Journal of Nature Studies 14 (2): 1-13
ISSN: 1655-3179

A SPATIAL ANALYSIS OF POPULATION GROWTH AND URBANIZATION IN CALAMBA CITY USING GIS

Ricardo T. Bagarinao
University of the Philippines Open University, Los Baños, Laguna, Philippines
Corresponding author: ricardo.bagarinao@upou.edu.ph

ABSTRACT – There is a need to analyze spatially population growth and urbanization in order to develop contextualized mitigating measures and integrated development plans for urbanizing areas. The rapid advances in GIS technology could support such analysis, and project which spatial unit needs an immediate implementation of interventions. The current study was conducted to analyze population growth and urbanization vis-à-vis their geographic location in the study site. Management and research implications are identified and recommended based on the observed trends of the spatial changes. The analysis covered two periods: 2003-2010 and 2010-2015. Digitized land use-land cover (LULC) maps of the City (i.e. 2003, 2010) were obtained from the National Mapping and Resource Information Authority (NAMRIA) and Calamba City Planning and Development Office, and were geoprocessed in a GIS environment. Population data (i.e. 2003-2015) were obtained from Calamba City Planning and Development Office (CCPDO) and National Statistics Office (NSO), and were fed to the barangay map of the City. Using the geoprocessing functionality of the GIS software, the three maps were intersected. The spatial distribution of the changes in LULC to built-up area and population within the period of analysis was determined. Results indicate that most of land conversions involved the conversion of annual cropland to built-up areas in highly populous barangays. This supports findings of other studies that population growth drives urbanization and landscape change. It is important that environmental policies and management strategies should effectively and efficiently be implemented in these areas to curtail environmental impacts of urbanization and population growth. Studies that monitor the behavior of the people towards environmental management and policies should be conducted.

Keywords: spatial analysis, population growth, urbanization, GIS, Calamba City

INTRODUCTION

For several decades, the world population is continuously increasing. The United Nations Population Fund, UNFPA (2015) reported that the global population has reached 7 billion in 2011 and is projected to reach at 9 billion in 2050. Such dramatic increase is largely due to the increasing numbers of people surviving to reproductive age, changing fertility rates, increasing urbanization, and accelerating migration (UNFPA, 2015).

To cite this paper: Bagarinao, R.T. 2015. A spatial analysis of the population growth and urbanization in Calamba City using GIS. Journal of Nature Studies. 14 (2): 1-13

Meanwhile, urbanization drives population growth. Satterthwaite, McGranahan, and Tacoli (2010) reported that more than 50% of the world's population is now concentrated in urban areas. The United Nations projected that urban population will grow by more than a billion people between 2010 and 2025 (UN, 2008 in Satterthwaite, McGranahan, and Tacoli, 2010). Such increase will have significant implications especially on food security of urban households and land use.

Several studies (e.g. O'Toole, 2007; Duh, et al., 2008; Satterthwaite, 2009) were done to analyze the environmental and social consequences of urbanization and population growth. For instance, Nagdeve (2002) indicated that increasing population would create tremendous pressure on natural resources like land, air, and water. As population grows, food demand increases. Consequently, agricultural production would be intensified to meet the growing food requirements. Intensive use of fertilizer, pesticides, and other chemicals to augment agricultural production degrades land and water (IDS Knowledge Services, 2009). Likewise, increased population results in a significant growth in consumers and levels of their consumption. According to Satterthwaite (2009), the growth in consumers and in their levels of consumption drives the growth in greenhouse gases emission. As more greenhouse gases are released to the environment, air is polluted while climate change is intensified, which consequently, leads to massive flooding and desertification (DCDC, 2007 in IDS Knowledge Services, 2009). Torrey (2004) also reported that changes in the consumption pattern and levels of urban people leads to polluted urban environment, which in turn, poses a risk or threat on the life of the urban population. Furthermore, Hove, Ngwerume, and Muchemwa (2013) concluded that accelerated and poorly managed urbanization has resulted in various types of atmospheric, land, and water pollution thereby jeopardizing human society.

