.26	0.22	0.39
Herbicide (li/ha)	3.13	1.34	1.08	2.46
Pesticides (li/ha)	1.63	0.67	1.741	1.49
Molluscicide (kg/ha)	-	0.30	0.51	0.06

Table 54. Average Input Use for Conventional Rice Farming, Abra, 2021 Dry Season

Item	Irrigated	SPIS	Pooled
Urea (kg/ha)	179.91	114.44	157.25
Triple 14 (kg/ha)	4.41	18.33	9.23
Ammonium Phosphate (kg/ha)	85.90	44.44	71.55
Foliar (li/ha)	0.29	-	0.20
Herbicide (li/ha)	0.93	1.39	1.09
Pesticides (li/ha)	0.84	2.27	1.33
Molluscicide (kg/ha)	1.49	0.02	0.98

Increase in yield. Figure 46 roughly shows the difference in the on-farm paddy yield distribution between rainfed farmers, irrigated rice farms, and SPIS beneficiaries. Most of the rainfed farmers' and SPIS beneficiaries' yields ranged from 1.1 to 2 tons/ha while farmers supported with irrigation systems had yields ranging from 2.1 to 3 tons/ha. Although some irrigation system and SPIS beneficiaries reach a yield ranging from 4.1-5 tons per hectare, even some SPIS farmer beneficiaries reach 7.1-8 tons per hectare, which is the same with the case of irrigated rice and water pump-supported rice farms in Ifugao reaching the range of 6.1 to 7 tons/ha and 7.1 to 8 tons/ha. However, for the dry season, most of the farmers with irrigation had yields ranging only from 3.1 to 4 tons/ha, while SPIS beneficiaries ranged from 2.1 to 3 tons/ha, which is a bit lower compared to the rice farmers in Ifugao which had yields ranging from 3.1 to 4 tons/ha for water pump supported rice farms and 5.1 to 6 tons/ha for rice farms with community irrigation systems (CIS) (AMIA Ifugao).

Change in income. Tables 52 and 53 present the detailed cost and return analysis of conventional rice production in Abra during the 2022 wet and dry seasons, respectively, comparing rain-dependent farmers, farmers with irrigated rice farms, and SPIS farmer-beneficiaries. For the WS the average yield is highest for SPIS farmer beneficiaries although close to the irrigated rice production. In terms of production cost, has the highest production cost is incurred during wet season for SPIS users, particularly the harvesting labor, which follows from the yield advantage of SPIS versus rainfed respondents. In terms of net profit for every peso harvested, Table 52 further shows that for wet season, rice production is highest for SPIS beneficiaries. However, for the dry season, those supported by irrigation canal receive a significantly higher net profit-cost ratio at 0.81 for every peso invested. The use of SPIS also results in positive net profit-cost ratio at 0.27 indicating that the use of SPIS during the dry season in Abra is a worthwhile investment.

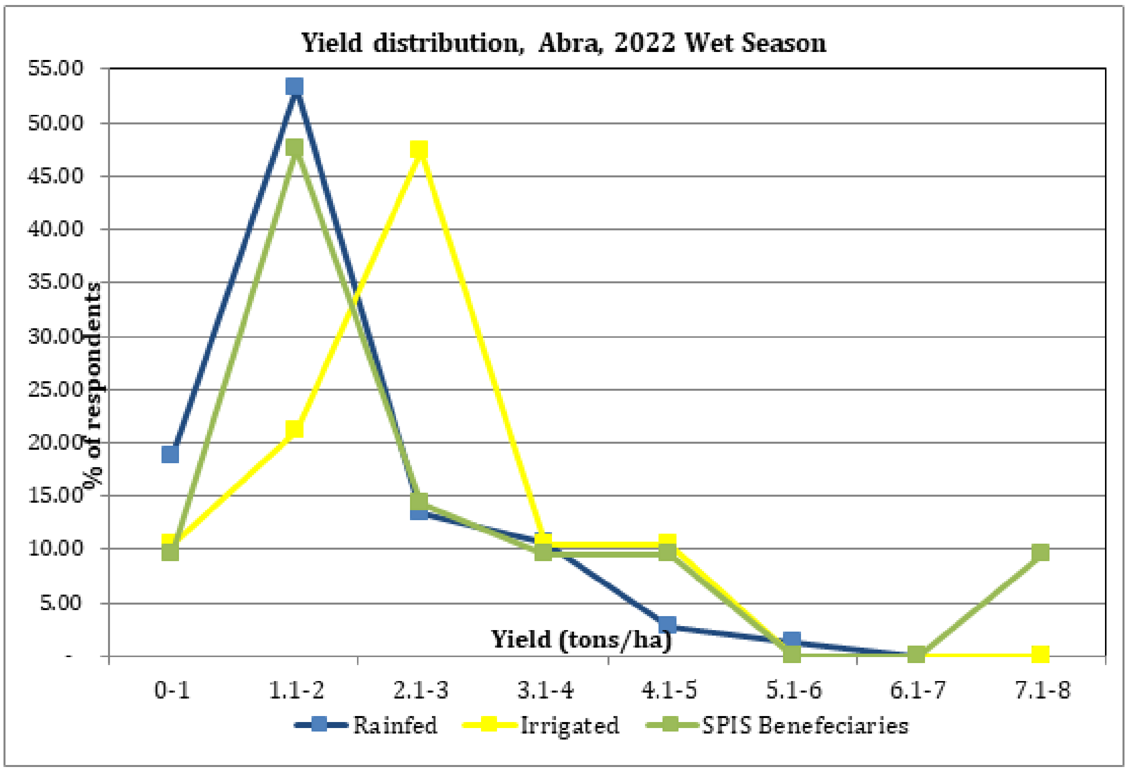


Figure 46. Yield distribution, Abra, 2022 Wet Season

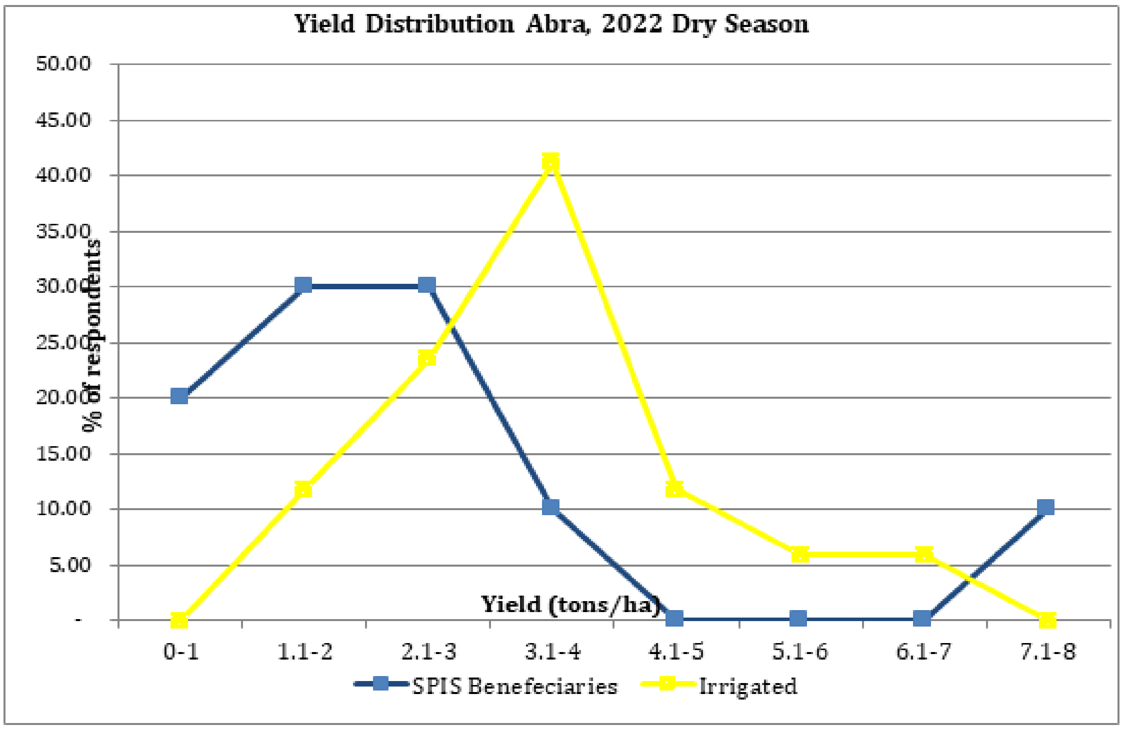


Figure 47. Yield distribution, Abra, 2022 Wet Season

Table 55. Cost and Return Analysis of Conventional Rice Production, Abra, 2022 Wet Season.

