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Changing Urban Landscape and Its Implications in Environmental Management: The Case of Calamba City, Philippines

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ABSTRACT

Urban landscape is a dynamic system that is altered by disturbances. The changes in landscape patterns between 2003 and 2010 of an urban area in the Philippines were analyzed by using landscape metrics related to size and shape. A transition table was created to determine the transformation of land class type within the period of analysis. Eight land class types were identified by using the land use-land cover classification scheme used by NAMRIA (i.e. closed forest, open forest, annual cropland, perennial cropland, built-up area, wooded grassland, grassland, and shrubland). Annual cropland dominated the landscape in 2003 while built-up area dominated in 2010. There is a significant reduction in the computed class area for annual cropland between 2003 and 2010 due to its conversion to built-up area, grassland, and forests in 2010. Computed landscape metrics indicate shape complexity for all land class types, and relatively less fragmented landscape. The increasing computed class area for built-up area between 2003 and 2010 highlights the need to implement an effective management strategy that can address flooding, solid waste disposal, and pollution. Unless this will be done, the rapid urbanization of the City will lead to a greater environmental catastrophe in the future.

KEYWORDS

Landscape Ecology, landscape, urban, metrics, environmental management, Calamba City, Philippines

INTRODUCTION

Urban landscape is a dynamic system whose structures are altered continually through time. Its attributes may be construed as by-products of the complex interactions between natural environment and human activities (Shi, Xiao, and Shena, 2008). From an ecological perspective, urban landscapes may be described as unique mosaics of sites that are constructed for residential, commercial, industrial, and infrastructural purposes interspersed with green spaces (Breuste, Niemelä, & Snep, 2008). The spatial characteristics of these sites are continually being altered to accommodate future expansions of urbanization. In landscape ecology, the complex process of urbanization causes profound changes in the functioning of a landscape, which consequently results in a changing spatial structure. The changing spatial structure will in turn alter "both biotic and abiotic ecosystem properties within, surrounding, and even at great distances from urban areas" (Grimm, et al., 2008). This will have several implications in managing urban environment.

Urbanization is a major driver of landscape change in many developing countries such as the Philippines. In recent years, several areas in the country had experienced a dramatic change in their landscape structure. According to Kelly (2000) in Malaque and Yokohari (2007), the peripheral provinces of Metro Manila experienced a widespread conversion of farmland into industrial estates and residential sub-divisions. Consequently, many agricultural production activities were stopped, resulting in the displacement of tenant farmers. The conversion is expected to continue while the land owners are speculating on the future sale of their land (Malaque and Yokohari, 2007). Currently, the landscape of the urban fringes of Metro Manila consists of a mosaic of residential, industrial, and commercial sites.

Calamba City is one of those areas that experienced a dramatic change in its landscape structure in the last two decades. The rapid urbanization of the City may be brought about by its declaration as the Regional Center of the Cavite-Laguna-Batangas-Rizal-Quezon (CALABARZON) economic region. Such declaration has increased its income significantly, and has attracted several investors to invest in the City. The expanding urbanization of the City does not only threaten the local agricultural production but may have some critical implications in its environment. Being at the northern slopes of Mt. Makiling and bounded by Laguna Lake at its northwestern side, the rapid urbanization of the City may further threaten the ecological integrity of both ecosystems. Mt. Makiling is a home to several floral and faunal species that are endemic to the country and Luzon. Some important species discovered in the mountain are Rafflesia species (Barcelona and Fernando, 2002), Odonata species (Ramos and Gapud, 2007), angiosperms (Fernando, 2004) and avian species (Gonzales, 2000). On the other hand, the Laguna Lake is already an extremely stressed ecosystem (Tamayo-Zafaralla et al., 2002) with levels of toxicity of chemicals that are beyond the safe allowable limits set for them. Thereby, any further unmanaged and unplanned expansion of urbanization in the City may significantly aggravate this current situation of the lake and/or threaten the integrity of Mt. Makiling as a habitat of a myriad ecologically important species.

