PATTERNS OF VULNERABILITY IN THE FORESTRY, AGRICULTURE, WATER, AND COASTAL SECTORS OF SILAGO, SOUTHERN LEYTE, PHILIPPINES

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MANILA OBSERVATORY

World Agroforestry Centre
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On behalf of

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

of the Federal Republic of Germany

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Patterns of Vulnerability in the Forestry, Agriculture, Water, and Coastal Sectors of Silago, Southern Leyte, Philippines

Manila Observatory
Gemma Teresa T. Narisma, May Celine T.M. Vicente, Emmi B. Capili-Tarroja, Faye Abigail T. Cruz, Rosa T. Perez, Raul S. Dayawon, Julie Mae B. Dado, Ma. Flordeliza P. Del Castillo, Marcelino Q. Villafuerte II, Leonard Christian G. Loo, Deanna Marie P. Olaguer, Ma. Antonia Y. Loyzaga

World Agroforestry Centre
Ma. Regina N. Banaticla-Altamirano, Lawrence T. Ramos, Christine Marie D. Habito, Rodel D. Lasco

Edited by: Joel T. Maquiling

On behalf of
Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
of the Federal Republic of Germany

The **Manila Observatory (MO)** is a scientific research institution established by the Jesuit order in the Philippines with over a hundred forty-five years of service in the fields of atmospheric and earth science. It advocates a science-based approach to sustainable development and poverty reduction through its principal focus on the areas of climate change and pre-disaster science. The Observatory actively confronts these challenges through investments and partnerships in scientific research which must inform and guide a safe and sustainable future for humankind.

The World Agroforestry Centre (ICRAF) is part of the alliance of the Consultative Group on International Agricultural Research (CGIAR) centres dedicated to generating and applying the best available knowledge to stimulate agricultural growth, raise farmers' incomes and protect the environment**.** ICRAF combines excellence in scientific research and development (R&D) to address poverty, hunger and environmental needs through collaborative programs and partnerships and is proud to be part of a multi-sector effort to promote agroforestry in the Philippines, especially among swidden agriculturists (slash-and-burn farmers) and upland farmers.

The **Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)**, is a federally-owned enterprise that supports the German government in the field of international development cooperation. For more than 30 years now, GIZ has been cooperating with Philippine partners in strengthening the capacity of people and institutions to improve the lives of Filipinos in this generation and generations to come. Together we work to balance economic, social and ecological interests through multi-stakeholder dialogue, participation and collaboration.

Cover Photo: Emmi Capili-Tarroja

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- Municipal Planning and Development Coordinator's Office (MPDC)
- Municipal Agricultural Office (MAO)
- Municipal Environment and Natural Resources Office (MENRO)
- Municipal Health Office (MHO)

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- National Economic and Development Authority (NEDA)
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- Regional Environment Information System (REIS)
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- Provincial Planning and Development Office (PPDO)

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FOREWORD

It is often said that climate change is an issue that requires global solutions and local actions. The Philippine Strategy on Climate Change Adaptation (PSCCA) picks up this principle by calling for an enabling environment for mainstreaming climate change adaptation based on a decentralized framework of good governance. It also calls for the establishment of credible science-based information linked to community knowledge on climate change and climate change adaptation at scales relevant to decision-makers and practitioners. The National Framework Strategy on Climate Change likewise gives a policy directive of building the adaptive capacity of communities and resilience of ecosystem to climate change.

The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) advocates the mainstreaming of climate change adaptation in development processes. Part of that is the integration of adaptation into local development planning by using and enhancing existing planning instruments and frameworks with a perspective of climate change. Through the Department of Environment and Natural Resources and GIZ joint project "Adaptation to Climate Change and Conservation of Biodiversity (ACCBio)," we had the opportunity to work together with local government units in mainstreaming climate change adaptation in the Comprehensive Land Use Plan (CLUP) prepared by municipal governments. The CLUP guides the growth and sustainable development of municipal governments by considering all sectors significant in the development process within the territorial jurisdiction. As a tool that reflects the development goals of the local community, the CLUP is a key instrument for analysis of local development policies and programs with regard to the risks and opportunities that climate change poses, and identifying measures to tackle these changes. The opportunity to support the Municipality of Silago, Southern Leyte in updating its CLUP presented an exceptional and welcome prospect for integrating CCA in the local development context. This provided the link to the local level of the mostly national-level interventions of the ACCBio Project through the introduction of the instrument of 'Climate Proofing for Development' developed for the Philippine context with the Environmental Management Bureau of DENR.

This publication is a contribution to action at the level of governance where impacts of climate change and the need for adaptation are inseparable. It presents the results of the impact analysis and vulnerability assessment to climate change of the forestry, water, agriculture and coastal sectors of the Municipality of Silago, Southern Leyte, as an input to the sectoral studies of the CLUP. The Manila Observatory and the World Agroforestry Center ICRAF with contributions from the State Universities in the region and the regional government agencies provided the science on which adaptation planning can be based. The Municipality of Silago, with the assistance of the DENR-GIZ ACCBio Project and the Environment and Rural Development (EnRD) Program, then took on the challenge of integrating this in the revision of the CLUP.

The goal of the PSCCA is to build the capacity of communities to adapt to climate change and increase the resilience of natural ecosystems to climate change. We hope to have contributed a small but significant part to this endeavor.

MABUHAY TAYONG LAHAT!

Bernd M. Liss

DR. BERND-MARKUS LISS
Principal Advisor, ACCBio Project

MESSAGE FROM THE MAYOR OF SILAGO

Silago has observed the changes in climate in recent years, being subject to unpredicted weather extremes that triggered damages in the productive sectors and threatened the livelihoods and well-being of our local communities.

In order to address the challenges presented by a changing climate and prepare for adaptation to the impacts of climate change, we have taken the opportunity offered by GIZ to support the Municipality in the development of a climate proof Comprehensive Land Use Plan (CLUP). With the assistance of the ACCBio Project in coordination with the ENRD Program, we were in a position to assess our water, agriculture, forestry and coastal sectors with regard to climate change impacts, to analyze the vulnerabilities and to elaborate options for improved resilience and adaptation to climate change at the local level and integrate them into our CLUP. This report documents the scientific inputs of Manila Observatory and ICRAF, PIK in this process to integrate climate change adaptation into our local development planning.

In this regard, let me thank and congratulate all local government agencies and key stakeholders for their commitment and tireless efforts towards a local planning that responds to the challenges of climate change. Thanks to the support of GIZ, we are now confident that our CLUP will provide a good basis for future development of the Municipality of Silago to make our programs and projects more adaptive to the impacts of climate change, thus more sustainable.

DAGHANG SALAMAT KANINJONG TANAN! Mabuhay!

HON. MANUEL A. LABRADOR, SR.
Municipal Mayor
Silago, Southern Leyte

MESSAGE FROM THE EXECUTIVE DIRECTOR OF THE MANILA OBSERVATORY

On behalf of the Manila Observatory, I wish to extend our sincerest congratulations and deep appreciation to all who have been part of this breakthrough work on patterns of vulnerability. This work is intended to enhance the capacities of coastal communities, as politico-ecological units, in confronting the unique challenges and opportunities posed by climate change. This publication represents a milestone in the achievement of our shared objective, namely, to address vulnerability by establishing the foundation for evidence-based policies in local governance.

The Manila Observatory wishes to thank the Municipality of Silago, the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and the World Agroforestry Center (ICRAF) for the privilege of being able to work on this unique collaborative opportunity. In particular, we wish to extend a special thanks to Hon. Manuel A. Labrador, Sr., his hospitality and the generosity of time and spirit he showed our teams during the course of the project. Moreover, we wish to express our sincerest appreciation to Dr. Bernd-Markus Liss and Ms. Agnes Balota of GIZ for their unwavering support, and to Dr. Rodel Lasco for contributing his valuable time and expertise. Lastly, I wish to acknowledge the hard work and leadership of Dr. Gemma T. Narisma and the vital contributions provided by Ms. Deanna Marie Olaguer and the entire Manila Observatory team.

It is hoped that Silago, the Province of Southern Leyte and other coastal communities may use this results of this collaboration in their search for ways to significantly overcome these patterns of vulnerability and achieve resilience in response to our changing climate.

MS. MA. ANTONIA YULO LOYZAGA
Executive Director
Manila Observatory

MESSAGE FROM THE DIRECTOR OF THE WORLD AGROFORESTERY CENTER (ICRAF)

The World Agroforestry Centre (ICRAF) exists to help smallholder farming communities develop their crops and manage their agricultural landscape in a more sustainable way. Being largely dependent on natural ecosystems and climate conditions for productivity often leaves these communities vulnerable to the brunt of climate variability and extremes which are expected to intensify as the climate changes. Thus, they are among the sectors who require locally-suited adaptation and climate-proofing mechanisms with minimal investment costs.

ICRAF and its partners like GIZ and the Manila Observatory have in many occasions echoed the need to come up with locally-suited climate change adaptation interventions. This document is an instance of that call. It examines the vulnerability patterns in the forestry, agriculture, water and coastal sectors in the Municipality of Silago, Southern Leyte with the end aim of providing guidance to policy makers in the drafting of an updated and climate-informed Comprehensive Land Use Plan (CLUP).

The CLUP is a key instrument with how good governance, land use and natural resources are interfaced with climate. With a CLUP designed with climate vulnerability in mind, we hope that the local government of Silago would be in a better position to address its climate-related problems.

Well wishes to a more sustainable Silago!

DR. RODEL D. LASCO
Director
World Agroforestry Centre

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EXECUTIVE SUMMARY

The Study

For developing countries that are highly vulnerable to climate change such as the Philippines, sound information on climate and its potential impacts need to be made available in a timely manner to enable decision- and policy makers to formulate the appropriate adaptation measures to climate risks. The Potsdam Institute for Climate Impact Research, PIK, in cooperation with the German Technical Cooperation, GTZ, developed an interactive web-based platform called CI:Grasp (**C**limate **I**mpact: **G**lobal and **R**egional **A**daptation **S**upport **P**latform), which provides information on climate change, its physical and socio-economic impacts, and adaptation options and experiences from across the world. The objective of the study is to conduct a case study on the patterns of vulnerability and impacts of climate change on the forestry, water, agriculture and coastal sectors of Silago, Southern Leyte, Philippines.

The process involved: 1) the identification and definition of impacts and typical patterns of vulnerability of the four identified sectors to climate change and climate change variability; 2) regional climate modeling to provide background and future climate profiles for Silago, Southern Leyte, 3) identification of crucial data and information for each sector for impacts and vulnearbility analysis, and 4) identification of the different physical and socio-economic variables that affect vulnerability, visualized through influence diagrams and impact chains. Consultations with local stakeholders in the municipality of Silago were conducted to validate the identified patterns, which could serve as basis for the formulation of appropriate adaptation options for each sector in the municipality's Comprehensive Land Use Plan.

The Study Area

The 4th class Municipality of Silago is one of the nineteen municipalities of Southern Leyte, located on the eastern side of Region VIII (Eastern Visayas). Climate is classified as Type II, characterized by no distinct dry season and a very pronounced maximum rainfall period from November to February. The municipality is generally mountainous in the hinterlands and plain to sloping near the coasts. The 15 barangays that make up the municipality are largely rural, with fishing and agriculture as the major source of livelihood, and rice and coconut as the major products. Included in the Municipality's identified development needs are insufficient social services (health, education and access to safe water), low income and few livelihood opportunities, and low agricultural productivity. Recently land transportation has improved significantly with the construction/paving of a national road which now directly links the municipality to the provincial capital.

Climate Projections

Climate projections for Silago were done using a regional climate model that downscaled the A1B scenario of the ECHAM5 global climate model to a resolution of 20km. Modeled historical climate was validated using ground observation data and results showed that the model was able to capture observed historical trends and seasonal variability. Projected climate changes for Silago indicate: a) a slight increase in mean rainfall for the dry season of 2020s and a decrease for all the other seasons. By the 2050s, mean rainfall is projected to decrease throughout the year with up to 25% decline in the dry season; b) as much as 2.2 deg Celsius increase in average temperature which may be expected during the warm dry months (of April & May) during the 2050s; c) warmer days and warmer nights are anticipated in the 2020s and 2050s. This is indicated by the rightward shifts, i.e. shifts into higher values, in the extremes (the lower and upper tails) of the probability distribution functions of the daily minimum and maximum temperatures; d) extremely high maximum and minimum temperatures (90th Percentile of the baseline period: 1961 to 1990) could last throughout the year in the 2050s; and e) consecutive dry days can occur for more than two months with fewer instances of month-long consecutive wet days in the future.

Forest Sector Climate Impacts and Key Vulnerabilities

The municipality has high forest cover relative to other parts of the island; dipterocarp forest remnants are now generally found in localities where large-scale logging was not profitable and where access was hampered by the difficult terrain. Deforestation in recent years can be attributed to the clearing of forests for commercial and marginal upland agriculture, and non-timber plantation establishment. Coconut plantations dominate low-lying areas and are the usual end land use to forestlands after clearing and annual crop cultivation. Five out of the 15 barangays of the municipality are situated in the hilly to mountainous interior where these forest remnants are found. Currently, four barangays are involved in a community –based forest management (CBFM) program. Forest cover loss over the last decade based on land cover change analysis using remotely-sensed data is considered minimal. There is evidence of increasing fragmentation, giving way to islands of scrubland and urban areas. Among the current important drivers of deforestation and degradation are the expansion of farming activities in forest lands; the current scarcity of timber in the region in the face of increasing demands for wood which could drive illegal logging activities, and road construction. A better understanding of how these threats operate at the local scale is needed.

Future changes in climate could induce productivity gains in forest areas where water is not limiting, and increases in productivity are not offset by deforestation or novel fire regimes. Strong warming, on the other hand (the trend predicted for Silago) and its accompanying effects on water availability could potentially induce drought conditions and negatively affect vegetation. A warming trend is also predicted to increase the likelihood of more fire disturbances. For Silago, climate change projections include a greater warming inland, where most of the forest land are located; these would have important implications to forest protection and production activities. While CBFM project sites will be among the areas that will be strongly affected by these changes in temperature and rainfall, attention should also be given to forest edges where most disturbances are occurring. Communities situated in the forest lands are vulnerable to the impacts of climate due to their poverty and high degree of dependence on forests for livelihood.

Water Sector Climate Impacts and Key Vulnerabilities

Silago`s forests provide important hydrological services availed not only by local residents but by adjacent municipalities. Hydrological analysis shows that the Municipality's river systems under average rainfall conditions can very well supply irrigation needs. There is a potentially large supply of water .In the context of the Municipality`s dependence on springs for both domestic use and irrigation needs, a continuing decrease in forest cover may result in the long-term to decreased aquifer recharge, spring flow and base flow and instead lead to increased runoff production, erosion and siltation. However, climate-sensitive variables are also present, particularly 1) the incidence of enteric waterborne diseases, and 2) water siltation. Incidence of enteric waterborne diseases can be exacerbated by the presence of favorable climatic (i.e. temperature, moisture) and other environmental conditions. Meanwhile, siltation – although also greatly affected by land use change – is aggravated by climate stimuli such as increase in rainfall, strong winds and occurrence of extreme climate events. An urgent need of the hydro-forest sector is the establishment of an improved distribution network to maximize the use of the currently underutilized water resources.

Agriculture Sector Climate Impacts and Key Vulnerabilities

Agriculture in Silago is extremely vulnerable to the projected negative impacts of climate change. Most of the changes in the different climate variables analyzed, such as changes in minimum temperatures, rainfall decreases especially during the wet season, will have adverse effects on rice yield. More importantly, the adverse effects of global warming on rice production will have serious socio-economic consequences given that rice is the most important food and commodity of the municipality. There are, however, alternative crops that may be more resilient to climate impacts, specifically to the decrease in rainfall. Coconut and abaca appear to be less vulnerable to the effects of the strong 1997-1998 El Nino and cassava is considered to be a drought tolerant crop. Projected warming is higher inland where most of the forest lands are located. In contrast, the decrease in rainfall is more severe along the coastal areas where majority of the rice paddies located. Sea level rise will inundate the rice paddies along the coast and land loss can be as a high as 20% of the total rice paddy areas with a 4 meter increase in sea level.

Coastal Sector Climate Impacts and Key Vulnerabilities

There are about 100 registered fisherfolks as of September 2009 in 12 coastal barangays in Silago and most of the residents in the coastal communities are involved in fishing and aquaculture. Most of the barangays in Silago are also located along the coast, implying a high dependence on the coastal resources by the populace for food consumption, trade, and income. Potential changes in climate that will affect the various ecosystems in the coastal sector, including coral reefs, seagrass and seaweed beds, mangroves, estuaries, and beaches, will hence have corresponding socio-economic impacts on Silago. The projections for temperature in Silago showed increases in temperature in the coastal areas for both 2020 and 2050. These can translate to changes in the SSTs as land and sea temperatures interact. A small increase in SSTs will have big impacts on marine life and processes. It will affect coral reef productivity and will alter the impact thresholds of coastal organisms. The projected changes in rainfall, on the other hand, can affect changes in the fresh and salt water balance thereby affecting salinity and pH of ocean waters, which is a critical part of primary productivity. The compounding effects of temperature and rainfall increase will have impacts on the state of the coastal resources and the sustainability of the coastal communities in the municipality.

Risk Implications of Future Climate Changes in Silago

The risk to the impacts of global warming is not solely dependent on the exposed sectors and the climate hazards. It is also very much affected by social vulnerabilities and the capacity to adapt to the adverse impacts of climate change change. A qualitative assessment of the overall risks to climate change that Silago may face in the future was made based on available indicator data. The barangays of the municipality were categorized according to climate change impact, sectoral impact due to climate change and vulnerability/exposure indicators. The barangays that are found to be more at risk to the projected impacts of climate change are Hingatungan, Salvacion, Lagoma, Poblacion District 2 (Pob Dist 2), Poblacion District 1 (Pob Dist 1), and Katipunan. Hingatungan, which is a coastal barangay, is particularly at risk because of very high- and high climate change impacts on rainfall decrease and sea level rise, respectively; very high climate impacts on rice production, and high population density. The inland barangay of Katipunan on the other hand is more at risk due to very high increase in temperature, very high impacts on rice (given the proportion of non-irrigated rice and the combined impacts of warming and decrease in rainfall), high temperature impacts on forest, and high percentage of malnourished children. The relatively high risk to climate change in Pob Dist 2 is mainly due to exposure/vulnerability indicators. Pob Dist 2 has a very high population density and very high cases of malnourished children and these combined with high rainfall impacts on rice, and high climate hazards in terms of sea level rise and rainfall decrease puts the barangay at a relatively greater risk compared with the other barangays. These assessments, though are qualitative and are very much reliant on 1) the projected climate changes using a particular regional climate model and scenario and 2) on the available data obtained for this study.

I. INTRODUCTION

A. THE PHILIPPINES AND CLIMATE IMPACTS

Climate change literature consistently emphasizes that countries located in tropical areas are among the most susceptible to the impacts of climate change. Southeast Asia, in particular, with its fast-growing population and increasing dependence on natural resources and agriculture, has already been experiencing climate change-induced phenomena, aside from pre-existing climatic conditions and events (Lasco et al., 2011). The Intergovernmental Panel on Climate Change (IPCC) noted in its Fourth Assessment Report (AR4) that Southeast Asia has experienced an increase in average temperature by 0.1 to 0.3°C every decade between 1951 to 2000 (Cruz et al., 2007). Conversely, precipitation in the region has exhibited a generally decreasing trend between 1961 and 1998, with a decline in the number of rainy days.

The Philippines is an archipelagic country in Southeast Asia (Figure I.1) made up of over 7,000 islands and 36,289 kilometers of coastline (CIA, 2009). It is located in the western Pacific Ocean and along the Pacific Ring of Fire, making it highly vulnerable to both earthquakes and volcanic eruptions. Its location along the west Pacific Typhoon Belt also places the Philippines in a collision course with an average of 20 tropical cyclones each year, of which 8 or 9 make landfall (Cruz et al., 2007). The Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) has established that between 1951 and 2006, there have been an increasing number of hot days and warm nights, and a decreasing number of cold days and cool nights (Hilario et al., 2009). In addition, between 1971 and 2000, there was an observed increase in mean annual, maximum and minimum temperatures in the Philippines by 0.14°C every year (Cruz et al., 2007).

Climate-related disasters in the Philippines are on the rise, with losses affecting the national economy dependent on natural resources. Since 1990, the frequency of tropical cyclones entering the PAR has increased by 4.2 (Cruz et al., 2007). The two largest calamities of 2009 combined – Tropical Storm Ketsana ("Ondoy") and Typhoon Parma ("Pepeng") – resulted in agricultural losses worth PhP 10 billion (Go, 2009). In October 2010, Super Typhoon Megi ("Juan") devastated 19 provinces from four regions, claiming 36 lives and resulting in agricultural losses amounting to over PhP 8 billion. Climate change impacts are foreseen to worsen poverty, further increasing the vulnerabilities of about a third of the population still living below the poverty line and heavily dependent on natural resources for subsistence. It will also derail the country's efforts to achieve its full development potential due to the economic impacts of climate-related disasters.

B. THE CI:GRASP PROJECT

For developing countries that are highly vulnerable to climate change such as the Philippines, sound information on climate and its potential impacts need to be made available in a timely manner to enable decision- and policy-makers to formulate the appropriate mitigation and adaptation measures to climate risks. However such information is available mainly for global trends and developed countries, is scattered across many sources, and is often difficult or cumbersome to access. To address this problem, the Potsdam Institute for Climate Impact Research, PIK, in cooperation with the German International Cooperation, GIZ, developed an interactive web-based platform called ci:grasp *(**C**limate **I**mpact: **G**lobal and **R**egional **A**daptation **S**upport **P**latform)*. The platform contains three main information layers that can be freely accessed and are mainly visualized through maps:

1. Climate change stimuli parameter (like temperature, precipitation, wind, etc.),
2. Physical and socio-economic impacts (e.g. sea-level rise, changes in agricultural production, losses due to extreme events, etc.)
3. Adaptation options and experiences.

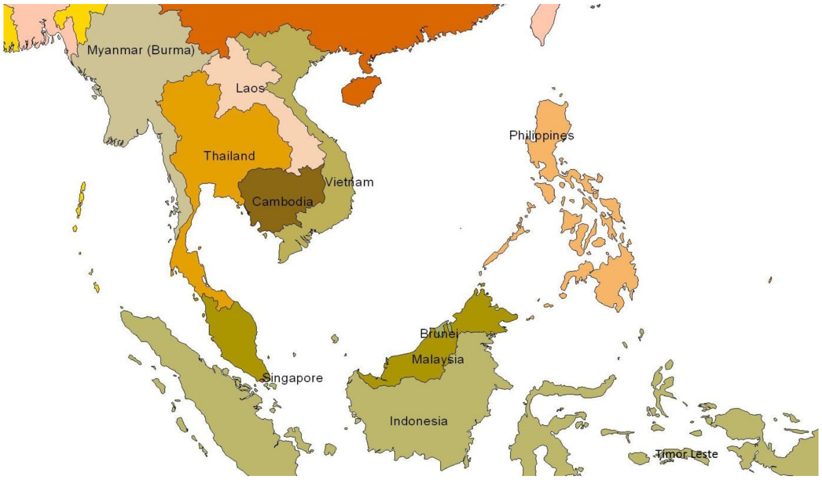

Figure I.1. *Map of Southeast Asia. Map generated by ICRAF.*

Through the latest Web 2.0 applications, adaptation experts and practitioners can provide feedback and add information through pre-structured web forms and geo-tags that will undergo quality control mechanisms.

The objective of the project is to conduct a case study on patterns of vulnerability (archetypes) and impacts of climate change on the forestry and water sectors of Silago, Southern Leyte, Philippines, as an input to CI-GRASP. This report aims to answer the following specific tasks:

1. Identify and define a limited number (2-3) of typical patterns (archetypes) of vulnerability (to climate change and climate change variability) and adverse impacts in the forestry and water sectors;
2. Describe the selected patterns of vulnerability (archetypes), including the impact of climate change, and provide for each archetype influence diagrams of relevant variables.
3. Identify and describe a set of indicators, which is capable of serving as proxies to the variables to quantify a given/defined archetype and its internal dynamics.
4. List possible data sources for the indicators and means of access to the data.

II. THE STUDY AREA: SILAGO, SOUTHERN LEYTE

A. BIOPHYSICAL PROFILE

The 4th class Municipality of Silago is one of the nineteen municipalities of Southern Leyte, located on the eastern side of Region VIII (Eastern Visayas) at coordinates 10°31’56” N and 125°9’56” E (Figure II.1). According to a recent perimeter survey conducted by the local government, Silago has a total land area of 21,995.13 hectares (ha)[1] and is bounded by the municipalities of Abuyog, Libagon and Hinunangan in the north, west and south, respectively (Figure II.2) (Draft CLUP, 2011). In the east, Silago is bounded by the Gulf of Leyte and the islands of Homonhon and Dinagat.

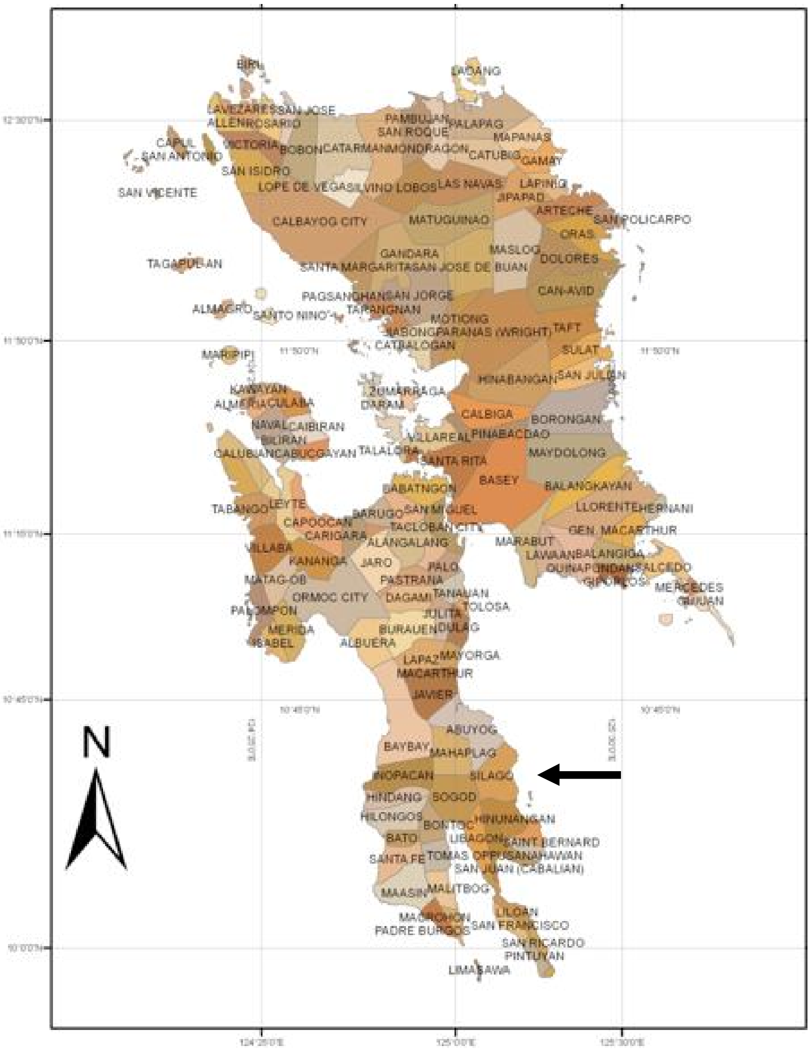

Figure II.1. Map of Region 8 – Eastern Visayas, Philippines. Map generated by ICRAF.

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[1] As of March 28, 2011, draft CLUP (2011) released by the MENRO states that the total land area of Silago is 21,995.13 ha, with 14,653.22 hectares (66%) determined for forest purposes, based on an actual perimeter survey conducted by the Municipal Implementing Team (MIT). However, data on land use classification are still to be reconciled with DENR official estimates before they can be considered final and authoritative.

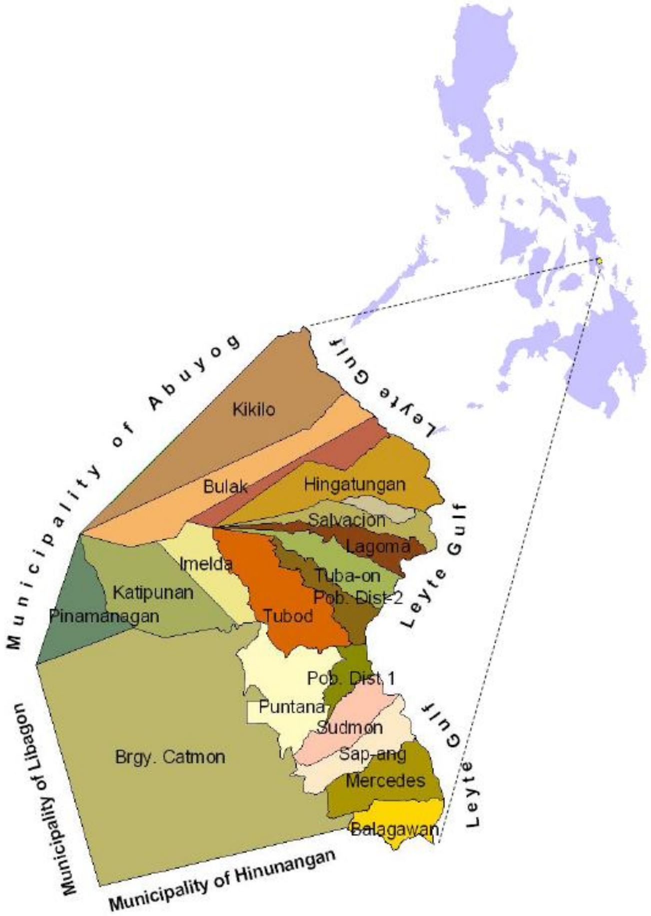

Figure II.2. *Map of the Municipality of Silago, Southern Leyte. Map generated by ICRAF.*

B. GEOLOGY, CLIMATE AND TOPOGRAPHY

The earth layers of Silago are made up of sedimentary and metamorphic rocks (Recent and Pliocene to Pleistocene) and igneous rocks (Miocene and older). About 84%of the municipality’s total land area is made up of Miocene and older rock systems. Meanwhile, Plio-Pleistocene series can be found in the south-west portion of the municipality, occupying about 15% of the municipality’s total land area. Recent deposits (Holocene series) cover the smallest amount of total land area (1%) concentrated in Poblacion Districts I and II, and are made up of unconsolidated fine sand, silt, clay with minor gravel-rich tuffaceous sediments.

Climate in Silago is classified as Type II. This climate type does not have a distinct dry season and experiences maximum rainfall in the period between November to February.

The topography of Silago is generally rolling to mountainous in the hinterlands and plain to slightly sloping near the coasts. The largest proportion of land is described as rolling to moderately steep, comprising 33% of Silago’s total land area (Table II.1).

Table II.1. *Land area by slope classification in the Municipality of Silago*[2].

Percent Slope (%)	Description	Land Area (ha)	Percent of total (%)
0-3	Level or nearly level to gently sloping	1,052	5%
3-8	Gently sloping to undulating	1,178	5%
9-18	Undulating to rolling	2,823	13%
18-30	Rolling to moderately steep	7,144	33%
30-50	Moderately steep to very steep	3,877	18%
>50	Very steep to precipitous	5,436	25%
	TOTAL	21,510	100%

Source: Silago CLUP, 2000

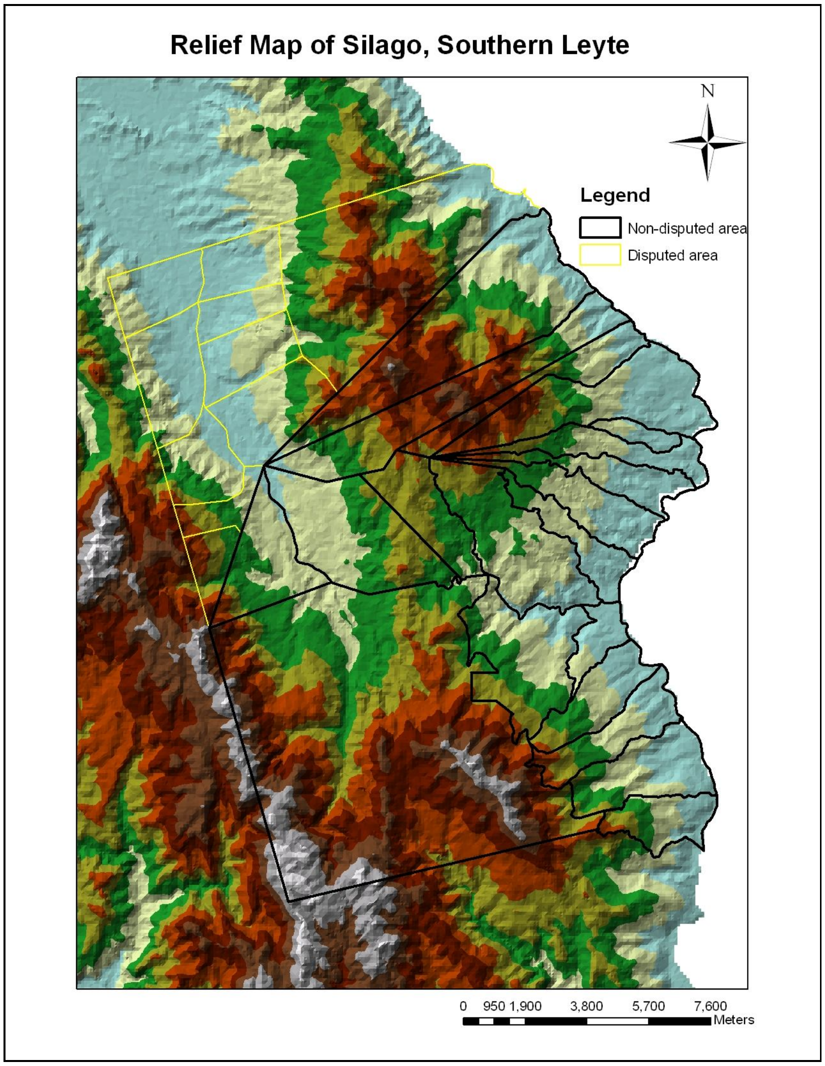

Figure II.3. *Relief map of Silago, Southern Leyte showing non-disputed and disputed land area. Map generated by ICRAF.*

Although anecdotal accounts reveal that the town rarely experiences climate extremes, its coastal barangays directly face the Pacific Ocean and are thus, prone to storm surge, typhoons and tsunami, while barangays in the mountains are prone to landslides and forest and bush fires.

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[2] Due to lack of updated estimates, land area by slope classification and total land area presented in the table were taken from the figures in the old CLUP (2000).

Figure II.4. *Boundary map of Silago showing national highway. Map generated by ICRAF.*

C. LAND USE

The Municipality of Silago is made up of 15 barangays, most of which are located along the coast. In terms of land use, more than half of the municipality's total land area is classified as forestland[3] (12,482 hectares) while another 8,363.11 hectares (38.88%) is used for agricultural production (Table II.2). Open grasslands occupy 2.3% of the municipality's land, with another 93 hectares (0.43%) housing the town's built-up areas, inclusive of residential, commercial and institutional areas, parks and open spaces, and transportation utilities. Other existing general land uses within the area are open water spaces, road networks and cemetery/memorial park.

Table II.2. *Land use classification in the Municipality of Silago[4].*

Classification	2009*(ha)
Agricultural land	8,363.11
Forest land	12,482.00
Built-up areas	93.00
Dumpsite	
Grassland/shrubland/pasture land	494.15
Mangroves/NIPA/fish ponds	
Beach sand	
Open water spaces	71.63
Road network	3.12
Cemetery/memorial park	3.00
TOTAL	21,510.00

*Source: *Municipal Ecological Profile, MPDO, 2009*

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[3] According to Philippine law, "forestlands" are lands within the public domain with a slope of 18% or higher, including those covering the foothills to the forest zone line, plateaus with elevations greater than 600 meters, and lands with more than 50% slope, which are categorized as protected forest. This definition however, does not distinguish the actual vegetative cover of an area.

[4] Due to lack of updated estimates, land area by land use classification and total land area presented in the table were taken from the figures in the old CLUP (2000) and the Municipal Ecological Profile (MPDO, 2009).

Silago's land resources can be subdivided into three broad land capability classes. Municipal records reveal that 12,197 hectares of land (57%) is classified as good land that is barely level and can be cultivated, but is shallow, drought-prone and has low soil fertility and slight alkalinity (BS) (Table II.3). This type of land is generally suited for legumes and tree crops. Another 5,436 hectares (25%) of land is moderately to very steep and excessively eroded, shallow, rough and dry for cultivation, and is considered best suited for forests (N). This type of land can also be used for grazing. The last 3,877 hectares is classified as very steep and severely to excessively eroded, shallow for cultivation and also best suited for forests (M).

Table II.3. *Land capability classes in the Municipality of Silago, by topographical and soil characteristics*[5].

Land Capability Class	Area (ha)	Percent of total area (%)
BS – Good land, barely level, can be cultivated, shallow, drought-prone and has low soil fertility and slight alkalinity, suited for legumes and tree crops	12,197	57%
N – Moderately to very steep land, excessively eroded, shallow, rough and dry for cultivation, best suited for forests, can also be used for grazing	5,436	25%
M – Very steep to precipitous land, severely to excessively eroded, shallow for cultivation, best suited for forests	3,877	18%
TOTAL	21,510	100%

Source: Municipal Ecological Profile, MPDO, 2009

The 2000 CLUP describes two dominant soil types in Silago based on records of the Bureau of Soils and Water Management: Guimbala-on clay and Laylay. Guimbala-on clay – composed of basaltic and andesite rocks – makes up approximately 99.5% of the total land area, while Laylay makes up the remaining 0.5% and can be found along shorelines bordering the coast of alluvial lands.

D. DEMOGRAPHIC PROFILE

Population

The urban portion of the Municipality of Silago is composed of three barangays: Poblacion Districts I and II, and Poblacion District III (Barangay Tubod). The rest of the barangays are considered rural. As of 2010, the urban population accounts for almost one-fourth of the total municipal population. Among the component barangays of Silago, Hingatungan had the largest population at 2,049, while Catmon had the smallest at 134 (Table II.4). Average annual growth rates from 2007 to 2010 (based on computations for this report) are considerably higher for populations in the barangays located in the mountainous interior.

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[5] Land area by land capability classes and total land area presented in the table were taken from the figures in the Municipal Ecological Profile (MPDO, 2009).

Table II.4. *Population by barangay in the Municipality of Silago, 2010 vs 2007.*

Barangay	Urban/ Rural	2010		2007		Average annual growth rate (%)
		Population	Percent of total	Population	Percent of total	
Pob. District I	Urban	1,071	8.50%	1,224	11.00%	-4%
Pob. District II	Urban	1,207	9.60%	1,007	9.00%	7%
Pob. District III (Tubod)	Urban	791	6.30%	839	7.50%	-2%
Balagawan	Rural	724	5.70%	727	6.50%	0%
Catmon	Rural	241	1.90%	134	1.20%	27%
Hingatungan	Rural	2,234	17.70%	2,049	18.40%	3%
Katipunan	Rural	645	5.10%	480	4.30%	11%
Laguma	Rural	781	6.20%	677	6.10%	5%
Mercedes	Rural	2,133	16.90%	1,767	15.80%	7%
Puntana	Rural	289	2.30%	171	1.50%	23%
Salvacion	Rural	610	4.80%	608	5.40%	0%
Sap-ang	Rural	681	5.40%	551	4.90%	8%
Sudmon	Rural	466	3.70%	315	2.80%	16%
Tuba-on	Rural	472	3.70%	438	3.90%	3%
Imelda	Rural	265	2.10%	176	1.60%	17%
TOTAL		12,610	100.00%	11,163	100.00%	

Sources: Silago Draft CLUP, 2011, NSO Census 2007

In 2010, Silago had a population of 12,610 and a land area of 215.10 square kilometers, resulting in an average population density of about 59 per square kilometer. Among all the barangays, Poblacion District I had the highest population density at 315 per square kilometer, followed by Mercedes with 188 per square kilometer (Table II.5).

Table II.5. *Population, land area and population density by barangay in the Municipality of Silago as of 2010.*

Barangay	Population	Land area		Population density (persons/km^2)
		ha	km^2	
Pob. Dist.I	1,071	340	3.4	315
Pob. Dist.II	1,207	710	7.1	170
Pob. Dist.III (Brgy. Tubod)	791	1,740	17.4	45
Balagawan	724	1,095	10.95	66
Catmon	241	8,475	84.75	3
Hingatungan	2,234	1,555	15.55	144
Katipunan	645	960	9.6	67
Laguma	781	580	5.8	135
Mercedes	2,133	1,135	11.35	188
Puntana	289	804	8.04	36
Salvacion	610	900	9	68
Sap-ang	681	740	7.4	92
Sudmon	466	885	8.85	53
Tubaon	472	575	5.75	82
Imelda	265	1,016	10.16	26
TOTAL	12,610	21,510	215.1	59

Sources: Silago Draft CLUP, 2011, MPDO, 2009

Households

Actual data gathered for the 2011 CLUP indeed revealed an increase in number of households in the Municipality, from 1,661 households in 1995 to 2,892 in 2010. Average household size in 2010 has remained constant relative to 1995 data, indicating that the increase in population was from the formation of new households rather than expansion of existing ones (Table II.6).

Table II.6. *Population, number of households and average household size in Silago by barangay, as of 2010.*

Barangay	Population	No. of Households	Average household size
Pob. District I	1,071	278	4
Pob. District II	1,207	304	4
Pob. District III (Brgy. Tubod)	791	212	4
Balagawan	724	210	3
Catmon	241	36	7
Hingatungan	2,234	465	5
Katipunan	645	113	6
Laguma	781	157	5
Mercedes	2,133	496	4
Puntana	289	76	4
Salvacion	610	151	4
Sap-ang	681	155	4
Sudmon	466	96	5
Tubaon	472	94	5
Imelda	265	49	5
TOTAL	12,610	2,892	4

Source: MPDO, 2010

E. SOCIOECONOMIC PROFILE

Local Economy and Business

Agriculture and fisheries

Agricultural and fisheries activities are the main sources of livelihood and income in Silago. According to the CBMS Survey (2006), 1,317 individuals were engaged in agricultural activities. This translates to just under half of the employed members of Silago's labor force numbering 2,771 people (CBMS Survey, 2006). The major agricultural crops in the Municipality are coconut, rice, corn, sweet potato (kamote), cassava, taro (gabi), and other assorted crops (i.e. vegetables). Coconut is the dominant agricultural product, covering slightly over 5,200 hectares of land area, with yield of about 1,000 kilograms per unit of land. Rice production occupies the next largest area of agricultural land, with 480 hectares cropped (Table II.7).

Table II.7. *Comparative agriculture areas and production in Silago, 2008, 2009 and 2010.*

	Area (ha)			Yield (tons/ha)		
	2008	2009	2010	2008	2009	2010
Rice	480.00	480.00	480.00			
Irrigated	477.00	477.00	477.00	5.1	5.0	5.2
Hybrid	60.00	40.00	110.00	4.0	4.2	4.54
Good Seeds	379.50	421.00	367.00	3.8	3.9	4.0
Certified seeds	37.50	16.00	0.00	4.0	4.1	4.2
Non-Irrigated	3.00	3.00	3.00	3.6	3.8	3.9
Coconut	5,247.00	5,269.00	5,269.00	0.83	0.9	1.0
Cassava	27.00	27.00	27.00	10	11	12
Taro (kamote)	17.00	17.00	17.00	10	11	12
Banana	25.00	25.00	25.00	2.0	2.2	2.4
Pineapple	28.75	28.75	28.75	7.5	8.75	10
Vegetable	21.43	21.43	21.43	2.8	3.0	4.0
Abaca	9.75	9.75	9.75	1.30	1.35	1.37
TOTAL	5,855.93	5,877.93	5,877.93			

Source: Municipal Data

The fisheries and aquaculture industry of Silago employs an estimated 117 people out of the 2,771 employed members of Silago's labor force (CBMS Survey, 2006). Over 1,100 hectares was reported under fisheries and aquaculture activities, including marine fishing grounds and inland tilapia and bangus aquaculture ponds. Latest available production data show that the local fisheries and aquaculture industry is valued at roughly PhP 17 million per year, assuming an average selling price of PhP 100.00 per kilogram of fish (Table II.8).

Coastal resources

With the majority of its barangays lining the coast, Silago is rich in coastal resources. Coral reefs can be found in the sea of barangays Balagawan, Mercedes, Sap-ang, Sudmon, Tubaon, Laguma, Salvacion, Hingatungan and Poblacion Districts I & II. Sea grass communities are spread across all 10 of Silago's coastal barangays, while mangrove forests can be spotted in barangays Hingatungan, Laguma, Tubaon and Sudmon. Marine protected areas have also been designated in barangays Hingatungan, Laguma and Sudmon.

Table II.8. *Existing fishing grounds and aquaculture production.*

Barangay	Fishing Ground	Area (ha)	Production	
			Volume (kg)	Value (PhP)
A. MARINE				
Hingatungan	1st Mabaw (1st Reef)	121.76	18,263.25	1,826,325.00
	Mabaw Tunga	55.27	8,290.16	829,015.50
	Mabaw Dako	100.47	15,070.61	1,507,060.50
	Mabaw Sa Lawaan	69.38	10,406.67	1,040,667.00
Salvacion	Labohan	20.92	3,138.56	313,855.50
Laguma	Mabaw sa batong Dako	363.66	54,548.82	5,454,882.00
	Mabaw sa Bulhang	26.98	4,047.51	404,751.00
Tubaon	Mabaw sa Matal –ay	87.34	13,100.78	1,310,077.50
	Batong Diyoy	44.12	6,617.61	661,761.00
	Lawis	13.88	2,081.67	208,167.00
	Lagubo	29.45	4,417.35	441,735.00
	Kapignis	0.71	106.92	10,692.00
Pob. Dist. II	Bato sa Tabon Tabon	0.82	123.54	12,354.00
Pob. Dist. I	Bato sa Simbahan	2.42	362.30	36,229.50
	Kaimog	0.45	66.96	6,696.00
Balagawan	Burawan	38.46	5,768.94	576,894.00
	Balagawan Reef	150.62	22,593.47	2,259,346.50
Sub-total		*1,126.70*	*169,005.12*	*16,900,509.00*
B. INLAND (AQUACULTURE)				
Puntana	Tilapia	0.09	60.00	6,000.00
Pob. Dist. II	Tilapia	0.25	250.00	25,000.00
Mercedes	Tilapia	0.18	120.00	12,000.00
Balagawan	Tilapia	0.06	30.00	3,000.00
Hingatungan	Bangus	0.25	550.00	66,000.00
Sub-total		0.83	1,010.00	112,000.00
	TOTAL	1,127.53	170,015.12	17,012,509.00

Source: Agriculture and Fisheries, Economic Sector, Municipal Data

F. *BASIC SOCIAL SERVICES*

Education

Day care centers are present in all barangays except Catmon and Puntana. There are 14 public and 1 private elementary schools in the Municipality, along with 4 high schools located in Poblacion District I, Hingatungan, Mercedes and Katipunan. As for school year 2009-2010, enrolment in Silago's primary schools was 950 male and 893 female students, totalling 1,843 elementary school students.

Enrolment in secondary schools during school year 2009-2010 was 1,049, with almost equal participation from male and female students. Based on Department of Education (DepEd) standards, Silago's national high schools have “manageable” conditions, with all 4 schools exhibiting ratios well below the ideal of 1 teacher for every 46 students.

Health facilities and situation

Silago has 1 rural health unit (RHU) which serves as the main health office of the Municipality. There are also 4 barangay health stations located in Hingatungan, Lagoma, Mercedes and Katipunan. Latest available data revealed that the leading causes of morbidity in the Municipality were hypertension, bronchitis and diarrhea (MPDO, 2010). Meanwhile, the leading causes of mortality were pneumonia, hypertension and drowning.

Electric power supply

Electric power supply is provided by the Southern Leyte Electric Company (SOLECO). Based on municipal data, 2,258 households in Silago have availed of electrical connections through SOLECO.

Water supply

According to consultations with local government officials and resource persons, the Municipality of Silago has an abundant supply of water. However, this supply is largely underutilized due to lack of necessary infrastructure and equipment, such as irrigation systems, filtering instruments and metering devices. Based on climate projections for the Eastern Visayas region, mean seasonal rainfall is expected to increase during wet months and decrease during summer (dry) months (Hilario et al., 2009).

Agricultural and support infrastructure

Communal irrigation systems (CIS) are installed in barangays Hingatungan, Sudmon, Salvacion and Lagoma. Meanwhile, there were 3 communal irrigation projects (CIP): Poblacion District II CIP, Sap-ang CIP and Mag-matal-ay CIP. Consultations revealed that the major development need for Silago’s agriculture sector is the development/upgrade of irrigation facilities. Although this concern is commonly flagged as a pitfall of the sector’s productivity, correspondence with local government officials and extension personnel established that there is currently no endeavor to address this concern.

Transportation and communication

Provincial buses pass through the Municipality providing transportation service to Manila, Maasin and Tacloban. Air transportation services can be availed in Tacloban City only. There are also no ports within Silago, but there is a wharf for small boats in barangay Hingatungan.

Land transportation in Silago has improved significantly since the construction/paving of the Junction Pan Philippine Highway (PPH) Himayangan-Silago-Abuyog Junction PPH Road commenced in 2004. The project was funded through the Japan Bank for International Cooperation (JBIC) 23rd Yen Loan Package as a subproject of the Arterial Road Link Development Project (ARLDP), Phase IV (Maris, 2006). The road is classified as a national road spanning 113.4 kilometers. Aside from serving as a provincial link, it is also an alternate route from the Pan Philippine Highway when roads in disaster prone areas are closed (Maris, 2006). Travel time from Tacloban to Silago has been reduced from 6 to 2 hours with the paving of the national road (Figure II.5).

The road traverses the coastal towns of St. Bernard, San Juan, Anahawan, Hinundayan, Hinunangan, and Silago in Southern Leyte. After Silago, the road alignment shifts toward the interior of the island along the provincial boundary (Maris, 2006).

