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

[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).

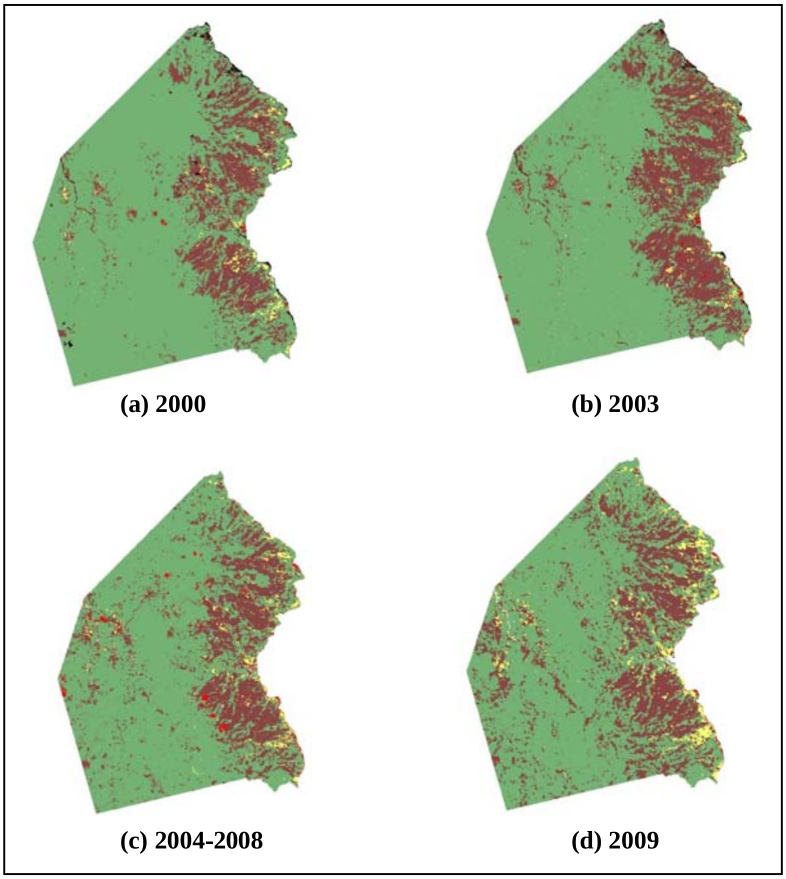
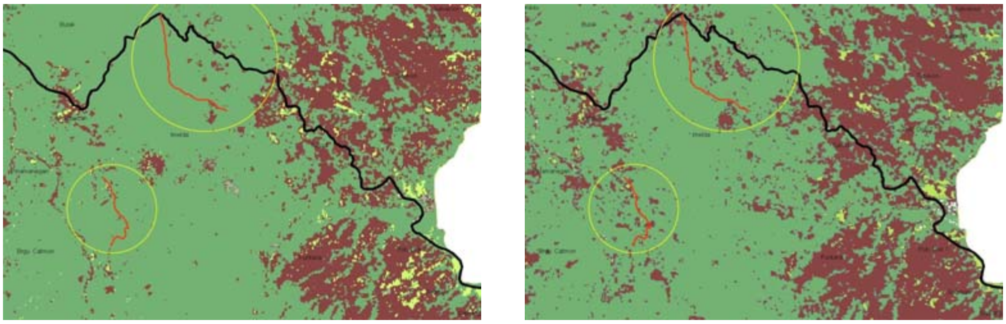


Figure V.1. *Land cover map of Silago, Southern Leyte.*
Legend: green: forest, brown: scrubland, yellow: paddy, red: urban, black: others.

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.

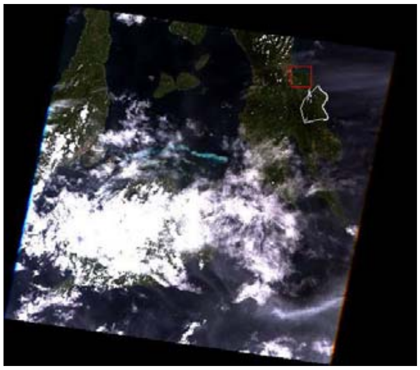


Figure V.3. *L71113053_05320001204, 4 Dec. 2000, Bands 3, 2, 1.*

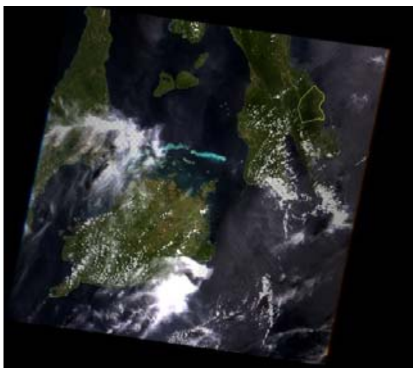


Figure V.4. *L71113053_05320030807, 7 Aug. 2003, Bands 3, 2, 1.*

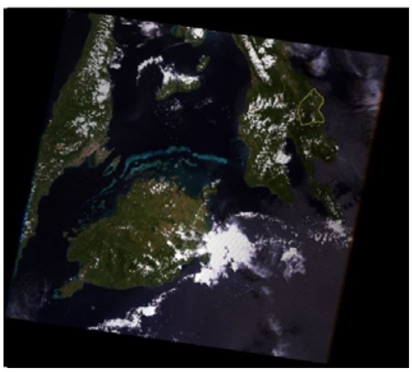


Figure V.5. *L71113053_0532009072, 7 July 2009, Bands 3, 2, 1.*

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.

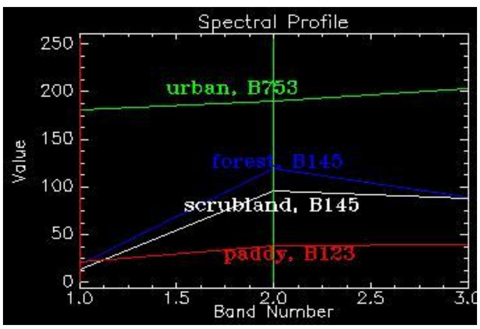


Figure V.7. *Spectral plots of training classes with corresponding band composites.*

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.