On the other hand, Dimmick (2014) reported that rapid growth of population might result in food insecurity especially among poor families in urban areas. They usually buy their food from common market at competitive prices while they earn meager income (Tacoli, Bukhari, and Fisher, 2013). Likewise, urban sprawl would significantly change the landscape of cities as the demand for habitation increases. Huang, Zhang, and Wu (2009) indicated that urbanization is rapidly increasing worldwide, creating extensive land use changes and urban spatial expansion. In Nigeria, for instance, cities have engulfed surrounding rural land and adjacent towns leading to continuous belts of settlement (Hove, Ngwerume, and Muchemwa, 2013). This highlights the importance of spatial information on urbanization and population growth.

While there are more studies done on the impacts of urbanization and population growth, there is a paucity of information on the spatial analysis of these social and developmental phenomena. But such spatial (locationally referenced) information has become indispensable for numerous aspects of urbanization especially in planning and management (Doytsher, et al., 2010). Doytsher, et al. (2010) indicate that the increasing importance of such information is due to the recent strides in spatial data capture, management, and access as well as the development of analytical techniques such as high resolutions mapping for urban environments. Spatial information and technologies are important to support the operthe allocation of property rights, housing needs, land use planning, land management and taxation. It is equally important in supporting management of key problems such as disaster management, flooding control, environmental management, health and transportation (Doytsher et al., 2010).

The increasing urbanization in the study site highlights the need for such spatial information for monitoring, evaluating, and reporting its performance vis-à-vis the environment. Calamba City lies in the northern slopes of Mt. Makiling, a highly important mountain ecosystem in the region and the country. It is also bordering the largest lake ecosystem in the country, the Laguna de Bay, which is currently receiving huge amounts of pollutants from industries, households, and other pollutive sources. Currently, Calamba City is economically active, and rapidly urbanizing. In fact, it is considered as a first class city in the CALABARZON region due to its high income (i.e. PhP1.5 billion in 2010) and the presence of several industrial parks, commercial centers, and residential estates. To cite, the City houses more than 250 public and private hotspring resorts, 9 industrial estates, over 200 multi-national industrial firms, and more than 5,000 commercial establishments (ICTD, 2015). Its population has reached 389,377 in 2010 (NSO, 2010), and is projected to continue to increase as migration from nearby rural provinces continues in the coming years. About 62.2% of its population is economically active, i.e. involve in various commercial and trading activities (ICTD, 2015).

The study aimed to spatially analyze the process of urbanization and population growth in the study area by using GIS as a tool and landscape dynamics and spatial heterogeneities as frameworks. Landscape dynamics simply states that a landscape is changing through time due to extrinsic and intrinsic factors. The changes however are not expected to be uniform across the landscape; rather they are spatially differentiated among spatial units due to the uneven distribution of the driving forces of these changes, hence spatial heterogeneity (Sklenička and Pixová, 2004).

Specifically, it computed the formation of built-up areas and correlated it with the change in population size from 2003 to 2015 at the barangay level by using GIS. Implications for environmental management, policies, and research were identified.

MATERIALS AND METHODS

The Study Site

The study was conducted in Calamba City, which is a first class city in Laguna province. It lies geographically 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.

In 2003, Calamba City has been declared as the regional center of the CALABARZON region. Since then, it has become a popular destination for tourists and investors alike due to its hot spring resorts and proximity to Metro Manila area. In fact, the number of investors increased by as much as 20 percent in just one year, i.e. 2007-2008 (ICTD, 2010). Currently, the City serves as an economic haven for more than 250 public and private hot spring resorts, nine (9) industrial parks, which house more than 200 multi-national industrial firms, and more than 5,000 commercial establishments (ICTD, 2010).

Being the center of 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).

Figure 1. Study site (source of map: http://goo.gl/NponXC)

Computation of Built-up Areas Formation and Changes in Population Size

Land use and land cover (LULC) digital maps were obtained from the National Mapping and Resources Information Authority (NAMRIA) and the City Planning and Development Office of Calamba. These maps were fed into the GIS software for geoprocessing and automatic computation of LULC changes from 2003-2010. Only the change of LULC to built-up area was considered since this is primarily the focus of the study. Eight LULC were identified in the study site, namely, open forest, closed forest, built-up areas, annual cropland, perennial cropland, grassland, shrubland, and wooded grassland. Changes of these LULCs to built-up areas were determined by intersecting the 2003 LULC map with the 2010 LULC map. The resulting map was geoprocessed and re-coded to reflect the specific LULC change. For instance, the intersection between a specific annual cropland spatial unit with specific built-up area unit was given a code of annual cropland-to-built-up area to signify that such geographic section of the annual cropland LULC in 2003 was converted to built-up area in 2010. The areas of the intersection between a LULC and built-up area were computed by running the calculate area-perimeter script of the software. A transition matrix was developed to present the patterns of LULC transformation between 2003 and 2010 periods.