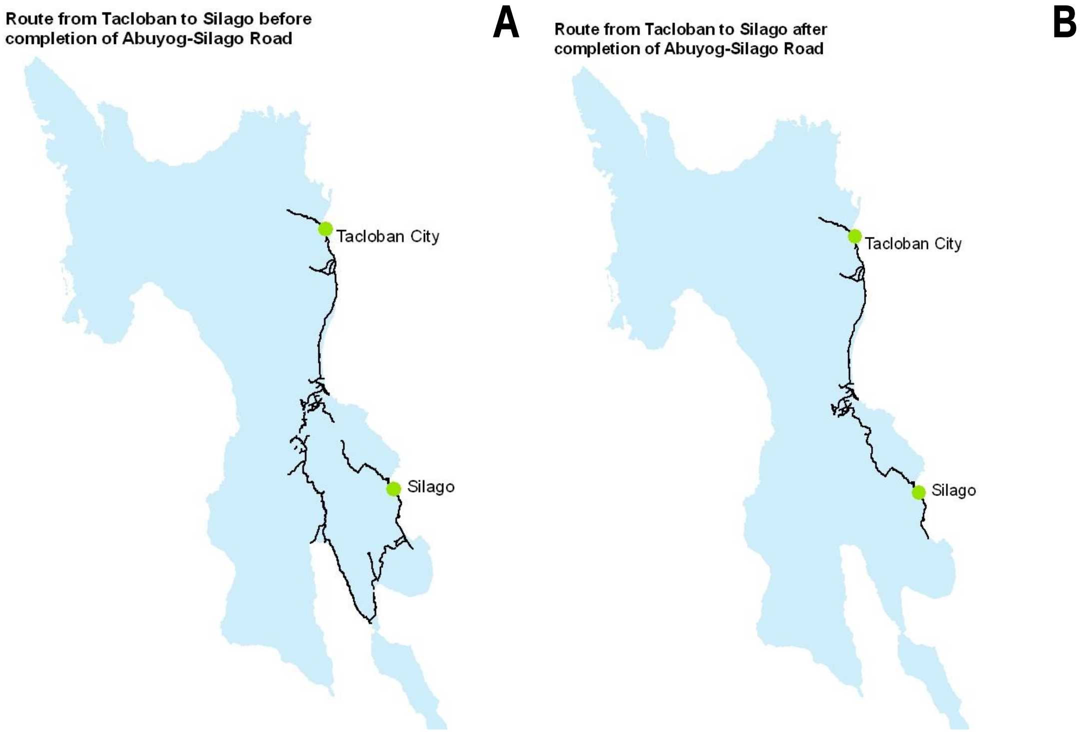


Figure II.5. *Route from Tacloban to Silago (A) before and (B) after the completion of the Junction PPH-Himayangan-Silago-Abuyog Junction PPH Road. Map generated by ICRAF.*

The two major telecommunications companies in the country – Globe Telecom and Smart Communications – provide wireless signal for cellular/mobile phones in Silago. Landline connections are also available via Globe Lines, a brand of Globe Telecom. The town's Bureau of Post (Postal Office) handles the mail and money order services of the community.

Employment and Income

Table II.9. *Labor force population by sex and employment status, as of 2010.*

	Population (15 yrs and over)	Employed	%	Unemployed	%
Male	3,661	1,663	45	1,998	55
Female	3,380	1,108	33	2,272	67
TOTAL	7,041	2,771	39	4,270	61

Source: Municipal estimates as of 2010 based on 2006 CBMS Survey(2006)

The most recent data from the local government shows that about 7,000 people make up the local labor force, with a larger percentage of employed males than females. According to a survey conducted in 2006, majority of the labor force is occupied with activities under the agriculture and fisheries sectors (CBMS Survey, 2006). Approximately 61% of the labor force is unemployed.

The 2011 draft of Silago's Comprehensive Land Use Plan (CLUP) identified some priority issues and problems regarding employment in the municipality. Lack of employment opportunities for workers was attributed largely to seasonal nature of employment in agriculture, while the lack of technical trainings on livelihood and specialty skills only added to the abundance of unskilled workers. As a result, members of the local labor force have resorted to out-migration, while those with college degrees have explored employment opportunities abroad.

III. OVERALL METHODOLOGY AND PROCESS

A. PROCESS FLOW

The research flow is shown in Figure III.3. The initial phase consists of the identification and definition of a limited number (2-3) of typical patterns (archetypes) of vulnerability of the identified sectors (forestry, agriculture, coastal and water resources) to climate variability and change and adverse impacts in each sector. These patterns were presented in the form of Pre-Analysis Impact Chains for each sector which identify the relevant climate stimuli, exposure units, direct and indirect impacts, and vulnerable groups in the society, based on current literature.

These generic pre-analysis impact chains were next presented to the local government, non-government organizations, people's organizations, academic institutions and other stakeholders in Silago in a scoping/consultation workshop held in June 2010. The consultation process enabled the research team to get information on the local priorities and climate-related problems and needs of the stakeholders, and ascertain the availability and quality of local data which can be used for climate impact and vulnerability assessments. The pre-analysis impact chains were then revised to reflect the inputs from the stakeholders and the availability of information which could allow the team to proceed with formal analyses.

The climate stimuli selected for the study (temperature and rainfall) were then generated through regional climate modeling to give background and future climate profiles for Silago, Southern Leyte. Additional information for each specific sector was generated to answer the inadequacy of basic data about the municipality. In the case of the forestry and water sectors, land cover change analysis and hydrological analysis were conducted, respectively, to augment the information provided by Silago's local government office (Draft CLUP, 2011).

With these additional information, influence diagrams were constructed, to show the interactions among different biophysical and socioeconomic variables relevant to the study area which affect the archetypes of vulnerability of the sectors to climate change and climate variability. Indicator data which could serve as proxies to the variables to quantify the defined archetypes and their internal dynamics were also identified.

The next steps involved validation of the identified patterns of vulnerability by the stakeholders of Silago and discussion on additional data needs and field studies to empirically validate the patterns identified in the diagrams. The influence diagrams will be further adjusted through a feedback process, and serve as basis for the formulation of appropriate adaptation options for each sector.

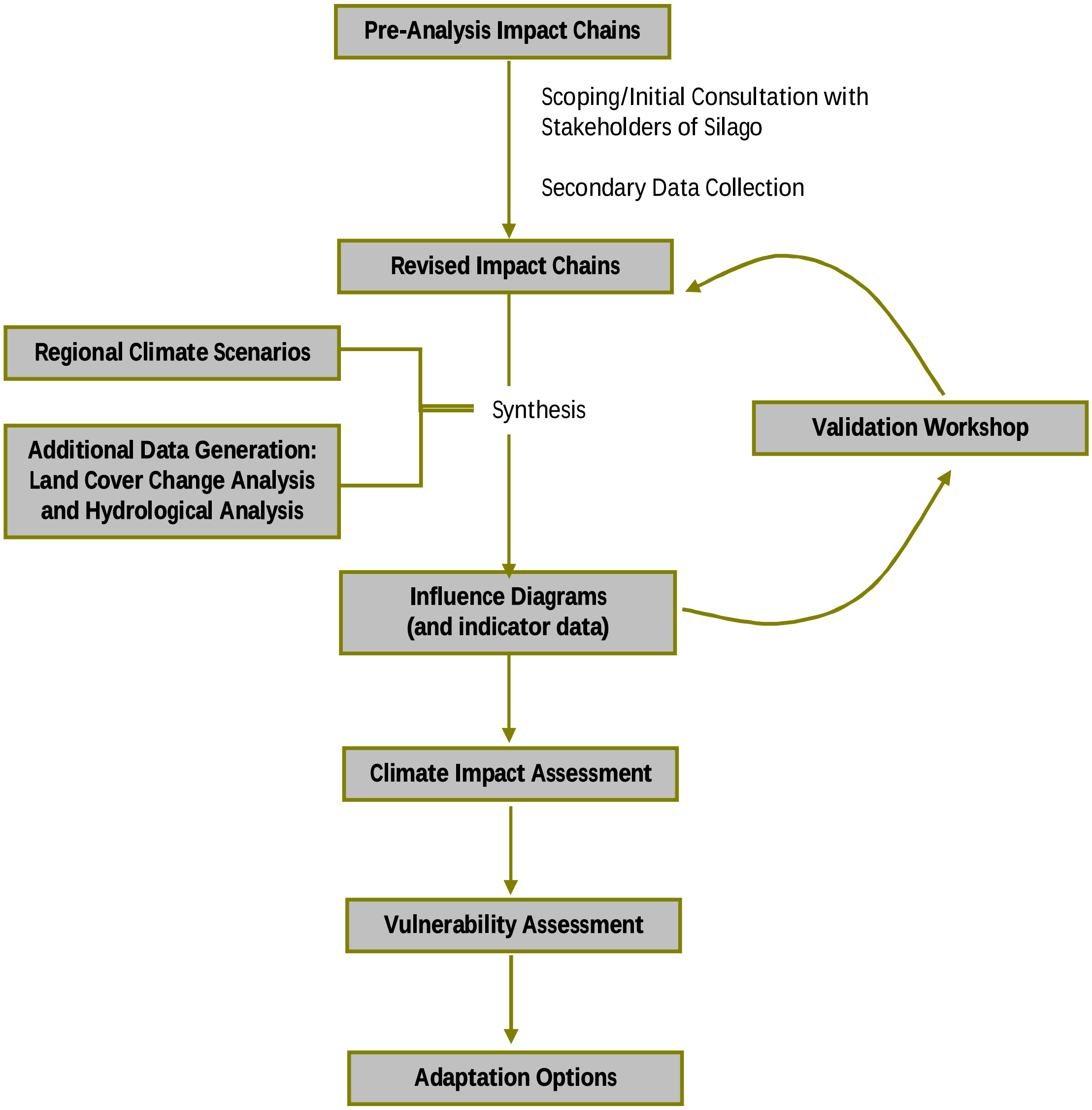


Figure III.1. *Process Flow of the ci:grasp Project for Silago, Southern Leyte, Philippines.*

B. DEVELOPMENT OF IMPACT CHAINS AND INFLUENCE DIAGRAMS

The scope and context for analyzing the impacts of climate change and variability on the forestry and water sectors of Silago were defined through the following processes:

- Meetings and consultation between members of the research team Manila Observatory (MO) and the World Agroforestry Centre (ICRAF) Philippines and GIZ were held between May and November 2010 to develop a common understanding of the ci:grasp approach, construct the pre-analysis impact chains, clarify methodologies and assess data gaps.

- A consultation workshop was held with the local stakeholders of Silago in June 2010 to present and validate the Pre-Analysis Impact Chains and assess the availability of local data for analysis.

- Literature review was conducted to provide context to the analysis of the forestry and water sectors of the study area. Baseline conditions of the forest and water sectors were described with data coming mainly from the draft Comprehensive Land Use Plan (2011) of the municipality of Silago. In the absence of specific information at the municipal level, the team made use of historical and geographical analogues (Feenstra et al., 1998) from findings from related studies conducted in the study area (Silago), its larger bounding provincial (Southern Leyte) and regional (Eastern Visayas) administrative units, and nearby areas under similar biophysical and socio-economic conditions to fill in data gaps and infer likely future change trajectories for each sector. Most of this information is qualitative in nature.

- A workshop was again held in March 2011 with the stakeholders of the municipality to present and validate the initial findings from the study. Based on this validation and updated information on the forest and water sectors of Silago, the influence diagrams and impact chains were revised accordingly.

IV. CLIMATE ANALYSIS AND PROJECTED CHANGE

A. *CLIMATE PROFILE OF SILAGO, SOUTHERN LEYTE*

The climate of Silago, a municipality of Southern Leyte (Figure IV.1) is classified as Type II as shown by the modified Coronas Classification (Figure IV.2; Kintanar 1984). Under this classification, rainfall over this area is most pronounced during the months of November to January without a distinct dry season.

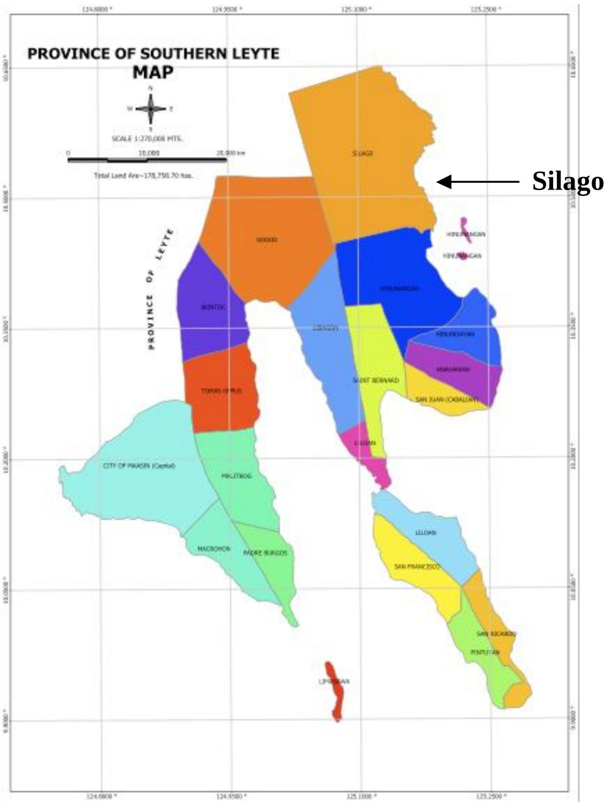


***Figure IV.1**. Area of study – Silago, Southern Leyte (Source: Silago CLUP, 2011).*

In this study, we aim to characterize the historical climate profile of Silago, using observed and modeled data. This profile will be used as a climate baseline. We then use a climate model for future climate projections and analyze the changes with respect to the climate baseline.

B. *REGIONAL CLIMATE MODELING SIMULATIONS*

RegCM3 Model

Regional climate models are used to dynamically downscale large-scale meteorological fields generated from global circulation models (GCM) to study the climate and seasonal predictability for a particular region. This is necessary since some features of a regional climate are lost or weakly represented in the relative coarseness in spatial resolution of a GCM. In this project, we use version 3 of the Abdus Salam International Centre for Theoretical Physics (ICTP) Regional Climate Model (RegCM3), a three-dimensional hydrostatic model developed in ICTP in Trieste, Italy (Pal et al., 2007). This model consists of mathematical equations dealing with climate dynamics and includes parameterization schemes to represent radiative transfer, planetary boundary layer, cloud and precipitation processes.

Type I: Two pronounced seasons: dry from November to April, wet during the rest of the year

Type II: No dry season with a very pronounced rainfall from November to January

Type III: Seasons are not very pronounced; relatively dry from November to April and wet during the rest of the year

Type IV: Rainfall is more or less evenly distributed through the year

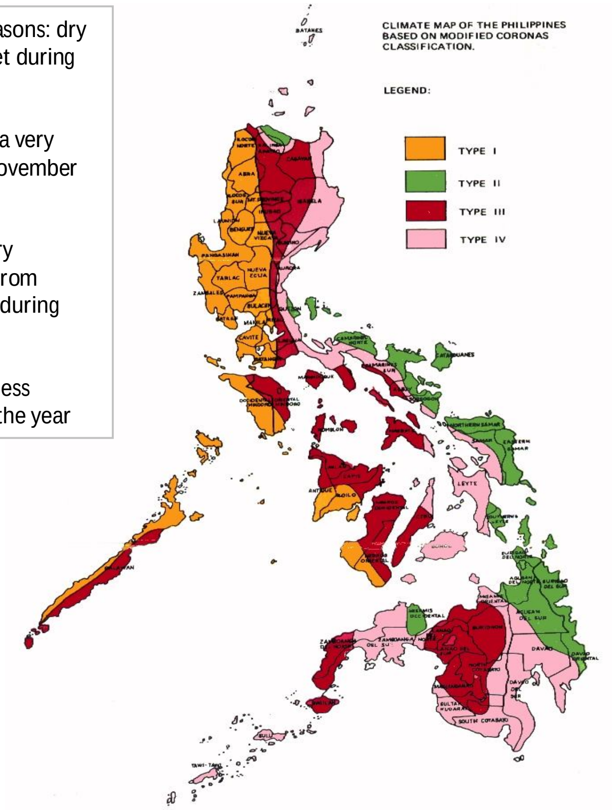


Figure IV.2. *Climate Classification of the Philippines based on modified Coronas (from Kintanar, 1984).*

Description of experiments

We run RegCM3 at a 40 km spatial resolution over the Philippine domain (Figure IV.3) for the years 1961 to 1990. Initial and boundary conditions for the model are derived from the ~200 km resolution output of ECHAM5/MPI-OM, which is a coupled atmosphere-ocean general circulation model of the Max Planck Institute for Meteorology (Roeckner et al., 2003; Marsland et al., 2003). However, to characterize the climate profile of Silago in finer detail, there is a need to further downscale this 40 km-resolution model output. Hence, RegCM3 is run again at a 20 km spatial resolution over a smaller area centered at Panay island (Figure IV.3) for the same 30-year period. The result of this simulation over Silago is used to establish its historical climate profile that will be used as a baseline climate.

The baseline climate is validated with observed datasets, including surface temperature and rainfall measurements. This is done to determine the model's skill in capturing the observed climate. It is important to establish the accuracy and reliability of the model since this will be used as a guide in analyzing the model results for projections of the future climate.

Additional experiments following the same procedure above are conducted to determine the projected climate of Silago. In this case, RegCM3 is run for two 30-year periods: 2010 to 2039 and 2040 to 2069. Simulations from the ECHAM5/MPI-OM using the A1B scenario of the IPCC are used as initial and boundary conditions for the model because the scenario represents a non-extreme case. The A1 family of the IPCC emission scenarios describes a future world with rapid economic growth where the growing population reaches its peak by 2050 and declines afterwards. In particular, the A1B scenario assumes a balanced use of fossil intensive and non-fossil energy sources. These assumptions are expressed in terms of anthropogenic emissions of these greenhouse gases: CO_2, CH_4, N_2O and SO_2 (IPCC, 2007). Model output is again downscaled to obtain a 20 km resolution output over Silago. Changes in the simulated projected climate are analyzed relative to the baseline climate.

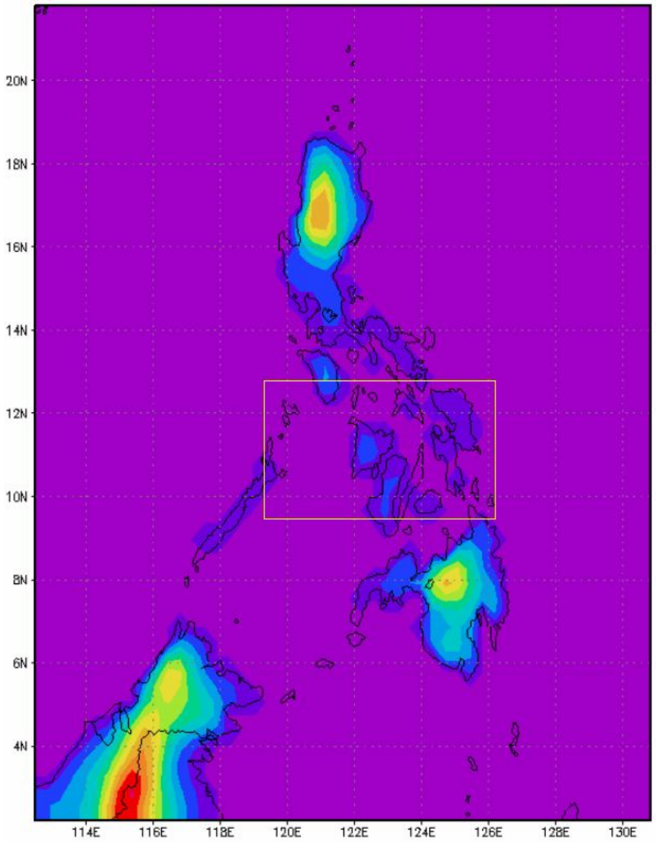


Figure IV.3. *RegCM3 model domains. Domain covering the Philippines at 40 km spatial resolution and domain centered at Panay at 20 km spatial resolution (inside the box).*

Observed Dataset

Surface observations in the area of study are needed to help establish its climate profile. Currently, there is no meteorological station from Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) in Silago. Thus, we intend to use temperature and rainfall data from two gridded reanalysis datasets. Temperature data will be obtained from the Climatic Research Unit (CRU), which provides monthly temperature data from 1901-2000 at 0.5 degree grid-point horizontal spacing (see Mitchell et al., 2003). On the other hand, rainfall data will be taken from Asian Precipitation – Highly Resolved Observational Data Integration Towards Evaluation (APHRODITE), a daily precipitation data from 1951-2004 obtained from rain-gauge observations interpolated on a 0.25 degree grid resolution (Yatagai et al., 2009).

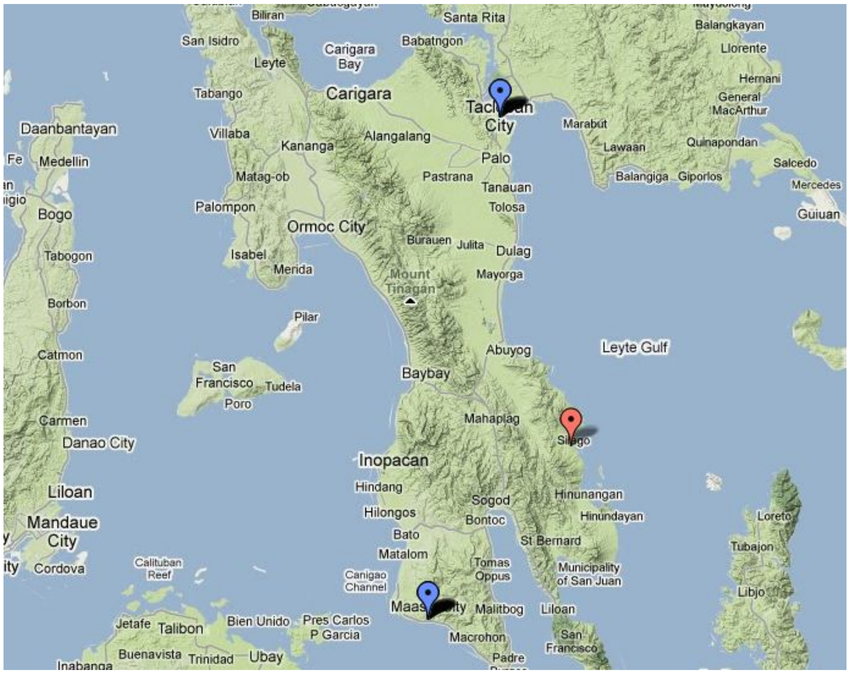


Figure IV.4. *Topography map of Leyte island. Red marker indicates location of Silago. Blue marker indicates location of PAGASA meteorological observing stations. (Mapped with Google Earth).*

Data from CRU and APHRODITE need to be evaluated over areas where surface observations from PAGASA are available. This is essential in establishing the validity in using these gridded datasets in the absence of an observation station in Silago. The nearest PAGASA stations are found in Maasin City, Southern Leyte (Maasin) and Tacloban City, Leyte (Tacloban) (Figure IV.4). The grid point from the CRU and APHRODITE datasets closest to the location of these stations is selected for comparison. Differences are anticipated since data at a point source will be compared with data averaged over an area. However, apart from actual values, there should be an agreement in the seasonal trends in both datasets.

C. GRIDDED DATA AND MODEL RESULTS VALIDATION

Validation of CRU Temperature Data

The monthly mean temperature from 1961 to 1990 is derived over Maasin and Tacloban stations to validate the CRU data with observed data from PAGASA (Figure IV.5 and Figure IV.6). In both locations, CRU follows the seasonal trend in temperature of PAGASA. While the CRU data underestimates the temperature in Maasin uniformly throughout the year, CRU is closer to PAGASA values in Tacloban.

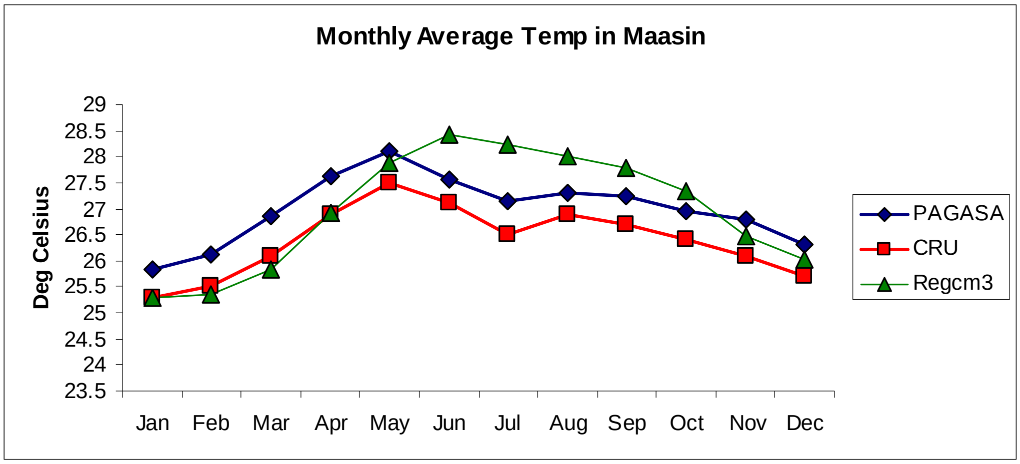


Figure IV.5. *Monthly mean temperature in Maasin from PAGASA, CRU and RegCM3.*

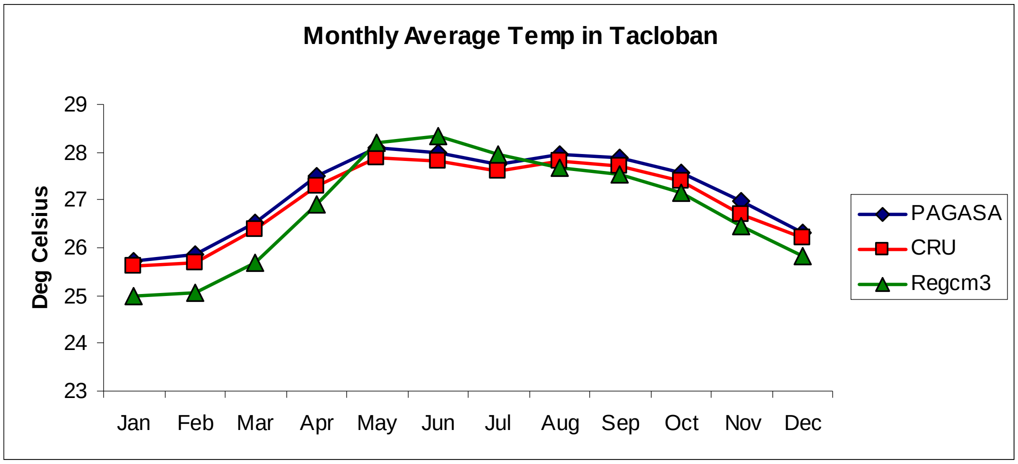


Figure IV.6. *As in Figure IV.5, but in Tacloban.*

Validation of APHRODITE Rainfall Data

A comparison of the monthly mean rainfall from 1961 to 1990 from PAGASA and APHRODITE indicates that both exhibit a similar seasonality in rainfall in Maasin (Figure IV.7) and in Tacloban (Figure IV.8).

While there is less rainfall in APHRODITE particularly in the wet months from July to January in Maasin, APHRODITE underestimates rainfall in Tacloban throughout the year.

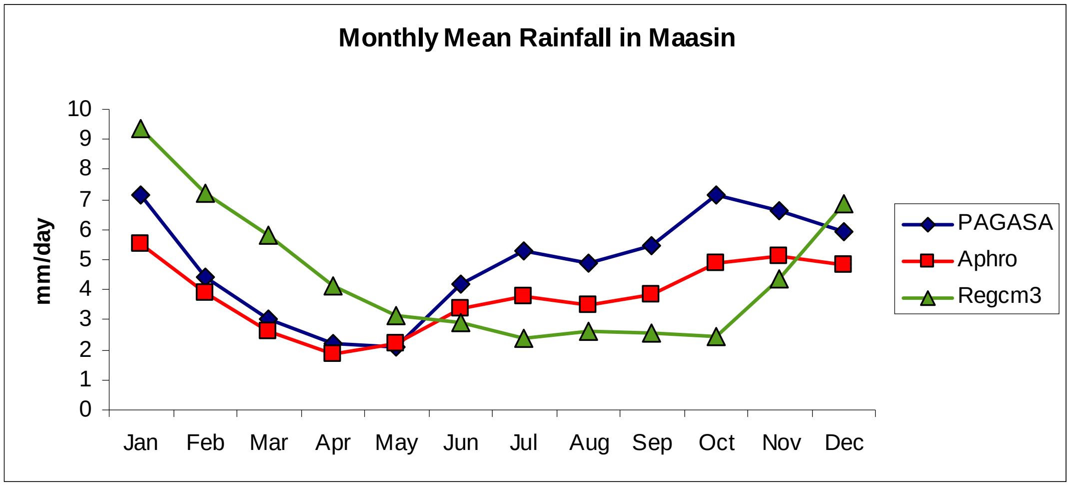


Figure IV.7. *Monthly mean rainfall in Maasin from PAGASA, APHRODITE and RegCM3.*

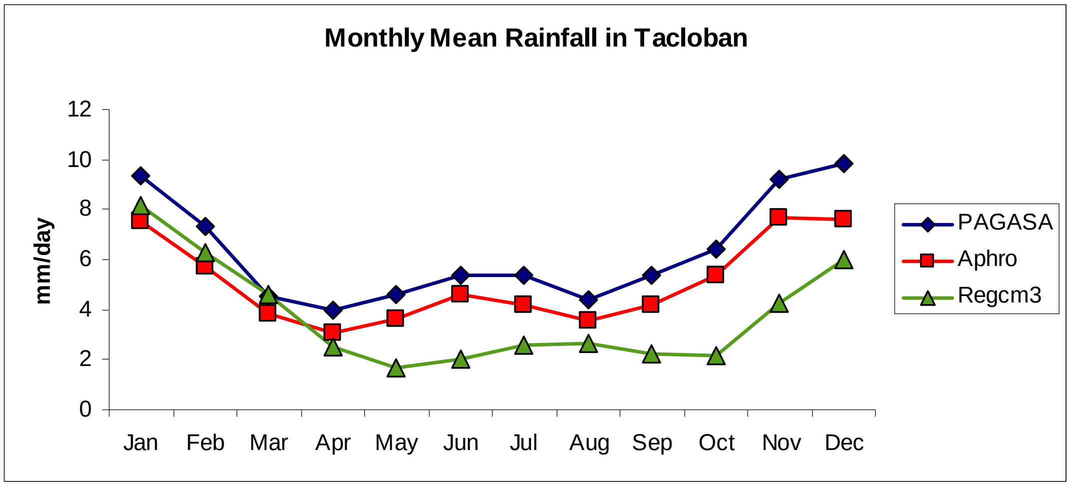


Figure IV.8. *As in Figure IV.7, but in Tacloban.*

Modeling Results Validation for Maasin and Tacloban

In this section, the model output from RegCM3 will be validated with data from PAGASA, CRU and APHRODITE. The monthly mean temperature in Maasin indicates that the model is able to generally follow the seasonal trend observed from both PAGASA and CRU but tends to overestimate the temperature from June to October (Figure IV.5). However, the model performs better in Tacloban (Figure IV.6).

In the case of rainfall, RegCM3 tends to simulate more rainfall in Maasin at the start of the year compared with observations (Figure IV.7). On the other hand, the model underestimates rainfall in the latter half of the year in both Maasin and Tacloban (Figure IV.7 and Figure IV.8).

Modeling Results Validation for Silago

In the previous section, we were able to show that the temperature from CRU and the rainfall from APHRODITE closely follow the values from PAGASA in Maasin and Tacloban. Thus, this provides additional confidence in the reliability of using data obtained from these gridded datasets over Silago, in the absence of an observation station at this location.

Figure IV.9 shows that RegCM3 is able to follow the seasonal variation in temperature over Silago, although the months of May to August tend to be warmer. In both observation and model output, pronounced wet months are seen from November to January with slightly wet months for the other months except March to May (Figure IV.10). However, the model tends to underestimate rainfall during the wet months.

While the model tends to have a warm and dry bias during the latter months of the year, it is able to capture the observed temperature and rainfall in Silago at other months. This relative skill of the model should be noted in the analysis of the simulated future projections in Silago.

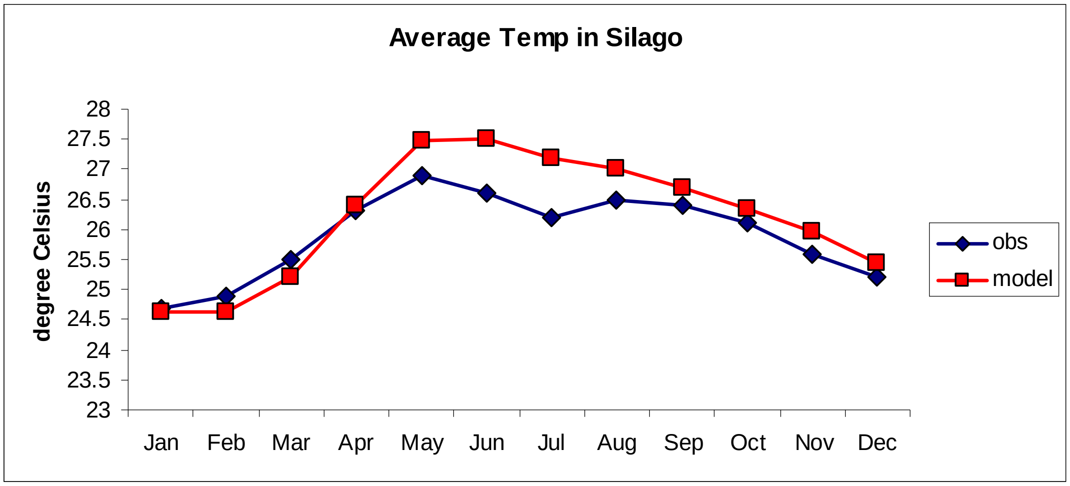


Figure IV.9. *Monthly average temperature in Silago from CRU (obs) and RegCM3 (model).*

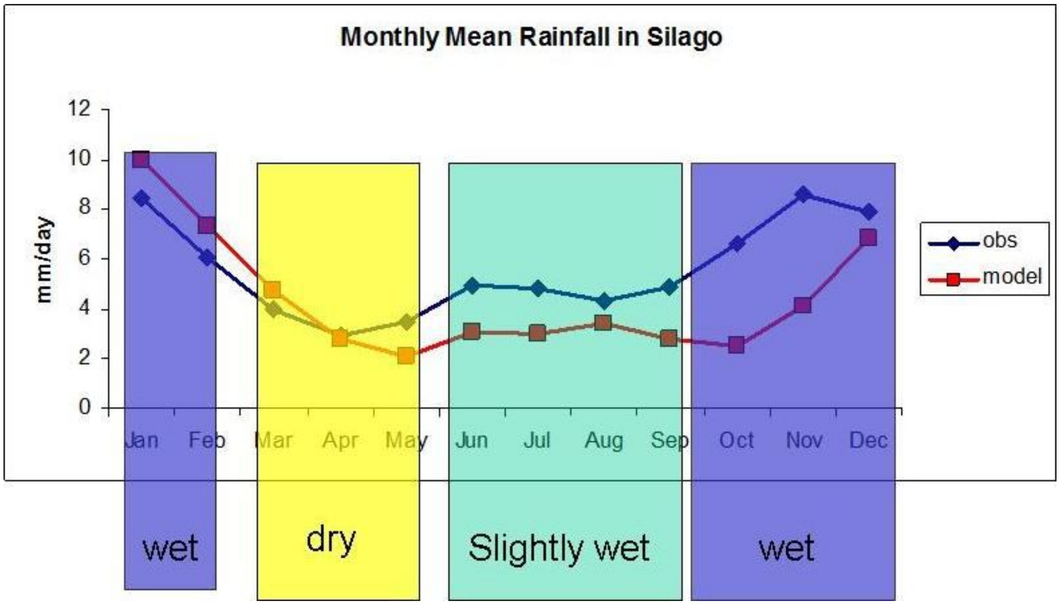


Figure IV.10. *Monthly mean rainfall in Silago from APHRODITE (obs) and RegCM3 (model).*

D. CLIMATE CHANGE PROJECTIONS FOR SILAGO

In this section, we characterize the changes in the projected future climate in Silago, relative to its baseline climate as simulated from RegCM3. Mean changes in the variations in temperature and rainfall will be examined in both time and space. In addition, the changes in selected indices of climate extremes will also be presented since these tend to have a more significant impact compared with the differences in the means.

Seasonal variation

Figure IV.11 shows a comparison of the simulated monthly mean temperatures in Silago for the three 30-year periods. The monthly variation is consistent across the periods, which indicates no change in the onset of the warm and cool seasons in Silago. However, throughout the year, there is a distinct uniform increase of about 1°C in the projected temperature in the 2020s and 2050s, relative to the baseline.

There seems to be no change in the timing of the rainfall season in Silago since there is no change in the monthly trend of the projected rainfall (Figure IV.12). In general, the projected rainfall is slightly lower than the baseline, particularly at the start of the year.

Spatial changes

One of the advantages of using a regional climate model is that it allows us to examine the spatial variation of the projected changes in regional climate, which is difficult to accomplish with few observation stations existing in the area of interest. Spatial variability in the climate response is anticipated because of local influences such as orography, land use, geographical location, such as distance from the coastline, in addition to the changes in the climate forcing, including the enhanced greenhouse effect.

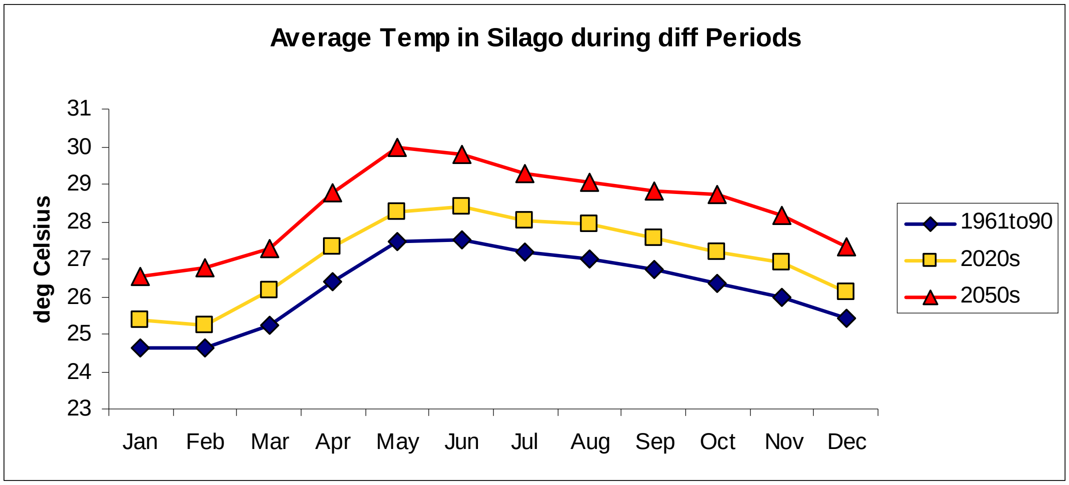


Figure IV.11. *Simulated monthly mean temperature in Silago for the years 1961 to 1990 (baseline), 2010 to 2039 (2020s) and 2040 to 2069 (2050s).*

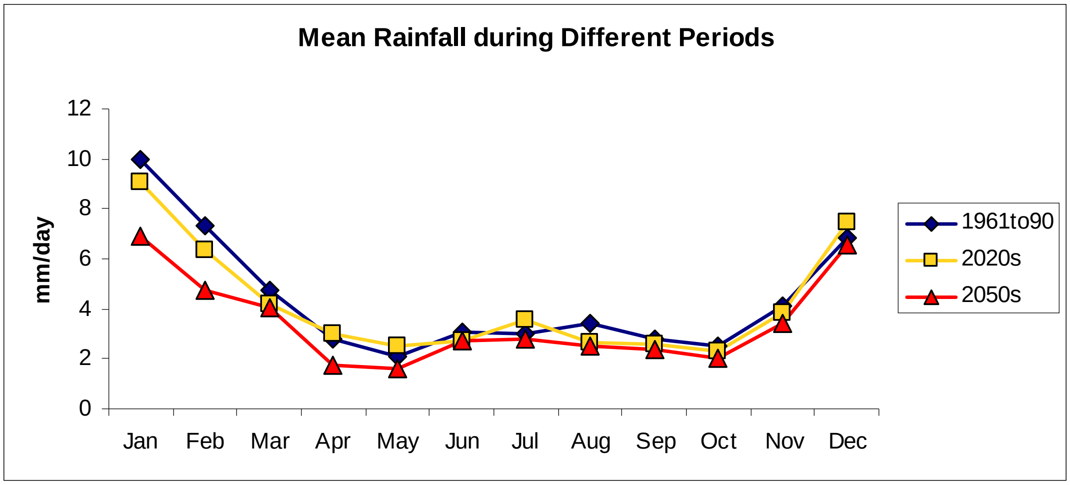


Figure IV.12. *As in Figure IV.11, but for rainfall.*

In the 2020s, there is an overall warming of up to 0.8°C in Leyte island during the cold, wet months from November to February (Figure IV.13a). The warming inland intensifies from April to May, making the temperature difference between the island and the surrounding ocean distinct (Figure IV.13b). A significant increase in temperature reaching 2°C can be found in the 2050s, particularly inland (Figure IV.13c). The warming inland becomes stronger and widespread over the island during the warm, dry months (Figure IV.13d). The sea surface temperature east of Silago warms by up to 1.8°C, whereas the sea surface west of Leyte island can reach the high temperatures shown over the island.

Changes in the area of Silago are highlighted in Figure IV.14. In the 2020s, there is a mean warming of 0.7°C in the area during the cold, wet season. However, a look at the spatial distribution of the warming indicates that the western section of Silago can be up to 0.1°C warmer, compared to the eastern section (Figure IV.14a). This may be attributed to its location near the coastline since the sea breeze can modulate temperature changes. In the warm, dry season, the mean temperature increase is 0.8°C, where the spatial gradient in the temperature change is still evident but smaller in magnitude (Figure IV.14b). The projected warming in Silago intensifies in the 2050s where the temperature increases by 1.9°C in the cold, wet season and by 2.2°C in the warm, dry season, relative to the baseline climate (Figure IV.14c and Figure IV.14d). The spatial temperature gradient between the inland and coastal areas of Silago also becomes more distinct.

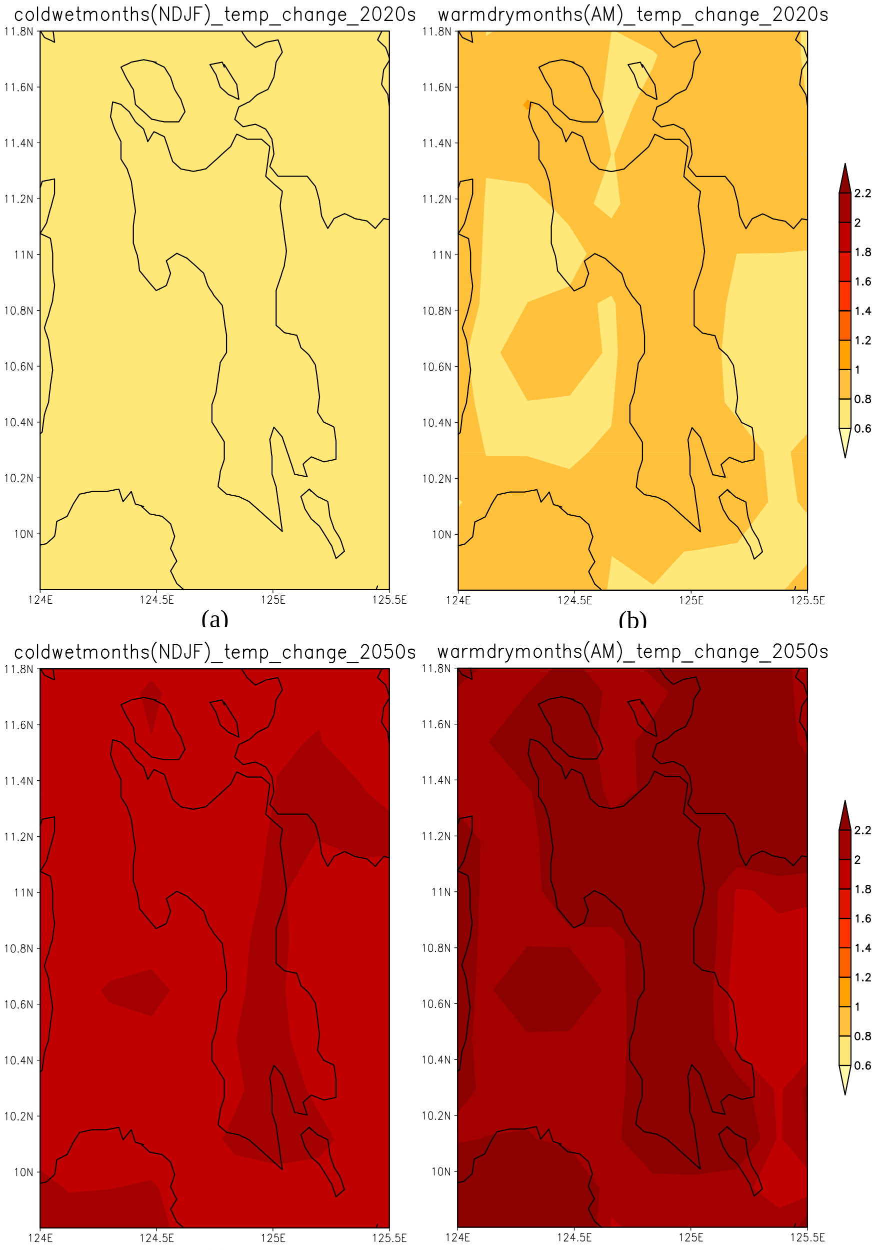
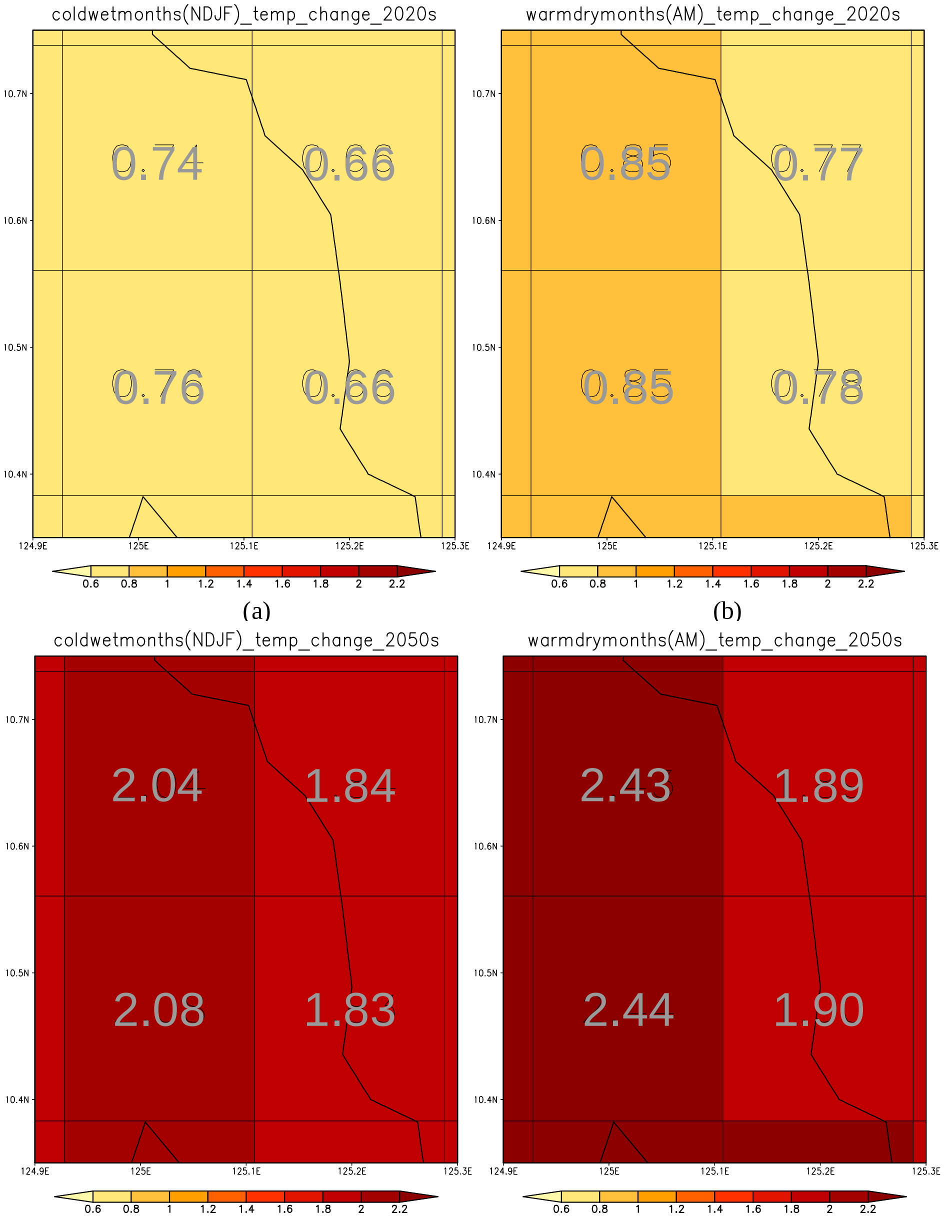


Figure IV.13. *Mean temperature difference (°C) over Leyte island from the baseline climate (1960 to 1990) averaged (a) over November to February and (b) April to May in the 2020s, and (c) over November to February and (d) April to May in the 2050s.*



(a) (b)

(c) (d)

Figure IV.14. *As in Figure IV.13, but over Silago. Temperature difference values over each grid point are also displayed.*

Changes in the rainfall are expressed as the percentage difference between the projected values and the baseline. A distinct gradient in the rainfall change is observed over Leyte island during the dry season in the 2020s (a). There is roughly a 10% increase in rainfall northeast of the island but a 5% decrease in the southwest. These drier areas extend to the northeast in the wet seasons (Figure IV.15b and Figure IV.15c). In the 2050s, there is a shift in the rainfall change towards drier conditions in the dry season (Figure IV.15d). While rainfall has further decreased during the wet seasons, there is minimal change in the spatial profile of the rainfall difference compared with the 2020s (Figure IV.15e and Figure IV.15f).