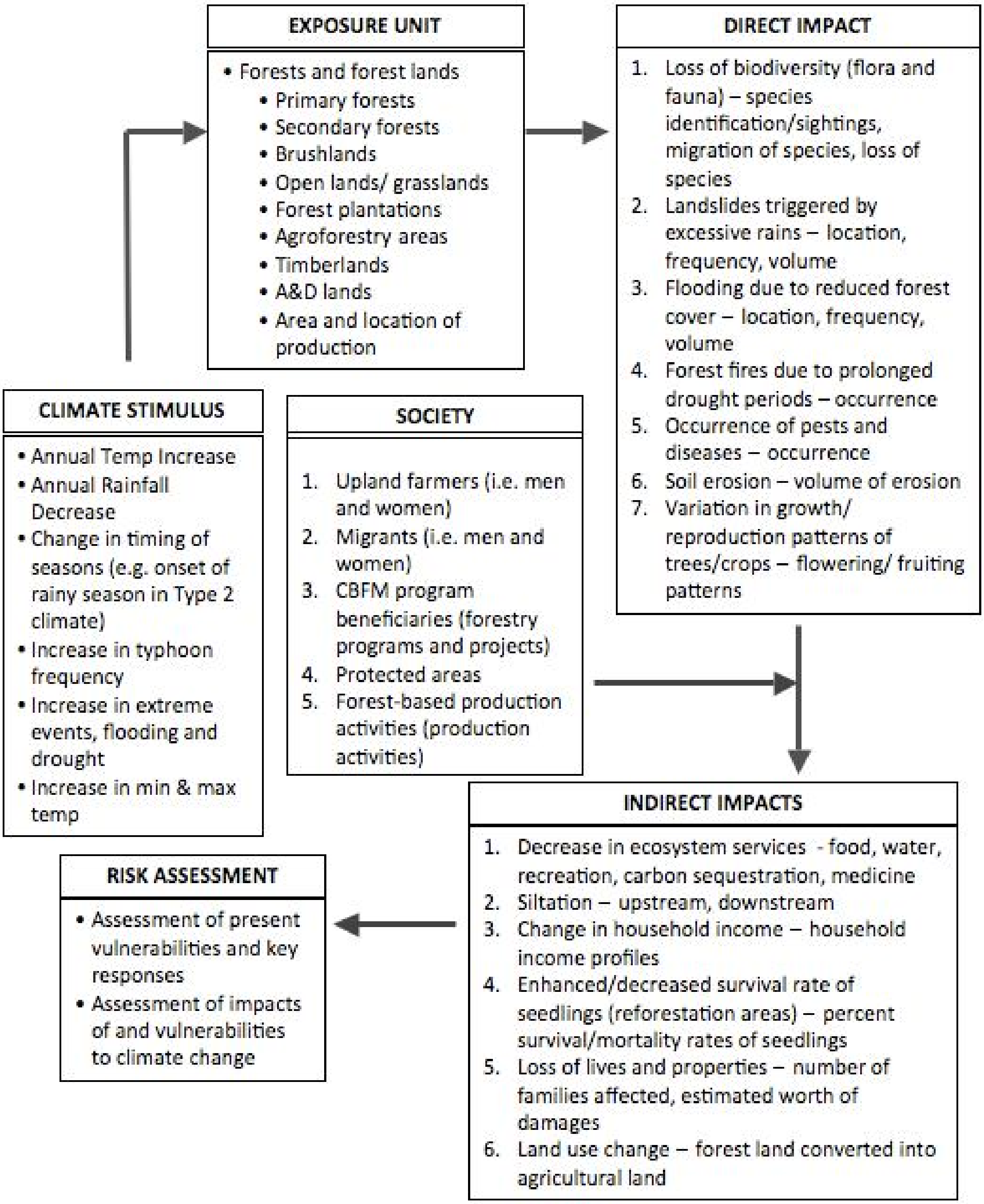


Figure V.8. *Impact chain for forestry sector of Silago, Southern Leyte.*

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.

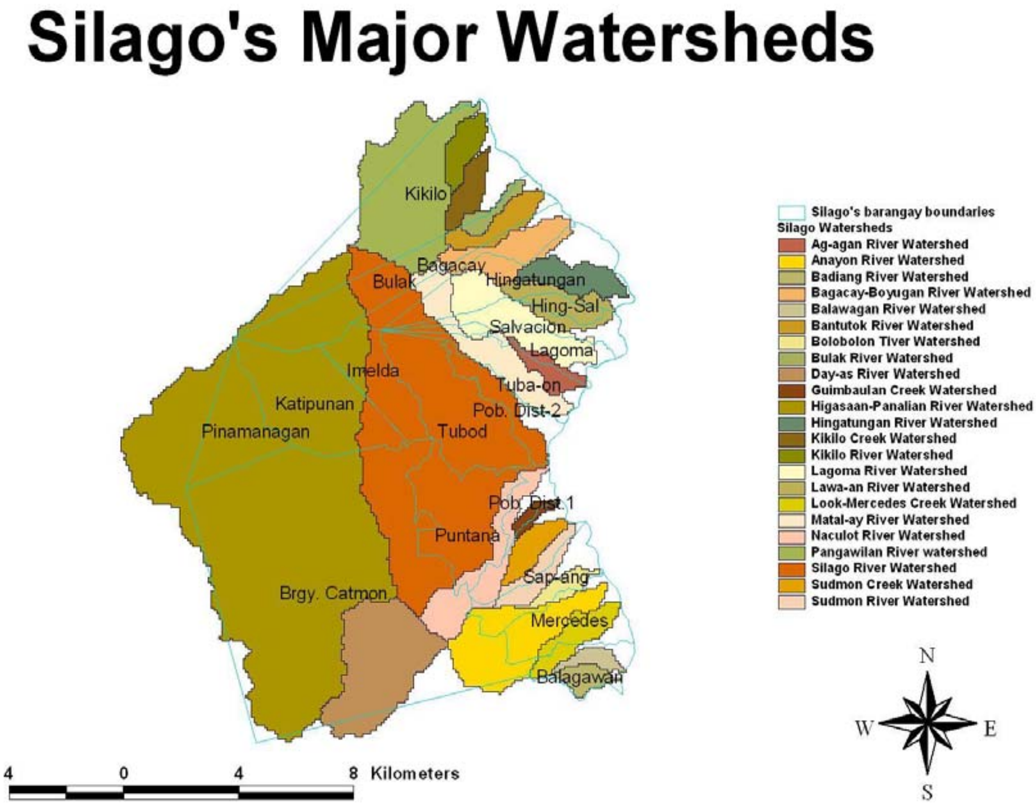


Figure VI.1. *Silago's major watersheds. Source: World Agroforestry Centre.*

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.

