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# SPATIO-TEMPORAL PATTERN OF LANDSCAPE CHANGE DUE TO URBANIZATION: A CASE OF BATANGAS CITY

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**ABSTRACT –** The new housing and other infrastructure built on former agricultural and green areas for the growing population usually lead to irreversible land use change. The loss and fragmentation of green areas, functional changes in habitat structure, terrestrial and aquatic ecosystems are among the ecological consequences that diminish essential ecosystem services, which are regarded important to human population living in urban areas. This study was conducted to determine the nature and magnitude of the landscape structural changes in Batangas City and suggest implication on the hydrology. The 2002 and 2008 satellite images (ASTER, 30m resolution) of Batangas City were downloaded from the National Astronomy and Space Administration (NASA). Images were processed and analyzed in Geographic Information System (GIS). Landscape metrics were computed using Patch Analyst extension for ArcGIS. All patch types tend to become evenly distributed (2002 to 2008) with agricultural land use (cropland with annuals and perennials) dominantly increasing and tend to aggregate in irregular shape. Built-up enormously increased in area (143.13%), number (56.73%), and density and tend to be irregular in shape. Grassland and shrubland decreased in area and number, patch size and density. Secondary forest decreased in area and patch size but increased in patch number and tends to be circular in shape. Landscape change has brought about by the rapid urbanization in Batangas City and its implications to hydrology were discussed.

*Key words: landscape change, patch type, agricultural land use, built-up, grassland, shrubland, secondary forest, Batangas City*

## INTRODUCTION

One of the environmental problems of urbanization is that when new residential areas are planned and built on former agricultural and green areas in the need of new housing and other infrastructure for the growing population, it usually leads to irreversible land-use change (Grimm *et al.*, 2000). This has ecological consequences such as the loss and fragmentation of green areas, functional changes in terrestrial and aquatic ecosystems, and changes in habitat structure, species richness and species composition (Bowman and Marzluff, 2001; Paul and Meyer, 2001; Shochat *et al.*, 2005). These consequences diminish essential ecosystem services, which are regarded important for



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human populations living in urban areas (Bolund and Hunhammar, 1999; Alberti and Marzluff, 2004). All this results in a conflict situation; how to meet the needs of city growth, and at the same time consider the principles of sustainable development and especially conserve important green areas within and around built-up areas.

Urban landscapes such cities, are complex dynamic systems that emerged from the local interactions of socio-economic and biophysical processes (Alberti, 1999; Alberti *et al*., 2003). These complex systems are highly heterogeneous, spatially nested, and hierarchically structured (Wu and David, 2002; Portugali, 2000; Gunderson and Holling, 2002). Patterns in urban landscapes result from numerous locally made decisions involving multiple human and biophysical agents interacting among themselves and with their environment. Interactions within this complex domain between agents and processes are scale dependent.

Cities are growing rapidly worldwide. The world's urban population has multiplied more than tenfold during the past century, from 224 million in 1900 to 2.9 billion in 1999 (United Nations, 1999). It has also risen from 14% to 50% of total world population. In 1900, only sixteen cities had a population exceeding 1 million; by 2000, more than four hundred did. By the year 2030, more than 60% (4.9 billion) of the estimated world population (8.1 billion) will live in cities: 56.2% of the population of developing countries (3.88 billion) and 83.5% of that of the developed countries (1.01 billion) (United Nations, 1999). The world's urban population will grow at an average annual rate of 1.8%, nearly doubles the rate expected for the total population of the world (1 % per year).

Urbanization has been an important component of land use and land cover change, and its significance will undoubtedly continue to increase with the majority of the world's population swarming into cities (Breuste *et al*., 1998; Pickett *et al*., 2001; Whitford *et al*., 2001). It significantly influences the functioning of local and global earth ecosystems and the services they provide to humans and other life on earth. Urban development fragments, isolates, and degrades natural habitats; simplifies and homogenizes species composition; disrupts hydrological systems; and modifies energy flow and nutrient cycling (Alberti *et al*., 2003). While urbanized area accounts only for ~1 to 6% of the earth surface, cities appropriate a large share of earth's carrying capacity in terms of resource input and waste sinks. Since humans depend on earth ecosystems for food, water, and other important products and services, changes in ecological conditions that result from human actions in urban areas ultimately affect human health and well-being.