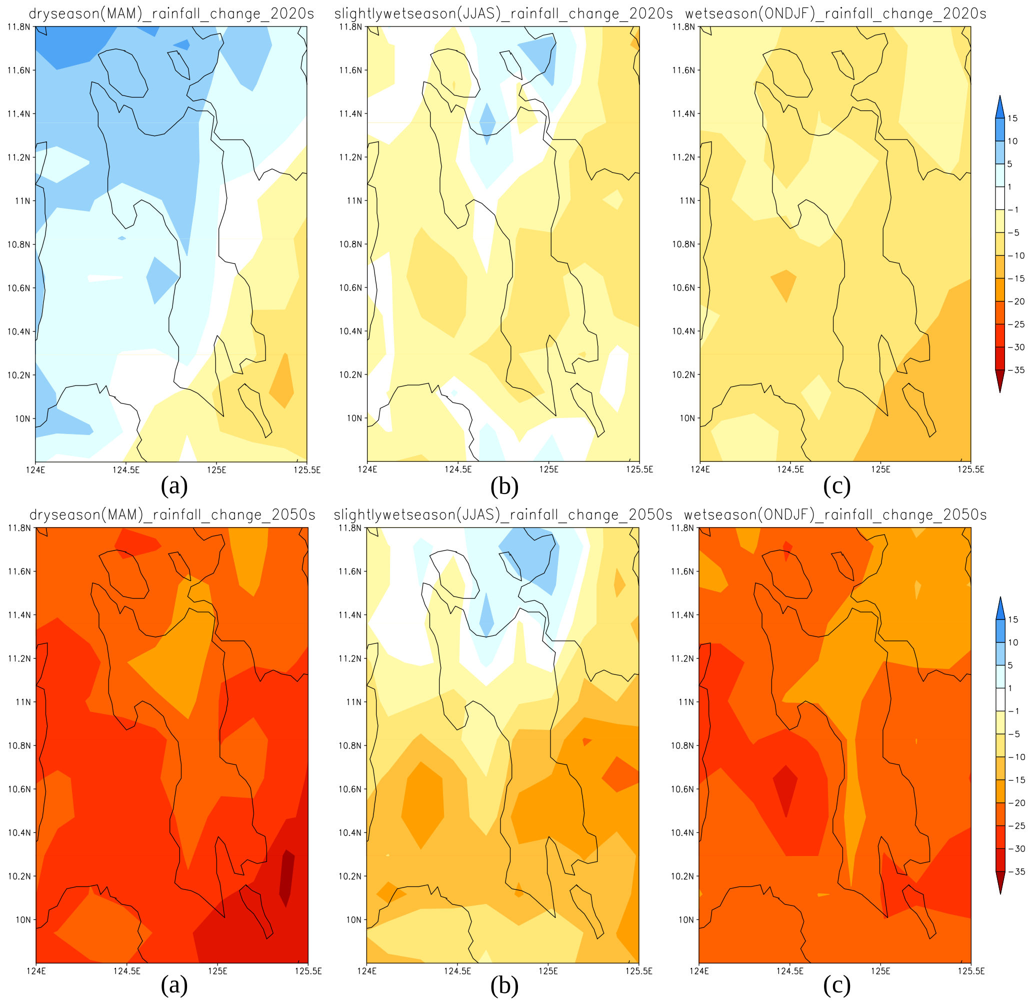
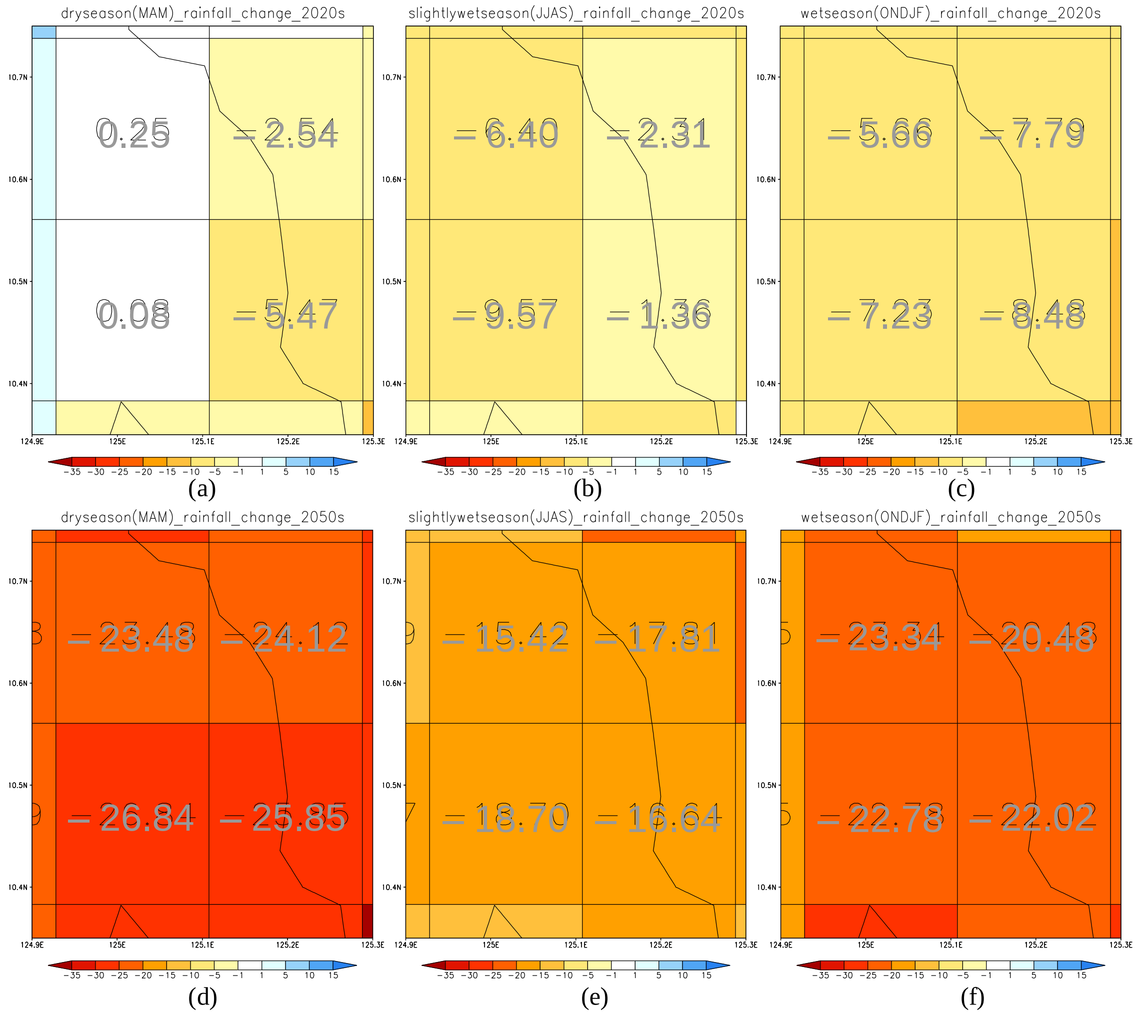

dryseason(MAM)_rainfall_change_2020s
slightlywetseason(JJAS)_rainfall_change_2020s
wetseason(ONDJF)_rainfall_change_2020s
(a) (b) (c)
dryseason(MAM)_rainfall_change_2050s
slightlywetseason(JJAS)_rainfall_change_2050s
wetseason(ONDJF)_rainfall_change_2050s
(a) (b) (c)

Figure IV.15. *Mean rainfall percentage difference (%) over Leyte island from the baseline climate (1960 to 1990) averaged (a) over the dry season, (b) slightly wet season, and (c) wet season in the 2020s, and (d) over the dry season, (e) slightly wet season, and (f) wet season in the 2050s. Seasons are defined in Figure IV.10.*

The rainfall change over Silago differs over the eastern and western sections during the dry season of the 2020s, where there is a slight increase in rainfall inland but a decrease simulated along the coastline (Figure IV.16a). Interestingly, the inland area becomes drier than the coastal area in the months of June to September (Figure IV.16b). In the wet season, the dry condition is more uniformly distributed over Silago (Figure IV.16c). In the 2050s, the mean decrease in rainfall over Silago is highest during the dry season (25%), compared to the slightly wet season (17.1%) and the wet season (22.2%) (Figure IV.16d, Figure IV.16e and Figure IV.16f).

In summary, a warmer and drier climate is projected generally over Leyte island, particularly Silago. However, the intensity of this change can vary according to season and geographical location.



(a) (b) (c)

(d) (e) (f)

Figure IV.16. *As in Figure IV.15, but over Silago. Rainfall percentage difference values over each grid point are also displayed.*

Changes in extremes

So far, we have only examined the projected changes in the mean values of temperature and rainfall. As mentioned, changes in the climate extremes will also be analyzed since these tend to have a more significant impact on the community and ecosystem. For example, increases in the frequency of extreme rainfall events can lead to higher incidences of flooding.

The probability density functions (PDF) of the monthly means of the daily maximum temperature and daily minimum temperature from the four grid points covering Silago (shown in Figure IV.14 and Figure IV.16) are derived for the three 30-year periods as simulated from RegCM3. A clear shift towards higher maximum temperatures is evident in the projected climate of the 2020s and 2050s relative to the baseline (Figure

IV.17a). Apart from Silago experiencing more days with warmer daytime temperatures as indicated by the change in the mean value or the peak of the PDF, there is also an increase in the minimum and maximum values of daytime temperature indicated by the tails of the PDF. A similar trend can be observed in the PDF of the minimum temperature which suggests the increase in the occurrence of warmer nights in the area (Figure IV.17b).

Selected climate extreme indices are derived based on the temperature and rainfall-based indices recommended by the CCl/CLIVAR Expert Team for Climate Change Detection Monitoring and Indices (ETCCDMI) with user-defined thresholds (Peterson, 2005). A FORTRAN-based program called FClimDex, was downloaded from http://cccma.seos.uvic.ca/ETCCDI/software.shtml, and used to perform data quality control and to calculate the indices. A comparison of the changes in the indices will be conducted for Silago across the three 30-year periods. Figure IV.18 shows the frequency distribution of the number of days in a year within each of the 30-year period over the four points in Silago, where the maximum and minimum temperatures exceeded thresholds we have defined. The thresholds have been selected from the 10th and 90th percentiles of the maximum and minimum temperatures from the baseline climate in Silago.

In the 2020s, there are more years that have more than 120 days where the maximum temperature is greater than 32.6 °C compared with the baseline (Figure IV.18a). This number increases in the 2050s where there are years in this period with high daytime temperatures lasting almost throughout the year. This is consistent with the trend in Figure IV.17a, where there are more hot days anticipated in Silago. On the other hand, all years in the 2050s are simulated to have only up to 30 days where the daily maximum temperature is less than 26.0 °C (Figure IV.18b).

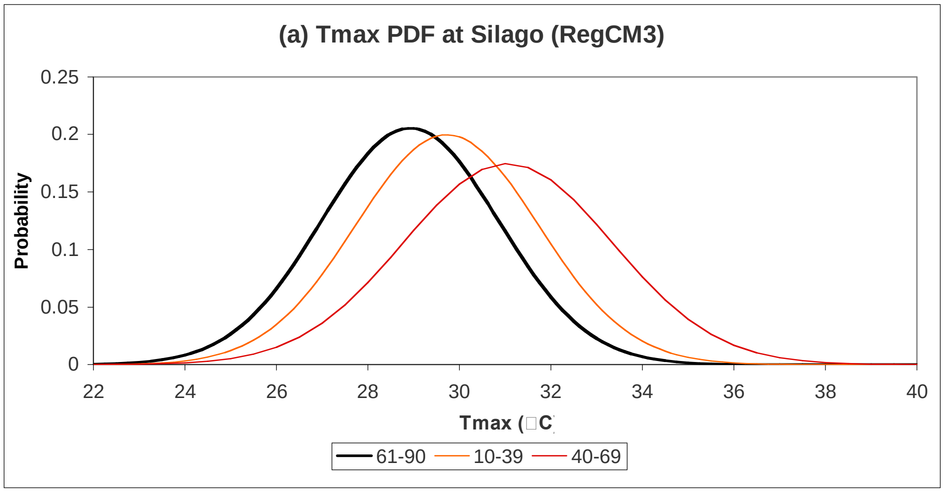


Figure IV.17. *Probability density functions of the monthly mean (a) daily maximum temperature, and (b) daily minimum temperature in Silago from the years 1961 to 1990, 2010 to 2039 and 2040 to 2069 from RegCM3.*

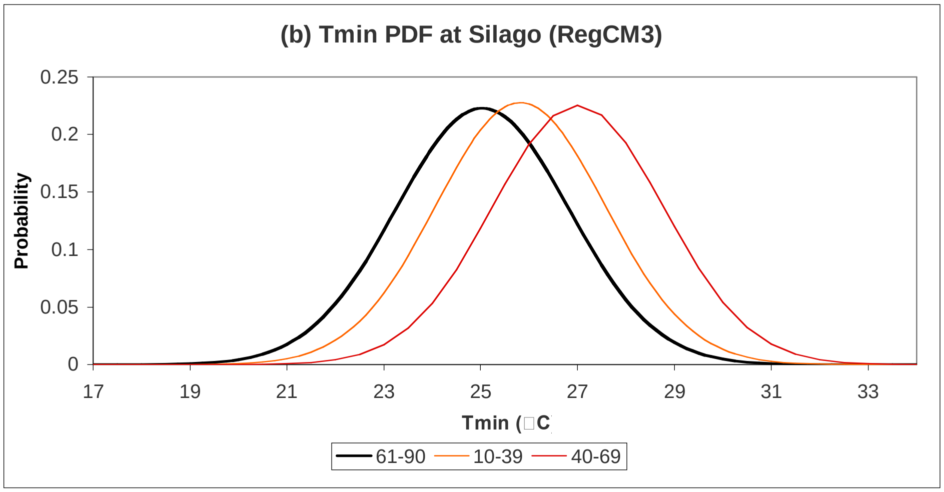


Figure IV.17. *Continued.*

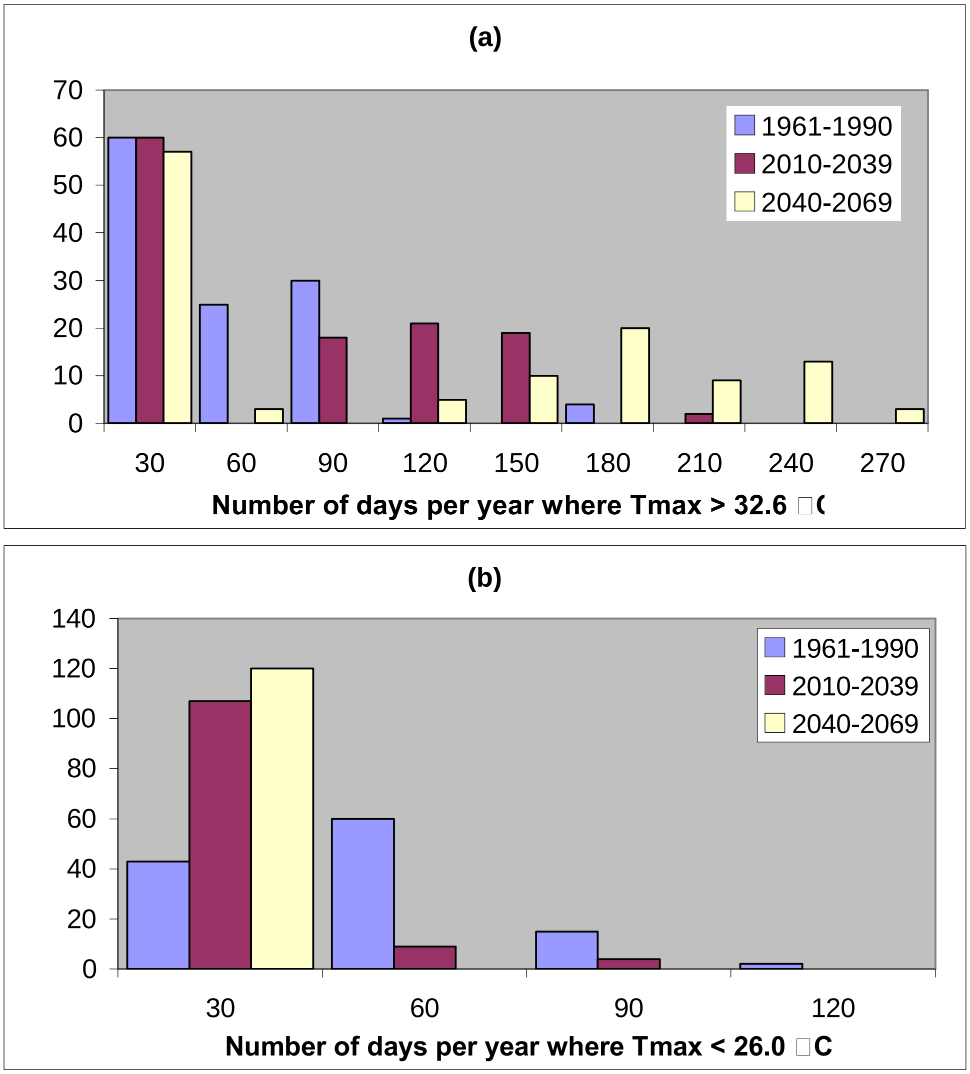
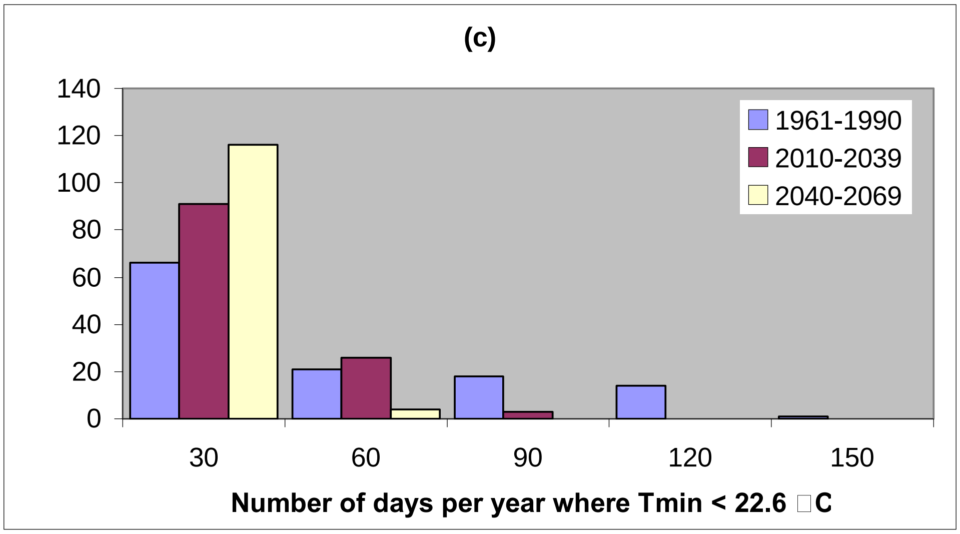


Figure IV.18*.* *Frequency distribution of days where the (a, b) daily maximum temperature and (c, d) daily minimum temperature exceeded defined thresholds in Silago from the years 1961 to 1990, 2010 to 2039 and 2040 to 2069 from RegCM3.*



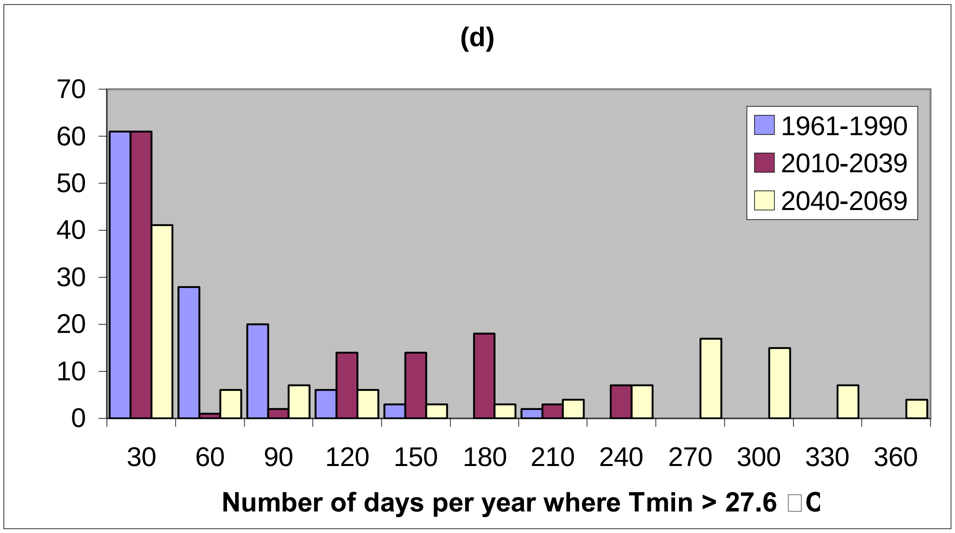


***Figure IV.18**. Continued.*

Whereas in the baseline there are years with up to 150 days which have minimum temperatures lower than 22.6 °C, the projection for 2050s indicates most years to have a maximum of 60 days with cool night time temperatures (Figure IV.18c). Interestingly, most of the 2050s is characterized by warmer nights (i.e. daily minimum temperature greater than 25 °C) during half or the entire year (Figure IV.18d).

Changes in indices based on rainfall are also examined. Unlike the change in the temperature indices, there is minimal difference in the distribution of years with periods where rainfall exceeds 10 mm across the three 30-year periods (Figure IV.19). However, the trend is to have fewer years with long periods of wet days in the future. The frequency distribution of the highest number of consecutive dry and wet days is shown in Figure IV.20 and Figure IV.21. A notable difference among the three periods is that the occurrence of consecutive dry days lasting more than 2 months is possible in the 2050s (Figure IV.20). On the other hand, there are fewer instances of consecutive wet days that last for more than 1 month in the 2020s and 2050s (Figure IV.21).

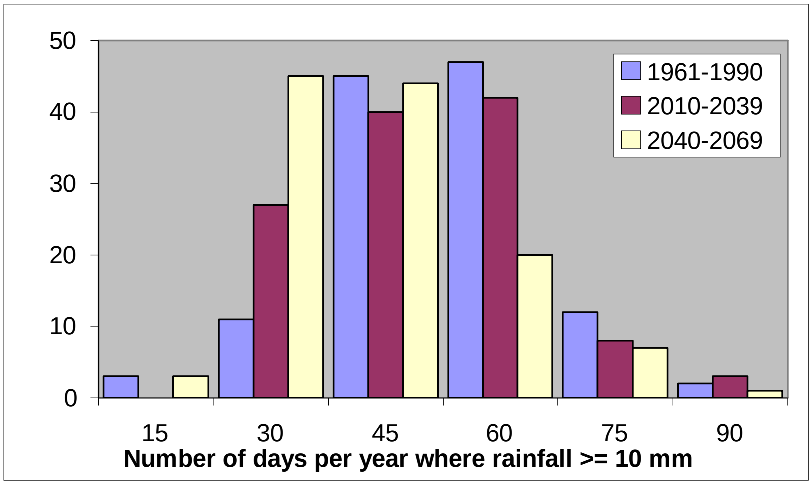


Figure IV.19. *Frequency distribution of days where the daily rainfall is greater than or equal to 10 mm in Silago from the years 1961 to 1990, 2010 to 2039 and 2040 to 2069 from RegCM3.*

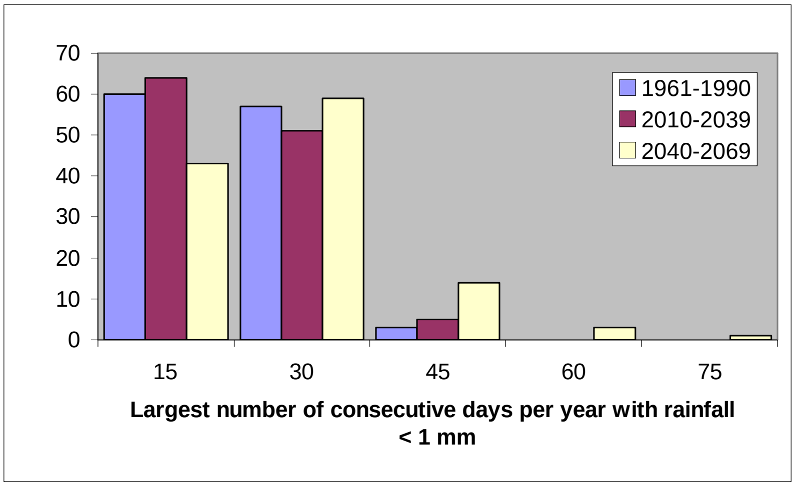


Figure IV.20. *Frequency distribution of the largest number of consecutive days where the daily rainfall is less than 1 mm (consecutive dry days) in Silago from the years 1961 to 1990, 2010 to 2039 and 2040 to 2069 from RegCM3.*

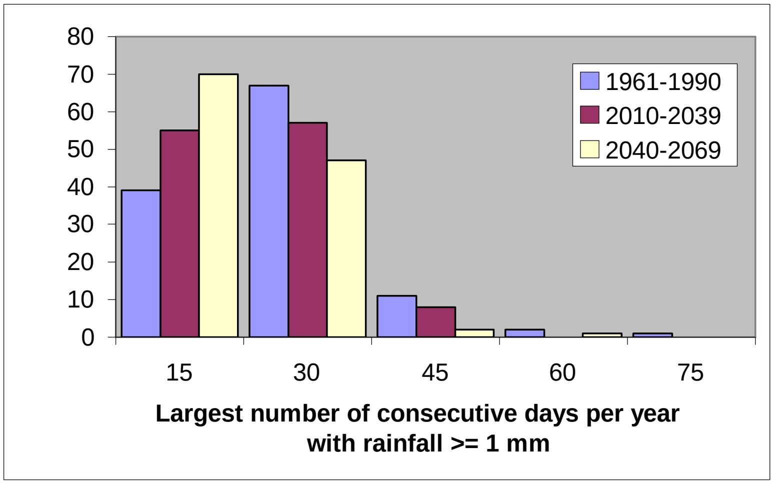


Figure IV.21. *Frequency distribution of the largest number of consecutive days where the daily rainfall is greater than or equal to 1 mm (consecutive wet days) in Silago from the years 1961 to 1990, 2010 to 2039 and 2040 to 2069 from RegCM3.*

V. VULNERABILITY AND IMPACTS OF CLIMATE CHANGE ON THE FORESTRY SECTOR

A. THE FORESTRY SECTOR OF SILAGO

Leyte Island is part of the Eastern Visayas and was formed through geologic uplifting during the tertiary and by a central, largely volcanic mountain ridge called the Leyte Cordillera, with its peak at Mt. Pangasugan (1150 m asl) (Margraf and Milan, 1996; Scinicz, 2005). Leyte island and the neighboring islands of Samar, Mindanao, and Bohol were most likely connected during the Pleistocene to form a single island called Greater Mindanao. The faunal affinities of these islands to each other persist to this day (Heaney and Regalado, 1998).

There is little published literature on the biodiversity of forests in Leyte island. Margraf and Milan (1996) in their reconstruction of the potential natural vegetation of the island, proposed the occurrence of 14 major vegetation types, mainly forest formations, which include lowland dipterocarp forests, as well as swamp forests that had been largely felled for timber and agricultural production. Deforestation in Leyte island in recent years can be attributed to the clearing of forests for commercial and marginal upland agriculture, and non-timber plantation establishment (mainly coconut)[6]. Settlement projects, agriculture and forestry development projects and road construction were said to have also contributed to forest loss (Dargantes and Koch, 1994). Forest clearing and repeated cultivation of root crops, abaca, banana, corn, coconut and use for livestock production result in the formation of degraded lands dominated by grasses such as *Chrysopogon acicularis, Imperata cylindrica*, *Axonopus compressus* or *Saccharum spontaneum*, (Quimio, 1996). Dipterocarp forest remnants are now generally found in localities where large-scale logging was not profitable and where access was hampered by the difficult terrain (Langerberger, 2006).

Agroforestry systems adopted by farmers in Leyte were broadly classified by Harrison et al. (2005b) as coconuts and timber trees, coconuts and other products (e.g. fruit trees, livestock), timber trees and fruit trees, and coconuts or timber trees and rice. Rice is widely grown on relatively flat coastal areas, while coconuts and bananas are commonly planted in sloping land. Analysis done at the farm and parcel level by the same authors showed the almost exclusive reliance on gmelina and mahogany for timber, and a resurgence in coconut production, following the recovery of the copra price, with little recent planting of timber trees. Fruit trees are typically a secondary crop on farms growing coconuts and timber trees and few farmers were involved in abaca growing. On a farm and land parcel basis, there were indications that growing multiple species provides income stability, increased self-sufficiency and some species complementarities, but the

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[6] There is information (www.forestry.denr.gov.ph) that a logging company once operated in Region 8, its Timber License Agreement (TLA) issued in 1972, with an annual allowable cut (AAC) of 80,000 m^3, and an area of 26,000 has encompassing the towns of Hinunungan, St. Bernard, Silago and Sogod in Southern Leyte, and Baybay, Javier and Abuyog in Leyte; the TLA was cancelled in 1993 by the DENR due to the declaration of a logging moratorium.

economic and ecological benefits associated with agroforestry interactions is not taken full advantage of (Harrison et al., 2005b).

At present, both natural forests and plantations are not able to fully provide local needs for wood in the region. In the Eastern Visayas, log production for lumber had reached an annual average of 212,589.86 m3 per year, but after the imposition of a logging moratorium in 1989, dropped to 4,391 m3 a year, causing a severe supply shortage for all wood requirements (DENR, 1990). In Leyte province, timber from native species including molave and narra has been decreasing, while the demand for high quality furniture and house construction is increasing. Even the supply of exotic timbers from plantation forests would not be able to meet the shortage, with wood-based industries procuring most of their timber from Cebu and Mindanao (Mangaoang et al., 2005). The supply problem is further complicated by the strict implementation of the DENR policies against illegal cutting of timber for forest preservation (Mangaoang et al., 2005).

Contemporary kaingin farming has a range of interpretations for upland communities in Leyte island, some of them akin to ‘shifting cultivation’, (involving rotation of fields and a forest fallow period), but now usually consistent with ‘slash and burn’ as a means to open new land, with most migrants actually practicing sedentary agriculture, the end point being either perennial plantations or *Imperata* wastelands, the latter “shifted” only in the sense of crop rotations and short-term fallow (Lawrence, 1997).

Forests are an important source of both subsistence and commercial goods. Lacuna-Richman (2003) reported the heavy extraction of rattan (*Calamus sp.*) by households living in the forest margins of the town of Cienda in Leyte province. Family members also take the opportunity to collect various non-wood forest products (NWFP) for food, medicine and building materials for houses, while growing and harvesting abaca (*Musa textilis L.*), in their kaingin plots in the forest margins. The same author reported the heavier use by poorer families of various NWFP for food.

Within the production forests of Silago (estimated at 6,233.15 has based on latest perimeter survey) are two Community-Based Forest Management (CBFM) projects, one managed by the Puntana Livelihood Project and Environmental Development Association, Inc (PLPEDA) in Barangay Puntana, and the other by the Katipunan Imelda Catmon Community Forestry Association (KICCFA) in Barangays Katipunan, Imelda and Catmon. Based on 2003 records of the Department of Environment and Natural Resources, the KICCFA CBFM area was measured at roughly 1,617 hectares with 110 households under its provisions. The KICCFA currently manages 1,698 hectares of the common forest area of the three barangays (FLUP, March 2011). The latest available data from the LGU shows that majority of the area is composed of growing forest trees, while there are equal areas covered with matured and young forest trees (Table V.1). Meanwhile, the PLPEDA CBFM area was 250 hectares, with 94 households under its jurisdiction (http://forestry.denr.gov.ph/CBFMP.xls). These projects are monitored by the Municipal Environment and Natural Resources Office (MENRO) and the Department of Environment and Natural Resources (DENR), with funding sourced from non-government organizations (NGOs), particularly the German Technical Cooperation (GTZ).

Table V.1. *Types of forest trees in the KICCFA CBFM project site by estimated area and percent of total area.*

Classification	Percent of total area (%)	Estimated area (ha)
Young forest trees	20	339.60
Growing forest trees	60	1,018.80
Matured forest trees	20	339.60
TOTAL	100	1,698.00

The local government also launched an agroforestry program by distributing 3,000 assorted fruit bearing tree seedlings, 10,000 coffee seedlings, 5,000 mangrove seedlings and 500 jackfruit seedlings. Forest-based production activities include planting of indigenous and fruit bearing trees, weeding, cleaning, monitoring and supervision of designated forest areas.

Langerberger (2006) reported that about 40% of the total land area of Leyte island was occupied by grasslands and barren lands; 40% by coconut plantations and only 2% by primary forests. A land cover analysis done by REIS (2009), on the other hand shows that, of the total surface area of 725, 810 ha, 31% of Leyte island is covered with closed forest; 31% with perennial crop, 16% with annual crops, and the rest with pastures, shrubland, and barren land (Table V.2).

Table V.2. *Percent land cover distribution of Leyte Island.*

Land Cover Class	Area (Ha)	Percent Cover
Closed Forest	228,665.33	31.50
Mangrove Forest	6,567.31	0.90
Shrubs	53,957.19	7.43
Barren Land	5,133.39	0.71
Annual Crop	117,022.72	16.12
Perennial Crop	229,610.37	31.64
Pastures	71,979.91	9.92
Road, Settlement, Rivers	12,873.98	1.77
TOTAL	725,810.19	100.00

Source: REIS, 2009

Latest estimates for the area of classified forest land in Silago vary, from 12,939.98 hectares (according to the mucipality’s draft Forest Land Use Plan (FLUP, March 2011)) to 14,653.22 hectares according to the perimeter survey conducted by the Municipal Investigating Team (MIT) and used in the Draft CLUP (March 2011). While discrepancies are still yet to be reconciled, these values indicate that forestlands make up more than half of the municipality`s total land area, showing the dominance of this ecosystem in the landscape. However, as stated earlier in this report, declared forest lands may not be under actual forest cover.

An analysis of remotely sensed data by the GTZ (2009) shows that Silago has 9,677 has of closed forests, which comprised almost half of the estimated total area of 19,610 has of the municipality, and 69% of the total forest cover of the province of Southern Leyte (Table V.3).

Table V.3. *Percent land cover distribution of Silago, Southern Leyte, GTZ (2009) data.*

Land cover type*	Area (ha)	Percent Share of Silago (%)
Grassland 70-coconut 30	1,004.16	5.12
Grassland 70-shrub 30	1,245.89	6.35
Shrubs	769.08	3.92
Shrubs 70-forest 30	1,710.00	8.72
Shrubs 70-coconut 30	370.73	1.89
Coconut	4,721.00	24.07
Settlements	111.91	0.57
Forest	9,677.59	49.35
TOTAL	19,610.36	100.00

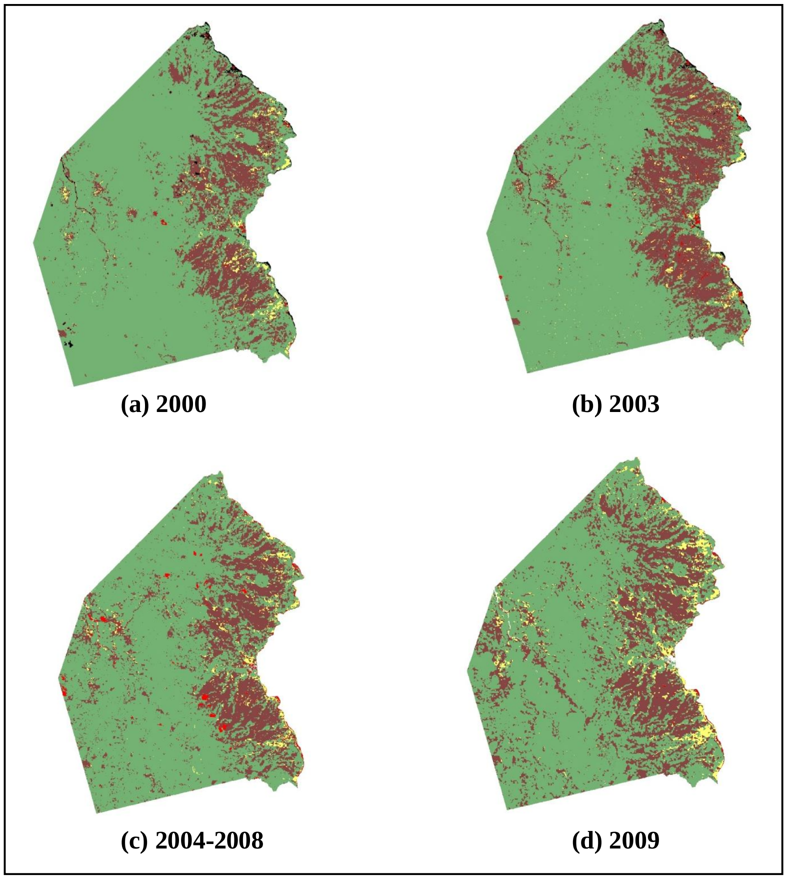
** Based on percent canopy cover distribution of selected vegetation type*
Source: GTZ, 2009

The results of the land cover change analysis done for this study is shown in Table V.4. While our analysis shows higher estimates of the area under forest compared with the GTZ study described earlier, what is consistent is the predominance of this land cover in Silago, succeeded in decreasing order by scrubland (which in this analysis, includes coconut plantations), paddy and urban. Forest cover loss based on this analysis is estimated at a total of 1,340 ha, or a rate of about 148 ha per year over the last decade. In contrast, the other land cover classes increased in area over time, with scrubland gaining the highest at about 123 ha/year, followed by the other classes, at relative much lower rates of increase. The area for paddy fields may not be reliable since the images were taken in different months. Paddies during the fallow season of wetland rice could have been underreported in some images. Urban areas have expanded almost four-fold yet remain trifle compared with the total area of Silago. If the classification holds true then it is evident that the forest area is also becoming patchier, giving way to islands of scrubland and urban areas surrounded by forest (Figure V.1). The impact of the newly-constructed Abuyog-Silago Road on land cover change may not yet be evident since it has only been completed recently. But newer patches of non-forest has been observed in the 2009 image that correspond to areas near farm to market roads (FMR) which became operational in the last 5 years (e.g. Imelda FMR and Catmon FMR) (Figure V.2).

Table V.4. *Relative areas of cover classes resulting from supervised classification of LandSat 7 images and REIS (2009) data.*

Cover class	Hectares							
	2000	**%**	**2003**	**%**	**2006**	**%**	**2009**	**%**
Forest	17,437.278	79.00	17,698.193	80.00	15,200.725	69.00	16,097.128	73.00
Scrubland	4,087.722	18.00	5,219.246	24.00	5,828.931	26.00	5,197.281	24.00
Paddy	358.196	1.60	282.152	1.30	862.576	3.90	530.637	2.4
Urban	56.107	0.25	150.135	0.68	48.861	0.22	210.950	0.94
Others	177.538	0.81	130.841	0.59	-	-	-	-

Recognizing the importance of conserving its forest resources, the town has been the site of reforestation projects which were implemented through community-based forest management (CBFM). Such projects are monitored by the Municipal Environment and Natural Resources Office (MENRO) and the Department of Environment and Natural Resources (DENR), with funding sourced from non-government organizations (NGOs), particularly the German Technical Cooperation (GTZ).



(a) 2000

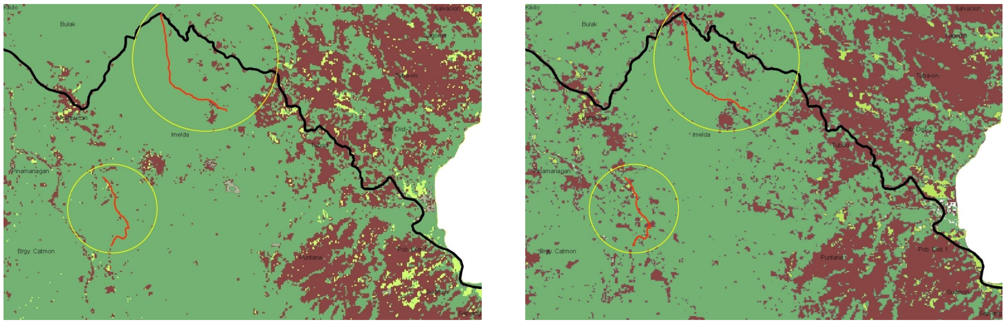
(b) 2003

(c) 2004-2008

(d) 2009

Figure V.1. *Land cover map of Silago, Southern Leyte.*
Legend: green: forest, brown: scrubland, yellow: paddy, red: urban, black: others.

In the absence of historical data, the analysis done serves as a preliminary investigation into the general patterns of change among the chosen land cover types over the last decade. The accuracy of the estimates is constrained by the availability of images with higher spatial resolution and low cloud cover, and validation (ground-truthing) data which would greatly improve classification and change detection. The data from the perimeter survey recently conducted by the MIT (Table V.5) indicate a lower forest cover (further classified into types: primary forest, secondary forest and plantation forest) at around 58% of the total land area of the municipality; still, this can be considered a good condition compared with background deforestation rates in the Philippines. However, it is important to note that there are many insidious activities in forest lands such as *kaingin*-making, timber poaching and fuelwood collection that occur in such a small scale that they escape detection by remote-sensing techniques, and thus for Silago a better understanding of how these threats operate at the local scale is needed.



(A) 2000 **(B) 2009**

***Figure V.2.**. Forest area in areas surrounding Abuyog-Silago Road in (A) 2000 and (B) 2009; forests became patchier near farm to market roads in Imelda and Catmon.*

***Table V.5.** General Land Use and Forest Cover Type by Land Classification, Silago, Southern Leyte, 2010.*

	Land Classification		Total Area	Percent
	FFL (Ha)	A & D (Ha)	Ha	%
Natural Forest Closed (NFC) Primary Forest	5,929.41	33.12	5,962.53	27.10
Natural Forest Fragmented (NFF) Secondary Forest	6,196.82	365.86	6,565.54	29.84
Plantation /Production Forest	149.61	66.92	217.55	0.98
Grassland/ Brush land (GL/BL)	1,394.87	3,833.67	5,228.54	23.77
Cultivated Area (AC,CC)	380.03	5,338.28	5,718.31	25.99
Urban Use area	0.30	53.77	54.07	0.24
Road Network	3.45	85.45	88.90	0.40
Foot trail	0.44	7.80	8.24	0.03
Agro-Industrial		4.85	4.85	0.02
Water Use Area:	9.53	39.76	49.27	0.22
Rivers	14.88	53.36	68.24	0.31
Creeks				
TOTAL	8,512.03	13,483.10	21,995.13	100.0

Source: Draft CLUP, 2011

LAND COVER CHANGE ANALYSIS

Recognizing the importance of land use as a dominant driver of change that encompasses the different sectors, land cover change analysis using remote sensing and GIS was done to assess the extent of deforestation and forest cover fragmentation in the landscape. Analysis was done for the period 2000-2009 using downloaded satellite images (www.usgs.gov).

The succeeding section details the methods used to explore land cover change in the Municipality of Silago in Southern Leyte Province from 2000 to 2009 using LandSat 7 images. For the period between 2003 and 2008, the resulting land cover map from REIS' Production of Enhanced Land Cover Map of Leyte Island Project was used as proxy. Supervised Image classification was done using Envi 4.x. Gap-filling via vector editing processes were done using ArcGIS 9.2. Results of unvalidated image classification and corresponding areas are then presented.

Data acquisition

The best LandSat 7 images in WRS-2 Path/Row 113,53 with least cloud cover over the area of Silago where selected and downloaded free from www.landsat.usgs.gov for the years 2000, 2003 and 2009. Specifically scene ID # L71113053_05320001204 dated 4 December 2000, L71113053_05320030807 dated 7 August 2003 and L71113053_0532009072 dated 22 July 2009 (Figure V.3, Figure V.4 and Figure V.5). The boundary delineation of the municipality used for this analysis was based on the area described in the Cadastral Survey of the Municipality of Silago (Bureau of Lands), and was also compared (clipped) with the shapefile data used in the municipality's Land Use\ Barangay Development Plan (LU-BDP) to determine the municipality`s official, undisputed boundary.

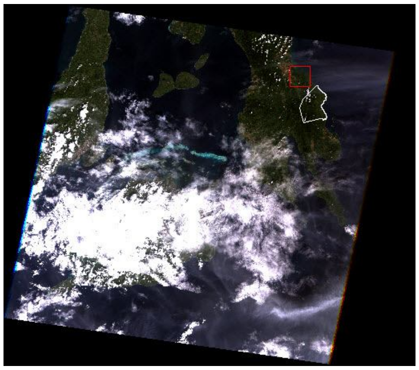


Figure V.3. *L71113053_05320001204, 4 Dec. 2000, Bands 3, 2, 1.*

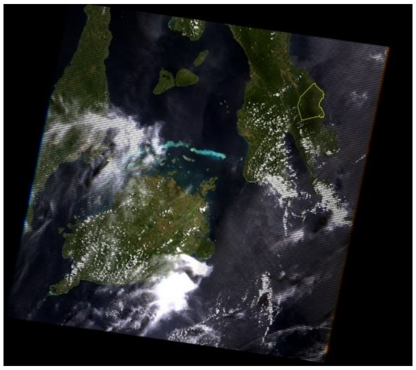


Figure V.4. *L71113053_05320030807, 7 Aug. 2003, Bands 3, 2, 1.*

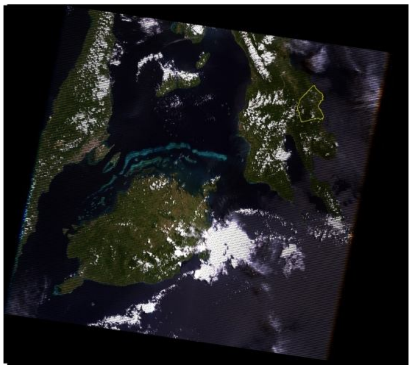


Figure V.5. *L71113053_0532009072, 7 July 2009, Bands 3, 2, 1.*

Pre-processing

Radiometric correction for Bands 1-5 and 7 of each image was done in ENVI by converting DN values to radiance values. Spatial subsetting of each band to cover only the area of Silago (Figure V.6) was done for more efficient processing. Stacks of RGB composites B145, B123, B753 and B321 were then prepared for image classification.

Figure V.6. *Subset of Landsat 7 image, RGB composite B753.*

Image classification

Training classes for classification were set for forests, scrubland, paddy fields and urban using the spectral profiles (Figure V.7) of each class at specific band composites where these classes have highest contrast. B145 was used for classifying forest and scrubland. B123 was used for classifying paddy while B753 was used for classifying urban surfaces.

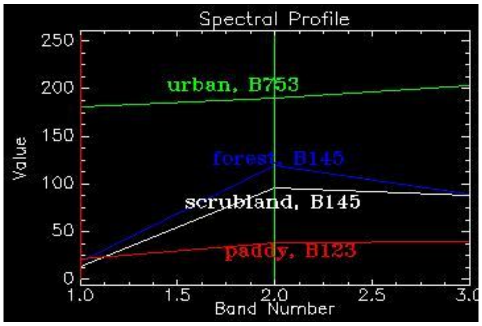


Figure V.7. *Spectral plots of training classes with corresponding band composites.*

Supervised classification was done using spectral angle mapper. Default values in Envi were used. Areas eclipsed by cloud and shadow were assumed to be forest areas. Classes were then converted to vectors for editing.

Post-classification

Vector editing was done in ArcGIS resulting to a harmonized land cover theme per satellite image acquired. A gap-filled land cover theme for 2003 (b) was produced by intersecting its LandSat 7 gap masks with the final land cover theme of year 2000 (a). As for the years between 2003 and 2008, the classification done by REIS which used SPOT 5 image for Silago taken in 2004, 2006 and 2008 (REIS, 2009) was used as proxy. The classes used by REIS where however simplified: 'forest' and 'perennial crops' were reclassified as forest, 'pastures' and 'shrubs' were reclassified to scrubland, 'annual crops' were reclassified to paddy and 'barren land' was reclassified to urban (c). Gaps in the 2009 classified LandSat 7 image were gap-filled using the reclassified REIS land cover map (d).

B. IMPACT CHAIN, INFLUENCE DIAGRAM, AND INDICATOR DATA FOR THE FORESTRY SECTOR OF SILAGO

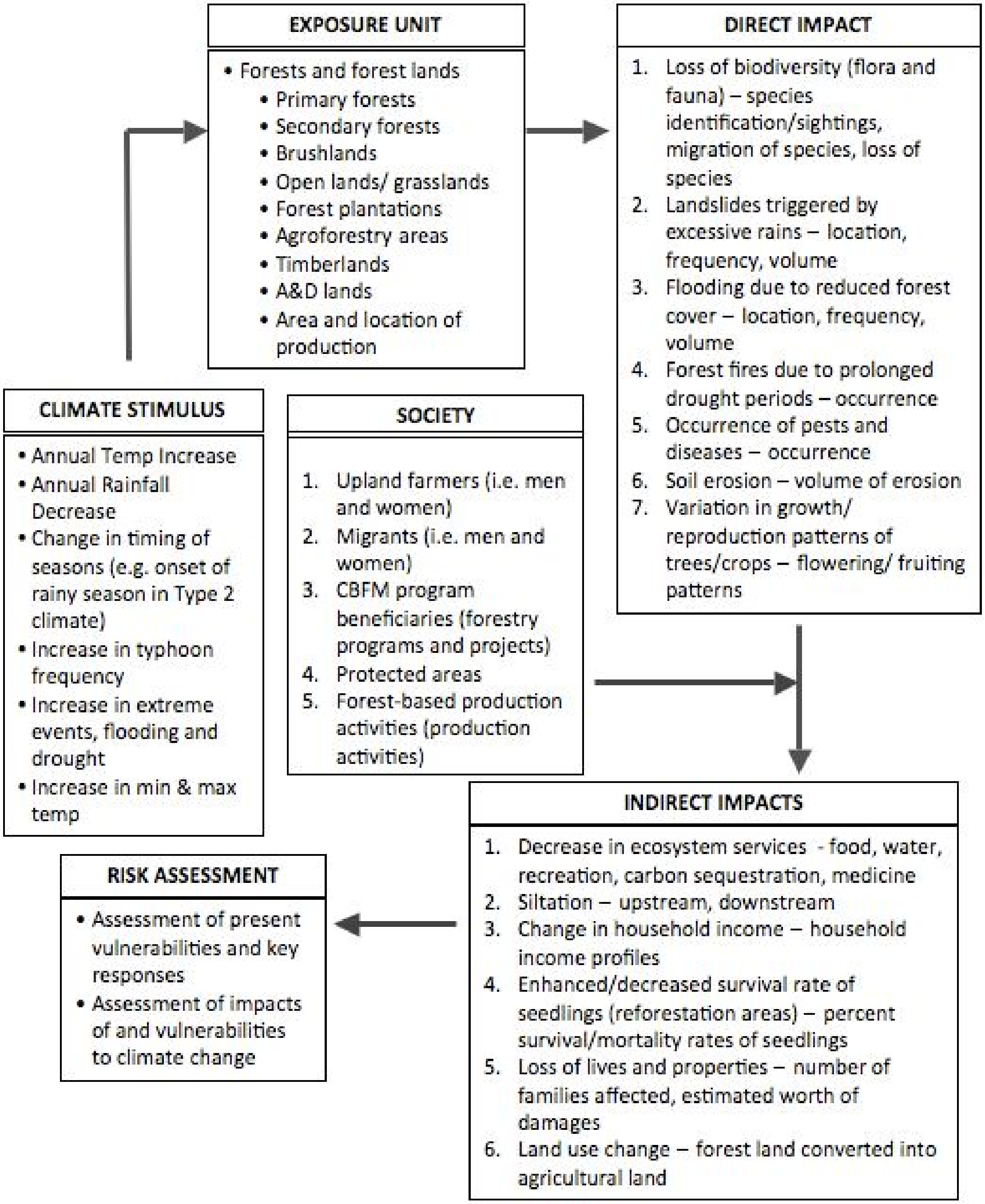
Impact Chain

Figure V.8 shows the refinement of the Pre-Analysis Impact Chains for the Forestry sector. The scoping process with the LGU and other stakeholder of Silago led to the identification of the exposure units and direct and indirect climate impacts that are deemed most relevant for the municipality. Further data collection efforts however showed that there was little substantive information on hand to support quantitative assessments at the level of the municipality, especially with regards to measures of direct and indirect impacts.