Items	Rainfed (n=70)	Irrigated (n=19)	SPIS Beneficiaries (n=18)
Average Area Cultivated (ha)	1.27	0.89	0.81
GROSS Returns (Php ha^{-1})	40,135.36	46,077.61	60,305.83
Total harvest (kg ha $^{-1}$)	2,178.90	2,501.50	3,273.93
Price (Php kg $^{-1}$)	18.42	18.42	18.42
COSTS (Php ha^{-1})			
CASH COST			
Seed/Planting Material	2,661.61	2.043.660	2,069.88
Fertilizer	11,490.31	13,043.247	13,534.34
Herbicides	2,100.65	818.350	915,68
Pesticides	1,770.37	613.836	2,120.03
Preharvest Labor	6,011.41	8,249.746	8,381.78
Harvesting	-	-	-
Hauling	349.07	872.085	217.22
Other Activities	4.29	75.29	-
Land Rental	-	-	-
Food Cost	3,588.15	5,309.875	5,401.23
Fuel Cost	288.37	792.080	957.78
Transportation Cost	220.77	620.225	661.67
Repair and Maintenance cost	107.81	73.684	558.33
Other Production Cost	583.21	657.279	885.99
Total Cash Costs	29,176.04	33,169.29	35,703.93
Non-Cash Costs			
Preharvest Labor	2735.63	2.952.169	3,522.33
Harvesting	5,646.45	5,757.959	8,841.57
Field Monitoring	2,112.03	1,389.726	6,229.56
Land Rental	11,095.89	11,775.249	12,752.49
Depreciation Cost	34.43	84.380	93.57
Total Non-cash Costs	10,494.12	10,099.85	18,593.47
Total Production Costs	39,670.16	43,269.14	54,297.39
Net Profit P/ha	465.20	2,808.47	6,008.44
Net Profit Cost-Ratio	0.01	0.06	0.11
Net Returns Land & Management	10,959.32	12,908.33	24,601.91

Table 56. Cost and Return Analysis of Conventional Rice Production in Abra, 2022 Dry Season.

Item	SPIS Beneficiaries (n=10)	Irrigated (n=17)
Average Area Cultivated (ha)	0.42	0.85
GROSS Returns (Php ha^{-1})	53,680.00	76,547.58
Total harvest (kg ha $^{-1}$)	2,440.00	3,479.44
Price (Php kg^{-1})	22.00	22.00
COSTS (Php ha^{-1})		
CASH COST		
Seed/Planting Material	2,266.67	1,977.87
Fertilizer	7,533.33	10,605.08
Herbicides	811.00	599.92
Pesticides	2,000.00	598.70

Item	SPIS Beneficiaries (n=10)	Irrigated (n=17)
Preharvest Labor	7,944.17	8,407.47
Harvesting	-	-
Hauling	40.00	1,313.11
Other Activities	-	72.30
Food Cost	2,520.00	4,727.73
Fuel Cost	1,359.67	895.07
Transportation Cost	1,020.00	687.80
Repair and Maintenance cost	5.00	82.35
Other Production Cost	924.67	605.78
Total Cash Costs	26,424.50	30,573.19
Non-Cash Costs		
Preharvest Labor	4,800.08	2,758.56
Harvesting	5,709.80	7,736.76
Other Activities	5,185.00	1,282.12
Land Rental	9,899.50	12,916.58
Depreciation Cost	118.31	91.33
Total Non-cash Costs	15,694.88	11,777.44
Total Production Costs	42,119.38	42,350.62
Net Profit P/ha	11,560.62	34,196.96
Net Profit Cost-Ratio	0.27	0.81
Net Returns Land & Management	27,255.50	45,974.40

Cost-Benefit Analysis of Using Solar-Powered Irrigation System (with River as Water Source)

SPIS (water source: river) Cases

Based on the Department of Agriculture database, they established four SPIS in Abra in 2019. The following are the description of the two SPIS subjected to CBA based on the KI interview with the Association presidents and project document.

Table 57. Department of Agriculture Funded Solar-Powered Irrigation System

Items	Case 1: San Vicente, Bagalay, Tayum, Abra	Case 2: Bangbangcag SPIS, Bucay, Abra
Association name	Bagalay Solar Irrigator's Association	
Cropping system	Rice-rice	Rice-rice
Total no. of hectares supported	8-9 ha (Actual) 10 ha (Target)	6 ha (Actual) 10 ha (Target)
Year completed	2019	2019
Design	128 panels; Storage tank: 2 (10x10x2m; 2*2*3); Area: 15*20m (panel location); 4x4m (pump location); 5x5m (storage tank location; 6 inches tube (mainline); 10 catchbasins with 2-3 hose/catchbasin	48 panels
Source of water	River; pump located in the irrigation intake area	River

Distribution system	hose	hose
Fee charged	Php1500/ha (cash or paddy rice) (from 2021)	

The following assumptions were considered in the baseline analysis:

a. The investment cost for SPIS is Php 6,000,000.00 for Bangbangcag SPIS and 5,999,000.00 for San Vicente SPIS based on the actual project cost per unit provided by the Department of Agriculture-CAR.
b. The maintenance cost of Php 1500 per hectare for San Vicente SPIS and 10,000 per year for Bangbangcag SPIS.
c. Solar Powered Irrigation System actual service area of 6 hectares for Bangbangcag SPIS and 9 hectares for San Vicente SPIS
d. Repair and Maintenance cost of SPIS is 5% of investment cost for every 5 year or a total of 20% investment cost for the 20 years.
e. The identified benefits were based on the survey and validated during focus group discussions, namely: increase in yield during wet and dry season, saved fuel use of 133L/season, saved repair and maintenance cost from using diesel pump, and estimated environmental benefit in terms of reduced carbon emission from combustion of diesel;
f. For the carbon emission calculation, the emission factors used are from EPA (2023) (Table 35), while Php278.15/kg CO_2-eq was used for carbon pricing based on actual carbon market in Singapore (Duggal, 2021; Singapore Ministry of Sustainability and the Environment, 2024).
g. The discount rate is 10% based on NEDA-ICC recommendation

Given the above assumptions, the estimated NPV is negative 2,013,317.69 for Bangbangcag SPIS with a BCR of 0.66 (Table 55). This result is because the SPIS established in 2019 was destroyed in 2021 and was repaired in 2022, also the 10-hectare target service area based on the project was not met. In the case of San Vicente SPIS, the NPV is positive at 31,509.83 and a BCR greater than 1, which is considered economically viable. Other identified benefits of the SPIS were nearby households used the water from the river for their laundry, water for their livestock/poultry. In the case of Bangbangcag SPIS farmer near the tank create fishpond and fingerling production which is an added benefit of the establishment of the SPIS.

Table 58. Cost and Benefit Analysis of DA-CAR funded Solar Powered Irrigation System for River Water Source, Abra

Item	NPV (Php)	BCR	IRR (%)	Payback period
Bangbangcag SPIS	-2,013,317.69	0.66	-9	11.98
San Vicente SPIS	31,509.83	1.01	0	8

Assuming that the supposed service area of 10 hectares was covered by the SPIS, even with allotted repair of 20% of investment cost for 20 years, it will be economically viable both SPIS

(Table 56). These results indicate that with the substantial investment cost of establishing a solar-powered irrigation system, it is important that the water source and estimated service area be ascertained, and the risks from extreme weather events like typhoons, be considered in the design. Further technical evaluation of design is also recommended for the SPIS established in Abra to understand why the target service area was not met. It should be noted that previous studies have shown that the use of Photovoltaic energy for water pumping systems is feasible and more profitable than diesel pump-supported farming (Dahdic and Shrivastava, 2017; Raza et al., 2022; Campana et al., 2016; Nowar, 2009).

Table 59. Results of Sensitivity Analysis on CBA assumptions of SPIS Dugwell, Abra

Item	NPV (Php)	BCR	IRR (%)	PP
Bangbangcag SPIS	1,235,977.60	1.21	6	7.20
San Vicente SPIS	1,612,668.96	1.29	8	7.21

Crop Insurance

Table 57 itemizes the perception of rice farmers in terms of advantages of availing crop insurance, most of rice farmers understands that crop insurance gives financial assistance to farmers when their rice farm is damaged by calamities such as typhoon or drought including pest infestation, most of these financial assistances was used by the farmer to buy farm inputs for their next cropping. However, there are still rice farmers (17%) that they don’t see any advantages of availing crop insurance, these farmers are those farmers who didn’t experience receiving financial assistance in the form of indemnity payment from the PCIC. On the other hand, Table 57 itemizes the perceived disadvantages of availing crop insurance most of the rice farmers claim that there’s no disadvantage for them, however some rice farmers (19.61) mention that one of the disadvantages they experienced is the late release of indemnity payment. During the validation LGU representatives mentioned that the late release of indemnity payment and slow processing of documents as one disadvantages mentioned by the farmers was because staff of PCIC in the province in Abra is not enough to cater all the applications and claims of rice farms, given that they need to consolidate all applications in claims in the province before sending it back to the regional office of PCIC in Urdaneta, Pangasinan.

