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Conservation under Regional Industrialization: Fragmentation and Cover Change in a Forest Reserve

ABSTRACT

Buffer zones are established along the perimeters of reserves for their protection. The literature is replete with examples of development in buffer zones that have been detrimental to the conservation efforts of the reserve. Barangay Puting Lupa in Calamba City, Philippines is adjacent to Zone 3 of the Mount Makiling Forest Reserve (MMFR). Despite industrial and settlement development in the periphery, the forest recovered its northwestern sub-watershed, as evidenced by satellite imagery, showing reduced fragmentation. Although the conservation strategy for MMFR changed from settler antagonism to a participative approach, other factors were involved that brought about the possible unassisted forest regrowth. Low density settlement development with corporate social responsibility committed to wildlife conservation; high demand for skilled labor due to rapid regional industrialization and urbanization; an aging corps of original farmers; the high regard of Filipino families for their children's education for better opportunities in life; and the livelihood preference of family members other than farming in lands with no security of tenure; all combined in an auspicious mix of factors to bring about apparent partial abandonment of farming within Zone 3 of the MMFR and conservation in the buffer zone. The forest recovered, and with decreased fragmentation, indicative of enhanced forest integrity.

Key words: *Makiling Forest Reserve, buffer zone, industrialization, urbanization, participatory conservation, community organizing, forest fragmentation, forest regrowth, GIS/RS*

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INTRODUCTION

Problems arising from unregulated extraction of forest resources have tremendously decimated Philippine forests, which are now at 5.4 million ha or 18% of land area nationwide (*FMB 2009*), from what used to be about 70% at the start of the 20th century (*DENR-FMB 2011*). What remains are forest reserves that include established timberlands, national parks, game reserves and sanctuaries, and forest fragments interspersed with grasslands and marginal areas where biodiversity are poorly understood. The conservation and management of forest fragments are issues that need to be taken into account in the light of climate change and the continuing degradation and poverty that haunt the rural and upland areas, with an estimated 20 million people growing at 2.8% per annum, greater than the national average by 0.7% (*ITTC 2003*).

Mt. Makiling Forest Reserve (MMFR), located at 14 8' North, 121 12' East and 65 km south of Metro Manila, Philippines, spans 4,244 ha of tropical rainforest. Its highest peak is at 1,090 masl. It has four sub-watersheds that nurture the peripheral populations in the City of Calamba and the municipalities of Los Baños and Bay in Laguna province, and Sto. Tomas in Batangas province *Pulhin and Tapia* (*2005*). Declared an Asian Heritage Park in 2013, it is a regional center for biodiversity and endemism. *Gonzales et al.* (*1997*) report 375 vertebrate species from seven sample sites with four types of cover. Others report 200 bird species identified (*UPLB 2014*), 59 of which are endemic (*Rabor 1977*). *UPLB* (*2014*) and *Pulhin and Tapia* (*2005*) report 2,038 floral species identified.

The management, administration, and supervision of the MMFR was restored to the University of the Philippines Los Baños (UPLB) by virtue of Republic Act 6967, passed by the Philippine Congress in 1990 (*Cruz et al. 1991, Lusterio 1996*). In the past, encroachment with slash-and-burn agriculture and timber poaching has led to extensive deforestation and fragmentation along the edges of this forest reserve. In a census and on-ground survey conducted in 1991, *Abraham et al.* (*1992*) report 992 upland farmers with 1,267 farm lots within the reserve, ranging from 0.5 to 6.0 ha, with an average size of 1.5 ha, for a total of 1,899 ha or 45% of the MMFR. With upland farming covering almost half the reserve, they recommended that the farmer occupants be involved in protection and conservation of the reserve, and in the monitoring and regulation of violators. From forced evictions in 1976 (*Pulhin and Tapia 2009*), the policy of UPLB on occupancy of the upland farmers in the reserve transitioned to cooperative forest conservation and protection in 1992, with agro-forestry as focus (*Lusterio 1996, Fernando et al. 2000*) Launched in 1992, the Mount Makiling Community-Based.

Conservation Project (MMCBP) was launched in 1992 (*Bagadion 2000*), as a pilot project for the change in strategy to participatory forest conservation, MMCBP initially involved only three barangays within the MMFR, namely: Bagong Silang, the most populous in terms of upland dwellers, and Timugan, both in the municipality of Los Baños, and Puting Lupa in Calamba City, the least populous, with only 41 confirmed farmers (3% of the total) in Zone 3 of the MMFR (*Abraham et al. 1992*).

The MMCBP adopted a community-centered, issue driven approach to organizing. Community organizers took up residence locally, which was then unprecedented, to show their sincerity and dedication. The move was done to overcome the initial hostile perceptions of the community toward any initiative of the university, due to past antagonistic conservation management measures. The residents of Bagong Silang were trained and assisted in the ground survey and planting of African tulip trees (*Spathodea campanulata*), indigenous to the Philippines with perennial red flowers, as border trees along the farm boundaries and protection areas. A series of workshops and seminars were jointly conducted by MMCBP and the residents, to train the upland dwellers on, among others, sustainable farming in the uplands. The residents even took the initiative in civil works for a community water system, reforestation, and rehabilitation of critical protection areas, sourcing their own funding and utilizing their own resources. The success of the program led to replication of the methodology in the other barangays of the MMFR (*Bagadion 2000*).

As a consequence, community organizing initially formed six Peoples Organizations (POs) of upland farmers within the MMFR from Bay and Los Baños towns in 1993. The POs federated into the Kapisanan ng mga Magsasaka sa Makiling (Federation of Farmers on Mount Makiling) in 1995, or KASAMA, to dialogue with UPLB (*Lusterio 1996*). But although four of the six POs entered into Memoranda of Agreement (MOAs) with UPLB, which was a landmark event for Philippine forest conservation and a precedent for other reserves to follow (*Bagadion 2000*), the MOAs then did not touch on the forest occupancy issue. Moreover, none of the original POs were from Calamba City. Ironically, although Barangay Puting Lupa was one of the three communities originally involved in the MMCBP, no PO was organized there.

Through their POs, the communities were later deputized as forest guards of the MMFR by then Sec. Angel Alcala of the Department of the Environment and Natural Resources (DENR). Meetings, seminars, and workshops were conducted to outline the policies for protection, conservation, and occupancy. The upland farmers were to strictly comply with the set policies as well as report violators (*Lusterio 1996*).

The Office of the Chancellor of UPLB issued Executive Order 2, series of 1994, entitled “Rules and Regulations in the Conservation, Sustainable Development and Management of the Mt. Makiling Forest Reserve”, which recognized the forest occupants who were in the reserve since 15 October 1990 and earlier “to work with UPLB.... in the conservation, sustainable development, and management” of the MMFR (*UPLB 1994*). As part of the agreement, no farm holding would be expanded, no new farms would be created, and border trees were to be planted along the boundaries of the farm lots to demarcate them. A Master Plan for MMFR was drawn up in 1995 to address, among others, the issue of forest occupancy. Although the intentions were for accreditation and stewardship awards for all recognized farmer occupants (*Fernando et al. 2000*), this did not come to fore with a change in the leadership of UPLB after the Master Plan was submitted for approval (*Barile pers. comm. 2016*). As such, the issue of the legality of the occupancy in the reserve of the farmers remains unresolved. Despite the initial survey, registration in the local barangays, and delineation of farm lot boundaries, no legal instrument exists for their claims. Despite all these setbacks for their accreditation, the communities embraced the concept of conserving the resource from which they derive their sustenance and shelter, and took to heart their new perceived roles as partners in its management. So regardless of the ambiguity of the legality of their tenure on the lands they farm, they police their members, protect their areas from poachers, apprehend violators, reforest denuded areas, rehabilitate damaged protection areas, and have independently drafted their own strategic plans for the MMFR (*Peñalba* *et al. undated*). During the early 1990s, nine POs, the original six plus two from Calamba City and one from the municipality of Sto. Tomas, Batangas, federated with KASAMA, which held its first congress in 1995 and drew up its own five-year development plan, including the issue of tenure on the lands they farm (*Bagadion 2000*). But still, no PO organized in Puting Lupa (*Barile pers. comm. 2016*).

In 2015, the MMFR Stakeholders Advisory Council (MMFRSAC) was created by a Memorandum of Agreement among the stakeholders. UPLB, the municipal and provincial governments, the regional offices of the DENR and Department of Tourism, the Biodiversity Management Bureau of DENR, the Laguna Lake Development Authority, the Water Districts of Laguna and Calamba, the Philippine National Police Region 4-A, and the Farmers Associations formed MMFRSAC as a venue for inter-agency cooperative projects for conservation and restoration projects (*MCME undated*).