The geo-processed and recoded map of the LULC change was then intersected with the barangay map of the City, which contains the population data. The resulting map reflects the specific spatial location of the conversion of LULC to built-up areas vis-à-vis the population distribution of the City. The area (in has) of the spatial unit in the map containing such conversion was computed. Scattered plot was created to reflect the relationship between this area and population size change. Actual and projected population data from 2003-2015 were used in the analysis. The analysis of the change in population distribution was done at the barangay level. The spatial relationship between the LULC change (to built up area) and the distribution of the change in population was determined by using the geostatistics of the software.

Data were visualized as graphs, maps, and tables.

RESULTS AND DISCUSSION

LULC Changes between 2003 and 2010 Periods

The intersect geoprocess between the 2003 and 2010 LULC maps generate the following transformation patterns of the land use-land cover of the study site:

Table 1. Transition table for the transformation of each land class type (values in has)

2003/ 2010	Closed forest	Open forest	Built-up area	Annual cropland	Perennial cropland	Grass land	Shru bland	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		

As indicated in Table 1, there were two LULCs (i.e. annual cropland and shrubland) in 2003 that were converted to built-up areas in 2010 though most of the conversion involved the annual cropland (Figure 2). To cite, of the 10,088.15 has of annual cropland in 2003, about 67% was lost to built-up area in 2010. Likewise, about 15.47 has of the shrubland areas in 2003 was converted to built-up areas in 2010. This finding corroborates with Ho and Lin’s (2004) observation in China as reported in Azadi, Ho, and Hasfiati (2010) where agricultural land conversion to non-agricultural uses is widespread and intense since 1980. Similar trend was observed in California where 25% of urban conversions were derived from irrigated farmland and 30% from dryland farming and grazing land (Brown, Laird, and Nichodom, 2014).