The study is grounded on the theory of disturbance that stresses the role of anthropogenic and/or natural factors on landscape heterogeneity. Burel and Baudry (2003), stated that the spatio-temporal heterogeneity of a landscape is the result of a set of natural or man-made disturbances. Both natural factors (e.g. forest fires, flood, and earthquake) and humans are entities that cause functional changes on the landscape (Sanderson and Harris, 2000). Burel and Baudry (2003) emphasized that "the variability of disturbances as well as their effects are vast and can be linked to the initial conditions as well as the internal heterogeneity at different places." Thus, analyzing any change in the structure and composition of the landscape under study should include a geographical approach. This is necessary to determine the multifunctional properties of the landscape (Ryszkowski, 2002). "Since changing disturbance regimes will produce acute changes in ecosystems and their services over the short and long terms" (Turner, 2010), the analysis should also include the identification of the potential environmental implications of the changes.

OBJECTIVES OF THE STUDY

The study aimed to analyze the changes in landscape patterns of Calamba City and identify the potential implications of these changes on its environment. The analysis was done by computing class area, transition rates, and landscape metrics related to size and shape. Land use and land cover classification system used by the National Mapping and Resources Information Authority (NAMRIA) was used in identifying the elements of the landscape. The study assesses the landscape changes between 2003 and 2010.

MATERIALS AND METHODS

The Study Site

Calamba City is a first class city in Laguna province. Geographically, the City is located at 14° 13′ 0″ N and 121° 10′ 0″ E with Cabuyao bordering its northern side, Los Baños in the eastern side and Batangas and Cavite in the southern and western sides, respectively (Figure 1). Laguna de Bay, which is the country's largest lake, bounded its northwestern side. Calamba City is the second largest city in Laguna Province in terms of land area, following San Pablo City" (CPDO, 2010).

As it lies at the northern slopes of Mt. Makiling, the City is endowed with hot springs that are developed for recreational purposes. These resources made the City a popular tourist destination. In addition, it has become the regional center of CALABARZON (Cavite, Laguna, Batangas, Rizal, Quezon) in 2003, and thus, has attracted several important modern industrial, residential, and commercial centers in the Province. In fact, the number of investors increased by as much as 20 percent in just one year, i.e. 2007-2008 (CPDO, 2010). This number continues to increase; thus, making the city the richest in CALABARZON area. Currently, it houses a large number of industrial parks and business estates.

Being the center for commerce and industry in the province, Calamba City has attracted several job seekers from nearby provinces. This has led to a significant increase in its population. According to the 2010 census, the City has a population of 389,377, which is far greater than its population size in 2000 (i.e. 281,146) (NSO, 2010).

Identification of Land Class Types (LCTs) and Computation of Landscape Metrics

The identification of the various land class types of the City was based primarily on the land use-land cover (LULC) classification scheme used by NAMRIA and the City Planning and Development Office (CPDO). Vector maps for 2003 and 2010 land use-land cover of Calamba were obtained from both offices, and were fed into a geographic information system (GIS) environment for the computation of class area, shape metric, and mean patch size. Computation of these metrics was done through the use of the patch analyst extension (version 3.1) of Arcview 3.2 (ESRI). A transition table was created to analyze the changes in class area of the land class types from 2003 to 2010. The 2003 vector map was intersected with the 2010 vector map by using the geoprocessing extension of the software. The resulting map shows the transformation of a land class type. The area for each resulting polygon was computed by using the sample script for calculating area and perimeter of the software.