Influence diagram

Climate variables (rainfall and temperature; the effects of increased atmospheric CO_2 concentrations was not considered here) affect ecophysiologal processes and ecosystem functions and properties which eventually would influence the way forests deliver the different services derived by both local communities in Silago and downstream users (Figure V.9). For Silago these important ecosystem services include the provision of goods (food, fuelwood and non-timber forest products), regulation of the flow and quality of water (considering the high dependence of the municipality on surface flows for its water and the absence of efficient storage and distribution infrastructure), and influences on soil formation and nutrient recovery (agriculture being the major source of livelihood), all of which have direct and indirect impacts on human well-being. However, the vulnerability of forests and forest ecosystem services to future climate impacts would be largely affected by current threats of deforestation and forest degradation. Silago's forests remained intact probably due to the area's inaccessibility for (commercial) logging operations in the past. Based on the information gathered, among the current important drivers of deforestation and degradation are the expansion of farming activities in forest lands; the current scarcity of timber in the region in the face of increasing demands for wood for construction and other uses, and road construction, particularly the Junction Abuyog-Silago junction road.

The potential direct and indirect damage of the construction of the new road to forests have been described earlier; socioeconomic impacts, such as the greater integration of the municipality with the regional economy would also likely further enhance the effects of land use change and links with demand for food and other agricultural products, creating pressures to clear more forest land. The resulting changes in land use would have consequences for the other priority sectors of the municipality.



EXPOSURE UNIT

- Forests and forest lands
  - Primary forests
  - Secondary forests
  - Brushlands
  - Open lands/ grasslands
  - Forest plantations
  - Agroforestry areas
  - Timberlands
  - A&D lands
  - Area and location of production

DIRECT IMPACT

1. Loss of biodiversity (flora and fauna) – species identification/sightings, migration of species, loss of species
2. Landslides triggered by excessive rains – location, frequency, volume
3. Flooding due to reduced forest cover – location, frequency, volume
4. Forest fires due to prolonged drought periods – occurrence
5. Occurrence of pests and diseases – occurrence
6. Soil erosion – volume of erosion
7. Variation in growth/ reproduction patterns of trees/crops – flowering/ fruiting patterns

CLIMATE STIMULUS

- Annual Temp Increase
- Annual Rainfall Decrease
- Change in timing of seasons (e.g. onset of rainy season in Type 2 climate)
- Increase in typhoon frequency
- Increase in extreme events, flooding and drought
- Increase in min & max temp

SOCIETY

1. Upland farmers (i.e. men and women)
2. Migrants (i.e. men and women)
3. CBFM program beneficiaries (forestry programs and projects)
4. Protected areas
5. Forest-based production activities (production activities)

INDIRECT IMPACTS

1. Decrease in ecosystem services - food, water, recreation, carbon sequestration, medicine
2. Siltation – upstream, downstream
3. Change in household income – household income profiles
4. Enhanced/decreased survival rate of seedlings (reforestation areas) – percent survival/mortality rates of seedlings
5. Loss of lives and properties – number of families affected, estimated worth of damages
6. Land use change – forest land converted into agricultural land

RISK ASSESSMENT

- Assessment of present vulnerabilities and key responses
- Assessment of impacts of and vulnerabilities to climate change

Figure V.8. *Impact chain for forestry sector of Silago, Southern Leyte.*

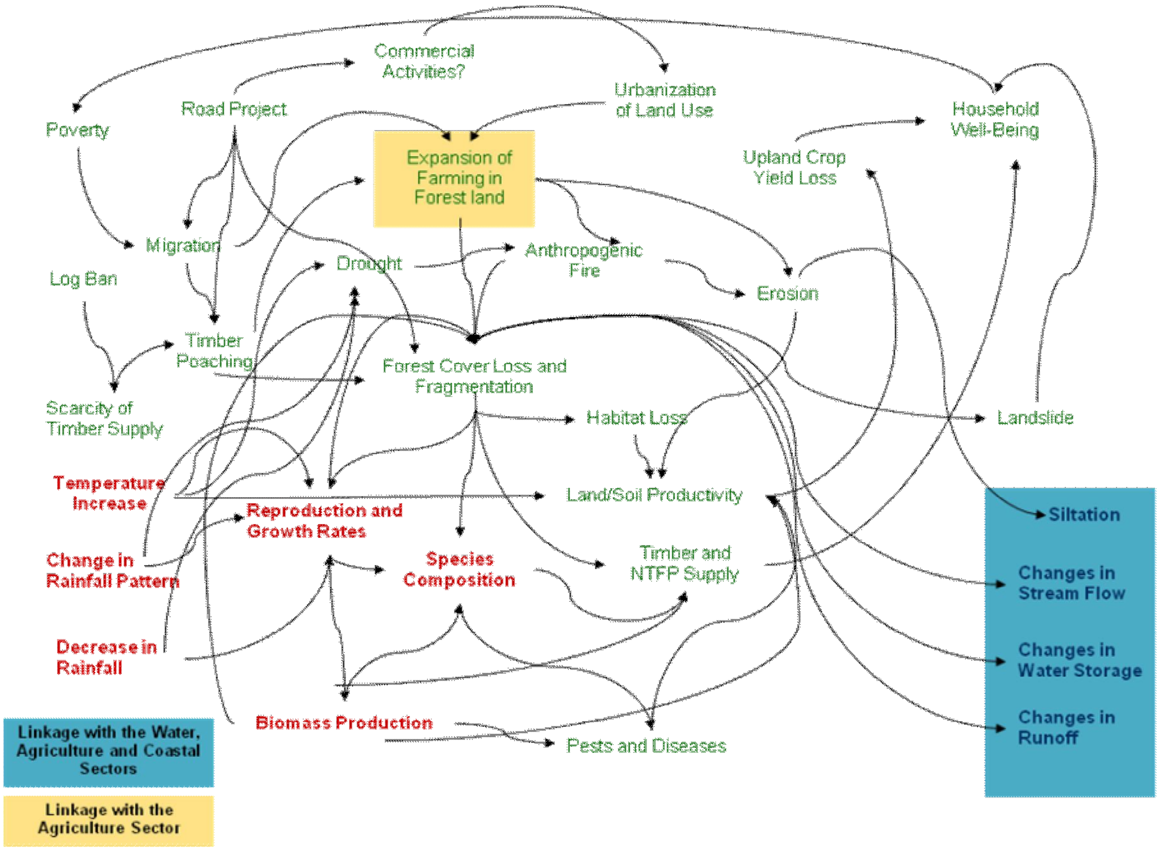


Figure V.9. *Influence diagram for the forestry sector of Silago.*

C. CLIMATE IMPACTS AND PATTERNS OF VULNERABILITY

One key vulnerability of Silago to climate change lies in its fresh water sector, the anthropogenic link between these two being land cover change. More forest cover means more freshwater sources. However it should also be noted that the significant threshold relating forest cover and springflow/streamflow production is still poorly understood. Although the volume of rainfall infiltrating into Silago's forest soils can be easily modelled, how these infiltrated water is partitioned underground is still a subject of a baseline study which, at least, requires measuring springflow rates, and ideally, mapping the aquifer structure. Only then can one fully understand the relationship between forest and the fresh water sector in the municipality.

In the context of Silago which is a municipality highly dependent on springs for both domestic use and irrigation needs, a continuing decrease in forest cover may result in the long-term to decreased aquifer recharge, spring flow and base flow and instead lead to increased runoff production, erosion and siltation. Conversion to urban, impermeable surfaces completely translates rainfall to runoff.

The absence of meters in the existing distribution system makes it difficult to ascertain the current demand for water in the Municipality, as well as project the future demand. At present, rough estimates indicate that there is a potentially large supply of water in Silago. However, climate-sensitive variables are also present, particularly 1) the incidence of enteric waterborne diseases, and 2) water siltation. Incidence of enteric waterborne diseases can be exacerbated by the presence of favorable climatic (i.e. temperature, moisture) and other environmental conditions. Meanwhile, siltation – although also greatly affected by land use change – is aggravated by climate stimuli such as increase in rainfall, strong winds and occurrence of extreme climate events.

Although we cannot categorically state how much forest cover is actually needed to sustain ample water supply for the needs of the Municipality's current and future population, it is evident that the urgent need of the hydro-forest sector is the establishment of an improved distribution network to maximize the use of the currently underutilized water resources.

A note regarding forest cover and hazards. Although Silago lies along a major faultline traversing Southern Leyte, there are no significant settlements near the faultzone. While landslides have been linked to deforestation and land degradation processes, important information on geology and soil properties specific to the municipality need to be obtained to clarify interactions between forest land use, climate and the occurrence of these hazards.

Indicator Data

Considering current inadequacies of basic data, local priorities for assessment, and resource limitations for data collection, the following set of indicator data for analyzing climate impacts and vulnerability and possible sources are identified (Table V.6).

Table V.6. *Possible indicators of vulnerability to climate variability and climate change of the forestry sector.*

Component of Vulnerability	Parameter	Proxy/Auxiliary Parameter	Possible Data Source
Exposure	Rainfall time series		Measured rainfall or proxy from the nearest PAGASA station
	Land use change (High resolution)		National mapping authority (NAMRIA)
	Land cover fragmentation		National mapping authority (NAMRIA),
	Timber and NFTP utilization	Production/ Harvest Data	Municipal Environment and Natural Resources Office (MENRO) (based on local monitoring records)
Sensitivity			
	Biodiversity	Floristic Inventory	Expert assessment/ Biodiversity assessment
	Productivity	Stand (Volume) Inventory	MENRO/ Local forest inventory
		Stand Biomass Assessment	MENRO/ Local forest inventory
	Soil properties	In-situ saturated hydraulic conductivity	Field measurements, laboratory procedures
	Geologic profile		MENRO and Bureau of Mines

D. ADAPTATION AND MITIGATION OPTIONS FOR THE FOREST SECTOR OF SILAGO

Adaptation Options for the Forestry Sector of Silago: Some Considerations

In implementing forest adaptation, it is important to account for local variations, i.e. differences in geographical and population characteristics among barangays or sub-watersheds, when establishing adaptation plans and policies. While it may be considered difficult, impractical and costly, peculiarities in different localities need to be considered to allow successful implementation of adaptation measures. In order to do this, local institutions and stakeholders need to become more involved in the adoption of adaptation strategies, from planning and implementation to monitoring and evaluation; the involvement of local people especially for the latter two activities (M & E) becoming all the more important given the scarcity of available information and the limited resources that the local government may have for data collection efforts.

Strengthening local institutions and establishing a greater sense of ownership and access among stakeholders are instrumental in adaptation implementation; in this aspect the municipality may have already some gains with the implementation of CBFM projects; the critical part would be in involving those lasting networks/institutions within this sector that would play a role in sustaining programs after external agencies withdraw support, and in the face of changing policies on forest lands and forest resource utilization.

Adaptation options for the forestry sector are hinged on the priority development needs of Silago; poverty in the municipality must be addressed to lend greater adaptive capacity to present- and future climate stresses. The importance of forest ecosystems to the local economy and the environment should therefore be realistically viewed within the context of the specific development goals of the different sectors of the municipality; this means that certain trade-offs may occur between development priorities vs. adaptation strategies for forests. An example given here are the results of the evaluation of the effects of selected adaptation strategies for the forest and agriculture sector on other sectors of the Pantabangan- Carranglan watershed (Table V.6) (Cruz et al., 2005).

It is also possible to come up with complementary strategies that would contribute to reducing the vulnerability of forests and forest- dependent communities at the same time create new opportunities for improved livelihoods. Agroforestry technologies, for instance could be tapped for their potential to address multiple problems in forest lands such as soil erosion, land degradation, food security and provision of additional/ alternative sources of incomes while contributing to the resilience of the system (see Box V.1 below).

Table V.7. *Adaptation options for forests and agriculture in the Pantabangan-Caranglan Watershed and their potential impacts on water resources, institutions and local communities.*

Adaptation Strategy for Forests and Agriculture	Effect on Water Resources	Effect on Institutions	Effects on Local Communities
Use of early maturing crops	+Low water demand	0	+Higher income
Use of drought-resistant crops	+Low water demand	0	+Higher income
Supplemental watering	-Higher demand for water	-Increase cost of developing alternative sources of water	-Greater labor demand +Higher income
Proper scheduling of planting	0	-Increase cost for training, technical assistance, R&D	-Cash expenses
Soil and water conservation	+ Conservation of water	- Increase cost for training, techinical assistance, R&D	- Cash expenses
Establishment of fire lines	+ More vegetative cover promotes good hydrology	+ Less expense for fire fighting	- More labor demand + Less damage to crops from fire; more income
Construction of drainage structures	+ Better water quality	- Increase cost of implementation	+ Less soil erosion in the farm; greater yield
Controlled burning	+ Less damage to watershed cover	0	0
Enhance community-based organizations	0	+ Better participation in the political process	+ Better participation
Total logging ban	+ More forest cover	- Increase cost of enforcement and protection	- Less income - Fewer sources of income
Use of appropriate silvicultural practices	+/- Could promote or impair hydrology depending on the practice	- Increase cost of implementation	- Increase cost of implementation
Better coordination between LGUs	+ Promotes better watershed management	+ Greater collaboration among LGUs	+ Better delivery of services to farmers
Informati0on campaign		+ Increase awareness and competence	+ Increase awareness and competence
Better implementation of forest laws	+ Promotes better watershed management	- Increase cost of implementation	+/- Could adversely affect current livelihood of farmers that are deemed "illegal"

Source: Cruz et al. 2005

The following are some considerations for climate change–related opportunities for the forest sector (Robledo and Forner, 2005):

- Recognition of local knowledge in coping with climate variability
- Promotion of native species that adapt better to climate variability
- Diversification of forest use so that the impact of each activity is reduced and, therefore, also the overall vulnerability
- Promotion of sustainable forest management as a means for reducing vulnerability
- Development of new market opportunities for traditional forest products that are highly resilient to climate change

- Sustainable forest management as a means for reducing GHG emissions and for enhancing carbon sinks.

Box V.1. Agroforestry options for Silago

Agroforestry is the practice of incorporating trees on farms. Trees on farms enhance the coping capacity of small farmers to climate risks through crop and income diversification, soil and water conservation and efficient nutrient cycling and conservation (Lasco and Pulhin, 2009). Agroforestry offers a means for diversifying production systems and increasing smallholder farms` agility in respond to climate changes because tree-based systems have the following characteristics and properties (Verchot et al., 2007):

- deep root systems that are able to explore larger soil volume for water and nutrients (helpful during droughts)
- increased soil porosity, reduced runoff and increased soil cover lead to increased water infiltration and retention in the soil profile that reduces moisture stress during low rainfall years
- higher evapotanspiration rates than row crops or pastures can maintain aerated soil conditions by pumping excess water out of the soil profile more rapidly than other production systems
- often produce crops of higher value than (annual) row crops

Diversifying the production system to include a significant tree component may buffer against income risks associated with climate variability. In addition to all these advantages, agroforestry management systems offer opportunities for synergies between adaptation and mitigation strategies.

Silago has an abundance of coconut plantations, also producing a small yield of bananas. A study by Magat (2007) discusses the suitable pairing of coconut and banana under an agroforestry system, since the two do not compete for soil resources (except in dry areas). With over 5,000 hectares of land dedicated to coconut production, there is potential to increase incomes through interplanting in areas previously mono-cropped. The additional income from the sale of banana and its processed forms could help augment household income. In doing so, the farming family becomes better equipped to avail of necessary goods and services in the face of climate –related stresses. Similarly, rubber-based agroforestry systems (RAS) like those in Mindanao can also provide alternative income prospects for smallholder farmers.

Correspondence with the LGU of Silago revealed intent to develop rubber plantations in the municipality. The rubber tree (*Heava brasiliensis*) grows in all soil types with year-round rainfall. Although these plans have not yet materialized, there is good demand for rubber latex both in local and export markets. In 2005, cup lump (naturally coagulated) rubber latex sold for PhP 14.26 per kilogram (BAS, 2010). According to the Department of Agriculture, typical yield is 1 to 1.8 tons of dry rubber per hectare per year (Young undated). The suitability of these suggested technologies/production systems to anticipated changes in climate in the municipality should of course need to be assessed.

Reducing Emissions from Deforestation and Forest Degradation (REDD)

Reducing Emissions from Deforestation and Forest Degradation (REDD) was conceptualized at the 11th Conference of Parties (COP) in Montreal in December 2005. The aim of the agenda was to reduce carbon dioxide emissions from land use and land use change by assigning financial value to carbon stored in forests. Aside from encouraging mitigation of carbon emissions, the corresponding income from carbon storage also doubles as an adaptation for the communities that stand to benefit from the monetary returns. With Silago's more than 12,000 hectares of forest land, including almost two thousand hectares under CBFM, implementation of REDD initiatives in the municipality – once materialized – could present viable alternative sources of income for locals involved in forest conservation and protection. REDD activities could be beneficial for adaptation, but badly designed projects could deprive people of their main sources of livelihoods (Guarigata et al., 2008) and leave out food security issues (DeFries and Rosenzweig, 2010).

VI. VULNERABILITY AND IMPACTS OF CLIMATE CHANGE ON THE WATER SECTOR

A. *GENERAL INTRODUCTION: WATER SECTOR*

Water Resources and Climate

The IPCC estimates in its Fourth Assessment Report that under any of the recognized emissions scenarios, 120 million to 1.2 billion people will experience water stress in 2020. By 2050, the number will range between 185 and 981 million (Cruz et al., 2007). Climate change is expected to induce changes in the storage and flow of water in glaciers and river systems, coupled with more intense rainfall over fewer days and drought in many areas. More intense rainfall implies higher risk of flooding during the monsoon while droughts can lead to decreased runoff in streams depended upon by various organisms and settlements. Decreased runoff in river systems can also push saltwater intrusion that deteriorates surface and groundwater quality. Higher water temperatures and variability in weather extremes are also projected to impact water quality and exacerbate water pollution. These impacts will further exacerbate food availability, existing operation of water infrastructure and access in water stress regions, on top of already existing stressors like population growth, economic activity, land-use change and urbanization (Bates et al., 2008).

Observational records and projections provide compelling evidence that freshwater resources will become more vulnerable and have higher potential to be impacted by climate change. These include projected increases in morbidity and mortality rates from waterborne diseases in both humid and drier scenarios (IPCC, 2007). Drier scenarios limit the recharge rate of aquifers which may lead to insufficient recharge of groundwater. Too much precipitation meanwhile risks higher pathogen presence, turbidity and nutrient loading in water, as well as flooding.

The Philippine Water Sector

The Philippines has a total land area of 300,000 square kilometers, with 421 rivers, 59 natural lakes and over 100,000 hectares of freshwater swamps (Peñaranda, 2009; AQUASTAT, 2010). The annual average rainfall is 2,400 mm. Rivers and lakes make up 1,830 km^2 of the country’s landscape, while bays and coastal areas cover approximately 266,000 km^2. River systems serve as an important means of transportation and source of irrigation water. The country’s water resources are divided into 12 regions which generally correspond to the 12 political regions. Slight deviations of water resource boundaries versus political ones (due to hydrography) occur only in Northern Luzon and Northern Mindanao (AQUASTAT, 2010).

The per capita water availability in the Philippines is estimated at 1,907 cubic meters, the second lowest in the Southeast Asian region. Water shortages are felt in many parts of the country, especially during the dry season, with 9 major cities vulnerable to significant water constraints. Although there are 421 rivers in the country, 50 of these are considered biologically dead, while more than half of sampled groundwater was found to be contaminated with coliform and thus, requires treatment (Peñaranda, 2009).

The same report summarizes the potential effect of climate variability on the water supply of the country. Increasing temperatures could translate to longer drought periods and further water shortages. Meanwhile, sea level rise threatens to increase salinity of surface and groundwater resources, making them unsuitable for human consumption (Peñaranda, 2009).

The frequency of occurrence of extreme events also affects rainfall and inflow patterns of reservoirs (Perez, 2007). From 1951 to 2008 PAGASA concluded observed increases in extreme rainfall intensity in most parts of the country, though not enough to show significant trends. Using the PRECIS climate model, PAGASA foretells that in 2020 and 2050 the Philippines can expect drier seasons of March-April-May to become drier still, while the wetter seasons of June-August and September-November will become wetter, under A1B emission scenario (Hilario et al., 2009). The general prediction is that more intense extreme rainfall events can be expected in the northern parts of the country, while less rainfall, drought and water scarcity are expected in provinces nearer to the equator (Peñaranda, 2009).

B. THE WATER SECTOR OF SILAGO

Forest Cover and the Hydrologic Cycle

There are 48 rivers and creeks that traverse the Municipality of Silago, providing an abundant supply of fresh water to the Municipality (CLUP, 2000). A GIS-based watershed delineation (see Hydrological analysis section) resulted to 23 major watersheds within the municipality, the boundaries of which do not correspond to barangay boundaries. The largest watershed area is hosted by barangay Catmon which is also the least populated barangay.

Climate, forests and water are interconnected through the hydrologic cycle. Silago's forests provide crucial hydrologic services by efficiently catching rain, reducing direct runoff and increasing soil drainage through evapotranspiration. Undisturbed forests are known to have very high infiltration capacities and very high hydraulic conductivities (Ks), especially in mineral forest soils in the tropics (Bonell et al., 1993). As early as 1978, Bonell and Gilmour have attributed the high infiltration capacities of undisturbed tropical forest soils to continued incorporation of organic matter interacting with high root density which leads to improved soil structure. A number of tropical studies have reported Ks in upper soil horizons between 10^{-6}m s^{-1} and 10^{-3}m s^{-1} and decreases dramatically as soil depth increases to 10^{-9}m s^{-1} ^{to} 10^{-5}m s^{-1} depending on soil characteristics (Dykes and Thornes, 2000). Elsenbeer (2001) indicates that an undisturbed tropical forest over acrisols have

Ks of > 1000 mm h^{-1} along a 1 m soil depth. Malmer (1993) indicates that a tropical rainforest over acrisol in Sabah, Malaysia has a surface Ks of 154 mm h^{-1} which declined to Ks = 0.68 mm h^{-1} at 0.20 m depth.

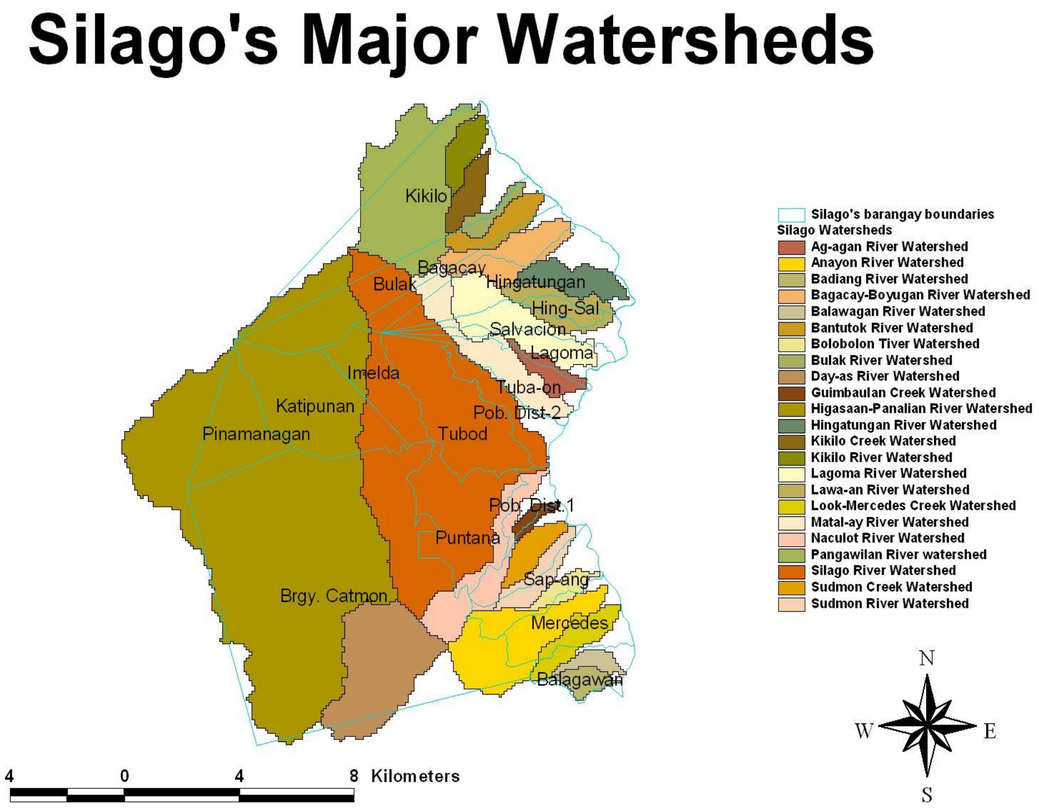


Figure VI.1. *Silago's major watersheds. Source: World Agroforestry Centre.*

The services provided by the watersheds are enjoyed not only by Silago but by adjacent municipalities of Abuyog, Hinunangan and Libagon as well. With a Type II climate and rare occurrence of extreme rainfall events or typhoons, it can be argued that almost all daily rainfall in Silago's forests translate to infiltration, part of it ending up recharging aquifers that in turn exfiltrate into springs where locals source domestic water and irrigation needs, particularly since most of Silago's streams are spring-fed.

For instance, a simple infiltration model considering only monthly projected rainfall (from 1961-1990) based on year 2000 land cover would yield 244 M m^3 of water infiltrating into the soil within a year for an area of forest covering 17,437.278 ha. The model assumed that the saturated hydraulic conductivity of the upper soil horizon is 100 mm hr^{-1}. That means runoff generation will only occur for hourly rainfall intensities beyond 100 mm. In the case of Silago, such rainfall extreme is a rarity. Locales report that the last typhoon they could remember was Typhoon Amy that occurred in the 1951. Better estimates can be arrived at if evapotranspiration rates are available to represent water withdrawn from the soil and cycled back to the atmosphere.

Water for Domestic Needs

According to the Municipal Ecological Profile (MPDO, 2009), Level III water supply is available throughout the Municipality, which pertains to direct service connection of households to the water supply system. Supply is managed by the respective barangay water system associations/councils, with water sourced from developed natural springs located within 3 to 5 kilometers of the service area. Other sources of domestic water are privately-owned shallow wells. Barangays located in the mountains rely on springs and surface water for drinking and other purposes. Correspondence with the municipality’s planning coordinator reveals that the municipality has sufficient and high quality domestic water supply from springs. However, this supply does not pass through any metering nor filtering process before ending up in people’s homes.

A CBMS Survey (2006) shows that out of the municipality’s 2,327 households (HH), 63% are classed under “without access to safe water.” These are households without access to either deep/artesian well or the community water systems; 8 out 15 barangays have 100% of households with access to safe water, while 5 out of 15 barangays, in particular those located in mountainous areas, have entire households without access to safe water.

Common problems encountered with the Municipality’s water supply are siltation in the intake facilities, and vulnerability to enteric and waterborne diseases due to contamination of water taken directly from the source (Municipal Health Office, 2010). According to key informants, the municipality has a regular number of juvenile patients who suffer from enteric waterborne diseases, especially when rain succeeds a series of warm days. The health report is not a surprise since areas with poor water supply infrastructure usually suffer the transmission of enteric pathogens that peak in the rainy season. On the other hand, higher temperatures are associated with increased incidence of diarrhea among children. Although there was a lack of data to quantify these claims at the Municipal level, the Field Health Survey Information System (FHSIS) Report of the Department of Health (DOH) reflects a significant number of cases of diarrhea throughout the region between 2006 and 2008 (FHSIS, 2006; FHSIS, 2007; FHSIS, 2008) (Table VI.1).

Table VI.1*. Incidence of acute watery diarrhea at national, regional and provincial levels, 2007 and 2008.*

Acute Watery Diarrhea	Number of Cases (2006)	Rate*	Number of Cases (2007)	Rate*	Number of Cases (2008)	Rate*
Philippines	572,259	707.7	539,701	640.0	434,445	485.4
Eastern Visayas (Region VIII)	29,543	700.2	40,888	1,044.9	32,476	760.0
Southern Leyte	3,720	1,165.1	4,022	1,292.8	3,530	1,052.5

*per 100,000 population

Water for irrigation

The results of the hydrological analysis (Table VI.2) shows that the Municipality of Silago’s river systems under average rainfall conditions can very well supply irrigation needs for paddy rice and can even be used to extend irrigation for other crops, provided that there are networks or infrastructure for river runoff to reach the farms. Among all Silago barangays, only Sap-ang, Sudmon and Poblacion Dist 1 require more water diverted from rivers (i.e. 1.1%, 3.5% and 1.1% more respectively) to supply rice paddies with irrigation at present conditions.

C. HYDROLOGICAL ANALYSIS

Estimating Silago's potential for rice irrigation from river runoff

Given the limited information regarding the available water resources for Silago, a hydrological analysis was done to come up with a ballpark estimate on the supply potential of the town's river systems for irrigated rice culture under average rainfall conditions in the area (Section B.2).

Table VI.2. *Silago's irrigation needs for paddy rice for one season versus available water supply.*

Barangays	Irrigated rice (ha)	% Total	Irrigation volume required in one season (m^3)*	Daily required irrigated volume	River source**	Daily discharge***	1% of daily discharge	Additional abstraction %
Balagawan	10	2.1	10,000	111	19, 20	26,653	266.528	
Mercedes	65	13.7	65,000	722	17, 18	123,151	1,231.51	
Sap-ang	15	3.2	15,000	167	16	17,226	172.258	1.1
Sudmon	68	14.3	68,000	756	14	21,939	219.393	3.5
Pob. Dist. 1	25	5.3	25,000	278	15	25,367	253.673	1.1
Pob. Dist. 2	50	10.5	50,000	556	13	517,007	5,170.07	
Tubod	35	7.4	35,000	389	13	517,007	5,170.07	
Tubaon	10	2.1	10,000	111	12	63,761	637.611	
Lagoma	45	9.5	45,000	500	10, 11	88,956	889.56	
Salvacion	30	6.3	30,000	333	9	38,051	380.509	
Hingatungan	73	15.4	73,000	811	7, 8	85,957	859.57	
Imelda	1	0.2	1,000	11	1	830,349	8,303.49	
Katipunan	30	6.3	30,000	333	1	830,349	8,303.49	
Puntana	10	2.1	10,000	111	13	517,007	5,170.07	
Catmon	8	1.7	8,000	89	23	115,952	1,159.52	
TOTAL	475	100	475,000	5,278		3,818,732	38,187.322	

Note: *based on 1000mm/unit area; **ID codes for pourpoints; ***from 10mm rain

Background and objectives

Out of a total area of 21, 995 hectares, only 475 hectares or around 2% is devoted for cultivation of irrigated rice. The two largest among the municipality's river systems are Silago River which drains into the Leyte Gulf and Higasaan River that drains into the Abuyog estuary.

It is known that Silago's forests act as rainfall catchments that recharge aquifers. In some points groundwater flow comes to the surface in the form of springs from which local residents are very dependent on both for domestic use and irrigation. However, the actual location of these springs is undocumented and the volume they produce remains unknown. Soil profiles, geologic structure and groundwater flow data which are important in understanding groundwater dynamics are non-existent. What is known for sure is that in downstream of these springs are found rice fields requiring irrigation.

Although there are a lot of unknown parameters in terms of how water is partitioned in Silago's watersheds, it is still possible to estimate Silago's potential for rice irrigation from streamflow following the assumption that a least 1% of average rainfall end up in Silago's river networks and are available for irrigation use, without regard if it came from either springflow, seepflow or surface runoff.

This exercise explores the supply potential of Silago's river systems for irrigated rice under average rainfall conditions to the scale of each barangay. The end of the exercise aims to achieve a ballpark estimate if a certain barangay has enough irrigation potential for irrigated rice.

Method

Data preparation. Topography, rainfall and drainage were the only input for the process. A digital elevation model (DEM) of Silago was clipped from SRTM v4 Tile 61-10 with a resolution of 90 m. Hydrological analysis was done in ArcGIS 9.2 to produce flow direction and flow accumulation rasters. A river map in vector format sourced from the Silago local government was overlaid with flow accumulation raster to verify the correctness of the DEM. Points intersecting Silago's rivers and its undisputed municipal boundary (see section: *Land Cover Change Analysis*) were then chosen as pourpoints to delineate different watersheds. A particular river system will then have a particular watershed. Daily rainfall depth was assumed equal to 10 mm, based on maximum values during the wet season for Silago.

Modeling. Modeling may proceed in two approaches: static and dynamic. The static approach only utilizes a user-defined amount of rainfall to drive the process and disregards temporal dimensions. The dynamic approach requires an input time series of rainfall depth to drive the model. Program runtime stops when the accumulated rainfall is > 10 mm. PCRaster was used for the modeling environment.

Criteria. Modelled discharge results were then compared with the volume of irrigation required by each barangay for irrigated rice. In medium to heavy textured soils a single rice-growing season may require 700 to 1,500 mm of water depth per field (Guerra et al., 1998). Tuong et al. (2005) reported that rice in clay soils and shallow groundwater table may require as little as 400 mm per field to as high as 2,000 mm per field in sandy or loamy soils with deep groundwater tables. The required water depth used in this case was an arbitrary 1,000 mm for the lack of field data. The volume of irrigation required was calculated by multiplying the area of rice paddies to 1,000 mm. The required volume can be divided to 90 days to derive an estimate for daily irrigation requirement.

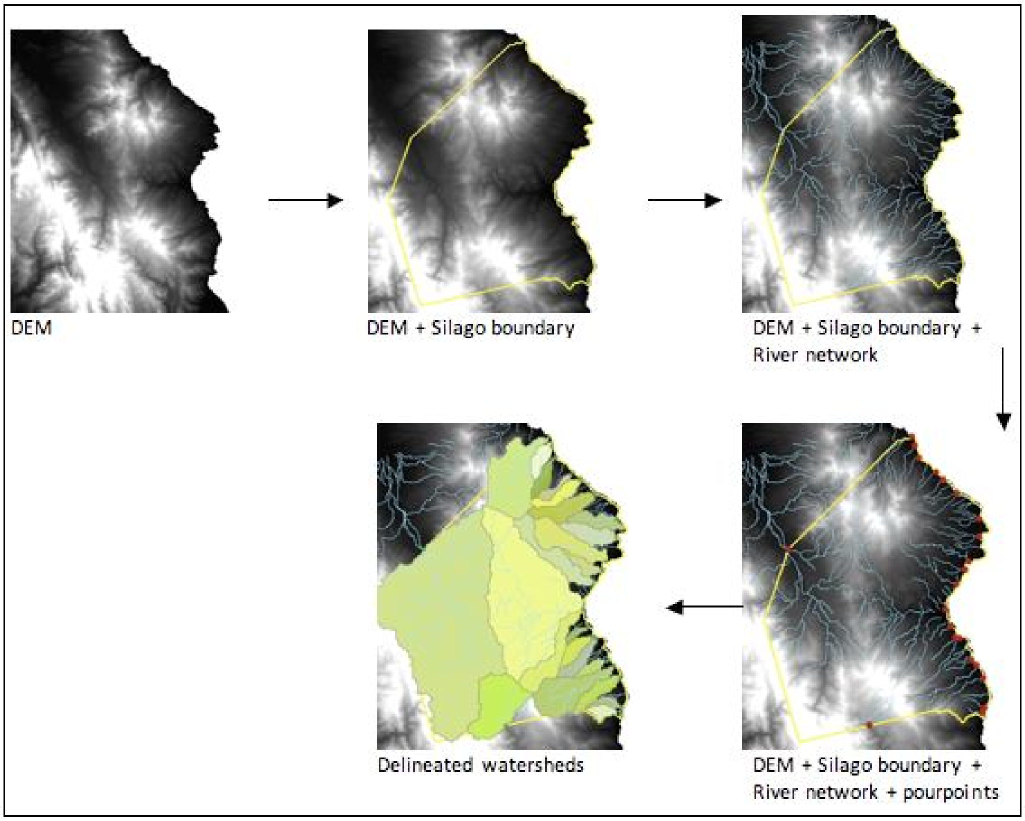


Figure VI.2. *Flow of hydrological analysis in delineating watershed boundaries.*

Decision. A level of user-subjectiveness is required for the decision process because barangay boundaries do not coincide with watershed boundaries. A barangay may be wholly located in one watershed, or may run through several adjacent watersheds. If a barangay is located within a single watershed, the decision is as easy as comparing the daily discharge with the daily irrigation requirement. The other case is more difficult especially because the location of rice paddies is merely assumed to be within a barangay's boundary. As a rule, one or two river systems is/are assigned as a barangay's irrigation source if either the barangay boundary contains the pourpoint to a watershed or if the barangay boundary covers a significant subcatchment of a particular river system. The same river system cannot be assigned to any two or more barangays, except in the case of medium to large river systems like that of Higasaan River and Silago River, the two biggest rivers in the municipality. As a conservative estimate, only 1% of total daily discharge is abstracted for irrigation use.

The effect of landuse is not considered in this analysis. We may be able to estimate from literature how much rain infiltrates into the soil for certain landuses/surface cover, but so much more information is needed to determine how much groundwater is discharged into springs/rivers. Landuse only determines the start of how rain is partitioned into the watershed but it is inadequate to comment significantly in relation to streamflow, unless Silago is not largely made up of forest.

Postscript. The dynamic approach provides an advantage of driving the model with actual rainfall measurements in discrete time intervals and thus can provide a deeper level of analysis. If more parameters are available, e.g. landsue map, soil map, hydraulic conductivities, soil water, surface roughnes, and stream widths, then infiltration and runoff and discharge height may also be computed, either instantaneously or cumulatively. If streamgauging and rainfall collection instruments are available, then the model maybe calibrated and validated particularly for Silago conditions.

D. IMPACT CHAIN, INFLUENCE DIAGRAM, AND INDICATOR DATA FOR THE WATER SECTOR OF SILAGO

Influence Diagrams and Impact Chains

The relevant factors affecting climate impacts on the water sector of Silago can be divided into three subsystems: those factors/parameters that are largely determined by man, those by the natural environment, and those that are climate-mediated (Figure VI.3). Water for domestic and irrigation needs in Silago mainly come from streamflow discharge, its quality and quantity determined by the geology, native vegetation and land features of the municipality, which in turn are affected by changes in land use. Future climate impacts would affect the interactions among the three subsystems. The priority exposure units and direct and indirect impacts for the water sector of Silago are shown in Figure VI.4.

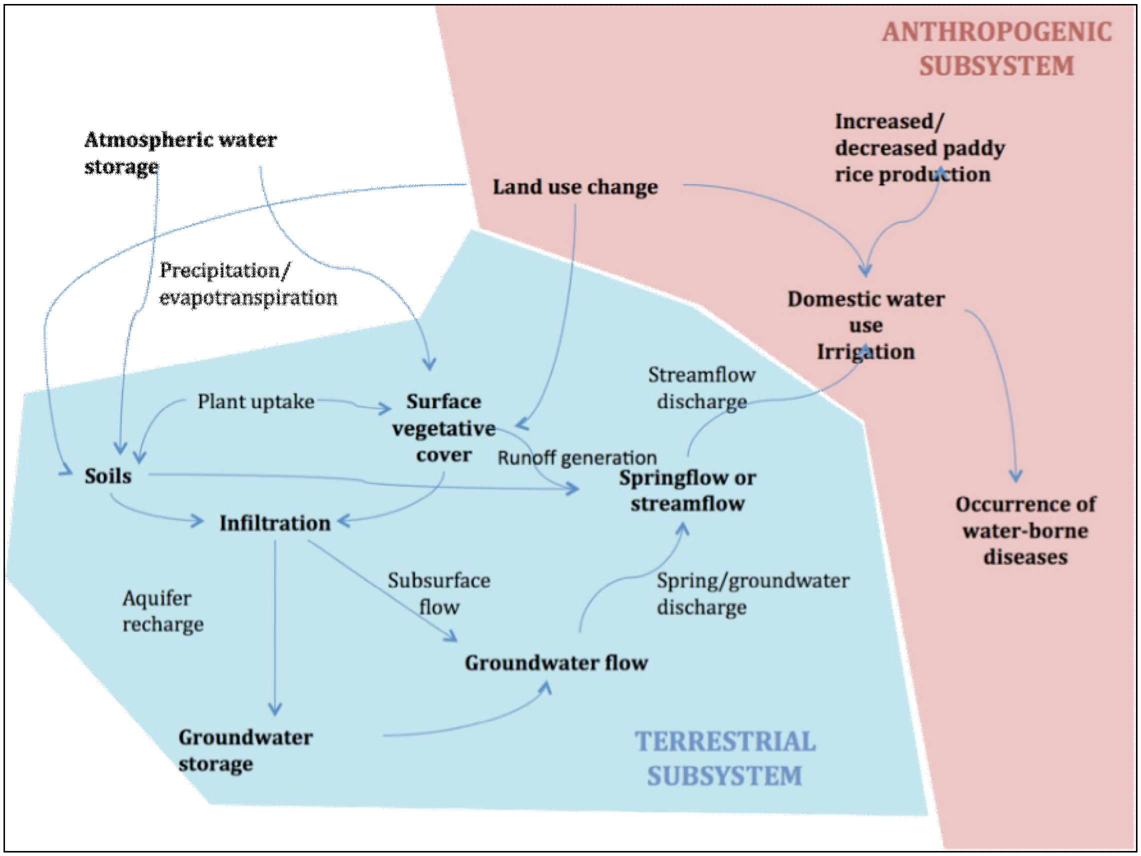


Figure VI.3. *Influence diagram for the water sector of Silago.*

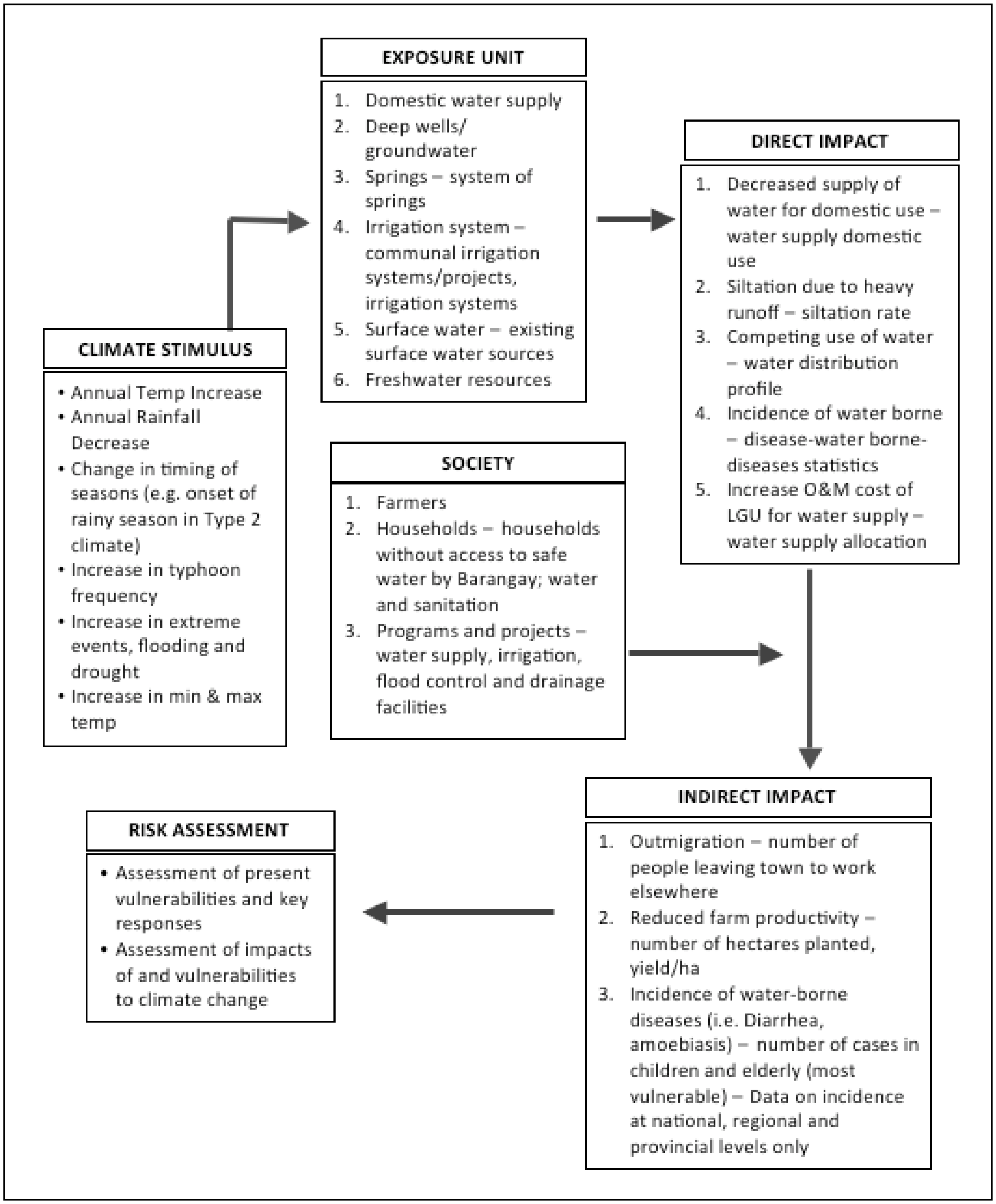


Figure VI.4. *Impact chain for water sector of Silago, Southern Leyte.*

Climate Impacts and Patterns of Vulnerability

One key vulnerability of Silago to climate change lies in its fresh water sector, the anthropogenic link between these two being land cover change. More forest cover means more freshwater sources. However it should also be noted that the significant threshold relating forest cover and springflow/streamflow production is still poorly understood. Although the volume of rainfall infiltrating into Silago's forest soils can be easily modelled, how these infiltrated water is partitioned underground is still a subject of a baseline study which, at least, requires measuring springflow rates, and ideally, mapping the aquifer structure. Only then can the relationship between forest and the fresh water sector in the municipality be understood.

In the context of Silago which is a municipality highly dependent on springs for both domestic use and irrigation needs, a continuing decrease in forest cover may result in the long-term to decreased aquifer recharge, spring flow and base flow and instead lead to increased runoff production, erosion and siltation. Modern land cover change, as opposed to traditional slash-and-burn cultivation, shifts hydrologic processes to more runoff generation with its resulting erosion and sedimentation problems (Elsenbeer, 2001). Conversion to urban, impermeable surfaces completely translates rainfall to runoff.

The absence of meters in the existing distribution system makes it difficult to ascertain the current demand for water in the Municipality, as well as project the future demand. At present, rough estimates indicate that there is a potentially large supply of water in Silago. However, climate-sensitive variables are also present, particularly 1) the incidence of enteric waterborne diseases, and 2) water siltation. Incidence of enteric waterborne diseases can be exacerbated by the presence of favorable climatic (i.e. temperature, moisture) and other environmental conditions. Meanwhile, siltation – although also greatly affected by land use change – is aggravated by climate stimuli such as increase in rainfall, strong winds and occurrence of extreme climate events.

Although it cannot be categorically stated how much forest cover is actually needed to sustain ample water supply for the needs of the Municipality's current and future population, it is evident that the urgent need of the hydro-forest sector is the establishment of an improved distribution network to maximize the use of the currently underutilized water resources.

On forest cover and hazards, note that, although Silago lies along a major faultline traversing Southern Leyte, there are no significant settlements near the faultzone. While landslides have been linked to deforestation and land degradation processes, important information on geology and soil properties specific to the municipality need to be obtained to clarify interactions between forest land use, climate and the occurrence of these hazards.

Indicator Data

Considering current inadequacies of basic data, local priorities for assessment, and resource limitations for data collection, the following set of indicator data for analyzing climate impacts and vulnerability and possible sources are identified (Table VI.3).

Table VI.3. *Possible indicators of vulnerability to climate variability and climate change of the water sector.*

Component of Vulnerability	Parameter	Proxy/Auxiliary Parameter	Possible Data Source
WATER			
Exposure			
	Domestic water demand		Consumer side water meters
	Springflow gauging		Metered springs
	Presence of pathogens		Microbial analysis of water samples
	Number of cases of enteric water-borne diseases		Municipal health center records
Sensitivity			
	Water quality		Microbial analysis of water samples
Coping Mechanism			
	Water storage and distribution plan		Municipal Office and Local Water District
COMMUNITIES			
	Diversification of sources of income	Livelihood profile(i.e. on-farm, off-farm and non-farm, seasonal)	Municipal records/data, census/CBMS survey
	Migration	Population data	Municipal records/data, census/CBMS survey

Sources: Lasco et al. 2010

E. *WATER SECTOR ADAPTATION OPTIONS*

Watershed-based water resource management

The results of the hydrological analysis done under this study showed that under average rainfall conditions, Silago's river systems are capable of supplying the irrigation needs for paddy rice, and potentially to even expand supply to other crops. Any lack of irrigation water being experienced on the ground was attributed not to the lack of supply but more to the absence of the necessary irrigation infrastructure to distribute the water where it is needed. However, Rola and colleagues (2004) also raise a valid point by emphasizing the importance of restoring/protecting the ecosystems that support the supply of water in combination with efforts to establish the necessary water distribution networks.

Watershed-based water resource management involves first taking the watershed as the planning unit so that local legislators can better plan the supply and distribution of water within the area in question, and more easily identify potential sources of pollution and/or contamination so that such problems can be remedied. After doing so, the approach largely revolves around integrating the biophysical and socioeconomic aspects of watersheds, which is usually done through a combination of soil conservation, reforestation, assisted natural regeneration, agroforestry, and other activities that engage the local communities spanning from the uplands to the lowlands. This kind of management strategy requires strong support from local government, both in terms of administration and budget allocation. It also requires strong leadership in order to effectively elicit the participation of all local stakeholders (Rola et al., 2004).

Box VI.1 Autonomous adaptation for building resilience in the water sector

A policy brief by Wilk and Wittgren (2009) discusses adaptation in the water sector to climate change in the context of developing countries. Autonomous adaptation is designed to build the resilience groups of people by incorporating climate-related objectives to other developmental goals. As such, autonomous adaptation is said to be more common than planned adaptation in developing countries such as the Philippines, given that there are many other developmental concerns that are deemed more of a priority than climate change. Below are some examples of adaptation options that are intended to target specific concerns of the water sector such as 1) increasing water supply and ecosystem services, 2) decreasing water demand and increase use efficiency, and 3) improving flood protection (Wilk and Wittgren, 2009).

Increasing water supply and ecosystem services:
- Expansion of rainwater harvesting to improve rainfed cultivation and groundwater recharge
- Adoption of water transfer schemes
- Restoration of aquatic habitats and ecosystem services
- Increased storage capacity by building reservoirs

Decreasing water demand and increasing use efficiency:
- Removal of invasive non-native vegetation from riparian areas
- Improvement of water-use efficiency by water recycling
- Spread of drought-resistant crops
- Improved management of irrigated agriculture, i.e. changing the cropping calendar and the cropping mix, irrigation method and repair and maintenance of irrigation infrastructure
- Expanded use of economic incentives to encourage water conservation
- Improvement of urban water and sanitation infrastructure

Improving flood protection:
- Construction of flood protection infrastructure
- Enlargement of riparian areas
- Increased upstream storage
- Restoration and maintenance of wetlands

VII. VULNERABILITY AND IMPACTS OF CLIMATE CHANGE ON THE AGRICULTURE SECTOR

A. GENERAL INTRODUCTION: AGRICULTURE SECTOR

Agriculture is a critical sector in climate change issues. In 2004, greenhouse gas emissions from agriculture (including agricultural waste and savannah burning but exluding CO_2 emissions and uptake from soils) accounted for 13.5% of the global emissions (Barker et al., 2007). More importantly, however, the agriculture sector is very vulnerable to changes in climate and variability. Temperature increase and extreme rainfall events, such as prolonged droughts and excessive rain, can affect agricultural productivity. The timing and onset of seasons can have significant impacts on crop yields. Future climate changes, can be more suitable for and hence can increase the occurrence of weeds and pests. Further, climate patterns can change consequently modifying regional or local crop suitability. The changes in climate variability and extremes, including prolonged and extremely dry conditions, can also severely damage arable land and water resources that may be beyond repair and recovery (Fischer et al., 2005). All these potential climatic impacts have serious consequences on agricultural production that will threaten both local and global food security.

