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Land Cover Change in the Silang-Santa Rosa River Subwatershed, Laguna, Philippines

ABSTRACT

Patterns of land cover change in the Silang-Santa Rosa River Subwatershed in Laguna province were documented through the conduct of Participatory Rural Appraisal approaches and GIS mapping. Drivers and impacts of land cover change in the upland, mid slope and lowland barangays of the subwatershed are influenced by local socioeconomic (investment and livelihood opportunities, and population increase) and biophysical conditions (fertile soil, abundance of quality groundwater, and suitability of land for conversion). For comparing land use changes, 1993 and 2008 land cover maps were generated from classified satellite images using ArcGIS. Land cover patterns in the subwatershed showed series of spatial changes as follows: perennials to grassland then to built-up in the uplands and farmlands to idle lands then to built-up in the lowlands.

Key words: *land cover change, land cover patterns*

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INTRODUCTION

In general, land cover is defined as the observed (bio)-physical cover on the Earth's surface is the most important element for description and study of the environment (*Harold et al. 2007*). The fast-paced urban development in the Laguna lakeshore municipalities of San Pedro to Calamba has influenced the increasing demand for land by the industrial and commercial sector as well as the rapidly growing populace. The extensive land use change from agriculture-based to industrial-based economy, coupled with influx of migrants and rapid population growth in the lakeshore municipalities at the western side of Laguna de Bay from San Pedro to Calamba, resulted in over-all decreased rice land areas and other agricultural areas. This has become a major challenge in the lakeshore municipalities of the Laguna Lake region for the past two decades as prime agricultural lands in these areas have faced a major transformation (*Sly 1993*).

The opportunity to attain economic development in the Laguna Lake region specifically in the west bay of the watershed has led to increased demand for land to accommodate industries, commercial establishments and residential lots. The Silang-Santa Rosa River Subwatershed is highly suitable for land use conversion due to its proximity to Metro Manila and abundance of quality groundwater. The conversion of farmlands to non-agricultural uses with higher economic returns has been a favorable option for land owners in Sta. Rosa City, one of the lakeshore municipalities administratively located in the subwatershed. However, while increasing socio-economic opportunities, such land conversion has negatively affected agricultural production in the area. The sloping areas in the headwaters of the subwatershed with agroforestry farming in Silang, Cavite are threatened by increasing soil erosion and surface run-off and decreasing agroforestry areas due to ongoing urban sprawl in the uplands. The agricultural progress in the uplands and industrial advancements in the lowlands have produced undesirable consequences in the region (*Lasco et al. 2005*).

This study aimed to identify and assess patterns and processes of land cover change (LCC) in the Silang-Santa Rosa River Subwatershed. The various drivers of LCC in the subwatershed included factors that influence human activities, economics, environmental conditions, land policy and development programs, including past human activities or cultural traditions about acquisition and land utilization (**Figure 1**). According to *Reger* (*2008*), the classification of current land-cover patterns with respect to their past dynamics allows one to systematically identify areas, which have been highly dynamic in the past and may also be potentially sensitive to future land-use change.

The results of the study will be used to support the local government and stakeholders of the Silang-Santa Rosa River Subwatershed make better decisions in formulating and implementing interventions that could improve land resources management in the subwatershed as it complements the Santa Rosa Watershed Management Project by the WWF-Philippines and the local government of Sta. Rosa City, Laguna and Silang, Cavite.

Land Cover of Silang-Santa Rosa River Subwatershed

Land use and land cover change (LULCC) is a general term for the human modification of Earth's terrestrial surface (*Ellis 2007*). Land cover refers to the physical material (water, bare soil, and/or artificial structures) and biological

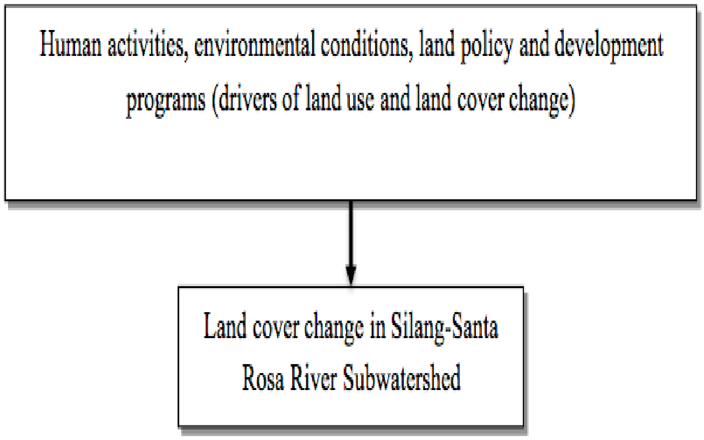

Figure 1. Conceptual framework of the study.

(grass and trees) cover over the surface of land while land use describes how man utilizes the land to improve their state of living. Land-mapping activities can be understood as process of information extraction governed by a process of generalization (*Harold et al. 2007*). The LULCC in the Laguna de Bay watershed has unique urban-rural features. The watershed was a serene rural landscape transformed into a busy centre of human activities since the 1980s stimulated by the constant urge to attract foreign investments, generate more employment opportunities, and decongest Metro Manila population. The west side of the lake region which is in close proximity to Metro Manila are largely industrialized, while other areas in the southern and eastern side are primarily devoted to agricultural purposes (**Figure 2**). Hence, a rural to urban convergence is evident in the lakeshore municipalities adjacent to the west side of the lake region.

The Silang-Santa Rosa River Subwatershed administratively located in the municipalities of Biñan and Sta. Rosa of Laguna province; and the municipality of Silang in the province of Cavite underwent a shift from forestry and agricultural activities to industrial and residential centers. The historical land cover of Carmona and Lipa soil types located in the midstream and lowland areas of the subwatershed were lowland rice, corn, sugarcane, orchard, legumes, plantation crops, root crops, tree perennials, upland rice, coconut, vegetables, and plantation crops.

The lowland areas of the subwatershed used to be one of the major food suppliers of Metro Manila. In 1946, around 96 percent of the land area of Sta. Rosa was devoted to agriculture until the late 1970's (Sta. Rosa Clup 2000-2015). In the 1940s to late 80's, agricultural lands in Sta. Rosa were utilized for rice farming and for other crops such as vegetables, high value commercial crops, fruit crops, corn and coconut covering more than 5000 ha previously designated as Special Agriculture and Fisheries development Zone (SAFDZ). However, major changes in Sta. Rosa happened in the 1980's to the early 1990's when the municipality started to shift from agriculture-based to an industry-based economy when Filsyn, CIGI and other small multinational companies were established in the area as the government BOI provided incentives to companies relocating not less than 40 kilometers away from Manila (*Sta. Rosa CLUP 2000-2015*). *Young* (*2011*) related rational users thinking in individualistic terms lack incentives to contribute to the common good. By virtue of Republic Act No. 9264, Sta. Rosa became a city which was ratified by the citizens on July 10, 2004 as Sta. Rosa became popular for its industrial parks, manufacturing plants and at present, housing developments (Sta. Rosa CLUP 2000-2015). These economic activities have reduced agricultural areas of Sta. Rosa. The Sta. Rosa City Agricultural Office reported that as of March 2009, the existing irrigated rice area in Sta. Rosa City is only 488.9 ha and 8.2 ha of upland rice farm under the Comprehensive Agrarian Reform Program. On the other hand, only 22 ha of vegetable and/or corn area can be found in Barangay Sto. Domingo.