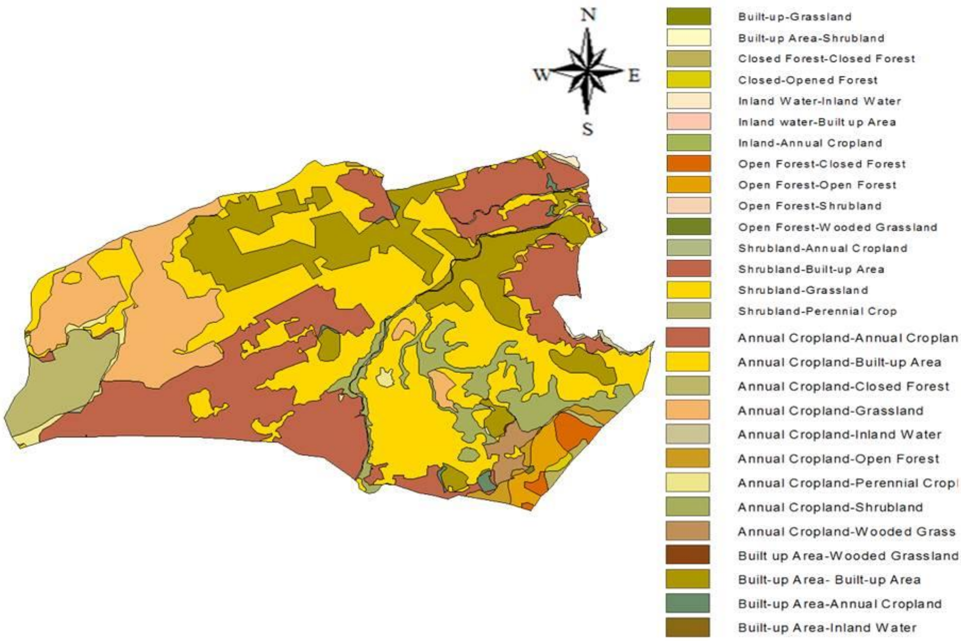

Figure 2. Land use-land cover changes from 2003-2010

Population Change: 2003-2015

Figure 3 shows the changes in population size of the study site from 2003 to 2015. The highest change in population size is projected in Barangay Canlubang, which is estimated to reach at 101,262 in 2015. It is followed by Mayapa (i.e. *2003*: 21,588; *2010*: 31,424; *2015*: 41,089), Parian (*2003*: 15,975; *2010*: 23,254; *2015*: 30,407), and Real (*2003*: 12,943; *2010*: 18,840; *2015*: 24,635). Mabato has the smallest population size with only 674 in 2003, which is projected to increase by as much as 1,283 in 2015. In addition, population in all barangays is projected to increase throughout the study periods. This is expected for an urbanizing area where opportunities for work and other economic activities could be created. Grant (2012) pointed out that urban areas have high capacity to create more jobs than their rural counterparts.

Sought for greener pasture, more people migrate to urban areas to seek for job opportunities. IFPRI (2005) indicated that people migrate to urban areas for work, even if they do not have a job secured. Gimba and Kumshe (2012) also reported that rural-urban migration occurs because people are seeking business opportunities and good quality education in urban centers. Whatever the reasons, migration to urban areas contributes to an increasing urban population, hence, the assumption of increasing population in all barangays in the study site.

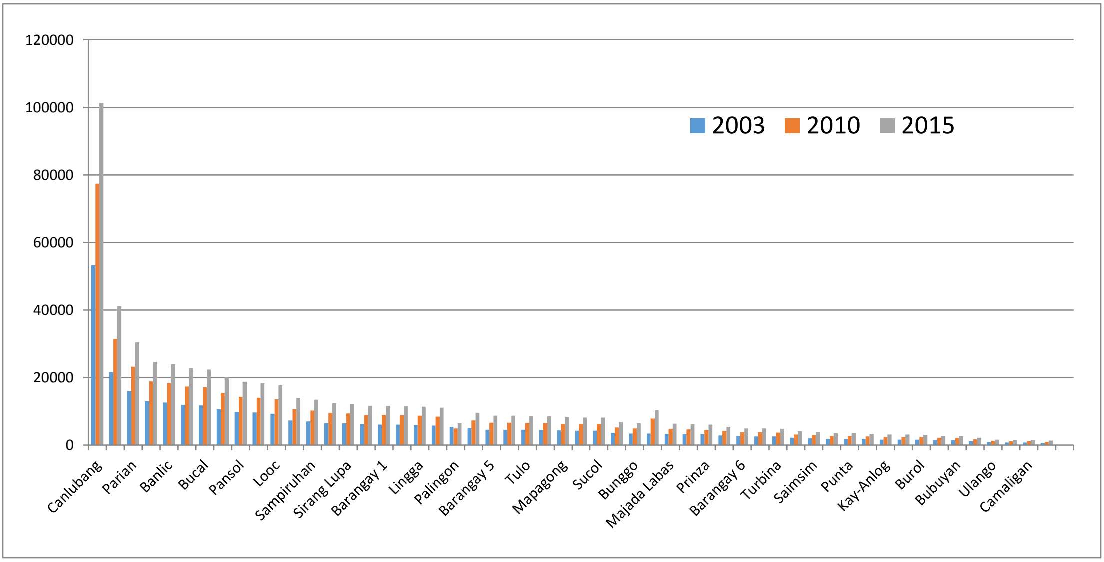

Figure 3. Population size (actual and projected) in the study site from 2003 to 2015 (source of data: NSO, 2010)

Spatial Distribution of LULC Change and Population Growth

Figure 4 shows the spatial relationship of the change of LULC to built-up areas and change in population size. As indicated in Figure 4, the creation of large-sized built-up areas is located in barangays that have high population change between 2003 and 2010. For instance, about 19% of the total land conversion from annual cropland to built-up area in 2010 occurs in Barangay Canlubang that has the highest change in population between 2003 and 2010, i.e. 24,241.