In this study, the landscape of Batangas City was investigated by comparing the 2002 and 2008 Aster satellite images 1) to determine the nature and magnitude of the landscape structural changes in Batangas City; and 2) to suggest implication of landscape change on the hydrology of Batangas City with emphasis on water quantity and water quality.

## MATERIALS AND METHODS

### Study Area

Batangas City, the capital of Batangas Province, is a coastal city lying in a covelike shape at the southeastern portion of Batangas Province (Batangas City Planning and Development Office, 2007). It is geographically situated at 13º 45" 25.96' north latitude and 121 º 3" 29.2' east longitude (Fig. 1). The

28,541.44 ha city is bounded on the northwest by the municipality of San Pascual; on the north by the municipality of San Jose; on the east by the municipalities of Ibaan, Taysan and Lobo; and on the south by the Batangas Bay.

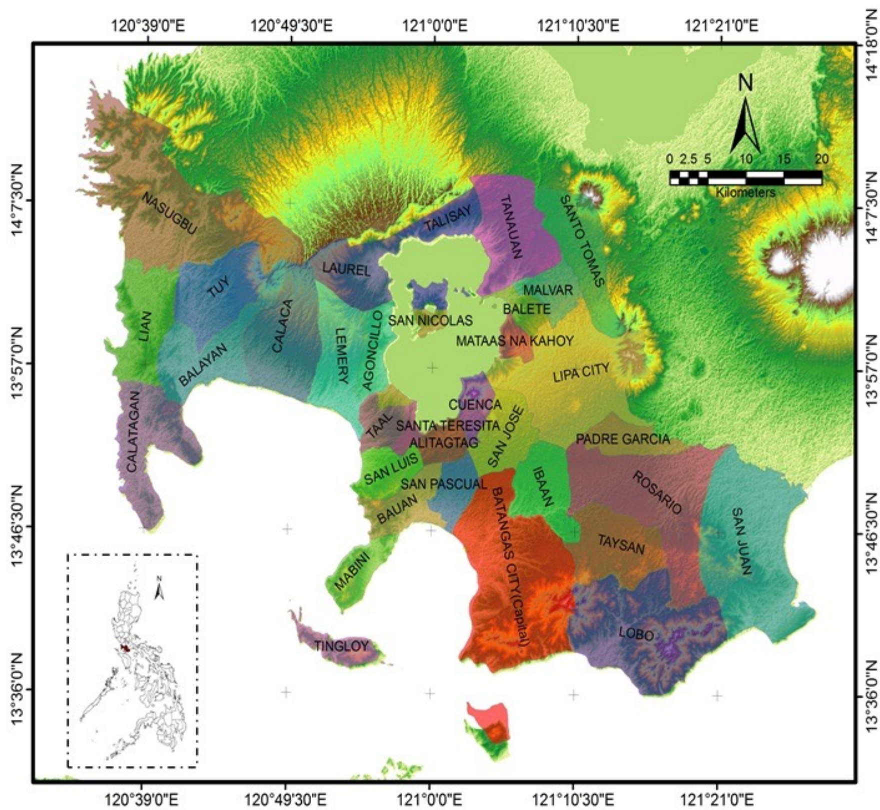


Figure 1. Municipality map of Batangas Province (DEM Source: Jarvis et al., 2008).

The rolling terrain of Batangas City ranges from 0% to 30% in slope (Fig. 2). Its highest point is Mount Banoy in Barangay Talumpok Silangan which is 968 m above sea level and about 13.50 km east of the Poblacion. The city's coastal barangays starting from Sta. Rita Aplaya from the north down to Ambulong on the south are nearly level at 0% to 3%. In the east beyond the barangays of Mabacong, Simlong and Pinamucan Ibaba, the slope rises from 8% to 30%. The Matuco Point at the southwest tip of the city along the Batangas Bay has a slope of 30%. To the immediate south is Verde Island composed of six (6) barangays which is mountainous and with a slope ranging from 3% to 30%.