Increasing carbon dioxide concentrations in the atmosphere has a direct fertilization affect that will increase crop yields. However, recent experimental results show that CO_2 fertilization factors may have been overestimated in models that project future yield given an increase in CO_2 levels. Hence, the fertilization effect of higher CO_2 concentration may not offset the negative impacts of increasing temperatures and decreasing water availability on crop yield (Long et al., 2006). The Stern Review (Stern, 2006) shows that high latitude agricultural areas may benefit initially from high CO_2 levels given moderate increases in temperature. But continued warming will lead to a global decrease in crop yield especially if CO_2 fertilization effects are actually smaller then previously estimated. Moreover, any increase in temperature, however small, will results in yield reduction in tropical countries.

What is clear and generally accepted is that despite the potential positive effects of higher CO_2 levels on crop fertilization, the negative impacts of climate change will affect developing countries more than the developed countries. The contrasting effects of climate change coupled with the differences in socio-economic structures may increase the disparity in production and consumption gaps between the developed and developing nations (Fischer et al., 2005). Figure VII.1 shows the projected changes in agricultural productivity in 2080 due climate change, including the positive effects of CO_2 fertilization, based on a study by Cline (2007) on global warming and agriculture. Most of the decrease in productivity will occur in developing countries, especially in Africa and East Asia. The Philippines will have a -5% to -15% change in productivity assuming an average increase of 2.7 ^{o}C in temperature and a very slight increase in rainfall. One of the major conclusions of Cline (2007) reiterates the fact that future climate change will have more negative impacts on developing countries (as seen in Figure VII.1). The results of Cline (2007) also show that Global warming will have negative impacts on the global average agricultural yield and the effects may be worse if CO_2 fertilization is not significant and if there is decreased water availability for irrigation.

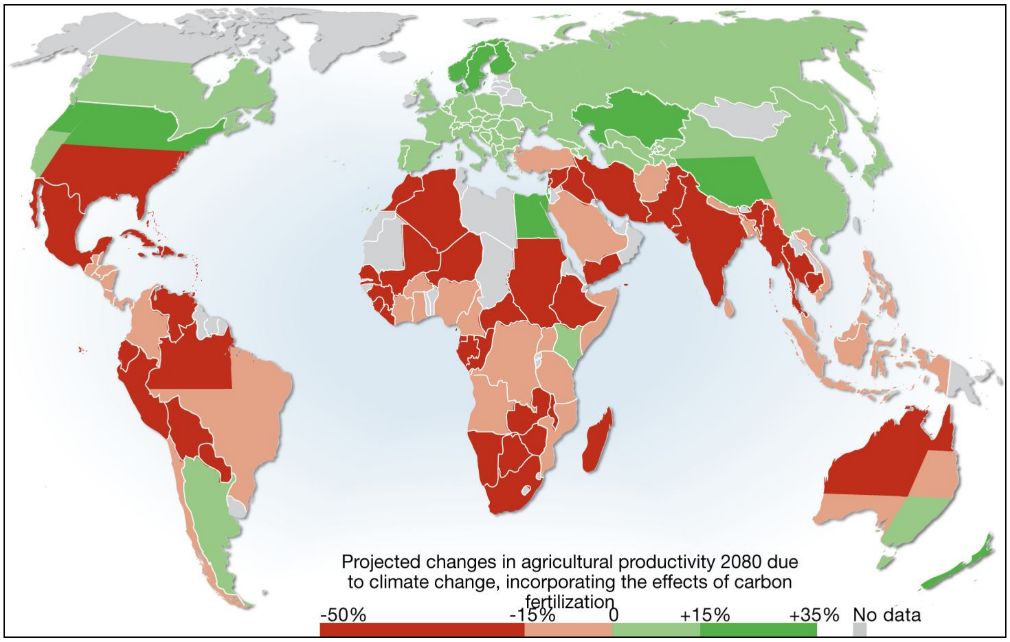


Figure VII.1. *Projected changes in agricultural productivity in 2080 due to climate change with CO_2 fertilization effects incorporated. (Source: Projected agriculture in 2080 due to climate change. (2008). In UNEP/GRID-Arendal Maps and Graphics Library. Retrieved 13:18, March 7, 2011 from http://maps.grida.no/go/graphic/projected-agriculture-in-2080-due-to-climate-change; Cartographer: Hugo Ahlenius, UNEP/GRID-Arendal; Data source from Cline, W. R. 2007. Global Warming and Agriculture: Impact Estimates by Country. Washington D.C., USA: Peterson Institute)*

Rosenzweig and Parry (1994) discussed that applying adaptation measures may not shift the imbalance of agricultural impacts between developed and developing countries. Their study also shows that developing countries will have decreased cereal production while developed countries will have increased yield when two levels of adaptation measures are applied. Level 1 adaptations in general are measures at the farm level, which include minor shifts in planting dates, additional water for irrigated crops, and changes in crop varieties. Level 2 adaptations involve major changes in farming system that include policy and government interventions, such as installation of irrigation systems and development of new crop varieties. Level 2 also include major shifts in planting dates and increased use of fertilizers. Although the Level 2 measures do decrease the negative impacts of climate change, there is still a net decrease of about 6% in cereal production in developing countries (Rosenzweig and Parry, 1994).

B. PHILIPPINE AGRICULTURE

Philippine agriculture is particularly vulnerable to changes in climate and climate variability. According to the Bureau of Agricultural Statistics (BAS), agriculture contributes about 18% to the national GDP and hence is an important variable in the national economy. According to the Food and Agriculture Organization, more than one third of the Philippine population is dependent on agriculture and fishing for their livelihood (http://faostat.fao.org/site/339/default.aspx). Agricultural land accounts for about 32% of the country's total land area and 51% of this is arable cropland while 44% is permanent cropland (Figure VII.2). Rice, corn, and coconut constitutes majority of the agricultural farms in the nation (see Table VII.1), but rice is the primary crop (and commodity) of the Philippines, especially in terms of value, followed by coconut as seen in Figure VII.3.

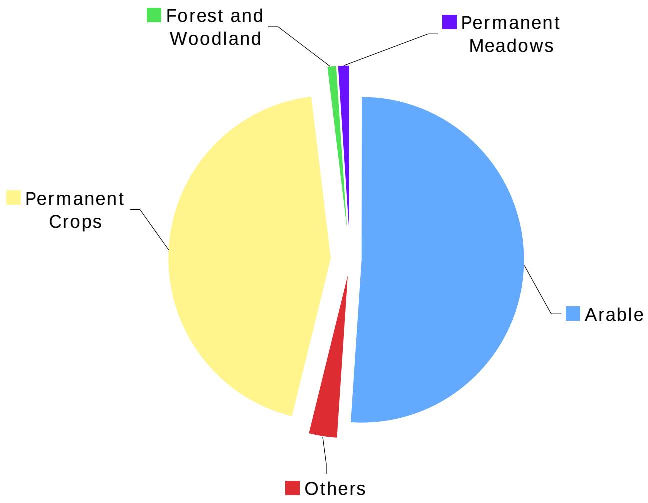


Figure VII.2. *Distribution of agricultural area by type of utilization. (Data from Bureau of Agricultural Statistics, Facts and Figures on the Philippine Agricultural Economy, 2009, http://countrystat.bas.gov.ph/index.asp?cont=factsandfigures)*

Table VII.1. *Number of Agricultural Farms in 2002. Source: Bureau of Agricultural Statistics.*

Crop Type	Number of Farms
Palay	2.15 million
Corn	1.46 million
Coconut	2.60 million
Sugarcane	0.17 million

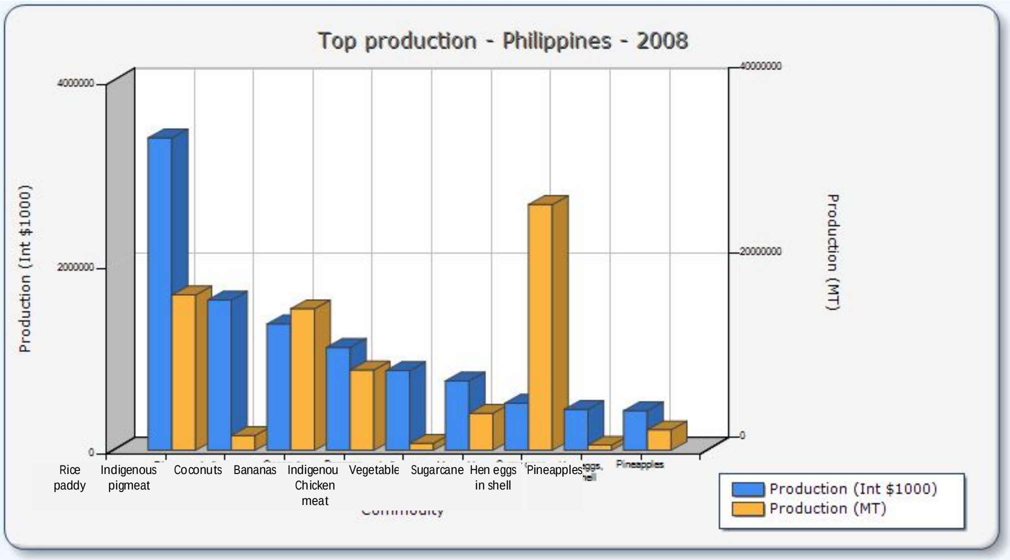


Figure VII.3. *Production of the 20 most important food and agricultural commodities (ranked by value) in the Philippines in 2008. (Figures generated and taken from http://faostat.fao.org/site/339/default.aspx)*

Changes in climate can affect rice yield significantly. Prolonged droughts, more intense and frequent typhoons and storms, intense rainfall, changes in maximum and minimum temperatures, and changes humidity and solar radiation can decrease rice yield significantly. Based on data obtained from the Philippine National Disaster Coordinating Council (NDCC), the agricultural sector for example has lost Php 133,096 million from 1970 to 2009 due to strong tropical cyclones. Typhoon Pepeng in 2009 has resulted in Php 20,494.689 million of losses while agricultural damage by Typhoon Rosing (1995) and Typhoon Frank (2008) are estimated to be around Php 9,037 million and Php 5,210 million, respectively. Severe flooding has also incurred agricultural damages of about Php 2,679 million. Droughts due to El Nino events have also affected crop production. The strong El Nino in 1982-1983 and 1997-1998 in particular affected 74,000 hectares of agricultural lands that translated into a considerable production and yield lost and consequently affected the national GDP. Figure VII.4 shows historical rice production in the Philippines since 1961 with the major El Nino events of 1972, 1982-1983, 1987, 1992, 1997-1998, and 2009 highlighted in red dots. All of these events caused a noticeable drop in rice production. Note though that the decrease in production in 2009 may be both due to El Nino impacts and the impacts of Typhoon Pepeng. Changes in minimum temperatures at night also affects rice yield. Peng et al. (2004) studied the relationship between yield and temperature using observed weather data and experimental data from irrigated rice fields at the International Rice Research Institute (IRRI) in Los Banos, Laguna from 1992-2003. Their study shows that the effect of maximum temperatures on crop yield is not significant. However, their results also show that for each 1^{o}C increase in minimum temperatures at night during the dry season, there is a corresponding 10% decrease in rice yield. It is important to note that increasing minimum temperatures at night is one of the more certain climate impacts of global warming.

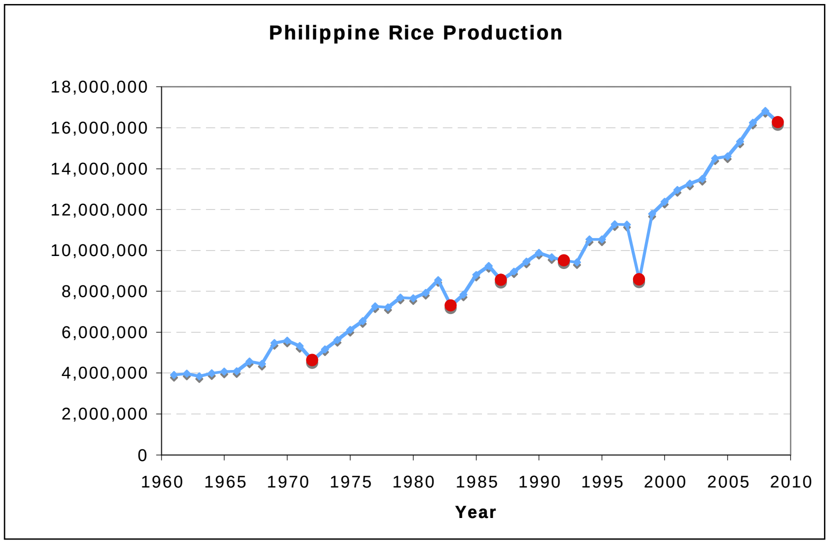


Figure VII.4. *Philippine rice production. The red dots denote major El Nino Events. (Source: Food and Agricultural Organization. http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567)*

Despite the the impacts of climate variability on agriculture, there is an increasing trend in rice production in the Philippines. This is true as well for the two other major crops, corn and coconut (see Figure VII.5). Rice, however, has the fastest rate of increase compared to corn and coconut. According to IRRI, rice yield in the country has more than tripled in the last 50 years, which is higher than the global average increase of about 2.3 times. Dr. William Padolina has attributed this increase in rice yield to farmers adopting appropriate technologies, which includes the use of 75 IRRI bred high yield rice varieties, better fertilizer and pest management and water-saving technology systems (http://irri.org/news-events/media-releases/the-philippines-triples-it-s-rice-yields).

It is interesting to note that while corn and rice show a noticeable drop in production as a result of the strong 1997-1998 El Nino, coconut production does not appear to have been severely affected by the drought. Compared with the scientific literature on climate change effects on rice, there are not that many research studies on the potential impacts of climate change on coconuts. But there are existing research initiatives to study the effects of climate variability and change on coconut production, including collaborative efforts between the International Research Institute at the University of Columbia and Sri Lankan Institutions such as the Coconut Research Institute and Department of Meteorology of Sri Lanka. Similar to the Philippines, coconut is one of the more important food crops of Sri Lanka, occupying 400,000 hectares of land and providing for about 22% of the calorie intake per capita (Fernando et al., 2007). It is not surprising therefore that the major research efforts in Sri Lanka are focused on analyzing the potential impacts of climate change on coconuts.

Changes in rainfall and temperature can affect coconut production. Extreme events such as prolonged drought or too much cloudiness in the wet season can affect yield, as with any other crops, (http://portal.iri.columbia.edu/portal/server.pt/gateway/PTARGS_0_4252_4030_0_0_18/). A study by Peiris (http://www.meteo.slt.lk/Res%20CRI.htm) showed that the effects of climate on coconut yield in Sri Lanka are dependent on geographical location and hence emphasizing the need for localized impacts and adaptation studies. Further, although the results show relationships between climate variables and yield, more studies are recommended to establish the potential impacts of climate change on coconut production. Nevertheless, Peiris and Thattil (1997) have shown that maximum temperature and relative humidity in the afternoon are two climate variables that can affect coconut yield significantly. Wind speed also influences yield depending on the development stage of the coconut. Further, the study identified critical months for Sri Lanka where the climate can affect the yield the most, depending on the time of plant development and harvesting. February specifically and the rainfall, temperature, and humidity durng this month were found to have the most impact on the total coconut yield. The resulting economic impacts on coconut production due to variabilities in climate in Sri Lanka were calculated in a paper by Fernando et al. (2007). Climate variability has the potential to incur income losses of about US$32 million to US$73 million on years during the years when there is extreme shortage in crop. However, during years when there is crop surplus, there can be income gains from US$42 million to US$ 87 million. Fernando et al. hence concludes that investing in climate adaptation measures on coconut production that will address the negative impacts of climate variability can have significant benefits on the economy of Sri Lanka.

Existing literature on the relationship between climate and coconut production clearly highlights the need for further and localized studies that will explore the potential impacts of climate change on coconut yield. More importantly, however, historical yield for the Philippines as illustrated in Figure VII.5 shows that coconut might be more resilient to the impacts of drought associated with strong El Nino events, indicating that increased coconut production can be an adaptation option in areas where existing crop types, such as rice, maybe more vulnerable to certain climate impacts. Research studies that are localized and that will explore the effects of different climate variables on coconut productivity will be very useful for identifying appropriate adaptation measures. As mentioned previously, suitable adaptation measures to address climate impacts on coconut can yield significant economic benefits.

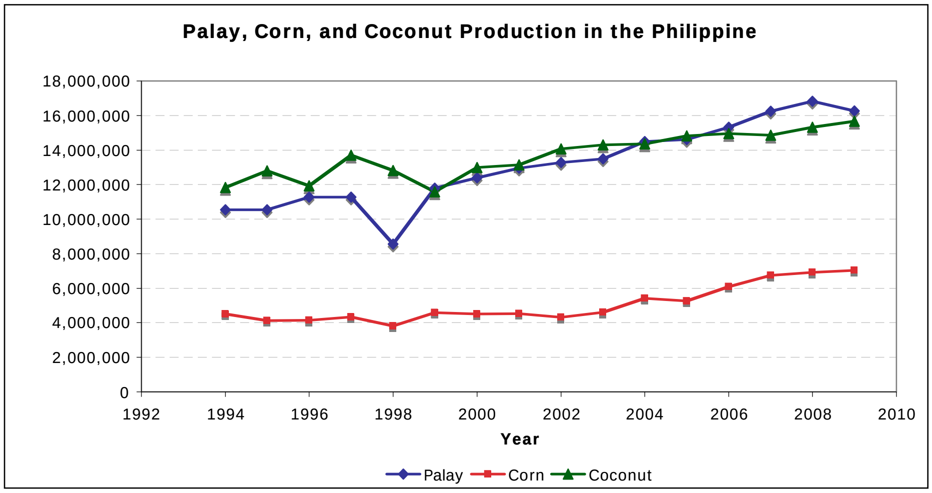


Figure VII.5. *Palay, Corn, and Coconut production in the Philippines from 1994-2009. (Data source: Bureau of Agricultural Statistics (http://countrystat.bas.gov.ph/)*

C. AGRICULTURE IN EASTERN VISAYAS AND SOUTHERN LEYTE

Relative to the different provinces of the Philippines, Southern Leyte is a fair producer of rice, producing about 114,168 metric tons of rice in 2009 (see Figure VII.6). This number has increased considerably since 1994. In sixteen years, from 1994-2010, rice production both from irrigated and rainfed rice in Southern Leyte has more than doubled (Figure VII.7). Similar to the national figures, palay production has been steadily increasing in time in Southern Leyte. Majority of the production, about 85% on the average, comes from rainfed palay. Note that there is again sharp dip in rice production as a result of the strong 1997-1998 El Nino indicating that the province was severely affected by the intense drought during that period. Interestingly, coconut again appears to be resilient to the negative effects of El Nino as illustrated in Figure VII.8, which shows production of the top three crops (rice, coconut, and banana) in Southern Leyte. In fact, coconut production is highest in 1997 and 1998 and the 1997 production is more than double the value of the previous year 1996. Banana production on the other hand experiences the same dip in production as with rice. On other crop types in the province, camote appears to be sensitive as well to the impacts of El Nino, while cassava and corn do not show substantial decreases in production (see Figure VII.9). Abaca on the other hand seems resilient to the intense drought and similar to coconut, exhibits an increase in production in 1998.

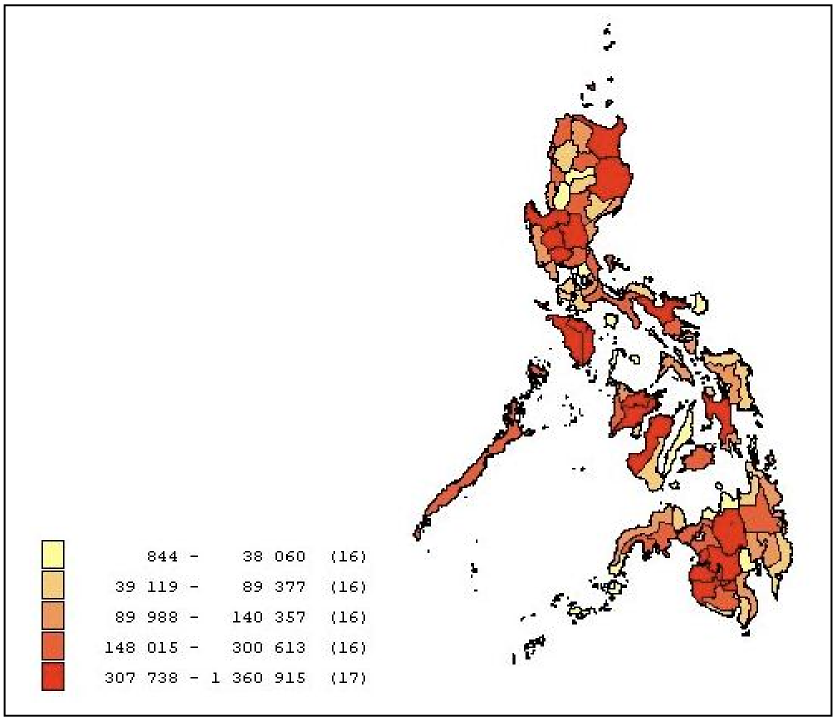


Figure VII.6. *Palay volume of production (metric tons) by province (2009). (Figure and data taken from Bureau of Agricultural Statistics; Map data: BAS-ICTD-IDSS (http://countrystat.bas.gov.ph/)*

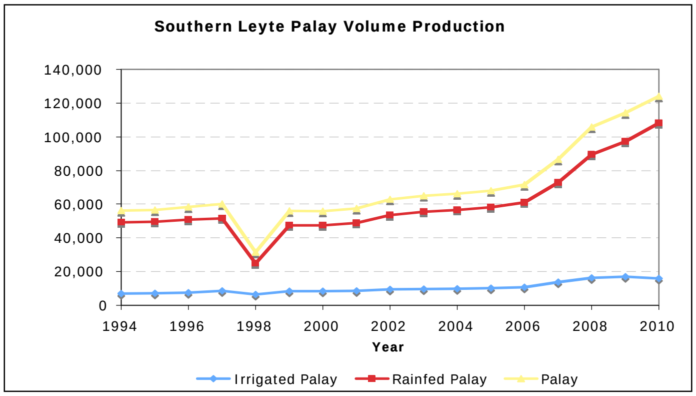


Figure VII.7. *Palay volume production in Southern Leyte. (Source: Bureau of Agricultural Statistics, http://countrystat.bas.gov.ph/)*

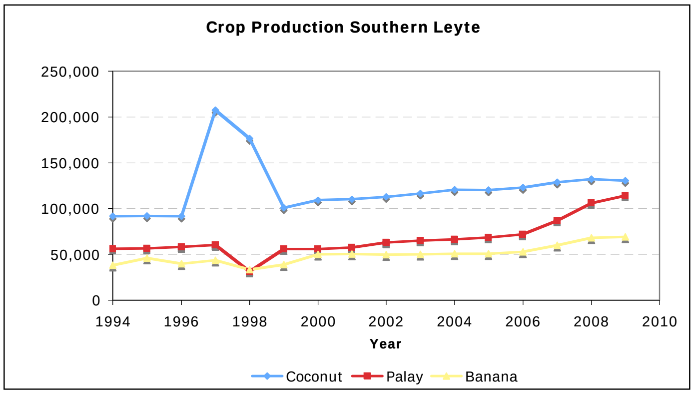


Figure VII.8. *Palay, coconut, and banana production in Southern Leyte. (Source: Bureau of Agricultural Statistics, http://countrystat.bas.gov.ph/)*

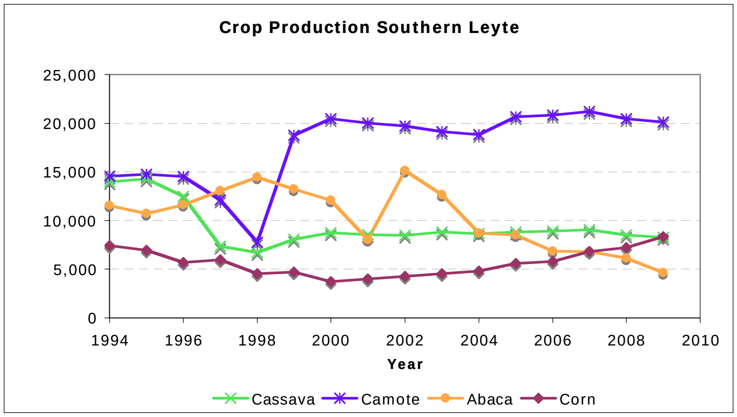


Figure VII.9. *Production volume of other crop types (cassava, camote, abaca, and corn) in Southern Leyte. (Source: Bureau of Agricultural Statistics, http://countrystat.bas.gov.ph/)*

The use of fertilizer is investigated to see if there are correlations between fertilizer application and production given the increase in rice production through time in Southern Leyte. Also, excessive use of fertilizer for agriculture has implications on water quality and may cause river, lake, and coastal water eutrophication. Data for the province however was not available. Hence, regional data on estimated inorganic fertilizer for Eastern Visayas is used instead. Figure VII.10 shows that there is no direct relationship between the amount of fertilizer applied either to the area planted or the area of application. In fact, the total quantity of fertilizers has a general decreasing trend while the planted area is, on the other hand, increasing. There appears to be a dip in the use of fertilizers in 2008 when the areas planted and applied have increased. There is also no direct correlation observed between rice production and fertilizer use. The dip in fertilizer application in 2006 and the sharp dip in 2008 did not result in any corresponding dips in production for either years. On the contrary, rice production has steadily increased regardless of the trend in fertilizer use. The increase in crop production, therefore, may generally be attributed to the increase in planting area and not to fertilizer application.

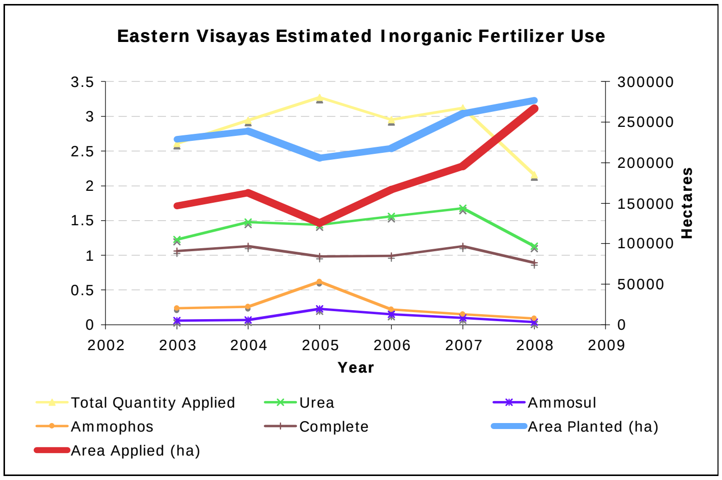


Figure VII.10. *Estimated use of Inorganic Fertilizers in the Eastern Visayas Region. (Source: Bureau of Agricultural Statistics - http://countrystat.bas.gov.ph/)*

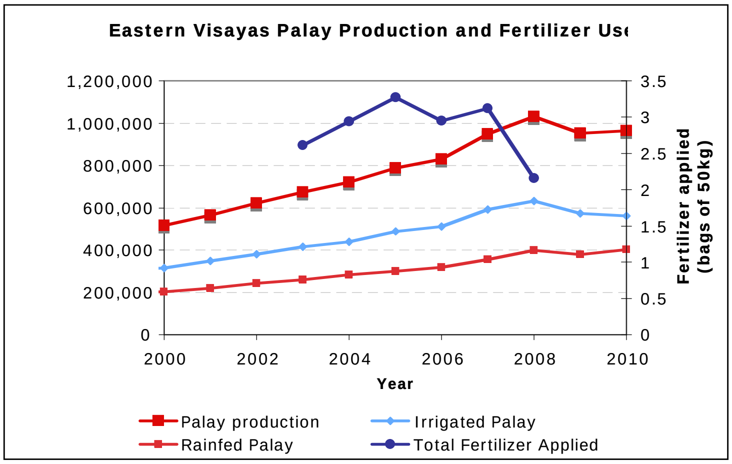


Figure VII.11. *Palay production and fertilizer use in Eastern Visayas. (Source: Bureau of Agricultural Statistics - http://countrystat.bas.gov.ph/)*

D. THE AGRICULTURE SECTOR OF SILAGO

Based on the Silago Municipal Ecological Profile (MPDO, 2009), agricultural land is the second largest land use in Silago, with 8,363 hectares of land or 38.88% of the total area of the municipality classified as agriculture (Table VII.2). Most of the agricultural land, about 89.2% is coconut, 6.5% is rice, 1.79% abaca, and the rest is classified to other crop types, including vegetables, root and fruit crops, and other food and commercial crops (MPDO, 2009). Table VII.3 shows the land capability classes that reflect the apportioning of land to major crop types in agriculture.

Table VII.2. *Land use for Silago based on the Municipal Ecological Profile in 2009.*

Land Uses	Area in Hectares	% of total Land Area
Built-up Area	93	0.43
Forest / Timber Land	12,482	58.03
Agricultural Land	8,363	38.88
Open Grassland	494	2.30
Open Water Spaces	71	0.33
Road Network	3	0.01
Cemetery/ Memorial Park	3	0.01
TOTAL	21,510	100.00

(Source: Silago Municipal Ecological Profile; MPDO, 2009).

Table VII.3. *Silago Land Capability Classes.*

Land Capability Classes	Area in Hectares	Barangay Covered
Coconut	7,458.6	15 barangays
Abaca	150.0	Barangays Puntana, Catmon, Imelda and Tubod
Rice Field	540.0	All 15 Barangays
Corn	4.0	Barangay Katipunan
Root Crops	140.0	All 15 Barangays
Forest Watershed	12,182.0	All 15 Barangays
Agro. Forestry	300.0	All 15 Barangays
Pasture Land	523.9	All 15 Barangays
TOTAL	21,298.5	

(Source: Silago Municipal Ecological Profile; MPDO, 2009).

Agriculture clearly plays a major role in the economy and food supply of Silago. Farming together with fishing are the major sources of income for the residents of Silago. Residents also rely on their own crop production for subsistence (MPDO, 2009). Similar to the national and provincial profile of Southern Leyte, rice and coconut are the most important food and agricultural commodities in Silago. Based on 1999 data from the Municipal Agricultural Office, rice production mostly comes from irrigated rice with 1,750 metric tons of rice produced annually compared with the 120 metric tons from non-irrigated or rainfed rice (Table VII.4). This is similar to the regional profile of Eastern Visayas but unlike the provincial profile where majority of rice production comes from rainfed paddies. The volume production of rice translates into value production of about Php 28 million and Php 1.92 million for irrigated and non-irrigated rice, respectively. The land area of irrigated rice is also much greater than non-irrigated rice. Irrigated rice occupies about 500 hectares of land, which is 2.32% of the total municipal land area. There are only 40 hectares of non-irrigated rice on the other hand, occupying about 0.185% of the municipal total. Coconut however has the highest land coverage of 7,459 hectares, which is about 34.7% of the total municipal land (Table VII.4).

Table VII.4. *Area, production, and Value of Production by Major Crops (1999).*

Crops	Area (Hectares)	Percentage Relative to Total Agricultural Land Devoted to Crop Production (%)	Percentage Relative to Total Municipal Land Area (%)	Total (MT)	Value of Production (x 1000)	Average Production per Hectare (cavans)
Food						
Rice (total)	540.00	6.450	2.510			
Irrigated	500.00	5.979	2.320	1,750	P28,000.00	70
Non-Irrigated	40.00	0.478	0.185	120	P1,920.00	60
Corn	4.00	0.047	0.018			
Fruit						
Banana	50.00	0.597	0.232			
Commercial						
Coconut	7,458.61	89.184	34.675			
Coffee	0.50	0.006	0.002			
Mongo	5.00	0.059	0.023			
Peanuts	0.00					
Others						
Vegetables	15.00	0.179	0.069			
Abaca	150.00	1.793	0.697			
Rootcrops						
Cassava	69.00	0.825	0.320			
Gabi	36.00	0.430	0.167			
Sweet Potato	35.00	0.418	0.162			
TOTAL	8,363.11	100.000	38.880			

(Source: Silago CLUP, 2000; MAO, Silago)

Crop production from 2008 to 2010 in Silago appears to be increasing in general (Figure VII.12). Specifically, rice (from hybrid and good and certified seeds), camote, pineapple, and cassava production have increased noticeably in the last years. Production from other crop types, including irrigated and non-irrigated rice inbrid, are on the average relatively constant. There is however, no corresponding change or increase in land use for all of the crop types and land area has remained constant in the last three years as shown in Table VII.5.

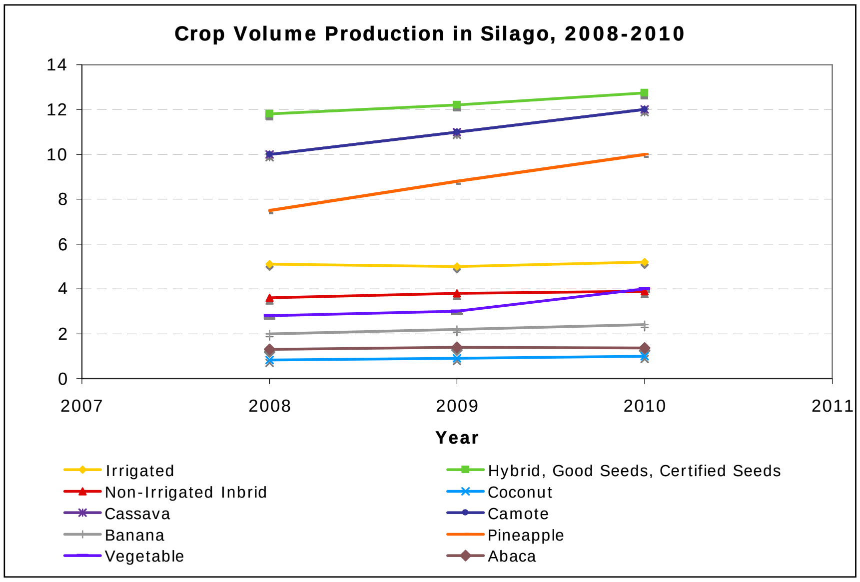


Figure VII.12. *Volume production in Silago from 2008-2010 for the different crop types. (Source: Silago Draft CLUP, 2011; MAO, Silago)*

Table VII.5. *Comparative Agriculture Areas and Production, 2008, 2009 and 2010.*

	Area			Volume of Production		
Major Crops	2008	2009	2010	2008	2009	2010
Rice				(MT/ha)	(MT/ha)	(MT/ha)
Irrigated				5.10	5.0	5.20
Hybrid	60.00	40.00	110.00	4.00	4.2	4.54
Good Seeds	379.50	421.00	367.00	3.80	3.9	4.00
Certified seeds	37.50	16.00	0.00	4.00	4.1	4.20
Non-Irrigated Inbrid	3.00	3.00	3.00	3.60	3.8	3.90
Coconut	5247.00	5269.00	5269.00	0.83	0.9	1.00
Cassava	27.00	27.00	27.00	10.00	11.0	12.00
Camote	17.00	17.00	17.00	10.00	11.0	12.00
Banana	25.00	25.00	25.00	2.00	2.2	2.40
Pineapple	28.75	28.75	28.75	7.50	8.8	10.00
Vegetable	21.43	21.43	21.43	2.80	3.0	4.00
Abaca	9.75	9.75	9.75	1.30	1.4	1.37
TOTAL	5855.93	5877.93	5877.93	49.83	54.2	59.37

(Source: Silago Draft CLUP, 2011; MAO, Silago)

E. PATTERNS OF VULNERABILITY AND THE POTENTIAL IMPACTS OF CLIMATE CHANGE ON AGRICULTURE IN SILAGO

The potential impacts of the projected climate changes discussed in Chapter Four in the agricultural sector are now analyzed. Agriculture in Silago is very vulnerable to the impacts of future changes in climate and variability given the importance of this sector in food supply and municipal economy and the negative effects of global warming on crop production and especially on rice yield, as discussed in the previous sections. Figure VII.13 shows the influence diagram for agriculture. This diagram is a general outline of how impacts due to climate change, such as increase in temperatures, decrease in rainfall, and sea level rise may adversely affect the agricultural sector, which consequently translates into socio-economic impacts. Sea-level rise and storm surges due to tropical storms for example, will lead to salt water intrusion causing losses in land for agriculture especially since a number of rice paddies in Silago are located along the coast. This will translate in a decrease in crop yield, which can have serious consequences in the economy and food supply of the municipality. Increasing temperatures can increase pest and insect infestation, crop diseases and can cause direct crop damages, which again translates into reduction in crop yields. Decrease in rainfall can decrease water availability for irrigation, which can have serious impacts on rice yield since majority of rice production in Silago comes from irrigated paddies. Both decrease in rainfall, specifically prolonged droughts that cause land degradation, and increase in tropical cyclone frequency and intensity can increase siltation due to run off that will in turn affect crop yield. Given these potential impacts, it is also very important to note that existing vulnerabilities, such as poverty and high population density, can increase the potential risks to the impacts of climate change.

The final impact chain for the agricultural sector is shown in Figure VII.14, which is a result of a series of consultations, workshop, and data gathering in Silago. Based on this influence diagram and the agricultural profile of Silago (refer to previous section), this study focused on analyzing the vulnerability of rice production in Silago to the projected climate changes.

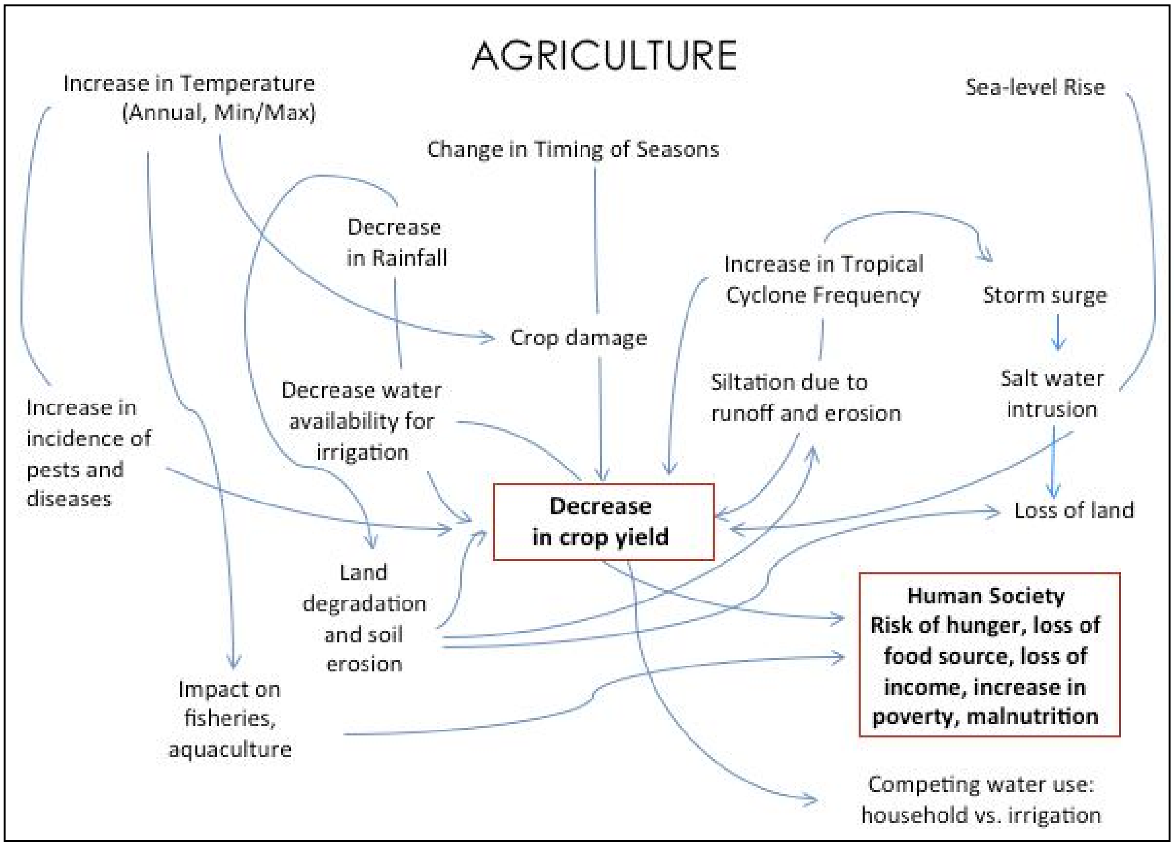


__Figure VII.13.__ Influence diagram illustrating the impacts of climate change on the agricultural sector.

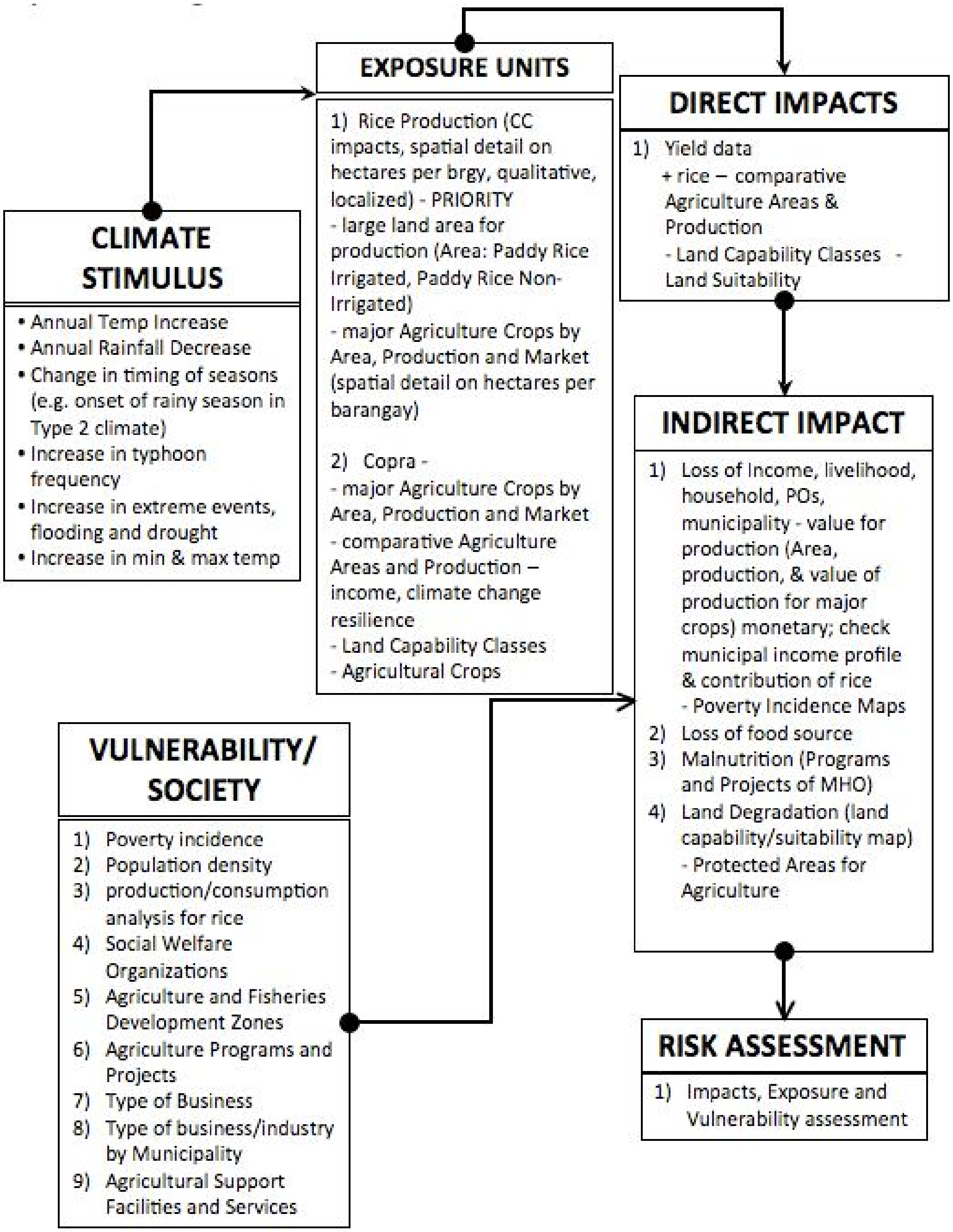


Figure VII.14. *Final impact chain for the agricultural sector in Silago.*

Figure VII.15 revisits the land cover of Silago for 2009 generated through land cover detection analysis using remote sensing data (refer to Chapter Five). This figure shows that there is a number of rice paddies (yellow regions) located along the coast of Silago. These areas will be highly vulnerable to potential sea level rise. Results from flood modeling based solely on topographic elevation show that an increase in sea level of 1 meter and 2 meters will inundate the rice paddies along the coast resulting in land losses of 11.2% and 13.8%, respectively, of the total rice paddy areas. A 4-meter sea level rise will potentially flood as much as 19.6% of the rice paddies in Silago.

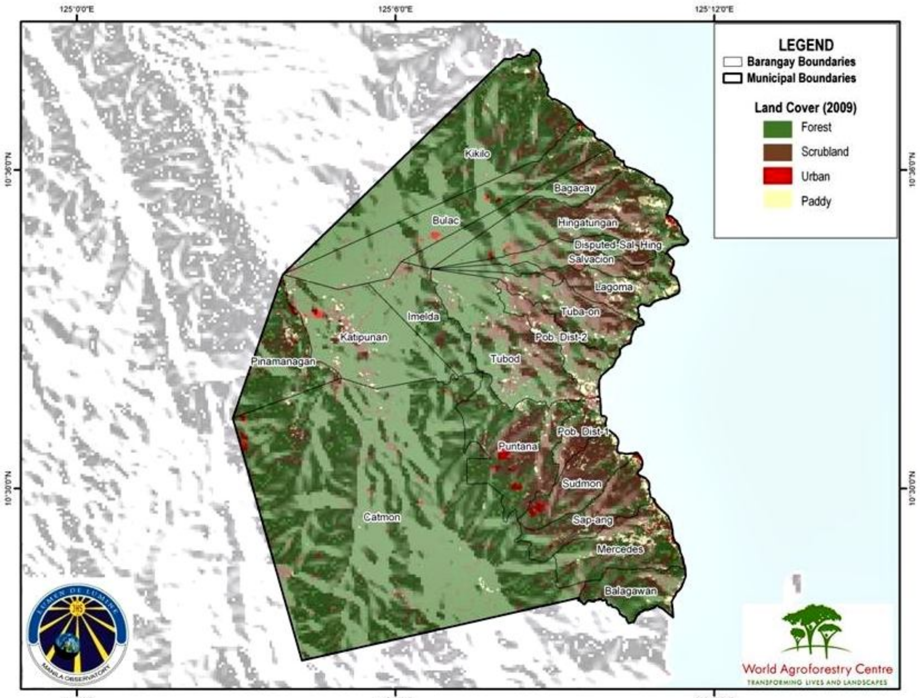
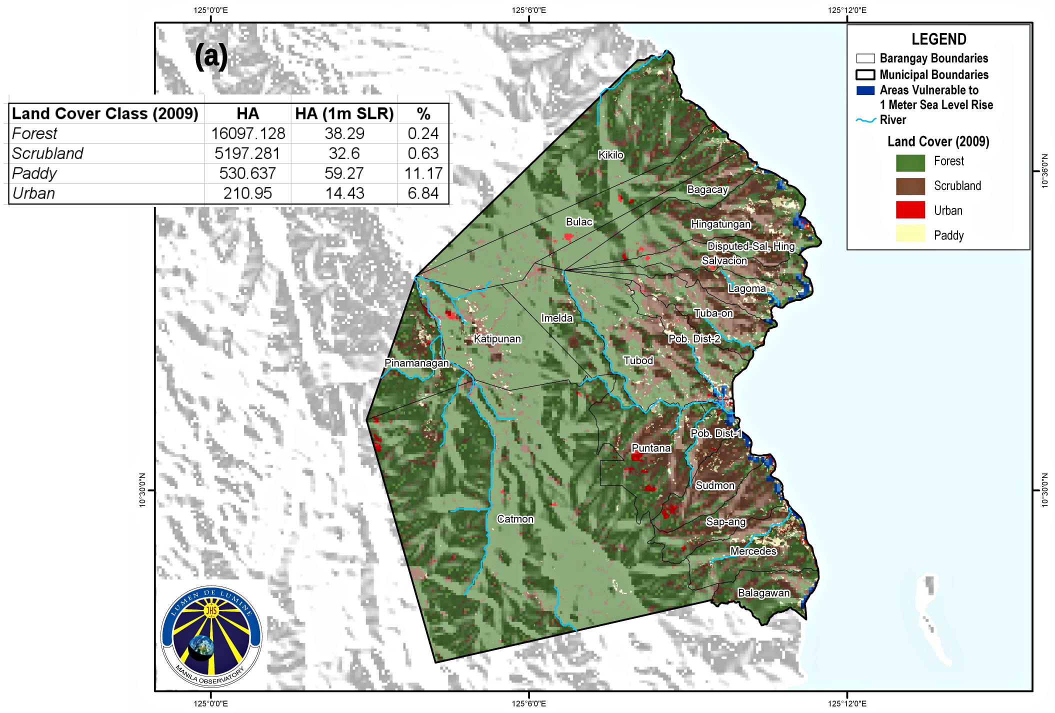
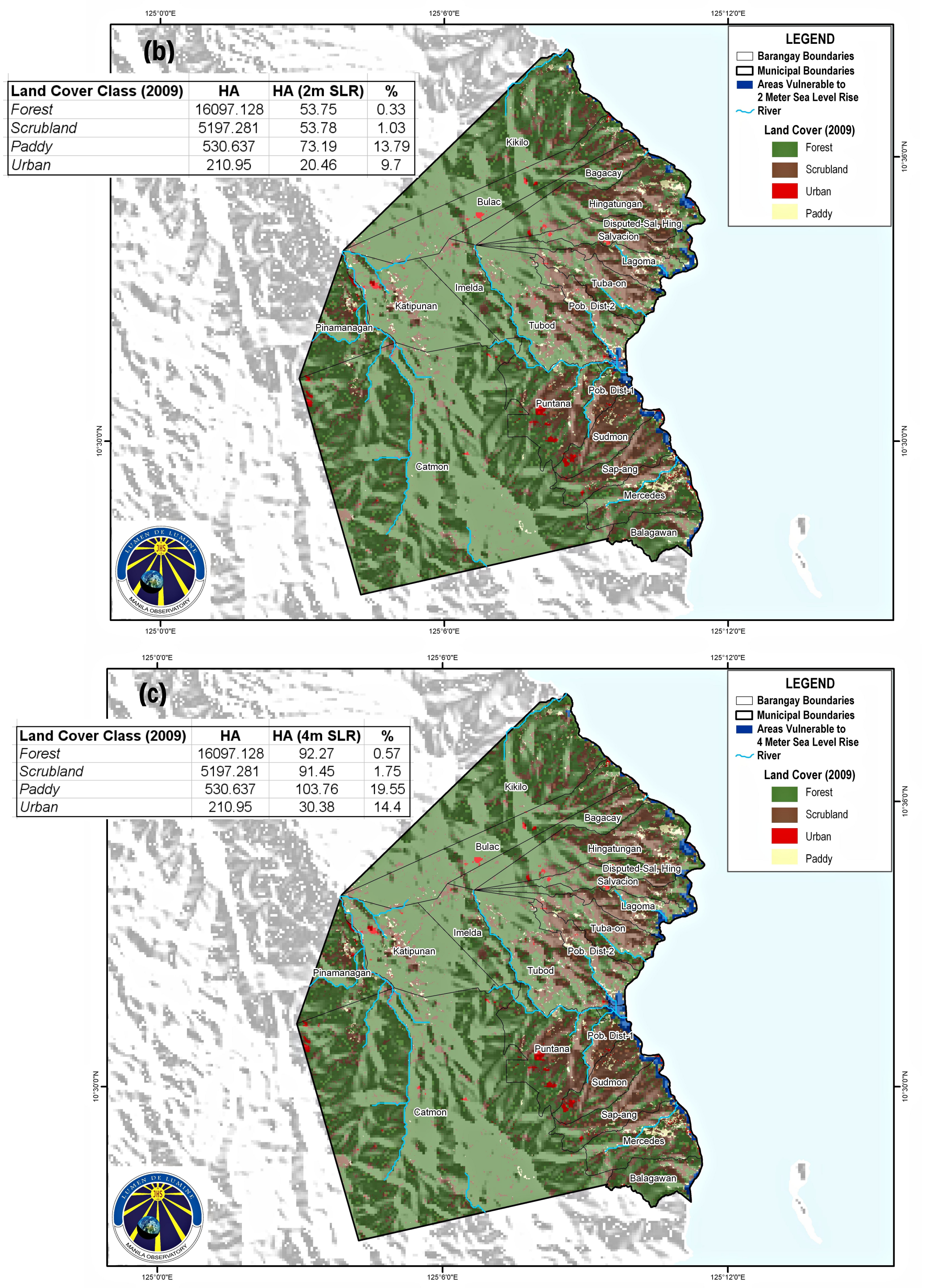


Figure VII.15. *Land cover of Silago based on satellite based image analysis (2009). (Map Data Sources: Shuttle Radar Topographic Mission version 4 (Feb. 2000), Landsat 2009).*



Land Cover Class (2009)	HA	HA (1m SLR)	%
Forest	16097.128	38.29	0.24
Scrubland	5197.281	32.6	0.63
Paddy	530.637	59.27	11.17
Urban	210.95	14.43	6.84

Figure VII.16. *Areas in Silago vulnerable to flooding due to increase in sea level at a) 1 meter, b) 2 meters, and c) 4 meters. Flooded areas are shaded in blue. (Map Data Sources: Shuttle Radar Topographic Mission version 4 (Feb. 2000), Landsat 2009).*



Land Cover Class (2009)	HA	HA (2m SLR)	%
Forest	16097.128	53.75	0.33
Scrubland	5197.281	53.78	1.03
Paddy	530.637	73.19	13.79
Urban	210.95	20.46	9.7

Land Cover Class (2009)	HA	HA (4m SLR)	%
Forest	16097.128	92.27	0.57
Scrubland	5197.281	91.45	1.75
Paddy	530.637	103.76	19.55
Urban	210.95	30.38	14.4

Figure VII.16. *Continued.*

The projected increase in temperature and changes in rainfall for 2050 are shown in Figure VII.17 and Figure VII.18, respectively, together with the 2009 land cover. There is greater warming inland in Silago where most of the forest land are located compared to the coastal areas as indicated by the larger red dots in Figure VII.17. This means that the forest areas may experience an increase in temperature of as much as 2.4^{o}C in the future especially during the warm dry months. Although the warming along the coast of Silago, where most of the rice paddies are located, is less than the warming inland, these areas will still experience an increase in temperature of about 1.8°C and 1.9°C during the cold wet months and the warm dry months, respectively, by 2050.