Table 60. Perceived Advantages of Availing Crop Insurance

Item (N-51)	FREQUENCY	Percentage
There is assistance (financial) given to farmers, in the occurrence of calamities and pests	42	82.36
If there are calamities or pest, we receive assistance to replace some of our expenses	13	25.50
None	9	17.65

Table 61. Perceived Disadvantages of Availing Crop Insurance

Item	FREQUENCY	Percentage
None (no disadvantages)	42	82.35
Late release of indemnity payment	10	19.61
Slow processing of documents	5	9.80
No indemnity payment received	5	9.80
Long Validation time “nabayag da mapan e validate”	3	5.88
Many documents needed	1	1.96

Use of Tractor for Land Preparation

The use of a tractor for land preparation was identified as one adaptation strategy for both drought and typhoon. Majority of the farmers answered that the advantage of using tractor in land preparation is the faster land preparation which also saves labor and time. This claim is supported by the comparison study of Sutjana & Adipura (2012) in using a plow, tractor, and cultivator which showed that it only takes 22.07 hours to complete the land preparation of a hectare when using a tractor compared to more than 3 weeks with 4-5 hours a day for manual land preparation since carabao needs to rest. Another claimed advantage of using this machinery is the farmers can now plant early and faster given that land preparation is faster, some farmer can now even plant earlier. On the other hand, even though most of the farmers claimed that there are no disadvantage of using tractor for land preparation, some farmers pointed out that fuel or rent of using tractor is costly/expensive for them (Table 60).

Table 62. Perceived Advantages of Using tractor

Item (N-90)	Frequency	Percentage
Faster land Preparation	70	77.78
Can plant early and faster	7	7.78
“maymayat pagka arado na”	5	5.56
Lesser Labor	3	3.33
Time and labor saving	1	8.89
Land preparation is more convenient	1	8.89
Planting is more convenient	1	8.89
Faster than manual	1	8.89
Faster land preparation even w/o water	1	8.89
“nalaklaka maburbur ti daga”	1	8.89
We can now plant earlier	1	8.89
Land preparation is more comfortable	1	8.89

Table 63. Perceived Disadvantages of Using Tractor

Item	Frequency
None	40
Costly/expensive (fuel/rent)	20
“narabaw ti arado na”	11
“haan na maala ejay egid”	7
“madadel ti tambak”	1
“naawan binmassit t amoyo” (displaced farm laborers)	1
“napitak arado na”	1

Economic Viability of the Prioritized Adaptation Practice for Pests in Mango Production in Abra

Use of Pre-harvest fruit bagging as an adaptation to Pests

Abra is the top producer of mango fruits in the Cordillera Administrative Region. Common mango varieties grown in the province include Carabao mango, Indian, and Hawaiian. Among these, carabao mango is what is commonly marketed because of its aroma and eating quality.

However, the interviews and focus group discussions revealed that around 2018-2019, mango orchards in Abra province began to experience Cecid fly infestation, also known as “kurikong”. In fact, mango growers in the province attributed their low production to Cecid fly infestation. The Philippine Mango Industry Roadmap from 2017 to 2022 described Cecid flies as “very small and delicate fly with long legs and antennae, and hairy transparent wings”. These pests usually affects the leaves *(Procontarinia pustulata)* and the fruits *(Procontarinia frugivora gagne)*. When this pest attacks the fruits, it typically results in tiny and slightly discolored pinpricks that become more apparent as the fruit grows and matures. The Department of Agriculture recommended several ways to manage the pest including pruning of crowded branches and infested leaves of the mango tree, management of weeds and other vegetation growing beneath its canopy, proper disposal of infested fruits and leaves, and smudging early in the morning and in the afternoon during the early stages of fruit development, and bagging of fruits early at 40 to 45 days after flower induction.

While the respondents attempted various strategies to combat the said insect including spraying, and hanging sticky traps using plastic bottles on the branches of the mango tree but these were deemed as not that effective against Cecid fly infestation. The respondents attributed this to the mobility of the insects as they could fly from one tree to another.

Another method tried by some of the respondents is pre-harvest fruit bagging which is quite effective in protecting the fruits from Cecid flies. However, only 4 out of 20 mango farmers interviewed have attempted utilizing the bagging technology. The low adoption rate of the technology is primarily attributed to safety concerns and the tedious process of bagging.

Safety of baggers. Pre-harvest bagging of individual fruits in the province of Abra is done by hand. Mango trees can reach heights of 15 to 30 meters (Bally, 2006) that is why climbing mango trees specially the century old trees poses significant risk on the baggers. This is also the primary reason why fruit-bagging is not done 100% on all the fruits of the mango tree. Only the fruits that are in the lower portions of its canopy or those that are accessible to baggers are bagged while the fruits located at the top of the tree’s canopy are left as is.

Labor-intensiveness of pre-harvest fruit bagging. Mango farmers can either opt to buy ready-made bags from agriculture supply stores or make their own bags from scratch using recycled papers. This indicates that should the farmer opt to make his own bags, he would have to produce roughly the same number of bgs as there are fruits on each tree. In addition to this is the work involved in the actual bagging of the individual fruits for each tree. Bagging the individual fruits of a single century carabao mango would take an average of 35 (5 baggers for 7 days) man-days.

Cost and Return Analysis of Mango Production in Abra

Out of the 20 farmers interviewed, only 17 were found to have mango fruit-bearing trees in 2022. The cost and return analysis of mango production in Abra was done per tree as most of the farmers can more accurately estimate their labor and input costs per tree. This is because most of the mango trees in the area are century old mixed with grafted mango trees. In addition, most of the farmers were unable to estimate their area planted by mango and there is no uniform planting distance.

Under normal conditions, the average yield of mango farmers for the year 2022 is 1,357 kg/tree. Bulk of the input costs incurred by a mango farmer are from pesticides and fruit inducers. In terms of farm management/labor cost, mango farmers in Abra only practice manual weeding, and application of fertilizer, pesticide, and fruit inducer. Activities such as smudging, and pruning are only done by a few farmers. In terms of profitability, table 60 shows that mango production for the cropping year of 2022 is profitable considering all cash and non-cash costs with net profit of Php 28, 468 per tree and a net profit-cost ratio of 1.78. This means that for every peso invested, there is a corresponding income of 1.78 pesos.

Table 64. Cost and Return Analysis of Mango Production in Abra for 2022 (n=17)

Item		
Average Tree Cultivated (pcs)	14	
Harvest (kg/tree)		Price (Php/kg)
Small	36.63	22.67
Medium	234.56	28.25
Large	180.56	35.25
Extra Large	12.25	45.00
Mix	627.08	41.00
Reject	262.95	16.50
Home Consumption	3.56	16.50
Total harvest (kg/tree)	1,357.67	
Gross Returns (P/tree)	44,483.08	
Costs (P/tree)		Cost/Kg
CASH COSTS		
Planting Material	280.00	0.21
Fertilizer	500.97	0.37
Herbicides	-	-
Pesticides	1,151.63	0.85
Fungicides	65.20	0.05
Fruit Inducer	2,762.94	2.04
Labor		
Pre-Harvest Labor	1,721.06	1.27
Harvesting	1,210.29	0.89
Food Cost	6,185.13	4.56
Fuel Cost	1,622.10	1.19
Transportation Cost	152.78	0.11
Total Cash Costs	15,652.10	11.53

Non-Cash Costs		
Labor		
Pre-Harvest Labor	245.19	0.18
Harvesting	117.72	0.09
Total Non-Cash Costs	362.91	0.27
Total Production Cost	16,015.01	
Net Profit P/Tree	**28,468.07**	
Net Profit Cost -Ratio	**1.78**	
Net returns to land & management	**28,830.98**	

Partial Budget Analysis of Fruit Bagging in Abra

Considering that only a few mango farmers practice fruit bagging due to its laboriousness, series of key informant interviews was conducted with farmers who have experience and are knowledgeable on fruit bagging with the following scenarios and assumptions.

a. Increase in yield was derived from the yield when there is no bagging applied versus with bagging in the scenario of (cecid fly) pest infestation;
b. Price increase was computed using the 5 peso difference in price as per experience of the respondent;
c. Labor cost was computed with the average man-days of fruit bagging per tree (5 man * 7 days * 500)
d. The farmer had an existing improvised ladder/s;
e. Only 50% of the fruits were bagged.
f. The bagging materials used are ready-made bought from the agriculture supply store.