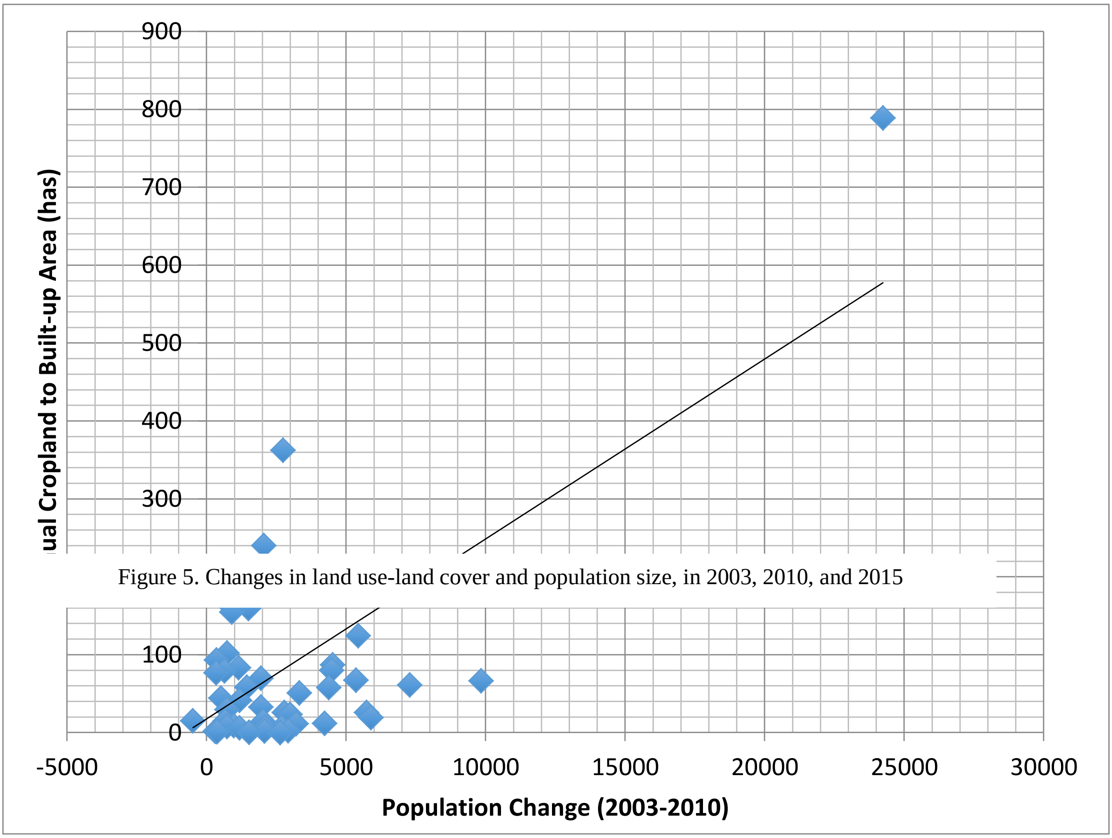

Figure 5. Changes in land use-land cover and population size, in 2003, 2010, and 2015

Figure 4. Relationship between the conversion of annual cropland to built-up areas (has) and change of population

Likewise, large conversions of annual cropland to built-up areas occurred in barangays with bigger changes in population size albeit most of the conversions are concentrated in areas with population change that is less than 5,000 (Figure 5).

The relationship is significant (p<0.05), and thereby, implying that most of the conversion of annual cropland are driven by the increasing demand for habitation. Population Matters (2012) made similar observations in the United Kingdom where agricultural land is accounted for 75% of the total greenfield land converted to residential uses. An estimated 27,000 has of greendfield were acquired for housing development in England alone from 1999 to 2008.

In the Philippines, there is a rapid conversion of urban agricultural farms to built-up areas because they became less productive, and therefore, less profitable. Most of the landowners are poor and often do not get adequate support services from the government to make their land productive (Ravanera

& Gorra, 2011). Consequently, most of the landowners are tempted to take the cash offered by developers.

The spatial distribution of urbanization in barangays with large population is critical and might have several social and environmental implications. Urbanization increases rural-to-urban migration (Becker, 2007), which in turn, causes population boom in urban barangays while taking away the working population from rural areas. When unmanaged and uncontrolled, rapid urban population growth can seriously constrain local governments' ability to provide basic services including employment, housing, electricity, water, sanitation, enforcement of law and order, and development of social capital (Buhaug & Urdal, 2013). According to Goldstone (2002) in Buhaug and Urdal (2013), "it is exactly when overurbanization combines with underdevelopment – where the job market and the economy cannot keep up with urban population growth – that violence and instability may arise." There is also the potential of increasing households who will live in slum areas due to unemployment. Kuiper and van der Ree (2006) reported that "slums will continue to expand, even in fast-growing developing country economies." They estimated that by 2020 this proportion could reach 45-50% of the total population in cities.