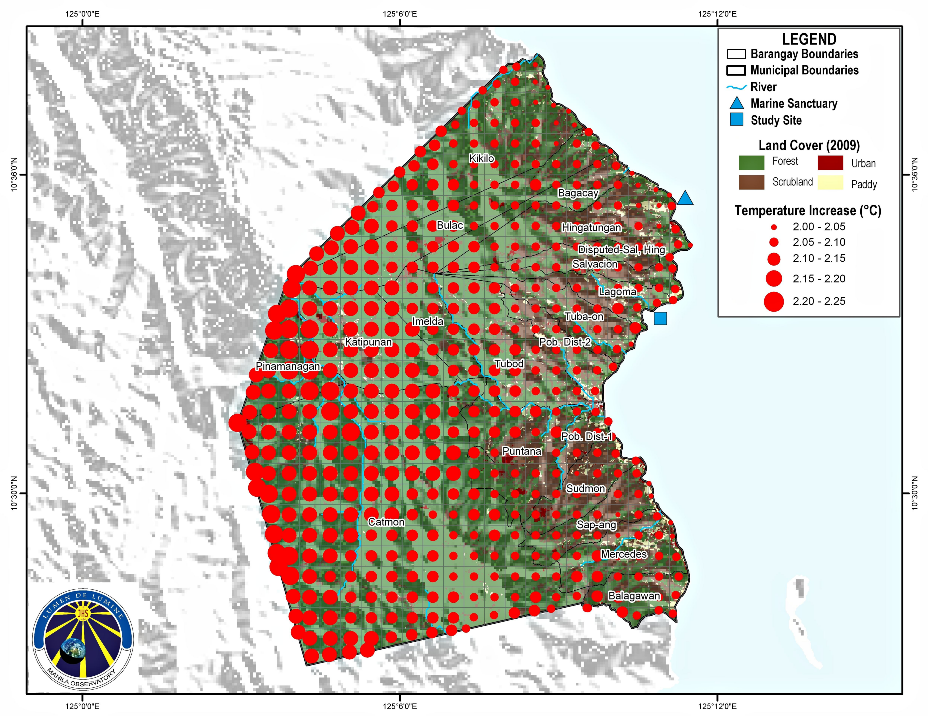


Figure VII.17. *Projected increase in temperature by 2050 and the 2009 land cover of Silago. Larger red dots indicate higher increase in temperature. (Map Data Sources: Shuttle Radar Topographic Mission version 4 (Feb. 2000), Temperature Anomaly RCS-MO, Landsat 2009).*

While the changes in temperature show greater impacts inland, the projected decrease in rainfall shows larger effects or drier conditions along the coastal areas of Silago by 2050 (this is represented in Figure VII.18 by the larger orange dots). The north-eastern barangays of Kikilo, Bulak, Hingatungan, Salvacion, and Lagoma will experience rainfall decreases of as much as -20% and -24% during the wet season and the dry season, respectively, in 2050. There are the barangays where most of the non-irrigated rice paddies of the municipality are located and hence, severe decreases in rainfall can have significant impacts on rice production from these rainfed areas. These barangays also have large areas apportioned to irrigated rice land. The implications of drier conditions on irrigated rice will depend on the source of water used for irrigation. However, although inland regions appear to have lower decreases in rainfall amounts relative to the coastal areas, these places are still projected to have decreases in rainfall ranging from -15% to -26% by 2050. Hence, the overall decrease in rainfall in Silago may have serious implications on water availability for agricultural land. It is encouraging to note though that three of the major crops shown in Figure VII.19 may be more resilient to drought compared with rice and the other crop types. Cassava is considered to be a drought tolerant crop and abaca and coconut did not have significant drops in production during the strong 1997-1998 El Nino (Figure VII.17 and Figure VII.18) although abaca is deemed to be more vulnerable to pest and insect infestation.

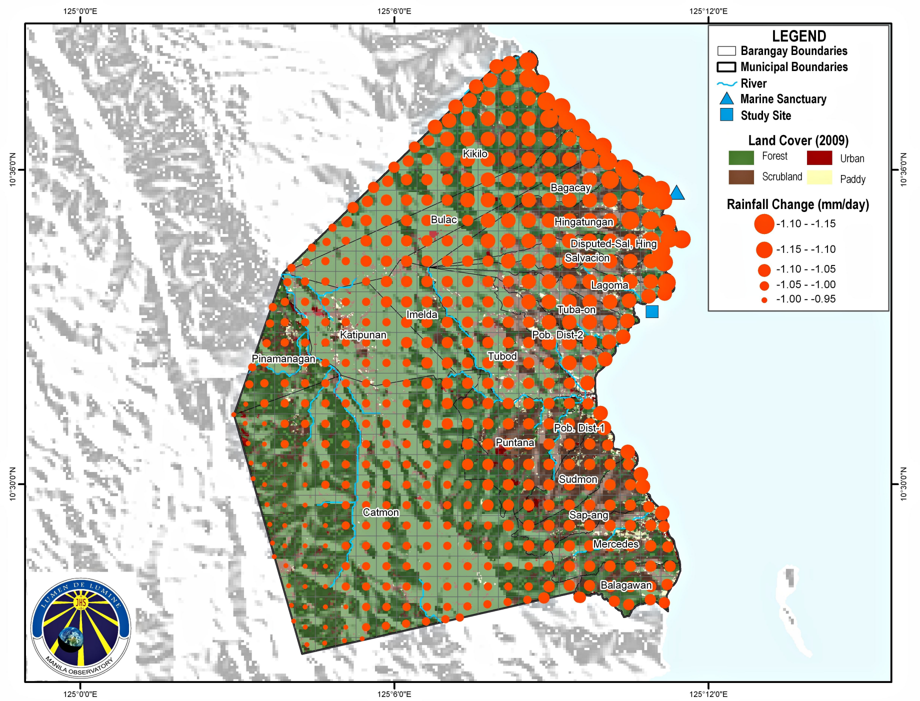


Figure VII.18. *Projected decrease in rainfall by 2050 and the 2009 land cover of Silago. Larger orange dots indicate drier conditions for 2050. . (Map Data Sources: Shuttle Radar Topographic Mission version 4 (Feb. 2000), Rainfall Anomaly RCS-MO, Landsat 2009).*

The projected changes in minimum temperatures as discussed in Chapter 4 will have serious consequences on rice yield. Figure VII.20 shows an illustration of a potential climate shift due to global warming. In this figure, the future climate will have greater of probabilities of experiencing an increase in the average values (in this case average temperatures), less cold weather, more hot weather, and more extreme hot weather. This behaviour of shifting climate is evident in the projected changes in minimum temperatures in Silago (Figure VII.21). This implies that the future climate regime will have average minimum temperatures that are about 3^{o}C higher than the previous or baseline climate. There will be more warm nights and more extreme warm nights. Figure VII.17 in Chapter 4 showed that there will be more years that will experience more than 270 days of minimum temperatures that are greater than 27.5^{o}C. This means that practically most of the nights throughout the year for these years will have higher night-time temperatures. These changes in minimum temperatures can have significant impacts on crop production. Maximum temperatures are also projected to be higher than normal by 2050. Although the impacts of these may not be as significant as the effects of increasing minimum temperatures, the changes can have potential direct (crop damage) and indirect (temperature related water stress) on agricultural crops. Results in Chapter 4 showed that there will be more years by 2050 that will have more than 180 days of maximum temperatures greater than 32.6^{o}C. There will also be greater variability in hot weather events, with higher probabilities of occurrence for extreme hot weather.

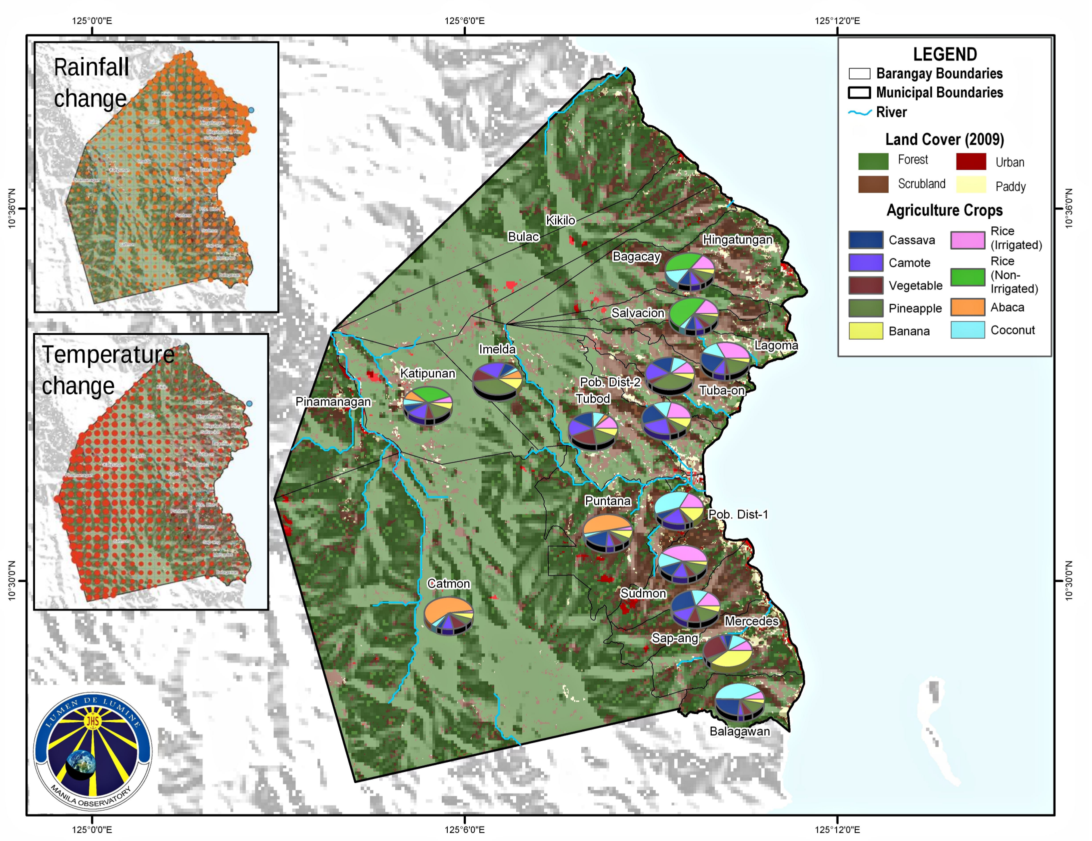


Figure VII.19. *Existing major agricultural crops in Silago per barangay. (Source: Silago CLUP, 2011). . (Map Data Sources: Shuttle Radar Topographic Mission version 4 (Feb. 2000), Temperature and Rainfall Anomalies RCS-MO, Landsat 2009)*

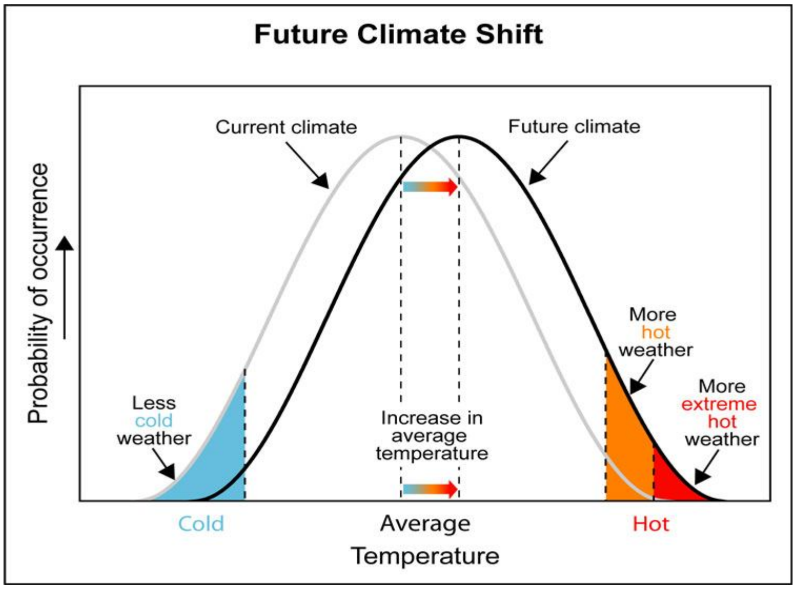


Figure VII.20. *An illustration of the impacts of global warming on future shifts in climate into a new regime. (Figure taken from: http://www.southwestclimatechange.org/figures/temperature-shift)*

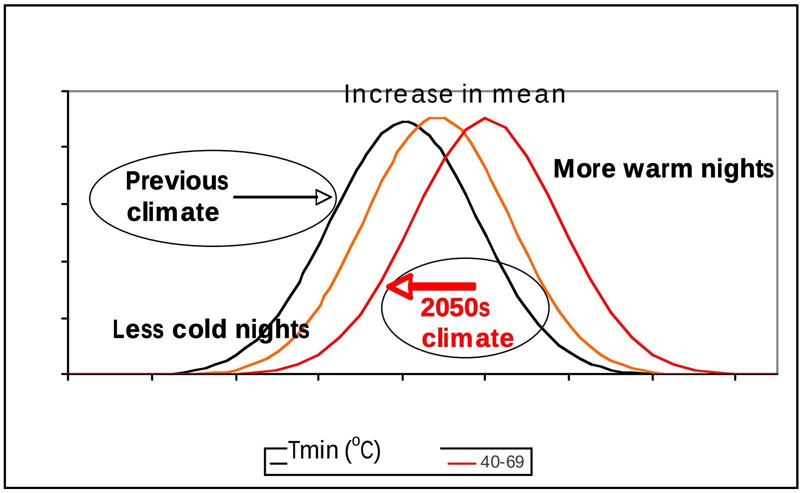


Figure VII.21. *The projected changes in minimum temperatures in Silago showing a potential shift into a new regime by 2020 and 2050.*

Agriculture is also vulnerable to any changes in climate during the planting season. Planting time for non-irrigated rice fields are often done during the rainy season in Silago (Table VII.6). Hence any future change in the wet season may affect rice production. Climate projection results (Figure VII.12) show that there is a slight decrease in rainfall for the month of December in 2050. However, the months of January and February (considered still to be part of the rainy season), will have larger decreases in rainfall. On average, by 2050 Silago will experience a -22% decrease in rainfall during the wet months of October, November, December, January, and February and a -17% decrease in the months of June, July, August, and September. These changes in seasonal climate may also affect the production of sweet potato, taro, and ube (planted in December), and vegetables (planted in February to March).

Table VII.6. *Crops and the corresponding labor peaks and acitvites in Silago.*

Crops	Activities
Abaca	Processing is done during dry season
Cassava	Planting time is April to May
Coconut	Processing is done every quarter of the year
Corn	Planting season is in March and harvesting is done after five months.
Irrigated rice field	Planting can be done three times per year.
Non irrigated field	Planting time during rainy season (June and December)
Pineapple	Harvesting is done during May after two years from planting
Sweet potato, taro, ube	August - October: Preparation of land (clearing, burning) December: planting
Vegetables	Planting time during February to March

(Source: NRMS, Leyte Island, 2001)

Given the projected severe impacts of climate change on rice yield in Silago, a production-consumption analysis for rice is useful to assess the current status of food supply in the municipality. Such an anlaysis was done in the CLUP of Silago (MPDO, 2010). Table VII.7 shows that, currently there is more than enough rice produced for consumption and that there was a projected net surplus of 200,588 kilograms of rice for 2010 given an estimated population of 13,463. Rice surplus, however, is estimated to have steeply decreased since 2000 as the population in Silago continues to increase. This inverse relationship is evident in Figure VII.22.

Hence, even without climate change, population increase alone may put pressures on the rice supply of Silago. Given the potential negative impacts of the projected changes in climate and climate variability on rice yield, it will be important for Silago to incorporate climate scenarios when analysing the future relationships between production and consumption.

Table VII.7. *Production-Consumption Analysis for Rice, 2000-2010.*

Year	Estimated Population
2000	10,963
2001	11,212
2005	12,199
2010	13,463
Rice Production Area Classification	Area (in Hectare)
Irrigated Rice Non-Irrigated Rice	500 40
Production	
Irrigated Rice	70,000 cavans of Palay/Annum
Non-Irrigated Rice	4,800 cavans of Palay/Annum
TOTAL	74,800 cavans of Palay
Total Rice Yield at 50% recovery	37,400 cavans of Rice
Total Rice in kgs. At 50 kgs./cavans of Rice	1,870,000 kgs. Of Rice
Population that can be supported by rice production from standard of 124 kgs. Per capita consumption	15,080
Rice Surplus in kgs.	Kilograms
2000	* 510,588 kgs.of Rice
2001	* 479,712 kgs.of Rice
2005	* 357,324 kgs.of Rice
2010	* 200,588 kgs.of rice

(Source: Silago CLUP, 2006; MPDO, 2010)

Assumptions as mentioned in the municipal CLUP:
a) Yield/hectare/harvest for irrigated rice = 70 cavans of palay
b) Yield/hectare/harvest for non irrigated rice = 60 cavans of palay
* Derived from multiplying the population by the standard of 124 kg per capita consumption, less rice production of 1,870,000 kg of rice.

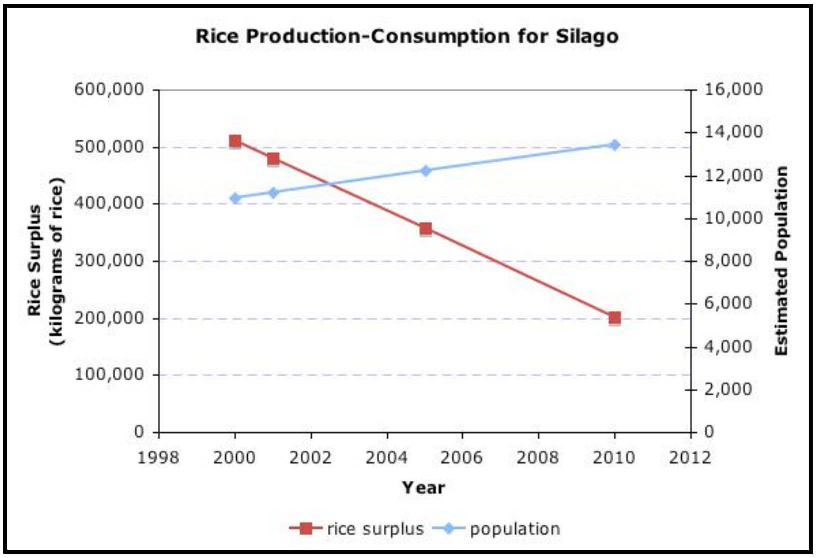


Figure VII.22. *Rice Production-Consumption analysis for Silago based on the data from the municipal CLUP. (Source: Silago CLUP, 2006)*

F. ADAPTATION OPTIONS FOR THE AGRICULTURAL SECTOR

There are numerous proposed adaptation options for the agricultural sector given the extreme vulnerability of this sector to the impacts of climate change. These measures range from technology advances (such as developing rice varieties), government interventions (such improving and building new irrigation infrastructures), farm productions (such as changes in planting date), and financial management systems. Table VII.8 outlines a series of adaptation options taken as is from different literature sources.

Table VII.8. *Adaptation options for the agricultural sector.*

Adaptation Options	References
TECHNOLOGICAL DEVELOPMENTS *Crop development* • Develop new crop varieties, including hybrids, to increase tolerance and suitability of plants to temperature, moisture and other relevant climatic conditions. *Weather and climate information systems* • Develop early warning systems that provide daily weather predictions and seasonal forecasts. *Resource management innovations* • Develop water management innovations, including irrigation, to address the risk of moisture deficiencies and increasing frequency of droughts. • Develop farm-level resource management innovations to address the risk associated with changing temperature, moisture and other relevant climatic conditions.	Smit, Barry and Skinner, Mark W. 2004. Adaptation Options in Agriculture to Climate Change: A Typology. (http://www.springerlink.com/content/w5j4ug89760tdbjd/fulltext.pdf). Journal: Mitigation and Adaptation Strategies for Global Change Volume 7, Number 1 / March, 2002 Publisher: Springer Netherlands
GOVERNMENT PROGRAMS AND INSURANCE *Agricultural subsidy and support programs* • Modify crop insurance programs to influence farm-level risk management strategies with respect to climate-related loss of crop yields. • Change investment in established income stabilization programs to influence farm-level risk management strategies with respect to climate-related income loss. • Modify subsidy, support and incentive programs to influence farm-level production practices and financial management. • Change ad hoc compensation and assistance programs to share publicly the risk of farmlevel income loss associated with disasters and extreme events. *Private insurance* • Develop private insurance to reduce climate-related risks to farm-level production, infrastructure and income. *Resource management programs* • Develop and implement policies and programs to influence farm-level land and water resource use and management practices in light of changing climate conditions.	
FARM PRODUCTION PRACTICES *Farm production* • Diversify crop types and varieties, including crop substitution, to address the environmental variations and economic risks associated with climate change. • Diversify livestock types and varieties to address the environmental variations and economic risks associated with climate change. • Change the intensification of production to address the environmental variations and economic risks associated with climate change. *Land Use* • Change the location of crop and livestock production to address the environmental variations and economic risks associated with climate change. • Use alternative fallow and tillage practices to address climate change-related moisture and nutrient deficiencies.	

Land topography • Change land topography to address the moisture deficiencies associated with climate change and reduce the risk of farm land degradation. *Irrigation* • Implement irrigation practices to address the moisture deficiencies associated with climate change and reduce the risk of income loss due to recurring drought. *Timing of operations* • Change timing of farm operations to address the changing duration of growing seasons and associated changes in temperature and moisture.	
FARM FINANCIAL MANAGEMENT *Crop insurance* • Purchase crop insurance to reduce the risks of climate-related income loss. *Crop shares and futures* • Invest in crop shares and futures to reduce the risks of climate-related income loss. *Income stabilization programs* • Participate in income stabilization programs to reduce the risk of income loss due to changing climate conditions and variability. *Household income* • Diversify source of household income in order to address the risk of climate-related income loss.	
Risk: Crop area changes due to decrease in optimal farming conditions Main climatic causes of risk: Changes in monthly precipitation distribution Increased temperatures in critical periods Increased erosion Loss of soil water retention capacity A. Farming optimal conditions altered resulting in creased risk to rural income • Livelihood diversification • Strengthen local capacity to reduce sensitivity • Conversion of ambient storage to refrigerated stores • Irrigation • Changing cultivation practices • Increased irrigation • Change of cropping mix • Switching to alternative crops B. Loss of Indigenous species • Climate change resilient crops • Insurance C. Soils deterioration due to land-use changes • Extensification: enhance carbon management and zero tillage • Precision agriculture: improve soil and crop management D. Land abandonment due to very large changes in optimal conditions • Intensify research efforts and an enhanced training • Livelihood diversification	Table 27 Potential consequences for agricultural production of the identified risks and opportunities, adaptation options, option category and level of implementation. * T: Technical / M: Management / I: Infrastructural / E: Equipment ** F: Farm level / S: Sector level Authors: Ana Iglesias, Keesje Avis, Magnus Benzie, Paul Fisher, Mike Harley, Nikki Hodgson, Lisa Horrocks, Marta Moneo, Jim Webb Report Title: Adaptation to Climate Change in the Agricultural Sector AGRI-2006-G4-05 AEA Energy & Environment and Universidad de Politécnica de Madrid Report to European Commission Directorate -
Risk: Decreased Crop Productivity Main climatic causes of risk: Changes in monthly precipitation distribution Increased temperatures in critical periods (heat stress)	

Loss of soil water retention capacity A. Crop productivity decrease • Change in crops and cropping patterns • Irrigation • Advisory services for farmers on adapted farming practices, new crops B. Crop productivity variability risk Increased • Agricultural insurance • Crop planting diversification C. Land abandonment • Design of regional adaptation plans • Livelihood diversification D. Agricultural trade intensification • Strengthen local capacity to reduce sensitivity	General for Agriculture and Rural Development Issue Number 1 December 2007
Risk: Increased risk of agricultural pests, diseases, weeds Main climatic causes of risk: Increased water logging Increased average temperatures A. Pest populations increase and distribution with increased temp • Use new pest resistant varieties • Develop sustainable integrated pesticides strategy • Use of natural predators • Vaccinate livestock • Monitoring of pests/diseases patterns to prevent damages B. Pollution by increased use of pesticides • Develop sustainable integrated pesticides strategy • Advisory support for farmers	
Risk: Crop quality decrease Main climatic causes of risk: Heat stress Changes in annual and seasonal precipitation distribution A. Crop quality reduction in fruits and vegetables • Thermal screens • Temperature control B. Damage to grain formation due to heat stress • Thermal screens • Temperature control	
Risk: Increased risk of floods Main climatic causes of risk Increase of extreme events frequency Loss of soil water retention capacity A. Increased expenditure in emergency and remediation actions • Develop contingency plans • Create/restore wetlands • Enhance flood plain management • Hard defences B. Flash flood frequency and intensity increase • Increase rainfall interception capacity	

• Move towards farmers as ‘custodians’ of floodplain lands with appropriate compensation • Reduce grazing pressures to protect against soil erosion from flash flooding C. Flooding and storm damage increase • Increase rainfall interception capacity/soil management • Contour ploughing • Increase drainage • Addition of organic material into clay soils (difficult to work in wetter conditions) • Insurance for farm infrastructure	
Risk: Increased risk of drought and water scarcity Main climatic causes of risk: Decreased annual and/ or seasonal precipitation Increase in the frequency of extreme conditions (droughts and heat waves) A. Conflicts among water users due to drought and water scarcity • Shift crops from areas that are vulnerable to drought • Set clear water use priorities • Increase water use efficiency B. Water supply reduced • Increase rainfall interception capacity (techniques for conserving soil moisture) • Improve field drainage and soil absorption capacity • Reduced run-off via contoured hedgerows and buffers • Altering crop rotations to introduce crops more tolerant to heat/drought • Woodland planting • Use of precision farming: tillage and timing of operations • Small-scale reservoirs and methods to collect water • Water management • Water audits • Water charging/tradable permit schemes to promote efficient use of prescribed (reduced) sources • Insurance (or other risk protection tools) C. Damage to Wetlands • Installation of small-scale water reservoirs on farmland • Recreate wetlands	
Risk: Increased irrigation requirements Main climatic causes of risk: Increased average and extreme temperature Increase of drought and heat stress conditions frequency Decreased precipitation A. Water availability decrease, Water shortage in irrigated areas • Invest in irrigation equipment that helps reduce the severity and collects rain water • Technical improvements in advanced irrigation equipment • Trickle irrigation • Irrigation during the night • Separation of clean and dirty water • Installation of small-scale water reservoirs on farmland	
Risk: Water quality deterioration Main climatic causes of risk: Increased precipitations extremes, flood and drought frequency A. Water quality loss due to the higher leaching and run-off • Aerating ploughing equipment	

• Develop less polluting inputs • Timed input of N inputs • Reduce N outputs from soil through enhanced efficiency of fertiliser use	
Risk: Soil erosion, salinisation, desertification Main climatic causes of risk: Increased temperature Sea level rise Decreased precipitation Extreme conditions (heavy precipitations, drought) A. Desertification due to water resources deficit, loss of soil structure, land abandonment • Livelihood diversification • Strengthen local capacity to reduce sensitivity • Intensify research efforts and an enhanced training B. Soil salinisation increases • Change in cropping • Allocate fields prone to flooding from sea level rise as set aside C. Erosion and accretion increase • Change fallow and mulching practices to retain moisture and organic matter • Use intercropping to maximise use of moisture D. Soil drainage changes leading to increased salinity • Change fallow and mulching practices to retain moisture and organic matter E. Water logging increases • Invest in machinery or development and disseminate good practices that minimise the adverse effects of water logging F. Loss of rural income • Change fallow and mulching practices to retain moisture and organic matter • Livelihood diversification • Strengthen local capacity to reduce sensitivity	
Risk: Sea-level rise Main climatic causes of risk: Increased sea temperature and accompanying thermal expansion of sea water A. Sea level intrusion in coastal agricultural areas and salination of water supply • Hard defences • Alternative drainage systems • Set aside of land for buffer zones • Alternative crops • Livelihood diversification • Research into other options for management of salt water intrusion	
Opportunity: Crop distribution changes leading to increase in optimal farming conditions Main climatic causes of opportunity: Increased availability of CO_2 Increased temperatures A. Crop suitability increase • Introduce more productive varieties • Increase range of crops (annual and permanent) • Grow quicker maturing varieties to maximize yields • Investment in energy crops, short-rotation coppice and miscanthus	
Opportunity: Crop productivity increase	

(Main climatic causes of opportunity Increased availability of CO_2 Increased temperatures A. Crop yield and biomass increase leading to increased potential efficiency of physiological water use due to CO_2 increase • Introduce more productive varieties • Grow quicker maturing varieties to maximize yields B. Reduced drought impacts and damage • Drought resistant varieties obtained by improved breeding or by importing them from drier locations	

VIII. VULNERABILITY AND IMPACTS OF CLIMATE CHANGE ON THE COASTAL SECTOR

A. GENERAL INTRODUCTION: COASTAL SECTOR

The Municipality of Silago is coastal in nature, with approximately 27.82 kms of coastline, covering 14 barangays namely: Kikilo, Bulac, Bagacay, Hingatungan, Salvacion, Lagoma, Tuba-on, Poblacion District 2, Poblacion District 1, Sudmon, Sap-ang, Mercedes, and Balagawan (Figure VIII.1).

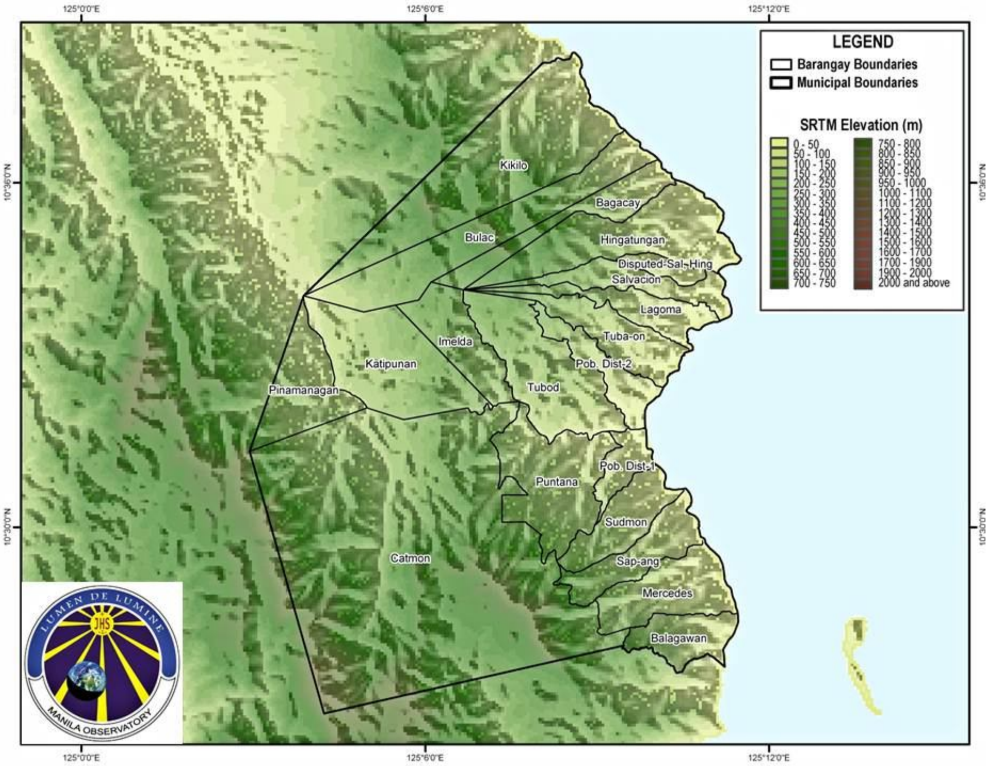


Figure VIII.1. *Map of Municipality of Silago, Southern Leyte. . (Map Data Sources: Shuttle Radar Topographic Mission version 4 (Feb. 2000))*

Various ecosystems can be found in the coastal area. These include coral reefs, seagrass and seaweed beds, mangroves, estuaries, and beaches. At present, there is no mapped information of the spatial location of these ecosystems. However, it has been mentioned in the municipality's CLUP (2000) that protected mangrove areas cover 40 hectares while beach areas cover 7 hectares. The mangrove areas contribute to 0.18% of the total general land-use in Silago, while the beach areas contribute 0.03%.

There is a marine sanctuary located in Brgy. Hingatungan with detailed resource and ecological assessment conducted (Cesar et al., 2003). The physico-chemical parameters for 2002 and 2003 were examined and compared. However, the gathered data were not complete for comparison and certain conditions (e.g. date of sampling and exact time) were not explicitly described in the report (see Table VIII.1).

Table VIII.1. *Physico-chemical parameters and GPS readings of Hingatungan Sanctuary, Silago, Southern Leyte.*

Parameters		2002	2003
Water Temperature (°C)	Surface	*	30
	Bottom	28.5	**
Salinity (o/°°)	Surface	*	35
	Bottom	31	**
pH	Surface	*	8.4
	Bottom	8.24	**
Depth (m)		6	12.5
Conductivity (µS/cm)	Surface	-	50,000
Water transparency (m)		*	17
GPS Readings	N 10° 35' 34.7" E 125° 11' 17.1"		
*No data gathered due to strong wave and current			
**Bottom water sample was not taken due nonfunctional water sampler.			

Source: Cesar et al., 2003

Mangroves species are present in Barangay Hingatungan (11 species) and Barangay Lagoma (4 species). Comparisons of the 2002 and 2003 data showed no significant changes in Barangay Lagoma while changes in composition for Barangay Hingatungan were attributed to transect locations surveyed during the different years.

There are three seaweed, four seagrass, and one associated species recorded inside the marine sanctuary of Hingatungan (see Table VIII.2). Changes in the seaweed/seagrass frequency and cover were noted for 2002 and 2003 and attributed to the location of the transect lines.

Table VIII.2. *Species composition, frequency of occurrence, cover of seaweeds and seagrasses and density associated invertebrates at the marine sanctuary of Hingatungan, Silago, Southern Leyte.*

Species	F	C	Remarks
Phaeophytes:	**10.4**	**4.5**	
Padina minor	2.8	0.3	(Transect was inside
Sargassum polycystum	7.6	4.1	marine sanctuary; 150m
Rhodophytes:	**6**	**0.2**	reef flat; intertidal area
Gracilaria eucheumoides	6	0.2	
Mean F/Total C	8.2	4.6	mainly sandy substrate;
Seagrasses:	22.3	25.1	lower intertidal rocky
Cymodocea serrulata	40.4	14.4	exposed to big waves)
Halodule uninervis	20	3.5	
H. pinifolia	24	5.3	
Thalassia hemprichii	4.8	2	
Associated Invertebrates:	0.2	0.2	
Univalve (no./0.25m²)	0.2	0.2	

Source: Cesar et al., 2003

The assessment for coral reefs was done only for 2003 due to constraints in weather condition during the 2002 sampling. The total live coral cover for the study area is 15.13% and is under the poor category. During the survey, there were minimal observations of destructive fishing that may contribute to the poor reef status. However, it was noted that the natural topography of the area makes it susceptible to strong currents and wave actions thereby lessens massive reef development.

The survey for fish resources showed a low fish counts for Hinatungan marine sanctuary, being attributed to the differences in the physical features of the reef (Figure VIII.2). The sanctuary's reef has many large smooth bare rocks and do not provide food for corallivores (fishes eating corals) nor shelter for other fishes. The area is also exposed to swells from the Pacific ocean resulting to stronger and heavier wave motion sending fishes to deeper waters or refuge into coral heads.

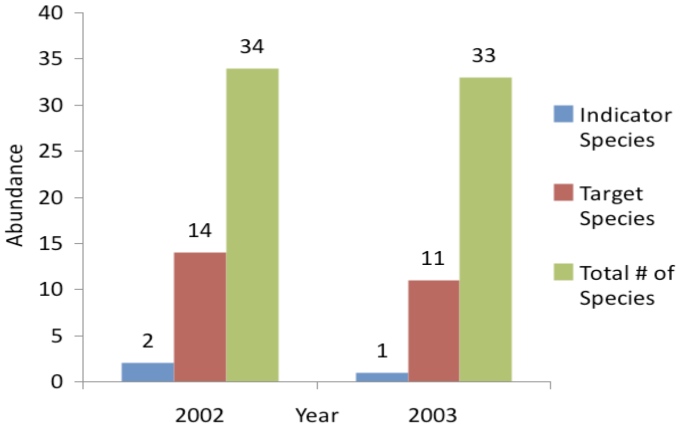


Figure VIII.2. *Results of fish visual census carried out at Hingatungan, Silago, Southern Leyte. (Source: Cesar et. al., 2003).*

The residents in the coastal communities are involved in fishing, farming, aquaculture, vending, and dealing goods. There were 100 registered fisherfolks in 12 coastal barangays as of September, 2009. Most of them are into part-time fishing and farming, aquaculture, vending, and dealing (see Figure VIII.3, Cesar et. al. 2003). Several fish dealers were noted in the municipality. However, they operate on a seasonal basis depending on the available supply (CLUP, 2000). Since most of the barangays in Silago are located along the coast, it implies a high dependence on the coastal resources by the populace for food consumption, trade, and income.

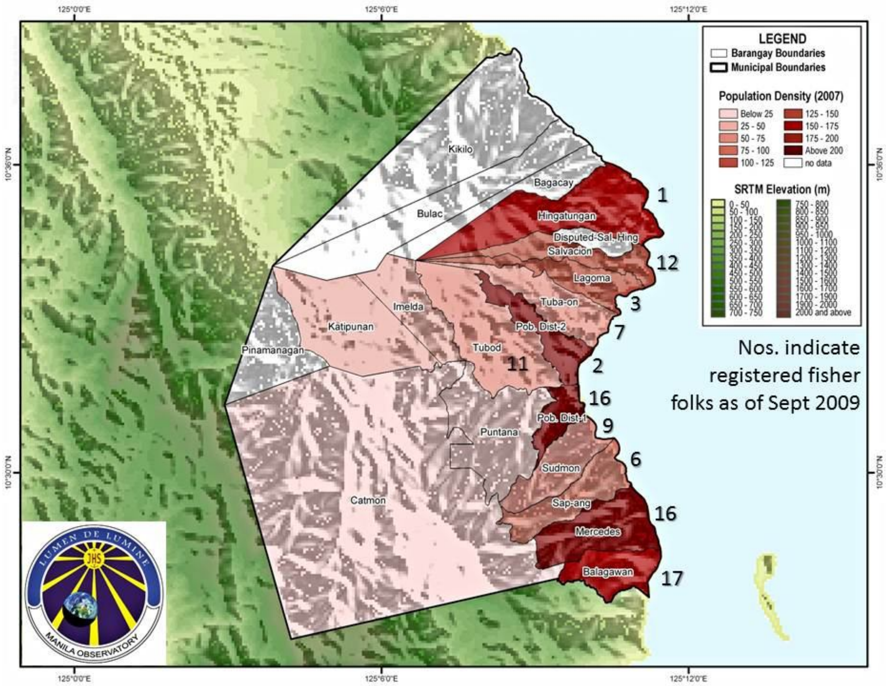


Figure VIII.3. *Population Density (2007) of Silago, Southern Leyte. The numbers indicate the registered fisherfolks as of September 2009. (Source: DA-LGU Silago). . (Map Data Sources: Shuttle Radar Topographic Mission version 4 (Feb. 2000), Population Density National Statistics Office).*

The municipality has identified a Fishery Development Zone of 40 hectares, comprising the 0.1% of the total development zone in the area. To help in protecting and conserving the coastal resources, efforts on coastal resource management were supported by GIZ (Silago-Anahawan) together with the implementing agencies namely: the Municipality of Silago LGU and people's organizations. The protected mangrove areas are located at Barangays Hingatungan, Lagoma, and Sudmon covering 40 hectares (CLUP, 2000).

B. *IMPACT CHAIN, INFLUENCE DIAGRAM, AND PROJECTIONS FOR THE COASTAL SECTOR OF SILAGO*

Impact Chain and Influence diagram

The changes in climate system affect ocean life and processes. Among the climate stimulus affecting the oceans include: increasing sea surface temperatures (SSTs), increasing number of tropical cyclones, increase in rainfall variation, and increasing concentrations of dust due to iron (Fe) fertilization.

The different climate stimulus influence ocean dynamics and processes, primarily the physic-chemical and biological properties of the oceans. The changes in the climate stimulus will definitely alter plankton dynamics and algal production. The changes will eventually cascade to the different coastal ecosystems such as estuaries, seagrass and seaweed beds, mangrove areas, beaches and shorelines, and coral reefs. The over-all impact of these changes will be felt by the coastal communities that depend on these areas for livelihood and sustainability (see Figure VIII.4).

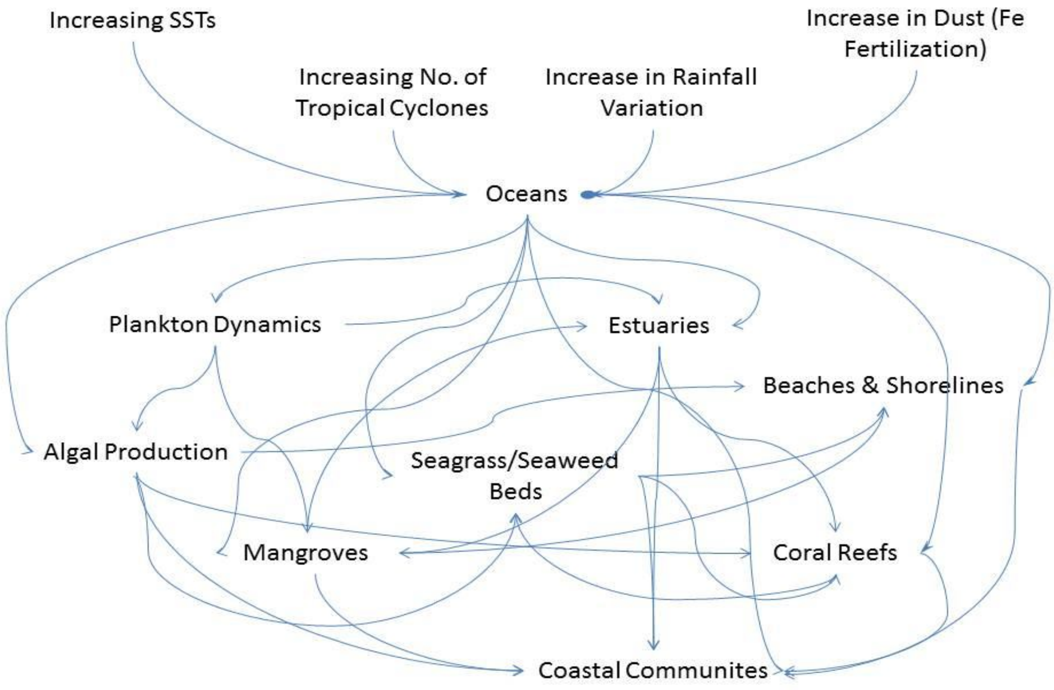


Figure VIII.4. *Influence Diagram for the Coastal Sector of the Municipality of Silago, Southern Leyte.*

The flow of impacts on various parameters is shown in the impact chain below (Figure VIII.5 and Figure VIII.6). The direct and indirect impacts for each ecosystem were identified by the research team and validated by the stakeholders in the municipality. The figures also indicate impacts to the society and implications for risk assessment. The different ecosystems exposed to climate changes include coral reefs, seagrass and seaweed beds, mangroves, estuaries, and beaches/shorelines. In Silago, all these ecosystems are present in the coastal zone.