Also located at the lower slopes of the subwatershed that is adjacent to Sta. Rosa is the municipality of Biñan. It was also observed that agricultural lands in Biñan had been declining from 86.9 percent since 1979 to 9.13 percent in 1999 of the total land area (*Biñan CLUP 1999*). Only 392.5 hectares of the 820 hectares of irrigated land are currently devoted to agricultural use in this municipality. It is reported in the *Biñan CLUP* (*1999*) that from 1989 to present, most of the agricultural areas of the municipality has been converted to commercial, residential, and industrial uses. Also, idle/undeveloped lands increased from 1979 to 1999 when agricultural land previously dedicated to livestock and other domestic animals, and production of traditional crops such as jackfruit, pineapple, lanzones, mango, tomato, and sugarcane became less productive (*Biñan CLUP 1999*). Built-up areas in the municipality have been increasing from 10.5 to 70.0 percent from year 1979 to 1999, respectively, with decreasing agricultural areas (*Biñan CLUP 1999*).

On the other hand, population increase in Silang, Cavite due to in-migration in the 1990's encouraged urbanization that resulted to a decline in agriculture. Coffee and fruit crops that replaced corn and sugarcane and commercial contract growing of poultry and animal also reflected urbanization and land conversion in the municipality (*Silang CLUP 2002-2011*). Furthermore, the construction of roads connecting Tagaytay and Silang and the existence of buses and jeepneys influenced urbanization in the area. In 1996, the Sangguniang Bayan reclassified 1,206 ha of the agricultural lands of Silang to non-farm uses such as subdivisions, private properties, etc as land value is increased by investments in prime realty and businesses (*Silang CLUP 2002-2011*). *Coxhead et al.* (*2005*) indicated virtually all production generates some environmental damage in the form of pollution and/or natural resource depletion, and it follows that, other things being equal, such damage or depletion increases as an economy expands.

The current economic developments and trends such as land conversion, rapid urbanization and industrialization have greatly affected agriculture thus the farming sector was badly hit in terms of low production due to fragmentation by the on-going developments in the subwatershed. However, the municipalities in the subwatershed benefited from land investments and still gain from the economic developments happening as people are offered with various job opportunities to improve their livelihood.

METHODOLOGY

Location and Description of the Study Site

The study was conducted from April 2010 to December 2010 in Silang-Santa Rosa River Subwatershed in the province of Laguna and Cavite. The subwatershed represents an emerging urban ecosystem with high demand and competition for land and water use by the residential, commercial and industrial sector. It is located at the western portion of the Laguna Lake Basin with centroid geographic coordinates of 14° 13' 44" N latitude and 121° 01' 05" E longitude. It is administratively located in the cities of Biñan and Sta.Rosa of the province of Laguna; and Silang and Tagaytay of Cavite province (**Figure 2**). It covers 4, 14, and 3 barangays in Sta. Rosa, Silang, and Biñan, respectively.

The total area of the subwatershed is 4156 ha. The subwatershed has a mean slope of 6.2 percent. The lowland portion of the subwatershed is level to nearly level lands with slope ranging from 0-3 percent which is most suitable for irrigation and lowland rice production while the areas with gently sloping to undulating slope (3-8 percent) and rolling to moderately steep (18-30 percent) lands located in the midstream and upstream of the subwatershed is suitable for upland crop production (*Sta. Rosa LEAP 2005*). Based on the Modified Corona's Climate Classification (kidlat.pagasa.dost.gov.ph), the general prevailing climate of the subwatershed belongs to Type 1 where there are two pronounced seasons – dry from November to April and wet during the rest of the year with a maximum rain period from June to September.

The Silang-Santa Rosa River Subwatershed consists of two major landforms, the upland and lowland. The subwatershed is principally drained by the Silang-Santa Rosa River which flows from the mountainous area of Silang, Cavite towards Laguna Lake.

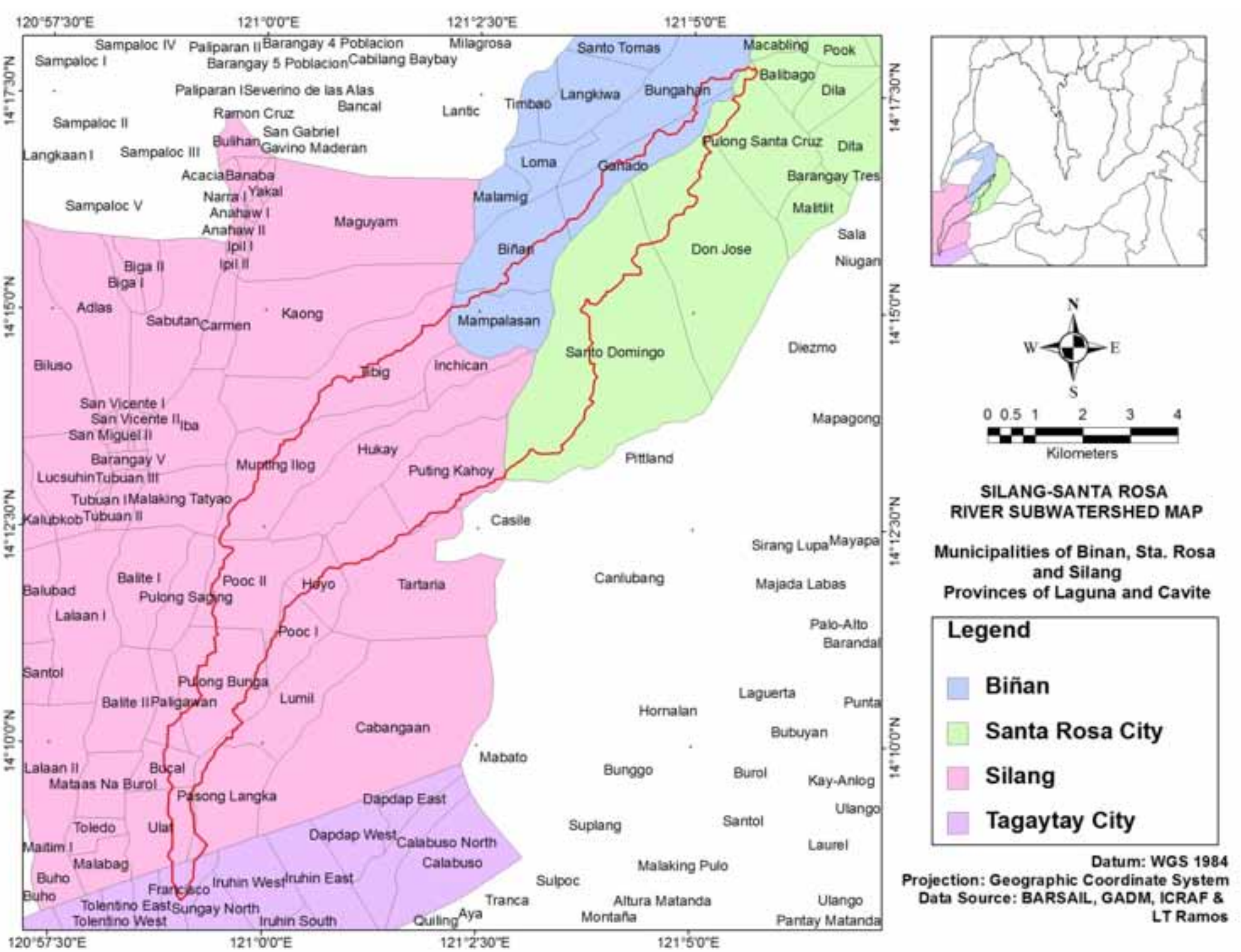

Figure 2. Map of Silang-Santa Rosa River Subwatershed showing the administrative boundary of the study site.