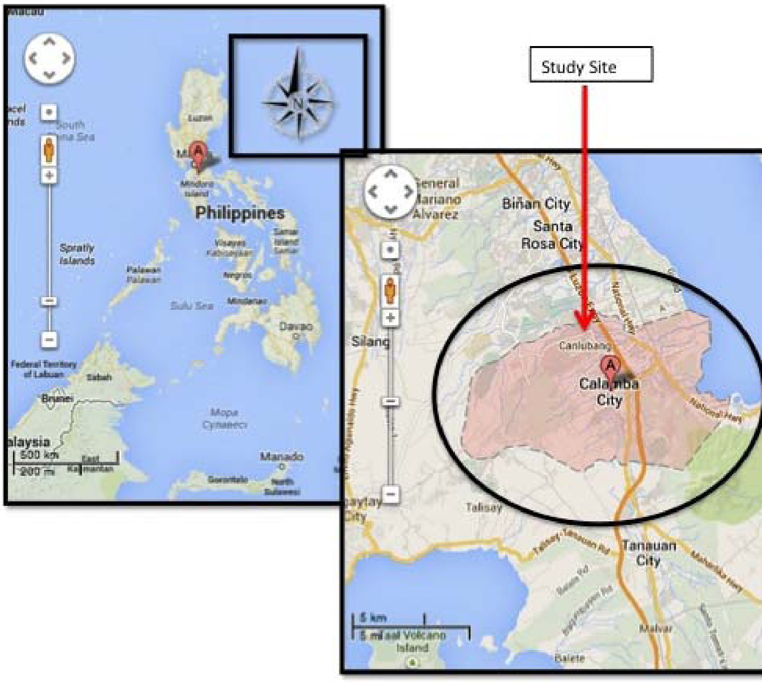

Figure 1. Location of the study site
(adopted from Google Maps, 2013)

Based on the GIS output, an attempt was made to analyze the changes in class types with the two-period images. The comparison of the different landscape pattern metrics between the two periods may help us determine if the anthropogenic disturbance zones are more complex than the natural landscape zone (Guo, 2006). "In the spatial pattern analysis, landscape elements changed with the effects of environmental and anthropogenic disturbances" (Guo, 2006). The environmental implications of these changes and disturbances were identified and discussed.

Geostatistics were computed, analyzed, and data were visualized as maps, graphs, and tables.

RESULTS AND DISCUSSION

Land Class Types and Computed Class Area (2003 and 2010)

The study site consists of eight land class types, namely: open forest, closed forest, built-up areas, annual cropland, perennial cropland, grassland, shrubland, and wooded grassland. Computed total land area (TLA) of the study site is 13,023.23 has, though in the City Comprehensive Land Use and Development Plan, TLA was projected to be 14,480 has. As indicated in Figure 2, the City's landscape in 2003 was dominated by annual cropland (78 percent), followed by built-up area (15 percent), shrubland (4 percent), and open forest (2 percent). The closed forest of broadleaved species is less than 1 percent of the computed TLA. The pattern significantly changed in 2010. To cite, the built-up areas (49 percent) dominated the landscape in 2010, followed by annual cropland (23 percent), and grassland (11 percent). Interestingly, forested areas in 2010 increased by 34 percent from its computed class area (CA) in 2003. Shrubland land class type has also increased by 35 percent in 2010. Figure 3 shows the spatial distribution of the various land classes in 2010.