Batangas City is generally coolest during the months of December to January with temperature ranging from 22ºC to 26ºC. The mean temperature rises and attains a maximum of 336 ºC in May. The month of July marks the steady fall of temperature. The driest months in Batangas City are from January to April, with the average monthly rainfall of less than 50 mm per month. The northeast monsoon (“*amihan*”) prevails starting the months of November up to April. Although originally moist, it becomes comparatively drier after crossing the Sierra Madre Range to the north and east of Batangas, thus attributing for predominantly dry weather during this period. By May to the later part of October, the situation is reversed. The southwest monsoon (“*habagat*”) prevails bringing with it considerable rain. A pronounced maximum rain period occurs in Batangas during the months of June, July, August and September when southwest monsoon flow is steadiest and the average monthly rainfall is 275 mm per month. By the end of October, the northeast monsoon starts to set again. However, the months from October to December are not characterized by dry weather as compared to the months from January to April. This is partly due to the fact that typhoons and depressions most frequently affect the city during the months from October to December.

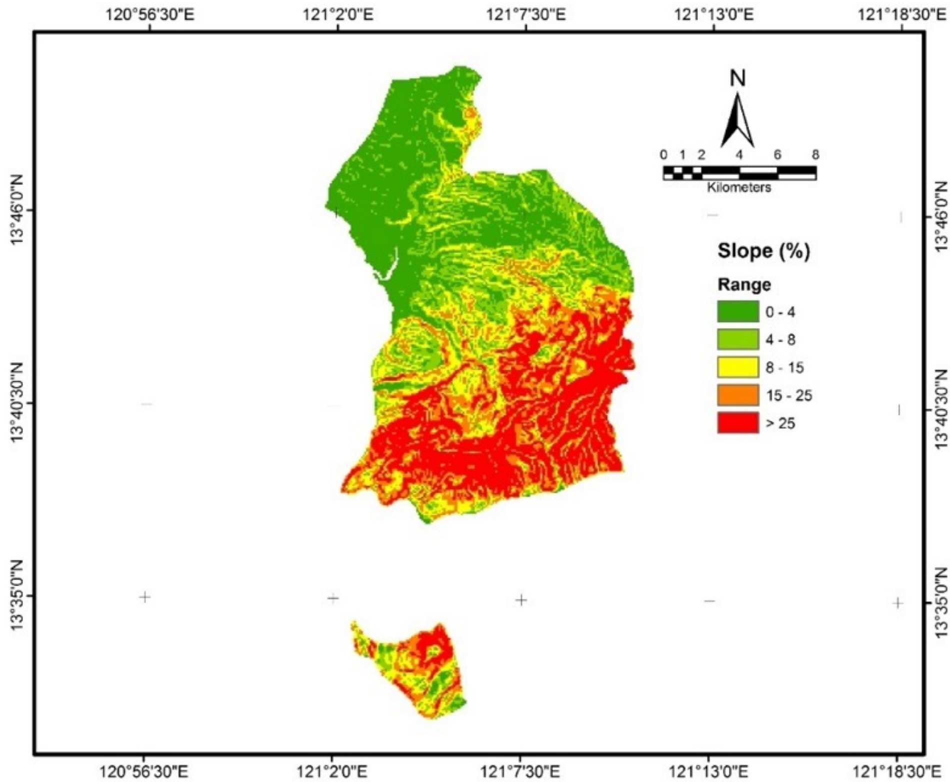


Figure 2. Slope map of Batangas City (Derived from SRTM DEM: Jarvis et al., 2008).

**Satellite Image Acquisition and Processing**

Downloadable Terralook satellite (aster) images from NASA (http://glovis.usgs.gov) in simulated true color and 3 bands (red, green, blue) of March 2002 and 2008, with 30-m resolution, were used in this study. The satellite images were processed in ArcGIS 9.2 and the projection of all maps was set to Geographic WGS84 to allow overlays of different map layers for analysis and comparison. Image Analyst for ArcGIS 9.2 was used for the image classification. Patch analyst extension (ver. 3 and 4) was used for the calculation of different landscape statistics. Prior to landscape calculation in patch analyst, the classified landscape was projected to Universal Transverse Mercantor (UTM) North Zone 51 format.

*Unsupervised classification*

An unsupervised image classification using maximum likehood was done for both aster image of 2002 and 2008. This image classification served will serves as the basis for the supervised classification.