Table 62 roughly shows the additional cost and benefits of practicing fruit bagging with the given assumptions mentioned. The partial budget analysis showed that pre-harvest fruit bagging is beneficial to the farmers with net benefits of Php15,255 per tree per season. However, as pointed out by the respondents, bagging is labor intensive and cost for bagging could exponentially increase with the number of fruit-bearing mango trees that the owner owns. In addition, the computed net benefits might decrease if the labor cost that the farmer would incur in personally and manually making the bags from recycled papers will be included.

Table 65. Partial Budget Analysis of Using Fruit Bagging

(A) Added Revenue		**(B) Added Cost**	
Increase in yield (fruit saved from pest infestation)	20,000.00	Fruit Bagging Materials	1,066.67
Price Increase	2,855.00	Fruit Bagging Labor	5,833.33
		Food Cost	700
Total	22,855.00	Total (B)	7,600.00
Net Benefits (A-B)	15,255.00		

Perceived Advantages and Disadvantages of Fruit Bagging

Advantages of Fruit Bagging

Based on the series of focus group discussions and key informant interviews conducted, informants observed that bagging the fruits early, or when the fruits are the size of a marble, results in better fruit quality. They described the fruit skin to be free of blemishes. This translates to higher selling price compared to the fruits that were not bagged. Moreover, adopters of pre-harvest fruit bagging observed a significant reduction in fruit damage caused by Cecid fly - from 50% to 5%. For the mango farmers, this means higher yield. They also added that by bagging the fruits early, they will still be able to harvest marketable fruits even if the trees will be attacked by insect pests.

Disadvantages of Fruit Bagging

Pre-harvest fruit bagging is done manually in the area that is why the work required for it is overwhelming for an average mango farmer. On average, bagging the fruits of a single century old carabao mango tree would require 35 man-days. Some of the mango farmers in the area own a mix of century old and grafted mango trees. And applying bagging on all their fruit-bearing mango trees for the season would exponentially increase the labor as well as its accompanying costs. That is why the laboriousness of pre-harvest bagging is one of reasons, alongside safety concerns for the bagger, identified by the respondents affecting the adoption of the technology. Nonetheless, some of the respondents also expressed their willingness to adopt pre-harvest fruit bagging technique if other technologies or new methods are introduced that would lessen the labor-intensive nature of bagging as well as lower the risk on the baggers.

VI. CONCLUSION

This research project assessed the vulnerability of crops particularly rice, corn, mango an d coffee. For the sensitivity analysis, municipalities of Malibcong, Daguioman, Boliney and Tubo has projected gains in suitability for rice, corn and mango however, only the municipality of Tubo will gain suitability for coffee production. On the other hand, based on the assessment of the exposure to climate-related natural hazards, the major driving factors of the overall hazard index in the province of Abra are drought, landslide, and soil erosion. Tineg, Licuan-Baay, Bucay, and Sallapadan are the most exposed to these hazards. Areas with higher elevation are exposed to tropical cyclone, landslide, and soil erosion while areas with lower elevation are exposed on flood, and drought. In terms of adaptive capacity, only Bangued has very high adaptive capacity compared to the rest of the municipalities of Abra. For the overall CRVA, the municipalities that need climate change mitigation or adaptation interventions for rice production are Sallapadan, Tayum, Manabo, Langiden, Lagangilang, San Isidro, and San Juan; for corn, San Quintin, San Juan, and Langiden; for mango, Lagangilang, Langiden, San

Juan, Sallapadan, San Isidro, and Villaviciosa; and lastly is the coffee, Malibcong, Daguioman, and Boliney.

The main climate hazards affecting the growth and yield of major crops in Abra are typhoons (accompanied by moderate to strong winds and light to heavy rain) and drought. The occurrence of these climate hazards coincides with critical stages of crop growth and may affect all stages of the value chain.

Severe damages and economic loss are incurred when typhoon or drought occur during the vegetative to reproductive stages of rice and corn. For mango, buying of inputs, land preparation, and planting on the 1st year of growth, and flower induction and fruit setting on the 3rd year of growth is most affected. Finally, the vegetative stage of coffee from 1-3 years after planting and flowering to maturing of berries is most vulnerable to typhoon or drought. Severe consequences of these climate hazards include flooding, damaged bunds, destroyed seedlings, and delay in harvesting in rice. Difficulty in preserving seeds during typhoon and severe crop damage in both typhoon and drought is experiences by corn farmer. Mango will have poor fruit quality and low yield when typhoon occur during the flowering stage. Lastly, there is increase in flower and fruit drop in coffee when typhoon occurs during the flowering to fruit initiation stage. These consequences are exacerbated by several underlying factors such as poor road conditions, lack of irrigation and postharvest facilities, limited technical knowledge on pest management, and lack of regulatory frameworks for the rice, corn, mango and coffee sector.

Some common adaptation strategies to typhoon and drought employed by farmers include rescheduling farm activities, availing of crop insurance, use of hand or wheel tractor for land preparation and planting appropriate varieties and quality seeds. Meanwhile coping strategies specific for typhoon are following: cleaning, repair and maintenance of bunds and use of combine harvester for rice; installation of flood control, rescheduling planting activities and early harvesting for corn; planting windbreaks and bagging of fruits for mango. However, only about one-third of the mango farmers practice the use of windbreaks and fruit bagging as adaptation options to reduce the impacts of typhoons and moderate winds with light rain. Most of the mango farmers perceive a lack of financial benefit from practicing these adaptation options.

Furthermore, lack of technical and human capacity, low institutional support, lack of regulatory framework, low awareness of climate smart techniques are among the factors hindering majority of the farmers from practicing adaptation options that may effectively mitigate the impacts of climate hazards.

This project used cost-benefit analysis to determine the economic viability of selected CRA practices. For corn, groundwater solar powered irrigation systems were found to be not economically viable in its current state, because most were destroyed by typhoons and have not been repaired yet. In addition, the actual area serviced is less than the planned target area to be irrigated, rendering the costs outweighing the benefits. On the other hand, the net profit-cost ratio of using electric irrigation pump for corn production during dry season is positive. However, the use of diesel-powered irrigation pump resulted in negative net profit-cost ratio, even without including the carbon footprints for using diesel fuel. Similarly, for the SPIS drawing water from rivers in order to support rice-rice cropping pattern, benefits outweighed the costs for the case in which 90% of the planned service area is supported, but the SPIS which only serviced 6 out of the 10 hectares planned had negative net present value. More techno-economic analysis is needed to ensure that designs result in optimal irrigation service areas. For mango, fruit bagging is seen to result in better fruit quality and higher selling price. However, this process requires additional labor. Partial budget analysis shows that there is still a positive net benefit when fruit bagging is adopted by mango farmers.

VII. RECOMMENDATION

Improving the adaptive capacity of the municipalities is necessary to minimize vulnerabilities in the production of the crops included in this study. Additional projects like infrastructures, irrigation and farming equipment for farmers may be considered in order to address lack of and ultimately drought. However, the cost-benefit analysis for solar powered irrigation system showed that the design needs to be optimized properly to ensure that the target area to be irrigated is actually serviced, risk from typhoons is mitigated, and farmer leaders are trained on irrigation management. A reduction in the actual service area and destroyed pump and curtailed operation will result in costs outweighing the benefits resulting in negative net present value or BCR<1. Other possible adaptation measures for municipalities with very high vulnerability may include changing cropping calendar for annual crops growing different crop or varieties. Municipalities with only one cropping season may try to plant alternative crops in the succeeding season to maximize the agricultural farms. In addition, the province may prioritize municipalities with moderate to very high vulnerability in the implementation of projects.

Findings of this study suggests that some adaptation measures done in response to climate change may not be sufficient. Hence, more strategies and actions for agricultural adaptation can be exploited at the local and regional levels to further capacitate farmers. Such interventions may encompass innovative breeding techniques for the development of climate-resilient crop varieties, farmer training and knowledge transfer on water, soil and pest management as well as other aspects of crop production. Agricultural and meteorological services including the development of early warning systems can be provided. Lenient financial schemes and insurance will benefit farmers more, and the establishment of price regulation in the market for major crops is most clamored.

VIII. IMPACTS OF THE PROJECT

The result of this research, specifically the identified vulnerable municipalities in terms of the production of the four crops, the identified adaptation practices which were eventually assessed as to their economic viability could serve as basis in the identification of location as well as type of interventions to be done. It could also be used as baseline in the conduct of other researches on the development of adaptation practices.