In addition, the mixing of people from various cultural and ethnic backgrounds coupled with the shifting demographic composition in these barangays could be central destabilizing factors in their environments (Buhaug & Urdal, 2013). The rapid increase in their population could lead to reduced per capita access to subsistence resources as resource reproduction is unable to keep up with the growing demand (Buhaug & Urdal, 2013). It is possible that with increasing population size in these barangays, there would be a decline in the overall supply of certain resources such as water and agricultural land due to pollution and/or land conversion for housing, industrial, and commercial uses. Congestion and increasing road traffic could likewise result in air pollution and increasing heat island effect. Both consequences may be critical for the study site. Figure 6 shows the spatial distribution of built up areas from 2003 to 2010.

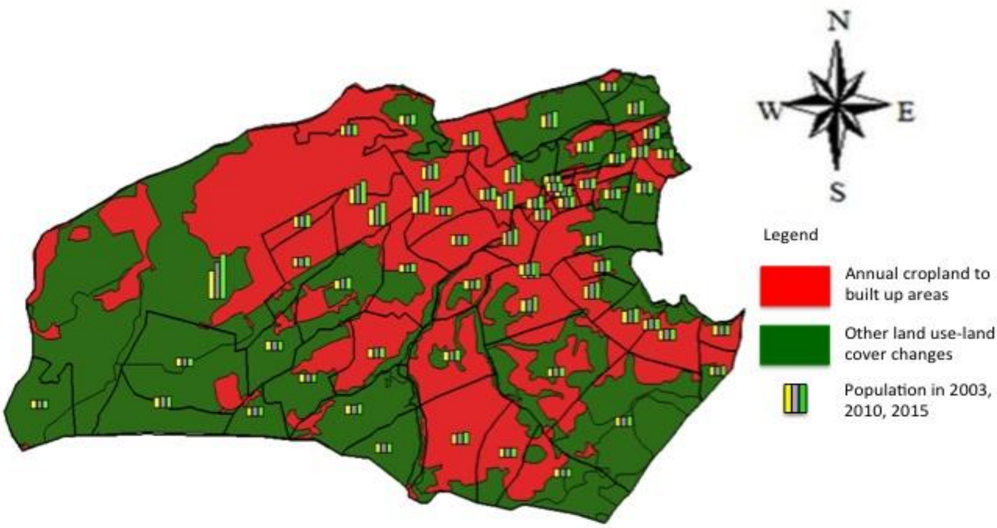

Figure 5. Changes in land use-land cover vs. population size

As indicated in Figure 6, conversion of land uses and land cover to built-up areas is spreading in all directions of the study site. It is projected to continue, and probably occupy most of its land area by 2020. With its geographic location, the continued growth in urbanization and population in the area might affect the two important ecosystems located in its periphery, namely, Mt. Makiling and Laguna de Bay. The economic prosperity that the City has experienced recently should integrate sound and effective environmental management strategies. This is necessary because the increasing urbanization and the unprecedented population growth as a consequence of growing urbanization may lead to unsustainable waste management. According to Lusterio-Berja and Colson (2008), solid waste collection in urban areas is not 100%. Thus, there are solid wastes that remain uncollected. Wastes that are not collected pose a public health threat due to surface and ground water contamination (Lusterio-Berja & Colson, 2008). Likewise, untreated sewers could also result in contamination, and thereby aggravating the contamination

