[Policy Advisory Report]

Climate Vulnerability and Risk Information System (CVRIS) for Agricultural Value Chain in Oriental Mindoro

GGGI KOICA Korea International Cooperation Agency Climate Change Commission Philippines dti Philippines Province of Oriental Mindoro Official Seal

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ACRONYMS

API	Application Programming Interface
ARBO	Agrarian Reform Beneficiary Program
ARG	automatic rain gauge
AWS	automatic weather station
BMS	battery management system
BSWM	Bureau of Soils and Water Management
CBMS	community-based monitoring system
CCC	Climate Change Commission
CLUP	Comprehensive Land Use Plan
CRM	climate risk management
CVRIS	Climate Vulnerability and Risk Information System
DA	Department of Agriculture
DAR	Department of Agrarian Reform
DCGE	Dynamic Computable General Equilibrium
DENR	Department of Environment and Natural Resources
DICT	Department of Information and Communications Technology
DILG	Department of Interior and Local Government
DOST	Department of Science and Technology
ECMWF	European Centre for Medium-Range Weather Forecast
ETL	extract-transform-load
FAO	Food and Agriculture Organization
FEWS	flood warly warning system
FGD	focused-group discussion
GCP	Google Cloud Platform
GFS	Global Forecast System
GIEWS	Global Information and Early Warning System on Food and Agriculture
GSM	Global System for Mobile Communications
GTZ	German Technical Cooperation
HVCC	high value commercial crops
IAM	identity and access management
ICON	Global German Standard
IEC	information, education and communication
IoT	Internet of Things
IPCC	Intergovernmental Panel on Climate Change
IRRI	International Rice Research Institute
JSON	JavaScript Object Notation
LAN	local area network
LDRRMF	Local Disaster Risk Reduction and Management Fund
LGU	local government unit
LoRa	long range
NAMRIA	National Mapping and Resource Information Authority
NCCAP	National Climate Change Action Plan
NEDA	National Economic Development Authority
NFSCC	National Framework Strategy on Climate Change
NIS	National Irrigation System
NIST	U.S. National Institute of Standards and Technology
NSCB	National Statistical Coordination Board
PAGASA	Philippine Atmospheric, Geophysical and Astronomical Services Administration
PAGASA-CIA	PAGASA-Climate Impact Assessment for Agriculture in the Philippines
PAgO	Provincial Agriculture Office
PAR	Philippine Area of Responsibility
PCA	Philippine Coconut Authority
PDCC	Provincial Disaster Coordinating Council
PDPFP	Provincial Development and Physical Framework Plan

PDRRMC	Provincial Disaster Risk Reduction and Management Council
PDRRMO	Provincial Disaster Risk Reduction and Management Office
PGOM	Provincial Government of Oriental Mindoro
PHIVOLCS	Philippine Institute of Volcanology and Seismology
PPDO	Provincial Planning and Development office
PPFP	Provincial Physical Framework Plan
PSA	Philippine Statistics Authority
PTWG	Provincial Technical Working Group
RDBMS	relational database management system
RSBSA	Registry System for Basic Sectors in Agriculture
SAFDZ	Strategic Agriculture and Fisheries Development Zones
sq km	square kilometer
sqm	square meter
UNDP	United Nations Development Programme
UNDRR	United Nations Office for Disaster Risk Reduction
USGS	United States Geological Survey
WLMS	Water Level Monitoring Sensors

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Executive Summary

Climate change risks and impacts are increasingly felt by Philippine communities and it is expected that the frequency and magnitude of these threats will continue to increase in the coming decades. The Province of Oriental Mindoro is highly vulnerable to climate change impacts as it is exposed to various natural calamities such as flooding, landslides, and typhoons. Thirteen out of fifteen municipalities in the province are located on the coastline and thus are at a greater risk of experiencing adverse impacts from storm surges and tsunamis. Coastal areas and the alluvial plains of the northeastern part of the province are furthermore considered vulnerable to flooding, liquefaction, and lateral spreading.

Nevertheless, the provincial economy is predominantly driven by agriculture. This presents a fundamental risk to poor and rural communities who are mostly dependent on agriculture, given that the sector is highly vulnerable to climate change impacts and disruptions will potentially affect their lives and primary source of income.

However, climate change impacts have been further exacerbated by inherent institutional and technical challenges of the local government units (LGUs) to anticipate, plan, and respond to climate risks, lacking the evidence-based and readily available local climate information that should serve as a fundamental reference for decision making. As frontline service providers and local development managers, LGUs are mandated to formulate and implement local climate change action plans, which should ideally provide the blueprint to enhance the adaptive capacities of local communities to climate change impacts. To overcome these challenges, the report proposes the establishment of the Climate Vulnerability and Risk Information System (CVRIS) for Oriental Mindoro which will serve as a policy advisory tool for decision makers with data-driven monitoring and analytical information as well as a reference tool for the local communities to have greater access to relevant climate change information at the local level.

Also, in order to implement CVRIS, the key is to input relevant data regularly at a local level and manage the system with a periodic update. Thus, the project will be supplemented by providing proper capacity development supports to the focal points of provincial and municipal officials.

Chapter 1 of the report covers the background of this project, which is originated from the project titled "Climate Resilient and Inclusive Green Growth: Accelerating Implementation in the Agriculture Value Chain," financed and implemented by the Korea International Cooperation Agency and the Global Green Growth Institute (GGGI). Chapter 2 consists of an overview of Oriental Mindoro and its current state in terms of climate change and agriculture. The succeeding Chapter 3 provides a review of international and local existing climate information systems to serve as the groundwork for the development of CVRIS. This chapter provides reference information by analyzing the pros and cons of the various existing systems. The last chapter covers the detailed plans for the development of CVRIS, supported by the proposed conceptual framework for the climate risk assessment in relation to agriculture as well as information on the conceptual design of the tool.

Note: This report covers an initial phase of the development stage of the CVRIS where further adjustments and refinements will be needed through rounds of consultations and validations with the relevant stakeholders.

1. Background

The report is one of the outputs of the project titled "Climate Resilient and Inclusive Green Growth: Accelerating Implementation in the Agriculture Value Chain," financed and implemented by the Korea International Cooperation Agency and the Global Green Growth Institute (GGGI), in close collaboration with the Department of Trade and Industry (DTI), the Climate Change Commission (CCC), and the Provincial Government of Oriental Mindoro (PGOM).

The project seeks to address three interlinked challenges that hinder the climate resilient and inclusive development of rural communities in the Province of Oriental Mindoro, which are: 1) low adaptive capacity against short and long-term risks of climate change among rural communities and agri micro-enterprises in Oriental Mindoro; 2) poor development of agri micro-enterprises; and 3) limited capacity of government and non-government stakeholders to design and implement climate resilient green growth initiatives at scale. In order to address these challenges, the project is composed of three main outcomes: 1) Outcome 1. Greater climate resilience of farmers, agribusinesses, and vulnerable local communities achieved through the implementation of evidence-based climate policies in Oriental Mindoro; 2) Outcome 2. Design, financing, and operationalization of micro-enterprises and a Provincial Agricultural Center (PAC) in Oriental Mindoro; and 3) Outcome 3. Improved capacity of government and non-government stakeholders to implement climate resilient, inclusive, and green agriculture value chain projects in Oriental Mindoro. This effort is one of the outputs of Outcome 1.

The report is designed to a) examine the current state of climate vulnerability and risks in relation to the agricultural value chain in Oriental Mindoro; b) analyze strengths and weaknesses of similar information systems implemented in the Philippines and other countries; and c) shape an envisioned vulnerability and risk assessment tool with integrated spatial-climate-socio-economic information fit to the situation in Oriental Mindoro.

What is CVRIS?

CVRIS is an online system that will collect, digitize, analyze and disseminate information relevant to climate change and agriculture value chain

What are CVRIS' Functions?

Integrate national level climate change information with municipal and barangay level data

Visualize the different layers of hazard and socio-economic factors at a glance

Provide objective basis for multi-sectoral local policy decisions

2. Baseline Information

2.1 Ecological Profile

Oriental Mindoro is a province of the Philippines under the MIMAROPA region in Luzon. The province has a total land area of 4,364.72 square kilometers and represents 1.5% of the total land area of the country.[1] Oriental Mindoro features three distinct geographical zone surfaces that consist of rugged terrain and an irregular coastline. It has a total of 342.45 kilometers of coastal areas, a total area of 81.28 square kilometers of lakes, and riparian areas, intermittent valleys and ranges of mountains covering 89% of its total land mass.[2] Several rivers and streams traverse the province, but none are navigable by large vessels.

Table 2.1: The total land area and number of barangays per city and municipality in Oriental Mindoro

Municipality	Land Area (sq km)	% of Total	No. of
Baco	241	5.5	27
Bansud	260	6	13
Bongabong	498	11	36
Bulalacao	305	7	15
Calapan City	265	6	62
Gloria	230	5	27
Mansalay	513	12	17
Naujan	528	12	70
Pinamalayan	277	6	37
Pola	130	3	23
Puerto Galera	223	5	13
Roxas	87	2	20
San Teodoro	369	8	8
Socorro	149	3	26
Victoria	286	6	32
Total	**4,364**	**100**	**426**

Source: PGOM PPDO (2020)

1 Oriental Mindoro Provincial Development & Physical Framework Plan (PDPFP) 2016-2025
2 Oriental Mindoro Facts and Figures 2018

Figure 2.1: Base map of Oriental Mindoro

Source: Provincial Government of Oriental Mindoro (PGOM)

The province is divided into two districts and is composed of 1 city, 14 municipalities, and 426 barangays. Table 2.1 shows the land area distribution per city and municipalities, as well as the number of barangays in each.

2.1.1 Topography

Oriental Mindoro has mountain ranges with varying elevation, including a volcanic peak. The highest peak of the island is Mount Halcon, located at the northern territorial area of the province, measuring approximately 2,585 meters above sea level. It is

Table 2.2: Distribution of land elevation slope ranges in Oriental Mindoro

Slope Range Description	Slope Percentage (%)	Land Area Covered (in sq km)	% of Total
Level to gently sloping	0-3	1,245	28.53%
Gently sloping to undulating	3-8	166	3.81%
Undulating to rolling slope	8-18	226	5.17%
Rolling and moderately steep slope	18-30	308	7.07%
Moderately steep to steep slope	30-50	703	16.1%
Steep to very steep slope	> 50	1,519	34.8%

Source: PGOM's PDPFP (2016)

considered as a dormant mountain range with no record of eruption.

Plains cover an estimated area of 1,316.82 square kilometers, with marshlands and swamps that cover 51.72 square kilometers. These plains stretch from Baco to Victoria in the northern part of the province, from Pinamalayan to Bongabong Coast in the central part, and Roxas to Mansalay in the southern part.

The province has six (6) slope ranges (as seen in Figure 2.2). The distribution of land area per slope range is shown in Table 2.2.

Figure 2.2: Slope map of Oriental Mindoro

Agricultural and economic activities are concentrated in level to gently sloping areas since there are minimal land limitations. Gently sloping to undulating areas are residual terraces where fruit trees and rice paddies are located. Areas covered within these two slope ranges can be planted with a variety of lowland crops.

Undulating to rolling slope areas are suitable for the cultivation of fruit trees and other perennial high value commercial crops. However, these lands require slight to moderate land development costs to optimize the crop production for these annual and seasonal crops. These areas are found mainly in Calapan City, Naujan, Victoria, and Pinamalayan.

Soil erosion is a problem in the hilly and mountainous areas with slopes that are rolling to moderately steep (18-30%) and moderately steep to steep (30-50%). Cultivation of seasonal and annual crops is not recommended in these areas, instead, forest preservation and reforestation is the main priority. Slope ranges of greater than 50% are located in rugged terrain areas with hilly and mountainous landscapes such as Puerto Galera, San Teodoro, Bansud, Bongabong, Roxas, Mansalay, and Bulalacao. Forest conservation and reforestation of denuded watersheds with mixed forest tree species are the main goals of these areas in order to reduce further environmental degradation.

2.1.2 Land Use

Based on the province's existing land classification system, approximately 2,134.29 sq km of land are

Table 2.3: Land area by classification

Land use	Area (sq km)	% of Total Land Area
Established forest reserves	857	19.66%
Established timberland	793	18.17%
National parks	443	10.15%
Civil reservation	37	0.84%

Source: Oriental Mindoro PPDO (2008 Philippine Forestry Statistics)

Table 2.4: Forest cover distribution

Land use	Area (sq km)	% of Total Land Area
Forest Cover	870	19.91%
Open Forest	777	17.81%
Closed Forest	53	1.21%
Mangrove Forest	39	0.90%

classified as forest land whereas 1.48 sq km are unclassified. Table 2.3 shows the land area and its proportion based on the land use classification.

2.1.3 Demography

Based on the 2015 Philippine Statistics Authority (PSA) Census, Oriental Mindoro has a total population of 844,059 (49% women; 51% men) with an average growth rate of 1.38%. The province contributes to 0.84% of the population of the country. The province is largely rural with urban population estimated at only 32% and rural population at 68%. Based on the average growth rate of the population, the province expects to double its population in 50 years.[3] By 2025, Oriental Mindoro expects its population to reach 968,045 or a projected increase of 123,986 people from the 2015 census.

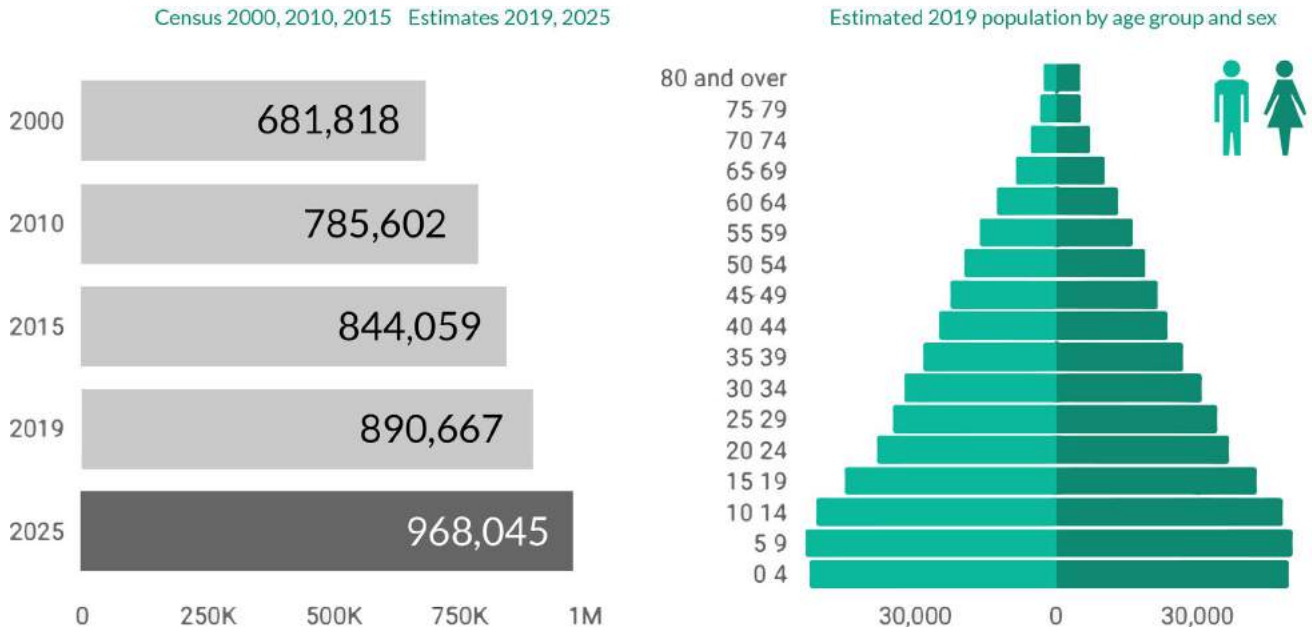
The population of Oriental Mindoro for the past two consecutive censual periods has been predominantly young, under 15 years old. However, 60.58% of the province's population belongs to the economically productive age group, aged 15-64 years old, which accounts for the largest percentage of Oriental Mindoro's total population. Having this type of

Table 2.4: Oriental Mindoro Population, Land Area and Population Density by City/Municipality in 2010 and 2015

City/ Municipality	Person		Density (per sq km)		Area (sq km)
	2010	2015	2010	2015	
Baco	35,060	37,215	145	154	242
Bansud	38,341	40,992	147	158	260
Bongabong	66,569	72,073	134	145	498
Bulalacao	33,754	39,107	111	128	305
Calapan City	124,173	113,893	468	505	265
Gloria	42,012	45,073	182	195	231
Mansalay	51,705	54,533	101	106	513
Naujan	94,497	102,998	179	195	528
Pinamalayan	81,666	86,172	295	311	277
Pola	32,984	34,701	253	267	130
Puerto Galera	32,521	36,606	146	164	223
Roxas	49,854	53,201	572	611	87
San Teodoro	15,810	17,904	43	49	369
Socorro	38,348	39,099	257	262	149
Victoria	48,308	50,492	169	177	286
ORIENTAL MINDORO	785,602	844,059	180	193	4,365

Source: Philippine Statistics Authority (PSA)

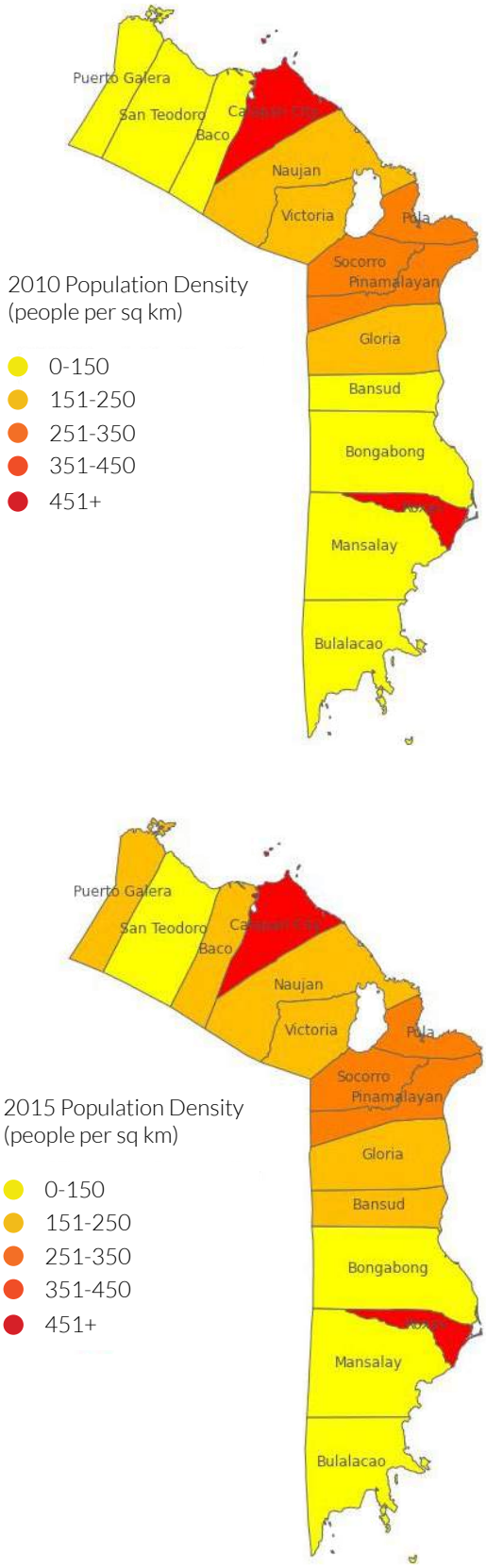
Figure 2.3: Total and Estimated Population of Oriental Mindoro and Estimated 2019 Population by age group and sex.



Source: Population for 2000, 2010, and 2015 are from the PSA census. The estimated population for 2019 is from PSA MIMAROPA's CoRe-Is and for 2025 is from Oriental Mindoro 2016-2025 PDPFP

3 Based on the Oriental Mindoro Provincial Development and Physical Framework Plan 2016-2025

Figure 2.4: Population density of Oriental Mindoro, by Municipality in 2010 (top) and 2015 (bottom).



Source: Philippine Statistics Authority (PSA).

expansive population pyramid with a broad base means that the population has high fertility rates but lower than average life expectancies (Saroha, 2018).

As seen in Figure 2.4, the municipalities with the highest densities relative to its provincial averages are Roxas, Calapan City, Pinamalayan, Pola, and Socorro. Although Calapan City is classified as a "primary urban center" or a large town in the province, it is considerably less dense than Roxas because of the latter's limited land area. The province's density is also expected to continuously increase with approximately 222 people per sq km from 193 people per square kilometer in 2015.

2.1.4 Rural-Urban Distribution of Population

Oriental Mindoro currently has 73 urban (17%) and 353 rural (83%) barangays among the total of 426 barangays. As the province remains predominantly rural, this justifies the geographic clustering wherein the rural areas serve as the main source of agri-industrial products. Comparing the 2010 and 2015 population change, both Calapan City and Roxas had the highest increase in urban population, while Naujan and Calapan City had the highest increase in rural population

2.1.5 Settlements

"Settlements" refers to the formal and informal communities, or built-up residential areas, and land areas classified, zoned, or converted for current or future residential or housing development purposes, which also includes socialized housing zones for the homeless and underprivileged citizens.[4] As of 2015, the total area occupied by built-up areas represents 2.11% (92 sq km) of the total land area of the province.

Oriental Mindoro follows the four levels of settlement hierarchy, namely Primary Urban Center B, Secondary Urban Center A, Secondary Urban Center B, and Tertiary Urban Center.[5] Table 2.5 shows the existing urban hierarchy level of the municipalities of Oriental Mindoro in 2015.

Based on the projections, only the municipality

4 Based on the Oriental Mindoro Provincial Development and Physical Framework Plan 2016-2025
5 Provincial Physical Framework Plan (PPFP) training program learning materials published by NEDA in 1996

Table 2.5: Existing hierarchy of urban centers of Oriental Mindoro, 2015

Urban Hierarchy Level	Urban Center in 2015
Primary Urban Center B	Calapan
Secondary Urban Center A	Pinamalayan Roxas
Secondary Urban Center B	Mansalay Bansud Gloria Puerto Galera Victoria Bongabong Bulalacao Socorro Naujan
Tertiary Urban Center	Baco San Teodoro Pola

Source: PGOM

of Baco is expected to be promoted to Secondary Urban Center B in 2025. The rest will maintain their hierarchy level. As the province aims to be the food base of the Luzon and Visayas regions, a premiere tourist destination and the center of investments, it is expected that the government's efforts and initiatives will generate employment opportunities and investments that will spur economic growth. This may result in a greater demand for housing and additional areas for urban expansion. Since slow growth is observed outside urban areas, there is a possibility of utilizing agricultural lands for non-agricultural uses. Proper planning and monitoring will have to be done to ensure that there will be sufficient agricultural produce generated despite conversions.

2.2 Economic Profile

Oriental Mindoro has a rich agricultural, tourism, and commerce industry. With its climate being conducive for vegetable growth year-round, agriculture is the primary economic driver of the province and approximately 62% of households in the region depend on farming and fishing. The province is also rich in greenery with 89% of its total land mass consists of riparian areas and approximately 32% of total land area is utilized for agriculture activities.

The province is known as the "Food Basket of the MIMAROPA Region" as it accounts for 36% of rice production in the Philippines. It is also considered the "Calamansi King" (Philippine Lemon) as it accounts for 98.66% of regional calamansi production and 59% of total production nationwide. Around 66% of regional banana production is also from Oriental Mindoro.

2.2.1 Agriculture

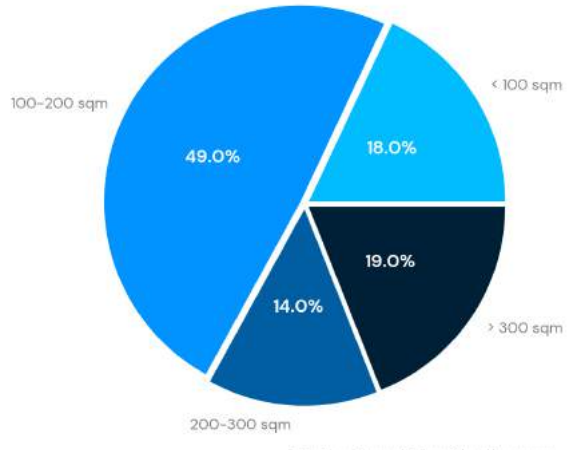
The agricultural activity in the province is mainly the production of food staples such as rice and corn, industrial crops like coconut, and other high value commercial crops (HVCC) such as calamansi, banana, root crops, and fruit-bearing trees. Over the past years, farmers have been shifting from the traditional production pattern to HVCCs as this can benefit farmers due to the increased labor requirement of the farm, as well as increased income for the investors of processing plants. These HVCCs have a longer value chain and can be used to produce various products such as virgin coconut oil, calamansi purees and concentrates, banana chips, and other root crop chips. As such, the PGOM views agri-business as a promising industry for the province since it creates higher value secondary agriculture products and generates more jobs, income and economic opportunities for agriculture workers and rural communities.

Currently, farmer associations are active across the province with each locality having more than one farmer association. It is through these associations that agricultural aid and information are cascaded down to the farmers and communities. From the conducted Focus Group Discussions,[6] it has been noted that the Municipality of Roxas has the most farmer associations with a total of 17 agricultural associations. It is worth noting that these associations encompass rice, fruit, coconut, and seaweed farmers, alongside livestock farmers and fisher folks.

Landless (tenant-farmers) and small land holders are common in the provincial agricultural situation. Around 51% of farmers are tenant-farmers, 46% are farmer-owners, and 3% of farmers lease the farm. Based on the land use assessment study conducted by the Bureau of Soils and Water Management (BSWM), 18% of farmers have a farm holding less than 100 sqm, 49% of farmers have a farm area ranging from 100-200 sqm, 14% with 200-300 sq m, and 19% with an area of more than 300 sqm (See Figure 2.6)

6 Focused group discussions with farmers of the municipality of Roxas conducted on February 23, 2021.

Figure 2.6: Distribution of farmers according to farm size



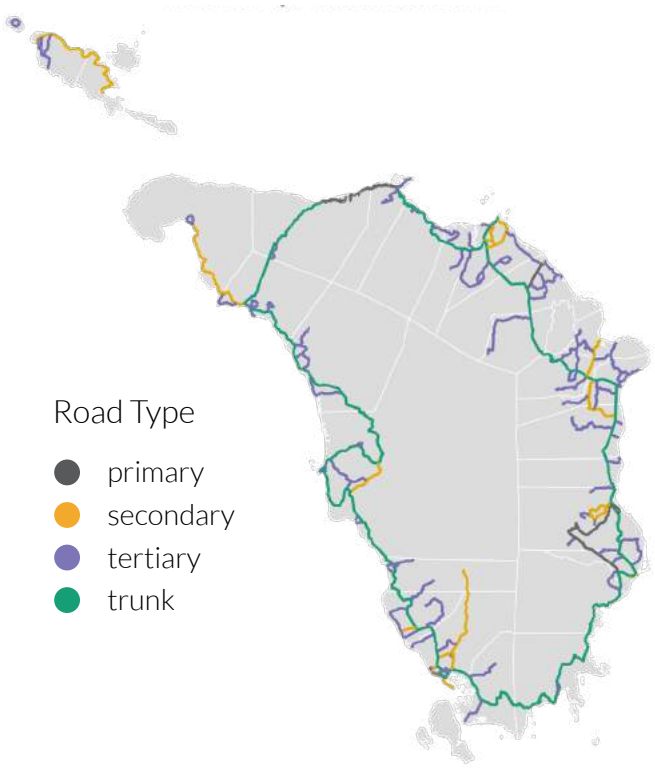
Source: BSWM

In support of the provincial agricultural value chain, it is noted that Oriental Mindoro has a total length of 329.80 kilometers of national roads and a total of 897.22 kilometers of provincial roads. In transporting agricultural goods within and across the province's rugged terrain, Oriental Mindoro has a total of 91 provincial bridges and 66 national bridges. Figure 2.7 shows the major roads on the island of Mindoro. The primary transportation backbone is labelled as "trunk" on OpenStreetMaps[7] while the primary, secondary, and tertiary roads are connecting roads to the town centers and barangays.