There have been efforts to reforest along the buffer zones, but evidence of forest regrowth were also observed in areas where no reforestation projects were implemented before 2014, an indication of natural recovery of the forest, possibly through cessation of farming in the area. Noteworthy of such phenomenon is the area within Zone 3 of the MMFR adjacent to Puting Lupa, Calamba City, and the peripheral buffer area. Currently, no study has been conducted as to why this has come about, hence this research.

This study seeks to analyze the land use and land cover (LULC) changes in the MMFR and its buffer zone, focusing on Puting Lupa, Calamba City, along the northwest edge of the MMFR, as far back as available satellite imagery will allow, to 2014; Quantify the changes in deforestation and fragmentation in Puting Lupa, Calamba, Laguna and Zone 3 of the MMFR; and Hypothesize the dynamism between local governanceand UPLB policies, regional industrialization, and forest regrowth in Puting Lupa, Calamba, Laguna, as a basis for advancing a conceptual model for the phenomenon.

Forest Resource Depletion and Forest Fragmentation

In the developing world, forests are treated as sources of fuel, fodder, industrial inputs, and as habitat for plant and animal species (*UNEP 2009*). In India, Basu and *Nayak* (*2011*) report a notable increasing pressure in the conversion to pastoral and agricultural land coupled with the demand of forest goods and services. Rural poverty, cropping intensity and forest roads are also observed to bring undesirable effects on open and total forests in the study area. But they explained that in Odisha, one of India's forested states, further damage to forests can be reduced if they are not made as sites for industrialization. Likewise, *Dubey et al.* (*2009*) studied forestry resources depletion particularly in developing countries and concluded that the main causes of depletion are the way people use these resources, i.e., conserved for their welfare as sources of fuel, fodder, medicine, etc., or converted through development for agriculture, settlements, and industries. They used a nonlinear mathematical model which showed that even if the population is only partially dependent on forest resources, these resources are still in danger of loss because of population pressure exacerbated by industrialization.

Urbanization, being complementary with and treated as the special support and expected outcome of industrialization, also affects forest resources. Though it is necessary in the economic development of society, rapid, unguided urbanization can cause various problems. Large populations, which come with urban development, can lead to exploitation of nature and affects urban forest users, Atmis et al (2007) show in the natural forests of Turkey. Furthermore, *Lu et al.* (*2011*) noted through spatial analysis that rapid urbanization and industrialization in China have significantly changed the pattern of arable lands, particularly the rural areas surrounding the big cities in the eastern part of the country. In the Shandong Peninsula, a traditional agricultural area, which has undergone rapid urbanization and industrialization. The most plausible reason they observed is the continuous adjustment of government's policies and shift of farmers' economic interests. *Garcia-Montiel and Scatena* (*1994*) likewise find that human disturbances in the watersheds of the Loquillo, used for agro-forestry, selective logging, charcoal production, and Experimental Forest timber management in Puerto Rico, contributed negative consequences and spatial heterogeneity of the forest. They even noted several impacts that are still apparent after 50 years of unhindered regeneration of the forest.

According to *Fahrig* (*2003*), deforestation should be distinguishable from forest fragmentation, or the breaking up of the cover resulting in discontiguities in the original cover mixed with other uses. Habitat loss may adversely affect community composition and dynamics, biodiversity, and endemicity (*Laurance 1999; Fahrig 2003; Allnutt et al. 2008, Pardini et al. 2018*). However, habitat fragmentation has more profound effects on the local biota than just loss of the forest cover (*Goldsmith 1998; Primack and Corlett 2005; Laurance and Peres 2006*). The effects of deforestation penetrate inward from the cleared border into the remaining forests. Known as the edge effect (*Laurance 1991; Murcia 1995, Broadbent et al. 2008*), it dominates fragment dynamics (*Laurance et al. 2011*). The edge effect distance would be highly contextual to the species involved. Hence fragmentation could exacerbate the results of deforestation (*Skole and Tucker 1993*), and *Broadbent et al.* (*2018*) recommend the imperative for research into the ecological impacts of fragmentation and edge effects.

Aside from just the loss of cover, the composition of the patches could affect fragmentation (*McGarigal 2015*). For example, the more complex the patch shape, the lesser the core habitat area, resulting in increased fragmentation, which could adversely affect populations (*Van Dyken and Zhang 2019*). The configuration, or spatial arrangements, of the patches could likewise affect fragmentation (*McGarigal 2015*). Here, as patches cluster, the distances between patch clusters increase, isolating populations by restricting the range of species that cannot overcome non-forest spaces between the patch clusters. Fragmentation is thus increased, which could stress the populations (*Van Dyken and Zhang 2019*).

Forest Buffer Zones

A buffer zone is defined as "a zone, peripheral to a national park or equivalent reserve, where restrictions are placed upon resource use or special development measures are undertaken to enhance the conservation value of an area" (*Sayer 1991*). In the Philippines, a number of integrated conservation development projects in buffer zones have been instituted to protect and conserve biodiversity, although demarcation of boundaries of buffer zones and its categorization could be difficult because of contextual uniqueness (*Garrity et al. 1995*). *Sayer* (*1991*) listed the benefits of a buffer zone as:

Biological benefits

- Provide a filter or barrier against human access and illegal use of the strictly protected core zone or conservation area;
- Protect the strictly protected core zone or conservation area from invasion by exotic plant and animal species;
- Provide extra protection against damage by storms, drought, erosion, etc;
- Extend the habitat and thus population size of large, wide-ranging species in the protected area.

Social benefits

- Provide a flexible mechanism for resolving conflicts between conservation and the interests of the inhabitants of adjacent lands;
- Compensate people for loss of access to the strictly protected core zone or conservation area;
- Improve the earning potential and quality of the environment of local people;
- Build local and regional support for conservation programmes;
- Safeguard traditional land rights and cultures of local people;
- Provide a reserve of animal and plant species for human use and for restoring species;
- Populations and ecological processes in degraded areas.

Makiling Buffer Zone Problems

According to Sargento of the College of Forestry and Natural Resources of the University of the Philippines Los Banos (UPLB-CFNR), the issues and problems in the Makiling Buffer Zone that were presented during the 1995 National Workshop in Buffer Zone Management and Agroforesty are:

- Unregulated and uncoordinated land use conversions to subdivisions, resorts, and industrial development;
- Water shortage in some areas;
- Climatic changes and environmental degradation;
- Indiscriminate and uncoordinated solid waste disposal;
- Lack of active community participation in the formulation and implementation of plans;
- Rapidly increasing populations;
- Lack of people's awareness on environmental issues;
- Weak linkages and networking among LGUs, UPLB institutions, and non-government organisations (NGOs).

MATERIALS AND METHOD

Profile of the Study Site

Barangay Puting Lupa, with center at 121°10' E and 14° 09' N, is at the foot of the MMFR Zone 3. It has a maximum mean elevation of about 687 masl and a mean slope of more than 45%; its terrain is generally hilly to steeply hilly. As of 2012, Puting Lupa had a total of 453 households and a population size of 1,854.

Materials

- Satellite imagery of the study site, from as far back as possible, to the present, in ten-year increments.
- Historical data on administrative policies of UPLB for

the MMFR.

- Historical data on the agricultural practices of the residents of Puting Lupa.
- Household surveys of the residents of Puting Lupa to validate livelihood, agricultural practices, and family traditions.
- Data on the industrial parks in Calamba, Laguna, particularly name, location, year established, and if possible, historical data on number of locators, total investments, gross revenues, total number of employees.

Methods

Socio-Economic Survey

Initial data gathering focused on the socio-economic profile of the community was conducted August 2012 at Barangay Puting Lupa, Calamba City. For this purpose, the team coordinated with the Office of the Mayor of Calamba City and the Barangay Office of Puting Lupa, for the site reconnaissance, preliminary interviews, and formal field survey.

Available materials regarding the historical account of the administration of the MMFR were gathered from the library of the School of Environmental Science and Management, UPLB (SESAM-UPLB) and the External Linkages and Decision Support section of the Makiling Center for Mountain Ecosystems (MCME) of the CFNR-UPLB. For spatial data, satellite images were downloaded from the EarthExplorer site of the United States Geological Survey (*USGS 2014*) for 1993, 2002, and 2014.