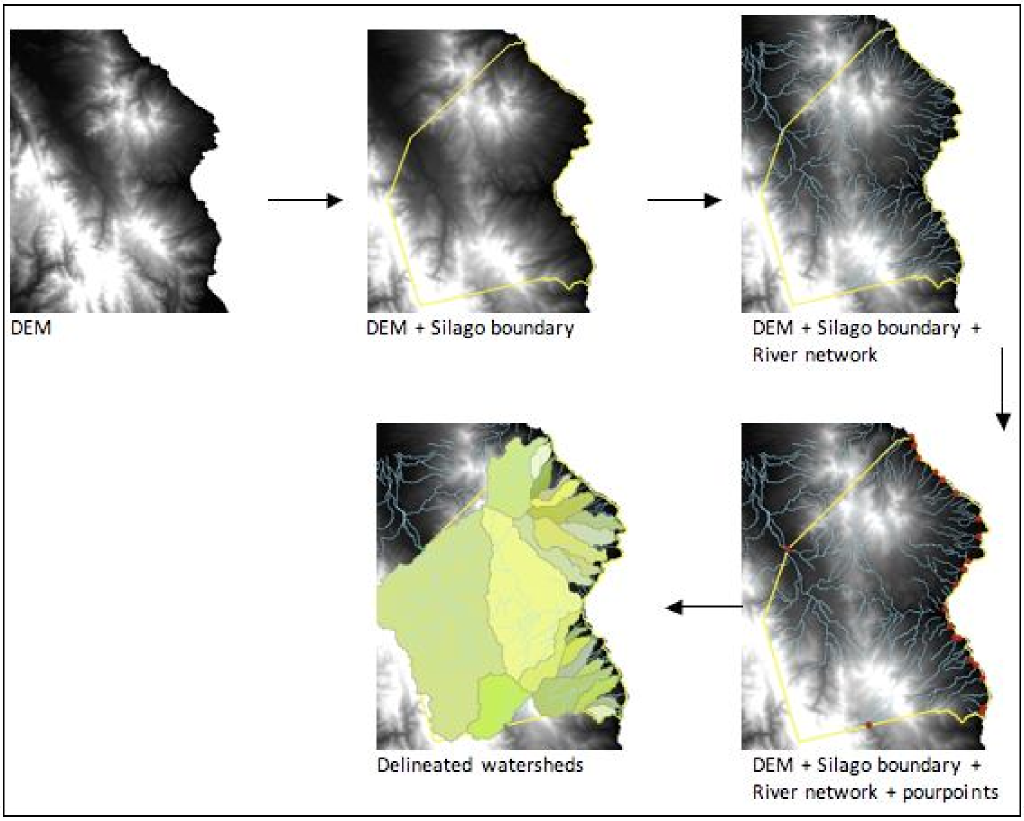


Figure VI.2. *Flow of hydrological analysis in delineating watershed boundaries.*

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.*

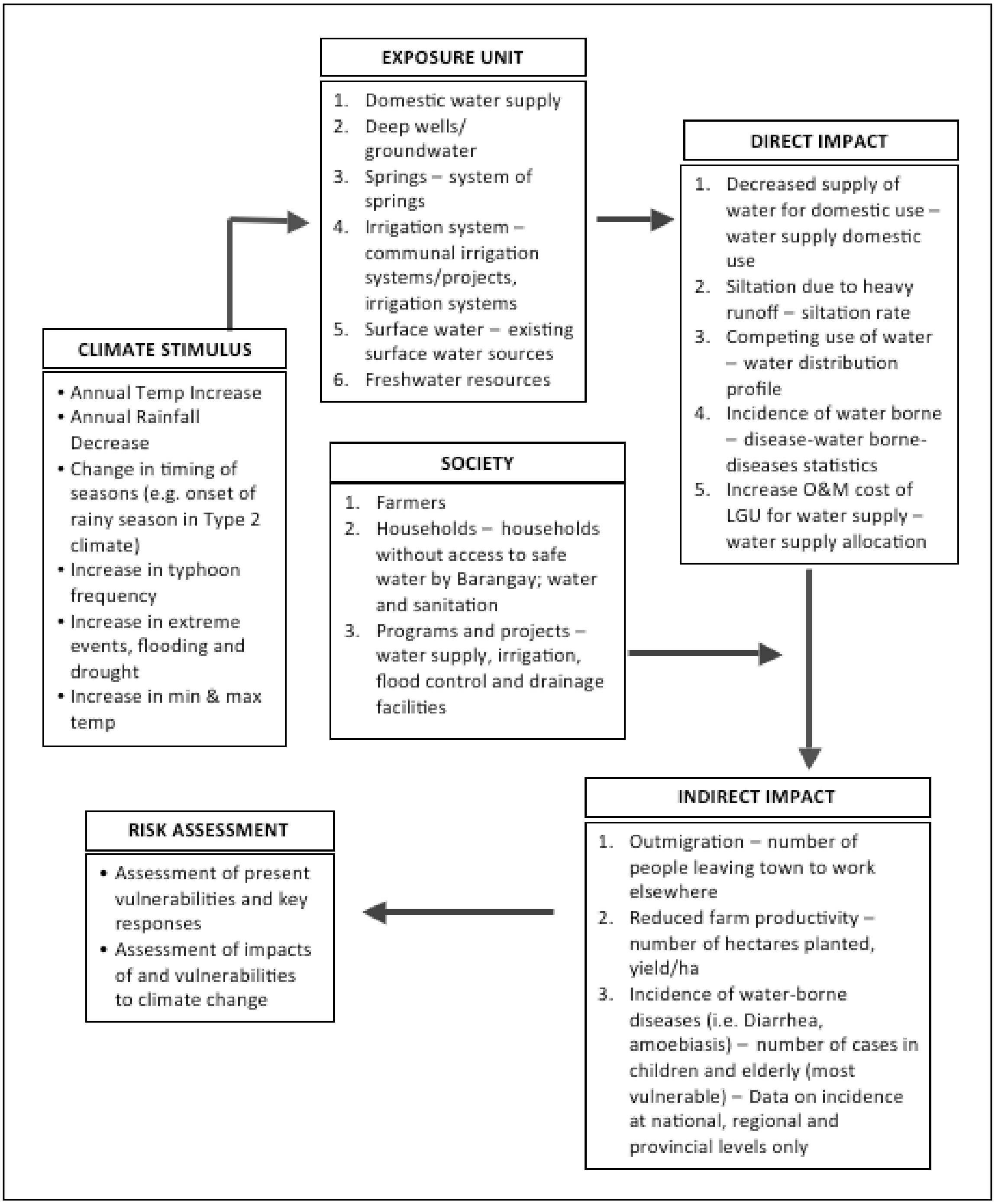


Figure VI.4. *Impact chain for water sector of Silago, Southern Leyte.*

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.

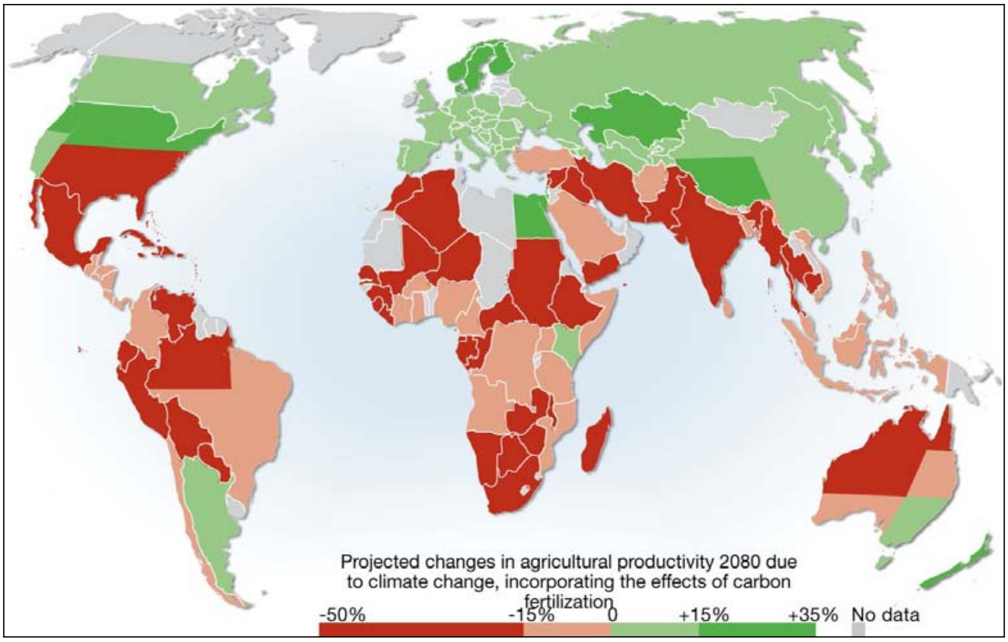


Figure VII.1. *Projected changes in agricultural productivity in 2080 due to climate change with CO_2 fertilization effects incorporated. (Source: Projected agriculture in 2080 due to climate change. (2008). In UNEP/GRID-Arendal Maps and Graphics Library. Retrieved 13:18, March 7, 2011 from http://maps.grida.no/go/graphic/projected-agriculture-in-2080-due-to-climate-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.