We identified the results of the unsupervised image classification into 1) built-up areas, 2) croplands with annuals, 3) croplands with perennials, 4) grasslands and shrubs, 5) secondary growth forest, 6) forest 7) water bodies, and 8) clouds and cloud shadows. These classifications were validated through field visit and from the high resolution images of Google Earth.

*Supervised classification*

The training units or signatures of the different land uses were prepared in ArcGIS 9.2 for both 2002 and 2008 images. At least 100 polygons of the land uses were digitized in ArcGIS 9.2. A supervised image classification was done using the prepared training units.

*Landscape statistics*

All calculations of the landscape metrics were computed in ArcGIS 9.2 and ArcView 3.3 using the patch analyst extension. For this study the metrics considered were 1) mean patch size, 2) patch size standard deviation, 3) edge density, 4) area weighted mean shape index, and 5) 1nterspersion and juxtaposition index.

## RESULTS AND DISCUSSION

Landscape Composition

There were noticeable changes on the land use of Batangas City from 2002 to 2008 (Fig. 3 and Table 1). Grassland and shrubland occupied the highest portion (33.98%) of Batangas City in 2002 but dramatically decreased by 60.39% in 2008 occupying only about 12.95% of the city with simultaneous decrease in the number of patches by 15.44%. This is followed by cropland with annuals and cropland with perennials, which showed an increasing trend from 2002 to 2008 with a noticeable increase of the latter by 23.29%. Taking these two patch types together as one land use (agriculture) would mean that a total of 10,772.1 ha was cultivated in Batangas City in 2002 and 12,369.51 ha in 2008. Needless to say then that agriculture dominated the landscape of Batangas City. Interestingly, the 1,835.64 ha of built-up (residential, commercial and industrial) area in 2002 increased more than twice (143.13%) after six years with a rate of 23.85% per year. In addition, the number of patches of built-up area increased by more than half (56.73%) in 2008. However, both patch class showed decrease in the number of patches by 29.66% for cropland with annuals and by 20.95% for cropland with perennials. The results indicate that, from 2002 to 2008, areas of croplands with annuals and perennials as well as the grassland and shrubland had been replaced by built-up areas. Continuous population increase in Batangas City is obviously the main reason for this high rate of urbanization coupled with the increase in industries and commercial establishment. According to Alberti (2005), humans increasingly dominate ecosystems and urban development affects the spatial heterogeneity of landscapes such as pattern of variation in land cover. The rapid urbanization of Batangas City without proper land use plan is alarming because urban development fragments, isolates and degrades natural habitats; disrupts hydrological systems and modifies energy flow and nutrient cycling (Alberti, 2005).

The remaining 3,569.94 ha of secondary forest growth in 2002 dwindled a little bit by 1.52% after six years and the number of patches was increased by 4.96%, which implies that it is becoming fragmented. This is partly attributed to the presence of 746.10-hectare forest growth depicted in the 2008 satellite image. It was noticed in the 2008 satellite image (Figure 4) that forest showed in locations of previously secondary forest growth. On the other hand, the continuous encroachment by settlements, commercial establishments (e.g. resorts) and industries is another reason for the decline and fragmentation of the remaining secondary forest.