For the survey, stratified random sampling was used to select the respondents. From the 453 total household population of the barangay, at 90% level of confidence, 75 household respondents were determined as the sample size. Allocating this sample size proportionately gives 15 samples for each of the five puroks, or local divisions of barangays, in Puting Lupa. The head of the household served as the main respondent for the survey. Simple random selection was used to determine the respondents for the study in each purok.

The survey questionnaire was designed and refined by pre-test surveys and group discussions. It specifically aimed to meet the objectives of the study. The questionnaire had six parts. Parts one to four are about the demographics of the household and migration patterns. The fifth part relates to community participation and organisation, while the sixth part is on community perception and aspiration.

Land Use Change Analysis

For the land use change analysis, Landsat images (Scene: Path = 116 and Row = 50) for 1993 and 2002 were downloaded (*USGS 2014*), to capture the changes during the early stages of the rapid urbanization of Calamba. The extents of the city were extracted from the Landsat scenes and subjected to unsupervised classification using IDRISI Taiga (*Clark Labs 2015*) as follows: forest, water, cloud, barren, mixed vegetation, and built-up areas. The images were then laid out using ArcMap (*ArcGIS 2016*). To complete the analysis, the area of each land use class was then calculated and correlated with population and policies.

Forest Fragmentation Analysis

To capture the eventual effects on the forest cover beyond the rapid urbanization phase of Calamba City (1993 to 2002), three Landsat images with less than 10% cloud cover at WRS 2 Path 161 and Row 50 approximately 10 years apart were acquired (*USGS 2014*) for the fragmentation analysis: 1993 Landsat 5 TM, 2002 Landsat 7 ETM+, and 2014 Landsat 8 OLI/TIRS scenes. The images were subsetted at upper left corner 14° 10' 43.0767" N, 121° 8' 26.600" E and lower right corner 14° 7' 54.602" N, 121° 11' 25.006" E, approximately 5 x 5 km for the study area. The extent enclosed Barangay Puting Lupa, parts of Calamba City in its periphery, and about 590 ha of Zone 3 of the MMFR adjacent to Barangay Puting Lupa. The same minimal cloud cover images for earlier years could not be obtained.

The boundary of the MMFR was obtained from the UPLB Titling Project. The boundary of Barangay Puting Lupa was digitized from scanned 1:50,000 map sheet 3229 III of the PNTMS series, edition 1 May 1993 from the National Mapping and Resource Information Authority (*NAMRIA 2014*). The farm lots in Zone 3 of the MMFR were digitized from a hand sketched map of their approximate locations (*Abraham et al. 1992*) rectified and georeferenced to the boundaries of the MMFR. The main highways and water drainage networks were acquired from online sources (P*hilGIS 2013*) and reprojected to WGS 1984 UTM 51N. The portion of the STAR Tollway and the secondary roads within the study area were digitized from satellite imagery and online sources. Other GPS points of interest were gathered during field visits and online sources as well.

Composites of the mid-infrared, near infrared, and visible red bands in the red, green, and blue channels overlaid with the water and appropriate road networks per year were used for the base maps (**Figures 1.a, 1.b,** and **1.c**) for the initial ground truthing and to guide activities in the field. The base maps also reflect the approximate road genesis and evolution in the area. Figure 2. Shows the land use map of Calamba City.

Bands 1, 2, 3, 4, 5, 7 of the Landsat 5 and Landsat 7 image subsets and bands 2, 3, 4, 5, 6, 7, 10 of the Landsat 8 image subset were statistically analyzed into 40 unsupervised Isodata classes at a standard deviation of 0.01, then grouped by spectral signatures and visual context into four land cover classes: forest, exposed soils, built-up, and other vegetation. The thermal bands were incorporated in the analysis to detect understory clearing as an aid in distinguishing forest from agro-forestry, where lush undergrowth characterizes forests, while farmers typically clear the undergrowth in agro-forestry plots to control weeds for understory agriculture.

Pixels indicative of high chlorophyll activity and lower mid-infrared and thermal responses, especially within the MMFR, were classified into forest. Pixels indicative of infrastructure (i.e. roads, buildings, parking lots), where chlorophyll activity were low with high visible and mid-infrared responses were classified as built-up. Since exposed soils with sparse vegetation were spatially correlated to both infrastructure and agricultural fields, it had to be included as a separate class otherwise land use between built-up and agriculture could get confused. Other pixels that did not qualify as any of the preceding, i.e., high chlorophyll activity and mid-infrared/thermal returns, were classified as other vegetation.

The land cover layers for succeeding periods were overlaid to obtain the land cover transitions. Zone 3 of the MMFR was used to clip the corresponding land cover layers. The clipped layers for succeeding periods were the transitions within Zone 3 of the MMFR. For the fragmentation analysis, the four classes were further reduced to forest and non-forest binary classifications of the study area and the MMFR Zone 3, for all three years.

Single-valued fragmentation indices have been proposed in the literature (*Eastman 1996; Matheron 1970, in Lambin and Ehrlich 1997; McGarigal and Marks 1995*). The Spatial Deforestation Fragmentation Index (SDFI) proposed by Cabral et al (2018) uses the eigenvectors of two principal components with the loadings of Fragstats metrices, i.e. standardized values for number of patches (NP), edge density (ED), mean patch area (MPS), and proximity (PROX). None of the proposed fragmentation

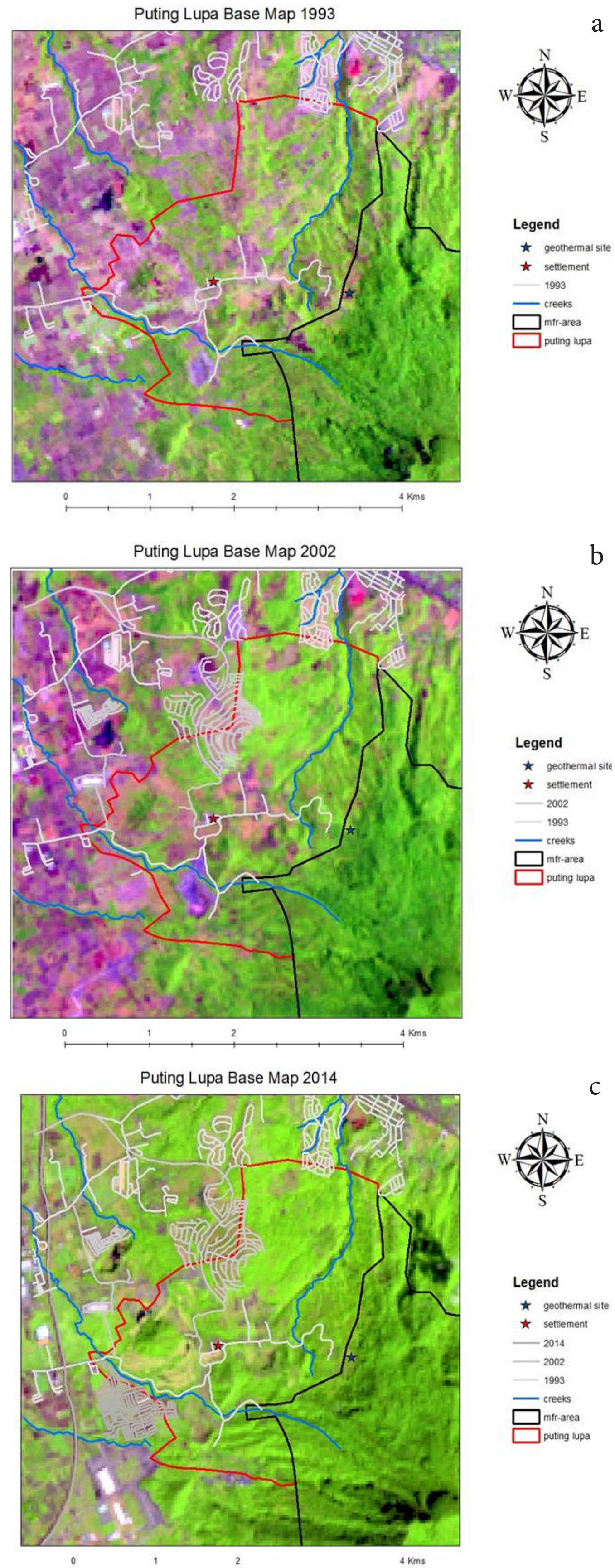

Figure 1. Puting Lupa Base Map, 1993 (a); Puting Lupa Base Map, 2002 (b); and Puting Lupa Base Map, 2014 (c).

