# VALUATION OF ECOSYSTEM SERVICE OF THE LAGUNA LAKE BASIN: EROSION CONTROL AND FLOOD WATER RETENTION

Alvin A. Faraon[1], Adelina C. Santos-Borja[2], Neil V. Varcas[3],
Brando M. Angeles[4], Erwin Kim P. Mercado[5]

[1]Project Evaluation Officer II, Project Development, Monitoring, Evaluation Division, Laguna Lake Development Authority
[2]Department Manager III, Resource Management and Development Department, Laguna Lake Development Authority
[3]Development Manager Officer II, Project Development, Monitoring, Evaluation Division, Laguna Lake Development Authority
[4]Project Development Officer II, Project Development, Monitoring, Evaluation Division, Laguna Lake Development Authority
[5]Engineer II, Project Development, Monitoring, Evaluation Division, Laguna Lake Development Authority

## *Abstract*

The Wealth Accounting and Valuation of Ecosystem Services (WAVES) is a global partnership program initiated by the World Bank in 2014. It aims to promote sustainable development by ensuring that accounting for natural resources and the services provided by the ecosystems are mainstreamed into development planning. One of the two pilot test sites in the Philippines is the Laguna Lake Basin where lies the largest and most economically important lake in the accounts was developed which includes a land account containing land Philippines. Based on the framework of the System of Environmental and Economic Accounts (SEEA) approved by the UN Statistical Commission (UNSC), a pilot ecosystem cover and changes; a water account providing information on water quantity; an ecosystem condition account indicating water quality, changes in bathymetry and sediment loading; an ecosystem production account looking at the flow of ecosystem services like fishery production, water supply, flood retention and soil erosion regulation. This paper focuses on two ecosystem services: erosion control and floodwater retention capacity, which is also referred to as flood control service, and their significance on the ecological integrity of the lake.

Erosion control is defined as the amount of sedimentation avoided because of the vegetation cover. This was calculated by comparing the erosion and sedimentation rates in the lake that would have taken place without vegetation cover with the actual erosion and sedimentation rates. Major land cover changes in the basin using satellite images were analyzed for the period 2003-2010. Closed forest decreased by 35% while built-up areas increased by 116%. There was rapid urbanization and industrialization in the lake region in particular in the northwest, western and southern portions of the watershed.

Using the SedNet Model and the 2010 land cover, the total sediment generated from the watershed under normal conditions was 2,011 kilo tons of sediment per year. Under simulated conditions, which entails all natural and semi natural ecosystems including close and open forest, shrublands, grasslands, and wooded grasslands being converted to bare lands, the sedimentation rate was 6,885 kilo tons of sediment per year. By deducting the sedimentation rate under normal condition from the simulated condition, the ecosystem service of closed forest, open forest, shrubs and wooded grasslands in terms of avoided erosion is 4,874 kilo tons of sediment per year.

The inflow of sediments affected the flood control service of the lake, which is its capacity to store water that would otherwise have led to flooding of houses and infrastructure. Sediments are being deposited in the form of backfilling of the lakeshore, which reduces its water retention volume. Equally significant is the effect of human settlement close to the mean annual high water level. An estimate of the monetary value of the water retention service of the lake was made based on the avoided damage costs from floods but this is highly influenced by different scenarios and assumptions.

Certain policy issues and challenges on management and development of the lake basin resources need to be addressed especially in this age of climate change.

Keywords: ecosystem service, valuation, land cover, sedimentation, water retention, avoided cost

## 1. Introduction

### 1.1 Background of the PhilWAVES project

Laguna Lake Basin is one of the two test sites in the Philippines for the Wealth Accounting and Valuation of Ecosystem Services (WAVES) project, a global partnership led by the World Bank that aims to promote sustainable development by mainstreaming natural capital in development planning and national accounting systems. One of the objectives of WAVES is to pilot and test different methodologies of compiling ecosystem accounts based on the SEEA-Experimental Ecosystem Accounting framework, which was endorsed as a framework by the UN Statistical Commission. In particular, it needs to be tested if and how the SEEA-Experimental Ecosystem Accounting framework can provide science-based evidence and information to help assess the economic, environmental and social trade-offs of different natural resource use options and their implications for sustainable development.