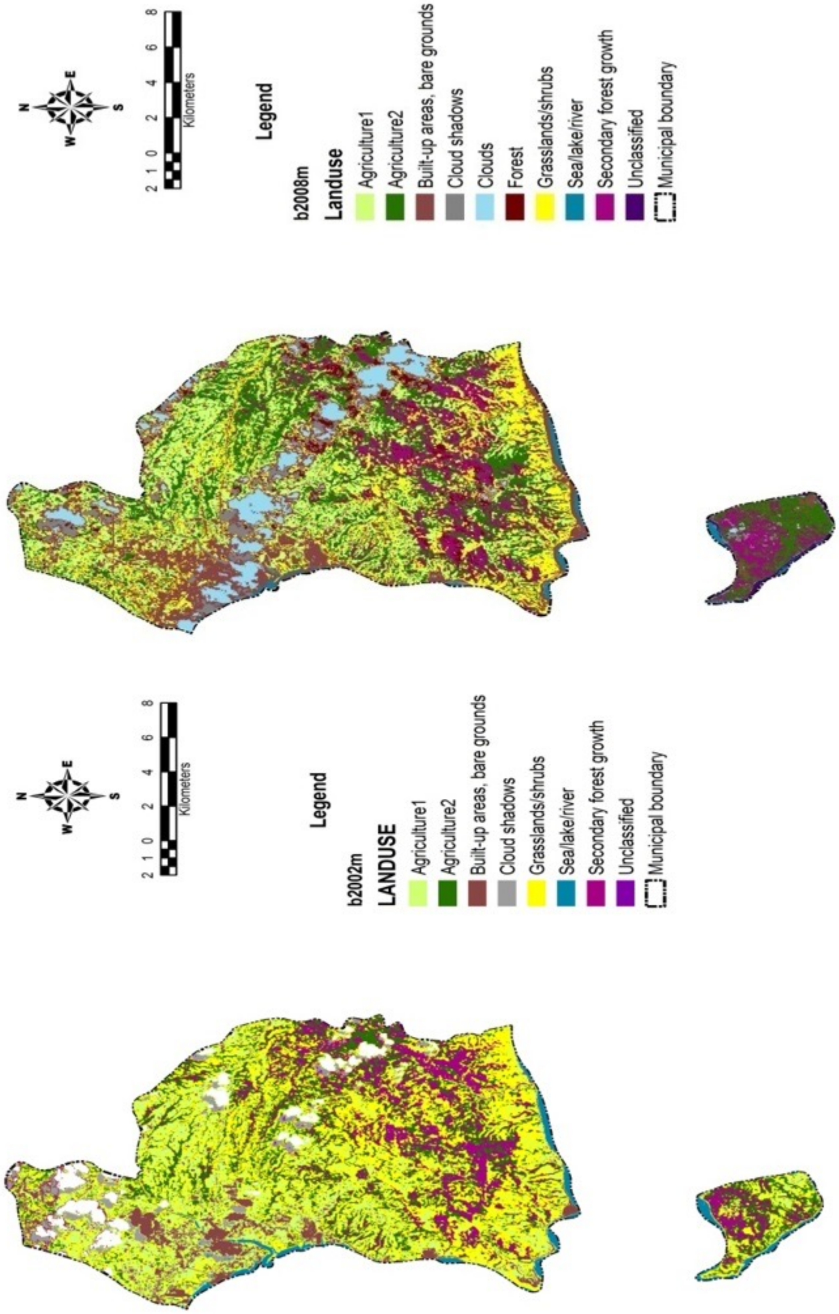


Figure 3. Land use change in Batangas City from 2002 to 2008.

Table 1. Area (ha and %) and number of patches of the different patch classes in Batangas City from 2002 to 2008.

| Patch Class | 2002 Area (ha) | 2002 % | 2008 Area (ha) | 2008 % | % Change | No of Patches 2002 | No of Patches 2008 | No of Patches % Change |
|---|---|---|---|---|---|---|---|---|
| Built-up area | 1835.64 | 6.96 | 4462.92 | 16.28 | 143.13 | 1456 | 2282 | 56.73 |
| Cropland with annuals | 5390.01 | 20.44 | 5734.17 | 20.92 | 6.39 | 4053 | 2851 | -29.66 |
| Cropland with perennials | 5382.09 | 20.41 | 6635.34 | 24.21 | 23.29 | 4063 | 3212 | -20.95 |
| Grassland and shrubland | 8961.48 | 33.98 | 3549.96 | 12.95 | -60.39 | 3816 | 3227 | -15.44 |
| Secondary forest growth | 3569.94 | 13.53 | 3515.67 | 12.83 | -1.52 | 3083 | 3236 | 4.96 |
| Water bodies | 527.13 | 2.00 | 239.04 | 0.87 | -54.65 | 94 | 137 | 45.74 |
| Forest | | | 746.10 | | | | 1219 | |
| Unclassified | 10.89 | 0.04 | 112.50 | 0.41 | 933.06 | 32 | 32 | 0.00 |

There was an observed decrease in water bodies in Batangas City by 54.65% from 2002 to 2008 which is doubtful since the digital satellite image captured clouds and river in the same spectral reflectance and some portions of the river was covered by clouds.