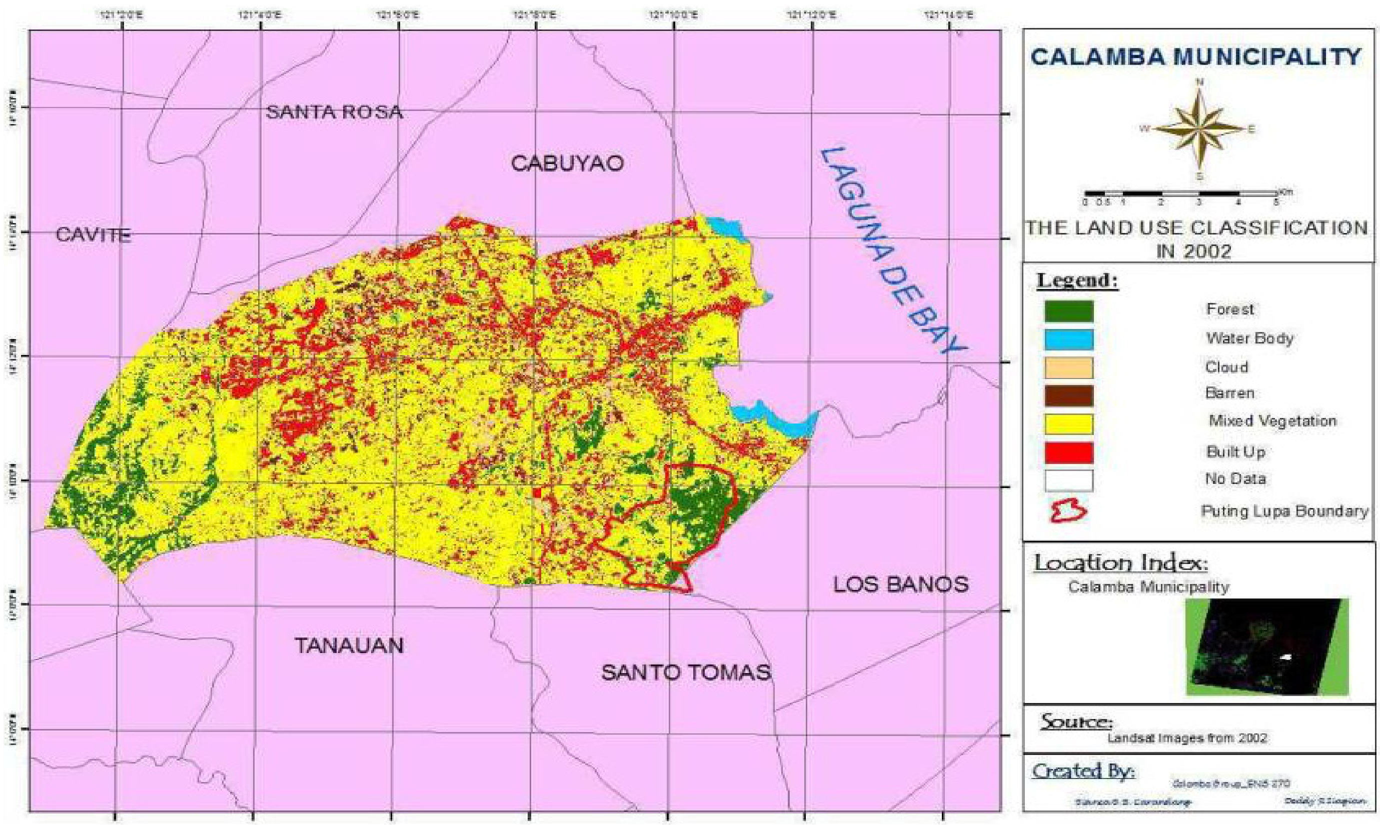

Figure 2. Land Use Map of Calamba City showing the study site.

indices, however, are in popular use. SDFI is very recent, but all require considerable computational effort for their application. The Matheron index will be used to measure forest fragmentation in this research, and will be computed from landscape indices derived from Fragstats.

Given a binary forest and non-forested landscape, the index due to Matheron is:

$$M = \frac{(\text{number of joins between forest and non-forest pixels})}{(\sqrt{\text{number of forest pixels}}) * (\sqrt{\text{number of total pixels}})} \qquad (1)$$

The index due to Matheron involves only joins between dissimilar pixels. Dissimilar pixels occur only along the edges of the patches in binary images. The Matheron index M is not in the suite of landscape indices in Fragstats (*McGarigal et al. 2012*). It can, however be estimated by adjusting for the area and distance units of the raster data for the Fragstats indices, given their resolution.

Total class area CA is given as hectares in Fragstats by default. So multiplying CA by 10,000 and dividing by the area per pixel, in this case 900 m^2 for 30 x 30 m pixels, or multiplying by 100/9, gives the number of y. pixels for any Fragstat class of the raster data derived from Landsat imager

Total edge (TE) in Fragstats is the total absolute edges of the patches in raster data, which is equal to the number of joins between dissimilar pixels, if adjusted for pixel dimension. TE is computed in the linear units of the pixels, so horizontal and vertical edges of a pixel would be exactly the side of a cell, in this case 30 m. Since FRAGSTATS measures absolute edges of raster data, i.e. there are no diagonal edges, a pixel at a corner of a forest patch would have an edge length equal to the cell size * 2, but would also have two joins with non-forest pixels. For a non-corner pixel along the border of a forest patch, the edge length would simply be the cell size, and there would only be one join with a non-forest patch. Since these are the only possibilities, The study has:

$$(\text{number of joins between forest and non-forest pixels}) * 30 = \textbf{TE} \text{ for Landsat derived data} \qquad (2)$$

thus:

$$M = \frac{(\textbf{TE} / 30)}{\text{SQRT}(\textbf{CA}_f * 100/9) * \text{SQRT}((\textbf{CA}_f + \textbf{CA}_{nf}) * 100/9)} \quad \text{........ eqn (3)} \qquad (3)$$

where, as computed using Fragstats :

TE : total edge, in meters,
CA_f : forest class area, in hectares,
CA_{nf} : non-forest class area, in hectares; and
M : the Matheron index

RESULTS AND DISCUSSIONS

Socioeconomic Profile of the Respondents

There were a total of 75 respondents with 49 males (65.3%) and 26 females (34.7%) and ages ranged from 18 to 80 years old (**Table 1**). Thirty-three of the 75 surveyed finished high school, while 20 attained at least an elementary education. The difference between the number of migrants and natives in the barangay is small. Out of the 55 respondents who were born in Laguna, 51 are native (68%) to Calamba. Forty of those native to Calamba are indigenes of the community. On the other hand, migration to the barangay of non-natives is usually by affinity through marriage to a native of the area.

Table 1. Respondent's Social Characteristics.

Variable	Category	Frequency	Percentage
Gender	Male	49	65.3
	Female	26	34.7
Age	18-30	9	12.0
	31-40	17	22.7
	41-50	14	18.7
	51-60	15	20.0
	61-70	15	20.0
	71 and above	4	5.3
	Missing*	1	1.3
Educational attainment	Elementary	20	26.7
	High School (started)	8	10.7
	High School (graduated)	33	44.0
	College (started)	9	12.0
	College (graduated)	4	5.3
	None	1	1.3
Native to the community	Yes	40	53.5
	No	35	46.7
Place of origin	Batangas	4	5.3
	Bicol	3	4.0
	Iloilo	2	2.7
	Laguna	55	73.3
	Marikina	1	1.3
	Marinduque	2	2.7
	Nueva Ecija	4	5.3
	Pangasinan	3	4.0
	Quezon	1	1.3

Household sizes ranged from 1 to 13 members, with an average household size of 5. Of the households interviewed, 50.7% are employed in industries within Calamba. Thus at least one member of every household interviewed works in the nearby industrial parks, factories, and business establishments in the environs of the MMFR, confirming the view that industrialization provides employment for the residents.

Majority of the households earn as much as PhP 20,000 monthly while a smaller fraction earns above this amount (**Table 2**). The average monthly income ranges from PhP 10,000 to PhP 20,000 (US$ 200-400). Three households derive livelihood solely from farming, with the farmers aged 60 and above, while three other households are both employed in industry and still continue farming. Since the MMFR Buffer Zone barangays were predominantly agricultural in the 1990's (*Cruz et al. 1991*), it could be deduced then that the growing industrial activities within the proximity of Barangay Puting Lupa were providing external sources of employment for the residents. Households classified as 'Others' are neither employed in industry within Calamba nor subsists on farming, and could include entrepreneurship or private/government employees. No

Table 2. Household Profile and Employment.