Using the SEEA accounting framework provides several advantages. It allows linking the analysis of natural capital with economic statistics, thereby clarifying the contribution of ecosystems to economic activities in both physical and monetary units. It is also intended to be an activity that is regularly undertaken so as to enable monitoring of trends in natural capital, effectiveness of resource management policies, etc, contrary to other assessments, which are typically one-off studies. Regular production of the accounts also contributes to capacity building and leads to greater cost-efficiency.

As Ecosystem Accounting is still a developing field, as distinct from the physical environmental accounts included in the SEEA-Central Framework, and also in some cases calls for quite advanced modeling exercises, it is often still undertaken at a sub-national level. As the methodologies and access to data are rapidly developing, it becomes increasingly viable to do this on a regional or national scale as well. The accounts presented in this report are part of this development.

The implementation of WAVES builds upon the Philippines' efforts on Natural Capital Accounting (NCA) during the 1990s and early 2000s, which created the advantage that considerable capacity and technical skills still exist. The Philippine WAVES focuses on Water, Mineral, Mangroves, Land and Ecosystem accounts. The first four of these accounts will be implemented at the national scale, whereas the ecosystem accounts are implemented at the scale of a test site. The Philippine government expects that the resulting methodologies and framework of this pilot can be applied in different settings in other parts of the country that also demand indicators, tools, and methodologies to inform development planning and policy analysis in support of the goals of sustaining the use of natural resources, economic growth, and alleviating poverty.

## 1.2 Objectives

The PhilWAVES Project in the Laguna de Bay Basin is a pilot project carried out by the Laguna Lake Development Authority (LLDA) in collaboration with the different offices under the Department of Environment and Natural Resources. The pilot accounts aim (i) to provide science-based information to set priorities for the water and fishery resource management in the lake; (ii) to identify priority areas for protection, for instance involving regulation of pollution and sediment loading; (iii) inform on possibilities for water pricing and greening of development planning. Apart from the intent to scale up the process, the pilot is also meant to generate lessons on how ecosystem accounting could be scaled up to the regional or national level, or how it could be replicated in other river basins and other wetland ecosystems.

The pilot ecosystem accounting covers a detailed description of the Laguna de Bay Basin from the Land Accounts, containing land cover and changes; to the Ecosystems Condition account, indicating various water quality indicators, soil types and elevation, changes in lake bathymetry and sediment loading; and to the Ecosystem Service Production account, indicating the flow of ecosystem services such as fishery production, water supply, flood mitigation and soil erosion and regulation; and an Asset account for water stock, however, this paper focuses on two ecosystem services: erosion control and floodwater retention capacity, which is also referred to as flood control service, and their significance on the ecological integrity of the lake.

## 1.3 Policy drivers

The Western and Northwestern part of the Laguna de Bay watershed is within Metro Manila, with over 16 million people home to most of the country's population and economic activity. Also the Southern part of the area is densely populated. The area has been subject to strong increases in population density, and expansion of economic activities in the last decades, leading to a progressive increase on pressures on natural resources.

On the use of terrestrial resources, the LLDA is confronted with unregulated conversion of forest lands, expansion of urban areas, encroachment of informal settlers on shore lands of the lake, rapid clearing of forests, and the conversion of prime agricultural lands to residential areas. The drivers of these terrestrial pressures are for an important part due to rapid population growth and in-migration to the region brought about by economic opportunities that are lacking in other regions of the country.

Adding to land policy drivers are issues on shore land reclamation particularly actions by local government units and private entities that are inconsistent with the national policy of controlling reclamation of foreshore areas and titling of reclaimed areas. Specifically, the land use plans of local government units are often not harmonized with the Laguna de Bay master development plan.