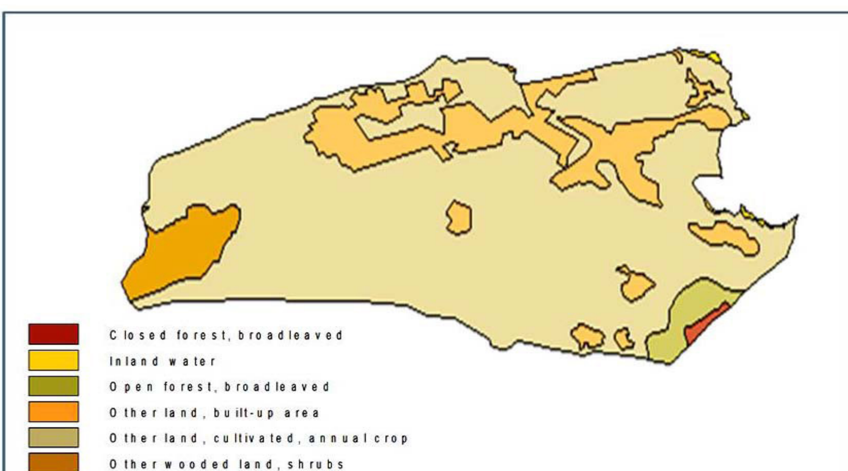

Figure 2. Land class type and distribution in 2003

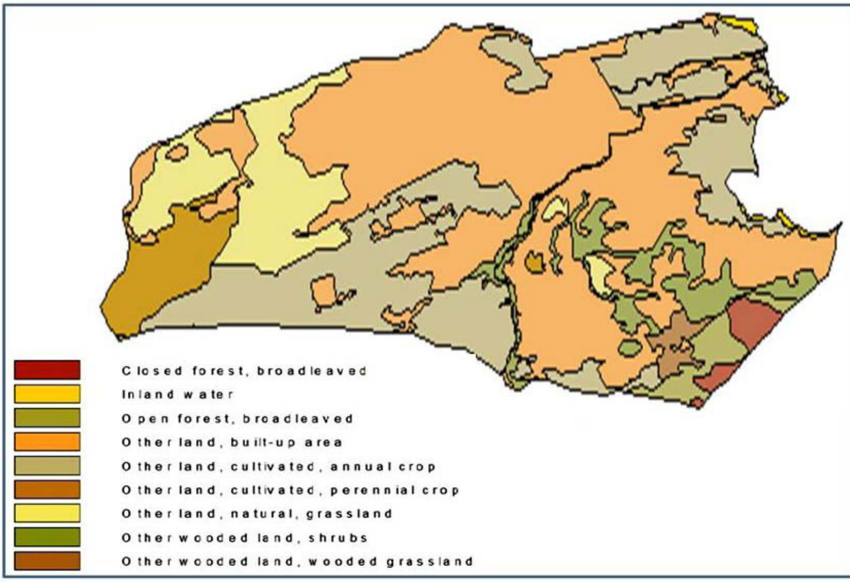

Figure 3. Changes in Landscape Pattern, 2003-2010

Figure 4 summarizes the changes in the landscape pattern of the study site during the period of analysis. As indicated in Figure 4, most of the changes occurred in the annual cropland and built-up area land class types. Annual cropland has been reduced by 67 percent from its 2003 computed area while built-up area has been increased by more than 200 percent in 2010 (Table 1). This can be attributed to the increasing demand for land for commercial, industrial, and residential purposes. According to ICTD (2010), there is a significant increase in the number of establishments in the City from 1997 to 2010. To cite, more than 250 public and private resorts and hot springs, 9 industrial estates, and more than 5,000 commercial centers are currently operating in the City. These figures are far above than the total establishments in 1997. These various developments had led to the reduction of the computed class area of the annual cropland land class type.

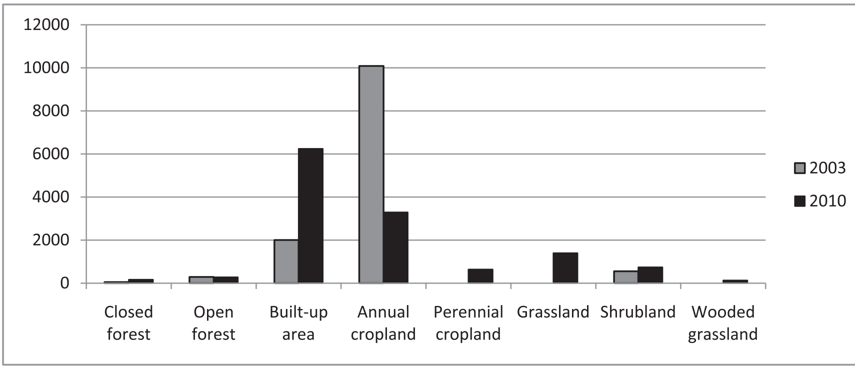

Figure 4. Changes in computed class area by land class type, 2003 and 2010

Table 1. Changes in class area within the study period

Land Class Type	Class Area		Increase/(Decrease)	Percent Change
	2003	2010		
Closed forest	49.96	170.09	120.13	240
Open forest	290.76	282.14	(8.62)	3
Built-up area	2004.66	6244.98	4240.32	212
Annual cropland	10088.15	3294.63	(6793.52)	67
Perennial cropland	0.00	640.73	640.73	100
Grassland	0.00	1398.31	1398.31	100
Shrubland	553.51	743.31	189.81	34
Wooded grassland	0.00	133.78	133.78	100