Variable	Category	Frequency	Percentage
Household size	1 – 5	48	64.0
	6 – 10	25	33.3
	10 and above	2	2.7
	Mean = 5		
Household Monthly Income (PhP)	< 5,000	14	18.7
	5,001 – 10,000	18	24.0
	10,001 – 15,000	11	14.7
	15,001 – 20,000	14	18.7
	20,001 – 25,000	4	5.3
	25,001 – 30,000	5	6.7
	30,001 – 35,000	1	1.3
	> 35,001	8	10.7
	Mode = 10,001 – 20,000		
Household Employment	Industry (within Calamba)	38	50.7
	Farming	3	4.0
	Both	3	4.0
	Others	30	40.0
	Retired	1	1.3

distinction was made for employment in industries outside of Calamba, as it is not the objective of this research.

Employment

One of the hypotheses of this study is that industrialization near the MMFR Buffer Zone provides employment opportunities for the residents of Barangay Puting Lupa. To validate this hypothesis, one of the objectives is to determine the age group and educational attainment of the working population as well as to deduce the relationship between household income and household employment.

Nearly 50% of the respondents (household heads) interviewed were unemployed. Only 10 were working in the industries within Calamba, while 28 were engaged in non-industrial work, and 2 were retired (**Table 3.a**). Of those working, 19 were aged from 31 to 60 years old.

There is a substantial difference between employment of the household head and the household unit. Household unit employment is used in this research as the basis for analysis in determining the impact of industrialization on the type of occupation. To reiterate, although only 13.33% of the respondents worked in industry, 50.7% of the total households had at least one member employed in the industries within Calamba.

Generally, majority of those who were employed in industry graduated from high school. There is a positively moderate relationship between household income and the number of members in the household employed in the industries within Calamba (**Table 3.b**). This means that household income increases with the number of members employed in industry.

Land Use Change Analysis

Built-up areas increased by 2,216.91 hectares (79%) and mixed vegetation decreased by 2,947.52 hectares (28.77%). Meanwhile, forest area increased by 246.88 ha

Table 3.b. Correlation between family income and the number of household members employed in industries in Calamba.

	Statistic	HH Income	MEIIC
HH Income	Pearson Correlation	1	.604**
	N	75	75
# of HH members employed in industries within Calamba (MEIIC)	Pearson Correlation	.604**	1
	N	75	75

(17.57%). (**Table 4**; **Figures 3.a** and **3.b**).

Correlation of the population to land use during 1993 and 2002 reveals that there is a strong inverse relationship between population and mixed vegetation. As population increases, the mixed vegetation area decreases. Moreover, there is a strong proportional relationship between population and built-up areas. As to be expected, as population increases, built-up areas also increase. Land use change is influenced by local needs, nearby urban demands and remote economic forces (*UNEP 2007*). The industrialization and population growth in Calamba led to the increase in number of infrastructure and human settlements. This drove the conversion of the mixed vegetation cover to built-up areas. Results of the correlation also revealed that there is a strong proportional relationship between population and forest cover area. As population increases, forest area also increases. According to *UNEP* (*2007*), the greatest changes over the last twenty years have been the conversion of forests to croplands; however, this was not the case for Puting Lupa. Although built-up areas increased within Puting Lupa in 2002, forest cover also increased (**Figure 3.b** and **3.a**). It is this seeming contradiction that prompted this research, the possible reasons for which will be discussed.

Forest Fragmentation Analysis

The classes are: 'forest', 'built-up', 'bare or exposed soils', and 'others'. So agriculture, grass, and mixed

Table 3.a. Respondent's Employment by Educational Status.

Employment	Educational Attainment						Total
	Elementary	High School (enrolled)	High School (graduate)	College (enrolled)	College (graduate)	None	
Industry within Calamba	1	0	8	0	1	0	10
Non-industry within Calamba	5	4	11	4	3	3	30
Unemployed	14	4	12	5	0	0	35
Total	20	8	31	9	4	3	75

Table 4. Land Use change in Calamba City.

Land use	1993		2002		Net Change	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Forest	1,157.94	7.50	1,404.82	9.11	246.88	17.57
Water	43.78	0.28	120.15	0.78	76.37	63.56
Cloud	186.90	1.21	515.80	3.34	328.90	63.77
Bare soil	257.00	1.67	335.02	2.17	78.02	23.29
Mixed Vegetation	13,193.86	85.51	10,246.34	66.41	(2,947.52)	(28.77)
Built-up	589.45	3.82	2,806.36	18.19	2,216.91	79.00

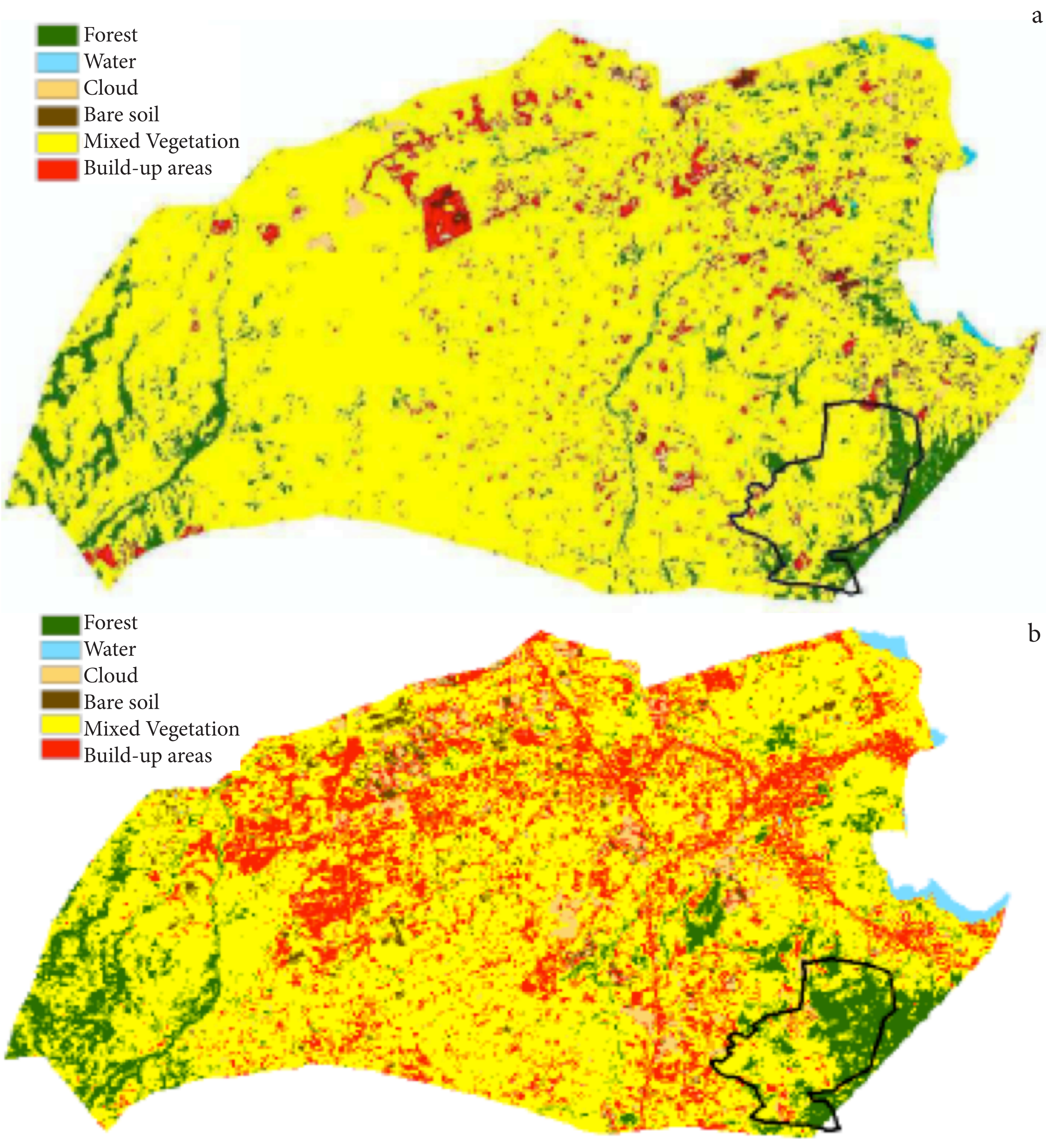

Figure 3. Land Use of Calamba City in 1993 (a); Land use of Calamba City in 2002 (b).

vegetation all fall under 'others'. Hardly any bare soils were detectable in 2014, which may have converted to 'built-up' or classified as 'others', as the Landsat 8 image was acquired in February, where the showers from a particularly wet Northeast monsoon toward the end of 2013 may have induced vegetative growth, whereas the Landsat 5 1993 and the Landsat 7 2002 images were acquired in April at the height of summer during particularly intense El Nino years, hence the prevalence of exposed or bare soils (**Figures 4.a, 4.b, and 4.c**).