The accounts provide the scientific basis for better land and water management in the Laguna de Bay Basin, by providing an up-to-date and comprehensive information system on the natural resources present in the basin, and the trends in the use and availability of these resources. The accounts focus on some of the most critical aspects, also based on the mandate of the LLDA, in particular: (i) hydrology and flood risk; (ii) terrestrial land cover change; (iii) erosion and sedimentation.

In addition to water use, a key issue in the lake area is flooding, given that the area is prone to high rainfall events including typhoons and that people have increasingly moved to the low lying parts of the watershed close to the shore of the lake. Given the increasing population density, there is also continuous infrastructure development, including upgrading of roads, public works, etc. A specific item currently discussed is the potential construction of flood protection structure plus land reclamation in the southwest corner of the Laguna Lake. Specific information could potentially be addressed with an ecosystem account, include information on flood-risk areas, determining damages and costs from floods, and determining/prioritizing areas requiring flood mitigation interventions. Erosion and sedimentation are linked to land cover change, and affect the hydrology and the flood control service of the lake by changing the lakes bathymetry.

With the production of accounts completed, policy analyses on these issues using the accounts produced follows. This will be achieved through the preparation of a set of specific policy briefs and policy scenario analysis to respond to several of the main policy issues in the Laguna de Bay area, including dealing with flood risks for local people and erosion control in the basin.

# 2. Methodology

## 2.1 SEEA-Experimental Ecosystem Accounting framework

The System of Environmental-Economic Accounts (SEEA) - Experimental Ecosystem Accounting (UN et al., 2014) approach (in the remainder of this document labeled 'ecosystem accounting') involves the measurement of: (i) the extent and condition of ecosystems; (ii) the ecosystem's capacity to generate ecosystem services as a function of its extent and condition; (iii) flows of ecosystem services; and (iv) the linkages between ecosystems and economic activity (UN et al., 2014; Edens and Hein, 2013).

Fundamental for ecosystem accounting is the spatial approach taken, as well as – in line with the SEEA framework and the System of National Accounts (SNA) - the distinction between flows of ecosystem services and stocks of ecosystem assets. In ecosystem accounting, ecosystem condition, capacity and services flows are analyzed in a spatially explicit approach, i.e. using maps as well as tables (UN et al., 2014). This is essential in order to allow integration of scarce data on multiple ecosystem services at aggregation levels relevant for accounting, such as the province or the country. The spatial approach also supports additional applications, such as land use planning. For instance, ecosystem accounts can indicate which parts of the landscape should be better protected in order to sustain the supply of regulating services such as water regulation that are critical to the supply of other ecosystem services such as crop production. Information on ecosystem condition, capacity and ecosystem service flow is measured in Basic Spatial Units, and may be aggregated for ecosystem types or administrative units (UN et al., 2014).

### 2.1.1 Land Account

The basic methodology for compiling land accounts includes a number of steps. These include: (i) data scoping and selection of parameters and aggregation level of information to be included in the account (e.g., land classification system to be used, land cover units, land use, etc. - with consideration of budget and data availability; (ii) Data collection (including ground truthing of data), preprocessing (e.g., preparing remote sensing images for classification through atmospheric correction and linking to relevant coordinate system) and processing; (iii) development of maps (following standard conventions on legend); (iv) preparing tables of land cover units; (v) calculating land cover change over time; and (vi) assessment of accuracy and validation activities.

The map data on land cover and land use came from the National Mapping and Resource Information Authority (NAMRIA), supplemented with information from the European Space Agency on forest cover (which was used in the erosion and sediment modelling). These data were presented and validated by the respective Technical Working Group (TWG) members to make sure it is up-to-date and valid. Processing of these map data included recalculation of area, reclassification of color codes, overlaying with the watershed and with the political boundaries in so far and the jurisdictional boundary of the Laguna de Bay Basin.