IX. BIBLIOGRAPHY (standard citation)

Adraneda, K. (2009). Climate change threatens Guimaras mango. Philstar.com. Retrieved from https://www.philstar.com

Aligah, M., (2011). Design of photovoltaic water pumping system and compare it with diesel powered 358 pump. Jordan J Mech Ind Eng 5(3), 273–280

Alliance of Bioversity International, International Center for Tropical Agriculture and World Food Programme. (2021). Philippine climate change and food security analysis. Manila, Philippines. Retrieved from https://docs.wfp.org

Alt, K., Osborn, T. C., & Dan, C. (1989). Soil Erosion: What Effect on Agriculture Productivity. New York: Economic Research Service. doi:https://doi.org/10.22004/ag.econ.309483

Aminata S., Lamin, D., Ibrahima, D., Deffa, W., Mariama, D., Bodian, A., Sidy, S, Luciano, M and Nicola, L. 2020. Knowledge-Based Engineering and Sciences Dec. 2020

Apdohan, A. G., Varela, R. P., and Balanay, R. M. (2021) Climate Risk Vulnerability Assessment of the Major Crops in the Province of Agusan Del Norte, Philippines, *International Archive Photogrammetry Remote Sensing and Spatial Information Sciences.*, XLVI-4/W6-2021, 27–33, https://doi.org/10.5194/isprs-archives-XLVI-4-W6-2021-27-2021

Araullo, D.B. (2006). Agricultural Cooperatives in the Philippines: Innovations and Opportunities in the 21st Century. Paper presented during the 2006 FFTCNACF Opportunities in the 21st Century, 11-15 September, Seoul, Korea.

Asare-Nuamah, P., Antwi-Agyei, P., and Dick-Sagoe, C. (2022). Mitigating the risks of climate variability and change on mango seedlings in Ghana: Evidence from mango seedlings producers in the Yilo Krobo Municipality. Environmental Challenges, Volume 8. https://doi.org/10.1016/j.envc.2022.100594

Asseng, S., Martre, P., Maiorano, A., Rötter, R. P., O'Leary, G., Fitzgerald, G. J., Girousse, C., Motzo, R., Giunta, F., Babar, A., Reynolds, M., Kheir, A. M. S., Thorburn, P. J., Waha, K., Ruane, A. C., Aggarwal, P. K., Ahmed, M., Balkovič, J., Basso, B., Ewert, F. (2018). Climate change impact and adaptation for wheat protein. Global Change Biology, 25(1), 155–173. https://doi.org/10.1111/gcb.14481

Ayal, D. Y., Nure, A., Tesfaye, B., Ture, K. and Zeleke, T. (2023). An appraisal on the determinants of adaptation responses to the impacts of climate variability on coffee Production: Implication to household food security in Nensebo Woreda, Ethiopia,. *ScienceDirect, Volume 30*. doi:doi.org/10.1016/j.cliser.2023.100383.

Baas, D., and Mathew, A. (2023). Perspectives on market stability. Institute for International Integration Studies IIIS Discussion Paper No.324. https://doi.org/10.68264/gcb.16321

Badajos, M. A. (2019). Vulnerability and Risk Assessment of State University in the Philippines. *Philippine Social Science Journal, 2*, 9-22. doi:10.52006/main.v2i2.78

BAFS-DA. (2021). Solar Powered Irrigation System – Specifications (PNS/BAFS 324: 2021). https://amtec.uplb.edu.ph/

Balahadia, F. (2019, March). Developing agricultural damage simulation in the impact of typhoon and flashflood in Laguna. *Research Gate*. Retrieved fromhttps://www.researchgate.net/publication/331928162_Developing_agricultural_damage_simulation_in_the_impact_of_typhoon_and_flashflood_in_Laguna

Bally, I.S.E. (2006). *Mangifera indica* (mango). *Species Profiles for Pacific Island Agroforestry.* www. traditionaltree.org

Basack S., Loganathan M.K., Goswami, G., and Khabbaz, H. (2022). Saltwater intrusion into Coastal Acquifers and Associated Risk Management: Critical Review and Research Directives. *The Journal of Coastal Research*, 654-672. 38. 10.2112/JCOASTRES-D-21-00116.1. Retrieved from https://www.jstor.org/stable/48668657

Bayogan, E.R.V., Esguerra, E.B., Campeon, R.T. (2006). 'Carabao' Mango Harvest Quality and Production Practices and Problems of Growers in Davao Oriental, Philippines. *Acta Horticulture, 699.* https://doi.org/10.17660/actahortic.2006.699

Bragais, M., Mohanty, S., and Baruah, S. (2020). Climate Risk Mapping in the Philippines for Sub-National Targeting and Prioritization for Crop Diversification to Increase Resilience of the Agricultural Sector. Hanoi, Vietnam: CGIAR Research Program on Climate Change, Agriculture and Food Security Southeast Asia (CCAFS). Retrieved from https://hdl.handle.net/10568/108583

Buan, R.D., Maglinao, A.R., Evangelista, P.P., Pajuelas, B.G. (1996). Vulnerability of Rice and Corn to Climate Change in the Philippines. In: Erda, L., *et al.* Climate Change Vulnerability and Adaptation in Asia and the Pacific. Springer, Dordrecht. https://doi.org/10.1007/978-94-017-1053-4_4

Buthelezi, N.M.D., Mafeo, T.P., Mathaba, N. (2021). Preharvest Bagging as an Altenative Technique for Enhancing Fruit Quality: A Review. *HortTechnology hortte 31(1).* https:/doi.org/10.21273/HORTTECH04658-20.

Campana, P., et.al. (2016). An economic analysis of photovoltaic water pumping irrigation systems. International Journal of Green Energy. https://doi.org/10.1080/15435075.2016.1161631

Cardona, O.D., M.K. Van Aalst, Birkmann J., Fordham M., McGregor G., Perez R., Pulwarty R.S., Schipper E.L.F., and Sinh B.T. (2012). Determinants of risk: exposure and vulnerability. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 65-108. Retrieved from https://www.ipcc.ch/site/assets/uploads/2018/03/SREX-Chap2_FINAL-1.pdf

Cayanan, E., Chen, Tsing-Chang., Argete, J., Yen, Ming-Cheng and Nilo, Prisco. (2011). The Effect of Tropical Cyclones on Southwest Monsoon Rainfall in the Philippines. *Journal of the Meteorological Society of Japan*. 89A. 123-139. 10.2151/jmsj.2011-A08

Chiou, C.R., Hsieh, T.Y. and Chien, C.C. (2015) Plant bioclimatic models in climate change research. *Bot Stud* 56, 26. https://doi.org/10.1186/s40529-015-0104-8

Cordillera Mountain Coffee. (2019, February 12). Retrieved from Cordillera Mountain Coffee: https://cordilleramountaincoffee.wordpress.com/

Craig D. Allen, Alison K. Macalady, Haroun Chenchouni, Dominique Bachelet, Nate McDowell, Michel Vennetier, Thomas Kitzberger, Andreas Rigling, David D. Breshears, E.H. (Ted) Hogg, Patrick Gonzalez, Rod Fensham, Zhen Zhang, Jorge Castro, Natalia Demidova, Jong-Hwan Lim, Gillian Allard, Steven W. Running, Akkin Semerci, Neil Cobb, (2010). A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests. *Forest Ecology and Management 259(4)*, 660-684. https://doi.org/10.1016/j.foreco.2009.09.001

Craurd, P.Q., Wheeler TR (2009). Climate change and the flowering time of annual crops. *Journal of Experimental Botany, Volume 60, No. 9*, 2529-2539. doi:doi:10.1093/jxb/erp196

Critical Ecosystem Partnership Fund, C. (2019). *KBA.* Quezon city: Abra River Basin stated as the Candidate Key Biodiversity Areas , Abra River Basin stated as the Candidate Key Biodiversity Areas , Abra River Basin stated as the Candidate Key Biodiversity Areas

Critical Ecosystem Partnership Fund, C. (2019). Priority Sites for Conservation in the Philippines: Key Biodiversity Areas. Quezon City: Conservation International Philippines, Department of Environment and Natural Resources, Haribon Foundation for the Conservation of Nature

Dadhick, G. and Shrivastava, V. 2017. Economic Comparison of Solar PV and Diesel Water Pumping System. International Conference on Information, Communication, Instrumentation and Control. Paper Id: 416.