In the agri-food value chain, processing raw materials can lead to a substantial increase in the value for the new product created. As part of the province's attempt to increase the value of their agricultural products, they have started to develop new products from rice, banana, coconut, calamansi, and other fruit and vegetables produced from their farms. They even have instruction manuals readily available for farmers on their Agri-Infohub website. Some of the products they have started to explore include rice cakes, rice noodles, wine, flour, dehydrated banana, vacuum-fried banana, chocolate-coated chips, coco sugar, dehydrated coconut, and other vacuum-fried fruits and vegetables.

However, according to data from the provincial government, the majority of crops produced in Oriental Mindoro are still being transported and processed outside of the province. This means that farmers only receive a small portion of the processed

Figure 2.7: Network of major roads on Mindoro Island



Source: Open Street Map

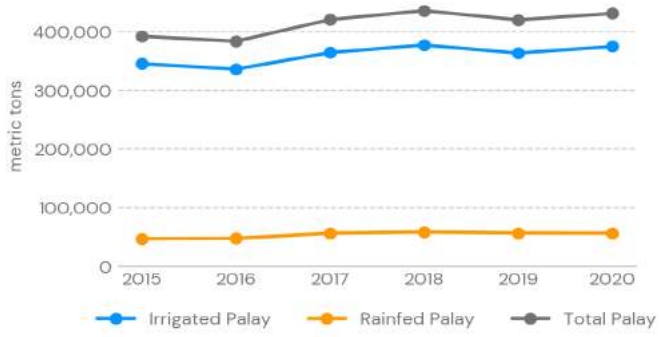
product's value. In addition to the lack of processing capacity, farmers are also challenged with establishing long-term relationships with the processors since their harvest is purchased by a handful of traders at spot prices. These traders use their bargaining power to depress prices to offload logistic risks. Since typhoons occur frequently in the country and roads in the provinces are limited, when flooding occurs, trucks end up waiting for long periods of time, causing their cargo to spoil. All these issues tend to continue in a vicious cycle of low agricultural productivity and poor economic performance.

Palay

Among its other titles, Oriental Mindoro is also considered as the Rice Granary of the MIMAROPA region representing approximately 36% (1,015.14 sq km of the region's total palay area (2,835.86 sq km). Based on the PSA data from 2015-2020, the total palay production of the region has continuously increased over the years, with a total of 430,967 metric tons produced in 2020 (see Figure 2.7).

7 https://wiki.openstreetmap.org/wiki/Philippines/Mapping_conventions#Roads

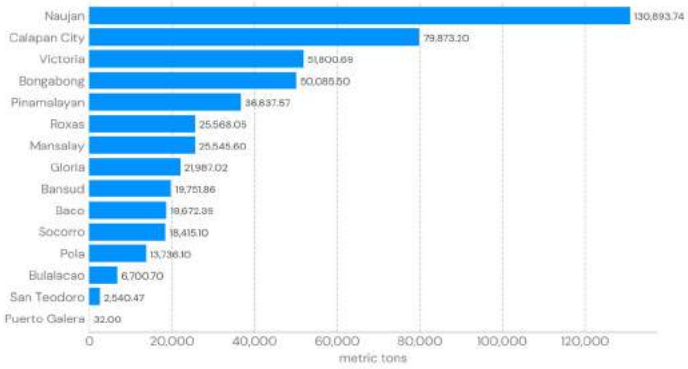
Figure 2.7: Volume of palay production of Oriental Mindoro from 2015-2020



Source: PSA

From the 2015 PAgO data, Naujan has the largest share of palay produced with 130,893.74 metric tons, followed by Calapan City with 79,873.20 metric tons. The remaining municipalities contributed 291,473.05 metric tons in total (see Figure 2.8).

Figure 2.8: Palay production of Oriental Mindoro by City/Municipality, 2015



Source: PAgO

Rice is a semi-aquatic crop but not all varieties have the ability to survive complete or partial flooding. The International Rice Research Institute (IRRI) has been continuously developing different variants of palay to help farmers adapt to the changing climate of the country (Baldosa, 2018). To this end, studies include the genetics of traditional rice varieties that can tolerate higher levels and longer duration of flooding. As part of the Philippines Rice Self-Sufficiency Plan, farmers of Oriental Mindoro were part of the beneficiaries of IRRI's field days where they share the latest and best-performing rice varieties to help these farmers produce more rice (Valmon, 2011). From the focused-group discussions conducted with farmers, they expressed their interest and requested for support to gain access to these flood-resistant variants of rice.

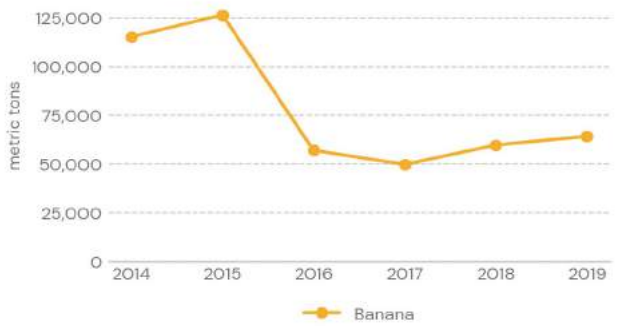
Banana

Banana is an important crop in the Philippines, and it is grown in every municipality in Oriental Mindoro. Of the six popular varieties of banana, the dominant type found in the province is Saba banana, which are used to make banana chips.

Banana plantations cover 22,450 hectares (5.14%) of land in the province with a total of 7,033,575 trees in 2016. Banana tops the province's fruit production with approximately 21% of its production located at the municipality of Bulalacao in the 2nd district of the province. Furthermore, banana trees are more vulnerable to damage due to typhoons given its structure – unlike mangoes and calamansi. As seen in Figure 2.9, there was a large drop in the production of bananas in 2016. The province was severely damaged back in 2013 due to Typhoon Yolanda. Additionally, in December of 2015, Typhoon Melor also caused a state of calamity in Oriental Mindoro (Virola, 2015).

Storms also affect the quality of the bananas in the province. As part of their preparation for storms and typhoons, some farmers start harvesting the bananas even if they are still raw. Some farmers have also shifted to planting Senoritas, a different variant of banana, which takes less time to mature.

Figure 2.9: Volume of banana production in Oriental Mindoro, 2014-2019



Source: PSA

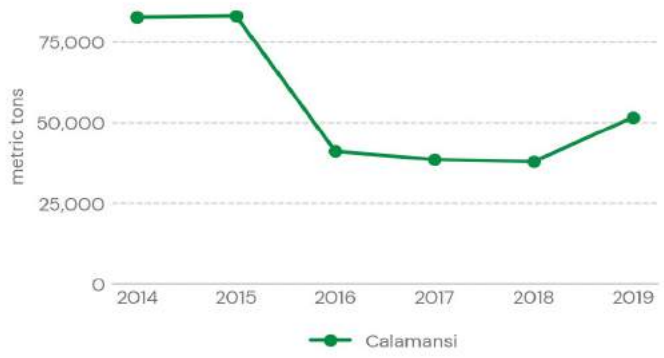
Calamansi

Calamansi, second of the HVCCs in the greatest number of trees, has an average yield rate of 9.96 metric tons per hectare. With the province serving as the primary source of calamansi for the MIMAROPA region and Luzon, it is considered as the "Calamansi King." Over the years, the production of calamansi has decreased since 2015, but it is slowly improving according to 2019 data from PSA (see Figure 2.10).

Based on the 2011-2015 data from PAgO, the top producers of calamansi are the municipalities of Naujan, Victoria, and Socorro (see Figure 2.11),

which benefit from their favorable agro-climatic conditions for growing calamansi, such as evenly distributed rainfall and a predominantly loam soil type.

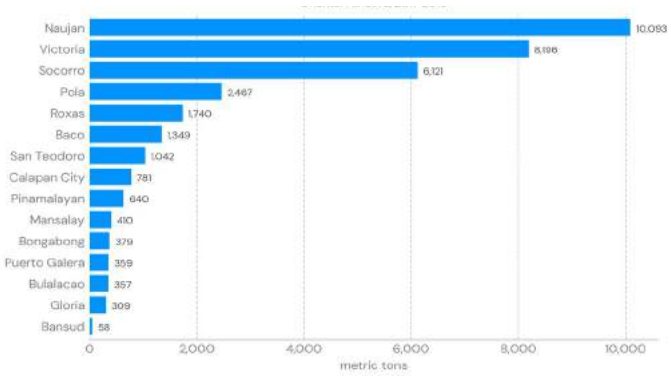
Figure 2.10: Volume of calamansi production in Oriental Mindoro, 2014-2019



Source: PSA

Most farmers sell their harvest in a single spot transaction to agents and traders. This is not a strategic nor profitable scenario for the farmers since it results in excess supply, leading to low farmgate prices that are disadvantageous for farmers. However, despite these supply-demand issues during the peak seasons, it has been noted by several farmers from the province through the conducted Focus Group Discussions, that farmers are now more inclined to plant calamansi due to its resilience to erratic weather changes. With this, several farms have now converted their crops to calamansi to accommodate the growth in the market for it.

Figure 2.11: Average annual production of calamansi by City/Municipality, Oriental Mindoro, 2011-2015



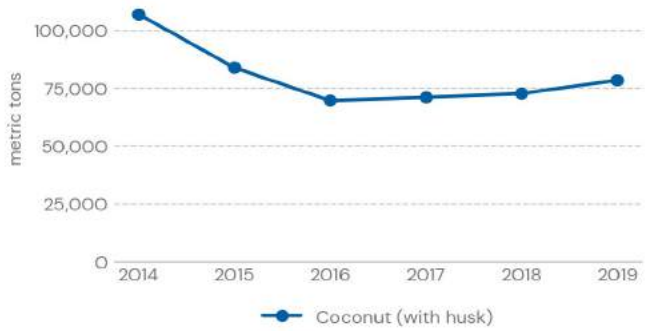
Source: PAgO

Coconut

The coconut industry in the Philippines remains to be an important agro-based industry for the country due to the sources of livelihood and income it provides to many Filipinos, as well as export earnings. Based on the 2019 PSA data, the production of the province has increased to 78,493 metric tons from the previous year's 72,731 metric tons.

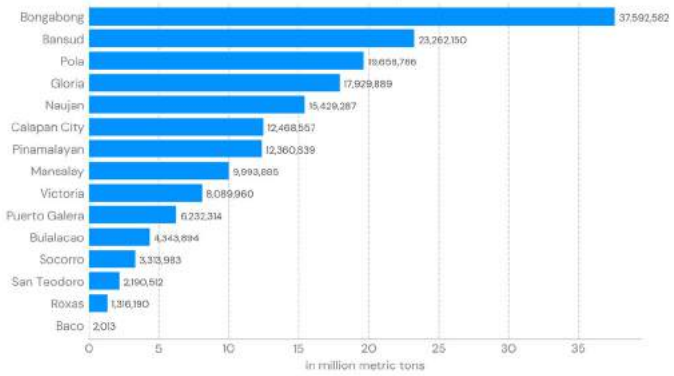
From the records of the Philippine Coconut Authority (PCA), the municipality with the highest average annual production is Bongabong, followed by the Bansud (see Figure 2.13). However in recent years, it is notable that of the different municipalities in Oriental Mindoro, Socorro is a town that is unable to sell and cultivate coconut farming. It has been discussed by the farmers that the coconut trees endemic to their area have been hit by a disease that has rooted several decades ago. The Socorro Wilt, this given agricultural disease has then led to the prohibition of exports and sales of coconut products coming from Socorro - only those that have under-gone pre-processing are allowed to be sold and exported from the town.

Figure 2.12: Volume of coconut production in Oriental Mindoro, 2014-2019



Source: PSA

Figure 2.13: Average annual production of coconut by City/Municipality, Oriental Mindoro, 2015



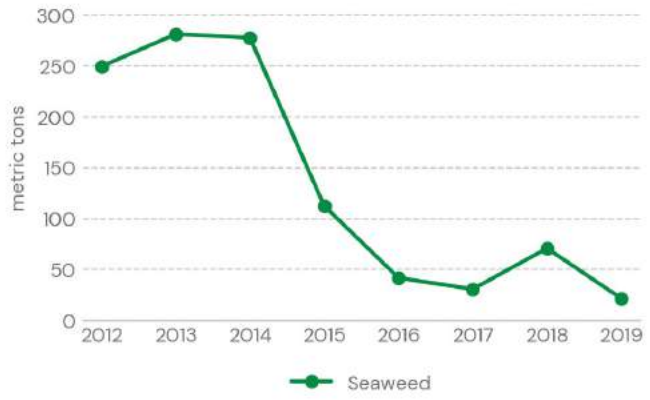
Source: PCA

Seaweed

Seaweed production in Oriental Mindoro takes place almost exclusively in the Bulalacao municipality. The Samahan ng Manggagawa sa Balatasan (SAMASABALATASAN) is a Department of Agrarian Reform (DAR)-assisted ARBO that takes seaweed produced by local farmers and processes it into instant noodles, pickles, soap, and shampoos. SAMASABALATASAN is the sole seaweed processor in the province and plays a vital role in linking seaweed farmers to the market. Even amidst the COVID-19 pandemic, the ARBO was able to help farmers earn money through their relief sales (Department of Agrarian Reform, 2020).

Seaweed is one of the priority fishery commodities being developed in the province with 66 seaweed farmers in Bulalacao.[8] As seen in Figure 2.14, although the production of seaweed decreased from 2015 to 2016, there was an increase in 2018. Given that seaweed can be processed into various products, the province is dedicated to collaborate with government and non-government organizations to increase capacity building for the seaweed farmers.

Figure 2.14: Volume of seaweed production in Oriental Mindoro, 2012-2019



Source: PSA

2.3 Social Development

2.3.1 Poverty

According to Republic Act 8425 of 1997, or the Social Reform and Poverty Alleviation Act, the poor, as defined by NEDA, are individuals or families whose income fall below the poverty threshold and/or cannot afford in a sustained manner to provide their minimum basic needs of food, health, education, housing, and other essential amenities of life. Various statistical measures are being used to quantify the state of poverty, among these are the poverty incidence and poverty gap. The poverty incidence refers to the proportion of families/individuals with per capita income or expenditure less than the per capita threshold to the total number of families/individuals[9]. The poverty gap on the other hand, refers to the total income/expenditure below the poverty threshold[10].

In 2018, the annual per capita poverty threshold of Oriental Mindoro was at PHP 24,470.[11] The poverty incidence of the province was estimated at 7.3%, which translates to 73 out of 1,000 families that have incomes below the amount needed to buy their basic food and non-food needs in 2018. Moreover, the poverty gap for Oriental Mindoro was estimated to be 0.4%, next to Occidental Mindoro with the worst rate in MIMAROPA with 0.7%.

Rural workers and households continue to suffer from higher levels of poverty incidence. According to the National Statistical Coordination Board (NSCB), the average daily income of a Filipino farmer and fisherman is about PHP156.80 (US$ 3.00) and PHP178.43 (US$ 3.50), respectively, which are below the daily national Minimum Wage Rates of PHP225 (US$ 4.50) to PHP 491.00 (US$ 9.82). In 2018, fisherfolks and farmers both had improved poverty incidences relative to the year 2015. The poverty incidence for fisherfolks improved from 24.5% in 2015 to 14.7% in 2018, while farmers improved from 30.8% to 20.7%.[12] However, despite the improvements for both sectors, poverty incidence is still evident and higher than the mean poverty incidence for the whole MIMAROPA region which is at 10.5%.

8 Oriental Mindoro Provincial Development and Physical Framework Plan 2016-2025.

9 PSA - Poverty Incidence - **https://psa.gov.ph/content/poverty-incidence-pi**

10 PSA - Poverty Gap - **https://psa.gov.ph/content/poverty-gap-pg**

11 PSA 2018 Full Year Poverty Statistics - **https://psa.gov.ph/content/updated-2015-and-2018-full-year-official-poverty-statistics**

12 Farmers, Fisherfolks, Individuals Residing in Rural Areas and Children Posted the Highest Poverty Incidences Among the Basic Sectors in 2018 - **https://psa.gov.ph/content/farmers-fisherfolks-individuals-residing-rural-areas-and-children-posted-highest-poverty**

2.3.2 Education

Table 2.6: Magnitude and proportion of households with children not attending school Oriental Mindoro

Basic Education Indicators	Households	
	Magnitude	Proportion
children five years old not attending kindergarten	4,275	31.6
children 6-11 years old not attending elementary	8,517	14
children 6-12 years old not attending elementary	17,232	26.1
children 12-15 years old not attending junior high school	9,584	22.2
children 13-16 years old not attending junior high school	11,866	27.9
children 16-17 years old not attending senior high school	12,475	51.8
children 6-15 years old not attending school	4,003	5
children 6-16 years old not attending school	5,177	6.2
children 6-17 years old not attending school	6,861	7.9

Source: CBMS Census 2010-2020 data provided by the PWTG

The state of education in Oriental Mindoro revolves around the differences in participation rate, cohort survival rate, classroom to pupil ratio, and access to higher education between the city of Calapan and the rest of Oriental Mindoro. This is supported by sources coming from Oriental Mindoro's Provincial Development and Physical Framework Plan for 2016-2025 and 2020 records coming from Oriental Mindoro's Community Based Monitoring System.

The national standard for classroom pupil ratio is 1:45. This ratio is well observed for elementary level, while in the secondary level, the ratio was as low as 42 and as high as 53 with a mean ratio of 48.75 for the whole of Oriental Mindoro.[13]

For higher education, records indicate that there exists a total of 84 schools in Oriental Mindoro composed of colleges, universities, and technical and vocational schools.[14] Colleges and Universities account for 29 out of the 84 schools, roughly about 34% of the total number of schools in Oriental Mindoro, while Technical and Vocational Schools account for the remaining 55. Calapan City has the most higher education schools with 8 colleges and 21 technical and vocational schools.

Table 2.7: Distribution of technical and vocational schools across the municipalities of Oriental Mindoro

City/Municipality	No. of Technical & Vocational Schools
Calapan City	21
Pinamalayan	10
Roxas	6
Victoria	3
Bongabong	3
Socorro	2
Puerto Galera	2
Gloria	2
Baco	1
Naujan	1
San Teodoro	1
Mansalay	1
Bulalacao	1
Bansud	1
TOTAL	55

Source: United States Geological Survey (USGS)

13 Data from Department of Education (DepEd) Oriental Mindoro and Calapan City Division for School Year 2010-2014

14 Data from CHED for School Year 2009-2015 and Technical Education and Skills Development Authority (TESDA) for School Year 2010 - 2015

2.4 Risk Profile

2.4.1 Climate

Out of the four climate types experienced by the country, Oriental Mindoro has two climate types: Type I and Type III. Type I is characterized by two pronounced seasons, dry from November to April and wet throughout the rest of the year. Type III climate is similar to Type I, but it's seasons are not pronounced. Based on the location of Mindoro, although some areas are shielded by mountain ranges, the province is still open to rains brought in by the Habagat and tropical cyclones.

During the site visit, it has been identified that according to the locals of the province, their respective towns and municipalities have displayed signs of being micro-climatic. This implies that the weather conditions across these small towns and areas do not follow the same trend and are often polar opposites of extremity. Areas such as Gloria and Victoria have noted instances wherein heavy rain and extreme heat were observed separately within the same time stamp and at different parts of the community.

2.4.2 Natural Disasters

Due to its geographical location and natural landscape, Oriental Mindoro is vulnerable to several natural hazards. The province is constantly affected by high frequencies of disasters annually, resulting in tremendous damage to properties, agriculture, infrastructure, and lives of some Mindoreños. Some of the most common disasters that affect the agricultural sector are tropical cyclones, floods, earthquakes, and tsunamis.

Eighty-five barangays, 20% of the total 426 barangays in Oriental Mindoro, are identified as highly susceptible to flooding. While Calapan City has the most barangays with high susceptibility, Baco has the highest percentage in total with 63%, followed by Roxas with 60%.

Typhoon

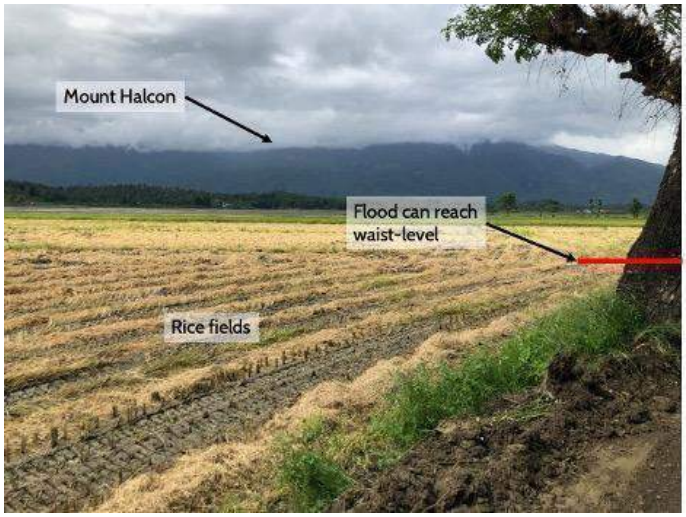
Over the course of a five year stretch from 2016 to 2020, PAGASA recorded a total of 100 tropical cyclones that entered the Philippine Area of Responsibility (PAR)[15]. Typhoons account for 36 out of the 100 recorded tropical cyclones and two of the 36 were classified as Super Typhoons. This makes up an average of 7.2 typhoons over the course of 2016 to 2020.

For Oriental Mindoro, three out of the 36 typhoons recorded caused major agricultural damage with an estimated combined amount of PHP 3.78 billion in the span of five years. Typhoon Nina, Usman, Tisoy, and Quinta are among the tropical cyclones that caused major damages, not only in the province's infrastructure but also in the agriculture sector. Typhoon Nina, from 2016, had an estimated total of over PHP 300 million in agricultural damages; Typhoon Usman, from 2018, had over 300 million; Typhoon Tisoy, from 2019, incurred an estimated total of PHP 1.4 billion; and the most recent, Typhoon Quinta, from 2020, has an estimated amount of over PHP 2 billion in agricultural damages. Table 2.8 shows a summary of the agricultural losses and damages incurred by the province over the years as reported by the PAgO.

Flood

Floods are considered as one of the most frequent and costly natural disasters that occur in the province of Oriental Mindoro. These are typically caused by typhoons and heavy or steady rainfall for several hours or days that saturate the ground. Additionally, Oriental Mindoro also suffers from flash floods which occur due to the rapid rising of water along a stream or low-lying areas. Historically, Oriental Mindoro has experienced a number of flash floods over the years. These resulted

Figure 2.14: A flood-prone location in a farmland near the Baco Municipal Hall



(Photo taken on February 2021)

15 Annual Tropical Cyclone Tracks - **http://bagong.pagasa.dost.gov.ph/information/annual-cyclone-track**

Table 2.8: Agriculture Loss and Damage Assessment Report from the Provincial Agriculturist's Office of Oriental Mindoro (2016-2020)

Year	Typhoon		Estimated Amount (PHP)	Total Amount (per year)
2016	**Nina**	Losses	455,688,057	471,214,077
		Damages	15,526,020	
2017	**Ramil**	Losses	42,860,716	125,013,005
		Damages	-	
	Urduja	Losses	80,177,289	
		Damages	1,975,000	
2018	**Usman**	Losses	308,996,278	310,250,178
		Damages	1,253,900	
2019	**Tisoy**	Losses	1,479,941,918	1,644,269,652
		Damages	9,466,670	
	Ursula	Losses	143,109,364	
		Damages	11,751,700	
2020	**Quinta**	Losses	2,951,636,193	3,054,796,186
		Damages	78,992,850	
	Rolly	Losses	60,985	
		Damages	40,000	
	Ulysses	Losses	23,826,158	
		Damages	240,000	

Source: Oriental Mindoro's Provincial Agriculturist's Office report as provided by the PTWG

Figure 2.15: Satellite view of the flood-prone area near the Baco Municipal Hall

in people dying and infrastructure and agricultural losses and damages.

During the site visit to Oriental Mindoro[16], the provincial DRRM officers pointed out the different locations that experienced high flooding in recent typhoons and heavy rainfall seasons. Figure 2.14 shows a farmland located near the Baco Municipal Hall experiencing height up to waist-level flooding (approximately 3 feet or 1 meter high). According to the Municipal Disaster Risk Reduction Management Office (DRRMO), the surface runoff coming from Mount Halcon is the main cause of flooding, which requires evacuation of people living in the area.

As seen in Figure 2.15, the nearest river where the flood waters can escape is at least 1 km away from the critical flooding area. Although it is relatively near, it can still take a few days for the water to subside.

One of the main rivers that runs through a number of municipalities in Oriental Mindoro is the Mag-asawang Tubig River. Historically, areas surrounding this river have experienced flash floods. In the municipality of Nuajan, the Mag-asawang Tubig River is the main body of water that carries flood water from Nuajan out to the sea. However, the low-lying areas surrounding the river suffer from overflows causing floods (as seen in Figure 2.16).

16 Site visit with the municipality of Baco on February 16, 2021.

Figure 2.16: Mag-asawang Tubig River, Naujan, Oriental Mindoro

(Photo taken February 2021)

Figure 2.17: An area in San Teodoro that experiences waist-level floods

(Photo taken February 2021)

In San Teodoro, floods in these areas can reach waist-level which completely submerge a lot of crops. The water in this area comes from different sources and the creek on the left, as indicated in Figure 2.17, is what directs the flood waters out to sea.

Earthquake

Historical data shows that Oriental Mindoro has already experienced two major earthquake events, one in March 1965 that was followed by a tsunami, and a 7.1 intensity earthquake that happened on November 15, 1994[17]. MMoreover, Oriental Mindoro was found to be sitting atop and nearby faults and trenches

17 Oriental Mindoro Provincial Risk Reduction and Management Plan CY 2020-2022

Table 2.9: Earthquake occurrences on-land, Oriental Mindoro, 2000-2020

Year	Epicenter	Magnitude
2000	San Teodoro (120.981, 13.343)	5.0
	Naujan (121.248, 13.25)	4.6
2001	Victoria (121.208, 13.187)	4.5
2006	Calapan City (121.162, 13.276)	5.1
2009	Puerto Galera (120.847, 13.327)	4.5
2010	San Teodoro (120.897, 13.281)	4.7
	Gloria (121.39, 12.898)	4.5
2011	San Teodoro (120.955, 13.339)	5.3
	Baco (121.033, 13.227)	4.6
2018	Naujan Lake (121.3349, 13.1739)	4.8
	Puerto Galera (120.9184, 13.3885)	4.7
2019	Victoria (121.2786, 13.1406)	4.5
	Puerto Galera (120.9428, 13.5027)	5.0

Source: United States Geological Survey (USGS)

which are known to generate earthquakes. The trenches are the East Mindoro Trench and Manila Trench while the active faults are the Lubang Fault, Aglubang River, and Central Mindoro faults.

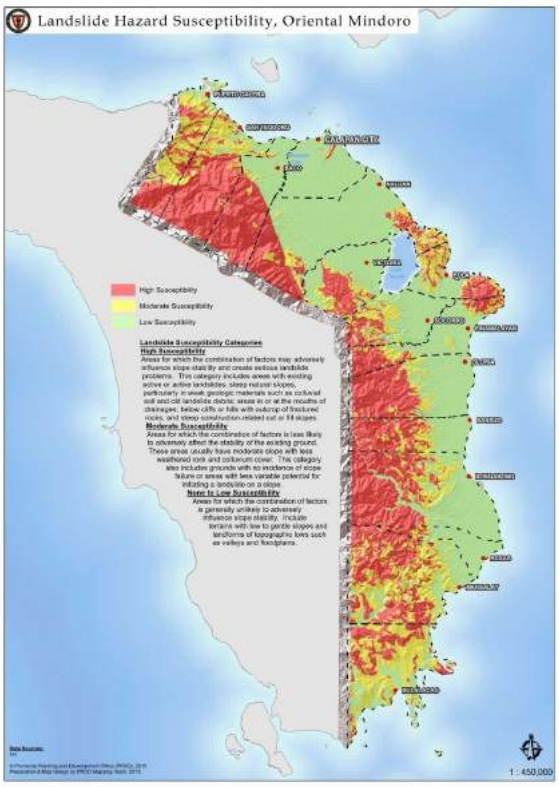
From 2000 to 2020, Oriental Mindoro has experienced 13 earthquakes with magnitudes of 4.5 and above. Table 2.9 shows a summary of the earthquakes that have occurred with an epicenter within Oriental Mindoro. There were also other earthquakes surrounding the island, however, most of the epicenters are on Occidental Mindoro.