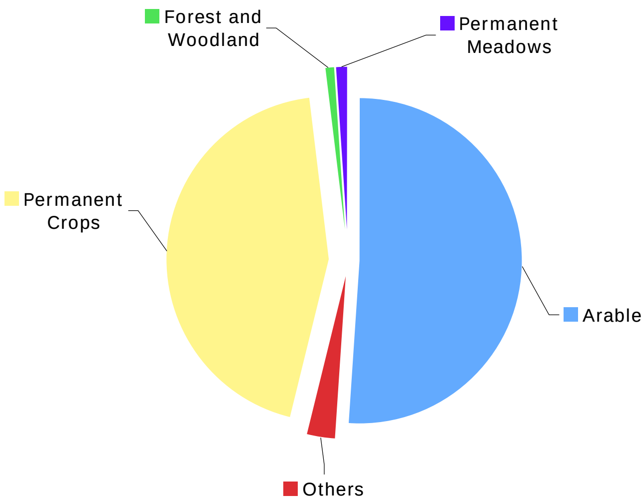


Figure VII.2. *Distribution of agricultural area by type of utilization. (Data from Bureau of Agricultural Statistics, Facts and Figures on the Philippine Agricultural Economy, 2009, http://countrystat.bas.gov.ph/index.asp?cont=factsandfigures)*

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

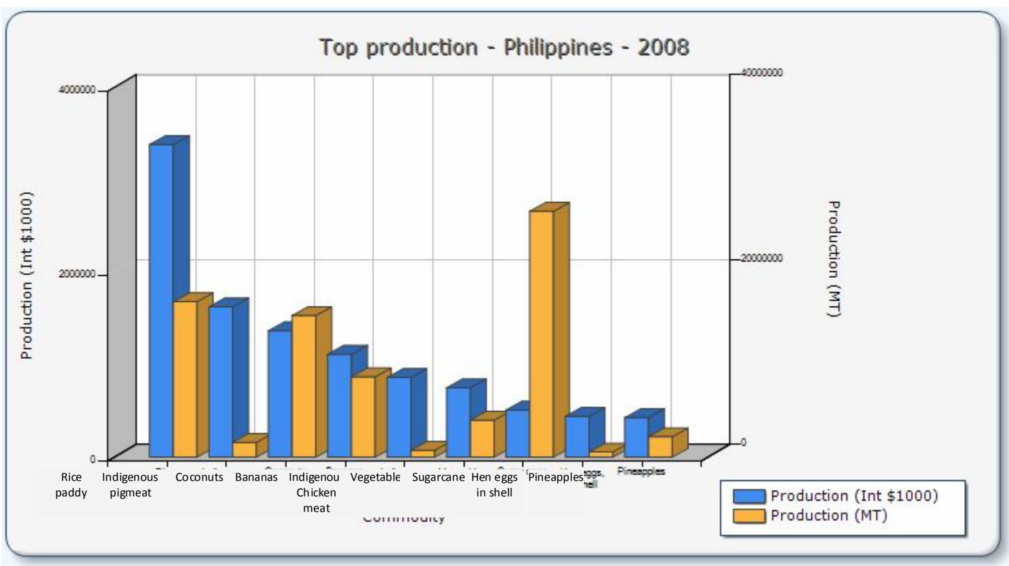


Figure VII.3. *Production of the 20 most important food and agricultural commodities (ranked by value) in the Philippines in 2008. (Figures generated and taken from http://faostat.fao.org/site/339/default.aspx)*

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.

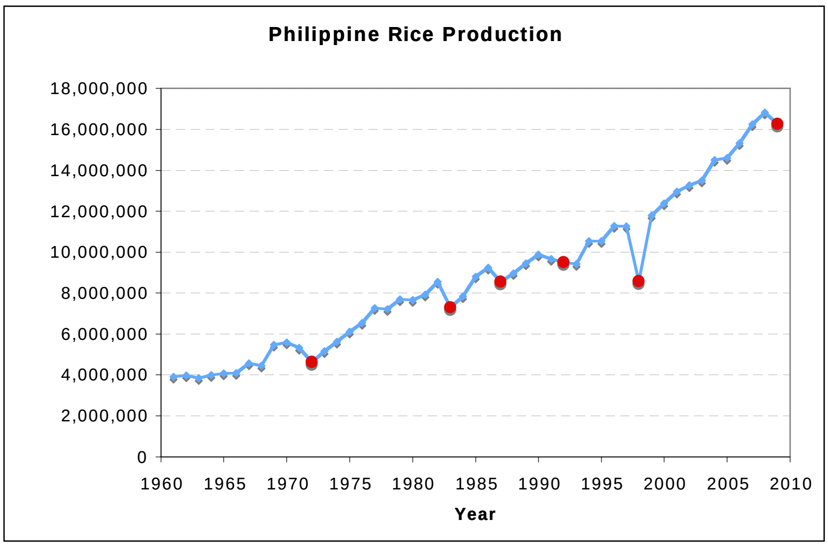


Figure VII.4. *Philippine rice production. The red dots denote major El Nino Events. (Source: Food and Agricultural Organization. http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567)*

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.

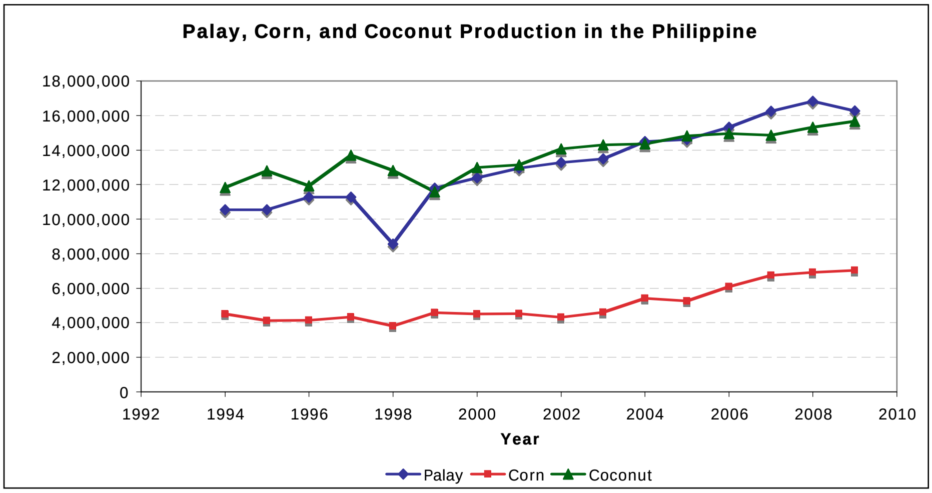


Figure VII.5. *Palay, Corn, and Coconut production in the Philippines from 1994-2009. (Data source: Bureau of Agricultural Statistics (http://countrystat.bas.gov.ph/)*

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.