**Landscape Structure**

Landscape structure of Batangas City also showed some degree of changes from 2002 to 2008 (Table 2). All patch types identified from the satellite images had increased Juxtaposition and Interspersion Index (IJI) except for water body and forest. Considering the land use/land cover individually, the Mean Patch Size (MPS), Area Weighted Mean Shape Index (AWMSI), and Edge Density (ED) of built-up area had increased while that of water body decreased. Cropland with annuals and perennials tend to increase in MPS and AWMSI but the reverse for ED. There was a decreased in MPS, AWMSI and ED for grassland and shrubland. Secondary forest decreased in MPS but increased in AWMSI and ED. The results suggest that, from 2002 to 2008, there is a tendency of the different patch types in Batangas City to be more evenly distributed. Built-up and agriculture areas (cropland with annuals and perennials) are becoming bigger in size and more irregular in shape but the former is becoming denser than the latter. Grassland and shrubland, which became replaced by built-up, tends to reduce in area and density and more circular in shape. The secondary forest was reduced in size and more fragmented but more irregular in shape. These are indications that urban development affects the patch structure by altering the size, shape, interconnectivity and composition of natural patches (Alberti, 2005). Natural areas (grasslands and shrublands, secondary forest) becomes pachy, since patchiness is likely to be heavily influenced by land use (Alberti, 2005).

Table 2. Metrics of different patch classes in Batangas City from 2002 to 2008.

| Patch Class | 2002 | | | | | 2008 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | MPS | PSSD | ED | AWMSI | IJI | MPS | PSSD | ED | AWMSI | IJI |
| Built-up areas | 1.26 | 9.94 | 29.39 | 4.58 | 31.94 | 1.96 | 40.78 | 59.48 | 13.69 | 68.97 |
| Cropland with annuals | 1.33 | 13.13 | 112.27 | 8.33 | 49.51 | 2.01 | 16.67 | 94.22 | 7.18 | 51.15 |
| Cropland with perennials | 1.32 | 7.69 | 119.27 | 6.02 | 45.8 | 2.07 | 22.18 | 112.75 | 10.44 | 53.34 |
| Grasslands and shrubland | 2.35 | 64.06 | 165.85 | 29.94 | 58.72 | 1.10 | 7.21 | 67.26 | 4.04 | 69.51 |
| Secondary forest growth | 1.16 | 10.30 | 64.38 | 5.57 | 38.96 | 1.09 | 13.22 | 68.05 | 9.14 | 51.83 |
| Water body | 5.61 | 15.42 | 4.56 | 3.06 | 64.20 | 1.74 | 5.99 | 3.14 | 2.68 | 45.70 |
| Forest | | | | | | 0.61 | 2.01 | 16.50 | 2.37 | 55.00 |
| Unclassified | 0.34 | 0.52 | 0.30 | 1.44 | 5.81 | 3.52 | 10.55 | 1.74 | 4.94 | 69.81 |

MPS – Mean Patch Size

PSSD – Patch Size Standard Deviation

ED – Edge Density

AWMSI – Area Weighted Mean Shape Index

IJI – Interspersion and Juxtaposition Index

**Implications of Landscape Change**

Although the interactions between urban development process and ecosystem dynamics are still poorly understood (Alberti, 2005), it reasonable to infer that landscape change in Batangas City has some ecological implications particularly on the hydrologic processes since urban development produces a variety of unprecedented and intense disturbance through physical changes in the landscape (Alberti, 2005).

Based on the results, it is clear that landscape change is brought about by the rapid urbanization in Batangas City. Therefore, rapid urbanization (residential, commercial, and industrial areas) and agriculturalization, and decreased forest, grassland and shrubland cover would mean:

1) Heavy demand for water supply. Increasing number of people, commercial establishments, industries and agricultural areas increases the demand for water and more water will be drawn from the groundwater as the main water source. It has been reported that the Batangas City Water District (BCWD) pumps an average of 1.0 cms (based on NWRB water permits granted in 2000) from the deep aquifer for its domestic and commercial customers (Tabios and Davis, 2004). Heavy industries along the coast of Batangas Bay such as Pilipinas Shell, First Gas, JV Industries, among others, extract as much as 1.1 cms of groundwater—slightly higher than what BCWD pumps—with their own deep well pumps. Households in the city and vicinity, especially along the coastal area of Batangas City, also draw groundwater from shallow wells.