Landslides

Landslides may be rain-induced landslides (RIL) or earthquake-induced landslides. The province has experienced more RIL due to the frequency of typhoons and long durations of rainfall in the province during the rainy seasons. A total of 1,499 square kilometers, or approximately 34.34% of the province, is highly susceptible to landslides[18]. The key municipalities identified are Puerto Galera, San Teodoro, Baco, Bongabong, and Mansalay.

18 Oriental Mindoro Provincial Development and Physical Framework Plan 2016-2025.

Figure 2.18: Landslide susceptibility map of Oriental Mindoro



Source: PGOM

Drought

While the Philippines has a considerable amount of annual rainfall, ranging from 960mm to 4000mm, it is not immune to the effects of climate induced disasters like drought. Historically, the Philippines has experienced drought every three to four years starting from the first recorded case of drought in 1968[19]. PAGASA's dry spell/drought assessment reports from 2015 to 2016 have always excluded Oriental Mindoro from the list of provinces expected to experience drought. However, this case changed during the March 2019 Dry Spell/Drought Assessment Report which put the whole island of Mindoro, including both Oriental and Occidental Mindoro, to be directly affected by drought.

2.5 Disaster Risk Reduction and Management

2.5.1 Sensor

DOST-PAGASA currently has a total of 54 sensors installed across the entire province of Oriental Mindoro (See Table 2.9). However, 22 of these sensors are not functioning[20] due to various reasons (See Table A.1). There are currently four types of sensors installed across Oriental Mindoro, namely Automatic Rain Gauge (ARG), Water Level Monitoring Sensors (WLMS), Flood Early Warning System (FEWS), and Automatic Weather Station (AWS).

ARG sensors record rainfall parameters such as rain amount, intensity, and duration in a specified time interval. It uses a tipping bucket mechanism which gauges rainfall data and automatically sends the data to the PAGASA database via a wireless network[21].

WLMS sensors are ultrasonic sensors that record both the depth of the river (or any body of water) and the surface level of the water.[22] The data is gathered in a predetermined time interval and is then sent through SMS or a satellite network.

FEWS is a collection of highly automated heavy instruments residing in an operations center, usually based in or near the flood-prone area and staffed with local personnel.[23] Rainfall and river level data are observed and reported to the operations center.

Table 2.9: Number of operational and non-functioning sensors deployed by DOST-PAGASA across Oriental Mindoro per Municipality

Location	Type of Sensors	Operational Sensors	Non-functioning Sensors	Total Sensors
Calapan City	ARG, WLMS, FEWS	4	1	5
Puerto Galera	ARG, WLMS	2	2	4
San Teodoro	ARG	1	0	1
Baco	ARG, WLMS, FEWS, Transponder (ARG)	5	0	5
Naujan	ARG, WLMS, FEWS	6	1	7
Victoria	ARG, Transponder (ARG)	0	3	3
Socorro	ARG, WLMS	1	2	3
Pola	ARG, FEWS	1	1	2
Pinamalayan	AWS	1	0	1
Gloria	ARG, WLMS	1	2	3
Bansud	ARG, WLMS	0	2	2
Bongabong	ARG, WLMS, FEWS	3	3	6
Roxas	ARG, WLMS	3	2	5
Mansalay	ARG, WLMS, FEWS	4	1	5
Bulalacao	ARG, WLMS	0	2	2
ORIENTAL MINDORO		32	22	54

Source: DOST-Oriental Mindoro presentation as of January 22, 2021 provided through PTWG

19 National Drought Plan for the Philippines - https://knowledge.unccd.int/sites/default/files/country_profile_documents/1%2520FINAL_NDP_Philippines.pdf

20 Based on the DOST-PAGASA Installed Hydrometer Devices report as of January 22, 2021.

21 http://bagong.pagasa.dost.gov.ph/products-and-services/engineering-services

22 https://techtrans.gov.ph/industrial-design/water-level-monitoring-station

23 https://reliefweb.int/report/philippines/local-flood-early-warning-systems-experiences-philippines

Automated gauges play a key role in the system and are augmented by local observers (mostly volunteers). In the experience of the local partners of German Technical Cooperation (GTZ), such as the provincial government and municipalities, the system can forecast flood events and reliably warn people in the hazard zone.

AWS is an automated station having built-in weather instruments with electronic sensors for measuring surface level air temperature pressure, solar radiation, rainfall, wind velocity, and other weather parameters. The station has integrated data banks for storage of recorded data for later retrieval.

Challenges

Based on discussions with the PAGASA representative from the Calapan station, most of the existing sensors are located along the downstream rivers due to low Global System for Mobile communication (GSM/satellite) signals. This reduces the effectiveness in providing early warning alerts and feedback to the residents of the province. One example of feedback indicated that PAGASA meteorologists were not consulted prior to the placements of the sensors which, therefore, caused the sensors to be placed in the unideal positions and not in an effective range. Additionally, the current ultrasonic WLMS sensors are not portable, thus resulting in zero value readings when the rivers branch out or when water levels recede.

2.5.2 Climate Change Risk Related Policies

In 2007, the Provincial Disaster Coordinating Council (PDCC) was created by virtue of Executive Order No. 23 Series of 2007, defining its composition, functions of different service committees, and funding allocation, which was later reconstituted and renamed into Provincial Disaster Risk Reduction and Management Council (PDRRMC) in 2010 through Executive Order No. 12 in cognizant with Republic Act 10121. The reorganized structure of the PDRRMC shall adopt an integrated and holistic approach in emergency management and disaster risk reduction program implementation thereby strengthening the province's institutional capacity for disaster risk reduction and management and, at the same time, building the community's resilience to disasters including climate change impacts.

As provided for in RA 10121, no less than 5% of the estimated revenue from regular sources is set aside as the LDRRMF to support disaster risk management activities such as, but not limited to, pre-disaster preparedness programs including training, purchasing life-saving rescue equipment, supplies and medicines, post-disaster activities, and the payment of premiums on calamity insurance.

Since its establishment, the Oriental Mindoro Provincial Disaster Risk Reduction and Management Office (PDRRMO) has conducted various participatory activities geared towards addressing disaster risk and climate change. Some of these activities include the development and improvement of hazard maps, installation of rain gauges, and conducting information, education, and communication (IEC) capability development activities for their citizens.

The PGOM also formulated the Provincial Development and Physical Framework Plan (PDPFP) which mainstreams the disaster risk reduction and climate change concerns of the plan. The LGUs have also integrated the same in their Comprehensive Land Use Plans (CLUPs). In addition to this, the PGOM values its ecosystems and natural buffers through the implementation of programs such as:

- Climate change adaptation and mitigation under the Coastal Resource Management (CRM) Program of the PAgO
- Mangrove Rehabilitation, Protection and Maintenance, Stream bank Stabilization/ Rehabilitation under the Environment and Natural Resources (ENRO)
- Conservation cum income diversification with Malampaya Foundation, Inc. and Conservation International
- Implementation of Climate Change Adaptation and Mitigation Plan (CCHAMP)
- Climate Resilient and Green Growth Planning (CRGGP)

As the climate continues to change, there are studies that show that the crop production in the Philippines will be negatively affected (Rosegrant, Perez, Pradesha, & Thomas, 2016). As part of the PDPFP of PGOM, the province aims to minimize and control agricultural land use conversion and maximize land utilization to be able to conserve their lands for agricultural use. To achieve this, land boundaries must be clearly delineated and laws prohibiting land conversion should be strictly enforced. As part of their plan, Strategic Agriculture and Fisheries Development Zones (SAFDZ) and prime agricultural lands with efficient irrigation should not be converted to other uses.

3. Case Study of Existing Systems

The main purpose of this case study is to analyze the relevant existing systems that were already developed for providing climate risk and vulnerability information and examine ways to design and develop the new Climate Information System (CVRIS). An overview of climate information systems and weather monitoring systems will be provided along with an assessment of their best practices and weaknesses. Each system will also be assessed on the potential for the data sources and frameworks to be replicated for CVRIS.

3.1 Climate Information Systems

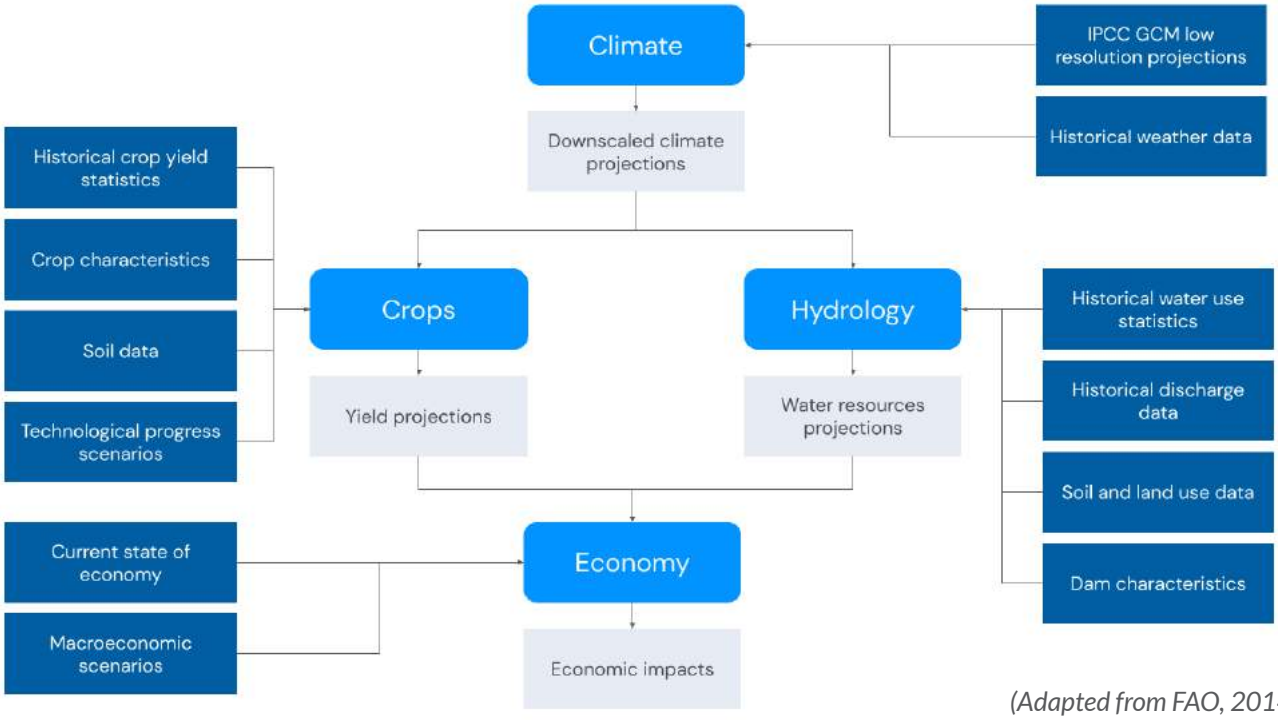
Table 3.2 shows a summary of the climate information systems relevant to the study followed by a more detailed analysis.

3.1.1 FAO Modelling System for Agricultural Impacts of Climate Change (FAO-MOSAICC)

The Food and Agriculture Organization (FAO) of the United Nations (UN) developed the Modelling System for Agricultural Impacts of Climate Change (MOSAICC) to formulate comprehensive strategies for mitigating potential adverse effects of climate change to national food security. The system is capable of climate data downscaling, spatial interpolation, hydrological modelling, and crop and economic simulations.

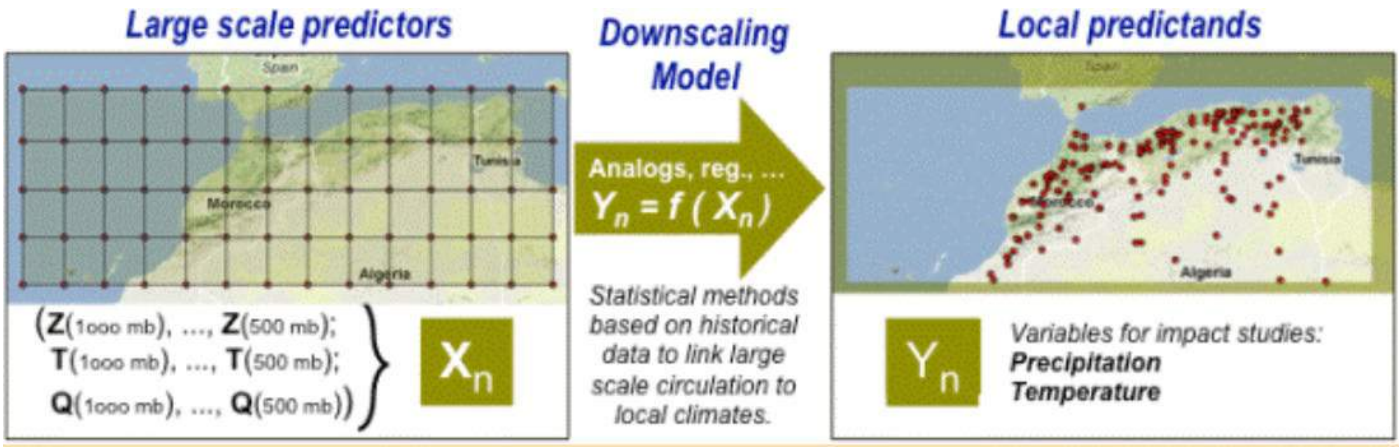
FAO-MOSAICC's general methodology assesses the impact of climate change on agriculture. The different analyses encompass crop yield projections,

Figure 3.2: Overall data flow in MOSAICC



(Adapted from FAO, 2014)

Figure 3.3: Data Access and Downscaling (DAD) implemented by the Santander Meteorology Group of the University of Cantabria



water resources estimations, and economic modelling with a primary focus on country wide assessments.

Figure 3.2 shows the overall data flow of the FAO-MOSAICC system. The downscaled climate projections are used as inputs for the crop yield projections and the hydrology or water resource projections. The outputs of the crop-specific yield and hydrology projections were then used as inputs for the economic implications on the national economy using a dynamic computable general equilibrium model (DCGE).

FAO-MOSAICC's climate change vulnerability framework and components were patterned after IPCC's General Circulation Models (GCMs) which relied on low resolution projections for future climates that are statistically downscaled onto the weather station network for the identified period. Data Access and Downscaling (DAD Portal) was used as a statistical tool in downscaling this data. These observations are spatially interpolated using various methods onto a convenient spatial resolution for subsequent crop and hydrology modelling.

The DAD Portal was developed by the Santander Meteorology Group of the University of Cantabria. As designed, the tool works on downscaling coarse climate grids generated by Global Climate Models (GCM) through the use of statistical downscaling techniques. As seen in Figure 3.3, the given and prescribed data can be simultaneously downscaled for several weather stations, but this is only possible if enough observation data are available. In ensuring spatial consistency, several methods such as instance weather typing methods and regression methods are available on the portal.

Aside from DAD, another tool was used for interpolating meteorological and hydrological data based on the analysis of the topography – Analyse Utilisant le RElief pour l'Hydrométéorologie (AURELHY).

In 2012 to 2015, the Philippines was a recipient of the Analysis and Mapping of Impacts under the Climate Change for Adaptation and Food Security (AMICAF) project by the FAO. Together with the Department of Agriculture (DA) and other government agencies and academic institutions, they were able to implement all four components of the project: (1) assessment of climate change impact on agriculture; (2) vulnerability analysis; (3) enhanced capacities of vulnerable communities to adapt to climate change; and (4) guidance in support of adaptation planning. The MOSAICC system was used in Component 1 of the project. However, only the climate, crop, and hydrology models were used in the AMICAF project for the Philippines.[24]

3.1.2 IRI/LDEO Climate Data Library

24 Impact Assessment - AMICAF (Philippines) http://www.fao.org/in-action/amicaf/countries/phl/impact-assessment/en/

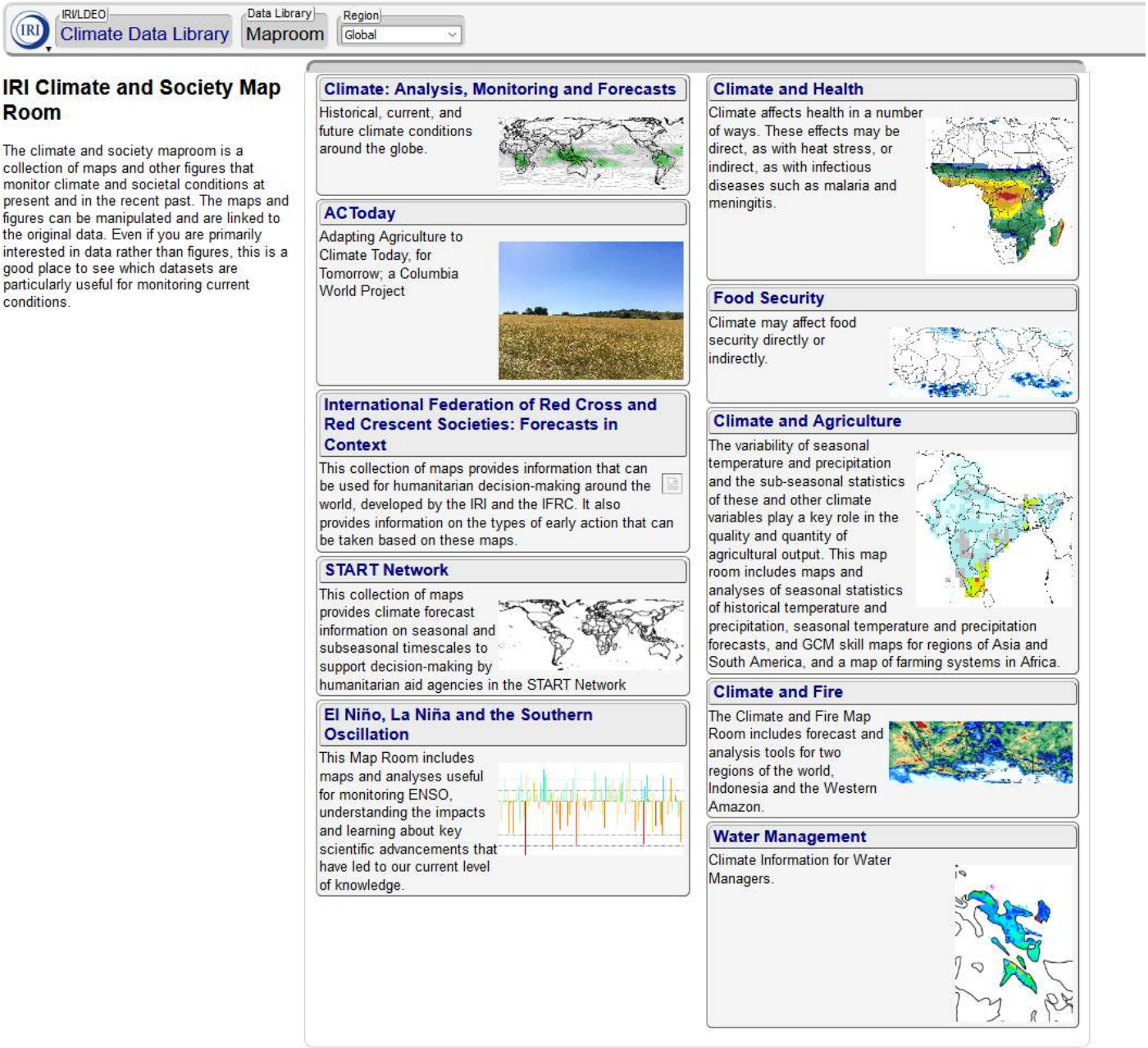
Table 3.1: Summary of climate information systems reviewed

System	Theme	Data
FAO-MOSAICC[25]	Climate	• IPCC GCM low resolution projections • Historical weather data
	Crop	• Historical crop yield statistics • Crop characteristics • Soil data • Technological progress scenarios
	Hydrology	• Historical water use statistics • Historical discharge data • Soil and land use data • Dam characteristics
	Economic	• Current state of economy • Macroeconomic statistics
Think Hazard![26]	Hazards	• GAR Atlas • Global Tsunami Hazard • Volcanic Hazard Level • Coastal Flood data • Global Landslize hazard map • Mean wind speed • Water Crowding Index (WCI) • Wet bulb global temperature
GIEWS	Agricultural Stress Index (ASI)	Satellite data and vegetation data derived from METOP-AVHRR sensor
	Drought intensity	Satellite data derived from METOP-AVHRR sensor
	Vegetation Health Index (VHI)	Vegetation data from the METOP-AVHRR sensor
	Normalized Difference Vegetation Index (NDVI)	
	Vegetation Condition Index (VCI)	
	Precipitation	• Absolute rainfall levels • Relative rainfall levels • Long-term average precipitation levels (mm)
AEWS-WRM	Climate	• Surface air temperature • Precipitation map • Solar radiation map • Wind distribution
	Crop Risk	• Crop disasters • Crop phenology • Crop growth rate • Crop growing degree day

25 Impact Assessment - AMICAF (Philippines) http://www.fao.org/in-action/amicaf/countries/phl/impact-assessment/en/
26 https://thinkhazard.org/en/

System	Theme	Data
UP-NOAH	Hazards	• Flood level reports • Rainfall data • Landslides records • Volcanic activities • Storm surges
PAGASA-CIA[27]	Agroclimatic	• Generalized Monsoon Index (GMI) • Yield Moisture Index (YMI)

27 http://bagong.pagasa.dost.gov.ph/agri-weather/impact-assessment-for-agriculture



IRI/LDEO Climate Data Library is a dynamic and freely available online data repository and tool used for viewing, analyzing, and downloading large volumes of climate-related data. This was developed by the International Research Institute for Climate and Society (IRI) of the Earth Institute, Columbia University.

As an open-source platform, it offers a no-cost variety of tools and resources for its users. The platform is equipped with features to enable its users to access, analyze, monitor, visualize, and download various climate-related data. It has the capability to analyze data using varying techniques from simple averaging to more sophisticated empirical orthogonal function (EOF) analysis using Ingrid Data Analysis Language. It monitors present climate conditions with maps and integrated analyses accessible through its IRI Climate and Society Map Room. In downloading data, the platform offers a variety of commonly-used formats, including GIS-compatible formats.

One of the key features of the data library is the IRI Climate and Society Map Room, which offers a collection of maps and other figures that monitor climate and societal conditions at present and in the recent past. These maps and figures are dynamic and may be manipulated because they are linked to the original data. Aside from the featured maps, this portal features datasets that are particularly useful for monitoring current conditions. These featured maps and datasets are of varying sources and subjects such as agriculture, El Niño-Southern Oscillation (ENSO), health effects, food security, water management, and fire vulnerability. Upon investigation for the Climate and Agriculture datasets available for the Philippines, only data directly connected through PAGASA is available.

3.1.3 Think Hazard!

Think Hazard! is an analytical tool developed by Global Facility for Disaster Reduction and Recovery (GFDRR) along with other global partners in research and technology, dedicated to enhancing and enriching knowledge and understanding of natural hazards. The tool provides a general view of the hazards in a given location which helps its users in project design and implementation. It was designed to aid users from the development sector in gathering hazard information alongside their project planning.

The online interface of the system enables the user to utilize information and features such as locational search, hazard overview according to 10 identified

Table 3.2: Data sources and indicators of the hazards presented on Think Hazard!

Hazard Type	Hazard	Data Owner	Data / Indicator
Geophysical	Earthquake	GFDRR	GAR Atlas, a fully probabilistic seismic hazard analysis at global level developed by CIMNE and INGENIAR Ltda
	Tsunami	GFDRR	Global Tsunami Hazard GTM based on the analysis of Davies et al. (2017), developed jointly by Geoscience Australia and NGI.
	Volcanic eruption	GFDRR	Volcanic Hazard Level derived from Smithsonian Institution Global Volcanism Program (GVP) volcano dataset, GVP eruption dataset, and the British Geological Survey LaMEVE (Large Magnitude Explosive Volcanic Eruptions) database
Hydraulic	Fluvial (or riverine) floods	GFDRR	FL-GLOBAL-FATHOM
	Pluvial (or surface water) floods	Fathom Global	UF-GLOBAL-FATHOM
	Coastal floods	Muis et al.	Muis et al Coastal Flood datasets
	Landslides	GFDRR	Simplified Global Landslide Hazard Map with four categories
Meteo-Climatological	Cyclonic Strong Winds	GFDRR	50 year return period 1-min mean wind speed in m/s for typhoon-induced winds derived from IBTRACS data
	Water scarcity	GFDRR	Water Crowding Index (WCI)
	Extreme temperatures	World Bank	Extreme Heat based on Wet Bulb Globe Temperature
	Wildfires	World Bank	WF-GLOBAL-CSIRO

hazards, and risk management. Table 3.1 shows the hazards according to the triggers and the datasets used for the map visualization. The majority of the datasets are raster geospatial data with simplified levels of intensity for each hazard formatted specifically for the Think Hazard! application.

3.1.4 Global Information and Early Warning System on Food and Agriculture (GIEWS)

The Global Information and Early Warning System on Food and Agriculture (GIEWS) by the Food and Agriculture Organization of the United Nations (FAO) continuously monitors and reports on food supply and demand across the entire world. This system provides two data exploration tools: (1) Earth Observation for crop monitoring and (2) Food Price Data and Analysis Tool (FPDA).

The Earth Observation tool shows global- and country-level generated maps of the seasonal, vegetation, and precipitation indices being monitored by GIEWS as summarized in Table 3.3. The FPDA, on the other hand, provides a tabular and graphical view of the domestic and international prices monitored. Users are able to search and filter on a country-level.

3.1.5 Agrometeorological Early Warning System for Weather Risk Management in South Korea (AEWS-WRM)

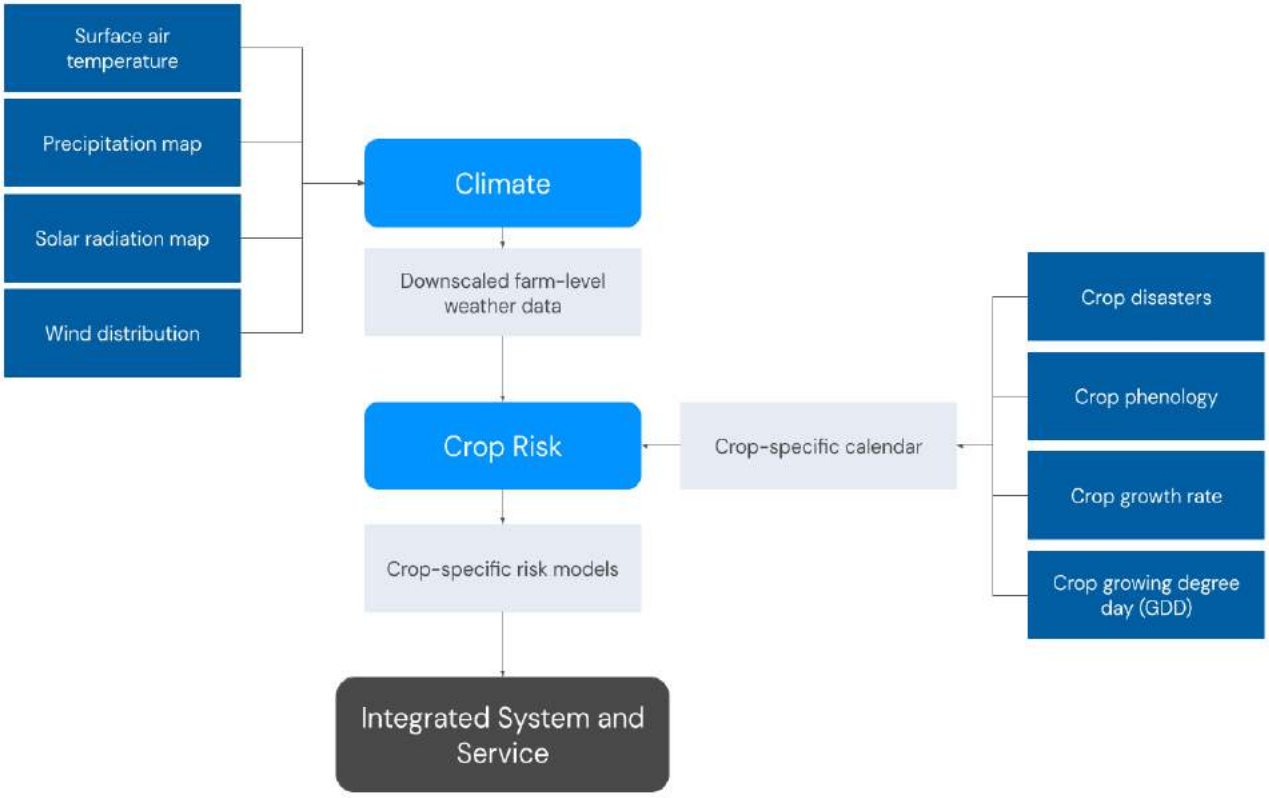
This project aims to develop custom risk management recommendations for individual farms threatened by climate change and its variability. It is an early warning system for risk management in the agricultural sector. It informs farmers through mobile phones to ensure that regardless of the availability of internet connection and access to technology, these farmers are able to be informed of the upcoming climactic event.