Daipan, L. E., Lumbres L., Lingaling M., Talkasen L., Godio Q., Mendoza G. (2023). Climate risk vulnerability assessment on the production of heirloom rice (*Oryza sativa* L.) and Arabica coffee (*Coffea arabica* L.) in Mountain Province, Philippines. *SciEnggJ*, 28-39

Davis AP, Gole TW, Baena S, Moat J. 2012. The impact of climate change on indigenous Arabica coffee (*Coffea arabica*): predicting future trends and identifying priorities. PLoS One. (2012). 7(11): e47981. doi: 10.1371/journal.pone.0047981. Epub 2012 Nov 7. PMID: 23144840; PMCID: PMC3492365

Defiesta, G., and Mediodía, H. (2016). Evaluation of the Impact of the Agricultural Insurance Program of the Philippine Crop Insurance Corporation (PCIC) on Rice Producers in Region VI (Western Visayas). PIDS Discussion Paper Series No. 2016-43

Department of Science and Technology. (2023). About Tropical Cyclones. Department of Science and Technology: Philippine Atmospheric, Geophysical and Astronomical Services Administration.. Retrieved from https://www.pagasa.dost.gov.ph/information/

Department of Agriculture (2022). From Business Mirror: Philippine Rice Production, Varieties and Research: What We Know So Far. Quezon City: Departmenty of Agriculture. https://www.da.gov.ph

Department of Agriculture- Bureau of Agricultural Research. (2022a). The Philippine coffee industry roadmap (2021-2025). Retrieved from https://da.gov.ph

Department of Agriculture - Bureau of Agricultural Research. (2022b). The Philippine mango industry roadmap (2021-2025). Retrieved from https://hvcdp.da.gov.ph

Department of Agriculture, n.d. Pestrivia. Powerpoint Presentation. https://cpmd.buplant.da.gov.ph/assets/pdf/trivia-pdf/cecidfly.pdf

Department of Agriculture. (n.d.). Philippine Manga Industry Roadmap (2017-2022). https://www.da.gov.ph/wp-content/uploads/2019/06/Philippine-Mango-Industry-Roadmap-2017-2022.pdf

Department of Environmental and Natural Resources. (2010). Forest Cover of Cordillera Administrative Region (by province in hectares as of December 31, 2010). Department of Environmental and Natural Resources: Forest Management Bureau. Retrieved from https://forestry.denr.gov.ph/index.php/forest-cover-car.

Deriada, Annie (2005). Assessment of cooperative movement in a developing country: The Philippine experience. Forum International Development Studies, 28

Doe, J. (2020). Challenges and opportunities in white corn farming: a case study of abra province. Journal of Agricultural Economics, 30(2), 123-145. DOI: 10.1234/jae.2020.123456789

Downing, Thomas E.; Patwardhan, Anand; Klein, Richard J.T.; Mukhala, Elija; Stephen, Linda; Winograd, Manuel; Ziervogel, Gina. (2005). Assessing Vulnerability for Climate Adaptation. Adaptation policy frameworks for climate change: Developing strategies, policies and measures. In *CIAT Book Chapters* (pp. 61-90). Cambridge: Cambridge University Press. Retrieved from https://hdl.handle.net/10568/55536

Elauria, M.M., Manilay, A.A., Abrigo, G.N.A. (2015). Adoption and Socio-Economic Impacts of the Pre-Harvest Disease Management Technology for *Carabao* Mango in the Philippines. *Journal of Economic, Management & Agricultural Development, 1(1).*

Elith J., and Burgman M.A. (2002). Predicting and their validation: Rare plants in the Central Highlands, Victoria, Australia. In: Predicting Species Occurrences: Issues of Accuracy and Scale, pp.303-314. Island press, Covelo, CA. Retrieved fromhttps://www.researchgate.net/publication/224040403

Esrael, D., and Briones R. (2012). Impacts of natural disasters on agriculture, food security, and natural resources and environment in the Philippines. Retrieved from https://pidswebs.pids.gov.Ph/Cdn/Publications/pidsdps1236.pdf

Exconde, O. R. (1975). Corn in the Philippines: It's production and research activities with emphasis on downy mildew*.* Tokyo: Tropical Agricuiltural Research Series

Fakhruddin B., Boylan K., Wild Alec., & Robertson R. (2019). :Assessing vulnerability and risk of climate change. In J. S. Sillmann (Ed.), *Climate Extremes and Their Implications for Impact and Risk Assessment* (pp. 217-241). doi:https://doi.org/10.1016/C2017-0-01794-9

Food and Agriculture Organization of the United Nations. (2023). Food and Agriculture Organization of the United Nations. Retrieved from Food and Agriculture Organization of the United Nations: https://www.fao.org/land/land-resources-planning-toolbox/category/details/en/c/1043064/

Food and Agriculture Organization. (2015). Climate change adversely affecting Cordillera's agriculture sector. Retrieved from https://www.searca.org

Gendre, I. (2022, September 29). Representative Concentration Pathway (RCP) :What is It? Retrieved November 21, 2023, from Greenly: https://greenly.earth/en-gb/blog/ecology-news/

Ghosal, M.K.; Sahoo, N.; Goel, S. Studies on Off-Grid Solar Photovoltaic-Powered Micro-Irrigation System in Aerobic Rice Cultivation for Sustainable Agriculture and Mitigating Greenhouse Gas Emission. In Innovation in Electrical Power Engineering, Communication, and Computing Technology; Lecture Notes in Electrical Engineering; Springer: Singapore, 2020; pp. 135–145.

Giles, J., Macandog, P., Sova, C., Seriño, M., Ruales, J., Enerlan, W. ,Grosjean, G. (2019). Climate-Resilient Agriculture in The Philippines: Climate Risk Profile, Visayas. International Center for Tropical Agriculture (CIAT); Department of Agriculture - Adaptation and Mitigation Initiative in Agriculture, Government of the Philippines. Manila, Philippines: The Food and Agriculture Organization of the United Nations (FAO). https://hdl.handle.net/10568/113568

Guno, C. S., & Agaton, C. B. (2022). Socio-Economic and environmental analyses of solar irrigation systems for sustainable agricultural production. *Sustainability*, *14*(11), 6834. https://doi.org/10.3390/su14116834

Hartung, H. and Pluschke. 2018. The benefits and risks of solar-powered irrigation – a global overview. FAO and Deutsche Gesellschaft fur Internationale Zusammenarbait.https://thesolarhub.org/wp-content/uploads/2020/10/The-benefits-and-risks-of-solar-powered-irrigation.pdf

Hermina, A. A. (n.d.). Soil resources depreciation and deforestation: Philippine case study in resource accounting. FAO. Retrieved from https://www.fao.org/3/AB604E/AB604E00.htm

Herrera, F. L. (2013). Climate Change Risk Profile in the Philippines: Country fact Sheet. Retrieved from https://www.climatelinks.org/sites/default/files/asset/document/2017_Climate%20Change%20Risk%20Profile_Philippines.pdf

High Value Crops Development Program Priority Crops Roadmap (2022). Philippine Mango Industry Roadmap (2017-2022). Office of the Undersecretary High Value Crops and Rural Credit. Retrieved from https://www.da.gov.ph

Hijmans, R., Cameron, S., Parra, J., Jones, P., & Jarvis, A. 2005. Very high-resolution interpolated climate surfaces for global land areas. International Journal of Climatology, 25(15), 1965-1978. doi: 10.1002/joc.1276

Intergovernmental Panel on Climate Change (2001). Climate Change 2001: Impacts, Adaptation, and Vulnerability. New York City: Press Syndicate of the University of Cambridge. Retrieved from https://www.ipcc.ch/site/assets/uploads/2018/03/WGII_TAR_full_report-2.pdf

Intergovernmental Panel on Climate Change (2007). Climate Change 2007: Working Group II: Impacts, Adaptation and Vulnerability. Retrieved from https://www.ipcc.ch/site/assets/uploads/2018/03/ar4_wg2_full_report.pdf

Intergovernmental Panel on Climate Change (2007). Climate Change: 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Retrieved from https://www.ipcc.ch/report/ar4/syr/

Intergovernmental Panel on Climate Change (2014). Summary for policymakers In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press. 2014:1-32. Retrieved fromhttps://www.cambridge.org/core/books/abs/

Intergovernmental Panel on Climate Change (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp. Retrieved fromhttps://www.ipcc.ch/site/assets/uploads/2018/02/AR5_SYR_FINAL_Front_matters.pdf

Intergovernmental Panel on Climate Change Data Distribution Center (2023). Representative Concentration Pathways (RCPs) Database (v 2.0). Retrieved from Climate-ADAPT: https://climate adapt.eea.europa.eu/en/metadata/portals/

IRENA (International Renewable Energy Agency) (2016). Solar pumping for irrigation: Improving 397 livelihoods and sustainability. Available at https://www.irena.org/publications/2016/Jun/ 398 (Accessed 24 March 2024)

Islam, M., Ratna, M., Akter, N., Yesmin, M.S., Rahman, M.M., Rahman, M.G., Ali, A.S.M.Y., Haque, M.E. (2023). Effect of Different Bagging Materials on Fruit Quality of Mango. *East African Scholars Journal of Agriculture and Life Sciences, 6(11).* https://doi.org/10.36349/easjals.2023.v06i11.001

Israel, D. and Briones R. (2012). Impacts of Natural Disasters on Agriculture, Food Security, and Natural Resources and Environmenta in the Philippines. *PIDS Discussion Paper Series*, 36. Retrieved from https://www.eria.org/ERIA-DP-2013-15.pdf