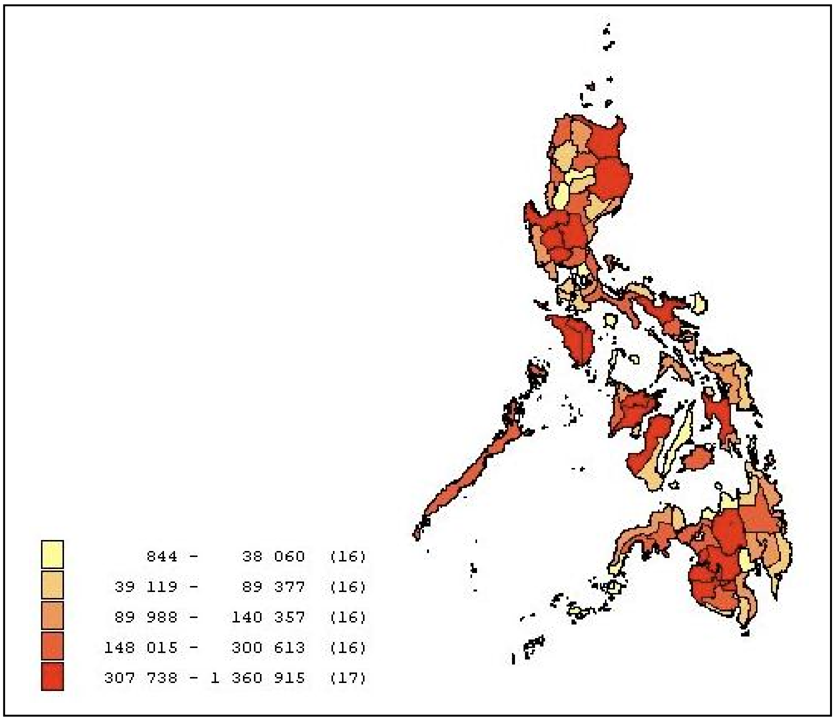


Figure VII.6. *Palay volume of production (metric tons) by province (2009). (Figure and data taken from Bureau of Agricultural Statistics; Map data: BAS-ICTD-IDSS (http://countrystat.bas.gov.ph/)*

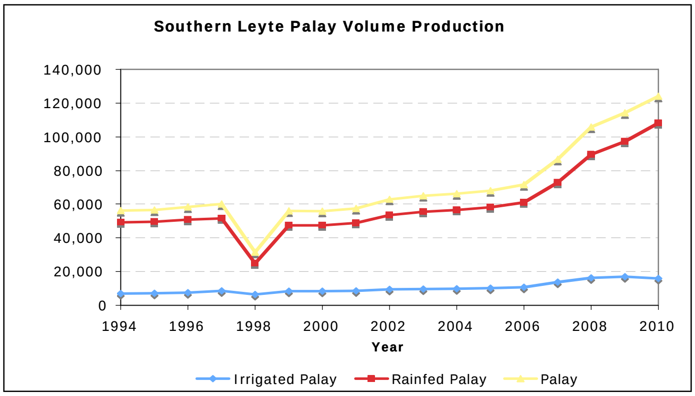


Figure VII.7. *Palay volume production in Southern Leyte. (Source: Bureau of Agricultural Statistics, http://countrystat.bas.gov.ph/)*

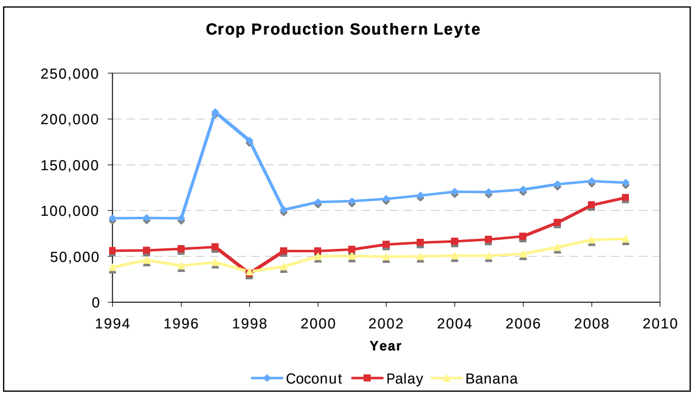


Figure VII.8. *Palay, coconut, and banana production in Southern Leyte. (Source: Bureau of Agricultural Statistics, http://countrystat.bas.gov.ph/)*

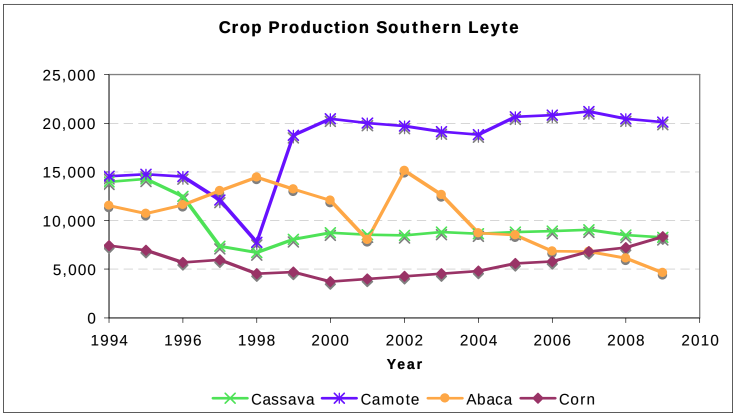


Figure VII.9. *Production volume of other crop types (cassava, camote, abaca, and corn) in Southern Leyte. (Source: Bureau of Agricultural Statistics, http://countrystat.bas.gov.ph/)*

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.

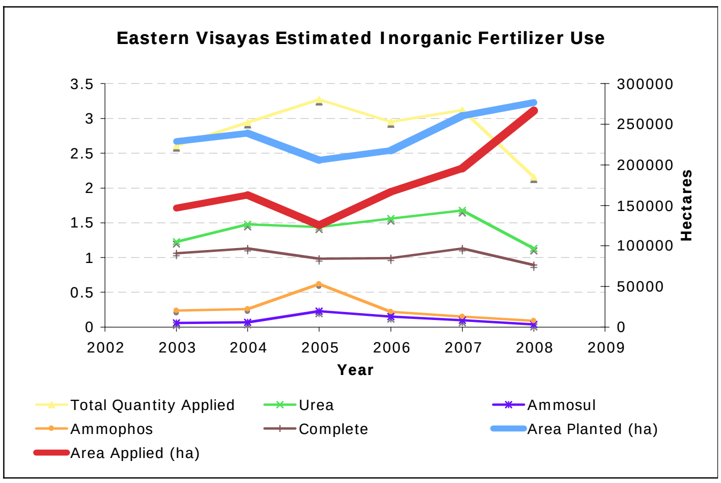


Figure VII.10. *Estimated use of Inorganic Fertilizers in the Eastern Visayas Region. (Source: Bureau of Agricultural Statistics - http://countrystat.bas.gov.ph/)*