Figure 3.4 shows the overall data flow and methodology of the AEWS-WRM. As a localized system, it translated global weather data to farm-level data in order to deliver real time risk notifications to the farmers of the identified area. The derived farm level weather data used and interpolated in the project

Table 3.3: Indicators presented in the Earth Observation report and interactive tool

Indicator Type	Indicator	Description
Seasonal	Agricultural Stress Index (ASI)	A quick-look indicator that facilitates the early identification of cropped land with a high likelihood of water stress (drought) developed.
	Drought Intensity	Calculated through the Weighted Mean Vegetation Health Index aggregated per GAUL 2 region.
	Progress of Season	Depicts the development of crops/pastures during the growing season.
	Mean Vegetation Health Index (VHI)	Average of the dekadal VHI values over the crop-growing season to date. It takes into account the sensitivity of a crop to water stress over its growing season and calculates the temporal impact of moisture deficits since the start of the growing season until the current dekad.
Vegetation	Normalized Difference Vegetation Index (NDVI)	Measures the "greenness" of ground cover and is used as a proxy to indicate the density and health of vegetation.
	Vegetation Condition Index (VCI)	Evaluates the current vegetation health in comparison to the historical trends.
	Vegetation Health Index (VHI)	Illustrates the severity of drought based on the vegetation health and the influence of temperature on plant conditions.
Precipitation	Estimated Precipitation	Cumulative rainfall volumes over a dekad (a 10-day period). Precipitation estimates are rainfall forecasts and are obtained from the European Centre for Medium-Range Weather Forecasts (ECMWF).
	Precipitation Anomaly	
	Estimated Precipitation - Long-term Average (LTA) [1989-2015]	

Figure 3.4: Data flow and methodology of AEWS-WRM in South Korea



are surface air temperature, precipitation data, solar radiation, and wind distribution. Once this weather data was downscaled, crop disasters and thermal-time-based models of the crop's phenology were used to create a crop calendar that shows the degree to which the disaster risk of the weather condition is expressed, relative to the normal climatic condition.

All of this generated data was then used to develop crop-specific risk models and presented in an integrated information system for farmers. The system serves both as an information dissemination service and a risk warning system to notify farmers within the service area through text messages.

3.1.6 The University of the Philippines Nationwide Operational Assessment of Hazards (UP-NOAH)

The University of the Philippines Nationwide Operational Assessment of Hazards (UP-NOAH) seeks to aid the Philippines in disaster risk reduction and management, climate change adaptation and mitigation efforts, and other subsequent related activities. To do so, UP-NOAH conducts research activities, development services, and other extension services. It is a multidisciplinary research center housed at the University of the Philippines National Institute of Geological Sciences.

UP-NOAH is capable of showing risk hazards around the Philippine archipelago. Amongst the different data hosted by UP-NOAH are flood level reports, rainfall data, landslides records, volcanic activities, and storm surges. It validates its risk hazard evaluations through these reports and other sensors connected within its network. This is made possible by the aggregate reports and sensor telemetry data within the system and the thematic maps used by its experts.

Despite being a comprehensive tool for the Philippines, and given the vulnerability of the archipelago, UP-NOAH exhibited various issues that needed to be mitigated in order to further improve its services. Most

Table 3.4: List of data layers presented in UP-NOAH.

Hazard	Data Layers	Description
Weather	Weather Contour	Estimated weather indicators based on the data recorded by Rain Gauges and Automatic Weather Stations
	Doppler Stations	Rain-bearing clouds as recorded by Doppler Radars
	Real Time River Inundations	Modeled river extent based on measurements gathered by Stream Gauges, Rain Gauges, and Weather Stations
	Satellite	Images used for typhoon monitoring
	Weather Outlook	Localized rain and weather forecasts
	Wind	Show animated wind forecast from the Global Forecast System model
Climate	Historical tropical cyclone tracks	Tracks of tropical cyclones that made landfall in the Philippines between January 1966 and December 2016
Sensors	Rain and Stream Gauges Weather Stations Tide Levels	Shows real-time information from the rain gauges, weather stations and tide levels which also serves as flood early warning systems.
Flood	Flood hazard maps (5-year, 25-year and 100-year return rate)	Shows flood hazard maps in accordance to the rainfall return rate per region and detailed flood reports from citizens
Landslides	Landslide hazard maps	Hazard map showing unstable slopes and landslide extent
	Unstable slopes maps	Areas that are likely to collapse during heavy rainfall or strong earthquake
	Alluvial Fan Hazards	Fan-shaped landforms most likely to experience floods and debris flow
Storm Surge	Storm Surge Advisory 1-4	Storm surge hazard maps based on predicted storm surge height
Earthquakes	Recent quakes	Shows the latest earthquakes of magnitude 3.0 or higher in the past 7 days from USGS, Geofon and PHIVOLCS
	Historical quakes	Shows all historical earthquakes recorded in the Philippines
	Significant historical quakes	Shows significant historical earthquakes in the Philippines divided by the decade (before 1990, 1990-1999, 2000-2009, 2010-present)
Volcanoes	Volcano locations	Shows the location of active, inactive and potentially active volcanoes according to PHIVOLCS
Critical facilities	Schools, health facilities, police stations and fire stations	Shows the locations of these critical facilities
Dengue Monitoring	Ovitrap Index	The Ovitrap Mosquito Index is a measurement of the ratio of mosquito eggs in Ovitraps that are located in specified areas. The index, then, in turn, reflects the distribution of Aedes mosquitoes, the vector for dengue.

of these issues pertain to the completeness and integrity of the data. UP-NOAH has identified that there is a great lack of streamlined data appropriate for their activities and analyses. Aside from this, sensor data accuracy alongside the reliability of data derived from survey reports were also raised as concerns.

3.1.7 PAGASA: Climate Impact Assessment for Agriculture in the Philippines (PAGASA-CIA)

The Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) regularly publishes reports on the effects of climactic occurrences to national agriculture. Climate Impact

Assessment for Agriculture in the Philippines is one of these several reports. It is a regular issue of a monthly bulletin that provides users qualitative information on the current and potential effects of climate and weather variability on rainfed crops, particularly rice and corn, on a provincial level. The targeted users are food security managers, economic policy makers, agricultural statisticians, and agricultural extension officials. It converts meteorological data into economic information, particularly on food security.

This regular bulletin looks at crop yield, crop stage, and rainfall. Each of which are localized on a provincial-level.[28] In summarizing these biophysical indicators to further illustrate food security, the report is broken down into several components namely: Generalized Northeast Monsoon Indices, Cumulative Yield Moisture Indices for Lowland 1st and 2nd palay, Cumulative Yield Moisture Indices for Dry Season Corn, Cumulative Yield Moisture Indices for Low Land Palay, Cumulative Yield Moisture Indices for Dry Season Corn, and Decadaland Cumulative Decadal Rainfall. Each of these reports are tabulated and presented through thematic maps; it takes into account two key models: (1) Generalized Monsoon Index (GMI) and the (2) Yield Moisture Index (YMI). However, a key weakness of this reporting is the poor interpretability of the information for grassroots farmers since the maps provided are not interactive.

3.1.8 Agri-Infohub

Agri-infohub[29] is a platform that connects local farmers from the grassroots level to the market by providing them with market leads, access to technological information, counseling, training, storage, transportation, seeds, and farm inputs. It is a project of the province of Oriental Mindoro that streamlines all agricultural information and services within one platform.

As a centralized platform for farmers, it features the following: soil map, fertilizer guide for rice, pest map, PAGASA weather advisory, agricultural overview of Oriental Mindoro, satellite imaging and weather forecasts through Windy, an online weather forecasting service. The information available on the website is primarily a compilation of the different reports and statistics compiled by the Department of Agriculture (DA), Department of Science and Technology (DOST), Department of Trade and Industry (DTI), and the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA). Although the platform provides an abundance of information, it is not organized in such a way that farmers may explore the information easily.

3.2 Weather Monitoring System

In addition to the specialized climate risk information systems, there are also readily available weather monitoring and warning systems that are currently being used by PAgO and the farmers.[30]

3.2.1 NDRRMC Updates

The National Disaster Risk Reduction and Management Council (NDRRMC) has been sending

Table 3.5: Reports and bulletins posted on the NDRRMC website

Report	Description
Earthquake Information	Includes day-to-day earthquake updates as well as a map of the Philippines and its affected areas
Tsunami Information	Includes day-to-day tsunami updates as well as a map of the Philippines and its affected areas
Volcano Advisory	Keeps track of the following volcanoes: Taal, Mayon, Kan-laon, Bulusan, and Pinatubo. For each volcano, there is a corresponding alert level as well as a bar chart describing the number of volcanic earthquakes
Rainfall Advisory	Day-to-day rainfall updates as well as a map of the Philippines and its affected areas
General flood advisory	Includes day-to-day general flood updates as well as a map of the Philippines and its affected areas
Gale Warning	Day-to-day general gale updates as well as a map of the Philip-pines and its affected areas
Severe Weather Bulletin	Day-to-day severe weather updates as well as a map of the Philippines and its affected areas
Incidents monitored	Day-to-day incidents monitored updates as well as a map of the Philippines and its affected areas

28 http://bagong.pagasa.dost.gov.ph/agri-weather/impact-assessment-for-agriculture
29 http://www.orminagri.com/
30 Based on the meetings conducted during the site visit to Oriental Mindoro in February 2021.

disaster updates via SMS and pop-up phone notifications. NDRRMS also provides monitoring reports on weather, flood, dam, earthquake, tsunami, and volcano on a day-to-day basis on the website.[31]

3.2.2 PAGASA Weather Bulletins

The DOST-PAGASA website[32] contains various weather bulletins with several components. Table 3.6 shows a summary of all the weather bulletins and their contents. The data is accurate and descriptive, but the visualizations are not intuitive.

3.2.3 Windy

Windy is a portal that provides interactive weather reports and forecasts worldwide. Users can view more than 35 different weather phenomena, such as wind, thunderstorms, snow, humidity, rain, etc. The following data are available: daily/hourly weather, climate, marine, air/air gases, and weather warnings.

For the weather forecasts, Windy shows the real-time and forecasted weather information for a certain geolocation (i.e. a city or a province). Users can choose to see the daily or the hourly forecasts. The basic

Table 3.6: A summary of the weather bulletins released by PAGASA

Bulletin	Textual Report	Maps
General Weather	• Synopsis • Forecast weather conditions • Temperature and relative humidity • Tides and Astronomical Information	• Satellite image of the Philippines from DOST PAGASA HIMAWARI-8 IR1 • Surface Map Analysis • Predicted Mean Sea Level Pressure Analysis • Predicted Mean Sea Level Wind Analysis
Marine	• Gale Warning • Area Synopsis and 24-hour shipping forecast	• Predicted Mean Sea • Level Streamline Analysis • Shipping Forecast Map
Flood	• Basin hydrological forecast - list of the 18 major river basins and their flood status • Dam information - list of all major dams and their water levels • Projects - list of all active projects for flood mitigation	• General Flood Advisory - map of the Philippines and the general flood advisory per area • Metro Manila Flood Monitoring - map of metro manila and the flood advisory per area
Tropical Cyclones	• 5-day weather outlook for Port Area, Manila • News media	• Weather forecast for port area, Manila • General map of the Philippines with tropical cyclone advisories for each area
Climate	• Daily rainfall monitoring • Daily temperature monitoring	
Agri-weather	• Synopsis • Soil Moisture Condition • Farming advisories • Fishing advisories • Red Tide alert • Philippine Agri-weather forecast • Farm advisories • Regional agrometeorological situation and prognosis	• Actual rainfall distribution • Ten-day regional rainfall forecast • Map per region

31 https://monitoring-dashboard.ndrrmc.gov.ph/

32 http://bagong.pagasa.dost.gov.ph/

Table 3.7: Weather forecast models used by Windy

Weather Forecast Model	Resolution	Forecast Depth	Step	Updates frequency
ECMWF	various (14km in Windy.app)	10 days	3 hours	2 times/day
GFS	27km	10 days	1 hour	4 times/day
ICON	various (global 13km, ICON13)	5, 1 day	1 hour	4 times/day

weather details provided are temperature, rain, wind, wind gusts, and wind distribution. In addition to these, it shows detailed waves data such as the real-time and forecasted wind speed, wind gusts, waves, swell, and swell period.

Windy also provides forecasted wind directions based on different models. The main global weather forecast models available are Global Forecast System (GFS), European Centre for Medium-Range Weather Forecasts (ECMWF), and Global German Standard (ICON).

The GFS is the most well-known model, and it is updated by the American meteorological service.[33] This model uses four separate models, namely, atmospheric, ocean, land/soil and sea ice, to be able to paint an accurate picture of the weather conditions. However, since it does not factor in topography and the shapes of coastlines, it is not very accurate for places next to bodies of water.

The ECMWF[34] is a European global forecast seamless model and is widely regarded as the most reliable model currently in existence. It utilizes an assimilation called 4D which allows the model to be constantly updated as new input data becomes available.

ICON was created by the German Meteorological Service (Deutscher Wetterdienst)[35] and is considered more accurate than the ECMWF model only in Europe due to the higher resolution. ICON considers air density and virtual potential temperature, horizontal and vertical wind speed, humidity, cloud water, cloud ice, rain, and snow in its forecast model. Table 3.7 shows the differences in resolution, forecast depth, step interval, and the update frequency of the models used in Windy.

In addition to weather forecasts, Windy also provides a hurricane tracker which shows hurricane, typhoon, and tropical cyclone activities across the globe. As an additional feature, Windy has elevation data between one location to another and can also provide route forecasts for different modes of transportation.

Despite the abundance of data provided by Windy, most of the data is only available through paid services. The high-resolution forecasts and precise data are only available to premium users of the application.

In terms of usability, Windy has a colorful interactive visualization of the weather forecasts which makes it appealing to general users. However, the website is highly technical and the terms used for its content may not fully grasp the amount of information provided to them on the site.

3.2.4 AccuWeather

AccuWeather[36] provides weather forecasts and warnings based on weather information derived from numerous sources, including weather observations and data gathered by the National Weather Service and meteorological organizations outside the United States. The data is divided into three main areas: radar, satellite, and current conditions.

For the weather radar, a heat map of the current area shows the intensity of the precipitation types nearby. It has a playback feature that allows users to see the movement from 1 hour back in 5-minute intervals.

For the satellite view, the RealVue™ Satellite shows the latest view of Earth from space, as taken from weather satellites. It includes a detailed view of clouds, weather systems, smoke, dust, and fog. The Enhanced RealVue™ displays a combination of the latest RealVue satellite image and the color enhanced infrared band of satellites. It provides a detailed view from above the clouds, weather systems, smoke, dust, and fog, while also allowing the colors to depict cloud heights and precipitation areas. For the Water Vapor view, it shows the locations of moisture and atmospheric circulations in the area.

33 https://www.ncdc.noaa.gov/data-access/model-data/model-datasets/global-forcast-system-gfs
34 https://www.ecmwf.int/
35 https://www.dwd.de/EN/research/weatherforecasting/num_modelling/01_num_weather_prediction_modells/icon_description.html

36 https://www.accuweather.com/

For the current conditions view, this shows an interactive heat map of the current temperature for the chosen area. AccuWeather also provides their RealFeel®and RealFeel Shade™ data as a map in comparison with the current temperature. It also provides data on the latest sustained wind speeds and wind gusts around the area and gives the latest liquid-equivalent precipitation measurements in and around the area for the past 24-hour period ending at the current hour.

In addition to these, AccuWeather also provides an interactive hurricane tracker map that shows active and recent storms across the oceans. They also provide Severe Weather watches and warnings and provide advisories depending on the level.

Similar to Windy, most of the data from AccuWeather are only accessible through their paid services. Long-range forecasts and historical data are only available to premium users.

3.3 Recommendations

Tables 3.8 and 3.9 provide a comparative summary, with assessment on the strengths and weaknesses of the examined systems which are grouped into internationally and locally developed cases. The results of these comparisons will be utilized to examine the type of data and lists of indicators relevant to climate risk assessment for agriculture, key features of the tools that will be useful to be included in the CVRIS, and the design of the visualization which may provide easy-to-understand information to the end users.

3.3.1 Data and Indicators

Most of the examined systems retrieve data from existing online sources, which may be one of the methods for data collection for the CVRIS. However, as these online sources provide processed and aggregated data, there is a need to identify the original source or data owners which provide raw and unprocessed data that will be essential for the local level analysis of the Philippines.

Agriculture data of the Philippines, for example, is an important prerequisite local-level data needed for the CVRIS. However, this data was not available and readily accessible even in the locally developed

Table 3.8: Comparative summary of the reviewed international systems and applications

System	Strengths	Weaknesses
FAO-MOSAICC	• Comprehensive framework for analyzing agricultural risk and vulnerability • Includes economic impact assessment	• System or modules not accessible to the public
IRI/LDEO Climate Data Library	• Comprehensive data library for different indicators with filters • Includes analysis modules (i.e. simple averaging, empirical orthogonal function (EOF) analysis using Ingrid Data Analysis Language)	• Limited data available for the Philippines • System filtering takes a while to load due to the amount of information loaded
Think Hazard!	• User-friendly interface • Focused exploration based on location • Provides link to data source from GFDRR	• Map only shows one hazard at a time and is quite small • Hazard levels are aggregated into four (4) simple criteria
GIEWS	• Comprehensive assessment of agriculture and food security across different countries	• Data is scattered in the webpage by topics • Main page shows static maps of the indicators
AEWS-WRM	• Comprehensive assessment of climate and agricultural risk • Made use of satellite imagery and sensors to strengthen analysis • Dissemination through text alerts to farmers • Localized information for the farmers	• Requires significant amount of resources for the initial system development

Table 3.9: Comparative summary of the reviewed Philippine-specific systems and applications

System	Strengths	Weaknesses
UP-NOAH	• Comprehensive localized data layers presented for public consumption • Data layers may be toggled and additional details are available upon select or hover	• Outdated data for some layers • Limited data downloadable with permission of relevant agencies • Difficulties in distinguishment of data at the barangay level
PAGASA CIA	• Direct-from-source information provided by the government • Reports are updated daily	• Reports are static maps and not easily explored through the website • Informative reports but not easily usable for future analysis • The data is visually provided at the regional level only
Agri-InfoHub	• Localized information for Oriental Mindoro • Reports and detailed information guides for farmers	• Static website and not an analytical tool • Focus solely on information sharing rather than data analysis

systems, which shows a necessity to provide a platform to collect first-hand data on agriculture. As seen from the AEWS-WRM, one possible solution would be using additional data from satellite imagery and sensors which may collect and enhance the analysis at a more localized level. This also provides a good reference to motivate the installation of sensors to obtain close to real-time data from the farms. By doing so, CVRIS can minimize its dependency on the schedule of the agencies to report and update data. However, granular data could easily lead to overwhelming amounts of data which may lead to failure to processing. Thus, it is recommended to look into the most appropriate and effective intervals for data reporting.

In terms of the indicators, most systems provide precipitation or rainfall and temperature indicators as a basis for climate assessment information. AEWS-WRM futhermore considers solar irradiation as climate information, but this indicator was not actually commonly used in other systems. Hazard indicators such as cyclones, flooding, earthquakes, and landslides are frequently used to analyze the capacity of social, economic, and environmental systems to cope with a hazardous events. In this case, crop-specific information was crucial to examine the exposure and sensitivity of the agricultural sector from such climate change impacts. It is also notable that FAO-MOSAICC included socio-economic indicators to understand how national economies might be affected due to climate change.

3.3.2 Visualization and Information Dissemination

The majority of the reviewed systems were online websites that are accessible by the public since the CVRIS aims to be also designed as an online platform which will be openly available to both government and public. With few exceptions, most system provides interactive maps with layer filter and toggle features which allow users to select and navigate the data to be shown on the map. For example, for the Agri-infohub and UP-NOAH, satellite map layers were used to represent the base map. However, it has been noticed that farmers and agriculture officers in Oriental Mindoro prefer the interface of Windy[37] due to the presentation of colors and layers in the application. These common design strategies may be considered as good examples when designing for the CVRIS' visualization dashboard for its users. Additionally, other tabular data may also be presented as time series visualizations as how IRI/LDEO Climate Data Library presents data together with their thematic maps.

37 From the focused group discussions and meetings with the local technical working group and farmers of Oriental Mindoro conducted on February 2021.

An interesting approach from AEWS-WRM, however, was the use of mobile text messaging to disseminate risk alerts to the farmers. For grassroot farmers, especially those in the Philippines, this would be a good, recommended feature since internet connectivity may not always be reliable in the rural areas of the provinces.

Aside from the means to which information would be cascaded to the end users, it is also suggested that the development of this CVRIS takes into account the interpretability of the information gathered. As seen in PAGASA-CIA and even the NDRRMC updates, a common pitfall for these reports and systems is its poor interpretability relative to its end users. Using highly technical jargons and terminologies may not effectively communicate the system's objectives, analyses, and findings to its users. This would not only affect their perception of this new technology but would also be a risk for the developed system to be underutilized by its intended users. Thus, it is highly suggested to ensure that the final output would be as interpretable to its final users.

4. Climate Vulnerability and Risk Information System (CVRIS)

As frontline service providers and local decision makers, Local Government Units (LGUs) are mandated to formulate and implement local climate change action plans, which should ideally provide the blueprint to enhance the adaptive capacities of local communities to climate change impacts. However, the quality of climate action planning and response among LGUs and communities is constrained by the necessity of evidence-based and readily available local climate information that should serve as a fundamental reference for these action plans. The lack of publicly available and easily understandable local climate information prevents LGUs from enhancing their awareness on climate change, which inhibits collective community action.

Presently, there are efforts from national government agencies to develop systems and disseminate climate change related information to LGUs and local communities. However, the limitation is that these systems do not capture local information that LGUs and communities can easily relate to and understand. The information on these systems is largely confined to macro level data, terminologies are mostly technical, and data is primarily only available to government technical staff and not readily accessible to common people. These limitations reduce the effectiveness of existing climate information systems to create the necessary level of awareness among communities, allow for informed climate action planning and implementation, and serve as basis for monitoring and evaluation. Hence, there is the need to develop an online system that will collect, digitize, analyze, and disseminate key and actionable information relevant to the climate change and agriculture value chain specific to the local level of Oriental Mindoro. This system is proposed to be called the Climate Vulnerability and Risk Information System (CVRIS).

One of the key features of the CVRIS will be the integration of national level climate change information with Municipal and Barangays (community) level data. The data will be composed of both socio-economic and hazard data that is relevant to agriculture. Local level data is important because the public, which is among the key information targets, should be able to personally relate to the information being conveyed by the system. If the system is able identify the barangays that are highly exposed to flooding, then the people living in said barangay will themselves be able to initiate the necessary climate action. This will also allow for the aggregation of such barangay level data for better climate action planning on the part of the municipal government. The municipal government will be able to assess and rank each barangay according to climate related indicators in order to prioritize LGU programs. Furthermore, if the municipal government is able to consolidate all Barangay data on the location of households or farmlands highly exposed to landslides, then for example, they will be able to better program its slope protection projects or initiate policies on relocation or 'no build zone restrictions' to control the number of settlements in these landslide prone areas. Thus, having a consolidated information on both socio-economic and hazard indicators of local level in a single platform will allow the LGUs to easily access climate risk information and assist them in making data-driven decisions and policies towards improving the agricultural value chain.

4.1 Theoretical framework

The CVRIS will have three main components: 1) the indicators, 2) the composite indices, and 3) the future scenarios. First, indicators will be used to measure hazards, exposure, sensitivity, and adaptive capacity. These indicators are derived from secondary data collected by national and sub-national agencies and government, complemented with raw data collected through the primary sources such as the sensors. Second, the indicators are grouped into four (4) composite indices which are hazards, exposure, sensitivity, and adaptive capacity. These 4 indices will be then aggregated to provide a single current risk value for the selected period. Third, for the future scenario, anticipated projections only for the hazard

index will be recalculated for the year 2050 based on the downscaled climate projection values provided by the Philippine Climate Extremes Report 2020 (DOST-PAGASA et. al., 2020). The new projected value of 'hazard' will be again aggregated with exposure, sensitivity, and adaptive capacity indices of the selected location to compute a new 'future risk' value for the year 2050.

The proposed framework on the risk is based on the 4th and 5th Assessment Reports for IPCC Conceptual Framework on Risk Assessment. Risk (R) is defined as the potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. It is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. Risk results from the interaction of vulnerability, hazard (H), and exposure (E), where vulnerability is defined as a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity (S), and its adaptive capacity (AC).

Risk(R) = Hazard(H) + Exposure(E) + Sensitivity (S) + Adaptive Capacity (AC)

4.2 Indicators

The first stage for the development of the CVRIS requires the identification of indicators according to the four (4) indices that will be used to measure the risk. These indicators are mainly derived from secondary data collected by national and sub-national agencies and government, complemented with raw data collected through the primary sources such as the sensors. Figure 4.2 illustrates the set of indicators for each index. Information on the definition and the data source of each indicator can be found in Appendix C.