Jagmohan S and Nijavalli R (2019). Applying IPCC 2014 framework for hazard-specicific vulnerability assessment under xclimate change. *Environmnetal Research Communications, Volume 1, Number 5*. doi:10.1088/2515-7620/ab24ed

Jayakumar S. , Kottarathu Kalarikkal, Remya & Ramachandrana, A.. (2015). Predicting the current and future suitable habitat distribution of Myristica dactyloides Gaertn. using MaxEnt model in the Eastern Ghats, India. Ecological Engineering. 82. 184-188. 10.1016/j.ecoleng.2015.04.053

Karunakaran, K.R. and Pansiami, Dr.K. 1998. An Analysis of Impact of Irrigation on Cropping Intensity in Tamil Nadu. Indian Economic Review 33(2):207-220. https://www.jstor.org/stable/29794170

Khalifa, S. M., and Abobatta, W. F. (2023). Climate changes and mango production (Temperature). IgMin Research, 1(1), 043–046. https://doi.org/10.61927/igmin115

Kumar, P., Tokar, T., Ma, X., & Wang, Y. (2017). Typhoon impact on agriculture: A comprehensive assessment in Zhejiang province, China. Environmental Monitoring and Assessment, 189(5), 219. https://doi.org/10.1007/s10661-017-5907-4

Laituri, M., Luizza, M.W., Hoover, J.D., and Allegretti, A.M.(2023) Questioning the practice of participation: Critical reflections on participatory mapping as a research tool, *Applied Geography*, Volume 152, 102900, ISSN 0143-6228, https://doi.org/10.1016/j.apgeog.2023.102900

Lang, A (2018). Adaptive Capacity : An Introduction. weADAPT. Retrieved from https://www.weadapt.org/

Lansigan, F.P., de los Santos, W.L. and Coladilla, J.O. (2000). Agronomic Impacts of Climate Variability on Rice Production in the Philippines. Agriculture, Ecosystems & Environment. Volume 82, Issues 1–3, Pages 129-137, ISSN 0167-8809, https://doi.org/10.1016/S0167-8809(00)00222-X

Luat Y. , Mendoza J., To M., and Cabauatan R. (2022). A study on the Economic Sustainability of Local Coffee production in the Philippines. *International Journal of Social , Policy and Laws, Vol. 2 No. 5*, 12-26. doi:https://doi.org/10.8888/ijospl.v2i5.76

Lucas, J. (2023). View of market chain analysis of white corn in Abra. Retrieved from http://portal.bsu.edu.ph:8083/index.php/BRJ/article/view/359/400

Magrath, J. (2015), “Transforming Lives in Zimbabwe: Rural Sustainable Energy Development Project”, Case Study, Oxfam, www.sun-connect-news.org/fileadmin/DATEIEN/Dateien/New/cs-zimbabwe-solarpower-170815-en.pdf

Maranan, C. (1985). COMPARATIVE EVALUATION OF TRACTOR AND CARABAO USE IN RICE LAND PREPARATION, NUEVA ECIJA, PHILIPPINES, 1980. Journal of Philippine Development, 113-140.

Margles S., Agostini V., Roth L., Gilmer B., Schill S., Knowles J., & Blyther R. (2016). Assessing vulnerability: an integrated approach for mapping adaptive capacity, sensitivity, and exposure. Climatic Change. 136. 10.1007/s10584-016-1642-0

Medina, S. M. (2019). The State of Agriculture in the Philippines. Retrieved from https://www.meiji.ac.jp/cip/researcher/6t5h7p00000ixpa5-att/material_2019f_kai.pdf

Moncado, C. (2019). Abra: Land, People, and History. *ICBE Through the Years* (p. 163). ICBE. Retrieved from https://mabikas-foundation.org/wp-content/uploads/2020/02/Abra-Culture.pdf

Mondal, T.K. and Sarkar, S. 2021. Analysis of cropping intensity and irrigation intensity in North Twenty Four Paraganas district, West Bengal, India. Miscellanea Geographia. 25(4): 1-13

Monod, H., Naud, C., and Makowski, D. (2006). Uncertainty and sensitivity analysis for crop models. In D. M. Wallach, *Working with dynamic Crop Models : Evaluation, Analysis, Parametrization, and Applications* (p. 55). The Netherlands: *Elsevier*

Nagar, N. (2023). Crop Suitability Modeling Techniques using CNNs in Context of Species Distribution Modeling: A Case Study on Distribution of Strawberries and Grapes in California. https://scholarworks.calstate.edu/

National Oceanic and Atmospheric Administration (n.d). National Weather Service. Retrieved from https://www.weather.gov/mrx/

National Disaster Risk Reduction Management Council (2018). Situational Report on Preparedness Measures and Effects of Southwest Monsoon Enhanced by Tropical Cyclones “Henry”, “Inday” and “Josie”. Retrieved from https://ndrrmc.gov.ph

Normand, F., Lauri, P., and Legave, J. M. (2015). Climate change and its probable effects on mango production and cultivation. Acta Horticulturae, 1075, 21–31. https://doi.org/10.17660/actahortic.2015.1075.1

Nowar, L. 2009. Nowar, L. 2009. Economic and Financial Assessment of Solar-Powered Irrigation. Journal of Agricultural Science. Retrieved from https://doi.org/10.5539/jas.v12n4p185

Odias, M. (2022). Growth and yield of rice (*Oryza sativa*) varieties under different planting time as an adaptation technology in Rizal, Kalinga Province

O’Donnel, M., and Ignizio, D. (2012) “Bioclimatic Predicators for Supporting Ecological Applications in the Conterminous United States” *Pubs.usgs.gov*. Available at: https://pubs.usgs.gov/ds/691/ds691.pdf

Olabisi, L. S. (2011). Uncovering the Root Causes of Soil Erosion in the Philippines. *Society & Natural Resources*, 37-51. doi:DOI: 10.1080/08941920.2011.563435

Paderes, N., Rynheart P., Atmosfera R., Quileza, MV., Abalos, HB. (2021). Climate Change Coping Mechanisms of Tingguian communities in the province of Abra: Basis for a climate change intervention program. *Journal of Critical Reviews*, 3. 8. 8021-8034. 10.31838/jcr.07.19.904

Paguia, R. Q., Paguia, H. M., Ventura, C. E., Javier, M., and Roldan, L. (2021). Sustainable mango production in Central Luzon, Philippines as affected by community-based model farms of improved crop management. IOP Conference Series: Earth and Environmental Science, 709(1), 012086. https://doi.org/10.1088/1755-1315/709/1/012086

Palanog A., Tayson C., Ciocon I., Ines L., Bibar JE., Seville C.,Palanog M., Donayre DK., Libetario E., Suñer AC. (2015). Grain yield performance and stability analysis of rice varieties under reainfed lowland onditions of Western Visayas, Philippines. *The Asian International Journal of Life Sciences*, 24. 399-408. Retrieved from https://www.researchgate.net/publication/

Palao, L., Guerten, N., Martinez, A., Parker, L., Balanza, J., Leyte, R., Dikitanan, R., & Burra D. 2017. A Climate Risk Vulnerability Assessment for the Adaptation and Mitigation Initiative in Agriculture program in the Philippines.

Paquit, Joseph, Climate-Risk Vulnerability Assessment of the Agriculture Sector in the Municipalities and Cities of Bukidnon, Philippines (2018). *International Journal of Biosciences*, Vol. 13, No. 6, p. 155-168, 2018, Retrieved from SSRN: https://ssrn.com/abstract=3574604

Parker, K., Hill, D., García-Medina, G., and Beamer, J. (2019) The effects of changing climate on estuarine water levels: A United States Pacific Northwest case study, Natural Hazards and Earth System Science, 19, 1601–1618, Retrieved fromhttps://doi.org/10.5194/nhess-19-1601-2019

Peñalba, L. M., and Elazegui D. (2013). Improving adaptive Capacity of Small-Scale Rice Farmers: Comparative Analysis of Lao Pdr and the Philippines. *World Applied Sciences Journal*, 1211-1220. doi: 10.5829/idosi.wasj.2013.24.09.13274

Philippine Rice Research Institute (2023). Yield per Hectare. The Rice Data Analytics Dashboard. Retrieved from https://www.philrice.gov.ph/

Philippine Statistics Authority (2023). Palay and Corn: Area Harvested by Ecosystem/Croptype, by Quarter, by Semester, by Region and by Province, 1987-

2023 by Ecosystem/Croptype, Geolocation, Year and Period. Retrived from https://openstat.psa.gov.ph/

Philippine Statistics Authority (2023). Major Non-Food and Industrial crops Quarterly Bulletin, April-June 2023. Philippine Statistics Authority. Retrieved November 21, 2023, from https://psa.gov.ph/