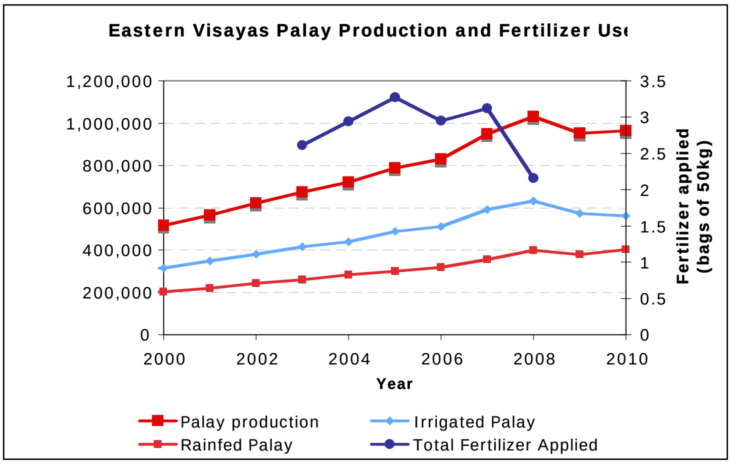


Figure VII.11. *Palay production and fertilizer use in Eastern Visayas. (Source: Bureau of Agricultural Statistics - http://countrystat.bas.gov.ph/)*

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.

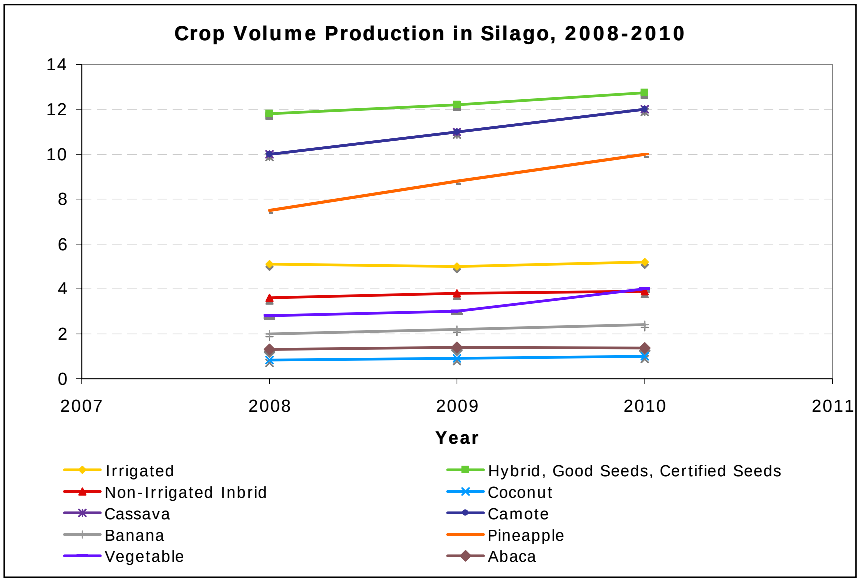


Figure VII.12. *Volume production in Silago from 2008-2010 for the different crop types. (Source: Silago Draft CLUP, 2011; MAO, Silago)*

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

Major Crops	Area			Volume of Production		
	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.

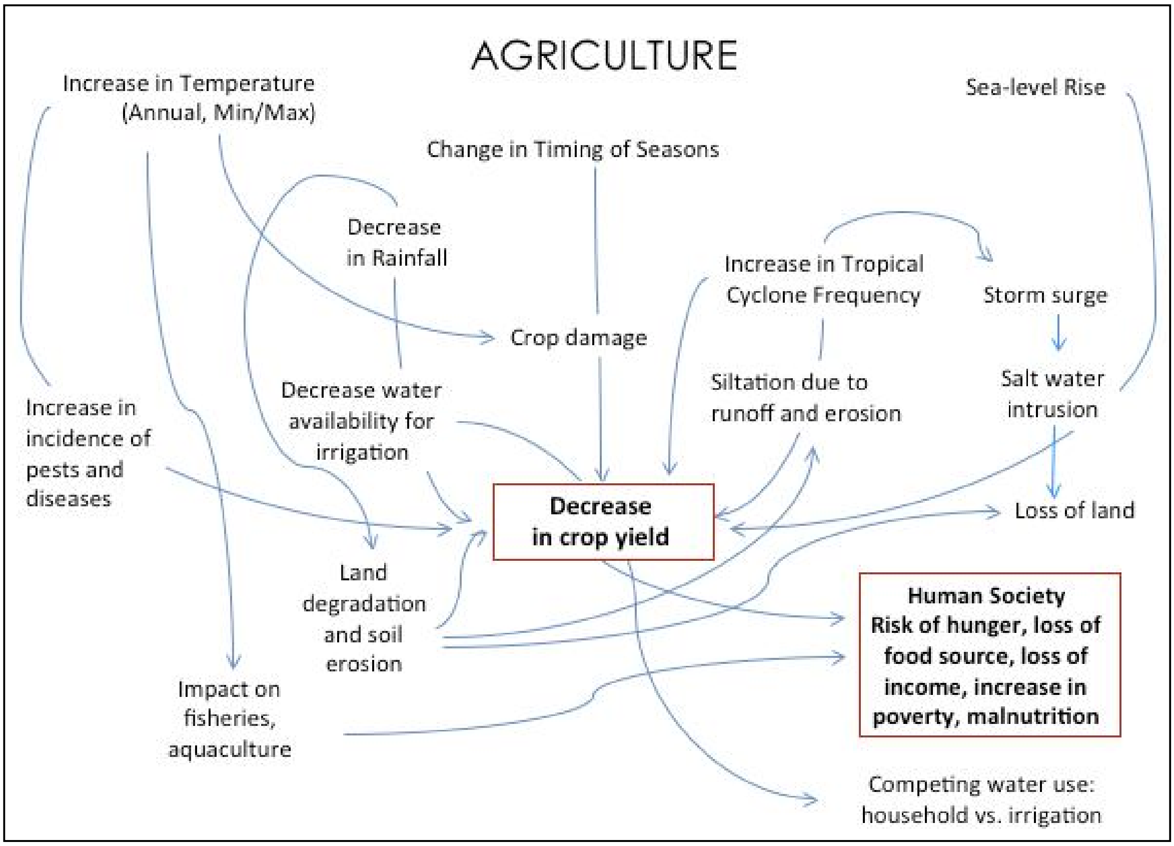


Figure VII.13. *Influence diagram illustrating the impacts of climate change on the agricultural sector.*