The resolutions of the imageries and the extents of the subsets used for the base maps vary slightly: 28.5 x 28.5m resolution for the 1993 Landsat 5 image with an extent of 184 rows by 187 columns, 30 x 30 m resolution for the 2002 Landsat 7 image with an extent of 174 rows and 177 columns, and 30 x 30m resolution for the 2014 Landsat 8 image with an extent of 175 rows and 178 columns. Hence the total pixels reported for the transitions in 1993 to 2002, and in 2002 to 2014 may vary slightly, as the image subsets from the full scenes may not exactly match. However, all reported pixels in the transition analysis are uniformly 30 x 30m.

From **Table 5.a**, of the total 9,301 forest pixels (837.09 ha) in 1993, 159 (14.31 ha or 2%)) converted to built-up, 463 (41.67 ha or 5%) went to 'bare soils', while 1,338 (120.42 ha or 14%) were lost to 'others' in 2002. However, forest pixels increased to 11,351 (1021.59 ha or 22%) in 2002, where built-up contributed 30 pixels (2.7 ha or <1%), bare soils added 528 pixels (47.52 ha or 5%), and 3,452 pixels (310.68 ha or 30%) from others, for a net gain of 2050 pixels or 184.5 ha (22.04%) from 1993 to 2002 (**Tables 5.a and 5.b**).

From **Table 5.b**, of the 11,314 forest pixels (1018.26 ha) in 2002, 660 (59.4 ha or 6%) converted to built-up while 1,058 (95.22 ha or 9%) were lost to others in 2014. However, forest pixels increased to 14,264 (1283.76 ha or 26%), of which 332 pixels (29.88 ha or 2%) came from built-up, 1,589 pixels (143.01 ha or 11%) from bare soils, and 2,747 pixels (247.23 ha or 19%) from others, for yet another net gain of 2,950 pixels or 265.5 ha (26.07%) from 2002 to 2014. Overall, the gain from 1993 to 2014 is 5000 pixels or 450 ha (53.76%).

From **Table 6.a**, from the MMFR portion in the study area, 5,466 forest pixels (491.94 ha) in 1993 increased to 5,661 pixels (509.49 ha) for a net gain of 195 pixels or 17.5 ha (3.58%) in 2002. Only 284 (25.56 ha or 5%) forest pixels in 1993 turned into others in 2002. Meanwhile, 44 pixels (3.96 ha or <1%) of bare soil and 436 pixels (39.24 ha or 8%) from others in 1993 returned to forest in 2002.

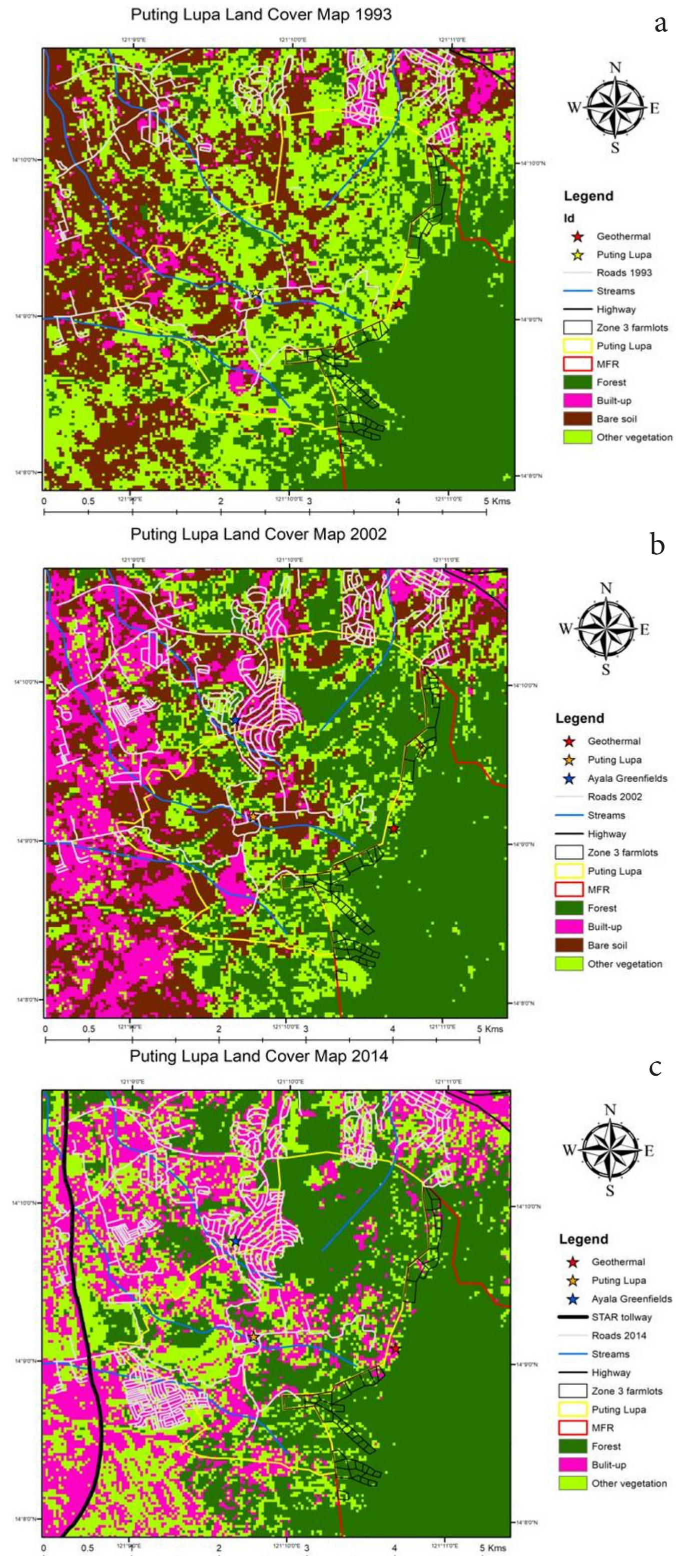

Figure 4. Puting Lupa Land Cover, 1993 (a); . Puting Lupa Land Cover, 2002 (b); and Puting Lupa Land Cover, 2014(c).

There is another increase from 5,664 forest pixels (509.76 ha) in 2002, to 5,854 (526.86 ha) for yet another net gain of 190 pixels or 17.1 ha (3.35%) in 2014 (**Table6.b**). The increase came from 388 (34.92 ha or 7%)

Table 5a. Puting Lupa Land Cover Transition Tables, 1993 to 2002.

pixels	2002				totals
1993	forest	built-up	soils	others	
forest	7,341	159	463	1,338	9301
built-up	30	537	646	192	1,405
soils	528	3,569	3,697	1,375	9,169
others	3,452	1,672	2,948	2,888	10,960
totals	11,351	5,937	7,754	5,793	30,835

Table 5.b. Puting Lupa Land Cover Transition Table, 2002 to 2014.

pixels	2014				totals
2002	forest	built-up	soils	others	
forest	9,596	660	0	1,058	11,314
built-up	332	3,399	0	2,206	5,937
soils	1,589	3,334	0	2,831	7,754
others	2,747	1,498	0	1,548	5,793
totals	14,264	8,891	0	7,643	30,798

Table 6.a. MMFR Land Cover Transition Table, 1993 to 2002.

pixels	2002				totals
1993	forest	built-up	soils	others	
forest	5,181	0	1	284	5,466
built-up	0	0	0	1	1
soils	44	0	10	18	72
others	436	1	24	225	686
totals	5,661	1	35	528	6,225

Table 6.b. MMFR Land Cover Transition Table, 2002 to 2014.

pixels	2014				totals
2002	forest	built-up	soils	others	
forest	5,465	37	0	162	5,664
built-up	1	0	0	0	1
soils	0	0	0	0	0
others	388	27	0	113	528
totals	5,854	64	0	275	6,193

others pixels in 2002 regaining forests in 2014. Thirty-seven forest pixels in 2002 (3.33 ha or <1%) turned into built-up, while 162 forest pixels (14.58 ha or 3%) went to others. Overall, from 1993 to 2014, forest gained 388 pixels or 34.92 ha (7.1%).