Philippine Statistics Authority (2023)*. Palay Production in Cordilllera Administrative Region by Province (2002-2022).* Philippine Rice Research Institute. Retrieved from https://www.philrice.gov.ph/

Philippine Statistics Authority (2023). Special Release: Corn Situation Outlook in Kalinga for July to December 2022. Philippine Statistics Authority

Philippine Statistics Authority (2023). Area harvested and volume of production 1987-2022. Retrieved from https://psa.gov.ph

Philippine Statistics Authority (2021). *2020* Census of Population and Housing (2020 CPH) Population Counts Declared Official by the President. Philippine Statistics Authority . Retrieved from https://psa.gov.ph/content/

Philippine Statistics Authority (2022). Abra Registered the Highest Growth in the Value of Production in Agriculture and Fisheries at 6.4 percent in 2021. Retrieved November 28, 2023, from https://psa.gov.ph/content/

Philippine Statistics Authority (2022). City of Baguio Leads the Economy of the Cordillera Administrative Region (CAR) in 2021. Philippine Statistics Authority. Retrieved from https://psa.gov.ph/content/

Philippine Statistics Authority (2022). Other Crops: Volume of Production, by Region and by Province, by Quarter and Semester, 2010-2023. open STAT. Retrieved November 24, 2023, from https://openstat.psa.gov.ph/

Phillips, S. J., Anderson, R.P., and Schapire, R. E. (2006) Maximum entropy modeling of species geographic distribu-tions. Ecol. Modell. 190: 231-259

Phillips, S.J. & Dudik, M. (2008). Modeling of Species Distributions with MaxEnt: New Extensions and a Comprehensive Evaluation. Ecography, 31, 161-175. Retrieved from http://dx.doi.org/10.1111/j.0906-7590.2008.5203.x

Porio E., Teresa G., Narisma T., Abigail F., Cruz T., Loyzaga AY. (2019). Drought and Urbanization: The Case of the Philippines. Singapore: Springer. doi:https://doi.org/10.1007/978-981-10-8947-3_12.

Rana, J., Kamruzzaman, M., Oliver, M. M. H., & Akhi, K. (2021). Financial and factors demand analysis of solar powered irrigation system in Boro rice production: A case study in Meherpur district of Bangladesh. *Renewable Energy*, *167*, 433–439. https://doi.org/10.1016/j.renene.2020.11.100

Rathnayaka, H. (2021). Importance of water stress management in mango productivity. Retrieved from https://www.linkedin.com/pulse/

Ravago ML., Roumasset, James Jandoc, Karl (2017). Risk Management and Coping Strategies:Climate Change and Agriculture in the Philippines. Retrieved November 28, 2023, from https://ageconsearch.umn.edu/record/284858.

Ravago, M. (2016). Risk management and coping strategies: climate change and agriculture in the Philippines. Retrieved from https://econ.upd.edu.ph/pre/index.php/pre/article /viewFile /943/862

Raza, F., et.al. (2022). The Socio-Economic Impact of Using Photovoltaic (PV) Energy for High-Efficiency Irrigation Systems: A Case Study. Energies. Retrieved from https://doi.org/10.3390/en15031198

Reisinger A., Garschagen M., Pathak M., Poloczanska E., Aalst M., Ruane A., Howden M., Hulbert M., Mintenbeck K., Pedace R.,Corradi M., Viner D., Vera C., Kreibiehl S., O'Neil B., Portner H., Sillmann J., Jones R., Ranasinghe R. (2020). *The concept of risk in the IPCC Sixth Assessment Report; a summary of cross-working group discussions.* Geneva: Intergovernmental panel on Clomate Change. Retrieved from https://www.ipcc.ch/site/assets/uploads/2021/01/The-concept-of-risk-in-the-IPCC-Sixth-Assessment-Report.pdf

Rezaei, E. E., Siebert, S., Huging, H., and Ewert, F. (2018). Climate change's effect on wheat phenology depends on cultivar change. Sci. Rep. 8, 48–91. doi: 10.1038/s41598-018-23101-2

Riahi, K., Rao, S., Krey, V., Cho, C., Chirkov, V., Fischer, G., Kinderman, G., Nakicenovic, N., & Rafaj, P. 2011. RCP 8.5—A scenario of comparatively high greenhouse gas emissions", *Climatic Change*, 109(1-2), pp. 33-57. doi: 10.1007/s10584-011-0149-y

Rosegrant, M., and Sombilla, M. (2018). The future of Philippine agriculture under changing climate: policies, investments and scenarios. ISEAS-Yusof Ishak Institute

Salvacion, A. (2022). Delineating soil erosion risk in Marinduque, Philippines using RUSLE. *GeoJournal*, 423-435. doi:https://doi.org/10.1007/s10708-020-10264-7

Salvaciona, R. (2015). Climatic change impact on corn productivity in the Philippines. International Journal of Sciences: Basic and Applied Research (IJSBAR). Retrieved from https://www.researchgate.net/publication/277559605

Santa Barbara, MT. (2022). The Rate of Coffee Production in the Philippines - A Study based on Demand and Supply. Retrieved from http://dx.doi.org/10.2139/ssrn.4120889

Sathyan R., Funk C., Aenis T., Winker P. & Breuer L. (2018, January 15). Sensitivity analysis of a climate vulnerability index-a case study from Indian watershed development programmes. 1-14. doi:https://doi.org/10.1186/s40665-018-0037-z

Sattar, M. A., & Rahman, M. M (2004). Agriculture Technology Handbook, 3rd ed., Joydebpur, Gazipur

Smit, Barry &. Wandel, Johanna (2006). Adaptation , adaptive capacity and vulnerability. *Science Direct, 16*(3), 282-292. doi:https://doi.org/10.1016/j.gloenvcha.2006.03.008

Smith J ., Klein R. and Huq S. (2003). *Climate Change, Adaptive Capacity and Development.* Imperial College Press. Retrieved from https://www.semanticscholar.org/paper/

Sutjana, I.D.P. & Adiputra, I. (2012). Comparison study in using plough, tractor, and cultivator for ricefield land preparation. Indonesia Journal of Biomedical Science. 2. 10.15562/ijbs.v2i1.50.

Statista. (2023). Coffee production value Philippines 2012-2022. Statista Research Department. Retrieved on November 20, 2023, from https://www.statista.com/

Statista Research Department. (2023). Number climate-related disasters due to landslide in the Philippines from 1980-2022. Statista Research Department. https://www.statista.com/statistics/1316049/

Statistica Research Development. (2023). Total land area in the Cordillera Administrative Region in the Philippines in 2021, by classification status. Retrieved from https://www.statista.com/

Stuecker M. F. , Tigchelaar M., & Kantar MB. (2018, August 9). Climate variability impacts on rice production in the Philippines. *Tenth International Congress in Peer Review and Scientific Publication*, https://doi.org/10.1371/journal.pone.0201426

Tababa, J. (2023). Five farming techniques to practice on sloping agricultural land to mitigate soil erosion and nutrient depletion. Retrieved from https://mb.com.ph/2023/5/3/

Tao S., Xu Y., Liu K., Pan J., & Gou S. (2011). Research Progress in Agricultural Vulnerability to climate Change. *Advances in climate Change Research, Volume 2*(Issue 4), 203-210. doi:10.3724/SP.J.1248.2011.00203

The World Bank. (2023). Towards a Comprehensive Disaster Risk Management System for the Philippines. Retrieved from https://www.worldbank.org/

United States Agency for International Development. (2015). Mango forum report. Retrieved from https://pdf.usaid.gov

United Nations Framework Convention on Climate Change. (n.d.). *Vulnerability and adaptation to Climate Change.* United Nations Framework Convention on Climate Change. Retrieved from https://unfccc.int/resource/docs/publications/08_resource_guide2.pdf

Ventura, C.E., Jorge-Acain, L.R., Paguia, R.Q., Paguia, H.M. (2022). Effects of Bagging of the Panicles of Philippine Carabao Mango *(Mangifera indica* L.*)* Using Waxed Paper Bags. *Agricultural Science, 4(2).* https:/doi.org/10.30560/as.v4n2p29

World Bank Group and the Asian Development (2017). Climate Change Risk Profile: Philippines. Retrieved from https://www.climatelinks.org/

World Bank Group (n.d.). Risk: historical Hazards. Retrieved November 14, 2023, from https://climateknowledgeportal.worldbank.org/

World Bank Group and the Asian Development Bank. (2017). Climate Change Risk Profile: Philippines

World Bank Group (2021). Risk- Historical Hazards. Climate Change Knowledge Portal. https://climateknowledgeportal.worldbank.org/

X. ACKNOWLEDGEMENT

The study implemented with funding from the DA-RFO-CAR (Department of Agriculture – Regional Field Office – Cordillera Administrative Region).