Land cover was analyzed using 2003 and 2010 maps provided by NAMRIA. The 2003 land cover map was generated from 30-m resolution images while the 2010 land cover map was processed from a 10-m resolution remote sensing image. Both used almost the same classifications based on the Food and Agriculture Organization (FAO), that includes Closed Forest, Open Forest, Annual Crop, Perennial Crop, Built-up Areas, Inland Water, Grassland, Shrubs, Wooded Grassland, Open/Barren, and Mangrove Forest. However, the 2003 classification has ‘Fallow’ while the 2010 added ‘Marshland/Swamp’ to its classifications. In future work, it needs to be examined how resampling the 2010 map to 30 m can be done in order to look at the accuracy differences between using 10 and 30 m resolution.

The difference in resolution affects the land cover change analysis. The 2003 land cover map, which has a coarser resolution, was not able to capture smaller details particularly inland waters, whereas the 2010 which has a finer resolution. Thus, in the 2010 land cover map it can be assumed that land cover, and in particular the land cover types that vary on relatively fine scales such as inland water, built-up areas and fishponds are more accurately mapped in 2010 compared with the 2003 map. The TWG will resample the 2010 map to 30 m resolution and check the accuracy differences between using 10 and 30 m resolution. The 2014 map is in preparation.

The Laguna de Bay Region is not synonymous to the lake’s watershed. The former refers to the administrative boundaries of the Laguna Lake Development Authority that takes into account the whole municipality or city even if only parts of it are within the watershed. Thus it is bigger in area of which the total is about 3,880 $km^2$. It is necessary to differentiate it with the Laguna de Bay watershed of which the total area is 2,920 $km^2$. The Land Cover data (2003 and 2010) from NAMRIA were processed in the context of the two LLDA jurisdictions: Administrative and Hydrological/Geographical boundaries. Initially, to cover the entire LLDA mandated jurisdiction, the Land Cover data from NAMRIA were processed/clipped using the municipal boundary to correlate land cover and land use of the region on a municipal context. Understanding the land cover data on a political unit aims to provide local officials with better understanding of their roles as watershed managers.

Information on political boundaries came from the 2000 data of the National Statistics Office, which is now called the Philippine Statistics Authority (PSA). This was used by LLDA since the

GIS unit incorporating these data was established in year 2000 through the Sustainable Development of the Laguna de Bay Environment (SDLBE) project. The boundary covered the Laguna de Bay Region comprising all cities and municipalities as mandated in Republic Act 4850. Modifications on the political jurisdiction were done in 2010 when the agency acquired barangay boundary shapefiles of Region 4A which covers five (5) provinces and the National Capital Region (NCR) from the Department of Agriculture-Bureau of Agrarian Reform (DA-BAR). Based on this, the municipal boundary was delineated to support the developmental and regulatory mandates of the (LLDA).

The watershed boundaries in the Laguna de Bay Basin were delineated by NAMRIA using version 2.1 of the 3-arc second Shuttle Radar Topography Mission (SRTM3) Digital Elevation Model (DEM) data collected in February 2000 by NASA. This is currently the highest-quality, highest-resolution, global-coverage (60°N-56°S) DEM available. At the equator, the resolution is approximately 90m. A general description of the data is at http://www2.jpl.nasa.gov/srtm/cbanddataproducts. html. The coverage area includes the twenty-four major sub-basins of the Laguna de Bay Basin namely: Marikina, Manggahan, Tanay, Morong, Baras, Angono, Pillila, Jala-jala, Sta. Maria, Siniloan, Pangil, Caliraya, Pagsanjan, Sta. Cruz, Pila, Victoria, Calauan, Los Banos, San Cristobal, San Juan, Santa Rosa, Binan, San Pedro, and Muntinlupa (Figure 1).