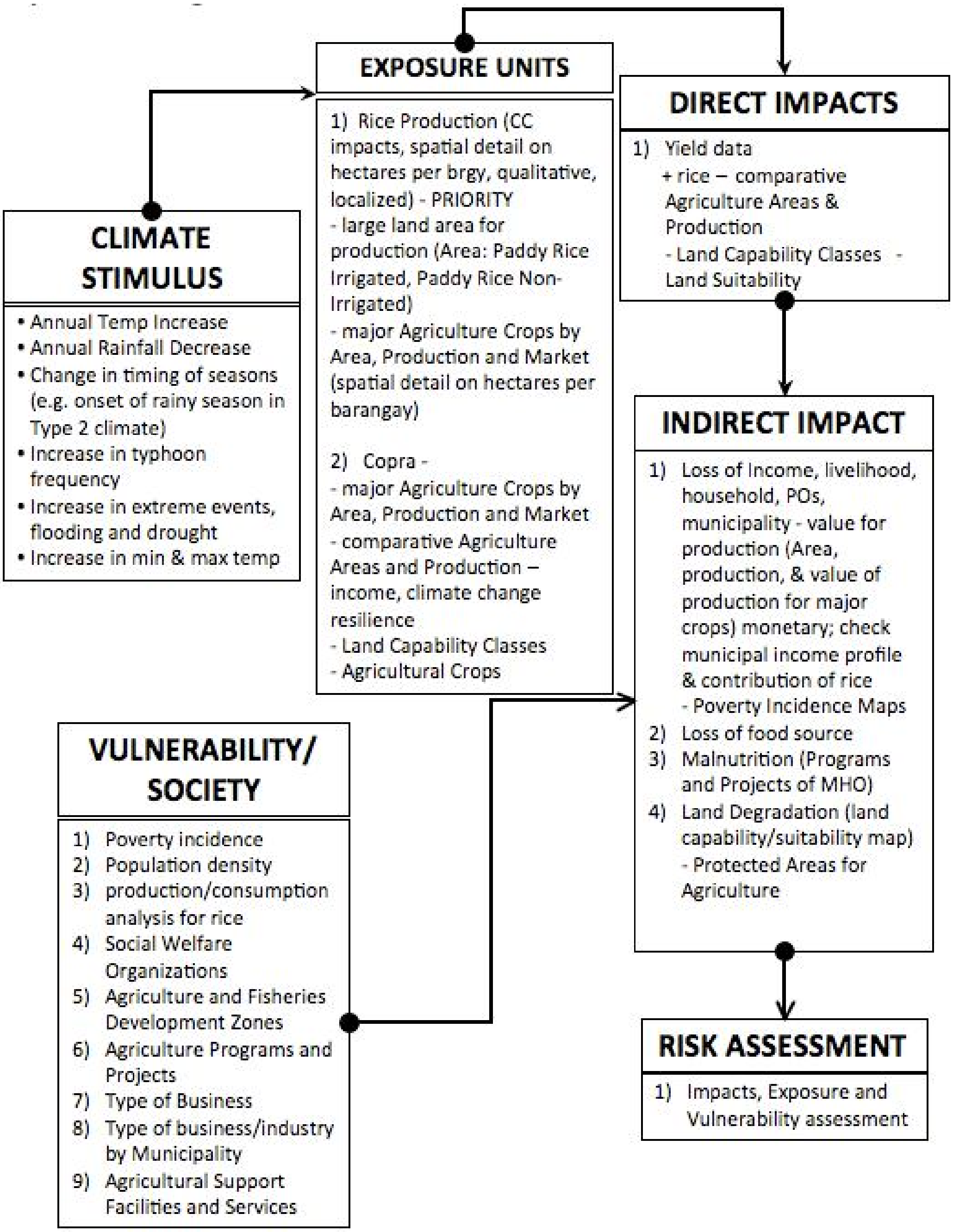


Figure VII.14. *Final impact chain for the agricultural sector in Silago.*

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.