The area and pecentage change of forest per year for the whole extent, and the portion of Zone 3 of the MMFR were summarized in **Tables 7.a and 7.b**.

The forest cover gained steadily over the years for both the whole extent (**Figure 5.a**) and the study area in the MMFR (**Figure 5.b**).

Table 7.a Forest Cover of Whole Extent and Percentage Change, 1993-2014.

Year	Area (ha)	% Change
1993	841.33	-
2002	1,018.26	21.03
2014	1,289.61	26.6484

Table 7.b. Forest Cover of MMFR in Study Area and Percent Change, 1993-2014.

Year	Area (ha)	% Change
1993	497.75	-
2002	510.75	2.61
2014	540.27	5.78

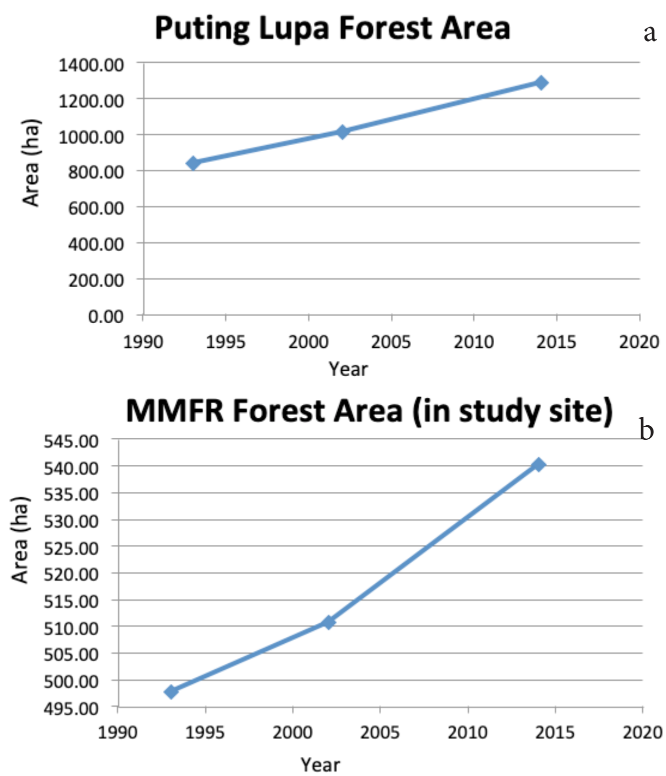

Figure 5. Puting Lupa Forest Cover, 1993-2014 (a); MMFR Forest Cover (in study area), 1993-2014(b).

The Matheron indices for the whole extent and for the portion of the MMFR in the study area were computed (**Tables 8.a. and 8.b.**). Over the 20 year span, the tables and graphs for forest cover and fragmentation show that for the whole extent, forest cover increased while forest fragmentation decreased then returned to its former level. However, for the portion of the MMFR within the study area, forest cover increased while fragmentation decreased (**Figures 6.a and 6.b**).

Between 1993 and 2002, both fragmentation and forest cover increased in the whole extent, counter to the notion of most regarding fragmentation. *Fahrig* (*2003*) wrote that deforestation should be distinguishable from fragmentation, a phenomenon that this fragmentation index seems to capture, given its definition of simply the ratio of unlike joins to the product of the square roots of the forest and total pixels. Increasing forest cover with generally constant or declining fragmentation indicates that during the 20 or so years in the study, the forest recovered in a manner that enhances its integrity and ability to perform its ecological functions (*Laurance et al. 2011*). Since there were no known replanting campaigns in the area prior to 2014, as corroborated by key informant interviews (*Barile 2016*), forest regrowth must have occurred naturally.

Table 8.a. Landscape and Matheron Indices: Puting Lupa.

Year		CA	PLAND	TE	M
1993	forest	841.33	30.10	177,156	0.35
	non-forest	1953.46	69.90		
	total	2,794.79			
	%non-forest	0.70			
2002	forest	1,018.26	36.74	173,940	0.31
	non-forest	1,753.56	63.26		
	total	2,771.82			
	%non-forest	0.63			
2014	forest	1,289.61	46.00	220,650	0.35
	non-forest	1,513.89	54.00		
	total	2,803.50			
	%non-forest	0.54			

Table 8.b. Landscape and Matheron Indices: Zone 3, MMFR in study area.

Year		CA	PLAND	TE	M
1993	forest	497.75	87.93	25,963.5	0.15
	non-forest	68.3103	12.07		
	total	566.06			
	%non-forest	0.12			
2002	forest	510.75	90.90	24,900	0.14
	non-forest	51.12	9.10		
	total	561.87			
	%non-forest	0.09			
2014	forest	540.27	94.33	21,750	0.12
	non-forest	32.49	5.67		
	total	572.76			
	%non-forest	0.06			

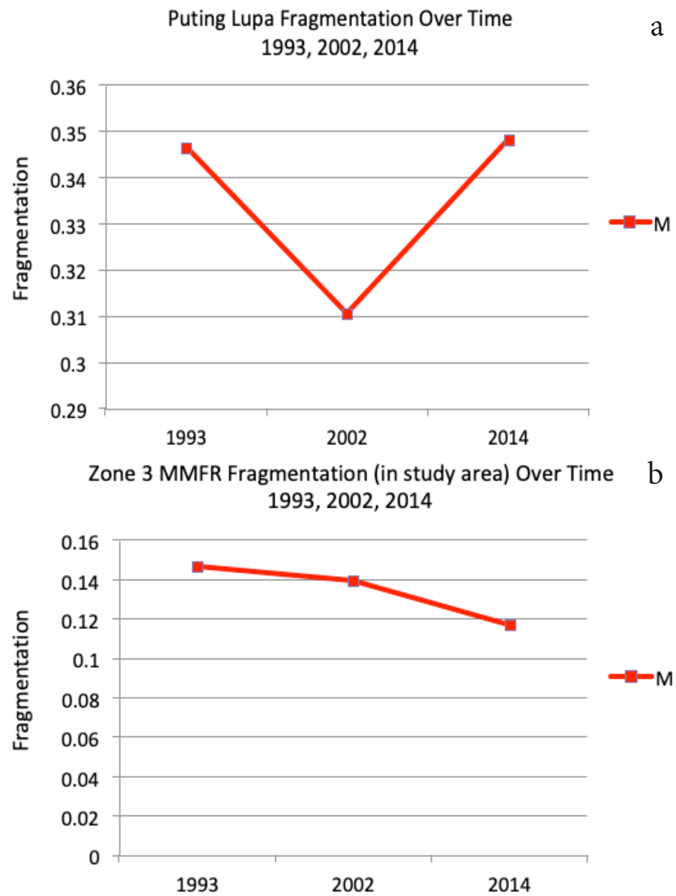

Figure 6. Puting Lupa Forest Fragmentation, 1993-2014 Zone 3, MMFR (in study area) Forest Fragmentation, 1993-2014(b).

Possible Explanations

So the question that comes to mind is why forest regrowth occurred at all? The first hunch was that access was hindered by settlement development in the buffer zone. Since the 1990s, upscale subdivisions and industries, most with gated, restricted entries, have flourished in the area, which could have denied access to the forest. Indeed, the literature is replete with examples of forest clearing after access is gained via roads (*Pfaff et al. 2007*).

However, it is not so in this case. The road that was cut in the mid-1980s passing through the settlements of the former upland farmers ascending to the then abandoned geothermal drill site (now actively generating power) just within the boundaries of the MMFR (**Figures 1.a, 1.b,** and **1.c**) still exists and is open to this day. Another road to the southwest of the geothermal site also serves as access into the MMFR for the residents. So the MMFR from these roads remain accessible, and yet the forest recovered in the periphery of the road termini.

Forest stewardship would have led to increased farming activity within the farm lots in Zone 3 of the MMFR, and thus cannot be the reason for the regrowth in the farm lots. Enforcement of protection policies by the community would induce regrowth outside the farm lots, (**Figures 4.a, 4.b,** and **4.c**), but would be presumptive with the knowledge that no PO organized in Puting Lupa. Indeed, the statutes that delineate the MMFR and designate UPLB as the sole entity for the management of the MMFR (*Cruz et al. 1991; Lusterio 1996)*, were re-emphasized in 1992 to all residents in the buffer zones, Puting Lupa included (*Cruz et al. 1991*). And although the residents in the buffer zone are aware that farming within the MMFR is restricted, MCME of the CFNR has only a handful of forest guards to cover the more than 4,900 ha of the MMFR (*MCME undated*), and enforcement by MCME has always been an issue in the past given the dearth of available resources (*Torres and Abraham undated*), and has even resulted in fatal events involving forest guards (*Senate of the Philippines 2011*).