Sources and Types of Data Collected

The study made use of both secondary and primary data. Secondary data were obtained from the local government units and other government agencies like the Laguna Lake Development Authority and Department of Agriculture - Bureau of Agricultural Research Spatial Analysis and Information Laboratory (DA-BARSAIL). DA-BARSAIL is a GIS-based management in agriculture and fishery network and a central repository of socioeconomic, demographic, biophysical, agroclimatic, and geostatistical data for agriculture and fishery in the Philippines (Cruz 2006). The Global Administrative Areas (GADM) spatial database of the location of the world's administrative areas (or administrative boundaries) for use in GIS and similar software (http://www.gadm.org/) was utilized to locate administrative boundary of the subwatershed. The secondary data collected include socioeconomic and land use profile for characterization of the subwatershed from the Laguna de Bay Environmental Action Planning for Sta. Rosa Microwatershed EcoProfile (July 2005) and Comprehensive Land Use Plan of Sta. Rosa (2000-2015), Biñan (1999) and Silang (2002-2011). The preliminary biophysical and socio-economic characterization provided an opportunity to identify information gaps from the available secondary data and was helpful in identifying primary data collection activities.

Characterization of Silang-Santa Rosa River Subwatershed

Soil sampling. Collection of soil samples was conducted in four barangays administratively located within the boundary of the subwatershed. The samples were brought to the Soil Science Laboratory of UPLB for chemical and physical analysis.

Terrestrial vegetation analysis. The distinct vegetation types in the Silang-Santa Rosa River Subwatershed were grasses, perennials, and agroforestry species. The two distinct vegetative covers considered for sampling in the subwatershed were: grass community (barangay Don Jose and Sto. Domingo, Sta. Rosa City, Laguna) and agroforestry (barangay Pulong Bunga, Silang, Cavite).

In sampling the grassland ecosystem of the subwatershed, a point sampling technique was used. Point sampling technique gives reliable results in open and semi-open habitats, such as grasslands when manpower and/or resources are limited (*Mitchell and Hughes 1995*). The set up consists of a one meter horizontal bar divided into ten intervals. The name and height of the plant were recorded and assessed in each sampling interval. The following were computed: cover, relative cover, frequency, relative frequency and summed dominance ratio.

The sampling parameters for determining the attributes of perennials in the agroforestry ecosystem include: frequency, cover or dominance, biomass, height, basal area, diameter at breast height, density and species composition using a quadrat method (*Braun-Blanquet 1932*). The following were computed: total density of all species, DBH, basal area, relative density, relative dominance or relative basal area, frequency, relative frequency and importance values.

Assessment of land cover change

The Participatory Rural Appraisal (PRA) activity was conducted together with the research team of the Laguna Lake Health, Environment and Diversity (LAKEHEAD) Program in Silang-Santa Rosa River Subwatershed.

The PRA approach was employed to determine the drivers of land cover change in the subwatershed which was attended by 20-30 people from each selected barangay of the subwatershed. In the activity, the people think about and write the reasons why they tend to change their land cover. The local people were asked to draw from their experience the primary drivers of land cover change and how the change affected their socioeconomic and biophysical condition.

Also, the local people were asked to identify specific time frames and compare the changes in land cover through the timeline activity. The participants in the activity were attended by various age groups where the elderly were mostly involved in the recollection because they can recall and provide information on the historical changes that happened in their locality.

GIS Mapping and Land Use Classification

Mapping was done using ArcGIS 9.2 licensed to SESAM-UPLB. Data from GADM and DA-BARSAIL were processed by either extracting or clipping feature data using Analysis Tools and Spatial Analysis Tools in ArcGIS to generate slope, soil and road maps.

On the other hand, the ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) three-band images downloaded from United States Geological Survey-Earth Resources Observation and Science Center (USGS-EROS) with a 30 mm resolution were used for rapid impression of the study sites' area, visible features and their visible interrelationships. This was followed by ground truthing three times in the upland, mid slope and lowland to validate or disprove the assessment and obtain additional information that cannot be captured from the photos. After which, image classification was conducted. In the image classification process the three-band raster imagery was converted to a single-band raster with a number of classes, which then was used for land cover mapping and land cover change detection (*ArcGIS Resource Center 2010*). Unsupervised classification. Image classification was performed to extract classes from ASTER images using the Spatial Analyst Tool of ArcGIS 9.2. Unsupervised classification was performed to find spectral classes (or clusters) in the three band ASTER image without the analyst's intervention. The output classes in the unsupervised classification were used to create training samples to represent classes to extract and for ease in creating signature file from the training samples which then be used in Spatial analyst multivariate classification tool to classify the image.

Supervised classification

The set of three-band ASTER image and signature file obtained from the training samples were used as input to conduct Maximum Likelihood in the Classification Tool. The output was a classified raster image with the distinct classes assigned in the signature file.

Land cover maps were generated from the image classification process. Two periods (1993 and 2008) were used to historically represent the land cover changes in the Silang-Santa River Subwatershed. Four land cover classes were identified and assigned in the land cover map: perennials and coconut, cultivated or tilled areas, fallow and grassland areas, and built-up areas (**Table 7**). The Spatial Statistics Tool in ArcGIS was used to calculate areas for each land cover class in the reclassified ASTER images representing the two periods.

RESULTS AND DISCUSSION

Soil

The textural grade of soil in Silang-Santa Rosa River Subwatershed is generally clay to clay loam. The soil in the mid slope and upland areas of the subwatershed located in Barangays Inchican, Pooc II, and Puting Kahoy is clay to silty clay, while silty clay to clay loam in the lowland. Silty clay, clay and clay loam soil textures are generally associated with shallow to deep in thickness and normally well-drained which is important for crop production in the subwatershed. These textural grades are very desirable for agricultural production since this is associated with soils with inherently high capacity for moisture and nutrient supply and storage. Hence, in the better drained sloping uplands of the subwatershed were devoted to diversified agricultural uses until the 1980's before its land conversion to residential use.

The soil pH in the upland areas of the subwatershed ranges from 3.8-4.3. The soil in this agroforestry portion of the subwatershed is extremely acidic due to heavy application of inorganic fertilizer to increase crop yields. Also, at thesepH levels, these volcanic derived soils may have significant allophanic materials in different stages of decomposition that are trapped in the organic materials that cause extreme acidity. The soil pH in the mid slope and lowland areas of the subwatershed ranges from very strongly acidic to slightly acidic (4.3-6.8, **Table 1**). Generally, soil acidity decreased from upland to lowland areas.

The soil organic matter content (OM) is low in the sampling sites that range from 0.8-3.4 percent (**Table 1**). The low percentage is due to intensive farming practices and erosion of the top soil in the upland areas.

The available phosphorous (P) content of the soil in the upland area is very low (5-13 ppm, **Table 1**) that's why farmers need to apply complete fertilizer in order to boost crop growth. Also, low levels of P due to poor availability is typical of volcanic soils. In the lowland area of Sto. Domingo, the available P content is high reaching up to 218 parts per million (**Table 1**). Lowland areas in the subwatershed are recipient of run-off loaded with sediments/eroded soils and from sediment-laden lake floodwaters which also contribute to high pH values and contributed to more P availability.

The exchangeable potassium (K) of the soil is quite low, ranging from 0.7 to 3.8 milli equivalent per 100 gram of soil (**Table 1**). Similar to the trends in OM and P contents, exchangeable K tends to increase from upland to lowland areas. In general, pH, OM, available P and exchangeable K increased from the upland areas down to lowland areas.