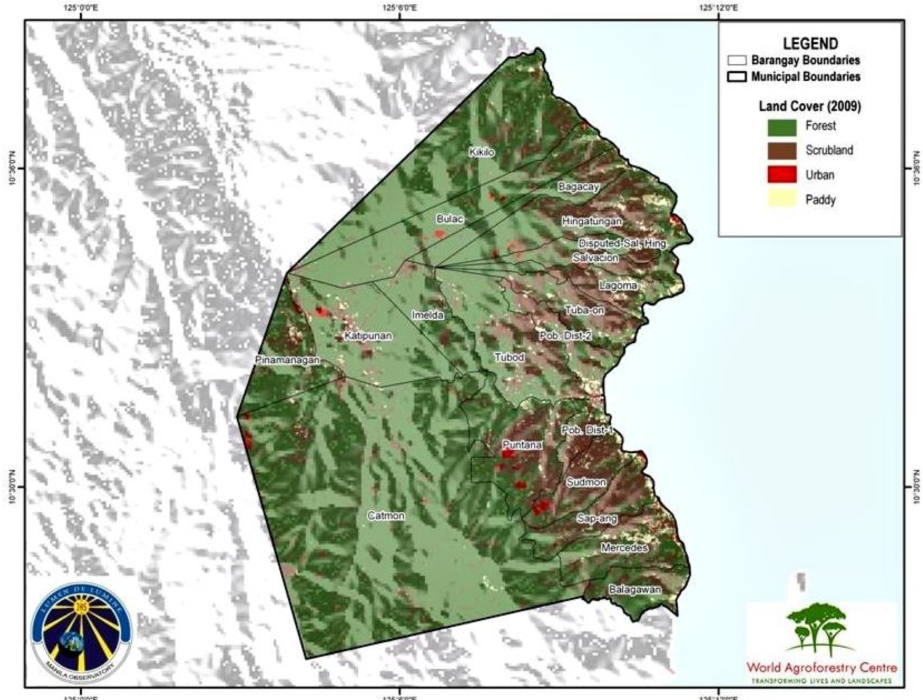
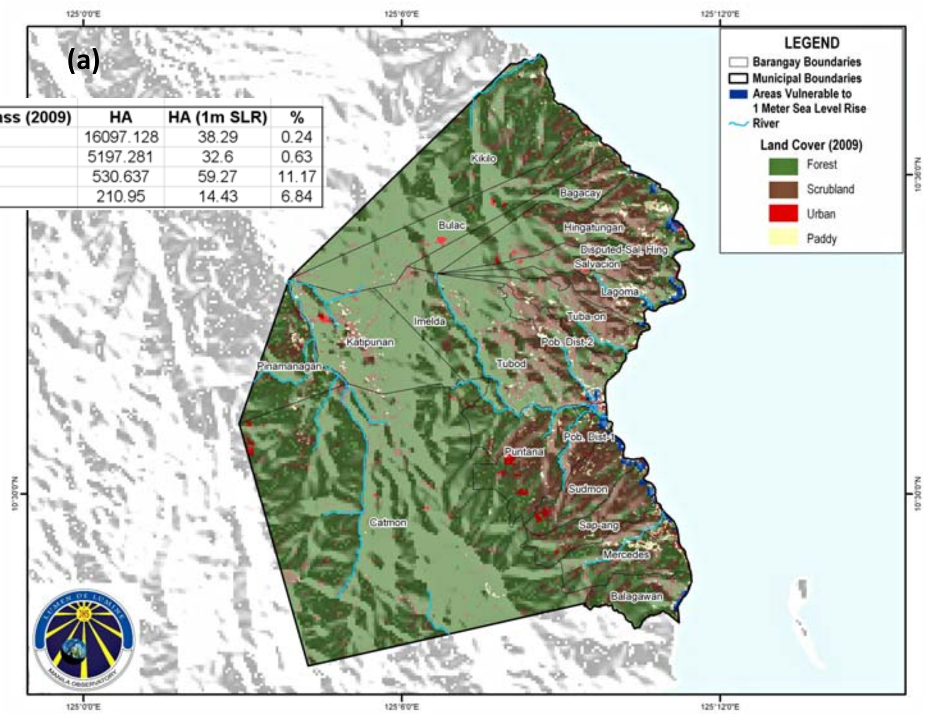
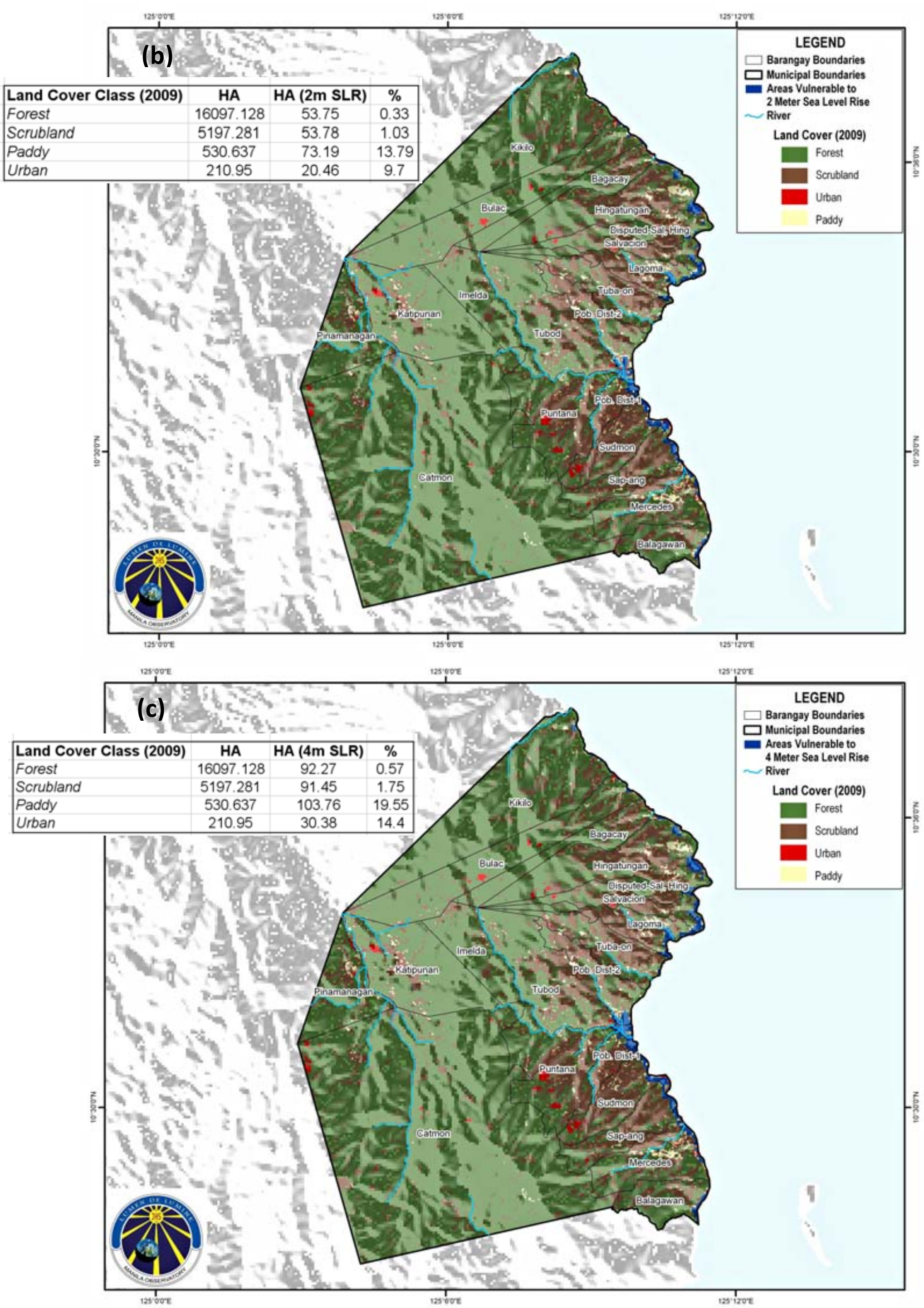


Figure VII.15. *Land cover of Silago based on satellite based image analysis (2009). (Map Data Sources: Shuttle Radar Topographic Mission version 4 (Feb. 2000), Landsat 2009).*



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°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.

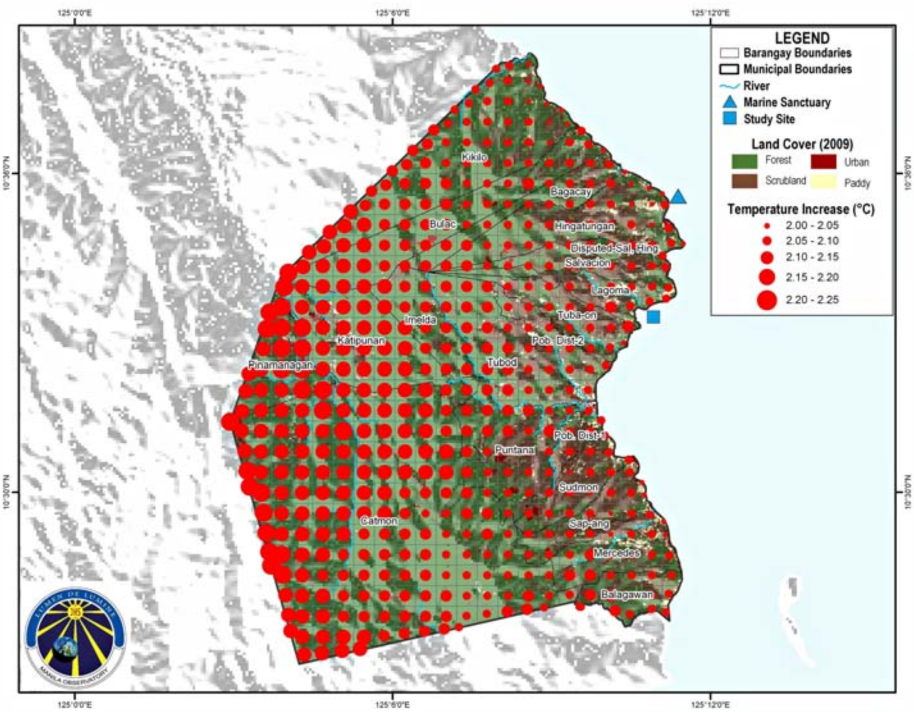


Figure VII.17. *Projected increase in temperature by 2050 and the 2009 land cover of Silago. Larger red dots indicate higher increase in temperature. (Map Data Sources: Shuttle Radar Topographic Mission version 4 (Feb. 2000), Temperature Anomaly RCS-MO, Landsat 2009).*

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.