So if enforcement by MCME or the community and restricted access were probably not the causes for the drastic reduction of farming within Zone 3 of the MMFR adjacent to Puting Lupa, the remaining assumption is that the farm plots within the MFR were abandoned voluntarily. But for what reasons, when just two decades ago there were perceived needs by the residents to supplement their family incomes by farming within the MMFR?

If the reasons are not exogeneous to the upland farmers, then they most probably are internal to them. And within their perceived needs or their current capacities may lay the answers this research seeks. The authors argue that at the time of the survey, the upland farmers of Puting Lupa saw less need to supplement their meagre incomes by farming within the MMFR, or that their capacity to do so has been severely reduced.

What then changed over the 20 years that may have altered these perceived needs or capacities? Definitely they would be much older, in their early fifties to early nineties (**Table 1**), if they had families then. To continue farming about 1.6 km away from their residences would require considerable effort, unless the farmer had additional manpower from either his children, who would rather enter the labor market, or through significant capital expense for hired labor, which would make little sense for farming on lands with no security of tenure. The money for labor would have been of better utility in other quick return ventures, such as a sari-sari store (small village stores that cater to the residents' needs), which are apparent in Puting Lupa and borne out by the survey.

Generally, Filipino families value formal education (*Federal Research Division, Library of Congress 2013*), especially for their children, in the hopes of raising their standards of living through employment or entrepreneurship. Landless farmers especially desire that their children need not lead the same spartan lives fate has dealt them, and a formal education has always been seen as a means to rise above one's current circumstances.

Since 1992, when Fidel V. Ramos assumed the presidency of the country, as a move to decongest Metro Manila, industries have been encouraged, through tax breaks and real estate tax structures, to locate in a rising number of industrial estates in the provinces to the south and north. The new policy induced rapid urbanization in Calamba, mostly in the former Canlubang Sugar Estate, which extended from Canlubang in Calamba to San Pedro, Laguna in the north, oriented length-wise a few kilometres parallel to the western edge of the South Luzon Expressway (SLEX). The extensive land holdings of the Yulo family converted from agricultural to industrial and commercial (*Rivera and Santos 2012*), pre-empting the implementation of the Comprehensive Land Reform Program or RA 6657 of 1988 (*DAR 2013*).

There are eight Manufacturing Industrial Estates and two Information Technology (IT) Parks and Centers in Calamba (*PEZA 2013*). At least two of these industrial estates, the Light Industry and Science Park I in Real, Calamba, who employ more than 10,000 workers (SPPI 2014), and the 265 ha Carmelray Industrial Park II in Tulo, Calamba (*The Carmelray Group 2010*) are within six km of Puting Lupa, an easy daily commute for potential workers from the community.

Another employment attraction is the ever lucrative overseas job market, whose remittances have kept the country afloat through the lean years of the 1990s. Remittances have steadily increased through the years, and reached US$ 17.35M in 2009 for 8,579,378 Overseas Filipino Workers, working from Algeria to Yemen or on the high seas, and US$ 22.97M in 2013 (*POEA 2014*). For both years, remittances were more than half the national budgets for the Philippines at PhP 1.44T (US$ 32.72M @ 1US$:44PhP) in 2010 and PhP 2.006T (US$ 45.59M) in 2013 (*BSP 2012*).

As corroborated by key informant interviews, most children of the upland farmers strive for at least a high school education, and prefer employment here or abroad, rather than work on a farm, which seems to be a trend for farming families in the country. Contributions to the family income would be welcome, and would dampen the perception for the need of supplemental income from farming in the MMFR. Moreover, transitioning of their children to the employment labor force irreversibly reduces the capacity of the upland families to continue farming in the MMFR, more so without tenure to the land they till.

Since these findings seem to go against the grain of popular wisdom between development in the buffer zone of a forest resource and deforestation within (*Garrity et al. 1995; Sayer 1991; Garrett et al. 2018; Mikusiński el al. 2018*), it would be wise to consider the results as highly contextual to the general economic environment in the periphery and the mode of development in the buffer zone. Calamba City, which has 580 ha in the MMFR and 333 ha in its buffer zone, has been riding an economic wave ever since cityhood in 2001, claiming an income of PhP 1.7B (US$ 38.6M) in 2012, mostly from the industrial parks and its locators (*City Government of Calamba 2012*). The housing developments in the study area are low-density, high-end market communities with gated, limited access entries, characterized by the Ayala Greenfield Estates, a 350-ha community that is committed to conserving the environment. A 15-ha Nature Park is maintained within the property (*Ayala 2014*), clearly discernible in the cover maps (**Figure 3 4.a, 4.b, and 4.c**), as refugia for 35 species and 21 families of endemic and migratory birds. Additional copses of trees and other vegetation scattered throughout serve as conservation patches and corridors.

CONCEPTUAL MODEL

From the discussion above, forest regrowth was not the consequence of just one factor or event, but a coincidence of several favorable factors occurring simultaneously. The most significant would arguably have to be the rapid industrialization of Calamba to provide livelihood for a growing population, and the City's policy of allowing only high-end, low density housing in the buffer zone of the MMFR, with conservation as their corporate social responsibility agenda. Complementing these are the availability of a literate labor force nurtured by the access to and esteem for education by the farming families, and the ageing corp of farmers themselves who abandoned farming in the MMFR. Of course none of these would matter were it not for responsible reserve management that was dedicated to its conservation (**Figure 7**). An active People's Organization, if one existed in Puting Lupa, Calamba, would have enhanced conservation, as happened in Bagong Silang, Los Banos. However, in this instance, neither did their absence lead to the degradation of the forest.

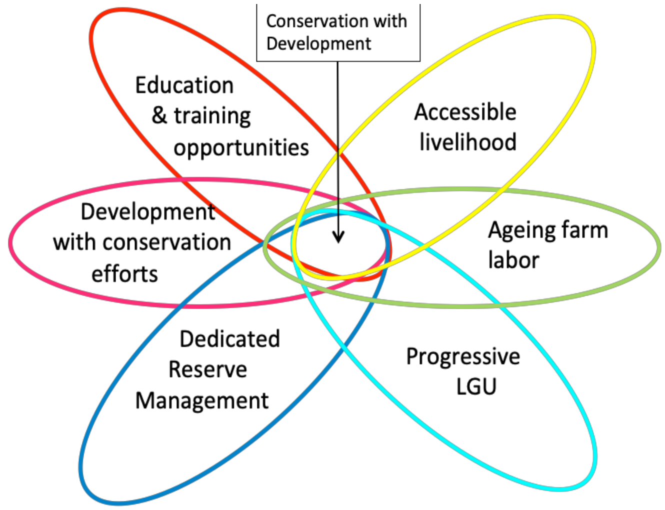

Figure 7. Conceptual model for conservation with development.

CONCLUSIONS AND RECOMMENDATIONS

The authors presented an example of forest conservation in a reserve and its buffer zone, in the context of regional industrialization and urbanization, which runs counter to popular opinion. However, the findings are highly contextual to economic and land development, a presumed community-based conservation effort, opportunities for at least a secondary education, and employment, either in the buffer zone or periphery of the reserve. One may ask whether policy between the local governments, the reserve managers, and the community itself could replicate forest regrowth elsewhere. In fact a body already exists for the MMFR specifically for this purpose. Would strengthening the MMFR Stakeholders Advisory Council result in policies that could lead to forest conservation and development elsewhere within the periphery of the reserve?

Further study is recommended in other communities where forest regrowth, in the MMFR or any other forest reserve, is observable, to ascertain whether Puting Lupa is a unique, isolated case of forest conservation cum development, or if there are any other positive trends of forest recovery in their buffer zones. But howsoever one finds, the knowledge that resource conservation and development in the buffer zones need not be incompatible, albeit in a highly contextual and auspicious confluence of factors, may be shared with other local government units and reserve managers. As such, the timing of the socio-economic survey was crucial to capture the conditions in the community relevant to the gains in the conservation of the reserve and its buffer zone, preceding any replanting campaigns in the area. More recent data may have not have captured the same dynamic.

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Ms. Cherry S. Padilla, a co-author of this article, is currently a member of the JESAM Editorial Staff. This study was conducted prior to her appointment. The review process of this article was administered exclusively by the Managing Editor, Dr. Rico C. Ancog.