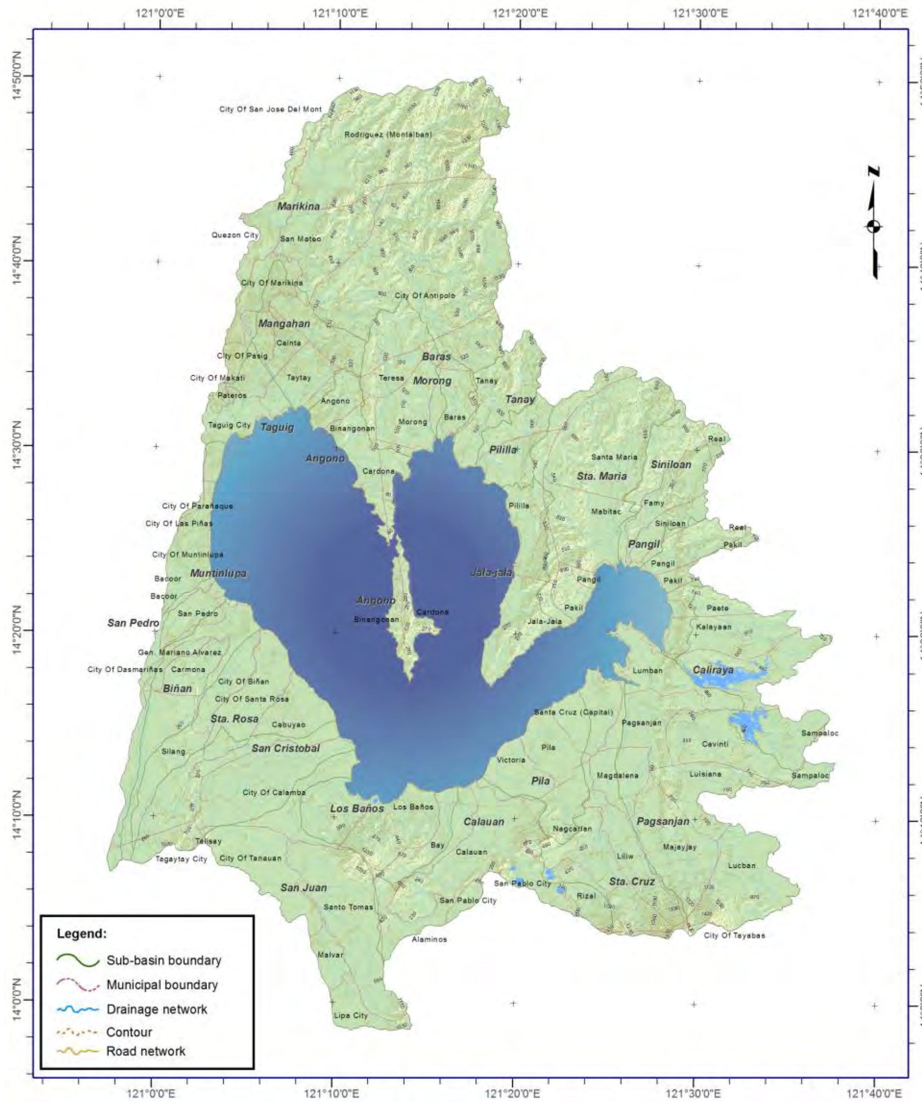


**Figure 1. Laguna Lake Basin showing its major sub-watersheds encompassing cities and municipalities**

The data were processed through ArcGIS 10 to come up with the delineation of different land cover classifications on political boundaries. From the original twenty-one (21) land cover classifications of NAMRIA following the FAO standard classification only fourteen (14) classifications remain and delineated within the municipal boundary of the region. The land cover matrix and physical accounts were prepared with the corresponding tables using pivot table in MS Excel. Land Cover maps of 2003 and 2010 were also prepared.

### 2.1.2 Aquatic Condition Account: Bathymetry

Bathymetry has been analyzed in order to assess how the lake volume has changed over time, and to establish if and how sedimentation has affected the water storage volume of the lake. Primary data was collected in the lake for two years using a multi-beam echo-sounder. In 1997, around 350+ points of water depth were measured. In 2014 over 500 points were analyzed.

Interpolation between points to model total depth of the basin was done using ArcGIS (Spline with barriers) and Delft3d (for comparison of results).

### 2.1.3 Ecosystem Service Account: Soil Erosion Control

The Laguna Lake Basin serves as a multipurpose resource for fisheries, navigation, flood water reservoir, power generation, recreation, irrigation, industrial cooling, wastes sink and source for potable water. Siltation has been identified as one of the pressures being experienced by the lake affecting several of these services. As erosion increases, the severity of siltation also increases. This may result in reductions in lake depth affecting navigation, decrease in water quality for potable water, and potentially leading to an increase in the risk of flooding.