The soil types in the Silang-Santa Rosa River Subwatershed are Lipa loam, Carmona clay loam, Carmona sandy clay loam, Tagaytay loam and Tagaytay sandy loam (**Figure 3**). Lipa loam is mostly found in Sta. Rosa City and Biñan, Laguna while the Carmona and Tagaytay soil series are found, respectively, in the midstream and upland area of Silang, Cavite. Carmona clay loam cover 1218 ha (29%) of the total subwatershed in the mid slope portion of the subwatershed. Carmona sandy clay loam occupies a very small portion of the subwatershed. Lipa Loam occupies 30% while Tagaytay loam and Tagaytay sandy loam cover 39% and 2% of the total land area of the subwatershed respectively (**Table 2**).

Carmona series has poor drainage properties and moderately slow hydraulic conductivity that occurs in rolling to strongly rolling contours of the subwatershed (*Sta. Rosa CLUP 2000-2015*). Lipa loam in the lowland site of the subwatershed has moderate hydraulic conductivity and infiltration rates with moderately well to well drainage capabilities (*Sta. Rosa CLUP 2000-2015*).

Tagaytay soil series is located in Silang, Cavite and Tagaytay City. Soil type found in Pooc II and Puting Kahoy sampling site is Tagaytay loam. Tagaytay series is of volcanic

Table 1. Results of chemical analysis of soil samples from various locations.

Barangay	Location	Textural Grade	pH (min-max)	OM (%) (min-max)	P (ppm) (min-max)	K (meq 100g^{-1} soil) (min-max)
Pooc II and Puting Kahoy	Upland	clay	3.8-4.4	1.2-2.7	5-13	0.6-1.9
Inchican	Mid slope	clay, silty clay	5.6-6.8	2.1-3.2	10-*92	1.5-2.4
Sto. Domingo	Lowland	clay, clay loam	5.6-6.2	0.8-2.6	*15-218	1.6-3.8

Table 2. Proportion of various soil types in Silang-Santa Rosa River Subwatershed.

Soil Type	Area	
	ha	%
Carmona sandy clay loam	1	0
Lipa loam	1242	30
Tagaytay loam	1594	39
Carmona clay loam	1218	29
Tagaytay sandy loam	101	2
	4156	100

Table 3. Results of physical analysis of soil samples from various locations.

Barangay	Location	Particle Density (g cm^{-3})	Water Holding Capacity (%)
Pooc II and Puting Kahoy	Upland	1.8-2.7	67-92
Inchican	Mid slope	2.4-2.6	66-74
Sto. Domingo	Lowland	2.4-2.9	73-95

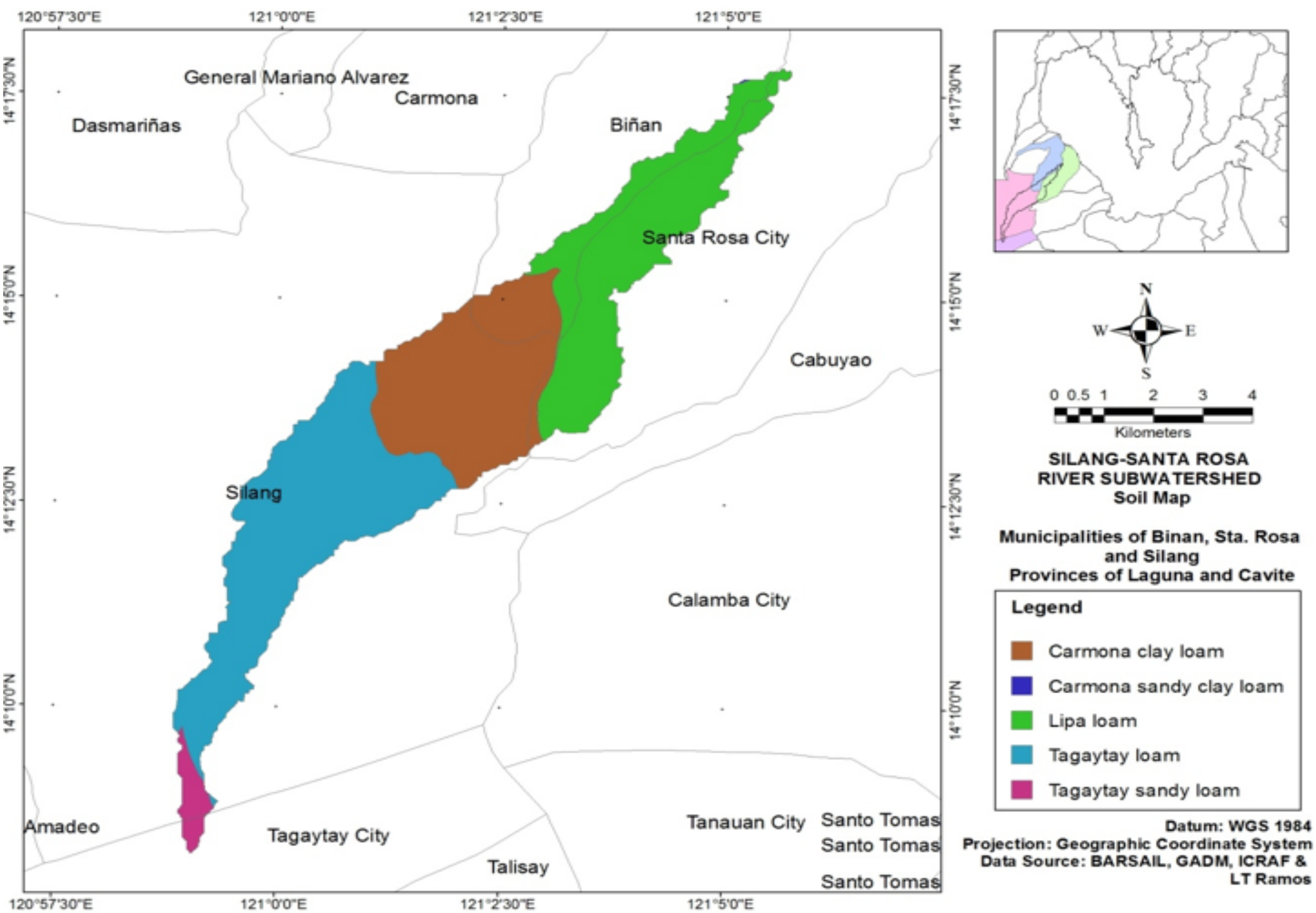

Figure 3. Soil map of Silang-Santa Rosa River Subwatershed.

origin with moderate inherent fertility highly suitable for the cultivation of upland and tree crops and favor shrub growth (*Silang CLUP 2002-2011*).

The particle density, the measure for permeability and soil compaction (soil tightness), of the soil ranged from 1.8-2.8 g cm-3 in the sampling sites in the subwatershed **(Table 3**). The relatively lower particle density values in the upland areas can be attributed to the frequent cultivation of the area to grow agricultural crops since the upland area is dominated by recent and old volcanic soils that has low particle density, making it porous which is attributed to the physical nature of organic matter. On the other hand, the higher particle density values in the lowland and mid slope areas can be attributed to the compaction and high clay content of the soil in these areas. Carmona soils have vertic properties as exhibited by deep cracking clays, and is expected to be associated to heavy soil texture (clay tightness), poor permeability and poor internal drainage and are saturated over longer periods due to closeness to water tables.

The water holding capacity in the lowland site is higher than the water holding capacity in the upland and mid slope areas. The higher water holding capacity of the lowland soil sites is also attributed to tightness of soil particles, generally clay soils, in the area (**Table 3**).