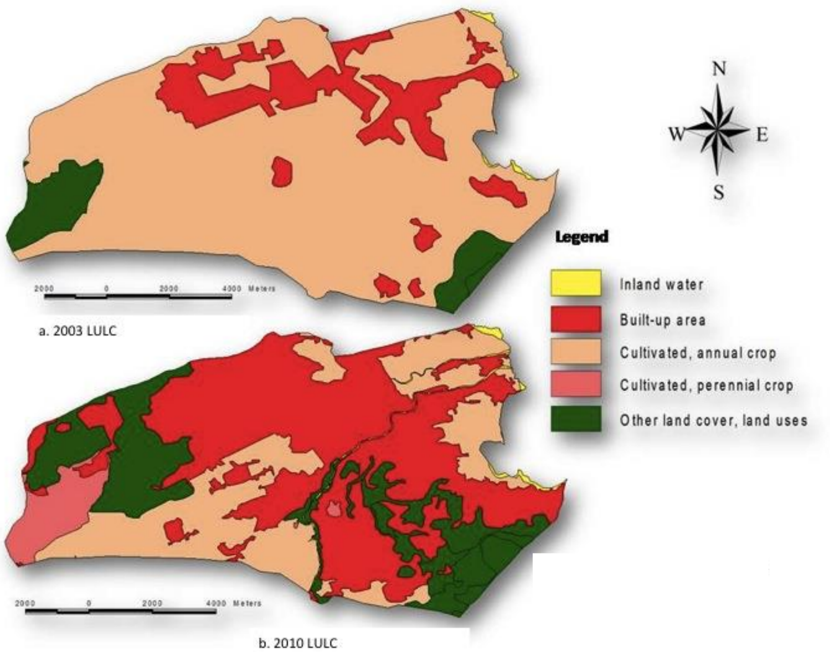

Figure 6. Land use-land cover of the study site (a.2003 and b. 2010)

caused uncollected wastes. The typhoid outbreak in the study site in March 2008 is a case on hand. About 732 residents were hospitalized because of typhoid fever due to contaminated water sources (Jaymalin, 2008).

This case and other social and environmental consequences highlight the need for an effective and strong implementation of management strategies and policies that could regulate urbanization and population growth. Unless planned and implemented, the development in the study site may not be sustainable in the long run.

CONCLUSION AND RECOMMENDATIONS

The use of GIS facilitated the analysis of the spatial distribution of urbanization and population growth. Results of the geoprocessing and intersection of the digital LULC maps for the periods 2003 and 2010 indicate that urbanization involved the rapid and massive conversion of annual cropland to built-up areas. The conversion occurred in barangays with large changes in population sizes. The conversion could probably be due to diminishing land productivity and increasing demand for land for habitation, commercial uses, and industrial estates. The increasing urbanization in the study site coupled with the rapid growth of its population necessitates the formulation and implementation of strong and effective management strategies. These strategies should be able to regulate urbanization and population growth especially in highly urbanized barangays of the study site. Continued monitoring of the trends and spatial movement of urbanization should be conducted to be able to project the trajectories of the occurrences of social and environmental issues. This is necessary to make the economic growth in the area inclusive, environmental-friendly, and sustainable.

ACKNOWLEDGMENT

The paper is one of the outputs of the author's research in landscape change in Calamba City, which was funded by the University of the Philippines System through the Office of the Vice-President for Academic Affairs' Creative Work and Research Grant. I wish to thank God also for this provision and His wisdom in conducting the research, and making this paper; the people in Calamba City government, Department of Environment and Natural Resources – Region 4A, Municipal Health Office, Laguna Province, and other institutions who have made their data freely available for this study; for my wife, kids, other family members, and church mates for their love, prayers, and moral support.

LITERATURE CITED

Azadi, H., Ho, P., and Hisfiati, L. (2010). Agricultural land conversion drivers: a comparison between less developed, developing, and countries. Land Degradation and Development, DOI: 10.1002/ldr.1037. Retrieved 8 May 2015 from http://goo.gl/1iK6AL

Becker, C.M. (2007). Urbanization and rural-urban migration. In A. Dutt & J. Ros (Eds.), *International handbook of Development Economics* (pp. 1-18). Durham, NC: Edward Elgar

Buhaug, H. and Urdal, H. (2013). An urbanization bomb? Population growth and social disorder in cities. Global Environmental Change, 23(1): 1–10. Retrieved 15 May 2015 from http://goo.gl/5aEruV

Dimmick, D. (2014). As world's population booms, will its resources be enough for us? National Geographic. Retrieved 6 May 2015 from http://goo.gl/wBhZQt

Doytsher, Y., Kelly, P., Khouri, R., McLarin, R., Mueller, H., and Potsiou, C. (2010). Rapid urbanization and mega-cities: the need for spatial information management. International Federation of Surveyors, FIG Report No.48. 91pp. Retrieved 8 May 2015 from http://goo.gl/VxDZsW

Duh, J., Shandas, V., Chang, H., and George, L. (2008). Rates of urbanisation and the resiliency of air and water quality. Science of the Total Environment, 400(1-3), 38-256. Retrieved 7 May 2015 from http://goo.gl/xZnIYd