Transition Matrix

Table 2 shows the transformation of land class types between 2003 and 2010. The values were based on the computed area for each polygon that resulted from intersecting the 2003 and 2010 vector maps. As indicated in Table 2, there is a significant loss in annual cropland computed class area to built-up area and grassland in 2010, further explaining the significant reduction of the computed class area of the annual cropland in 2010. Interestingly, the forest land class types (open and closed) had gained a considerable increase in its computed area. Some of these areas came from the conversion of annual cropland to forest land class type (Table 2). To cite, they have gained at least 100 has from annual cropland in 2010.

Table 2. Transition table for each land class type

2003/2010	Closed forest	Open forest	Built-up area	Annual cropland	Perennial cropland	Grassland	Shrubland	Wooded grassland
Closed forest	31.6	18.36						
Open forest	120.05	164.18					1.67	4.88
Built-up area			1923.82	56.03		2.7		1.37
Annual cropland	18.44	104.33	4305.36	3228.34	111.7	1391.68		127.53
Shrubland			15.47	5.07	529.04	3.93		

It is also evident that no forest land class type had been converted to accommodate the continuing urbanization of the City and/or agricultural development. Instead, there is a significant increase in the number of hectares that were devoted to forest reservation between 2003 to 2010. As shown in Figure 3, the forest reserved area in the southeastern side of the City has been enhanced and increased in area. According to CPDO (2010), this is to provide buffer area in the City to prevent further encroachment of anthropogenic activities on the Makiling Forest Reserve that would create disturbance or damage on the ecology of the area.

Landscape Metrics, 2010

Table 3 summarizes the computed values of all landscape metrics (i.e. patch number, PN, mean patch size, MPS and mean shape index, MSI) considered in the analysis. Expectedly, computed values of landscape metrics indicated a more or less complex shape (MSI > 1.0) but not fragmented land class types, except for built-up area and annual cropland. Both land class types are highly affected by the City's urbanization process.

Table 3. Landscape metrics, 2010

Land Class Type	Number of Patches	Mean Patch Size (has)	Mean Shape Index
Closed forest	2	85.04	1.46
Open Forest	1	282.14	2.58
Built-up area	18	346.94	2.05

Annual Cropland	12	274.55	1.94
Perennial Cropland	4	160.18	1.42
Grassland	3	466.10	1.91
Shrubland	6	123.89	2.82
Wooded grassland	2	66.89	1.79

Shrubland has the highest computed mean shape index (MSI = 2.82), followed by open forest (MSI = 2.58), and built-up area (MSI = 2.05). This is expected for the former two land class types but may not be for the latter. Likewise, the annual cropland land class type also showed a certain degree of shape complexity (MSI > 1.0). According to Krummel et al., (1987), anthropogenic activities tend to produce regularly shaped land classes (as indicated by small fractal dimension values) while natural patches (e.g. large forest areas) have irregularly shaped units with less distinct boundaries (i.e. higher fractal dimension values). But this is not the case in the study site as indicated in Figure 5. Both natural and man-made patches showed irregularly shaped units without distinct borders.

Shape complexity is crucial especially for the forest land class types. According to Lindenmayer et al., (2008), there is a strong correlation between shape complexity of vegetation and species richness. Also, Hill and Curran (2005) reported that there is an increasing population of rare species with increasing shape irregularity of forest fragments. This is critical for forest areas that are managed for conservation and protection purposes since this means a strong edge effect. Core-dependent species are at risk when there is a high probability of contact between them and edge species. For conservation purposes, regularly shaped units of forests should be maintained to limit edge effects.

On the other hand, the computed MPS and PN for each land class type showed a relatively intact land classes. Grassland class type showed the highest computed MPS value (MPS = 466.10 has) with only 3 patches. It is followed by built-up area with computed MPS of 346.96 has but with more patches (PN = 18) than the grassland. This result further indicates that several spaces in the City had been established for built-up areas (Figure 5).