Terrestrial Vegetation

The terrestrial vegetation shows the association of ecologically related plant communities in the upland, midslope and lowland portions, to show the ecological properties of land surfaces in the subwatershed.

The agroforestry system in the upland portion of the subwatershed is located in barangay Pulong Bunga in Silang, Cavite. It is dominated by coconut, fruit-bearing trees, banana, papaya, coffee, and pineapple. Tree crops documented in this system are Hagimit (*Ficus minahassae* (Teijsm. & de Vriese) Miq.), Alagau (*Premna odorata* Blanco), and Tibig (*Ficus nota* (Blanco) Merr) (**Table 4**). Other tree crops include Hauili (*Ficus septica*) and Is-is (*Ficus ulmifolia* Lam.). The most common fruit crops are Lansones (*Lansium domesticum* Corr.), Langka (*Artocarpus heterophyllus* Lam.), Mangga (*Mangifera indica* L.), Kamias (*Averrhoa bilimbi* L.), Kape (*Coffea* sp.), and Avocado (*Persea americana* Mill.) (**Table 4**). These fruit crops provide high diversity of fruits harvested in the area.

The relative dominance value of 16.3 percent for Hagimit is highest among the tree crops and fruit crops in the site which means that this tree crop has a relatively high contribution to the total biomass of all crops found in the area (**Table 4**). Also, high relative density values for Hagimit and Lansones is shown in **Table 4** as these trees make up 20 percent of the total population of perennials sampled in the area. The relative frequency values of perennials in this area are the same which means that all tree species have the same number of occurrence all throughout the area sampled. In general, Lansones and Hagimit have high importance values based from number of occurrence, total number of individuals and area occupied by these species in the sampling site.

Most of the undergrowths observed in Pulong Bunga are Cogon (*Imperata cylindrical*), *Oplismenus* sp., *Crassocephalum crepidiodes* (Benth.) S. Moore, andCinderella weed (*Synedrella nodiflora* (L.) Gaertn).

The riparian vegetation in Barangay Sto. Domingo of Sta. Rosa City, Laguna represents the midstream of the subwatershed. The perennials recorded were mostly dominated by Igyo (*Dysoxylum gaudichaudianum* (A.Juss.) Miq), Kupang (*Parkia roxburghii* G. Don), Basikong (*Ficus botryocarpa* Miq). and Alim (*Melanolepis multiglandulosa* (Reinw. ex Blume) Rchb.f. & Zoll.) with IV's 61.1, 56.1, 43.5 and 36.1 percent, respectively (**Table 5**). Igyo and Kupang were observed to have high relative dominance values showing that these tree species have high contribution to the total biomass in the area (**Table 5**). However, relative density values showed that Basikong and Igyo have the highest number of individuals with 20 percent of the total population of tree species occupying the area sampled. Igyo, Basikong and Alim commonly occur in the area as shown by the relative frequency values in **Table 5**.

The listed understorey tree species were: Is-is (*Ficus ulmifolia* Lam.), Kakauate (*Gliricidia sepium*), Ipil-ipil (*Leucaena leucocephala* (Lam.) De Wit), and Tubang-bakod (*Jatropha curcas*). Shrubs and weeds include: Tikas-pula (*Canna coccinea* Blanc), *Pipturus asper*, *Clerodendrum* sp., Hagonoi (*Chromolaena odorata* (L.) King), and Coronitas (*Lantana camara*).

Data collection for grassland ecosystem of the subwatershed was conducted in Barangay Don Jose in Sta. Rosa City, Laguna. The grasses recorded were dominated by Cogon (*Imperata cyclindrica* (L.) Beauv.) and Talahib (*Saccharum spontaneum* L.) with cumulative values of 22.9 and 19.7 percent, respectively (**Table 6**). Talahib commonly occurs across the site with a relative frequency value of 12.5 percent. The relative height for Cogon is 44.5 percent (**Table 6**).

Land Cover Map

In 1993, perennials and coconut areas were about 1140 hectares in the 18-30 percent slope of the subwatershed which covered mostly the municipality of Silang (**Figure 4**). The cultivated areas were distributed across the subwatershed with associated fallow areas of 8 percent (**Table 7**). Fallow and/or grassland areas indicated conversion to commercial and industrial lots in the near future. About a quarter of the total land area was devoted to built-up which was mostly concentrated in the 0-18 percent slope of the subwatershed. This includes the lowland areas of Sta. Rosa and Biñan and a portion of the sloping area in Sta. Rosa.

Based upon the classification, fallow and grassland areas increased to 18 percent in year 2008 which was more than double the percentage in 1993. This was observed in the mid slope of the subwatershed which was previously cultivated with sugarcane and corn. Also, commercial developments and real estate investments were currently

Table 4. Computed importance values of perennials in a multi-storey agroforestry system in the upland portion of the subwatershed in Barangay Pulong Bunga, Silang, Cavite.

Common Name	Scientific Name	Family Name	RDOM (%)	RDEN (%)	RFREQ (%)	IV(%)
Bogus	*Acalypha amentacea* Roxb.	Euphorbiaceae	2.6	6.7	9.1	18.4
	Acalypha caturus Blume	Euphorbiaceae	3.8	6.7	9.1	19.5
Guayabano	*Annona muricata* L.	Annonaceae	3.8	6.7	9.1	19.5
Nangka	*Artocarpus heterophyllus* Lam.	Moraceae	12.6	6.7	9.1	28.4
Kamias	*Averrhoa bilimbi* L.	Oxalidaceae	10.4	6.7	9.1	26.2
Hagimit	*Ficus minahassae* (Teijsm. & de Vriese) Miq.	Moraceae	16.3	20.0	9.1	45.4
Tibig	*Ficus nota* (Blanco) Merr	Moraceae	5.9	6.7	9.1	21.6
Lansones	*Lansium domesticum* Corr.	Meliaceae	10.1	20.0	9.1	39.2
Mangga	*Mangifera indica* L.	Anacardiaceae	11.5	6.7	9.1	27.3
Avocado	*Persea americana* Mill.	Lauraceae	10.4	6.7	9.1	26.2
Alagau	*Premna odorata* Blanco	Lamiaceae	12.6	6.7	9.1	28.0

Legend: RDOM = relative dominance RDEN = relative density RFREQ = relative frequency IV = importance value

Table 5. Computed importance values of perennials in the riparian zone and midstream portion of the subwatershed in Barangay Sto. Domingo, Sta. Rosa City Laguna.