Gimbah, Z. and Kumshe, M. (2012). Causes and effects of rural-urban migration in Borno State: A case study of Maiduguri Metropolis. Asian Journal of Business and Management Sciences, 1(1), 168-172. Retrieved 9 May 2015 from http://goo.gl/A4fgx

Grant, U. (2012). Urbanization and the Employment Opportunities of Youth in Developing Countries. Background paper prepared for the Education for All Global Monitoring Report 2012. Retrieved 9 May 2015 from http://goo.gl/0zRUxx

Hove, M., Ngwerume, E., and Mechumwa, C. (2013). The urban crisis in Sub-Saharan Africa: a threat to human security and sustainable development. Stability: International Journal of Security and Development. Retrieved 7 May 2015 from http://goo.gl/BmmeZs

IDS Knowledge Services. (2009). Population growth, environment, and food security: what does the future hold? Horizon: Future Issues for Development. Retrieved 6 May 2015 from http://goo.gl/ZMQjgY

Information and Communication Technology Department, Calamba City. (2015).The City of Calamba. Retrieved 8 May 2015 from http://goo.gl/vlUYTS

Jaymalin, M. (2008 March 12). DOH: contaminated water behind typhoid outbreak. Philstar. Retrieved 15 May 2015 from http://goo.gl/rI1x8f

Lusterio-Berja, C. and Colson, L. (2008). Population, environment and health issues in the Philippines: a profile of CALABARZON (Region 4-A). Population Reference Bureau. 6 pp. Retrieved 15 May 2015 from http://goo.gl/z9hLff

Millennium Project. (2008). State of the Future. A Summary: The Millenium Project. Retrieved 6 May 2015 from http://goo.gl/2Iht1n

International Food Policy Research Institute, IFPRI. (2005). Mobility, migration, rural-urban changes. Brief 2. 2pp. Retrieved 9 May 2015 from http://goo.gl/gFDBXw

Nagdeve, D.A. (2002). Environment and health in India. A paper presented at the IUSSP Regional Population Conference on 'Southeast Asia's Population in a Changing Asian Context at Bangkok, Thailand, 10-13 June 2002. Retrieved 6 May 2015 from http://goo.gl/mGj0GP

National Statistics Office, NSO. (2010). 2010 Census of population and housing. Retrieved 8 May 2015 from http://goo.gl/xzAjUL

Population Matters. (2012). Population growth and housing expansion in the UK. Retrieved 9 May 2015 from https://goo.gl/OnH5MK

O'Toole, R. (2007). Population growth and cities. Electronic Journal of Sustainable Development, 1(3). Retrieved 7 May 2015 from http://goo.gl/1oubqG

Ravanera, R.R. and Gorra, V. (2011). Commercial pressures on land in Asia: An overview. A report prepared for the International Land Coalition. 52 pp. Retrieved 15 May 2015 from http://goo.gl/TCUxjJ

Satterthwaite, D. (2009). The implications of population growth and urbanization for climate change. Environment and Urbanization, 21(2), 545-567. DOI: 10.1177/0956247809344361. Retrieved 7 May 2015 from http://goo.gl/pJ5kPy

Satterthwaithe, D., McGranahan, G. and Tacoli, C. (2010). Urbanization and its implications for food and farming. Philosophical Transactions B of the Royal Society, 365, 2808-2820, doi:10.1098/rstb.2010.0136. Retrieved 6 May 2015 from http://goo.gl/uoUWfj

Sklenička, P. and Pixová, K. 2004. Importance of spatial heterogeneity to landscape planning and management. Ekológia (Bratislava), 23(1): 310-319. Retrieved August 3, 2013 from http://www.centrumprokrajinu.cz/doc/PDF_03.pdf

Tacoli, C., Bukhari, B., and Fisher, S. (2013). Urban poverty, food security and climate change. Human Settlements working Paper No. 37. 35 pp. Retrieved 6 May 2015 from http://goo.gl/uYLSYH

Torrey, B.B. (2004). Urbanization: an environmental force to be reckoned with. Population Reference Bureau. Retrieved 7 May 2015 from http://goo.gl/t4kOUk

United Nations Population Fund, UNFPA. (2015). World population trends. Retrieved 3 May 2015 from http://goo.gl/NNoUex

JOURNAL OF NATURE STUDIES
(formerly Nature's Bulletin)
ISSN: 1655-3179