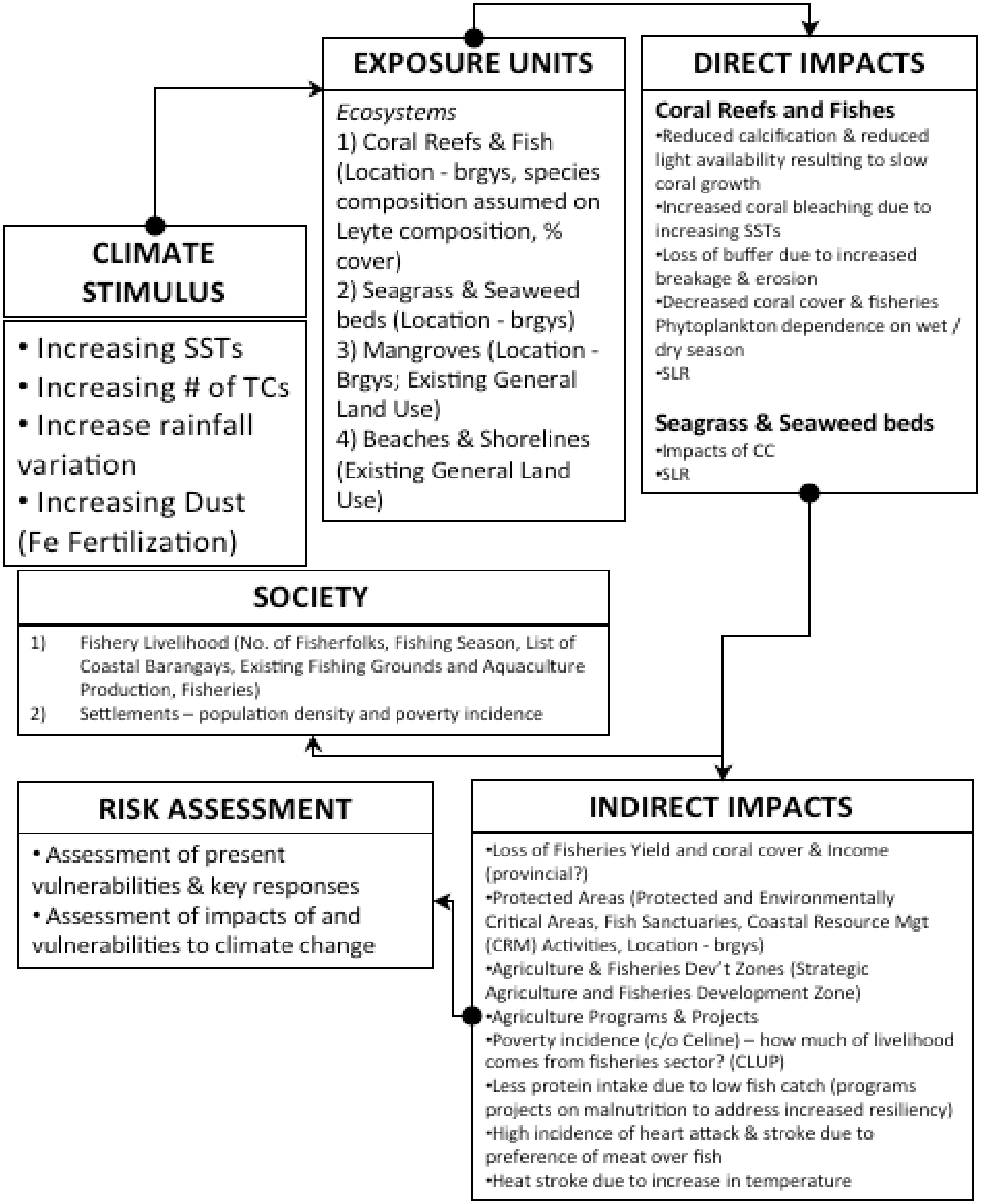


Figure VIII.5. *Impact Chain for the Coastal Sector (1 of 2).*

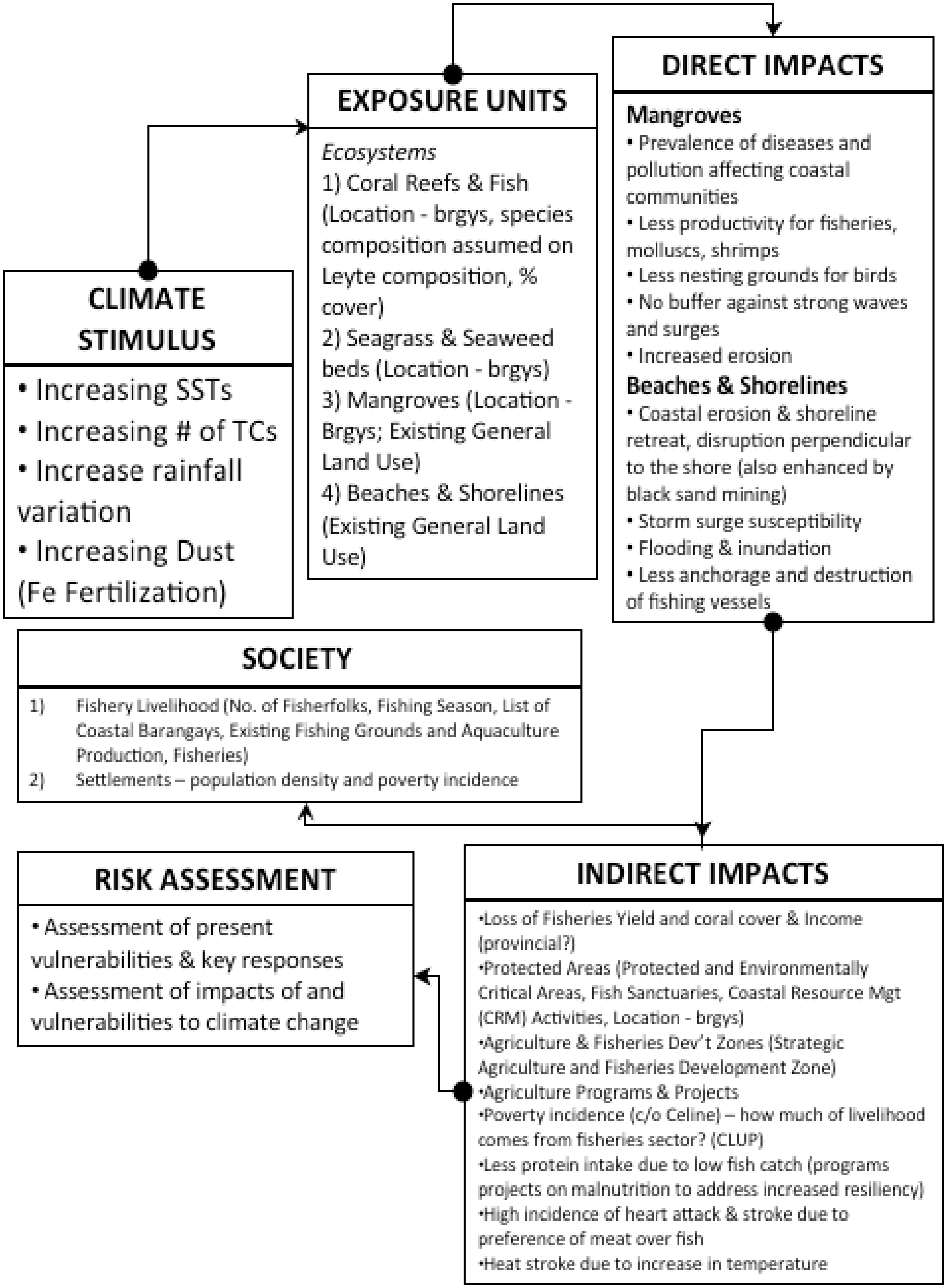


Figure VIII.6. *Impact Chain for the Coastal Sector (2 of 2).*

The changes in climate will definitely affect ocean dynamics and processes. These impacts include: a) differential increase in sea surface temperature (SST), b) variations in SST due to the changing frequency of the El Nino Southern Oscillation or ENSO, c) changes in the South China Sea (SCS) wind system during ENSO periods resulting in warming of surface waters, d) strengthening of alongshore winds that eventually enhance upwelling, e) lowering of thermocline (depth in the ocean zone where abrupt change in temperature is observed) resulting to disrupted upwelling areas, f) decrease capacity to dissolve carbon dioxide resulting in a decrease in biological carbonate formation, and g) sea-level rise resulting in increased water depths, tidal variations, and water movement alterations (Capili et al., 2005).

Moreover, Capili et al. (2005) also discussed that:

- Shifts in the physico-chemical properties of ocean waters may result in enhanced upwelling, where nutrients from deeper waters are transported to the shallower areas of the oceans. These shifts will impact plankton dynamics. Any change in plankton productivity, especially in shallow waters, will affect primary production. The increase concentrations of atmospheric carbon dioxide will result to an increase in primary production for carbon limited areas. This implies shifts in plankton abundance that will affect fishery production in the municipality of Silago. Such changes need to be considered in the efforts of the municipality's Fishery Development Zone as well as other associated livelihood activities. The same shifts may also increase the occurrence of toxic algal blooms that may result in mortality of various marine organisms, especially reef fishes.

- The changes in temperature and rainfall will affect the salinity and pH of the ocean, thereby disrupting the balance of fresh and salt waters in estuaries. This will eventually lead to reduced water mixing and oxygen depletion, affecting the nursery grounds of juvenile fishes and shell fishes. This will also block the normal migration routes outside the estuaries, resulting in mismatches between plankton blooms and juvenile fishes affecting food chain.

- Impacts in the seagrass and seaweed beds will also be evident at the onset of climatic changes. Expect altered growth rates, physiological functions, distribution, and reproduction patterns in these organisms. Also, the changes in the climate stimulus will disrupt competition and interaction among species and between seagrass and algal populations. In addition, there will be reduced productivity due to decrease light availability caused by water depths by sea-level rise. The changes in salinity will alter photosynthesis, growth, and biomass while frequent erosion alter nearshore areas where most seagrasses and seaweeds thrive.

- In mangrove areas, a decrease in run-off and increase in salinity will result to lesser mangrove production. These areas will also be affected by the disrupted balance of fresh and salt waters.

The changes in climate will alter the mangroves' reproductive patterns and seasonality, and may cause mortality during extreme conditions. These will have significant implications in terms of the viability of nursery grounds for fisheries and other associated livelihood in Silago.

- The beaches and shorelines of Silago are important locations for tourism and livelihood. The onset of erosion, however, may increase susceptibility of storm surges in these areas. They will also be exposed to salt-water intrusion and flooding that will affect coastal infrastructure and other activities.

- For coral reefs, changes in the SSTs will result in stress and coral bleaching that may lead to decrease in productivity and mortality. This will also increase the chances of disease incidence. Elevated sea-levels and lowering of pH will affect light availability thereby disrupting coral reef formation and productivity. These will all cascade to a decrease in the abundance of herbivores and result in an exponential decrease in fisheries yield. A redistribution of fish populations may also be observed as well as disrupted migration patterns of pelagic fishes. Coral species diversity and assemblage structure of recruits will also change.

All the changes in the coastal ecosystems will hit the coastal communities in one way or another. These communities will experience decline in fisheries yield, shifting livelihood sources, dietary constraints and poisoning due to toxic blooms, relocation of homes and may increase in migration of people (Capili et al., 2005).

The projections for temperature increase in Silago (see Figure VIII.7 and Figure VIII.8) showed increases in temperature in the coastal areas for both 2020 and 2050. These may also translate to changes in the SSTs as land and sea temperatures interact. A small increase in SSTs will have big impacts in marine life and processes. It will definitely impact coral reef productivity and will alter the impact thresholds of coastal organisms. All the above-mentioned impacts in the coastal zone are probable to happen.

The projected changes in rainfall for Silago (see Figure VIII.9 and Figure VIII.10) showed increased incidences of rainfall in coastal areas for both 2020 and 2050. These imply changes in the fresh and salt water balance thereby affecting salinity and pH of ocean waters, a critical part of primary productivity. The compounding effects of temperature and rainfall increase will definitely impact the state of the coastal resources and the sustainability of the coastal communities in the municipality.

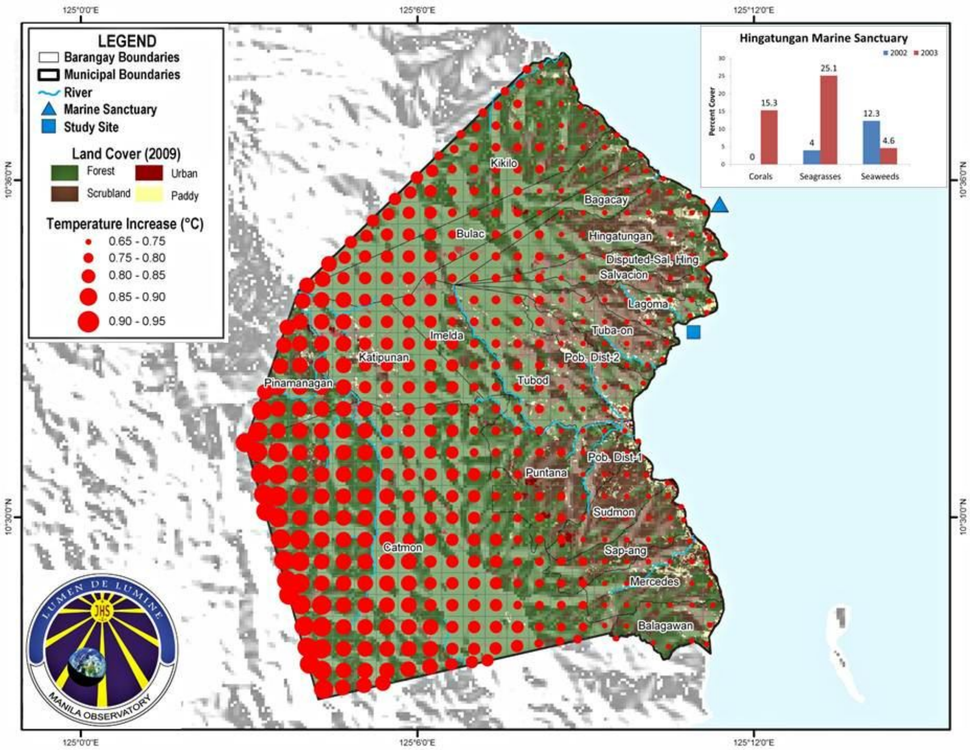


Figure VIII.7. *Land Cover (2009) and Projected Temperature Increase (2020) of Silago, Southern Leyte. Inset: Percent Cover of Corals, Seagrasses, and Seaweeds during 2002 and 2003 in Hingatungan Marine Sanctuary. Changes in temperature will affect productivity of coastal ecosystems. (Map Data Sources: Shuttle Radar Topographic Mission version 4 (Feb. 2000), Temperature Anomaly RCS-MO, Landsat 2009).*

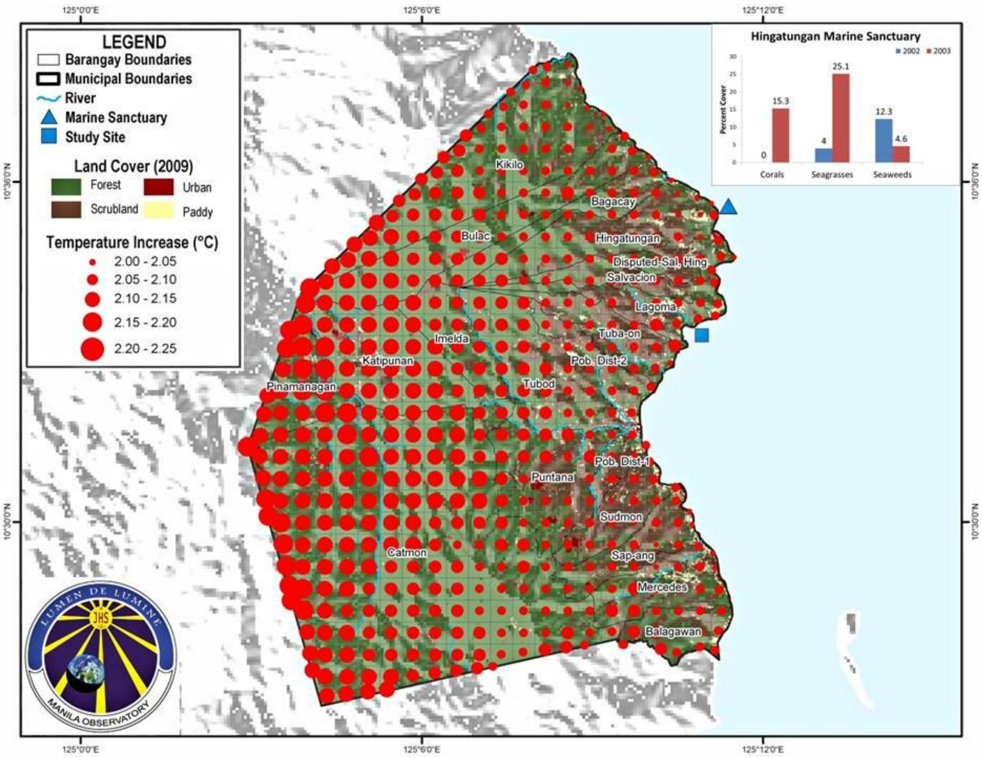


Figure VIII.8. *As in Figure VIII.7 but for 2050.*

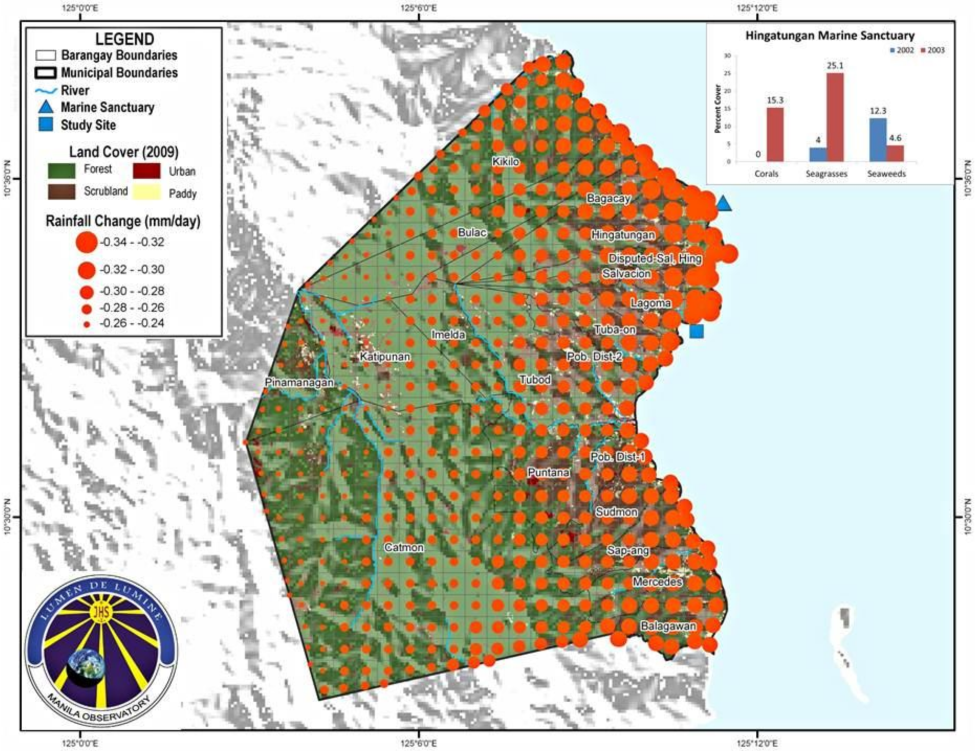


Figure VIII.9. *Land Cover (2009) and Projected Rainfall Change (2020) of Silago, Southern Leyte. Inset: Percent Cover of Corals, Seagrasses, and Seaweeds during 2002 and 2003 in Hingatungan Marine Sanctuary. Changes in rainfall will affect pH and salinity of ocean waters thereby affecting coastal ecosystems. (Map Data Sources: Shuttle Radar Topographic Mission version 4 (Feb. 2000), Rainfall Anomaly RCS-MO, Landsat 2009).*

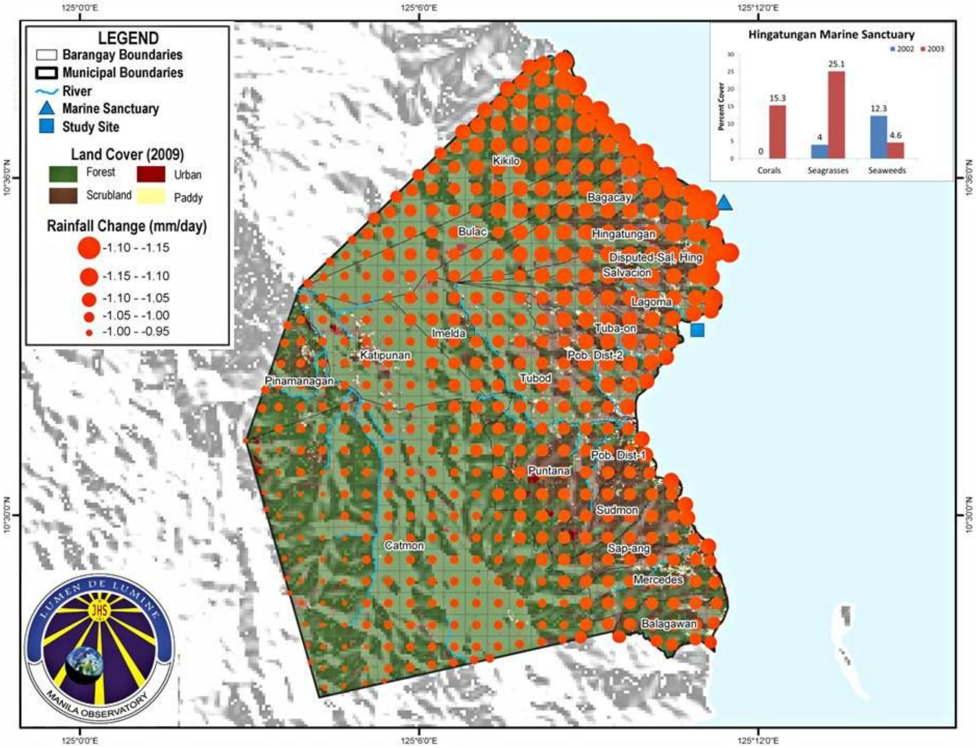


Figure VIII.10. *As in Figure VIII.9 but for 2050.*

IX. DISCUSSION AND CONCLUSION

This study aims to describe the patterns of vulnerability of the forestry, water, agriculture, and coastal sectors of Silago, Southern Leyte, using the archetype approach prescribed within the CI:GRASP Framework.

A. THE STUDY AREA

The 4th class Municipality of Silago is one of the nineteen municipalities of Southern Leyte, located on the eastern side of Region VIII (Eastern Visayas). Climate is classified as Type II, characterized by no distinct dry season and a very pronounced maximum rainfall period from November to February. The municipality is generally mountainous in the hinterlands and plain to sloping near the coasts. The 15 barangays that make up the municipality are largely rural, with fishing and agriculture as the major source of livelihood, and coconut as the major product. Among the identified development needs include the improvement of social services (health, education and access to safe water), low income and few livelihood opportunities and low agricultural productivity. Recently land transportation has improved significantly with the construction/paving of a national road which now directly links the municipality to the provincial capital.

B. CLIMATE PROJECTIONS

Climate projections for Silago indicate: a) a slight increase in mean rainfall for the dry season of 2020s while a decrease for the other seasons. 2050s might reach a decrease on its mean rainfall by as much as 20-25% during the dry season; b) as much as 1.9 to 2 ^{o}C increase in average temperature which might be expected during the warm dry months (April & May) during the 2050’s, and c) extremely hot maximum temperature (95th Percentile of the baseline period, 1961 to 1990) which will be more common by at least 50 percent during the 2050’s.

C. CLIMATE IMPACTS AND KEY VULNERABILITIES

Forest Sector

The municipality has high forest cover relative to other parts of the island; dipterocarp forest remnants are now generally found in localities where large-scale logging was not profitable and where access was hampered by the difficult terrain. Deforestation in recent years can be attributed to the clearing of forests for commercial and marginal upland agriculture, and non-timber plantation establishment. Coconut plantations dominate low-lying areas and are the usual end land use to forestlands after clearing and annual crop cultivation. Five out of the 15 barangays of the municipality are situated in the hilly to mountainous interior where these forest remnants are found. Currently, four barangays are involved in a community –based forest management (CBFM) program. Forest cover loss over the last decade based on land cover change analysis using remotely-sensed data is considered minimal. There is evidence of increasing fragmentation, giving way to islands of scrubland and urban areas. Among the current important drivers of deforestation and degradation are the expansion of farming activities in forest lands; the current scarcity of timber in the region in the face of increasing demands for wood which could drive illegal logging activities, and road construction.

Future changes in climate could induce productivity gains in forest areas where water is not limiting, and increases in productivity are not offset by deforestation or novel fire regimes. Strong warming, on the other hand (the trend predicted for Silago) and its accompanying effects on water availability could potentially induce drought conditions and negatively affect vegetation. A warming trend is also predicted to increase the likelihood of more fire disturbances. For Silago, climate change projections include a greater warming inland, where most of the forest land are located; these would have important implications to forest protection and production activities. While CBFM project sites will be among the areas that will be strongly affected by these changes in temperature and rainfall, attention should also be given to forest edges where most disturbances are occurring. Communities situated in the forest lands are vulnerable to the impacts of climate due to their poverty and high degree of dependence on forests for livelihood.

Water Sector

Silago`s forests provide important hydrological services availed not only by local residents but by adjacent municipalities. Hydrological analysis shows that the Municipality’s river systems under average rainfall conditions can very well supply irrigation needs. There is a potentially large supply of water .In the context of the Municipality`s dependence on springs for both domestic use and irrigation needs, a continuing decrease in forest cover may result in the long-term to decreased aquifer recharge, spring flow and base flow and instead lead to increased runoff production, erosion and siltation. However, climate-sensitive variables are also present, particularly 1) the incidence of enteric waterborne diseases, and 2) water siltation. Incidence of enteric waterborne diseases can be exacerbated by the presence of favorable climatic (i.e. temperature, moisture) and other environmental conditions. Meanwhile, siltation – although also greatly affected by land use change – is aggravated by climate stimuli such as increase in rainfall, strong winds and occurrence of extreme climate events. An urgent need of the hydro-forest sector is the establishment of an improved distribution network to maximize the use of the currently underutilized water resources.

Agriculture Sector

Agriculture in Silago is extremely vulnerable to the projected negative impacts of climate change. Most of the changes in the different climate variables analyzed, such as changes in minimum temperatures, rainfall decreases especially during the wet season, will have adverse effects on rice yield. More importantly, the adverse effects of global warming on rice production will have serious socio-economic consequences given that rice is the most important food and commodity of the municipality. There are, however, alternative crops that may be more resilient to climate impacts, specifically to the decrease in rainfall. Coconut and abaca appear to be less vulnerable to the effects of the strong 1997-1998 El Nino and cassava is considered to be a drought tolerant crop. Projected warming is higher inland where most of the forest lands are located. In contrast, the decrease in rainfall is more severe along the coastal areas where majority of the rice paddies located. Sea level rise will inundate the rice paddies along the coast and land loss can be as a high as 20% of the total rice paddy areas with a 4 meter increase in sea level.

D. RISK IMPLICATIONS OF FUTURE CLIMATE CHANGES IN SILAGO

Patterns of vulnerabilities and the potential adverse effects of future climate changes on the four sectors of forestry, water, agriculture and coastal have been discussed. The analyses have mainly centered on the climate stimulus, i.e. the projected impacts of climate change on temperature, rainfall, and sea level rise. But the risk to the impacts of global warming is not solely dependent on the exposed sectors and the climate hazards. It is also very much affected by social vulnerabilities and the capacity to adapt to the adverse impacts of climate change change. Here, indicators based on available data on these two important factors are discussed and shown to provide a qualitative assessment of the overall risks to climate change that Silago may face in the future.

Population density can be one indicator of social exposure and consequently vulnerability. Figure IX.1 shows the 2007 population density for Silago and the potential impacts of various levels of increase in sea level on these population. Barangays Hingatungan, Poblacion District 2, Poblacion District 1, Mercedes are the most vulnerable given the high population density and larger flooded areas in these barangays. Note that decreases in rainfall will also affect rice production in Hingatungan where most of the municipal’s non-irrigated riceland are located. Changes in temperature will affect the population inland, which is relatively small compared with the population density along the coastal areas (Figure IX.2). Rainfall decrease, however, will affect the most the highly populated areas in Bgys Hingatungan, Salvaction, and Lagoma. Barangays Kikilo, Bulac, Bagacay, Tuba-on, and Poblacion District 2 will also be affected by the drier conditions.

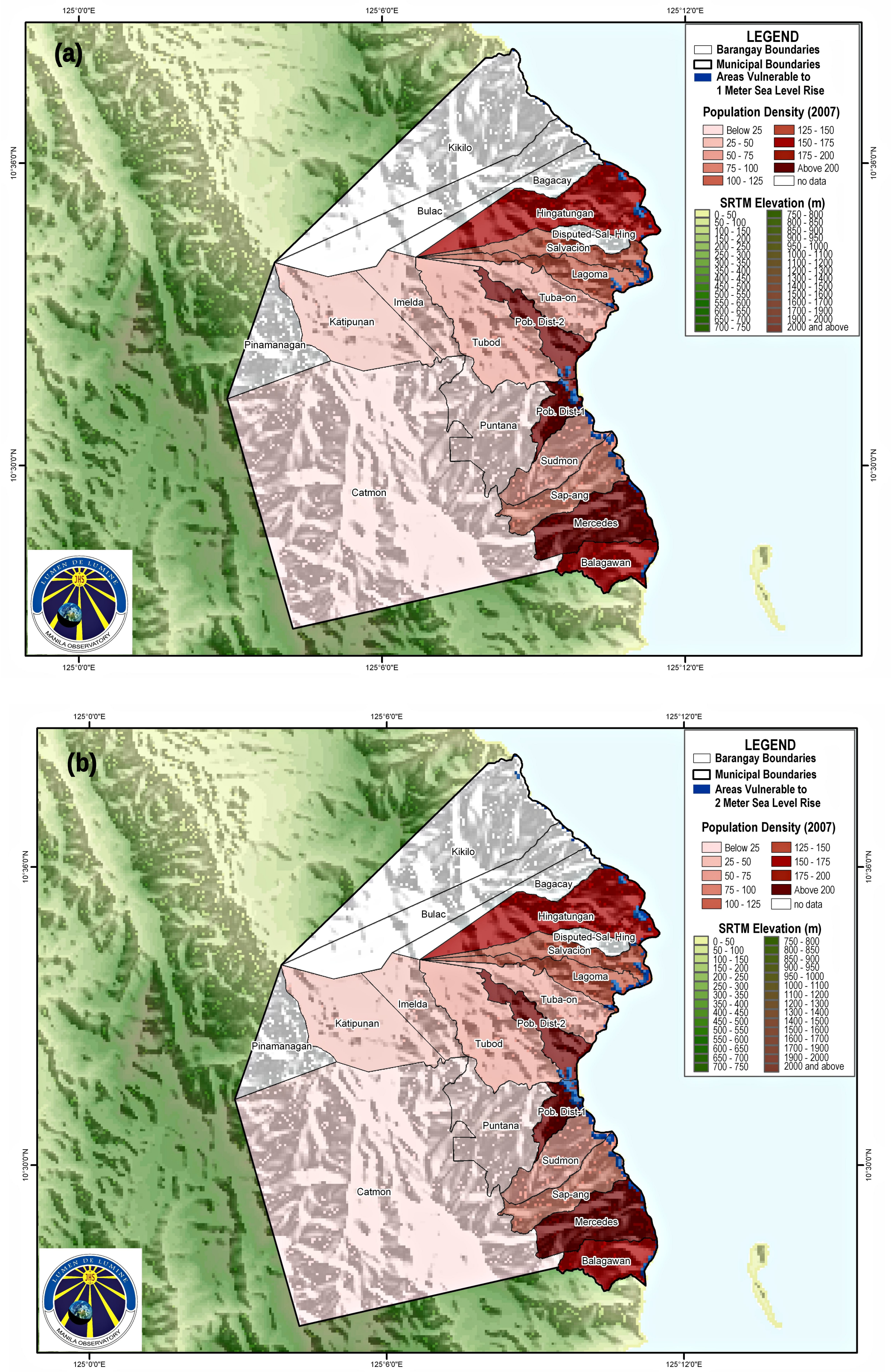


Figure IX.1. *Areas and population densities vulnerable to a a) 1 meter-, b) 2 meter-, and c) 4-meter rise in sea level. (Population data source: National Statistics Office) (Map Data Sources: Shuttle Radar Topographic Mission version 4 (Feb. 2000), Population Density National Statistics Office).*

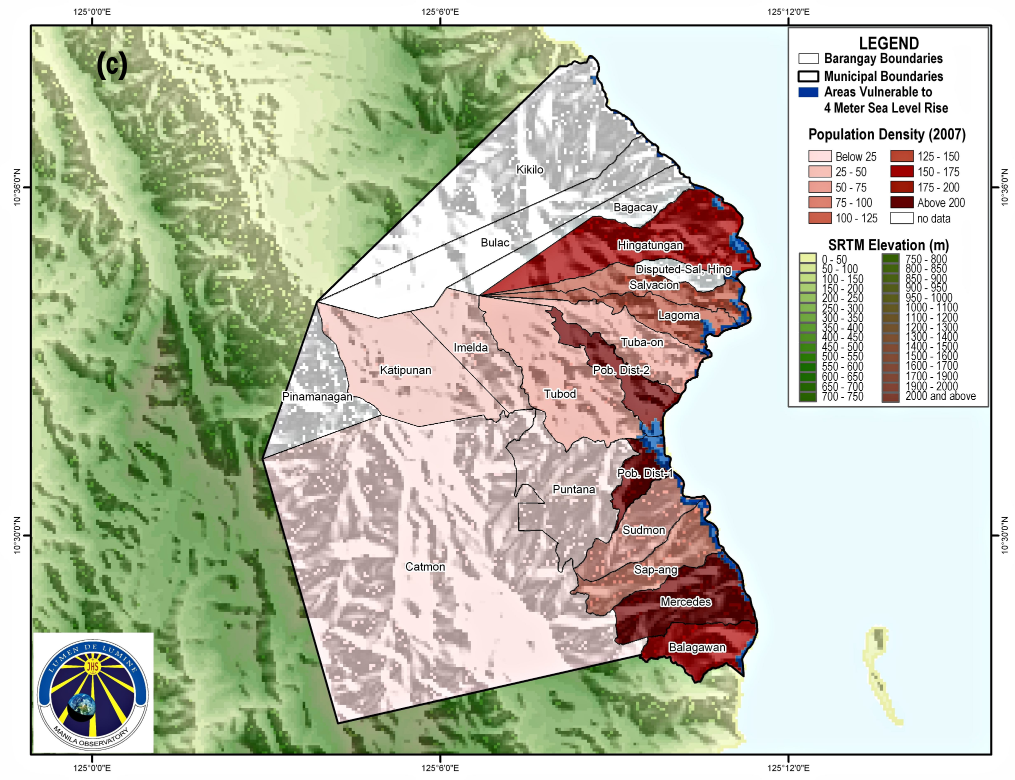


Figure IX.1. *Continued.*

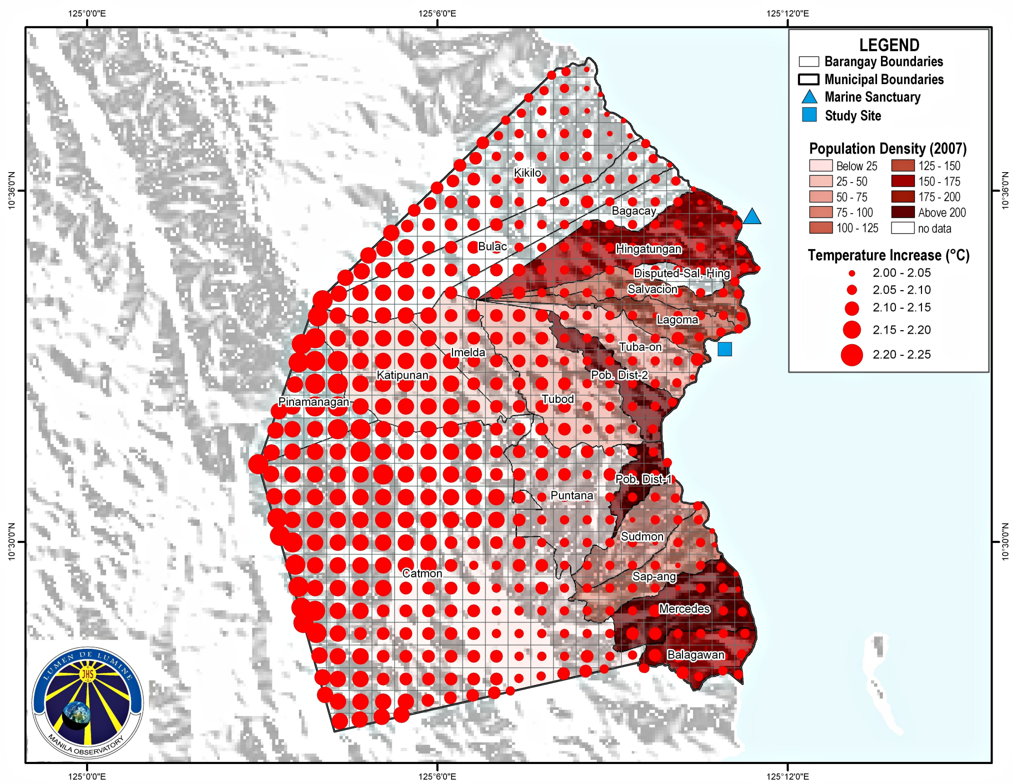


Figure IX.2. *Projected increase in temperature by 2050 in Silago and the 2007 population density. (Map Data Sources: Shuttle Radar Topographic Mission version 4 (Feb. 2000), Population Density National Statistics Office, Temperature Anomaly RCS-MO).*

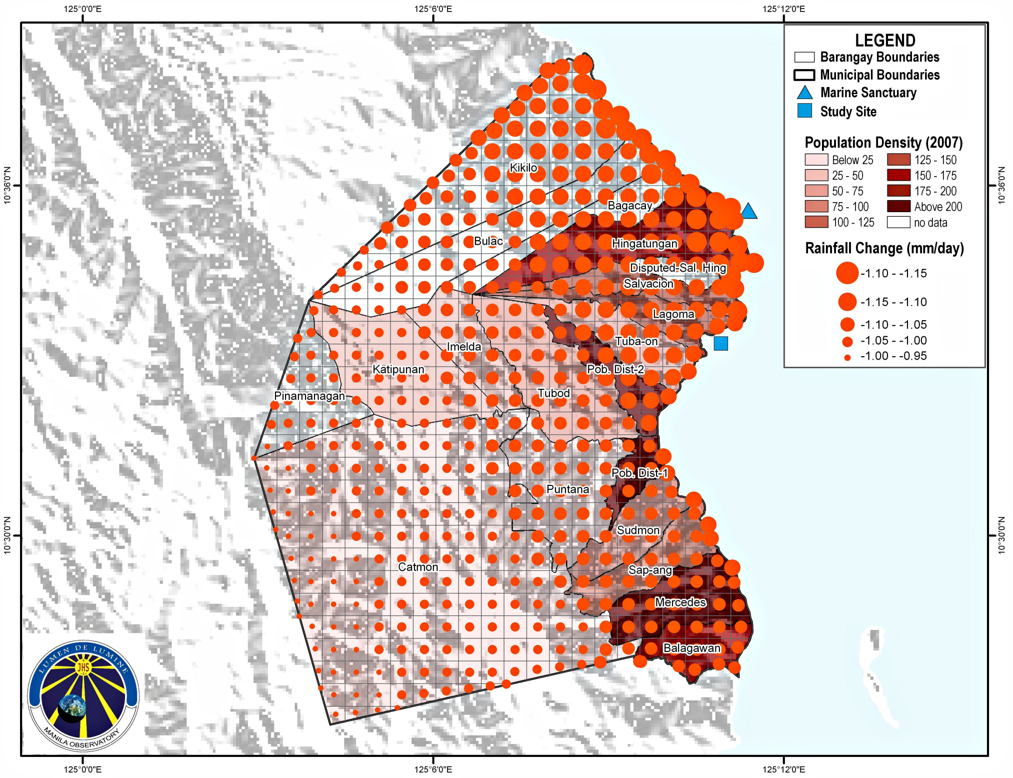


Figure IX.3. *Projected decrease in rainfall by 2050 in Silago and the 2007 population density. (Map Data Sources: Shuttle Radar Topographic Mission version 4 (Feb. 2000), Population Density National Statistics Office, Rainfall Anomaly RCS-MO).*

The number of malnourished children is a useful indicator of vulnerability to climate change effects. In a policy report by the International Food Policy Research Institute on “climate change impact on agriculture and costs of adaptation” (Nelson et al., 2009), the study used per capita calorie consumption and child malnutrition as the two indicators for assessing the impacts of climate change on food security and human well-being. The report assessed how much it would cost in investments to return the values of the two indicators into a no climate change scenario in 2050. Their analysis shows that using the projections of two global climate models, it will cost developing countries around US$7.1 to US$7.3 billion of investments on agricultural research, irrigation, and rural roads to counteract the impacts of climate change on child malnutrition. Hence, pre-existing high occurrences of child malnutrition indicate greater vulnerabilities to climate change effects on the health and well-being of children. Figure IX.4 shows the number of malnourished children in Silago in 1999 per barangay expressed as a percentage of the population 14 years old and below. Barangays Tubod, Imelda, and Poblacion District 2 have the highest percentage, 50% and above, of malnourished children. Cases child malnutrition in Puntana, Mercedes, Tuba-on and Lagoma are also relatively high, with values ranging from 35% to 47%.

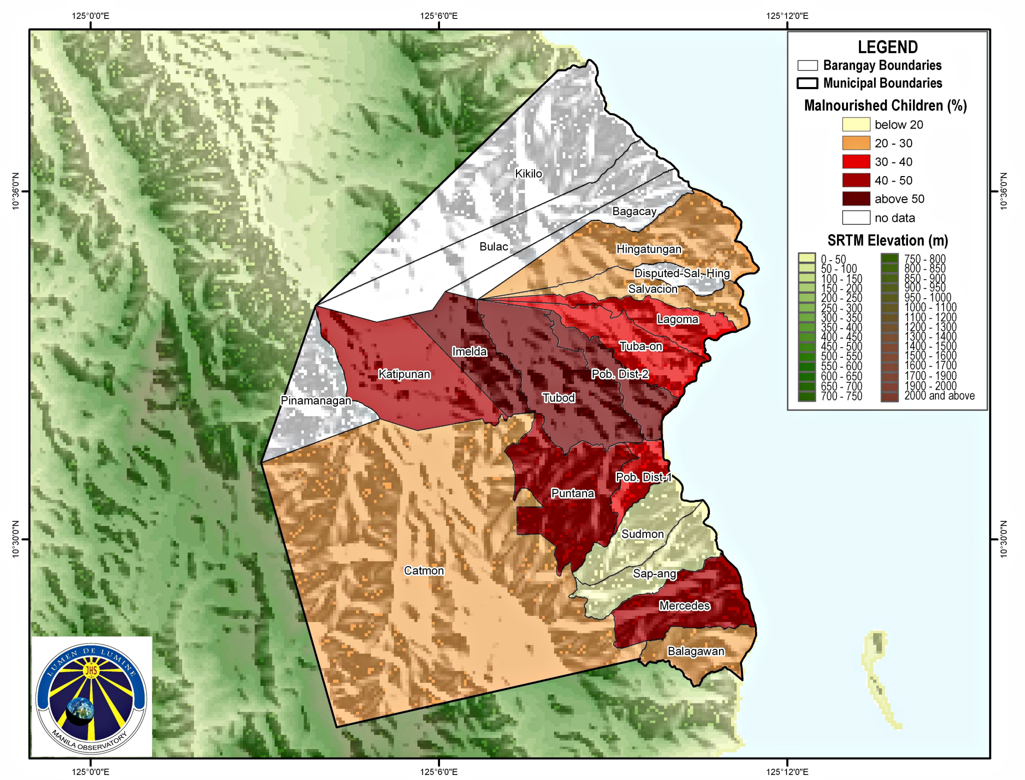


Figure IX.4. *Malnourished children in Silago in 1999 per barangay expressed as a percentage of the population 14 years old and below. (Data taken from Silago CLUP (MPDO, 2010). Source of data cited in the CLUP is from RHU Silago). . (Map Data Source: Shuttle Radar Topographic Mission version 4 (Feb. 2000)).*

While there are pre-existing vulnerabilities in Silago, it is important to note as well existing measures or programs that may be indicators of resilience and better capacity to adapt to the negative impacts of future climate change. In the forestry sector, for example, there were forestry programs in barangays Catmon, Katipunan, Imelda, and Puntana. Note that Catmon and Katipunan are projected to have higher increase in temperatures compared with the other barangays in Silago (Figure IX.5). For the agricultural sector, the Municipal Ecological Profile also enumerates agricultural support facilities that are being implemented per barangay. Production support facilities include Farm to Market roads, solar driers, rice, corn, vegetable seeds and fruit trees seedlings, fertilizers and fertilizer loans among others (MPDO, 2009). There are also irrigation systems in place in Silago. There are communal irrigation systems in Hingatungan, Salvacion, and Laguma and a communical irrigation project in Pob Dist II that may help alleviate the adverse impacts of rainfall decrease in these barangays. The strategic agriculture and fisheries development zones (SAFDZ) in Silago are shown in Figure IX.6. Barangay Catmon, which will have greater temperature impacts is essentially a primary forestry/watershed zone. Major portions of Katipunan, however, which will have the same temperature impacts as Catmon, are agro-industrial zones and more than a fourth of the barangay are forestry/watershed zone. Many food crop zones are located along the coastal region, for example Hingatunan and Salvacion where decrease in rainfall are relatively stronger. With these development zones, the projected climate impacts in this study maybe used to enhance and/or support the effectivity of defining the specific zones in Silago.

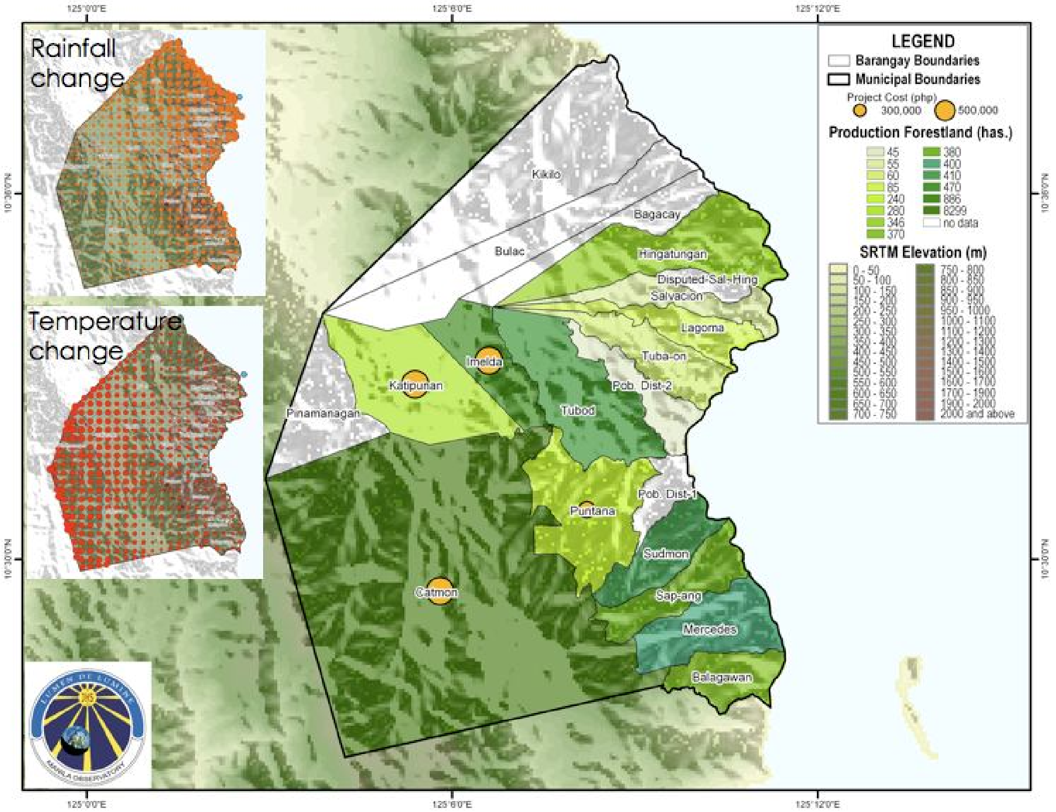


Figure IX.5. *Forestry programs and projects in Silago. . (Map Data Sources: Shuttle Radar Topographic Mission version 4 (Feb. 2000), Temperature and Rainfall Anomalies RCS-MO)*

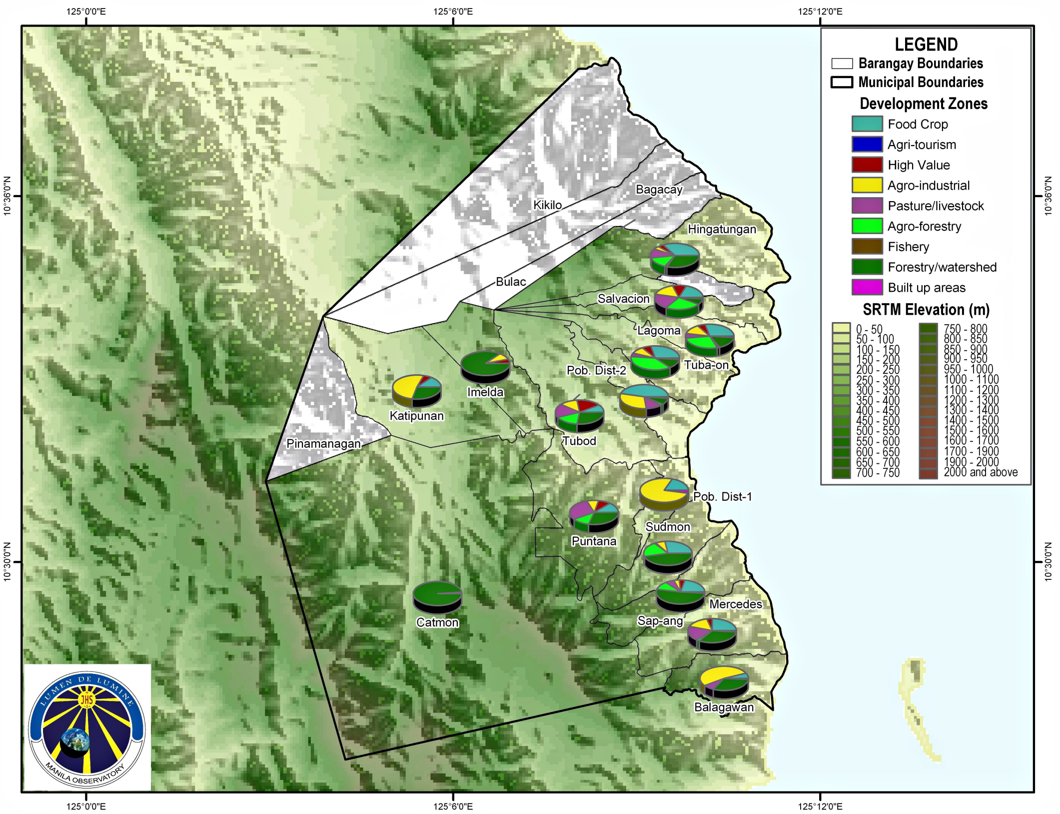


Figure IX.6. *Strategic agriculture and fisheries development zones in Silago. (Data taken from the Silago CLUP (MPDO, 2010)). . (Map Data Source: Shuttle Radar Topographic Mission version 4 (Feb. 2000)).*

Table IX.1 provides a qualitative assessment and summary of the projected impacts and exposure/vulnerability indicators for the different barangays in Silago. There are three qualitative categories of impacts and vulnerability: very high, high, and mid. Very high means that the barangay experiences the greatest climate change impact (categories colored in blue) or the greatest sectoral impact due to climate change (categories colored in orange) or the highest vulnerability/exposure indicator (categories in green). The barangays highlighted in red are the top six barangays that are more at risk to the projected impacts of climate change based on the data collected and the results and analysis of this study. The barangays are Hingatungan, Salvacion, Lagoma, Poblacion District 2, Poblacion District1, and Katipunan. Based on the table, Hingatungan, which is a coastal barangay, is particularly at risk because of very high and high climate change impacts on rainfall decrease and sea level rise, respectively, very high climate impacts on rice production, and high population density. The inland barangay of katipunan on the other hand is more at risk due to very high increase in temperature, very high impacts on rice (given the proportion of non-irrigated rice and the combined impacts of warming and decrease in rainfall), high temperature impacts on forest, and high percentage of malnourished children. The relatively high risk to climate change in Poblacion District 2 is mainly due to exposure/vulnerability indicators. Poblacion District 2 has a very high population density and very high cases of malnourished children and these combined with high rainfall impacts on rice, and high climate hazards in terms of sea level rise and rainfall decrease puts the barangay at a relatively greater risk compared with the other barangays. It is important to note though that these assessments are qualitative and are very much reliant on 1) the projected climate changes using a particular regional climate model and scenario and 2) on the available data obtained for this study.

Table IX.1. *Qualitative assessment of climate impacts and exposure,vulnerability indicators per barangay in Silago.*

Barangay	**Tmp Inc**	**Rain Dec**	**Sea level rise**	**Tmp Impact Rice**	**Rain impact Rice**	**Tmp Impact Forest**	**Popula tion Density**	**Malnouri shed Children**	**Irrig**	**Forestry Programs**
Kikilo	-	High	-	-	-	-	-	-	-	-
Bulac	High	High	-	-	-	-	-	-	-	-
Bagacay	-	High	-	-	-	-	-	-	-	-
Hingatungan	-	**Very high**	**High**	**Very high**	**Very high**	Mid	**High**	-	CIS	-
Salvacion	-	**Very high**	**High**	**Very high**	**Very high**	-	Mid	Mid	CIS	-
Lagoma	-	**Very high**	**High**	**High**	**High**	-	Mid	**High**	CIS	-
Tuba-on	-	High	-	-	-	-	-	High	-	-
Pob Dist 2	-	**High**	**High**	**High**	**High**	-	**Very high**	**Very high**	CIP	-
Tubod	Mid	Mid	Mid	-	High	Mid	-	Very high	-	-
Pob Dist 1	-	Mid	**Very high**	**High**	**High**	-	**Very high**	**High**	-	-
Puntana	-	-	-	-	-	-	-	High	-	Yes
Sudmon	-	Mid	High	Very High	High	-	-	-	CIS	-
Sap-ang	-	Mid	High	-	Mid	-	-	-	CIP	-
Mercedes	Mid	Mid	High	-	Mid	-	Very high	High	-	-
Balagawan	Mid	Mid	High	-	Mid	-	High	Mid	-	-
Catmon	Very high	-	-	-	-	High	-	Mid	-	Yes
Katipunan	**Very high**	-	-	**Very high**	-	**High**	-	**High**	-	**Yes**
Pinamanagan	Very high	-	-	-	-	Very high	-	-	-	-
Imelda	High	Mid	-	-	-	Mid		Very high	-	Yes

E. INTEGRATION IN CLIMATE CHANGE: CROSS-SECTOR RELATIONSHIPS

Impacts, Vulnerability and Risks

The term 'integration' in climate change Vulnerability and Adaptation (V & A) assessments refers to a coordinated and holistic approach to the development and the implementation of adaptation options or strategies. When considering integration in the context of V & A, the interaction of various climate change impacts across sectors or within a particular area needs to be considered. Integration can also be useful for examining total vulnerabilities to climate change[7]. Cross sector integration links two or more related sectors, models relationships and promotes thinking about the cross-cutting implications of climate change. Figure IX.7 below gives us a schematic overview of this relationship among sectors under assessment.