Common Name	Scientific Name	Family Name	RDOM (%)	RDEN (%)	RFREQ (%)	IV(%)
Igyo	*Dysoxylum gaudichaudianum* (A.Juss.) Miq	Meliaceae	24.4	20.0	16.7	61.1
Basikong	*Ficus botryocarpa* Miq.	Moraceae	6.8	20.0	16.7	43.5
Kakauate	*Gliricidia sepium* (Jacq.) Kunth ex Walp	Fabaceae	5.2	6.7	8.3	20.2
Uas	*Harpullia arborea* (Blanco) Radlk	Sapindaceae	3.1	13.3	8.3	24.8
Mangga	*Mangifera indica* L.	Anacardiaceae	2.2	6.7	8.3	17.2
Alim	*Melanolepis multiglandulosa* (Reinw. ex Blume) Rchb.f. & Zoll.	Euphorbiaceae	6.1	13.3	16.7	36.1
Kupang	*Parkia roxburghii* G. Don	Fabaceae	41.1	6.7	8.3	56.1
African tulip	*Spathodea campanulata*	Bignoniaceae	0.8	6.7	8.3	15.8
Sampalok	*Tamarindus indica*	Fabaceae	10.3	6.7	8.3	25.8

Legend: RDOM = relative dominance RDEN = relative density RFREQ = relative frequency IV = importance value

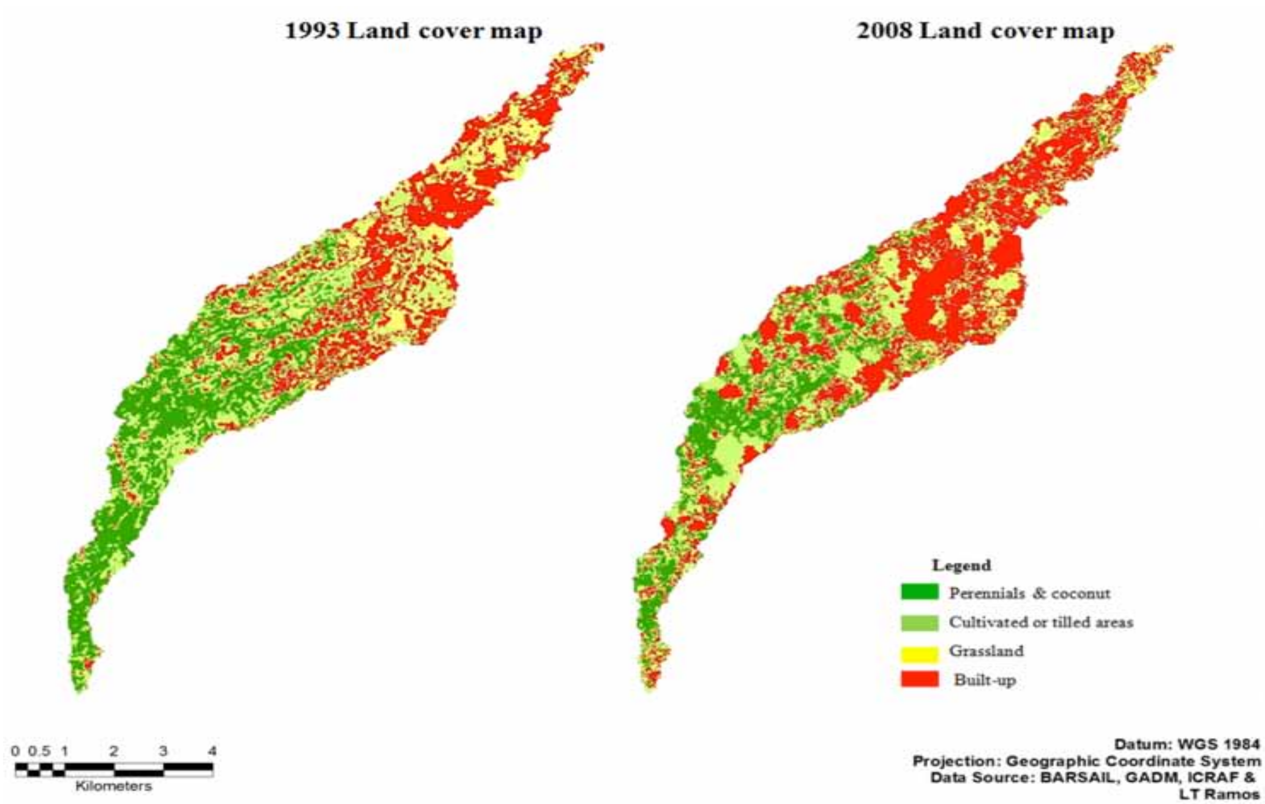

Figure 4. Land cover map of Silang-Santa Rosa River Subwatershed.

Table 6. Relative cover, relative frequency and relative height of grasses in the lowland portion of the subwatershed in Barangay Don Jose, Sta. Rosa City Laguna.

Common Name	Scientific Name	Family Name	RDOM (%)	RDEN (%)	RFREQ (%)	IV(%)
Pukingan	*Arachis* sp.	Fabaceae	2.0	4.2	0.0	2.1
	Centrosema pubescens Benth.	Fabaceae	4.0	8.3	0.0	4.1
Thickhead	*Crassocephalum crepidiodes* (Benth.) S. Moore	Asteraceae	2.0	4.2	8.9	5.0
	Crotolaria sp.	Fabaceae	2.0	4.2	0.0	2.1
Kawad-kawad	*Cynodon dactylon* (L.) Pers.	Graminae	4.0	8.3	5.6	6.0
	Desmodium sp	Fabaceae	4.0	8.3	0.0	4.1
Paragis	*Eleusine indica* (L.) Gaertn.	Graminae	4.0	4.2	11.1	6.4
Cogon	*Imperata cyclindrica* (L.) Beauv.	Graminae	20.0	4.2	44.5	22.9
	Meremia sp.	Convolvulaceae	4.0	8.3	0.0	4.1
Makahiyang lalaki	*Mimosa invisa* Mart.	Fabaceae	4.0	8.3	0.0	4.1
Makahiya	*Mimosa pudica* L.	Fabaceae	10.0	8.3	0.0	6.1
	Panicum sp.	Graminae	4.0	4.2	2.2	3.5
Talahib	*Saccharum spontaneum* L.	Graminae	30.0	12.5	16.5	19.7
Walis-walisan	*Sida rhombifolia* L.	Malvaceae	2.0	4.2	2.2	2.8
Tuhod-manok	*Synedrella nodiflora* (L.) Gaertn.	Asteraceae	2.0	4.2	6.7	4.3
Tridax daisy	*Tridax procumbens* L.	Asteraceae	2.0	4.2	2.2	2.8

Legend: RDOM = relative dominance RDEN = relative density RFREQ = relative frequency IV = importance value

Table 7. Proportion of land cover classes in Silang-Santa Rosa River Subwatershed based from classification.

Land Cover Class	1993		2008	
	ha	%	ha	%
Perennials and coconut	1140	27	713	17
Cultivated or tilled areas	1543	37	987	24
Fallow and grassland areas	336	8	761	18
Built-up areas	1137	27	1688	41
TOTAL	4156	100	4156	100

occurring at a very rapid pace with the existing technology parks in this portion of the subwatershed. From 1993 to 2008, perennials and cultivated areas continued to decrease from 27 to 17 percent as built-up areas increased in the mid slope of the subwatershed towards the upper slopes of Silang, Cavite.

The market-driven succession in land cover in the subwatershed is characterized by conversion of agroforestry areas to grassland then to built-up; and riceland areas to built-up areas from the 1990s to 2008. The land cover map showcases the period where land conversion for commercial, industrial and residential uses were occurring at a very rapid pace. One of the impacts of land conversion in the subwatershed is sedimentation due to flooding where the most susceptible is the southwestern tip of Sto. Domingo. This portion of the subwatershed is devoted to real estate development and technology parks.

The ongoing conversion has varying impacts on the local economy as there are increasing socioeconomic opportunities for other sources of livelihood from the industries, commercial establishments and housing. The loss of agricultural lands will also mean loss of livelihood opportunities for many of the farmers in the lowlands. This creates a demand for using the natural resources in the fragile mountain ecosystems leading to degradation of not only the upland ecosystems but also of the riverine, lake, and coastal ecosystems that are intricately linked with the upstream areas (*Sta. Rosa LEAP 2005*).

Drivers and Impacts of Land Cover Change

The PRA activity conducted in three selected barangays of the subwatershed resulted to identification of localized pattern of land cover change (**Figure 5**) with associated socioeconomic drivers and biophysical impacts of change (**Figure 6**). The three barangays represented the upland, mid slope and lowland portions of the subwatershed.