Figure 4.1: Overall CVRIS methodology and components

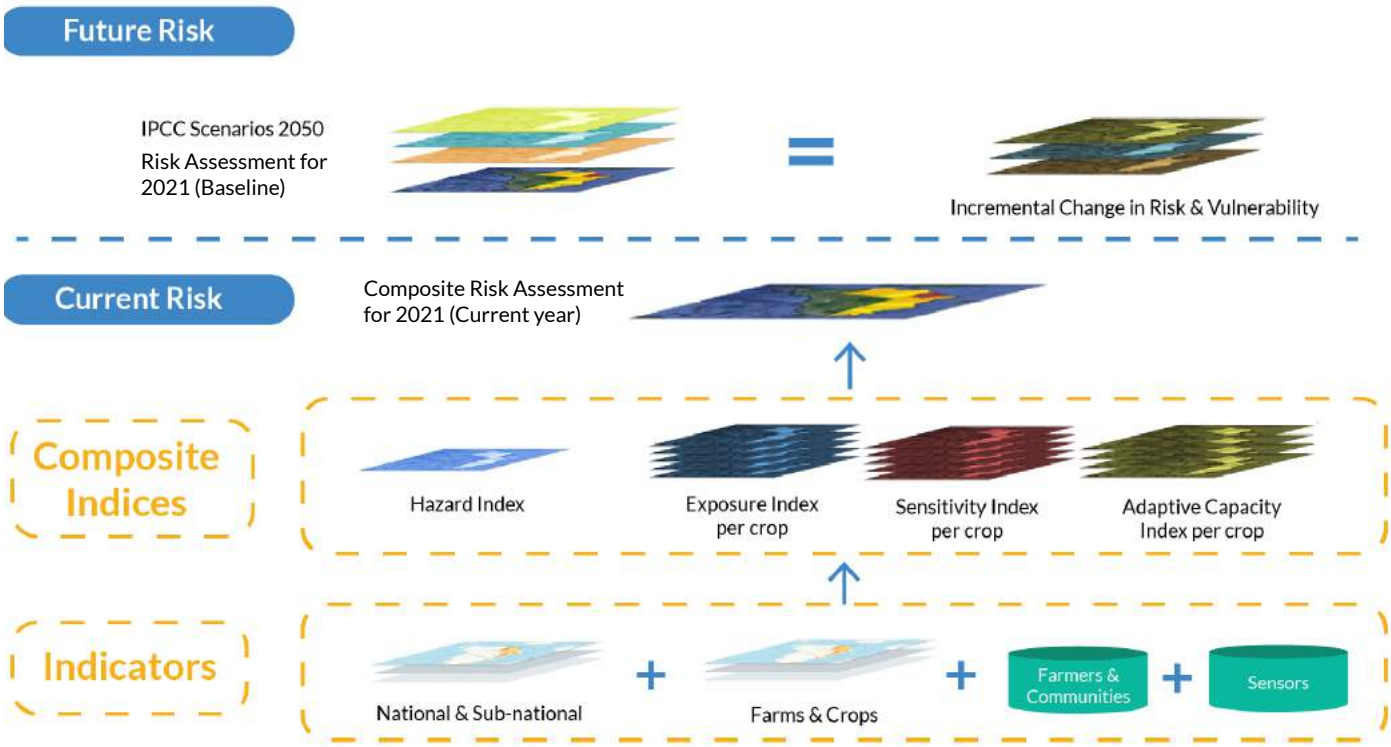
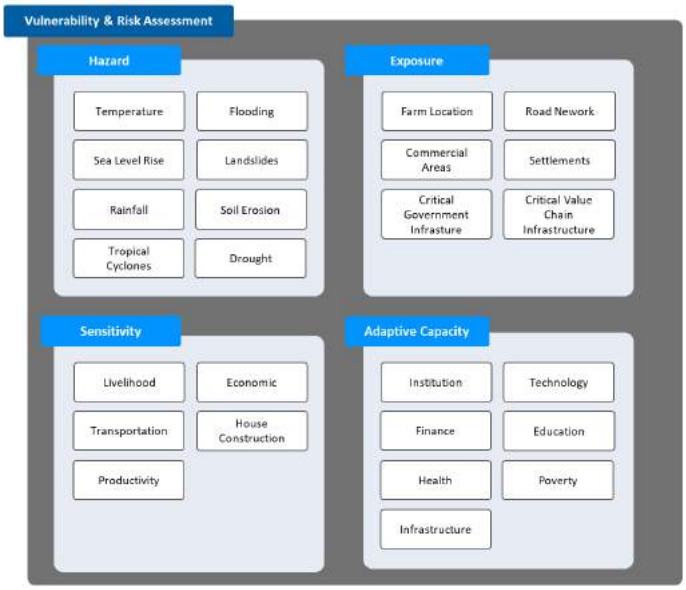


Figure 4.2: Indicator themes and factors for each dimension of risk for CVRIS



The proposed set of indicators were selected based on four criteria: 1) relevance to the main objective of measuring climate-related risk to the agricultural sector, 2) data availability, 3) data quality, and 4) stakeholder validation. Specific details on the rationale for selecting the indicators based on these criteria is provided through Appendix C.

First, relevance captures two aspects. It asks for the proximity between the measurements and phenomena they are meant to capture while data quality refers the degree to which the numerical values of these measurements are reliable. Relevance also covers the adequacy of the definitions of concepts, target populations, variables, and terminology underlying the data.

Second, data availability refers to timeliness and geographical coverage, with the aim to rely on data that contains few gaps over time and between different locations.

Third, data quality asks for the degree to which the numerical values measuring a certain phenomenon can be considered reliable. For that purpose, the objectivity of the data is evaluated, including whether the data is collected and compiled professionally in accordance with appropriate statistical standards and policies, following transparent practices. It also considers whether the data is easy to access, regarding verification of the original source and gaining information on definitions, assumptions, and limitations, among others

Fourth, indicators are subject to validation by stakeholders. Stakeholder validation ensures that their priorities and their understanding of risk are reflected in the set of indicators (Moret, 2014; Vogel & O'Brien, 2006). Validation also ensures that the outputs are aligned with stakeholders' information needs as opposed to idealized assumptions (Mase & Prokopy, 2014). Finally, stakeholder involvement increases acceptance and facilitates learning on how to assess risk (Preston et al., 2011).

4.2.1 Hazard

Hazard (H) refers to the occurrence of natural or human-induced events that may cause injury, loss of life, or other health impacts as well as damage and loss to property, infrastructure, livelihoods, service provision, and environmental resources. Oriental Mindoro experiences a number of natural disasters, and these have a significant impact on the agricultural sector of the province. Climate change furthermore exacerbates some of these phenomena as it is dependent on the level of factors, such as temperature and rainfall. In specific, some of the hazard indicators listed in the Appendix C are directly linked to climate change (e.g., temperature and sea level rise), while others are secondary or even tertiary results of other hazards (e.g., landslides being the result of heavy rainfalls). There are also hazards such as cyclones that have no evidence of being related to climate change but have been included since it would cause significant impact to the agriculture.

4.2.2 Exposure

Exposure (E) assesses the presence of people, livelihood, species, ecosystems, services, infrastructure, and socioeconomic and cultural assets in places and settings that could be adversely affected. Thus, this definition connotes a spatial concept where the location is exposed to hazards and has adverse impacts.

4.2.3 Sensitivity

Sensitivity (S) refers to the degree to which a system or species is affected (adversely in this case) by climate variability or change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea level rise). It can be seen as similar to concept exposure, where the sensitivity implies non-spatial values.

4.2.4 Adaptive capacity

Adaptive capacity (AC) refers to the ability of the system to cope with, absorb, and moderate damages, and rebound from the consequences of climate change. Higher adaptive capacity provides more capacity to respond to and overcome adverse impacts, whereas lack of adaptive capacity will lead to more vulnerability to climate change.

4.3 Composite indices

Once all of the indicators are collected, the system will group them into four (4) composite indices including hazards, exposure, sensitivity, and adaptive capacity. These 4 indices will be then aggregated to provide a single current risk value for the selected period. For the initial stage, it is assumed that equal weights will be used for each indicator under the themes based on the high, medium, and low relevance that are explained in more detail in Appendix C for each indicator. The initial weights and computation methodologies will be further discussed and validated with the Provincial Technical Working Group (PTWG) and other stakeholders for further refinement once the beta version CVRIS tool becomes available for trial.

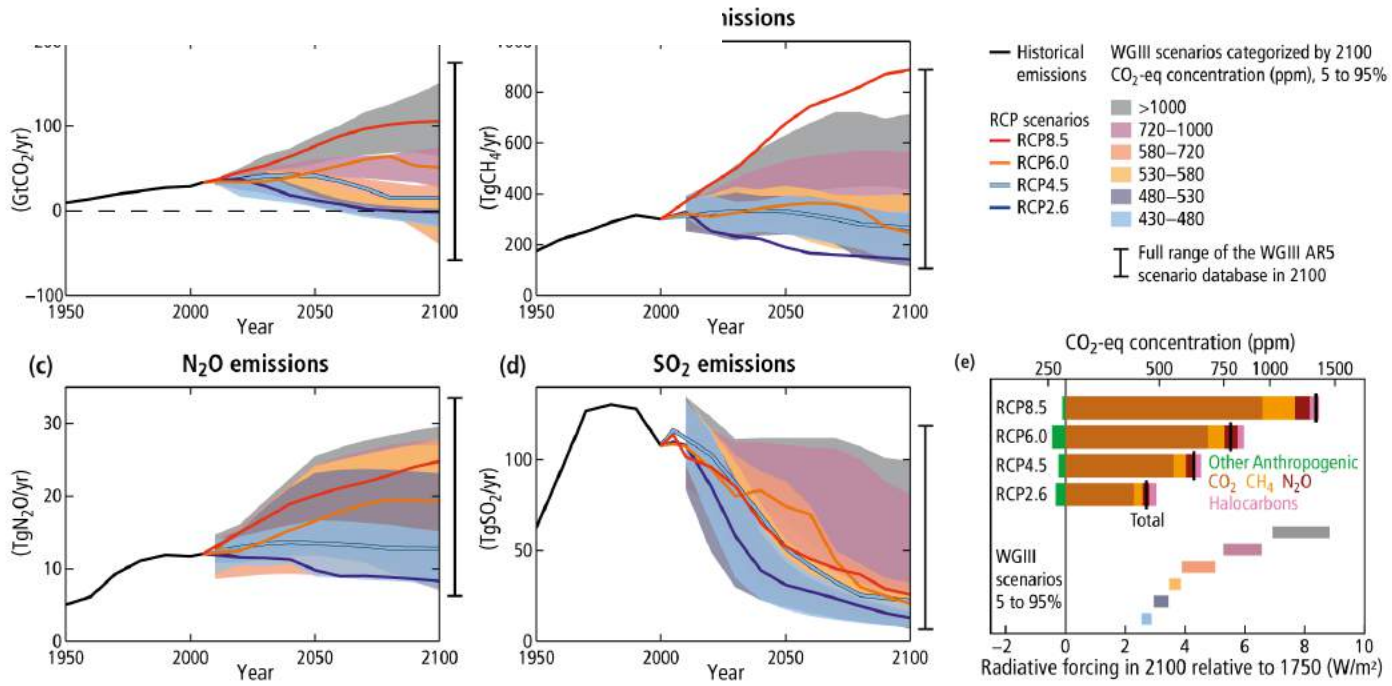
4.4 Future scenarios

To help Oriental Mindoro prepare for future climate scenarios, the CVRIS will project risks under two different greenhouse gas (GHG) emission scenarios: Representative Concentration Pathway (RCP) 4.5 and 8.5. In specific, RCP 4.5 represents an intermediate scenario where greenhouse gas emissions will peak by 2040 and then decline by 2050. RCP 8.5 represents a worst-case scenario where emissions will continue to rise for the rest of the 21st century.

4.5 Data flow

To assess climate projections, the CVRIS will use downscaled provincial level projections for twenty-four (24) climate indicators that have already been calculated by the Philippine Climate Extremes Report 2020 (DOST-PAGASA et. al., 2020) for the mid-future year 2050. The current report only provides projections for climate-related indicators, where the hazard index will be subject to these projections. The projected value of the other indices (i.e., exposure, sensitivity, and adaptive capacity) will remain unchanged for CVRIS, but will be examined to be

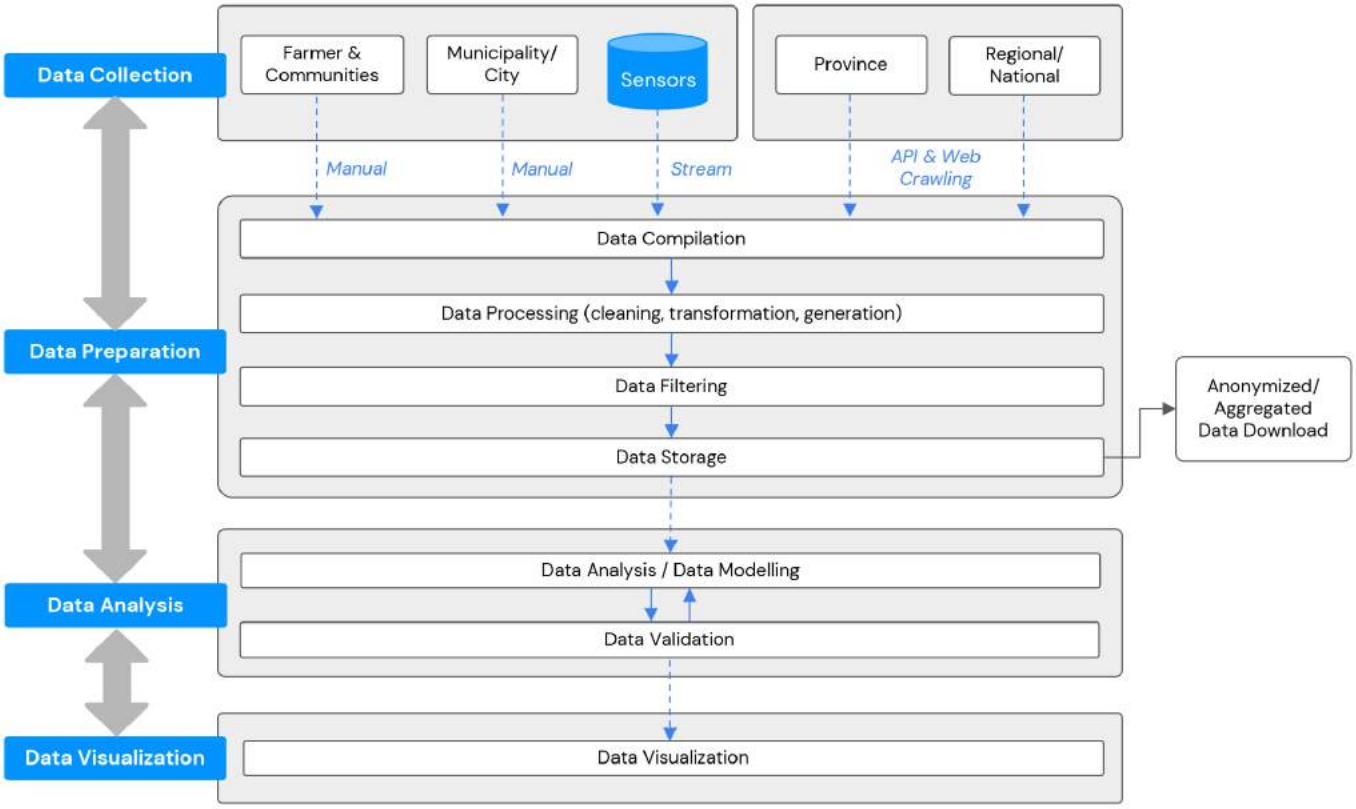
Figure 4.3: Greenhouse gas emission scenarios and concentrations for the different Representative Concentration Pathways (RCPs) as adopted by the IPCC



This is lifted from Topic 2 of IPCC's AR5[37]

37 https://ar5-syr.ipcc.ch/topic_futurechanges.php

Figure 4.4: The Data Flow for CVRIS



included once the necessary information becomes available.

Most data is aimed to be collected from various secondary online sources such as government agencies, local government units, world climate data, and other agricultural and climate data portals with pre-existing data on weather and climate conditions. An application programming interface (API) and web crawling function will be embedded in the CVRIS system to automate the retrieval of these data available online. For necessary data that are not readily available online and may not be downloaded or accessed, it will be manually requested from the responsible provincial and national agencies directly for retrieval.

Because most of the weather data from open sources and government agencies are only representative of one area in Oriental Mindoro, which is Calapan City, the collected data may lack faithfulness for other parts of the province. Thus, in addition to collecting data from existing sources, sensors will also be deployed in different parts of Oriental Mindoro and will collect regular weather data that will be processed and used by CVRIS. The infrastructure of the sensors will automatically upload the collected data to the system's database and will be accessible through the web application. These sensors are intended to complement existing sensors by other projects and national agencies that are already installed in Oriental Mindoro. Appendix B provide more details on the plan and the types of sensors for deployment.

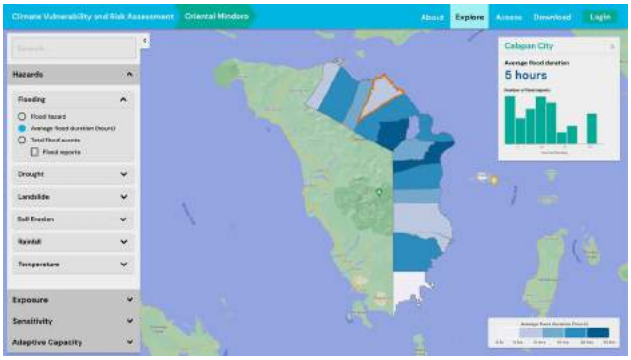
After the collection process, the collected data will be filtered and processed to include the data only for Oriental Mindoro. These processed data will be then computed and stored in the database for easy retrieval through one of the CVRIS functions that will present the collected data in a comma-separated values (CSV) format. Once all of the data has been processed and stored, it will be analyzed to compute the risk by grouping into four (4) composite indices, i.e., hazards, exposure, sensitivity, and adaptive capacity, which will visualized in the CVRIS tool.

4.6 Visualization

The main output of the CVRIS will be an online web application that will present the collected data, computed indicators, and the composite indices through an interactive visualization tool. The visualization will be designed to be easily understandable with interactive functions which the user can maneuver according to their interest.

The visualization will be presented mainly in three (3) main formats: 1) maps for data with geospatial component, 2) summary dashboards with graphs for analytical information, and 3) excel tables for aggregated or bulk data download. In this respect, the current plan of the beta version aims to provide three (3) main tabs in the tool. First, the 'Explore' tab will visualize each indicator that composes the composite indices for hazard, exposure, sensitivity, and adaptive capacity into individual layers of mapping. The side panel will provide users with filters to select the indicators to be visualized on the map. Second, the 'Assess' tab will provide the computed risk scores based on the integrated value of the composite indices along with the risk value for each index. The projected risk value for the year 2050 will be also accessible through this tab. Third, the 'Download' tab will provide all data in a table format which will be downloadable in a CSV format.

Figure 4.10: Prototype of the Explore page of CVRIS



Users may choose to zoom in further into the map and select a specific city or municipality. Once a geographic location and a specific indicator have been selected, additional details about the selected indicator for the location will be displayed on the upper right panel. The information presented will depend on the selected indicator and is subject to change depending on the outcome of the analysis.

Figure 4.11: Prototype of the flood hazard map layer with farm locations on the Explore page

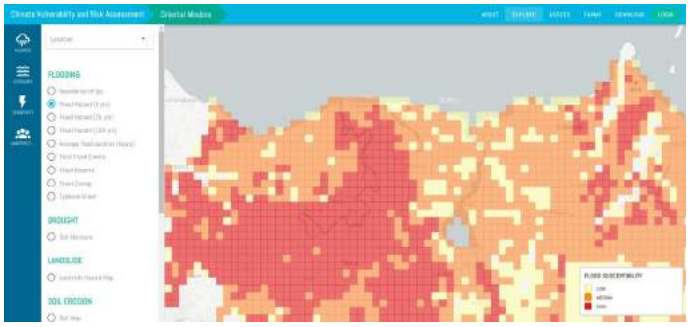


Figure 4.12: Prototype of the Assess page of CVRIS

Figure 4.13: Prototype of the Assess LGU page of CVRIS

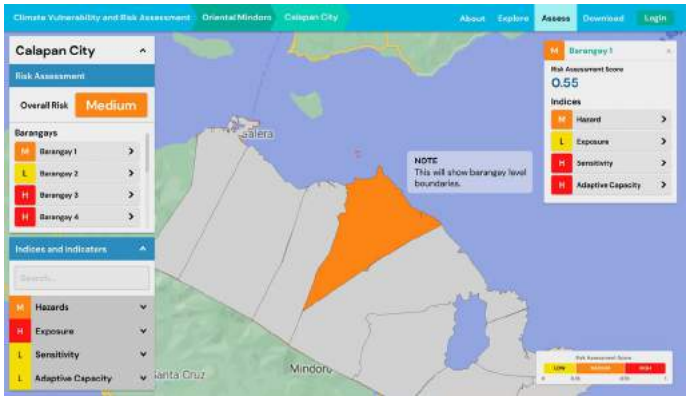
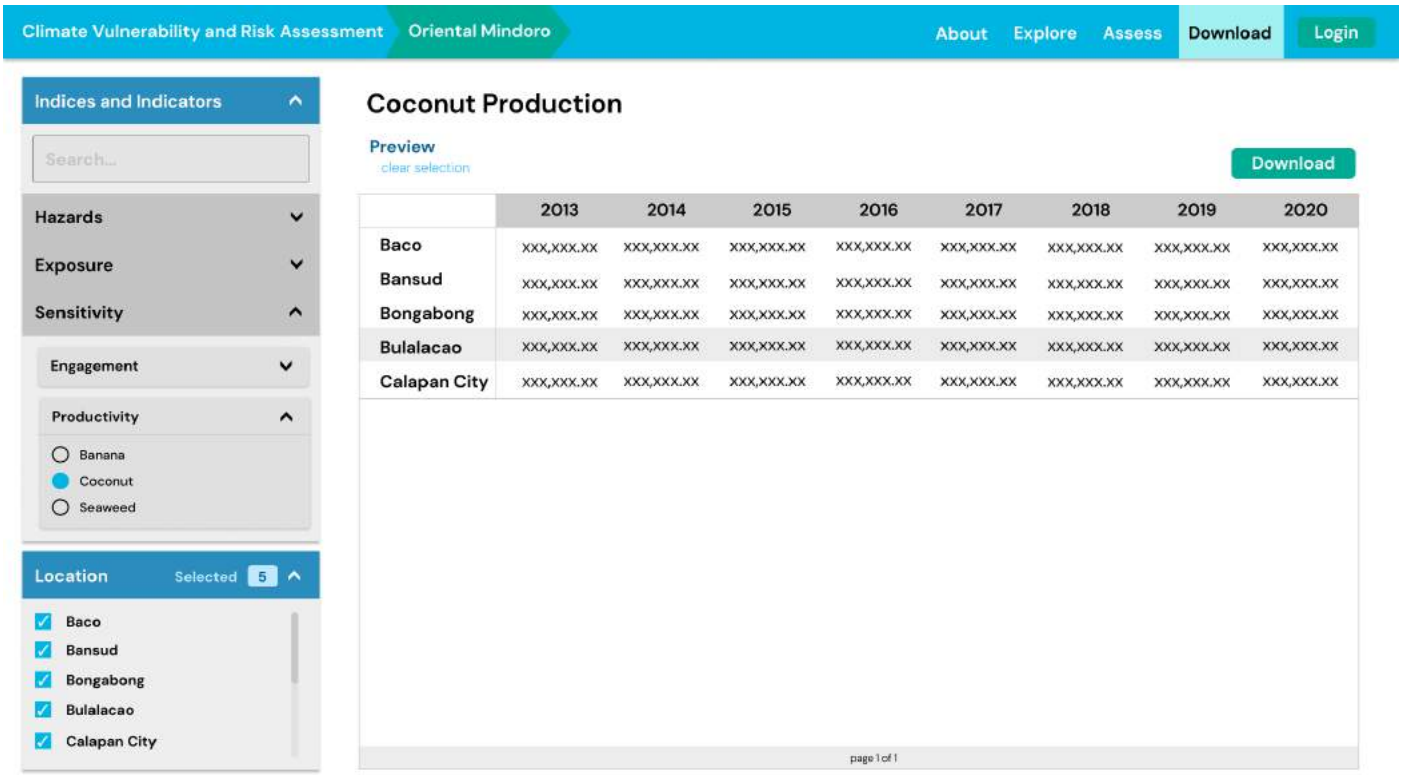


Figure 4.13: Prototype of the Assess LGU page of CVRIS



5. Conclusion

Climate change risks and impacts are increasingly felt by Philippine communities and is expected that the frequency and magnitude of these threats will continue to increase in the coming decades. These risks specifically intensify the damages caused to the agriculture sector where productivity and yield is highly affected by various hazards such as typhoons and flooding. Agriculture furthermore is an important economic sector that needs to be monitored very closely given that the majority of the poor in the Philippines are found in the rural areas where agriculture is the dominant source of livelihood and employment.

Oriental Mindoro is also not exceptional to this situation where its economy is predominantly driven by agriculture. To minimize and adapt to the climate risk and vulnerability of the agricultural value chain of the province, this report presents a conceptual design of the Climate Vulnerability and Risk Information System (CVRIS) which can provide decision makers with a policy advisory tool based on data-driven monitoring and analytic information as well as local communities with a better informed and readily accessible reference tool based on local climate risk information related to agriculture.

It was examined that there are no existing climate risk assessment systems that provide consolidated data of both climate risk information and socio-economic relevant to agriculture. Both of these data are necessary to capture the risks and analytically examine the situation in the local context of Oriental Mindoro. Thus, having a consolidated information of both socio-economic and hazard data in a single platform will better inform of climate action planning and implementation, create necessary level of awareness among communities, and serve as basis for monitoring and evaluation towards improving the agricultural value chain. Additionally, the CVRIS will also provided future projected risk assessments to support in anticipating possible future risk scenarios due to climate change and greenhouse gas emissions.

Also, in order to implement CVRIS, the key is to input relevant data regularly at a local level and manage the system with a periodic update. Thus, the project will be supplemented by providing proper capacity development supports to the focal points of provincial and municipal officials.

In summary, the CVRIS will address the challenges that comes from the lack of local climate information in relation to agriculture and enhance climate change awareness that would lead to collective community action. As this report being the initial phase of the CVRIS development stage, the CVRIS will continue to go through rounds of consultations and validations with relevant stakeholders for further adjustments and refinements in order to provide with more reliable and applicable information in the local context of Oriental Mindoro.

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Appendix

A Existing DOST-PAGASA Sensors in Oriental Mindoro

Table A.1 shows all of the sensors deployed in Oriental Mindoro by DOST and their corresponding status and remarks. All these information were provided by the DOST-Oriental Mindoro office through the PTWG.