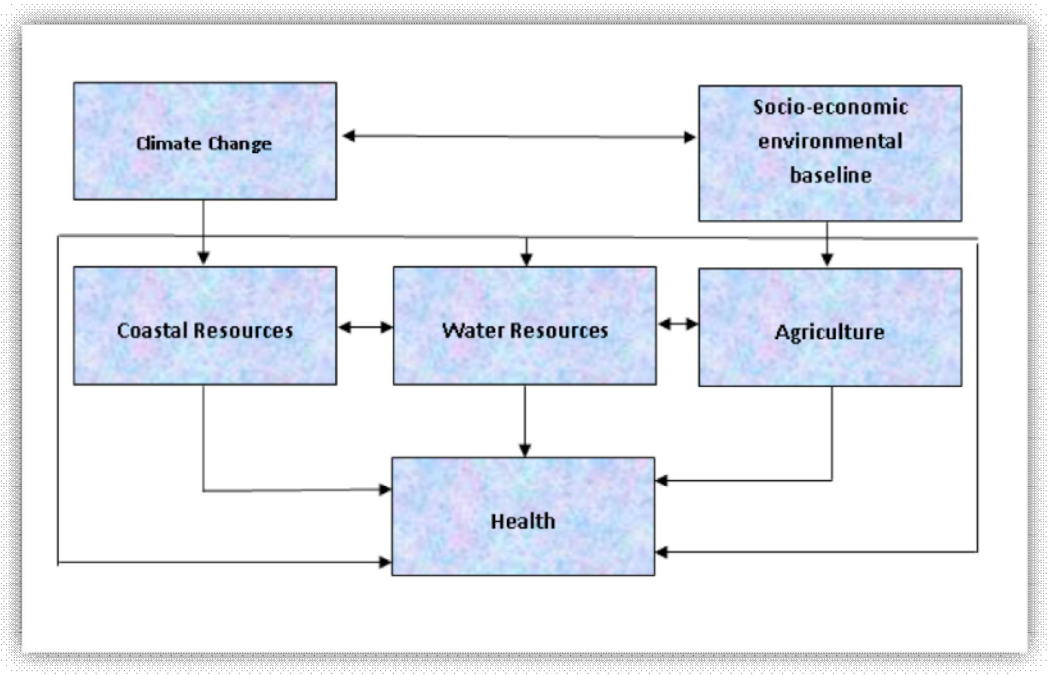


Figure IX.7. *Simple Schematic Diagram of Qualitative Cross-Sector Relationships. (Adapted from "UNFCCC: Handbook on vulnerability and adaptation assessment").*

Integration is important because impacts do not happen in isolation; they can adversely or positively affect one sector or another. Some sectors maybe affected directly, indirectly or can offset the effect of climate change in another sector. Quantitative integration is necessary for ranking vulnerabilities and adaptations for prioritization.

For Silago, integration was done thematically by sectors for all barangays; using the results presented in the influence diagrams and qualitative vulnerabilities presented in Table IX.I. With reference to Figure IX.7, the integrated vulnerability of Silago is presented in Figure IX.8.

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[7] UNFCCC,2008 Resource Guide: Module 2: Vulnerability and Adaptation to Climate Change

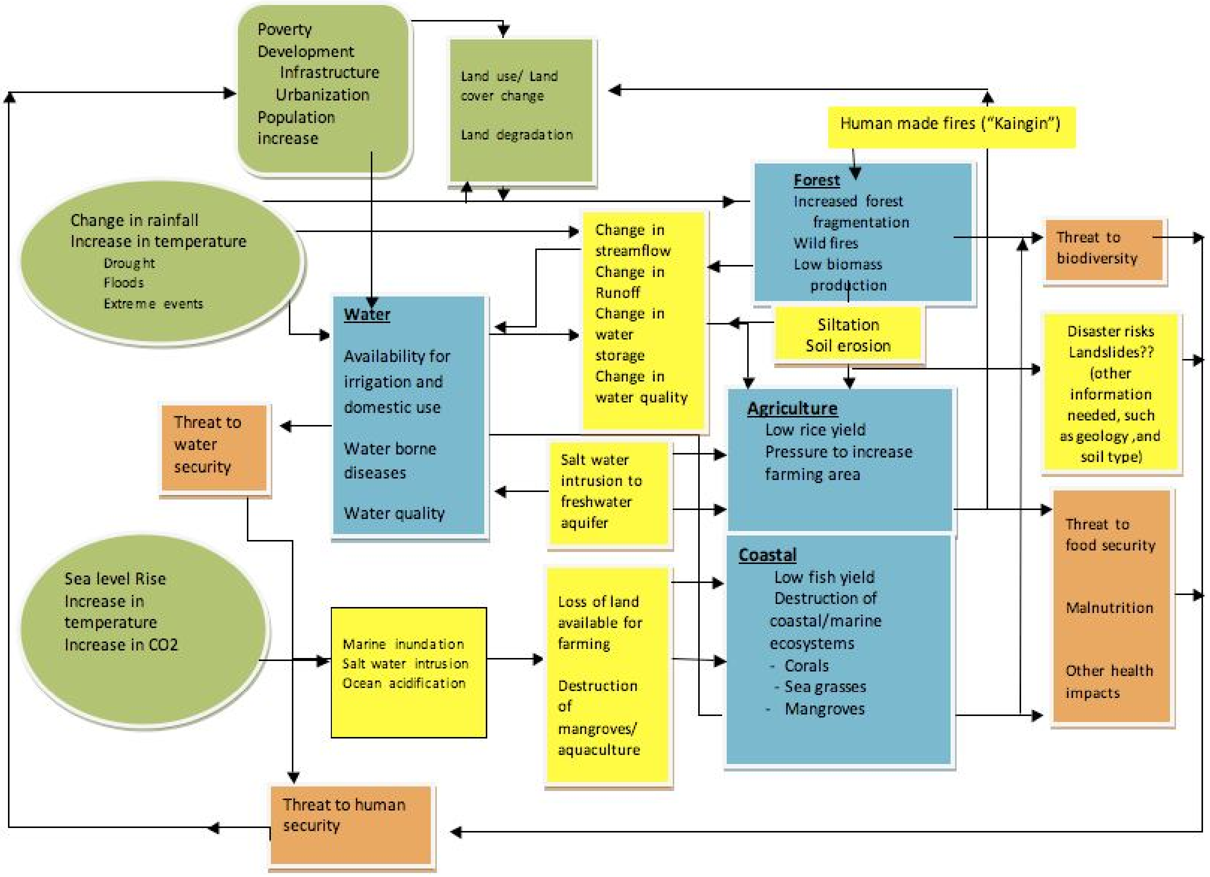

Figure IX.8. *Integrated risks and vulnerability assessment of Silago.*

The green objects are primary physical and socio-economic (oval and rounded square) and secondary (box) drivers of vulnerability. The physical drivers consist of changes in the climate parameters such as rainfall and temperature. Other factors are sea level rise and increase in carbon dioxide emissions. The socio-economic drivers such as poverty (26% of total number of households are below the poverty threshold), development and population increase are only indicative. Other factors may exist in reality but were not available to the study team at the time. The green box contains the secondary drivers as a result of the biophysical and socio-economic baseline. Because of economic reasons, there is a need to till the land for agriculture, use forestry resources for livelihood, particularly the less fortunate ones, hence land cover change occurs. Because of conversion, probably due to infrastructure development (such as road construction) and urbanization, there is land use change. All of these drivers directly affect the sectors under the study: forestry, water, agriculture and coastal (in blue boxes). In the analyses, it appears that water is the most limiting sector and can be directly linked to hydro-meteorological and environmental changes. The yellow boxes are biophysical impacts while the orange boxes represent the general risks or threats.

While water availability is still not yet a challenging issue in Silago at the moment, human activities such as land conversion, increase in temperature, and changes in rainfall patterns can affect the regeneration rate of water aquifers in the future. Different water users such as in the domestic and in the agriculture may compete for fresh water. Agriculture, the largest water user will be greatly affected. Pressure to convert more upland areas into farm land could happen because lower rice yields and loss of coastal agricultural lands due to marine flooding when sea level rises. Further land use conversion will continue to pose threat to the forest sector. Forest will respond naturally by shrinking and further fragmentation would occur. Long period of droughts followed by very wet rainy season could lead to soil erosion and siltation of waterways. Water pollution and waterborne pathogens will affect the available safe water for consumption, thereby posing a threat to water security and health. As Silago is within the vicinity of areas where landslides have previously occurred, it would be good to seek more information on the matter. Certainly, the silts and debris will be carried downstream to the coastal areas, where these can affect the coastal ecosystems particularly sea grasses. Turbidity and sea level rise may cause mangroves and corals to "drown"[8]. Municipal and subsistence fishers will be most affected as they will have low fish catch if there is at all. Clearly, unless acted upon, this is a large threat to food security together with decrease agricultural productivity, can cause malnutrition and compound other health impacts. Loss of upland forests due to various reasons, including climate change and loss of coastal ecosystems due to sea level rise and ocean acidification, are threats to biodiversity. All these risks, if not attended to are threat to human security over all, and may perpetuate poverty and misalign development efforts.

Responding to present and futures threats

Identification of adaptation options is a logical step after an integrated analysis of vulnerability, impacts and risks. The study team provide general measures for the sectors that are found in adaptation literatures. Aside from those, some recommendations were also given for the specific sectors. Table IX.2 provide additional analyses[9] as to the potential of these strategies to enhance the social or community cohesion /cooperation, potential for disaster risk reduction, particularly flooding and landslides, sand nutrition. Technological viability and costs are also used where applicable.

While the water and agriculture sectors noted that irrigation infrastructure should be put in place to address the water needs of the Municipality, this should be taken in the context of integrated approach. Building large irrigation infrastructure may help in storing water for future needs and can serve as flood control structures as well. Cost wise, it is very expensive to build. It may also prevent or cut off nutrients downstream, which is detrimental for the health of coastal ecosystems. As such, these irrigation facilities should continue the nature

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[8] Marine scientists say that sediment loading and heavy rainfall events can literally drown and kill mangroves. Source: (http://www.epa.qld.gov.au/wetlandinfo/site/factsfigeures/FloraAndFauna/Flora/mangroves/mangrove dieback.html). For corals, there is a critical depth or rate of sea level rise that usually lead to coral drowning. See, for example: Grigg, R. W. and D. Epp, 1989: Critical Depth for the Survival of Coral Islands: Effects on the Hawaiian Archipelago, Science 3 February 1989: Vol. 243 no. 4891 pp. 638-6412004: DOI: 10.1126/science.243.4891.638

[9] Methodology was used in the Vulnerability and Adaptation Assessment Component, Second National Communication, 2010.

of current structures: small and communal but should be distributed strategically in order to service more users.

With or without climate change, social and health services must be continued by the LGU to uplift the living conditions of the residents, create more sources of livelihood to broaden economic opportunities and lessen dependency on single agricultural crop alone (e.g., rice). This is a way to increase adaptive capacity of the people, along with health, education and general well being.

Generally, most of the recommended adaptation strategies in Table IX.2 are geared towards the improvement or enhancement of the adaptive capacity of the people. Adaptation activities currently being undertaken are listed in Table IX.3, which also includes suggestions for actions. For if ever the leaders in Silago expect transformative results, new information, including appropriate climate change and socio-economic scenarios, is essential.

Table IX.2. *Assessing Adaptation Potential*[a]

Proposed Adaptation Strategies	Potential for					Technological viability	Estimated Cost
	Enhancing social cohesion	Increasing disaster risks reduction	Improving adaptive capacity	Generating livelihoods	Improving health and nutrition		
Forest sector							
Erosion control measures		X	X		X	X	Medium
Agroforestry	X		X	X			Medium
Community-based forest management REDD	X		X	X		X	High
Water Sector							
Irrigation infrastructure		X	X			X	Medium to high
Rainwater harvesting			X		X	X	Low to high
Agriculture							
Planting appropriate rice varieties			X	X	X	X	Low to Medium
Improved farm production	X		X	X	X	X	Low to high
Switch to cash crops[b]	X		X	X	X		
Post harvest/Storage [b]facilties		X	X	X	X	X	Medium to high
Financial management systems	X	X	X			X	Low to medium
Irrigation systems		X				X	
Coastal Sector[b]							
Integrated coastal management	X	X	X	X			Low to medium
Marine protected areas	X	X		X		X	Medium
Mangrove reforestation		X			X	X	Medium

[a] Methodology adapted from Perez and Taylor, 2010: Integrated V and A for the Second National Communication (Unpublished)

Table IX.3. *Existing adaptation initiatives.*

Adaptation Measures	Current Practices / Recommended Additional activities	Remarks:
Erosion Control	Use of coconut husks and coconut-derived geotextiles across slope contours to control soil erosion	Need to evaluate the effectiveness of such method, and the areal coverage – is it enough? Additional technical information needed
Agroforestry	To go into rubber tree plantation.	Rubber trees are water guzzlers. Need to study the impacts on water availability in relation to water supply and demand.
Community based forest management	To go into REDD	REDD is a political issue and expensive too. It can be done but needs a lot of safety nets. A simple CBFM would be good, the challenge is who will finance when REDD has theinternational financial support.
Flood Risks	Regional DPWH Flood response	Better to go into preparedness, include into the infrastructure design the return periods of most probable extreme rain in the future.
Food security	Rice sufficiency is monitored through a production - consumption analysis	Given the potential negative impacts on rice yield dueto projected changes in climate and climate variability, it will be important for Silago to incorporate climate scenarios when analysing the future relationships between production and consumption

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ANNEXES

A. PROJECT DETAILS OF THE JUNCTION PPH HIMAYANGAN-SILAGO-ABUYOG JUNCTION PPH ROAD PROJECT

The implementation of the project was divided into two contract packages. Contract Package I covered all construction activities between the Junction PPH Himayangan and Silago. Meanwhile, Contract Package II addressed all construction activities between Junction PPH Abuyog and Silago (Table 1).

Table 1. *Construction/rehabilitation activities associated with ARLDP Phase IV – Junction PPH Himangayan-Silago-Abuyog Junction PPH Road.*

Activity	Length	Width
Contract Package I		
Construction of Pavement (Junction PPH Himayangan-Silago)	44.703 km	6.10 m
Improvement/upgrade of drainage and shoulders		
Replacement of 17 bridges	566.806 m (total length)	
Rehabilitation of 3 existing bridges	187.62 m (total length)	
Drainage, slope protection and miscellaneous structures		
Contract Package II		
Construction of Pavement (Junction PPH Abuyog-Silago)	44.005 km	6.10 m
Improvement/upgrade of drainage and shoulders		
Replacement of 13 bridges	424.988 m (total length)	
Rehabilitation of 2 existing bridges	184.4 m (total length)	
Drainage, slope protection and miscellaneous structures		

SOURCE: MARIS J, 2006

B. *EVOLUTION OF IMPACT CHAINS*

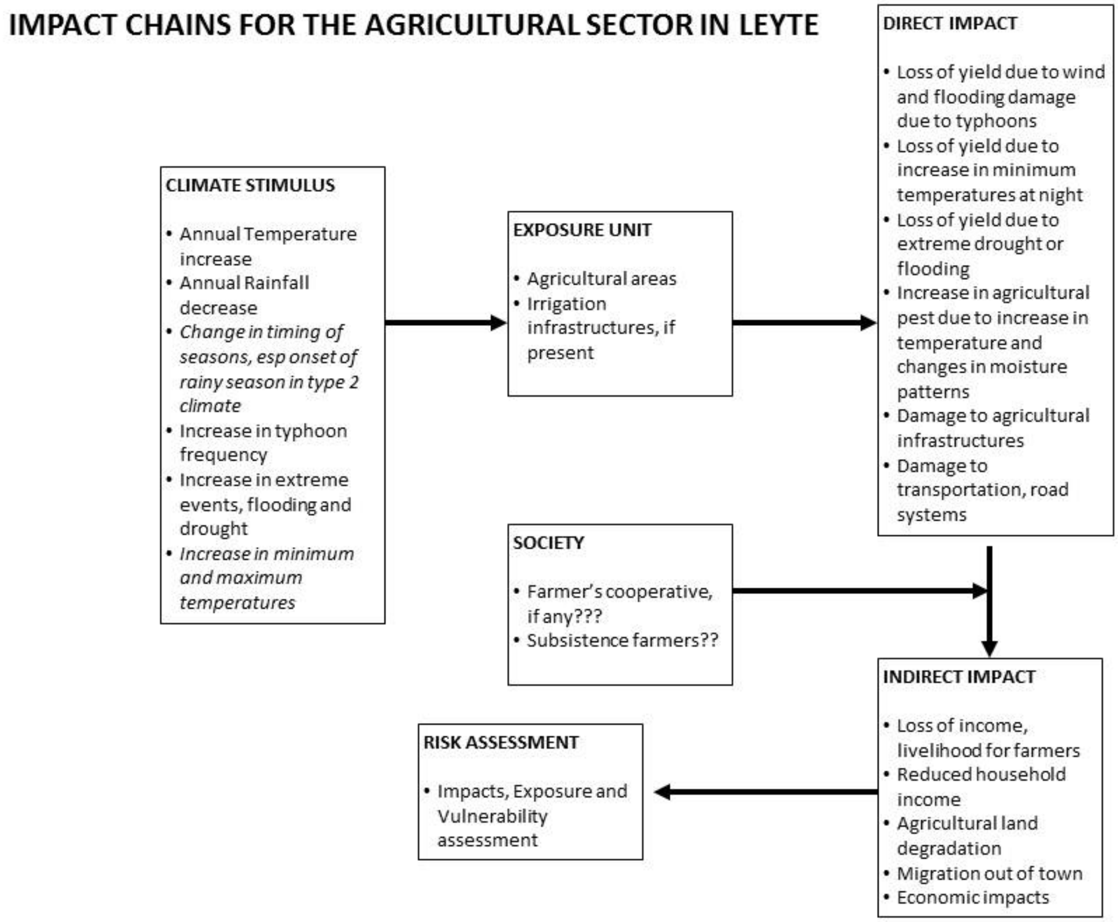
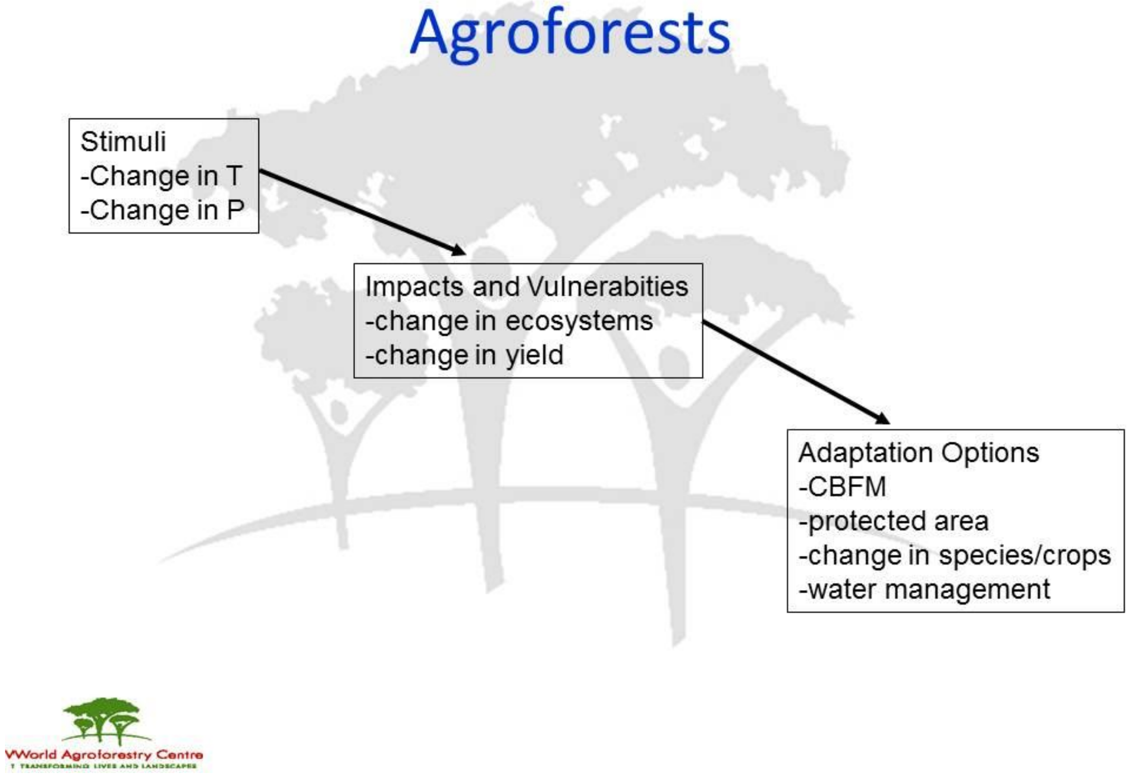


Figure 1. *Original Impact Chain for the Agriculture Sector.*



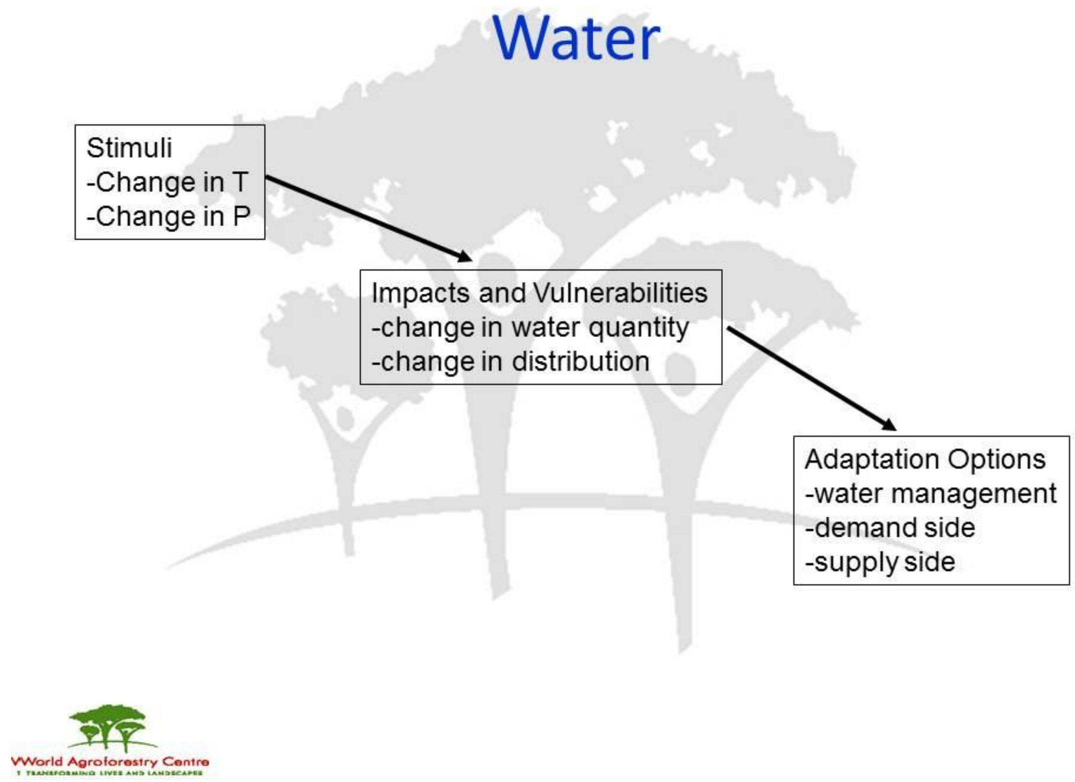
Agroforests

Stimuli
-Change in T
-Change in P

Impacts and Vulnerabities
-change in ecosystems
-change in yield

Adaptation Options
-CBFM
-protected area
-change in species/crops
-water management

Figure 2. *Original Impact Chain for the Agroforestry Sector.*



Water

Stimuli
-Change in T
-Change in P

Impacts and Vulnerabilities
-change in water quantity
-change in distribution

Adaptation Options
-water management
-demand side
-supply side

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__Figure 3.__ Original Impact Chain for the Water Sector.

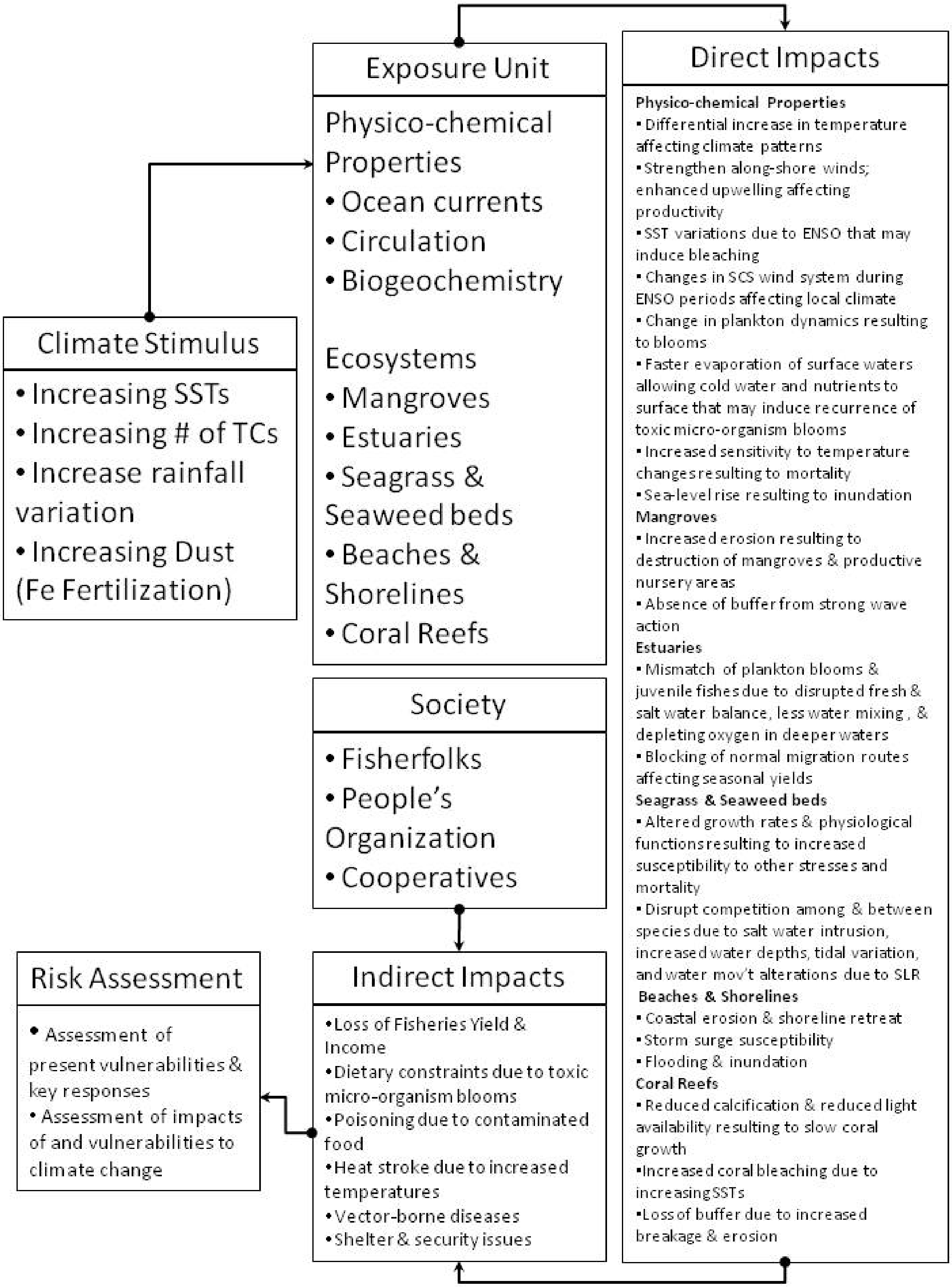

Figure 4. *Original Impact Chain for the Coastal Sector.*

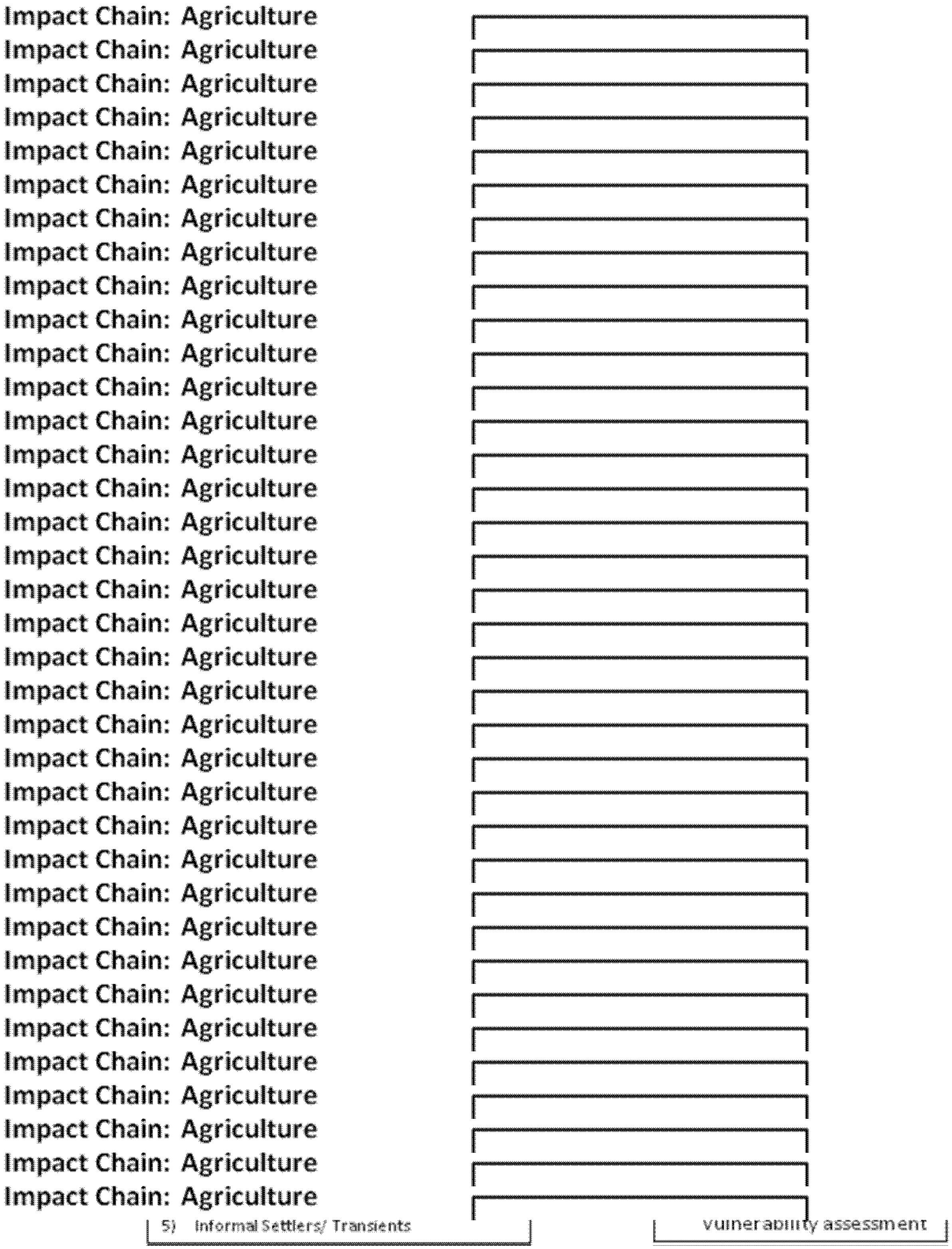

Figure 5. *Modified Impact Chain for the Agriculture Sector with inputs from the Stakeholders' Workshop and Identified Data Sources.*

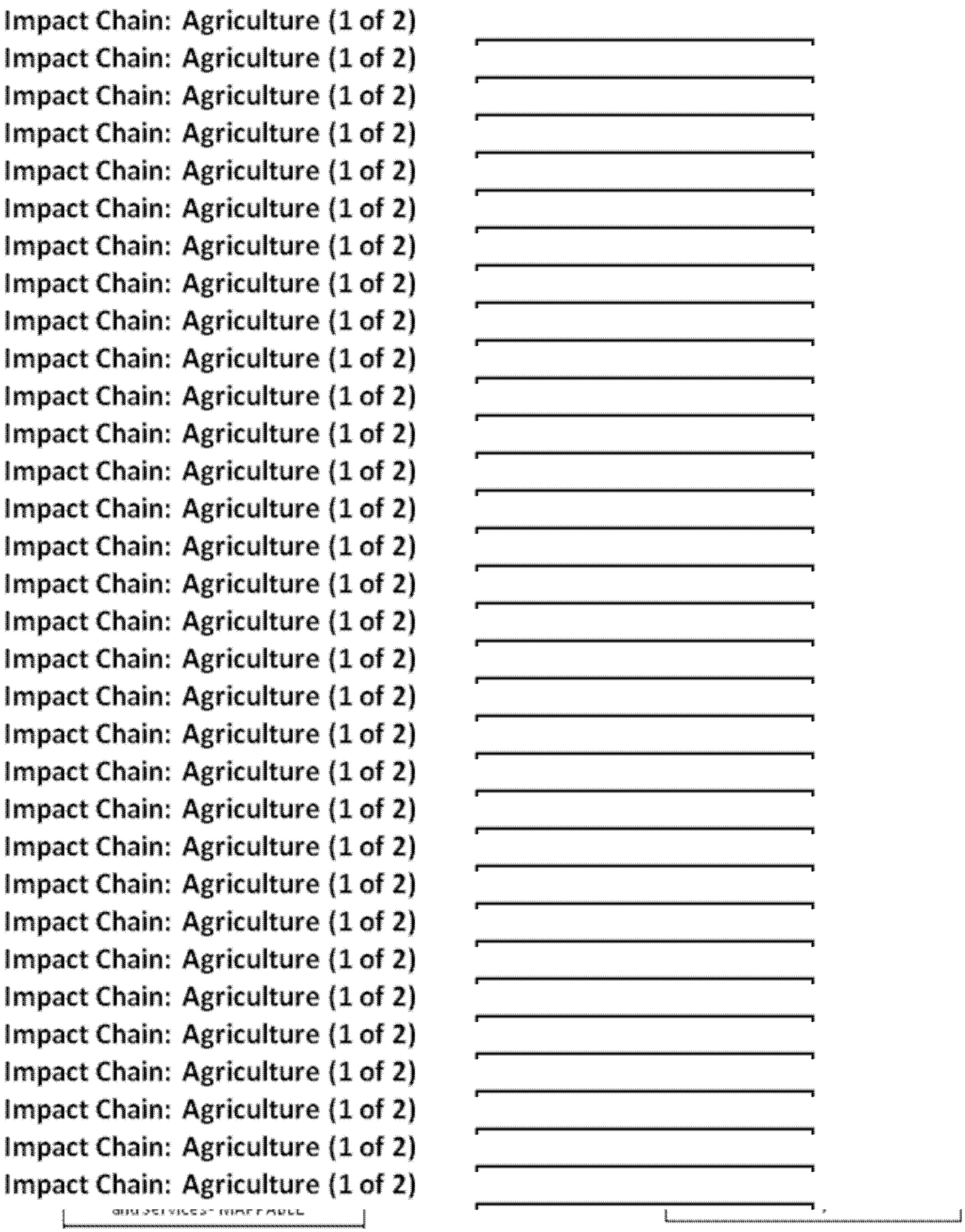

Figure 6. *Modified Impact Chain for the Agriculture Sector with Identified Priority Data.*

Impact Chain: Agriculture (2 of 2)
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Figure 7. *Modified Impact Chain for the Agriculture Sector with Identified Priority Data.*

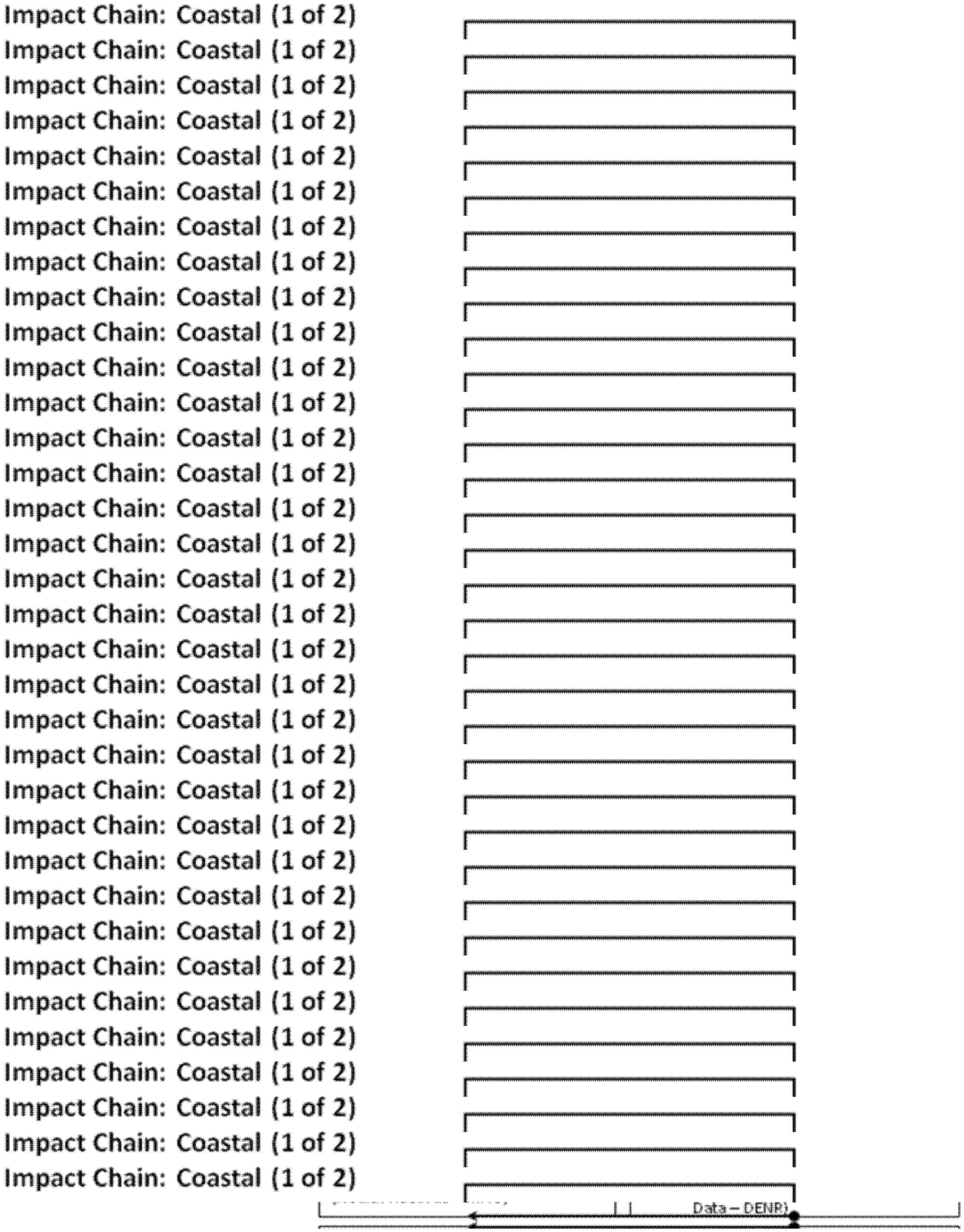

Figure 8. *Modified Impact Chain for the Coastal Sector with inputs from the Stakeholders' Workshop and Identified Data Sources.*

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Figure 9. *Modified Impact Chain for the Coastal Sector with inputs from the Stakeholders' Workshop and Identified Data Sources.*

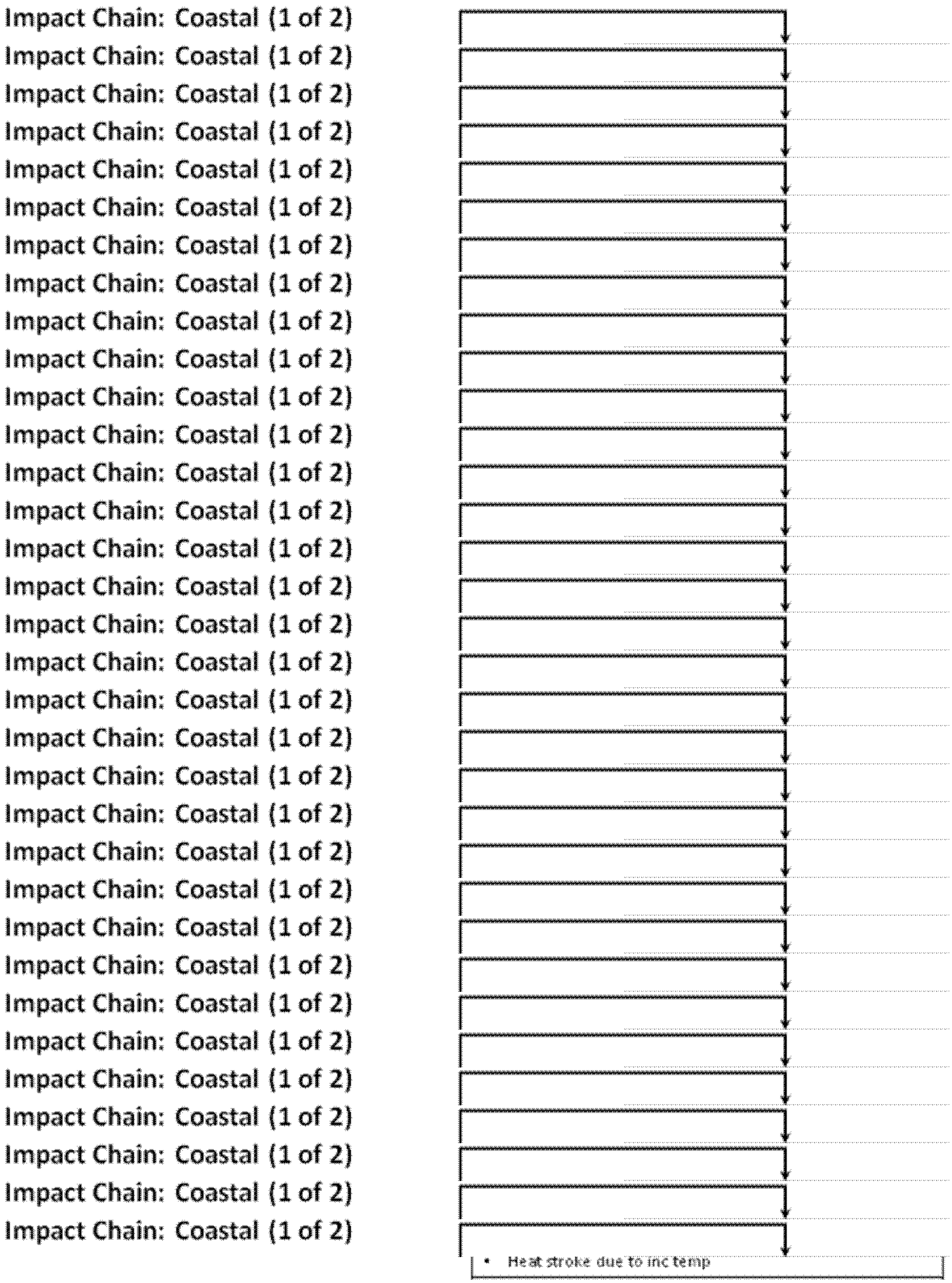


Figure 10. *Modified Impact Chain for the Coastal Sector with Identified Priority Data.*

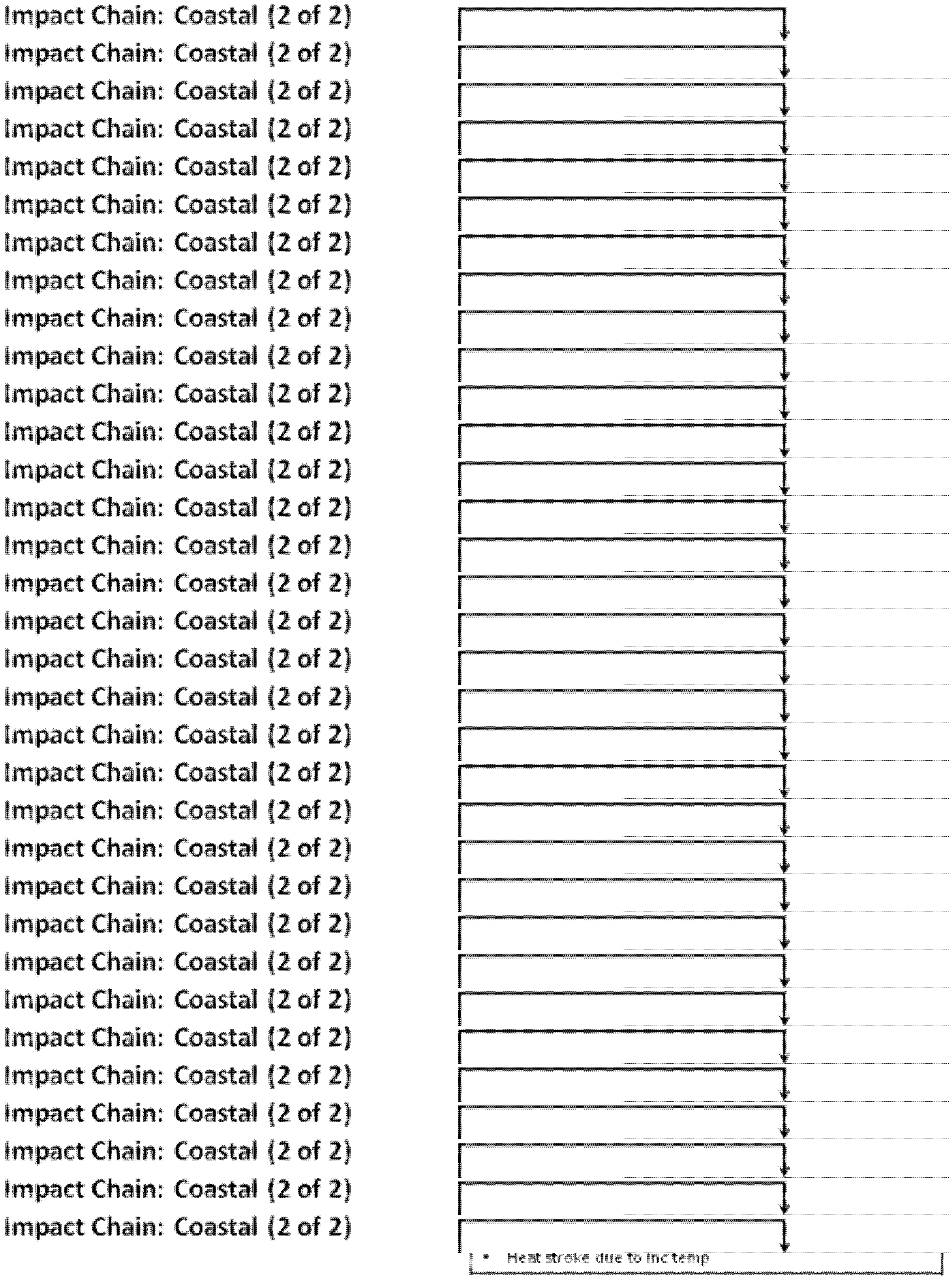
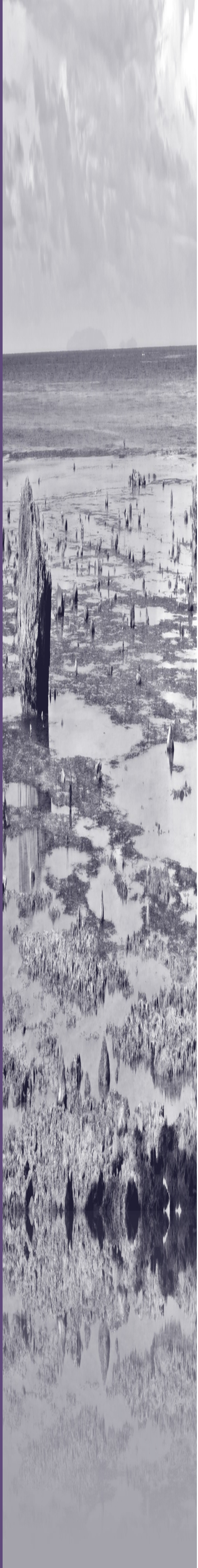


Figure 11. *Modified Impact Chain for the Coastal Sector with Identified Priority Data.*

Climate projections analyses and indicator data on exposure and vulnerability show that the municipality of Silago, Southern Leyte is at risk to the impacts of future climate changes. The coastal barangays, where most of agricultural land are located and which have high population density, are especially at risk due to the projected decrease in rainfall and the potential increase in sea levels. Inland barangays, on the other hand, are at risk because of relatively higher increases in temperature, which may also have adverse effects on the inland forests located in the area. These results are based on the projected climate changes for an A1B scenario using a regional climate model, RS-GIS analyses, and the available data obtained for the study.



CONTRIBUTORS

Manila Observatory (MO)

Gemma Teresa T. Narisma, PhD (Climate Scientist)
May Celine T. M. Vicente, PhD (Risk-Mapping Scientist)
Emmi B. Capili-Tarroja (Project Research Assistant)
Faye Abigail Cruz, PhD (Climate Scientist)
Rosa T. Perez, PhD (Integration, Vulnerability and Adaptation Options Specialist)
Raul S. Dayawon (RS-GIS Researcher)
Julie Mae Dado (Researcher, Climate)
Ma. Flordeliza P. del Castillo (RS-GIS Researcher)
Marcelino Q. Villafuerte II (Researcher, Climate)
Leonard Christian G. Loo (Project Research Assistant)
Deanna Marie P. Olaguer (Project Coordinator)
Ma. Antonia Y. Loyzaga (Executive Director, Manila Observatory)
Joel T. Maquiling (Editor)

World Agroforestry Centre (ICRAF)

Ma. Regina N. Banaticla-Altamirano (Research Scientist, Forest and Water Sectors)
Lawrence T. Ramos (Researcher)
Christine Marie D. Habito (Researcher)
Rodel D. Lasco, PhD (Country Programme Coordinator, ICRAF Philippines)

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