2) Reduced recharge of the aquifer. The city generally depends on its immediate watersheds for continuous water supply with groundwater as the main source. As watersheds of Batangas City have been devoid of good stand of trees, although there was reforestation reportedly done in the past, recharge of the aquifer is reduced. With increasing number of people, commercial establishments, industries and agricultural areas that increases the demand for water, more water will be drawn from the groundwater.

3) Saltwater intrusion. The shortage of drinking water causes saltwater intrusion near the coastal area is unavoidable. Salination (seawater intrusion) of shallow well water supply of households along the coast has raised alarm (Tabios and David, 2004). Households living along the coast of Batangas Bay blame the heavy industries for causing the salinization. The possible causes of saltwater intrusion aside from overdrafting of groundwater are forest denudation and commercial and residential developments in the nearby areas.

4) Reduction in the seepage of water into the ground, thereby increasing surface flow. Concentration of population in built-up area of Batangas City modified the surface features by replacing natural and open areas with buildings and roads. The concentration of population in built-up area of Batangas City modified the surface features by replacing natural and open areas with buildings and roads. This gives rise to the reduction in the seepage of water into the ground, thereby increasing surface flow. The natural drainage system, consisting of streams and creeks as tributaries of the rivers gets disrupted due to construction. The amount of water to be handled by the storm water drainage network during heavy rains increases. This may result to catastrophic flooding particularly during heavy rain.

5) Water pollution. Water pollution is another issue arose from land use change in Batangas City. The denuded forest/watershed can cause soil erosion particularly during heavy rains resulting to sedimentation of rivers and streams and ultimately the Batangas Bay. Wastewater from residential areas and commercial establishments may be released also into rivers and streams ending up to the bay or may contaminate the groundwater particularly the shallow ones. Pesticides and fertilizers from agricultural areas may reach surface waters and the bay.

6) Susceptibility to flooding. Batangas City belongs in a tropical monsoon climate with rainfall is concentrated in a few months particularly in June, July, August and September when southwest monsoon flow is steadiest and the average monthly rainfall is 275 mm per month. The intensity of rainfall is very high on some days. The quantum of water to be drained by the city may exceed the capacity of the network. The problem can be accentuated if the spell of heavy rainfall coincides with a period of high tide in coastal area and may result to flooding of low-lying areas. The network of streams and rivers is part of the natural drainage system. However, the filling up of several streams for providing roads may create drainage problems. The situation can be exacerbated by informal seetlers building their houses along the rivers. The increase in built-up area can eat up the rivers and streams and can increase susceptibility to flooding.

## CONCLUSION AND RECOMMENDATION

Ecosystem function is the ability of the earth processes to sustain life over a long period of time. Hydrologic cycle is one of the ecological processes, among the function of which is the maintenance of water quantity and quality, particularly the freshwater, for human use. These two functions of the hydrology of Batangas City are disrupted by the landscape pattern. The following are recommended for research and development planning directions for water resource management in Batangas City:

1. Improvement of land use practices in the uplands to improve watershed management;
2. Integrated soil and water management technologies (sustainable land management, disseminate water saving technologies);
3. Ecological assessment and valuation of environmental services, sustainable water protection, and increase economic competitiveness of upland communities;
4. Sustainable watershed landscape management of upland, lowland and coastal ecosystem to sustain availability of fresh water for various uses;
5. Environmental management of surface and groundwater resources through an establishment of an efficient local database and monitoring system;
6. Minimization of pollution and other environmental damages to water bodies and groundwater;
7. Rehabilitation of grasslands and degraded forest lands;
8. Assessment, rehabilitation, and conservation of riparian corridors of forest landscapes; development and adoption of soil and water conservation techniques;
9. Assess and conduct valuation of environmental service of watershed;
10. Greenway development of the degraded riparian corridors;
11. Identification and evaluation of environmental indicators for monitoring environmental performance of policies and programs;
12. Effective communication strategies to enhance environmental awareness in watershed protection and rehabilitation;
13. Assessment and management of groundwater resources; and
14. Improvement of comprehensive ecological land use planning process for the entire city.

## STATEMENT OF AUTHORSHIP

The team conceptualized and conducted the study led by GOS. ERA processed the satellite images and PRS did the calculation. HMC and DTM provided the secondary data. Everyone contributed to the analysis of the data to come up with this paper.

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