Table A.1: Currently deployed sensors of DOST in Oriental Mindoro as of January 22, 2021 (Source: DOST-Oriental Mindoro)

Device Number	Hygrometer Device Type	Location	Status	Remarks
1	ARG	Brgy. Bucayao, Calapan City	Down	Dismantled due to on-going construction of Health Center
2	WLMS	Bucayao Bridge, Brgy. Bucayao, Calapan City	Operational	
3	WLMS	Panggalaan Bridge, Brgy. Panggalaan, Calapan City	Operational	
4	WLMS	Longos Bridge, Brgy. Sta. Rita, Calapan City	Operational	
5	FEWS	Brgy. Bucayao, Calapan City	Operational	
6	ARG	Public Market, Brgy. Poblacion, Puerto Galera	Operational	
7	ARG	Minolo Pier, Brgy. San Isidro, Puerto Galera	Operational	
8	WLMS	Poblacion Bridge, Brgy. Poblacion, Puerto Galera	Down	ARQ was pulled-out and forwarded to ASTI for repair (for re-installation)
9	WLMS	Balatero, Puerto Galera	Down	Malfunctioning Sensor (for replacement)
10	ARG	Poblacion, San Teodoro	Operational	
11	ARG	Bayanan, Baco	Operational	
12	ARG	Baras, Baco	Operational	
13	WLMS	Alag Bridge, Brgy. Alag, Baco	Operational	
14	FEWS	Poblacion, Baco	Operational	
15	Transponder (ARG)	Malmis, Baras, Baco	Operational	
16	ARG	Mahabang Parang Elementary School, Mahabang, Parang, Naujan	Down	DOST-PAGASA conducted ocular visit last February 14, 2020
17	ARG	Brgy. Malvar, Naujan	Operational	
18	ARG	Bagong Buhay, Naujan	Operational	
19	WLMS	Mag-asawang Tubig Bridge, Brgy. Pinagsabangan II, Naujan	Operational	
20	WLMS	Mulawin, Naujan	Operational	
21	AWS	Santiago, Naujan	Operational	

Device Number	Hygrometer Device Type	Location	Status	Remarks
22	FEWS	Munisipyo, Brgy. Inaarawan, Naujan	Operational	
23	ARG	Villa Cerveza Elementary School, Brgy. Villa Cerveza, Victoria	Down	DOST-PAGASA conducted ocular visit last February 13, 2020
24	ARG	Sitio Kisloyan, Brgy. Villa Cerveza, Victoria	Down	For inspection
25	Transponder(ARG)	Villa Cerveza, Victoria	Down	Signal repeater is not yet installed (to be visited by FAME)
26	ARG	Bugtong na Tuog, Socorro	Down	For inspection
27	WLMS	Catingingan Bridge, Brgy. Catingan, Socorro	Down	DOST-PAGASA conducted ocular visit last February 13, 2020
28	WLMS	Subaan, Socorro	Operational	
29	ARG	Matula-tula, Pola	Operational	
30	FEWS	Brgy. Pula, Pola	Down	DOST-PAGASA conducted ocular visit last February 13, 2020
31	AWS	Brgy. Sto Nino, Pinamalayan	Operational	
32	ARG	Brgy. Malubay, Gloria	Down	DOST-PAGASA conducted ocular visit last February 13, 2020
33	ARG	Manguyang Elementary School, Brgy. Manguyang, Gloria	Down	For inspection
34	WLMS	Balete Bridge, Brgy. Balete, Gloria	Operational	
35	ARG	Sumague Bridge, Brgy. Sumague, Bansud	Down	DOST-PAGASA conducted ocular visit last February 12, 2020
36	WLMS	Villapag-asa National High School, Brgy. Villapag-asa, Bansud	Down	DOST-PAGASA conducted ocular visit last February 12, 2020
37	ARG	MinSCAT-Bongabong, Brgy. Labasan, Bongabong	Down	DOST-PAGASA conducted ocular visit last February 12, 2020 (sensor is to be replaced)
38	ARG	Siange, Brgy. Lisap Bongabong	Down	Relocated to Brgy. Morente due to lack of signal connection at Lisap.
39	ARG	Panluan, Bongabong	Operational	
40	WLMS	Orconuma Bridge, Brgy. Orconuma, Bongabong	Operational	
41	WLMS	Lisap Bridge, Brgy. Lisap, Bongabong	Down	DOST-PAGASA conducted ocular visit last February 12, 2020 (sensor is to be replaced)
42	FEWS	Brgy. Orconuma, Bongabong	Operational	
43	ARG	Brgy. Happy Valley, Roxas	Operational	
44	ARG	Brgy. Libertad, Roxas	Operational	
45	ARG	Brgy. San Vicente, Roxas	Down	Poor signal connection
46	WLMS	Madugo Bridge I, Brgy. Bagumbayan, Roxas	Down	For re-configuration

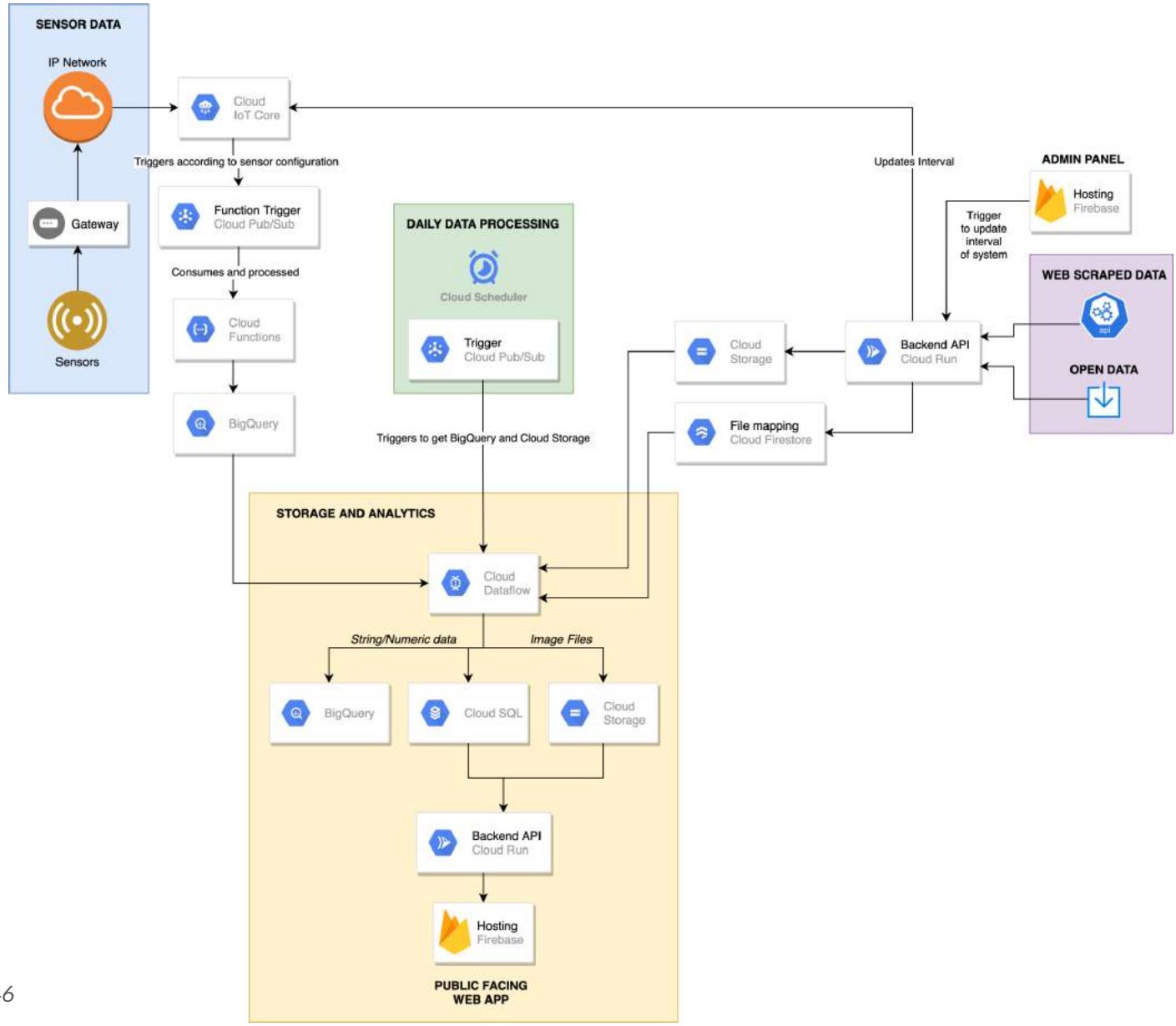
Device Number	Hygrometer Device Type	Location	Status	Remarks
47	WLMS	Madugo Bridge II, Brgy. Bagumbayan, Roxas	Operational	
48	ARG	Leonard Delos Reyes Memorial Elementary School, Brgy. Villa Celestial, Mansalay	Operational	
49	ARG	Brgy. Sta. Maria, Mansalay	Operational	
50	WLMS	Brgy. Balugo, Mansalay	Operational	
51	WLMS	Wasig Bridge, Brgy. Wasig, Mansalay	Down	DOST-PAGASA conducted ocular visit last February 12, 2020
52	FEWS	Brgy. Villa Celestial, Mansalay	Operational	
53	ARG	Brgy. Nasucob, Bulalacao	Down	DOST-PAGASA conducted ocular visit last February 11, 2020
54	WLMS	Cawacat Bridge, Brgy. Campaasan, Bulalacao	Down	DOST-PAGASA conducted ocular visit last February 11, 2020

B Database Design and Infrastructure

Table B.1: Description of the Google Cloud services used in the proposed CVRIS infrastructure

Service	Description
Cloud Function	Code scripts hosted on the cloud that can be triggered or manually run at any time.
Cloud IoT Core	Responsible for managing and connecting IoT devices with the data center.
Cloud Pub/Sub	Real-time scalable messaging service that forwards data through different components in the cloud environment.
Cloud Storage	Multi-purpose storage for all kinds of data.
Dataflow	Tool for ETL (extract, load, transform) operations that are essential for data processing.
BigQuery	Powerful data warehousing service that can store terabytes of data and query them with low latency. This service offers in-place analysis and ML.
Cloud SQL	Relational database that comes in the following variants: MySQL, POSTGRESQL, and SQL server.
Firebase	App hosting service
Cloud Run	Containerized app service

Figure B.2: Proposed cloud data and system architecture for the CVRIS



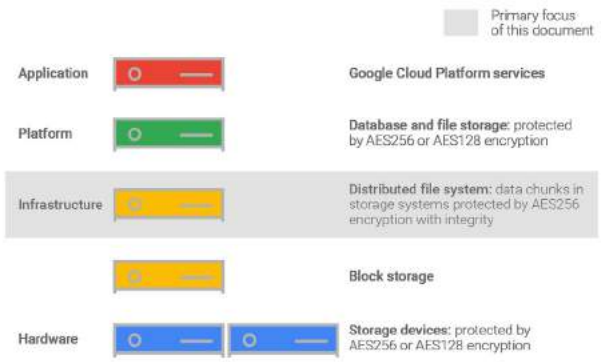
The entire system will be built using cloud-based services, specifically Google Cloud Platform (GCP) tools and services. Table B.1 provides short descriptions of all the Google Cloud services used in the proposed cloud architecture. The main deciding factor for using GCP is in accordance with the Department Circular 2017-002 of the DICT to adopt a cloud first policy.

Since the CVRIS would be completely turned over to the provincial government of Oriental Mindoro, the system needs to meet the requirements of the Department of Information and Communications Technology (DICT) so that the data and any other information is secure. By default, Google Cloud Platform employs data encryption at rest. The layers of encryption used are seen in Figure B.1.

On the infrastructure side, the AES256 encryption scheme is used. This is an industry standard encryption scheme established by the U.S. National Institute of Standards and Technology (NIST). This is also in compliance with DICT cloud standards.

Additionally, the cloud environment will also employ proper Identity and Access Management (IAM) policies to manage permissions between users and developers. Once organizational roles have been established, granular policies for each cloud service will be employed in line with the principle of least privilege. These privileges will be provided to the identified system administrators of the provincial government of Oriental Mindoro, as well as the system administrators of each local government unit in the province.

Figure B.1: Data encryption schemes used by the Google Cloud Platform services; Source: Google Cloud Platform, 2020



The proposed system architecture in Figure B.2 is divided into four main components: (1) the sensors, (2) the daily processing pipeline, (3) the data storage, and (4) the CVRIS web application.

B1 Data Collection

Each data source will have a specific data collection script since the website and API response structures are not uniform. These data collection scripts will be written in Python. All the web-scraped data and open data will be fetched via the Backend API and the raw data files will be stored in the Cloud Storage, and indexed in the Cloud Firestore.

Since cloud services pricing is based on usage, data collected will be processed by batch. This is so that web-scraped data and sensor data may all be processed together on a daily basis. At a fixed time of the day, the Cloud Scheduler will trigger a Pub/Sub that will activate a Dataflow job that will pull the sensor data from BigQuery and the web-scraped data from Cloud Storage. The data processing pipeline will then ingest the raw data, run extract-transform-load (ETL) operations on them, and store them accordingly in BigQuery and Cloud SQL, depending on their usage in the CVRIS analysis and visualization modules.

Sensors

As an additional data source for CVRIS, sensors will be deployed across Oriental Mindoro to complement the secondary weather data coming from PAGASA. For example, current installations of water-level sensors by Project NOAH are focused on downstream areas. Thus, the current installations only allow monitoring of bridges in low-lying areas, which according to the PDRRMC, is already too late for disaster preparations as flood waters are already in susceptible areas. The CVRIS sensors can supplement the current monitoring done by the province by having installations in upstream areas where the onset of rising water levels begin.

Aside from water-level sensors, CVRIS will also deploy and collect data from sensors to be deployed at farms so that these sensors can measure temperature, air humidity, rainfall, and soil humidity. It was examined that the Calapan Weather Station is the only facility that regularly collects weather data for the entirety of Oriental Mindoro. However, as observed by the resident meteorologist and concurred by the farmers and local government officials in different municipalities, Oriental Mindoro experiences microclimatic conditions and the use of data from Calapan to represent the climate conditions for the entire Oriental Mindoro is not enough and results in inaccurate weather forecasting. CVRIS will examine whether the installation of

sensors in each municipality might supplement and address the limited weather and climate data collection for Oriental Mindoro.

The ownership and management of the sensors will be transferred to the identified representatives of the LGUs. The sensors will be owned and eventually maintained by the Provincial Government of Oriental Mindoro. Corresponding training sessions will be conducted to ensure that the representatives are aware of the needed maintenance and how to handle the operation of the sensors.

All of the sensors and gateways are monitored in real-time and may be configured to notify the user if a sensor needs maintenance. Most of the hardware, except for the gateways which are connected to the grid, use a solar powered battery which is easily swappable. The hygrometer, and soil humidity sensors are designed to be low maintenance, resilient to moderate weather conditions, and will be deployed on a set and forget basis.

There will only be instances wherein the temperature reader module might need to be recalibrated or replaced at minimal cost due to weathering or displacement of the soil humidity sensor due to potential erosion/soil movement in elevated areas. The rain gauge sensors will require daily inspection for debris at the mesh filter of the bucket and will require monthly cleanup. Basic instructions will be provided on how to clean the device, and will also not require technical expertise.

As for the water level sensors, these will need constant monitoring and calibration every month due to the dynamic nature of rivers and lakes in Oriental Mindoro. These will also require the constant support of the LGUs/PTWG or the identified caretaker during turnover to make sure the infrastructure set in place such as the mount/posts used for supporting the water level sensor are stable, and that these sensors are still in their proper positions after a given period of time.

A third party infrastructure service integrator may also be engaged and trained to ensure reliable communication between the sensors and gateways. The service integrator will also need to coordinate with the LGUs to ensure infrastructure stability. In the case of a device failure, the defective devices will be replaced and pulled-out from the field to be repaired for future use.

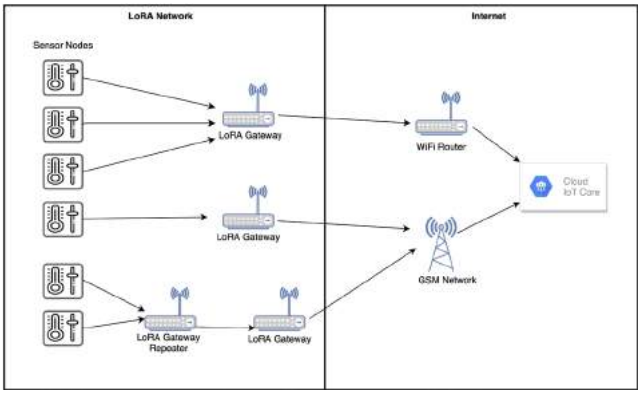
Sensor Deployment Plan

The main components of the sensor infrastructure are (1) the sensor nodes and (2) the communication network for transmitting data (See Figure 4.4).

The sensor infrastructure will consist of several modular sensor nodes, each built around a specific sensor type. All sensors selected will be portable and modular, to adjust to the dynamic environment of Oriental Mindoro. Each sensor will be powered by a lithium ion battery, controlled by a Battery Management System (BMS) along with a solar panel. Provisions will be made to connect the BMS with a solar powered charging module to add longevity and mobility to sensors in remote locations. Sensor nodes will transmit data using a Long Range, Low-Power Wide Area Network modulation technique (LoRAWAN/LoRA) through LoRA transceivers, which operate with low power requirements and are capable of sending small data packets over long distances.

Data transmitted from the sensor nodes will be routed through LoRa gateways connected to the internet using Global System for Mobile communication (GSM) modems, existing Local Area Network (LAN) or Wireless Fidelity (Wi-Fi) networks, whichever is available. For sensors requiring longer transmission range, a LoRa Gateway Repeater will be deployed. These gateways forward packets to another gateway to extend the range of coverage.

Figure 4.4: General sensor communication infrastructure for the CVRIS



LoRa sensor networks are based on a star topology. The sensor nodes transmit data to gateway devices, which in turn encrypt and forward data to the cloud platform via the Internet. Sensor nodes can associate with more than one gateway. The gateways will mostly be positioned in an elevated area to maximize reach. LoRa transceivers have a typical range of up to 5 kilometers. However, network and node-gateway positioning, environment and topographical conditions

(presence of physical obstacles, etc.) also directly affect the effective range on the field.

The sensors will be configured to transmit data every hour to the Cloud IoT Core. The Cloud IoT Core is responsible for managing and connecting all of the deployed Internet of things (IoT) devices. For every push of data from the sensors, a Pub/Sub will trigger a cloud function that will insert the raw data in JavaScript Object Notation (JSON) format from the sensors into the BigQuery data storage.

LoRa Gateway Deployment

The gateways (internet backhaul) are responsible for transmitting the sensor data to the CVRIS. Given this, gateways need to be mounted on a tower or elevated structure, with a stable source of electricity and an ample amount of internet bandwidth in the area either through WiFi or GSM to maximize the coverage of the radio signals it transmits in the surrounding area. On the other hand, a repeater gateway will require the same scenario except for the need for internet bandwidth since it is intended to extend the connection to areas that have low/no connectivity. To allow the team to install the gateways, coordination and assistance of the PTWG and a local service integrator would be necessary since these devices are infrastructure dependent.

Given these conditions, the initial proposed locations of the gateways will be dependent on the radio signal coverage map and the land elevation map. Areas with high elevation and strong radio signal reception will be prioritized. Once these areas have been identified, places within these areas with high hazard and risk exposure will be considered first for the installation of the other sensors. Additionally, areas with no existing monitoring systems will also have a higher priority since the objective of the sensors to be deployed by CVRIS are supplementary to the existing sensors already installed in Oriental Mindoro.

Once the locations of the gateways are finalized, the farm-level sensors and the water level sensors will be deployed within the 5-kilometer radius range of the gateway to ensure that transmission between devices is possible. Locations will be discussed and coordinated with the PAGASA meteorologist of Calapan and the PTWG.

Farm Deployment (Rain Gauge, Hygrometer, Soil Moisture Sensors)

As part of the vulnerability and risk assessment, gathering farm-level data may allow for a more accurate measure of the current conditions at the farms. The sensor deployment in the farms will focus on the collection of farmland data such as precipitation, air humidity, soil humidity and temperature.

There will be three types of sensors involved in this type of deployment: (1) Temperature and Humidity (Hygrometer), (2) Rain Gauge, and (3) Soil Humidity sensors. The proposed layout of the sensors are shown in Figure 4.6 and the features and models of the sensors to be deployed are listed in Table 4.5.

Figure B.2: Proposed deployment positioning of sensors for farm deployment

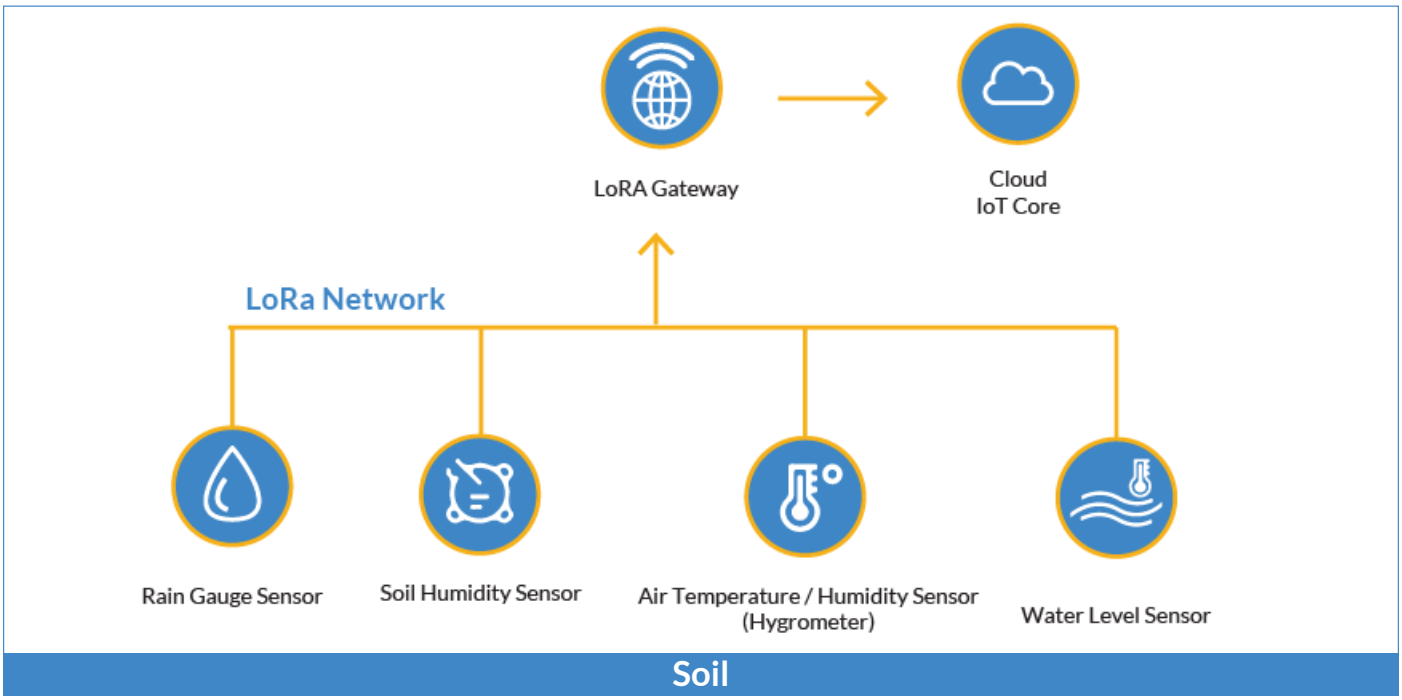


Table B.1: Target deployment location and specifications of the sensors to be deployed for CVRIS

Deployment Location	Sensor Type	Model	Features
Farms	Temperature and Humidity (Hygrometer)	HDC2080	• Integrated humidity and temperature sensor • Condensation / moisture resistant • Low power • ±2% humidity accuracy • ±0.2°C temperature accuracy • Powered via 1.62-3.6V DC
	Rain Gauge	RENKE RS-YL	• Tipping bucket rain rouge • 200mm inner diameter • ±2% accuracy • 0.5mm resolution • 0-4mm/min measuring range • RS485 output • Powered via 10-30V DC
	Soil Humidity	RD-CSM-1	• Capacitive soil moisture sensor with RS485 output • Non corrosive • Waterproof • 1% resolution • Epoxy Resin package • Powered via 5V DC
Upstream River and Downstream River Basin	Ultrasonic Water Level sensor	UE3003	• Liquid level measuring • 0-15 meters range • With 4-20mA / RS485 output • Powered via 12V or 24V DC

The soil humidity and hygrometer sensors will be deployed in areas of the farm identified to host high value crops in order to closely monitor environmental conditions that could potentially affect production. As for the rain gauge, they will be placed in proximity to farm households due to the required frequency of cleaning required to maintain them.

Water Level Sensor Deployment

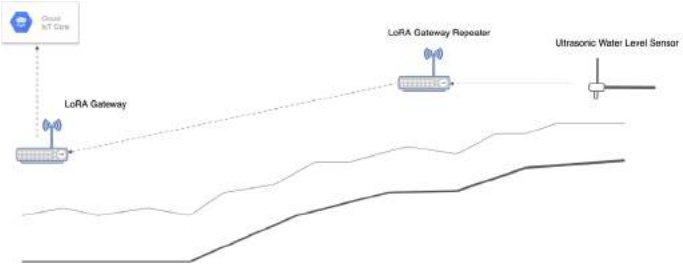
This deployment will require an ultrasonic water level sensor in order to detect both the surface level of the water up and depth of the river up to 10 meters. The calibration metrics will also be set in order to identify both the average and threshold water levels in order to provide data on potential flooding.

The sensors deployed in the upstream river areas will focus on the collection of water levels in these areas. It is assumed that there will be low levels of GSM signal in this area because they are located in the upland and thus a gateway repeater may presumably be needed to allow data transmission from far-flung and mountainous areas (See Figure 4.7).

Table B.2: Target deployment location and specifications of the sensors to be deployed for CVRIS

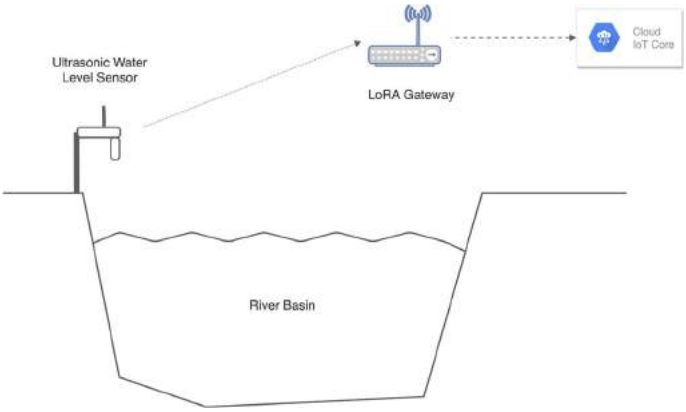
Deployment Location	Sensor Type	Model	Features
Upstream River and Downstream River Basin	Ultrasonic Water Level sensor	UE3003	• Liquid level measuring • 0-15 meters range • With 4-20mA / RS485 output • Powered via 12V or 24V DC

Figure 4.7: Proposed deployment positioning of water level sensors in the upstream rivers



For downstream river basins, sensors will focus on the collection of water levels in this area. However, in contrast to the upstream deployment, signal is presumed to be more stable and sufficient thus will not require a repeater gateway, as shown in Figure 4.8.

Figure 4.8: Proposed deployment positioning of water level sensors in the downstream river basins



Overall, following this planned deployment has its advantages. First, all sensors will be portable and modular, which can be redeployed elsewhere to address the dynamic environment and climate of Oriental Mindoro. The LoRa Gateways and repeaters will be deployed to address signal issues in far-flung and upland areas, which will enable our upstream deployment of water-level sensors. Also, the sensor architecture allows for new sensors to be installed easily as long as they are within the proximity of the gateways. Lastly, a battery management system supported by a solar panel will be installed to add longevity and mobility to sensors in remote and off-grid locations.

B2 Data Preparation

Due to the variety of the data files and structures, we will be utilizing three different data management solutions provided by Google Cloud Platform (GCP): BigQuery, Cloud SQL and Cloud Storage.

Cloud Storage is mainly for storing and managing image files and other non-String or non-numerical data. Since we are dealing with maps and other geospatial datasets, these data usually come in images or raster files. Cloud Storage will also be utilized to store the raw data files prior to any processing as backup files.

BigQuery is a serverless, highly scalable, and cost-effective data warehouse designed to help you turn big data into informed business decisions. For the sensor data and other data needed for analysis and modeling, BigQuery would be a more beneficial data management solution since it was designed to handle Big Data. Since the sensor data would be collected hourly at the minimum and the system should also be able to process municipal to barangay level data, BigQuery can query and process large amounts of data ideally for analysis and additional processing or aggregation.

Cloud SQL is the traditional Relational Database Management System (RDBMS) and can support MySQL and PostgreSQL. The rationale for including a Cloud SQL solution for data management is for the public-facing web application. Specifically for the CVRIS, there will be data visualizations that require limitless combinations of query parameters from different users. For this type of task, relational databases with configurable search indices is better than using BigQuery. The data to be stored in Cloud SQL will be the processed data and the resulting indices from the vulnerability and risk assessments done. Data needed for the web application's visualization and other reports will be stored and managed here.

B3 Data Compilation

For the data that are requested from each local and national government agency, the files would first need to be compiled and organized to verify that the collected data is complete and aligned between all LGUs. As an example, the flood hazard maps downloaded are separated per LGU. However, these can be combined into a single shapefile or raster file to cover the entire province of Oriental Mindoro. Merging does not mean that the data will be aggregated, it will simply be combined into a single file, maintaining the resolution of the original data.

B4 Data Filtering

Some of the publicly available data like the temperature and rainfall data are provided for the whole world. To

minimize the data to be included in the storage, all data at a world level will be filtered to include only Oriental Mindoro data. For geospatial data files, a bounding box using the Oriental Mindoro bounds will be used.

B5 Data Processing

The indicators are mostly derived data from the original datasets provided. Each indicator will be carefully evaluated and aggregated according to the conditions and constraints specified. When available, counts for infrastructure will be done at the most granular level: on the household level. This will allow for flexibility in the spatial aggregation to the barangay level and the city/municipality level. In cases where gender data is available, like in CBMS, these data will be disaggregated as recommended by Malapit et al. (2020) as the impacts and benefits of value chain participation are not gender neutral.

To be able to compare the data from different sources with various spatial and temporal resolutions, it is necessary to select a single unit of measure for the resolution. In cases that unit conversion may not be possible, the data will be normalized. Spatial data will also be reprojected to use the same map projection to allow for correct comparison and derivation of data.

B6 Data Storage

Once all of the data have been cleaned and processed, these will be inserted into the database ready for the analysis. The database design will depend on the data columns that were extracted from the data collected directly by the LGUs and data which are publicly available. However, it will be ensured that the database design will be optimized for both analysis and data visualization.

B7 Application Development

The public-facing online portal will have two components: (1) a Backend API (i.e. Firebase) which will handle the retrieval of data from storage to be displayed in the user interface and (2) the Web Application which is the user-facing interface that shows the visualization and allows users to interact with the data provided.

The design of the web application will follow a mobile-first approach. This simply means that the design and layout of the interface will consider the viewing sizes of mobile devices first to ensure that the system display is optimized for small screens. By designing the web interface to fit mobile devices, this will make the design more responsive and adjust according to the screen size of the device used, be it a tablet or a laptop.