Tartaria, Silang, Cavite (upland). The upland portion of subwatershed was previously devoted to forest which was deforested to accommodate settlements and abaca cultivation (1920s-1940s) (**Figure 5**). Before the entry of the migrants, the upland area of the subwatershed was a forested land dominated by tree species such as Molave, Narra, Guijo, Apitong, Madre cacao, Acacia, and Mango. In the 1940s, the population in the upper slopes of the subwatershed was composed of evacuees from Batangas who cleared the forest and later cultivated sweet potato and upland rice for household food security in the 1950s to 1960s (**Figure 6**). Palms like coconut were also planted which was brought by their ancestors from San Pablo. Consequently, soil erosion has become evident in this portion of the subwatershed due to forest clearing but the local community developed the multi-storey agroforestry farming practices to solve this problem.

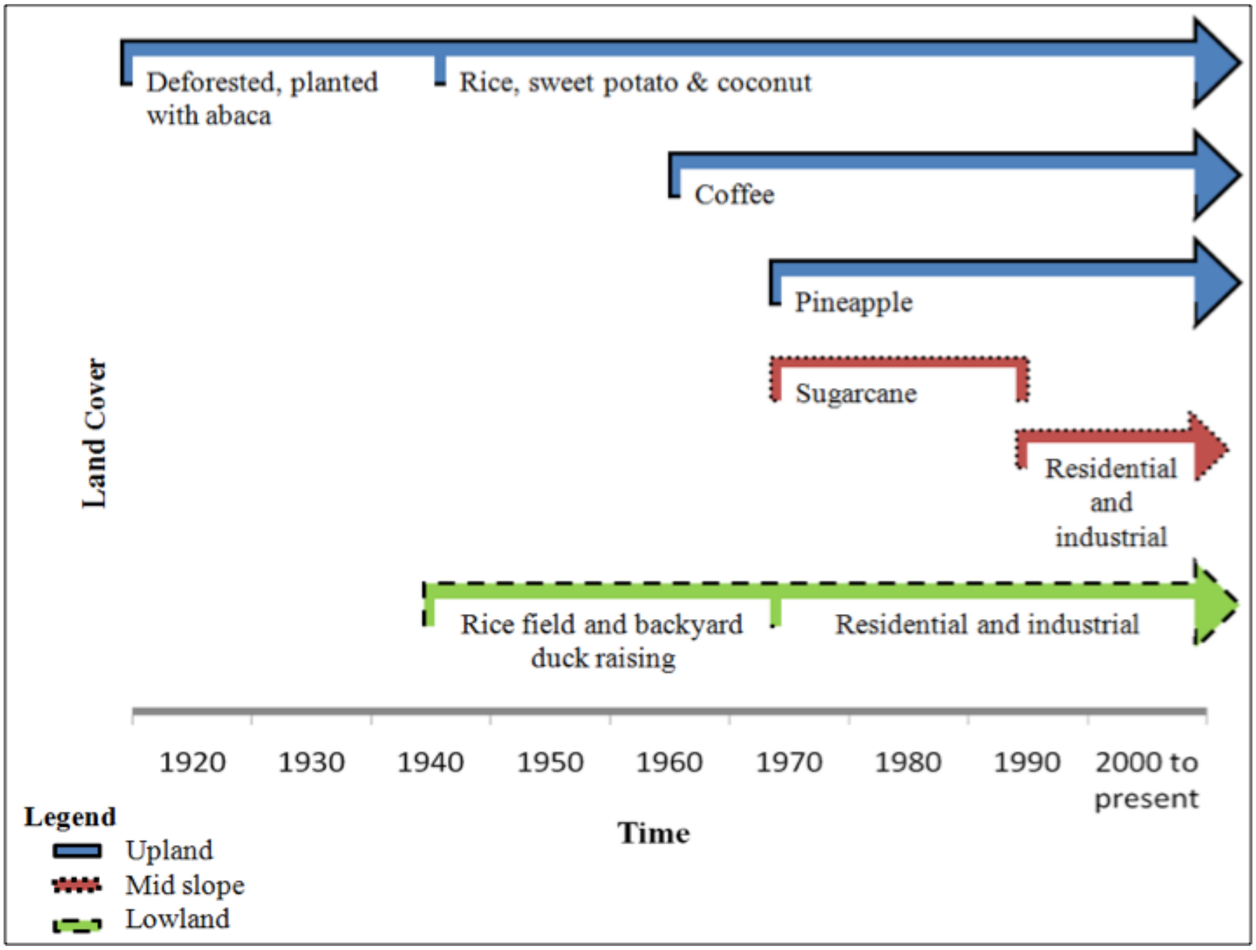

Figure 5. Dominant land cover patterns in the upland, mid slope and lowland portion of the subwatershed.

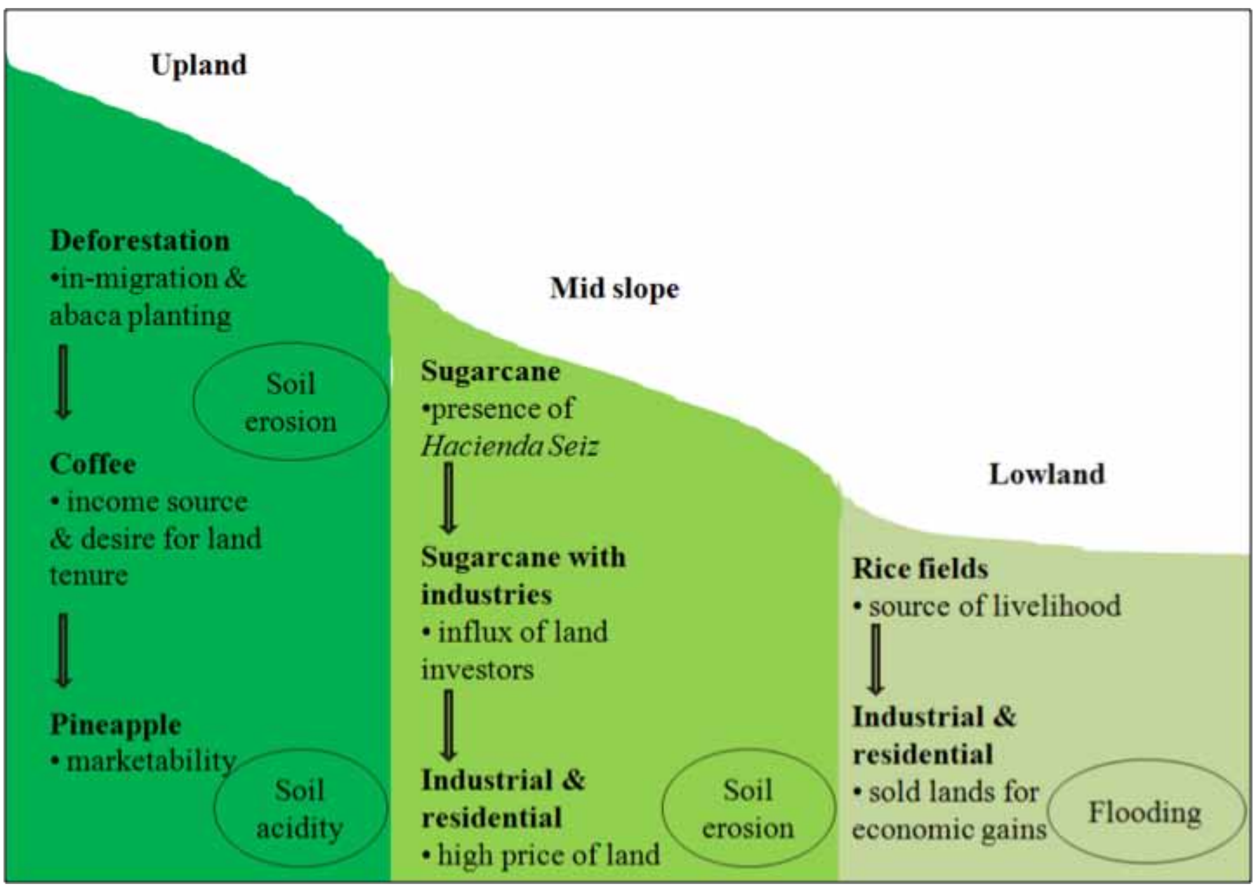

Figure 6. Drivers and impacts of land cover change in the subwatershed.