Figure 5. An aerial view of the built up areas dispersed in the City's landscape (adopted from Google Map, 2013)

Though forest land class types exhibited a certain degree of shape irregularity and occupied only 4 percent of the computed TLA of the study site, they are not fragmented. This is indicated with the low number of patches and a relatively greater computed mean patch size of this land class type. Intact forests are important in organism movement and seed dispersion. Both processes are, in turn, essential in maintaining the biodiversity of these forests.

Implications in Environmental Management

The rapid urbanization of the City has resulted in a significant loss in agricultural production. Agricultural lands had been converted to industrial, residential, and commercial uses to accommodate its increasing demand. This may threaten the local food security of the City as it becomes more dependent on external sources for their food supply. This is further aggravated by the non-suitability of other areas for agriculture (CPDO, 2010).

The increasing computed CA for built-up area between 2003 and 2010 necessitates a strong implementation of effective environmental management strategies. The strategies should be able to address issues such as flooding, solid wastes disposal, water consumption, and pollution in rivers and lake. Flooding may result from the increasing area of land being made impervious due to the construction of buildings, roads, subdivisions, and the like. Impervious surfaces are more likely to increase surface runoff both along the roads and river channels. According to USGS (2013), increasing impervious surfaces will reduce the area where infiltration to ground water can occur. This will result in an increased likelihood of more frequent and more severe flooding (USGS, 2013). In fact, the City had been placed under a state of calamity in 2009 (Cinco, 2009) and 2012 (Chiu, 2012) due to severe flooding.

In addition, the rapid population growth of the City may result in solid waste disposal problem. Manaf, Samah, and Zukki (2009) indicated that rapid growth population coupled with rapid economic development, inadequate infrastructure and expertise, and land scarcity will lead to an acute solid waste management problem. This is significant in the study site because it has a very low solid waste collection. The unserved household had practiced open-pit dumping, which may pose health problems as well as pollution threats to the groundwater and surface water resources (CPDO, 2010). Health problems and pollution may be aggravated when industries and commercial centers will indiscriminately dispose of their wastes to the environment. This requires a strong political will that will compel these establishments to manage their wastes and comply to existing waste management policies.

On the other hand, the complexity of shape of the forest land class types implies that they are not a good habitat for specialist species that require a larger area for evading predators. Irregular shaped forests have long edge perimeter (Abdullah and Sulistyawati, 2009), which facilitates higher contact to disturbance that originates from the edge (Lele et al., 2007). If these forests are to be protected, extra effort that will increase their core area should be implemented.

It should be noted however that these implications are dependent on the accuracy of the information obtained through the processing of images of the study site. In many instances, geospatial studies rely on the quality of the image being processed. Both locational and attribute data are never completely accurate though some steps have been taken to reduce the impacts of errors. Using the data in this study should therefore be done with precaution, and may be re-interpreted within the context of the study.

CONCLUSIONS

GIS has been useful in analyzing the spatial heterogeneity of the landscape being investigated through time. Results of the study indicate that there is variability of the computed values of the metrics computed for the landscape within the period of analysis (2003-2010). Though the studied landscape is already heterogeneous, its pattern has changed through time indicating a change in disturbance regimes acting on the landscape. The landscape in 2003 has been dominated by annual cropland, followed by built-up area. This has changed however in 2010 where built-up area dominated the landscape. The computed class area of annual cropland has been reduced significantly within the period of analysis. This is due to its conversion to built-up area, grassland, and forests in 2010. There is also a considerable increase in the computed class area of the forest land class type between 2003 and 2010 though it exhibits a more complex shape. The complexity of its shape is crucial in its management as a conservation and protected area because it increases edge effect. While there is a plan to establish a forest buffer area in the City, there is a need to address the irregularity in shape of forests to make them more habitable for specialist species.

The increasing computed class area for built-up land class type between 2003 and 2010 highlights the need to implement a strong and effective management strategy to address the problem of flooding, solid waste disposal, and pollution. Unless this will be done, the rapid urbanization of the City will lead to a greater environmental catastrophe.

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