Since the CVRIS is aimed for various users with varying levels of access, there would be a user registration and login feature to provide administrative access to the system administrators of the LGUs and other assigned officers in charge of the system. The provincial system administrators can add new users to the system and delegate permission to city/municipal administrators who are in charge of their local data and analysis. For the general public, no registration or login would be required to access the visualization dashboard and complete vulnerability and risk assessments of the CVRIS.

The main functionality of the CVRIS is to present the data to users and allow them to explore the available data to make informed decisions. This feature will be available for both public and authenticated users.

Users will be presented with a visualization dashboard with an interactive map and accompanying navigation and filtering panel. This panel will allow users to freely explore the data by selecting the indicators they would like to view and compare. Users may also search and choose the city or municipality that they would like to analyze further. They could also filter the results of the assessment at the farm- and crop-level. Other than spatial navigation through the map, users may also view the indicators according to the crops included in the vulnerability assessment.

For the map visualization, we plan to explore Leaflet.js[39] and Mapbox GL JS[40]. Both are JavaScript libraries for interactive maps on the Web with similar features. The advantage of Leaflet is its lightweight size which makes it suitable for mobile-friendly designs. On the other hand, Mapbox GL JS uses vector maps which provides better resolution when zooming in and allows for 3D mapping which may be useful for viewing elevation maps and the like.

Depending on the needs and requirements of the government of Oriental Mindoro, reports may be generated by the CVRIS based on the availability of the data and indicators. The reports to be generated will be designed after the vulnerability and risk assessment has been completed.

In addition to the visualizations, a separate

39 Leaflet Official Website - **https://leafletjs.com/**
40 Mapbox GL JS - **https://www.mapbox.com/mapbox-gljs**

Table 4.8: Comparison of Mapbox GL JS and Leaflet.js

Features	Mapbox	Leaflet
Open-source library	☑	☑
Mobile compatibility	☑	☑
3D layers	☑	☑
Tile format	vector	raster
Size	858 KB	156 KB

administrative panel will also be developed to help manage and configure the frequency of data transmission for the installed sensors through the Cloud IoT Core. We envision this feature as an additional tool supplementary to the CVRIS in case of heavy rains, typhoons, and potential flooding. Through this portal, system administrators may be able to set the upload of data to the CVRIS at a shorter interval to be able to provide a more timely response.

Administrative users will also be provided with a platform in the system for them to upload and input data directly into the CVRIS for cases wherein the data is not readily available. Currently, two options are being evaluated to complement the existing data that will be collected.

- **Third-party Tool** — We plan to use open-source tools to collect additional data, train the local government officers to use these tools, and use the output generated from the tool to be uploaded to the CVRIS.
- **Integrated Map Editor** — Alternatively, we may also include an embedded interface within the CVRIS to plot and input markers and shapes onto a map. These data will be automatically saved in the database and ready for use in the analysis.

All administrative panel functionalities will only be available to the authenticated users of the CVRIS such as the assigned officers of the system and administrators that manage the overall system.

C Indicators

The CVRIS framework follows the IPCC Annual Report (4th and 5th annual reports) definition of risk, which is composed of hazard, exposure, sensitivity, and adaptive capacity. For this project, the following indicators will be considered and will be updated through validation processes.

Hazard (25%)

Hazard (H) refers to the occurrence of natural or human-induced events that may cause injury, loss of life, or other health impacts as well as damage and loss to property, infrastructure, livelihoods, service provision, and environmental resources.

1. The following steps will be done in computing for the Hazard Indicator score:
   The estimated potential soil erosion will be computed using the Universal Soil Loss Equation. The raster data for soil type, land cover, average monthly total rainfall, and land elevation will be combined using a raster calculator.

2. Different hazard values for each administrative shapefile or geographical unit will be extracted and scaled to values between 0 and 1.

3. The Hazard Indicator score for each administrative shapefile or geographical unit will be the weighted average of all rescaled hazard scores computed using zonal statistics or raster calculator.

Table C.1: Hazard-related indicators to be used for CVRIS

Theme	Sub-indicator Relevance	Sub-Indicator Weight	Indicator	Source of Data	Rationale	File Type	Data Processing & Sub-Indicator Score Computation	Data Relevance	Data Weight	Reason for relevance	Availability	Update Frequency
Flooding	High	16.25%	Flood hazard maps	LiPAD	Flood hazard maps provides the susceptibility of areas to floods for different return periods.	GIS file	Flood Hazard Maps for Puerto Galero and Roxas are not available from the LiPAD portal. These will be requested from the respective municipalities. Once the maps are complete, a single map will be derived for provincial-level assessments. Municipal-level maps will be retained and used for municipal-level assessments.	High	33%	Oriental Mindoro experiences a Type 1 and Type 3 climates, which means there are areas with pronounced wet and dry seasons, and some areas with not so pronounced wet and dry seasons. Although some areas are shielded bymountain ranges, the province is still open to rains brought in by the Habagat and tropical cyclones. Thus, flooding is quite frequent and causes large damage to crops and soil quality of farmlands.	Flood hazard maps for Oriental Mindoro are available from DOST's Project LiPAD as raster files for 5-year, 25-year and 100-year return periods. It can be downloaded per municipality. This is a one time download. Additionally, flood hazard maps were also requested from the LGUs.	Updates necessary after new developments and the completion of flood-control and mitigation projects.
			Average duration of flood (hours)	PDRRMC	Empirical reports of flooding can supplement the susceptibility information from hazard maps.	Tabular data	Per assessment area, the duration of reported flood events will be averaged.	High	33%		To be checked with and requested from PDRRMO and local DRRMOs	Annual
			Total number of flood events	PDRRMC		Tabular data	The on-the-ground reports of flood events will be counted per assessment area.	High	33%		To be checked with and requested from PDRRMO and local DRRMOs	Annual

Theme	Sub-indicator Relevance	Sub-Indicator Weight	Indicator	Source of Data	Rationale	File Type	Data Processing & Sub-Indicator Score Computation	Data Relevance	Data Weight	Reason for relevance	Availability	Update Frequency
Drought	Medium	6.25%	Soil moisture	PEARS Lab of UP IESM; Farm-level sensors	Dry soil affects the quality of the crops.	GIS file	Drought scores will be computed using raster calculators with the combined soil moisture estimates and the total annual or monthly reports of dry spell and drought in an area.	High	33%	Provinces that rely heavily on its agricultural sector are prone to risks posed by drought seasons. However for Oriental Mindoro, there is already a significant area of irrigated farmlands that are less exposed to droughts. In the field study, drought wasn't usually raised by farmers as a significant issue in their farming.	The PEARS lab of UP IESM conducts regular remote sensing studies including the estimation of soil moisture across the Philippines. These are validated with ground measurements. Soil moisture maps will be requested from the lab. NASA's National Snow and Ice Data Center also provides soil moisture maps that are estimated using ASMR2 which was validated by the PEARS lab of UP IESM. It has a temporal coverage from July 2, 2012 to present. It is updated daily.	Daily
			Total duration of dry spell (days)	PDRRMC; PAO of OM	On-the-ground reports of instances of dry spell from farmers provide empirical evidence of dry spell exposure which can augment remote sensing estimates. Farmers are expected to provide location information and the length of dry spell. A dry spell is defined as a period of 15 or more consecutive days with less then 1 mm of rainfall on each; and absolute drought is a period of 15 or more consecutive days with less than 0.2 mm on each	Tabular data		High	33%		Drought and dry spell reports will be requested from the LGUs to augment the estimates provided by the soil moisture maps. The frequency of local reports is still uncertain but it can be assumed that regular monitoring happens during dry and El Niño seasons. Alternatively, PAGASA also has Dry Spell Assessment reports for 2016 and 2019 available on their website in a PDF format. However, this is only an image with codes for each province. Dry Spell/Drought Assessments for 2015, 2016 and 2019 are also available in Reliefweb as PDFs. The infographic shows the different provinces in the Philippines labelled as either having potential for drought, dry spell, dry condition, or no effect at all.	Annual

Theme	Sub-indicator Relevance	Sub-Indicator Weight	Indicator	Source of Data	Rationale	File Type	Data Processing & Sub-Indicator Score Computation	Data Relevance	Data Weight	Reason for relevance	Availability	Update Frequency
Drought	Medium	6.25%	Total duration of drought (days)	PDRRMC; PAO of OM	On-the-ground reports of instances of drought from farmers provide empirical evidence of drought exposure which can augment remote sensing estimates. Farmers are expected to provide location information and the length of drought. A dry spell is defined as a period of 15 or more consecutive days with less then 1 mm of rainfall on each; and absolute drought is a period of 15 or more consecutive days with less than 0.2 mm on each	Tabular data	Drought scores will be computed using raster calculators with the combined soil moisture estimates and the total annual or monthly reports of dry spell and drought in an area.	High	33%	Provinces that rely heavily on its agricultural sector are prone to risks posed by drought seasons. However for Oriental Mindoro, there is already a significant area of irrigated farmlands that are less exposed to droughts. In the field study, drought wasn't usually raised by farmers as a significant issue in their farming.	Drought and dry spell reports will be requested from the LGUs to augment the estimates provided by the soil moisture maps. The frequency of local reports is still uncertain but it can be assumed that regular monitoring happens during dry and El Niño seasons. Alternatively, PAGASA also has Dry Spell Assessment reports for 2016 and 2019 available on their website in a PDF format. However, this is only an image with codes for each province. Dry Spell/Drought Assessments for 2015, 2016 and 2019 are also available in Reliefweb as PDFs. The infographic shows the different provinces in the Philippines labelled as either having potential for drought, dry spell, dry condition, or no effect at all.	Annual
Landslide	Medium	6.25%	Landslide hazard map	PDRRMC	Landslide hazard maps provides the susceptibility of areas to landslides.	GIS File	Landslide hazard maps will be used as is.	High	50%	Because of Oriental Mindoro's climate, landslides are usually triggered by heavy rains especially in municipalities with upland communities. Aside from landslides, they also experience road slips.	Landslide maps are available from the local DRRMOs and PHIVOLCS-DOST. We have already requested landslide hazard maps from the LGUs. From MGB-MIMAROPA, we can download images of landslide maps for all municipalities and city in Oriental Mindoro. From PHIVOLCS, we can download maps for earthquake-induced landslides.	Extreme Event-driven
			Total landslide instances	PDRRMC	Empirical reports of landslide of road slip can supplement the susceptibility information from hazard maps.	Tabular data	The on-the-ground reports of landslide and road slip events will be counted per assessment area.	High	50%		Landslide reports will be requested from the LGUs to augment the estimates from the landslide susceptibility maps. The frequency of local reports is still uncertain but it can be assumed that regular monitoring happens during wet and heavy rain seasons.	Annual

Theme	Sub-indicator Relevance	Sub-Indicator Weight	Indicator	Source of Data	Rationale	File Type	Data Processing & Sub-Indicator Score Computation	Data Relevance	Data Weight	Reason for relevance	Availability	Update Frequency
Tropical Cyclones	Medium	6.25%	Total number of typhoons that hit (direct) by signal level	PAGASA; NOAA; NASA	Typhoons frequently pass the island and causes damage to crop production of coconuts and bananas.	GIS file and Tabular data	The number of cyclones that pass Oriental Mindoro will be counted using the cyclone tracks data. This will be counted per signal level.	High	75%	Oriental Mindoro experiences a Type 1 and Type 3 climates, which means there are areas with pronounced wet and dry seasons, and some areas with not so pronounced wet and dry seasons. It is also frequented by the Habagat and tropical cyclones, but not as much as the other provinces. Because of the significant number of upland farms in Oriental Mindoro, tropical cyclones are included as a sub-indicator.	Cyclone tracks are available from the International Best Track Archive for Climate Stewardship (IBTrACS v4) that is maintained by the National Climatic Data Center of NOAA. They can be downloaded as GIS files that contain the different points along a cyclone's path. It merges best track data from all official Tropical Cyclone Warning Centers (TCWCs) and the WMO Regional Specialized Meteorological Centers (RSMCs) who are responsible for developing and archiving best track data worldwide. The dataset contains the position, maximum sustained winds, minimum central pressure, and storm nature for every tropical cyclone globally at 6-hr intervals in UTC. Statistics from the merge are also provided (such as number of centers tracking the storm, range in pressure, median wind speed, etc.). The dataset period is from 1848 to the present with dataset updates performed annually in August. The dataset is archived as netCDF files but can be accessed via a variety of user-friendly formats to facilitate data analysis, including netCDF, Shapefile, and CSV formatted files.	Monthly
			Maximum sea level (king tide)	PAGASA; NOAA; NASA	King tides are abnormally high tides, that when combined with typhoons can cause extreme flooding in coastal and low-lying communities.	Tabular data	The mean sea level on months when tropical cyclones made landfall in Oriental Mindoro will be extracted and averaged.	Medium	25%		Tide gauge data are available from the Permanent Service for Mean Sea Level (PSMSL) at the National Oceanography Centre in the UK. The datasets are available for both monthly and annual mean sea level in millimeters. The closest station to Oriental Mindoro with available data is in Marinduque, which is the nearby island on its right. It was last updated on October 2020.	Monthly

Theme	Sub-indicator Relevance	Sub-Indicator Weight	Indicator	Source of Data	Rationale	File Type	Data Processing & Sub-Indicator Score Computation	Data Relevance	Data Weight	Reason for relevance	Availability	Update Frequency
Soil Erosion	High	16.25%	Soil map	PAO of OM; FAO (HWSD v1.2)	The type of soil is needed to assess soil erosion severity; Will be used for estimating potential soil erosion using Universal Soil Loss Equation.	GIS file	Soil erosion maps will be created using the Universal Soil Loss Equation. It will use the soil map, land cover map, lan elevation map, and monthly total rainfall as inputs. Maps for each input have to be in raster files and raster calculators will be used to compute potential soil erosion susceptibility per zone. Required for USLE: http://www.omafra.gov.on.ca/english/engineer/facts/12-051.htm#t1	High	USLE weights	Oriental Mindoro has a substantial number of upland farmlands in the municipalities of Victoria, Socorro and Pola that grow high-value crops and fruit trees. These areas experience soil erosion and road slips during heavy rains that affect their farmlands and the transport of their crop harvest. Soil maps describe the type of soil in a given area and can be used to estimate its susceptibility to soil erosion.	Available as an image of a scanned map on Agri-InfoHub but there is no year specified. The Harmonized World Soil Database is a 30 arc-second raster database with over 15 000 different soil mapping units that combines existing regional and national updates of soil information worldwide with the information contained within the 1:5 000 000 scale FAO-UNESCO Soil Map of the World (FAO, 1971-1981). Its raster database consists of 21600 rows and 43200 columns, which are linked to harmonized soil property data. The use of a standardized structure allows for the linkage of the attribute data with the raster map to display or query the composition in terms of soil units and the characterization of selected soil parameters (organic Carbon, pH, water storage capacity, soil depth, cation exchange capacity of the soil and the clay fraction, total exchangeable nutrients, lime and gypsum contents, sodium exchange percentage, salinity, textural class and granulometry). The database was last updated in 2013 but there is no specific mention how often it gets updated. The Digital Soil Map of the World can be downloaded as shapefiles from FAO's GeoNetwork portal as well as Harvard's Digital Soil Map of the World portal. The soil map information is available at 1:5.000.000 scale. Its latest version 3.6 was completed last 2007. It is updated as needed with no regular schedule.	Annual if available

Theme	Sub-indicator Relevance	Sub-Indicator Weight	Indicator	Source of Data	Rationale	File Type	Data Processing & Sub-Indicator Score Computation	Data Relevance	Data Weight	Reason for relevance	Availability	Update Frequency
Soil Erosion	High	16.25%	Land cover	OCHA Philippines; MODIS NASA; Copernicus Global Land Service	The land cover map provides information about natural vegetation, human-altered, and non-vegetated areas; Will be used for estimating potential soil erosion using Universal Soil Loss Equation.	GIS file	Soil erosion maps will be created using the Universal Soil Loss Equation. It will use the soil map, land cover map, lan elevation map, and monthly total rainfall as inputs. Maps for each input have to be in raster files and raster calculators will be used to compute potential soil erosion susceptibility per zone. Required for USLE: http://www.omafra.gov.on.ca/english/engineer/facts/12-051.htm#t1	High	USLE weights	Oriental Mindoro has a substantial number of upland farmlands in the municipalities of Victoria, Socorro and Pola that grow high-value crops and fruit trees. These areas experience soil erosion and road slips during heavy rains that affect their farmlands and the transport of their crop harvest. Land cover maps describe the spatial information about "the different types of physical coverage of the Earth's surface" (Copernicus Global Land Service). These can be forests, grasslands, croplands, lakes and wetlands, among others. Knowing the current land cover can give a better a estimate on the susceptibility of an area to soil erosion.	Land cover maps from the Copernicus Land Cover Service have a temporal coverage from 2015 to 2019, with a 100m resolution. These are updated annually and can be downloaded per year as a raster file. Land cover maps from MODIS NASA are available with resolution of 500m and 1km, with a temporal coverage from 2001 to 2019. It is updated annually.	Annual
			Land elevation / slope	PhilGIS; NASA	The land elevation map provides information about high terrains and elevation points that have potential for soil erosion; Will be used for estimating potential soil erosion using Universal Soil Loss Equation.	GIS file		High	USLE weights	Oriental Mindoro has a substantial number of upland farmlands in the municipalities of Victoria, Socorro and Pola that grow high-value crops and fruit trees. These areas experience soil erosion and road slips during heavy rains that affect their farmlands and the transport of their crop harvest. Land elevation maps describe the elevation of an area above sea-level. It can be used to estimate slopes and thus useful in estimating the susceptibility of an area to soil erosion.	NASA Digital Elevation maps (DEM) are available with 1 arc second resolution. DOST's Project LiPAD also provides LiDAR data upon request, subject to approval by the team. Available data are the digital terrain model and digital surface model for the specified area. However, the coverage of the data does not include the entirety of Oriental Mindoro.	No need to update. Land elevation is static.
			Tillage Method	Survey	Tillage method can also be a contributing factor to soil erosion.	Tabular data		Medium	USLE weights	Tillage method can also be a contributing factor to soil erosion.	This will be checked with and requested from PAgO.	Unknown

Theme	Sub-indicator Relevance	Sub-Indicator Weight	Indicator	Source of Data	Rationale	File Type	Data Processing & Sub-Indicator Score Computation	Data Relevance	Data Weight	Reason for relevance	Availability	Update Frequency
Soil Erosion	High	16.25%	Monthly total rainfall	World-Clim; PAGASA	Frequent and large amounts of rainfall causes flooding but a good watering source for non-irrigated arable land. The total rainfall and its periodicity dictates the crop rotation system of farmers.	GIS file	Soil erosion maps will be created using the Universal Soil Loss Equation. It will use the soil map, land cover map, lan elevation map, and monthly total rainfall as inputs. Maps for each input have to be in raster files and raster calculators will be used to compute potential soil erosion susceptibility per zone. Required for USLE: http://www.omafra.gov.on.ca/english/engineer/facts/12-051.htm#t1	High	USLE weights	Oriental Mindoro experiences a Type 1 and Type 3 climates, which means there are areas with pronounced wet and dry seasons, and some areas with not so pronounced wet and dry seasons. It is important to assess the frequency and amount of rainfall on rainfed farmlands.	Rainfall data are available as raster files from WorldClim and it spans from 1960 to 2018. The data is divided per decade so there are a total of six raster files for the specificed timeframe. NASA also provides rainfall or precipitation data from 2000 to 2010. The data provided is the average hourly precipitation recorded monthly. The file format is in hdf5 which can be programmatically opened through Python. Rainfall data is also available as daily reports from PAGASA's Project NOAH web portal. However, this data will require custom web scraping scripts to extract.	Monthly
Rainfall	High	16.25%	Monthly total rainfall	World-Clim; PAGASA	Frequent and large amounts of rainfall causes flooding but a good watering source for non-irrigated arable land. The total rainfall and its periodicity dictates the crop rotation system of farmers.	GIS file	Monthly total rainfall will be aggregated for a year and used as input for the raster calculator in assessing the Hazard score.	High	14.29%	Oriental Mindoro experiences a Type 1 and Type 3 climates, which means there are areas with pronounced wet and dry seasons, and some areas with not so pronounced wet and dry seasons. It is important to assess the frequency and amount of rainfall on rainfed farmlands.	Rainfall data are available as raster files from WorldClim and it spans from 1960 to 2018. The data is divided per decade so there are a total of six raster files for the specificed timeframe. NASA also provides rainfall or precipitation data from 2000 to 2010. The data provided is the average hourly precipitation recorded monthly. The file format is in hdf5 which can be programmatically opened through Python. Rainfall data is also available as daily reports from PAGASA's Project NOAH web portal. However, this data will require custom web scraping scripts to extract.	Monthly

Theme	Sub-indicator Relevance	Sub-Indicator Weight	Indicator	Source of Data	Rationale	File Type	Data Processing & Sub-Indicator Score Computation	Data Relevance	Data Weight	Reason for relevance	Availability	Update Frequency
Rainfall	High	16.25%	Maximum monthly rainfall	World Bank	Frequent and large amounts of rainfall causes flooding but a good watering source for non-irrigated arable land. The total rainfall and its periodicity dictates the crop rotation system of farmers.	Tabular data	The maximum monthly rainfall will be divided by the average monthly total rainfall.	High	14.29%	Oriental Mindoro experiences a Type 1 and Type 3 climates, which means there are areas with pronounced wet and dry seasons, and some areas with not so pronounced wet and dry seasons. It is important to assess the frequency and amount of rainfall on rainfed farmlands.	Currently, the data available from the Word Bank are projections.	Annual
			Minimum monthly rainfall	World Bank		Tabular data	The minimum monthly rainfall will be divided by the average monthly total rainfall.	High	14.29%			Annual
			Number of days with rainfall >20mm	World Bank		Tabular data	This will be divided by 31 to get the proportion of days within a month.	High	14.29%			Annual
			Number of days with rainfall >50mm	World Bank		Tabular data	This will be divided by 31 to get the proportion of days within a month.	High	14.29%			Annual
			Largest single day rainfall	World Bank		Tabular data	The largest single day rainfall will be divided by the average monthly total rainfall.	High	14.29%			Annual
			Largest 5-day cumulative rainfall	World Bank		Tabular data	The largest 5-day cumulative rainfall will be divided by the average monthly total rainfall.	High	14.29%			Annual
Sea level rise	High	16.25%	Current sea level (mm) Year-on-year sea level rise (mm)	NASA	Most of the municipalities and city in Oriental Mindoro have coastal areas. Seaweed is considered a high-value crop for Bulalacao. Sea level rise can increase the depth of water, reducing the amount of light to seaweeds and limiting their photosynthesis [source]	Tabular data	The current sea level and the linear relative sea level trend will be used as separate factors in the raster calculator for the Hazard score.	High	100%	Because seaweed is one of the high-value crops focused in the CVRIS project, it is highly relevant to include sea level rise in the vulnerability and risk assessment to investigate	Relative sea level trend data for the Philippines is available from the NOAA Tides and Currents portal. There are regular measurements from 5 stations: Manila, Legaspi, Cebu, Davao, and Jolo. Measurements can be downloaded as CSV files. Additionally, NASA also provides the sea level rise data from 1993 to 2020 in a text file. It provides the global mean sea level (GMSL) variation in mm with respect to 20-year TOPEX/Jason Collinear mean reference and various statistical measures with respect to the measurements such as the standard deviation in mm.	Annual

Theme	Sub-indicator Relevance	Sub-Indicator Weight	Indicator	Source of Data	Rationale	File Type	Data Processing & Sub-Indicator Score Computation	Data Relevance	Data Weight	Reason for relevance	Availability	Update Frequency
Temperature	High	16.25%	Monthly average temperature	World-Clim; PAGASA	Changes in temperature can affect the productivity and quality of crops	GIS file	Monthly average temperature will be aggregated for a year and used as input for the raster calculator in assessing the Hazard score.	High	16.67%	According to our field study, different parts of Oriental Mindoro already microclimatic conditions, and farmers have already recorded significant changes in average tempareture over the years.	Daily temperature data is available from the PAGASA DOST website and it is updated on a daily basis. However, this is only the weather forecast for Calapan City and it provides the high and low temperature measurements for the day (°C). However, this data will require custom web scraping scripts to extract. WorldClim also provides downscaled temperature data per decade from 1960 to 2018 in raster format. The spatial resolution is 2.5 minutes (~21 km2). The variables available are average minimum temperature (°C), average maximum temperature (°C) and total precipitation (mm).	Monthly
			Maximum daily temperature	World Bank		Tabular data	The maximum daily tetmperaturer will be divided by the annual average temperature.	High	16.67%		Currently, the data available from the Word Bank are projections.	Annual
			Minimum daily temperature	World Bank		Tabular data	The minimum daily tetmperaturer will be divided by the annual average temperature.	High	16.67%			Annual
			Number of hot days >35°C	World Bank		Tabular data	This will be divided by 31 to get the proportion of days within a month.	High	16.67%			Annual
			Number of hot days >40°C	World Bank		Tabular data	This will be divided by 31 to get the proportion of days within a month.	High	16.67%			Annual
			Number of tropical nights (>20°C)	World Bank		Tabular data	This will be divided by 31 to get the proportion of days within a month.	High	16.67%			Annual

Exposure (25%)

Exposure (E) assesses the presence of people, livelihood, species, ecosystems, services, and infrastructure, socioeconomic and cultural assets in places and settings that could be adversely affected. Unlike the alternative exposure definition, this definition has an explicitly spatial dimension and refers to a location where lives and assets are potentially affected by a hazard.

The following steps will be done in computing for the Exposure Indicator score:
1. The values for each variable will be computed for each geographical unit and rescaled to values between 0 and 1.
2. There will be separate Critical Value Chain Infrastructure score and Farms score for each high-value crop because they have different value chain components. The 4 or 5 crop-specific scores will be rescaled to values between 0 and 1, and then averaged to get the final Critical Value Chain Infrastructure score and Farms score.
3. The Exposure Indicator score for each administrative shapefile or geographical unit will be the weighted average of all rescaled variable scores computed using zonal statistics or raster calculator.