The soil in Silang is volcanic in origin and its moderate inherent fertility makes the soil highly suitable for the cultivation of upland and tree crops (*Silang CLUP 2000-2015*). Hence, coffee planting began in the 1960's that sustained the local people high income but with the gradual price decrease of coffee, pineapple growing in the 1970's together with coffee was practiced due to its marketability.

However, cultivation of coffee, pineapple and other high value crops in the upland with frequent fertilizer application and soil erosion has turned the soil acidic. Also, the previously abundant water in rivers and springs of the upland gradually dries up. At present, the National Water and Sewerage Authority (NAWASA) operation in the area is being patronized by the residents to meet their water needs.

Upper portion of Sto. Domingo, Sta. Rosa City, Laguna (mid slope). The mid slope of the subwatershed was previously sugarcane area in the 1940s to 1970s (**Figure 5**). The sugarcane plantation in the 1940s was the main source of income by the inhabitants of Sto. Domingo. The mid slope was the then Hacienda Seiz manned by the Yulo family. During that period, water for domestic purposes was abundant which was sourced from the river, spring or manually pumped well.

However, the land owner of Hacienda Seiz sold the area in the 1990s that gave way to industrial development and gradually decreased sugarcane areas; and reduced river flow and springs due to poor recharge and/or sedimentation (**Figure 6**). The dominance of industries and paved road networks resulted into zero recharge and increased run-off,which may partly explain the reduce spring and river flows.

At present, commercial zones, industrial parks and residential lots are situated in this area of the subwatershed. In-migration and illegal squatting also increased as people seek livelihood opportunities in this economically growing zone. As observed by the residents with the present industrialization and urbanization in the mid slope of the subwatershed, there is less water available in the river and sediment-laden flooding occurs during heavy rains which is a result of quarrying that widens the river. But not only that the commercial, industrial and residential lots that generate effluents and solid wastes as well impacts of land cover change and economic development.

Aplaya, Sta. Rosa City, Laguna (lowland). The lowland's historical land cover change was from rice fields to industrial parks and residential lots (**Figure 5**). The lowland was also devoted to backyard duck-raising and vegetable gardens in the 1940s to 1970s.

A significant change in land use and land cover happened in the mid 1980s to early 1990s when roads were paved and lands were bought by private people/corporation for conversion to industrial estates and later to residential lots.

The change brought the lowland farmers economic losses with low rice yields and high price of duck feeds that encouraged them to sell their farmlands (**Figure 6**). However, the rise of commercial establishments and industrial estates increased further built-up areas and urbanization implying lifestyle changes that lead to adverse environmental impacts. One of the impacts includes industrial effluents and domestic wastes improperly disposed to river systems that ultimately drained into the Laguna Lake. Also, flooding occurs in the events of typhoons Milenyo (2006) and Ondoy (2009) due to huge impervious surfaces and low infiltration rates in the area and loss of surface areas taken over by houses, commercial establishments and road network.

The high suitability and economic attractiveness for land conversion due to proximity to Metro Manila and abundance of quality groundwater of the Silang-Santa Rosa River Subwatershed has been favourable for industrial, commercial and residential uses which, likewise, encouraged in-migration of people/workers from adjacent municipalities and provinces. The economic development in the subwatershed has been increasing the rate of resource utilization particularly groundwater. Land cover change in the subwatershed from permeable to impervious surfaces has also been increasing the risk of the lowland of the subwatershed to flooding due to increased surface runoff (poor land drainage and lower land surface areas to absorb the detained excess run-off water). Land conversion from perennials to annual crops in the upland of the subwatershed has increased soil acidity and rapid destruction of organic matter leading to surface soil sealing and soil erosion in the sloping areas.

SUMMARY AND CONCLUSION

Collection and the integrated assessment of land cover, soils, and socioeconomic information is important in conducting assessment of land cover change in the Silang-Santa Rosa River Subwatershed.

Soil types found in the subwatershed include Lipa loam, Carmona clay loam, Carmona sandy clay loam, Tagaytay loam and Tagaytay sandy clay loam. These soils have low pH, OM content and fertility levels. The water holding capacity of lowland areas was relatively higher than in the upland areas. The intrinsic soil characteristics of the subwatershed varied relative to land practices in the subwatershed.

The dominant vegetative cover in the upland areas of the subwatershed includes fruit crops, tree crops and understorey. In the upland agroforestry system, coconut, fruit crops, banana, papaya, coffee and pineapple were found. The riparian vegetation in the mid slope of the subwatershed was dominated by tree crops and some grasses. At the lowland portion, grasses such as cogon and talahib were dominant. The vegetation cover in the subwatershed affects water yield of the subwatershed and determines the amount of excess rainfall that becomes runoff.

The market-driven succession in land cover in the subwatershed is characterized by conversion of agroforestry areas to idle lands awaiting conversion to built-up areas; and conversion of riceland areas to built-up areas. Based from the results of the PRA activity, the land cover change was driven by their local socioeconomic (investment and livelihood opportunities, and population increase) and biophysical condition (fertile soil, abundance of quality groundwater, and suitability of land for conversion). The lowland areas of the subwatershed serve as the water depletion/consuming zone and the mid slope and upland areas of the subwatershed provide the recharge of water for the subwatershed. Socioeconomic development is currently occurring at a very rapid pace in the subwatershed where most of the local people benefit from land investments and provision of job opportunities. But undesirable consequences such as sedimentation and flooding are now evident based from the reports made by the local people especially on their land resource.

Understanding the patterns and drivers of land cover change is important because it is closely-linked to the sustainability of socio-economic development and conservation of quality and functions of natural resources of the subwatershed. Assessment of the impacts of land cover change is crucial in order to support stakeholders and/or decision-makers in formulating and implementing policies to improve the management of land and water resources in the subwatershed.

This study complements the existing Santa Rosa Watershed Management Project by the WWF-Philippines and the local government of Sta. Rosa City, Laguna and Silang, Cavite as well as the LAKEHEAD Program of the Japan Research Institute for Humanity and Nature (RIHN) and University of the Philippines Los Baños (UPLB).

Recommendations

Further in depth study is recommended particularly on the projection of the future land cover of the subwatershed based from the patterns of land cover changes. Observe and document changing economic scenario vs economic opportunities in the continuous use of farm lands which changes must be market driven and profitable/improving net disposable incomes to catch up with economic values of non-farm uses. The impacts of land cover change on surface water and groundwater resources of the subwatershed should be evaluated through GIS-based modelling. Further, this GIS-based modelling approach can be used to determine the impacts of land cover changes on soil erosion particularly in the sloping areas of the subwatershed.

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