Table C.2: Exposure-related indicators to be used for CVRIS

Indicator / Sub-indicator	Sub-indicator Relevance	Sub-Indicator Weight	Data	Source of Data	Rationale	File Type	Data Processing & Sub-Indicator Score Computation	Data Relevance	Data Weight	Reason for relevance	Availability	Recommended Update Frequency
Road network	High	20%	Percentage of road segments exposed to hazards (Computed by road category)	OpenStreet-Maps	A reliable road network is critical in maintaining the productivity of a crop's value chain (e.g. farm-to-market roads). They are also essential in assessing the connectivity of an area in cases of severe calamity. Losing access to critical infrastructure can trap and incapacitate poor farmer communities. A road segment is a stretch of street or road between two road intersections.	GIS file	OSM data can be downloaded and stored in a spatial database. The road networks are encoded as LINESTRING geometric shapes. The road segments can be counted and labeled based on the hazards intersecting with the location of the road segment. Road categories can be primary, secondary, tertiary, residential, track, service, or unclassified. A score will be computer for each hazard (flood, landslide, typhoon) and aggregated.	High	33%	Crops are volatile and perishable products once harvested. Transporting these harvested crops within the optimial time frame is key to getting the best value for the products. However, due to the hazards present in Oriental Mindoro, roads become congested when flooding occurs. Delivery trucks may end up stuck in standstill traffic for days.	OpenStreetMaps have road networks in vector geospatial format. The Philippine data is available for download from the Geofabrik download server and may be loaded into a PostGRE SQL database with a PostGIS extension.	Annual or when new road projects are completed or when new hazard maps are created
			Total length of road exposed to hazards (Computed by road category)			GIS file	OSM data can be downloaded and stored in a spatial database. The road networks are encoded as LINESTRING geometric shapes. Using geospatial computational techniques, the length of the road segments can be computed from end to end using the longitude and latitude. There are available formulas on calculating the earth distance from longitude and latitude pairs. Road categories can be primary, secondary, tertiary, residential, track, service, or unclassified. A score will be computer for each hazard (flood, landslide, typhoon) and aggregated.	High	33%		OpenStreetMaps have road networks in vector geospatial format. The Philippine data is available for download from the Geofabrik download server and may be loaded into a PostGRE SQL database with a PostGIS extension.	
			Number of people living nearby exposed road segments	CBMS	Aside from counting the number of exposed roads, it is also important to count the number of people who might be affected when these roads become inaccessible because of these hazards.	Tabular data	The number of people living within a 50m radius will be counted.	High	33%	The people living near these road segments are directly affected and cutoff from essential services and immediate help during a disaster.		Annual or synced with National Census

Indicator / Sub-indicator	Sub-indicator Relevance	Sub-Indicator Weight	Data	Source of Data	Rationale	File Type	Data Processing & Sub-Indicator Score Computation	Data Relevance	Data Weight	Reason for relevance	Availability	Recommended Update Frequency
Critical Government Infrastructure	High	20%	Number of exposed hospitals	OpenStreet-Maps	Hospitals are critical government infrastrucure during calamities. Having nearby hospitals that are left unexposed to disasters are critical in ensuring the health of poor households.	GIS file	OSM data can be downloaded and stored in a spatial database. The buildings, or points of interest (POI) are stored as POINT or POLYGON shapes. Specific building structures can be extracted according to the amenity tags and other Philippine-specific tags set by OSM mapping conventions. Exposed infrastructures will be counted based on the number of infrastructures found within areas that susceptible to the different hazards listed above. Different numbers per hazard will be counted. Then, the proportion will be computed against the total number of infrastructures per type.	High	18.33%	Hospitals are critical government infrastrucure during calamities. Having nearby hospitals that are left unexposed to disasters are critical in ensuring the health of poor households.	OpenStreet-Maps contains the building footprints of the physical structures in Oriental Mindoro. The buildings are also tagged according to their use or category. For a list of the tags and mapping conventions used in the Philippines, refer to this page.	Annual or when new developments and infrastructure projects are completed
			Number of exposed evacuation centers		Having access to nearby evacuation centers provide an important safety net for poor households. If households are in disaster-prone areas, it is more important that they have direct access to evacuation centers to help them prepare for recovery.	GIS file		High	18.33%	Having access to nearby evacuation centers provide an important safety net for poor households. If households are in disaster-prone areas, it is more important that they have direct access to evacuation centers to help them prepare for recovery.		
			Number of exposed water processing and supply centres (groundwater wells, refilling centers)		Continuous access to water is crucial in surviving disasters.	GIS file and or tabular data		High	18.33%	Continuous access to water is crucial in surviving disasters.	If not available in OpenStreet-Maps, this will be requested from the infrastructure inventory of the provincial and local governments.	
			Number of exposed power transmission and distribution facilities		The robustness of the power grid can help ensure that everyone will still have access to electrivity even during disasters.	GIS file and or tabular data		High	18.33%	The robustness of the power grid can help ensure that everyone will still have access to electrivity even during disasters.	If not available in OpenStreet-Maps, this will be requested from the infrastructure inventory of the provincial and local governments.	

Indicator / Sub-indicator	Sub-indicator Relevance	Sub-Indicator Weight	Data	Source of Data	Rationale	File Type	Data Processing & Sub-Indicator Score Computation	Data Relevance	Data Weight	Reason for relevance	Availability	Recommended Update Frequency
			Number of exposed markets		Markets are important actors and infrastructure in a crop's value chain. Having less exposed markets can ensure continuous economic activity.	GIS file		High	18.33%	Markets are important actors and infrastructure in a crop's value chain. Having less exposed markets can ensure continuous economic activity.	OpenStreetMaps contains the building footprints of the physical structures in Oriental Mindoro. The buildings are also tagged according to their use or category. For a list of the tags and mapping conventions used in the Philippines, refer to this page.	
			Number of exposed wastewater treatment plants		Wastewater treatment plants are important in ensuring that pollutants are removed from industrial wastewater that gets streamed back to natural bodies of water. Less exposed wastewater treatment plants means less pollutants can leak back to the environment.	GIS file and or tabular data		Medium	8.33%	Wastewater treatment plants are important in ensuring that pollutants are removed from industrial wastewater that gets streamed back to natural bodies of water. Less exposed wastewater treatment plants means less pollutants can leak back to the environment. The relevance is set to medium because there are only a few industrial plants in Oriental Mindoro aside from crop processing centers.	If not available in OpenStreetMaps, this will be requested from the infrastructure inventory of the provincial and local governments.	

Indicator / Sub-indicator	Sub-indicator Relevance	Sub-Indicator Weight	Data	Source of Data	Rationale	File Type	Data Processing & Sub-Indicator Score Computation	Data Relevance	Data Weight	Reason for relevance	Availability	Recommended Update Frequency
Critical Value Chain Infrastructure	High	20%	Number of exposed farms	OpenStreetMaps	For value chain assessment	GIS file	OSM data can be downloaded and stored in a spatial database. The buildings, or points of interest (POI) are stored as POINT or POLYGON shapes. Specific building structures can be extracted according to the amenity tags and other Philippine-specific tags set by OSM mapping conventions. Exposed infrastructures will be counted based on the number of infrastructures found within areas that susceptible to the different hazards listed above. Different numbers per focus crop and hazard will be counted. Then, the proportion will be computed against the total number of infrastructures per type. When aggregated, they will be weighted by the focus crop's total harvested area divided by the total harvested area for all focus crops.	High	16.67%	These facilities are critical to the value chain assessment of the crops. Farms are the source of the crops when planted, while the processing facilities, nurseries, and other storage facilities are where the harvested crops will be stored. There are facilities that are also exposed to the different identified hazards present in Oriental Mindoro. Processed products from the raw crops have more value and is also part of the initiatives of Oriental Mindoro to improve their agriculture sector.	If not available in OpenStreetMaps, this will be requested from the infrastructure inventory of the provincial and local governments. Other value chain components can be added upon validation and request of the PTWG.	Annual
			Number of exposed processing facilities		For value chain assessment	GIS file		High	16.67%			
			Number of exposed agricultural nurseries		For value chain assessment	GIS file		High	16.67%			
			Number of exposed storage facilities		For value chain assessment	GIS file		High	16.67%			
			Number of exposed agricultural processors and producers		For value chain assessment	GIS file		High	16.67%			
			Number of exposed other physical assets related to the agriculture value chain to hazards		For value chain assessment	GIS file		High	16.67%			

Indicator / Sub-indicator	Sub-indicator Relevance	Sub-Indicator Weight	Data	Source of Data	Rationale	File Type	Data Processing & Sub-Indicator Score Computation	Data Relevance	Data Weight	Reason for relevance	Availability	Recommended Update Frequency
Settlements	High	20%	Proportion of residential area exposed to hazards	PGOM; OpenStreetMaps	Identifying the total residential areas exposed to disasters can estimate the amount of households that could be affected.	GIS file	Using the Land Use map, the amount of residential areas overlapping with areas susceptible to hazards will be calculated. A score will be calculated for each hazard.	High	33%	Settlements are where farmers live. Knowing their exposure is a critical sub-indicator of the assessment.	OpenStreetMaps contains the building footprints of the physical structures in Oriental Mindoro. The buildings are also tagged according to their use or category. For a list of the tags and mapping conventions used in the Philippines, refer to this page. CBMS data requested from LGUs (pending response from LGU)	Annual or when new developments and rezoning projects are completed.
			Number of households exposed to hazards	CBMS	Identifying the number of households exposed to disasters can estimate the number of people that could be affected.	Tabular data	Using the household locations from the CBMS data, the number of households that are within the susceptible areas will be counted. A score will be calculated for each hazard.	High	33%			
			Number of households who were evacuated at least once because of a hazard	CBMS	Counting the number of households that have a history of evacuation for a particular hazard can illustrate the realized risk of living in these susceptible areas.	Tabular data	Using the evacuation details of households from the CBMS data, the number of households that were evacuated at least once because of a hazard will be counted. A score will be calculated for each hazard.	High	33%			

Indicator / Sub-indicator	Sub-indicator Relevance	Sub-Indicator Weight	Data	Source of Data	Rationale	File Type	Data Processing & Sub-Indicator Score Computation	Data Relevance	Data Weight	Reason for relevance	Availability	Recommended Update Frequency
Farms	High	20%	Proportion of farmland area exposed to hazards	RS-BSA; PAO	Identifying the total farmland areas exposed to disasters can estimate the amount of productive arable land that could be affected.	GIS file	Using the Land Use map, the amount of farmland areas overlapping with areas susceptible to hazards will be calculated. A score will be calculated for each hazard.	High	33%	Simply knowing the proportion of farms exposed to hazards does not depict a complete picture of the province's vulnerability and risk. This sub-indicator computes the proportion of farmland area per high-value crop that is exposed for each hazard.	If not available in OpenStreetMaps, this will be requested from the infrastructure inventory of the provincial and local governments. We are also planning to request data on land deeds because those might contain coordinates of the different farmlands.	Annual or when new developments and rezoning projects are completed.
			Number of farmers exposed to hazards	CBMS	Identifying the number of farmer households exposed to disasters can estimate the number of farmers that could be affected.	Tabular data	Using the household locations from the CBMS data, the number of households with at least 1 member who works as a farmer and are within the susceptible areas will be counted. A score will be calculated for each hazard and focus crop.	High	33%	Aside from counting the total population and households that might be affected by hazards, it equally important in the context of the agricultural sector to also count the number of farmers that might be affected.	CBMS data requested from LGUs (pending response from LGU)	Annual or synced with National Census
			Proportion of harvested or productive farmland exposed to hazards	CBMS; PAO	Identifying the total farmland areas that are harvested or used to grow each focus crop, and are also exposed to hazards can estimate how much productive farmland could be affected.	GIS file	Using the farm layouts, the amount of harvested/productive farmland areas overlapping with areas susceptible to hazards will be calculated. A score will be calculated for each focus crop and hazard.	High	33%	Because not all farmland areas on a Land Use map is being used for growing crops, it is also important to calculate a score for farmlands that are actually used for each focus crop.	If not available in OpenStreetMaps, this will be requested from the infrastructure inventory of the provincial and local governments. We are also planning to request data on land deeds because those might contain coordinates of the different farmlands.	Annual or when new developments and rezoning projects are completed.

Sensitivity (25%)

Sensitivity (S) refers to the degree to which a system or species is affected (adversely in this case) by climate variability or change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea level rise).

The following steps will be done in computing for the Vulnerability Indicator score:

1. The values for each variable will be computed for each geographical unit and rescaled to values between 0 and 1.
2. There will be separate Soil Suitability score and Farms score for each high-value crop because they have different value chain components. The 4 or 5 crop-specific scores will be rescaled to values between 0 and 1, and then averaged to get the final Critical Value Chain Infrastructure score and Farms score.
3. The Exposure Indicator score for each administrative shapefile or geographical unit will be the weighted average of all rescaled variable scores computed using zonal statistics or raster calculator.

Table C.3: Sensitivity-related indicators to be used for CVRIS

Indicator / Sub-indicator	Sub-indicator Relevance	Sub-Indicator Weight	Data	Source of Data	Rationale	File Type	Data Processing & Sub-Indicator Score Computation	Data Relevance	Data Weight	Reason for relevance	Availability	Recommended Update Frequency
Livelihood	High	5.56%	Share of Households engaged in agriculture	CBMS	The agricultural sector is divided into farming, fishing and livestock. Determining the share of each sub-sector is important in quantifying sensitivity to future disturbances in productivity.	Tabular data	The number of households that engage in agricultural farming divided by the total number of households in the assessment area. This will be computed per crop.	High	20%	During a disaster, it is important to know how much of the total population will be affected in terms of agricultural output. It's also important to know how many in each agricultural sector can be affected.	CBMS data requested from LGUs (pending response from some LGU) On a household level, it collects information from each household member on demography, health and nutrition, housing conditions, water and sanitation, basic education, income and livelihood, peace and order, and government subsidies. In terms of agricultural information, it collects data from the farmer household about the area of agricultural land, tenure status, temporary and permanent crops, total harvest, and agricultural equipment and facility/structure. It also collects data about livestock and poultry raising as well as fishing activities.	Annual or synced with National Census
			Share of Households in agriculture with decreased crop harvested (by crop)	CBMS		Tabular data	The number of households that engage in agricultural farming but had decrease in total output divided by the total number of agricultural farming households in the assessment area. This will be computed per crop and hazard.	High	20%			
			Share of Households in agriculture with decreased livestock raised	CBMS		Tabular data	The number of households that engage in agriculture but had decrease in livestock output divided by the total number of agricultural households in the assessment area. This will be done per hazard.	High	20%			
			Share of Households engaged in fishing	CBMS		Tabular data	The number of households that engage in fishing divided by the total number of households in the assessment area.	High	20%			
			Share of Households engaged in livestock raising	CBMS		Tabular data	The number of households that engage in livestock farming divided by the total number of households in the assessment area.	High	20%			

Indicator / Sub-indicator	Sub-indicator Relevance	Sub-Indicator Weight	Data	Source of Data	Rationale	File Type	Data Processing & Sub-Indicator Score Computation	Data Relevance	Data Weight	Reason for relevance	Availability	Recommended Update Frequency
Economic	High	5.56%	Share of commerical agriculture in GDP (OM)	PGOM	The monetary contribution of the agriculture across different sectors is essential	Tabular data	Total output from commercial agriculture will be divided by the total economic output.	High	33%	It is also important to check how much of the province's GDP may be impacted by sudden disturbances in agricultural output.	Will be checked with and requested from the provincial government.	Annuak
			Share of agricultural export in GDP (OM)	PGOM		Tabular data	Total output from agriculture exports will be divided by the total economic output.	High	33%			
			Share of fishing in GDP (broken down into large-scale commerical versus artisanal) (OM)	PGOM		Tabular data	Total output from commercial fishing will be divided by the total economic output. Another will be that the total output from artisanal fishing will be divided by the total economic output.	High	33%			
Transportation	High	5.56%	Average distance of households from a nearby road	CBMS; OpenStreetMap	During a disaster, access to national roads allows households to evacuate to safer zones where they could wait and recover.	GIS file	Per assessment area, the distance from each household to their nearest road will be averaged.	High	50%	During a disaster, access to national roads and public transport allows households to evacuate to safer zones where they could wait and recover.	OpenStreetMaps have road networks in vector geospatial format. The Philippine data is available for download from the Geofabrik download server and may be loaded into a PostGRE SQL database with a PostGIS extension.	Static unless new routes are added
			Average number of accessible modes of public transportation	PGOM; LTFRB	During a disaster, access to public transport allows households to evacuate to safer zones where they could wait and recover.	Tabular data	Per assessment area, the maximum number of public transport modes (5-10km) that are accessible to each household will be computed.	High	50%		Will be requested from PGOM or LTFRB	Static unless new routes are added
House Construction	High	5.56%	Proportion of houses made of strong materials	CBMS	Materials used for home construction have different levels of endurance to different types of hazards and calamities. Houses and facilities with weaker materials would be easier to damage	Tabular data	Per assessment area, the number of houses built with strong materials will be counted and divided over the number of houses built with weak materials	High	100%	Materials used for home construction have different levels of endurance to different types of hazards and calamities. Houses and facilities with weaker materials would be easier to damage	CBMS data requested from LGUs (pending response from LGU)	Annual or synced with National Census

Indicator / Sub-indicator	Sub-indicator Relevance	Sub-Indicator Weight	Data	Source of Data	Rationale	File Type	Data Processing & Sub-Indicator Score Computation	Data Relevance	Data Weight	Reason for relevance	Availability	Recommended Update Frequency
Productivity	High	5.56%	Share of each crop in total agricultural ouput over total agricultural area	PGOM	This indicator will illustrate the relative impact of each crop per assessment area.	GIS and Tabular data	For the whole of Oriental Mindoro, the percentage share of the total production for each crop against the total agricultural output per assessment area will be computed.	High	33%	Different crops are affected depending on the area hit by disasters.	Will be requested from the provincial government.	Annual
			Total output per crop	PGOM; PAO	A separate count of total output per crop is important in estimating how each crop contributes to the overall vulnerability of the province.	Tabular data	Per assessment area, the total volume of harvested crops (in metric tons) will be calculated. This will be done per focus crop.	High	33%		Will be requested from the provincial government and LGUs	Annual
			Total harvested area that is suitable for growing each crop	PAO of OM	Each crop grows on soil that is most suitable for their growth. Mapping out areas that are suitable for each crop will help identify farm lands that are growing crops unsuitable on their land.	GIS file and or Tabular data	Using the crop suitability map and farm layouts per crop, the amount of harvested area that overlaps areas suitable for growing certain crops will be computed. For example, this sub-indicator checks the size of current calamansi farms that are on soil or land that are suitable for growing calamnsi.	High	33%	Crop suitability plays a big role in determining the vulnerability of an area because it describes how sustainable it is to continue growing the same high-value crop without much intervention.	Request lodged with the responsible agency (Agri-Info Hub) Need to request as well from the main DA office for access to shapefiles of crop suitability maps.	Annual if available

Adaptive Capacity (25%)

Adaptive capacity (AC) is the ability of the system to cope with, absorb and moderate damages, and rebound from the consequences of climate change.

The following steps will be done in computing for the Vulnerability Indicator score:

1. The values for each variable will be computed for each geographical unit and rescaled to values between 0 and 1.
2. There will be separate Soil Suitability score and Farms score for each high-value crop because they have different value chain components. The 4 or 5 crop-specific scores will be rescaled to values between 0 and 1, and then averaged to get the final Critical Value Chain Infrastructure score and Farms score.
3. The Exposure Indicator score for each administrative shapefile or geographical unit will be the weighted average of all rescaled variable scores computed using zonal statistics or raster calculator.

Table C.4: Adaptive Capacity-related indicators to be used for CVRIS

Indicator / Sub-indicator		Sub-indicator Relevance	Sub-Indicator Weight	Data	Source of Data	Rationale	File Type	Data Processing & Sub-Indicator Score Computation	Data Relevance	Data Weight	Reason for relevance	Availability	Recom-mended Update Frequency
Institution	Farmer association	High	5.56%	Proportion of farmers that are members	RS-BSA; CBMS	From the field work, it was noted how important association membership is for farmers to get access to financial and livelihood assistance.	Tabular data	This will be computed by dividing the number of farmers who are members of associations/cooperatives over the total number of farmers.	High	50%	Farmers who are members of the associations receive various support from the organization. However, those who are not members do not receive notifications or early warnings from the communication network of the association. Post disaster support is also not easily accessible for those who are not members.	Request lodged with the responsible agency (RSBSA and LGUs for CBMS)	Annual
				Share of house-holds with crop insurance	CBMS	Crop insurance is one entitlement that farmers can avail from banks to shsield them from potential financial losses after a disaster.	Tabular data	This will be computed by dividing the number of farmer households who have availed of crop insurance over the total number of farmer households.	High	50%		CBMS data requested from LGUs (pending response from LGU)	Annual or synced with National Census

Indicator / Sub-indicator		Sub-indicator Relevance	Sub-Indicator Weight	Data	Source of Data	Rationale	File Type	Data Processing & Sub-Indicator Score Computation	Data Relevance	Data Weight	Reason for relevance	Availability	Recom-mended Update Frequency
Infrastructure	Road network	High	5.56%	Share of paved roads in the road network	Open-Street-Maps	Having more house-holds that live far from the nearest roads and critical government and agricultural facilities will affect their access.	GIS file	The distances of each settlement to the nearest road and different critical infrastructures listed above will be com-puted and averaged at different levels of spatial granularity.	High	100%	Having more households that live far from the nearest roads and critical govern-ment and agricultural facili-ties will affect their access.	OpenStreetMaps have road networks in vector geospatial format. The Philippine data is available for download from the Geofabrik download server and may be loaded into a PostGRE SQL database with a PostGIS extension.	Annual or when new develop-ments and infrastruc-ture pro-jects are completed
	Access to power	High	5.56%	Proportion of house-holds with access to electricity	CBMS	Energy and power is needed to run certain tools and equipment for the maintenance of the farmlands.	Tabular data	Per assessment area, the total number of households with access to electricity will be computed and divided over the total number of households	High	100%	Energy and power is needed to run certain tools and equipment for the mainte-nance of the farmlands. Hav-ing no access to electricity delays recovery efforts.	CBMS data requested from LGUs (pending response from LGU)	Annual or synced with National Census
	Access to sanitation	High	5.56%	Proportion of house-holds with access to toilet	CBMS	Proper sanitation is important to ensure the health of the farmers and the environment.	Tabular data	Per assessment area, the total number of households with access to toilets will be computed and divided over the total number of households	High	100%	Proper sanitation is impor-tant to ensure the health of the farmers and the environment.		

Indicator / Sub-indicator		Sub-indicator Relevance	Sub-Indicator Weight	Data	Source of Data	Rationale	File Type	Data Processing & Sub-Indicator Score Computation	Data Relevance	Data Weight	Reason for relevance	Availability	Recom-mended Update Frequency
Communica-tion	Access to commu-nication devices	High	5.56%	Proportion of house-holds with access to commu-nication devices (posses-sion)	CBMS; Survey; PGOM; Open-street-maps; Ookla	Farmer rely on warnings from local government officials for incoming weather conditions and other important information. Having households with at least 1 communi-cation device allows them access to these warnings. The cellular towers and strength of communica-tion signal also affects the timely delivery and receipt of these warnings to ensure that farmers can make nec-essary preparations.	GIS file	Per assessment area, the number of households with at least 1 mobile device is counted and divided over the total number of households.	High	50%	Farmer rely on warnings from local government officials for incoming weather conditions and other important information. Having households with at least 1 communication device allows them access to these warnings. The cellular towers and strength of communication signal also affects the timely delivery and receipt of these warnings to ensure that farmers can make necessary preparations.	CBMS data requested from LGUs (pending response from some LGU) On a household level, it collects information from each household member on demography, health and nutrition, housing condi-tions, water and sanitation, basic education, income and livelihood, peace and order, and government subsidies. In terms of agricultural infor-mation, it collects data from the farmer household about the area of agricultural land, tenure status, temporary and permanent crops, total har-vest, and agricultural equip-ment and facility/structure. It also collects data about livestock and poultry raising as well as fishing activities.	Annual or when new develop-ments and infrastruc-ture pro-jects are completed
				Coverage of mobile network			GIS file	Using the signal strength data from Ookla, the average cellular data signal strength for each area will be computed.	High	50%			
	Access to agricultur-al equip-ment	High	5.56%	Proportion of farmers with access to agricultur-al equip-ment	PGOM; CBMS; Survey	Access to agricultural equipment like plow, hand tractor, and pesti-cide sprayer, can lead to production efficiency	Tabular data	Per assessment area, the number of farmers who own agricultural equipment and or live near a facility with rental agricultural equipment will be counted and divided over the total number of farmers.	High	100%	Access to agricultural equip-ment like plow, hand tractor, and pesticide sprayer, can lead to production efficiency		Annual or synced with National Census

Indicator / Sub-indicator		Sub-indicator Relevance	Sub-Indicator Weight	Data	Source of Data	Rationale	File Type	Data Processing & Sub-Indicator Score Computation	Data Relevance	Data Weight	Reason for relevance	Availability	Recom-mended Update Frequency
Finance	Access to credit / finance	High	5.56%	Share of farmers with bank accounts	Survey	Access to financial resources despite the lack of capital. This is essential to continue their farming activities as part of their recovery.	Tabular data	Per assessment area, the total number of farmer households that have any kind of bank account will be calculated and divided by the total number of farmer households.	High	33%	Access to financial resources despite the lack of capital. Knowing this is essential to assess their capacity to continue their farming activities as part of their recovery.	CBMS data requested from LGUs (pending response from LGU) On a household level, it collects information from each household member on demography, health and nutrition, housing conditions, water and sanitation, basic education, income and livelihood, peace and order, and government subsidies. In terms of agricultural information, it collects data from the farmer household about the area of agricultural land, tenure status, temporary and permanent crops, total harvest, and agricultural equipment and facility/structure. It also collects data about livestock and poultry raising as well as fishing activities. For income, an alternative source would be the Family Income and Expenditure Survey with the latest report provided by PSA in 2018. However, this survey is conducted only every 3 years and is published only on a national and regional scale.	Annual or synced with National Census
				Average amount of remittances received	CBMS		Tabular data	Per assessment area, the average amount received by households from remittances will be computed.	High	33%			
				Share of people per income range	CBMS		Tabular data	Per assessment area, the number of households that fall within a household income bracket will be counted.	High	33%			
Education	Access to education	High	5.56%	Net intake rate	CBMS; PGOM	Education is a critical determinant for an individual's income and skills across the workforce	Tabular data	Per assessment area, the number of students enrolled in Grade 1 (K-12) will be counted and divided by the total number of children from 6-7 years of age, since this is the age of entry to K-12 in the Philippines	High	16.67%	Education is a critical determinant for an individual's income and skills across the workforce.		Annual or synced with National Census
				Graduation rate	CBMS; PGOM		Tabular data	Per assessment area, the number of students who graduated from Grade 12 (K-12) will be counted and divided by the total number of enrolled students in Grade 12	High	16.67%			
				Primary completion rate	CBMS; PGOM		Tabular data	The number of students who completed primary school (Kindergarten to Grade 7) divided by the number of enrollments.	High	16.67%			
				Secondary completion rate	CBMS; PGOM		Tabular data	The number of students who completed secondary school (Grades 8 to 12) divided by the number of enrollments.	High	16.67%			
				Tertiary completion rate	CBMS; PGOM		Tabular data	The number of students who completed tertiary school (University/Vocational Schools) divided by the number of enrollments.	High	16.67%			
				Illiteracy rate	CBMS		Tabular data	Per assessment area, the illiteracy rate will be computed by sex.	High	16.67%			
Health	Access to health	High	5.56%	The number of health workers per 1,000 people	PGOM	Health is an important factor to be able to continue managing and tilling the land.	Tabular data	The number of health workers (i.e. doctors, nurses) will be calculated per 1,000 people.	High	50%	Households with sickly members are more vulnerable to future disasters.		Annual or synced with National Census
Health				Average distance to nearest health facility	Open-Street-Maps		Tabular data	The distances of each household to the nearest health facility (within 5km) will be computed and averaged at different levels of spatial granularity.	High	50%	Households that are far from any healthcare facility are more vulnerable to future disasters.	OpenStreetMaps contains the building footprints of the physical structures in Oriental Mindoro. The buildings are also tagged according to their use or category. For a list of the tags and mapping conventions used in the Philippines, refer to this page.	Annual or synced with National Census

Indicator / Sub-indicator		Sub-indicator Relevance	Sub-Indicator Weight	Data	Source of Data	Rationale	File Type	Data Processing & Sub-Indicator Score Computation	Data Relevance	Data Weight	Reason for relevance	Availability	Recom-mended Update Frequency
Health	Access to water	High	5.56%	Proportion of house-holds with access to clean water	CBMS; Survey	Water is an essential substance for all living organisms	GIS file	Per assessment area, the number of groundwater wells and water refilling stations will be identified. Then, the number of households within a 15-min walking distance from these water sources will be counted and divided over the total number of households. Redundant households will be removed from the final count.	High	100%	Water is an essential sub-stance for all living organisms		Annual or synced with National Census
Poverty	Unemploy-ment	High	5.56%	Proportion of unem-ployed members of the la-bor force	CBMS	High unemployment rates put more citizens at risk of non-recovery from future disasters.	Tabular data	The number of unemployment households will be divided by the total population segregated by sex and per barangay.	High	100%	Unemployment rates are important indicators for economic growth and func-tioning of communities.		Annual or synced with National Census
	Poverty	High	5.56%	Proportion of house-holds with income below poverty threshold	CBMS	High poverty rates put more citizens at risk of non-recovery from future disasters. This also equates to more people that will need longer assistance for subsistence to help in recovery efforts.	Tabular data	The number of households that fall below national poverty line will be counted and divided by the total number of households per assessment area.	High	100%	Although Oriental Mindoro has a relatively lower poverty incidence within MIMAROPA, poverty rate and extent of poverty are still important indicators to illustrate the vulnerability of the province to extreme weather events.		
	Food security	High	5.56%	Proportion of farmers growing crops and livestock for personal consump-tion	CBMS; Survey	Farmers may also plant crops for their personal consumption to avoid additional costs of purchasing from other sources	Tabular data	This will be derived from the boolean indicator whether a farmer have grows crops and manages livestock for their personal consumption. For each assess-ment area, the total number of farmers that do this will be divided by the total number of farmers in that area.	High	100%	Farmers may also plant crops for their personal con-sumption to avoid additional costs of purchasing from other sources. Having no other crop or livestock for food security increases their vulnerabilty.		

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