As part of the Phil-Waves project, LLDA has identified flood retention as one the key ecosystem services that needs to be included in ecosystem accounting. In line with this, the objective of this component is to model and map the sedimentation load coming from the 24 sub-basins contributing to the Laguna Lake Basin's siltation using normal and simulated conditions. The modelling and mapping of sediment load has been conducted for the 24 sub-basins feeding to the lake using the 2010 input data (since 2014 input date on land cover were not yet available).

The modelling and mapping of sediment loads for the first seven sub-watersheds was conducted with the Sediment River Network Model (SedNet). Sednet is a GIS-based water quality modelling software package originally developed by CSIRO Land and Water as part of the Australian National Land and Water Resources Audit (Wilkinson et al., 2004). SedNet identifies major erosion processes and constructs sediment budgets on a regional scale to identify patterns in the material fluxes under normal and simulated conditions. The resulting budget accounts for the major sources, storage and fluxes of sediment material. The SedNet software and its on-line documentation are available via the toolkit website of the Cooperative Research Centre (CRC) for Catchment Hydrology (http://www.toolkit.net.au). The data used in the SedNet modelling of Laguna Lake are shown in Table 1.

The SedNet model use a simple annual mean conceptualization of transport and deposition processes in streams (Hartcher et al., 2005). Spatial patterns of sediment sources, stream loads, and areas of deposition within the system can be produced. The contribution from each watershed to the river mouth can be traced back through the system, allowing downstream impacts to be put into a regional perspective (Kinsey-Henderson et al., 2003).

Table 1. List of input data for SedNet

| **SedNet DataRequirement** | **Metadata** | |
|---|---|---|
| | **Source** | **Formula and Method used** |
| **<u>Base data, Stream define</u>** | | |
| • DEM | SRTM 90 meter resolution<br>DTM-IFSAR 5 meter resolution | Filling sinks |
| Flood Plain | | |
| **<u>Physical and Climatic, Spatial inputs</u>** | | |
| • Rainfall Erosivity (R) | world climate data | Empirical equation |
| • Soil Erodibility (K) | Bureau of Soils and Water Management | Empirical equation |

| | | |
|---|---|---|
| • Slope Length-Steepness (LS) | SRTM 90 meter resolution<br>DTM-IFSAR 5 meter resolution | Empirical equation |
| • Land Use (C) | land cover 2010 | Empirical equation |
| • Gully Density | sub-basins, rivers | Conservative estimate |
| • Mean Annual Rainfall | 2010 mean annual rainfall | Hydrologic modeling |
| • Potential Evapotranspiration-Rainfall Ratio (PET) | 2010 mean annual rainfall | Hydrologic modeling |
| • Riparian Vegetation | land cover 2010 | Map overlay |
| **Flow data** | | |
| • Streamflow data | Weather stations of the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) | Hydrologic modeling |
| • Gauge locations | Gauge points | |

SedNet is composed of several modules. Central to the structure and operation of the SedNet model is a stream network defined from a digital elevation model. The network is composed of links that extend between each stream junction. For each link in the network, separate budgets for sediment (i.e., bedload and suspended load) and nutrients (i.e., phosphorus and nitrogen) are computed. The budgets are each a mass balance of inputs and outputs.

The Spatial data module calculates the inputs and outputs that come from grids. For example, hillslope sediment supply comes from a grid of hillslope erosion. The Flow module computes measures of flow required for calculating terms in the budget; for example bank flow is used to calculate bank erosion and overbank flow is used to calculate floodplain deposition.

The input data sets are divided into three categories, the base data, the physical and climatic data and the flow data. Figure 3 provides the hillslope factors that are needed to model erosion. The preparation of input data including the combination of measurements of river discharge, conceptual representation of material transport, soil types, land use and vegetation cover, terrain and climate were done using ArcMap in ArcGIS.

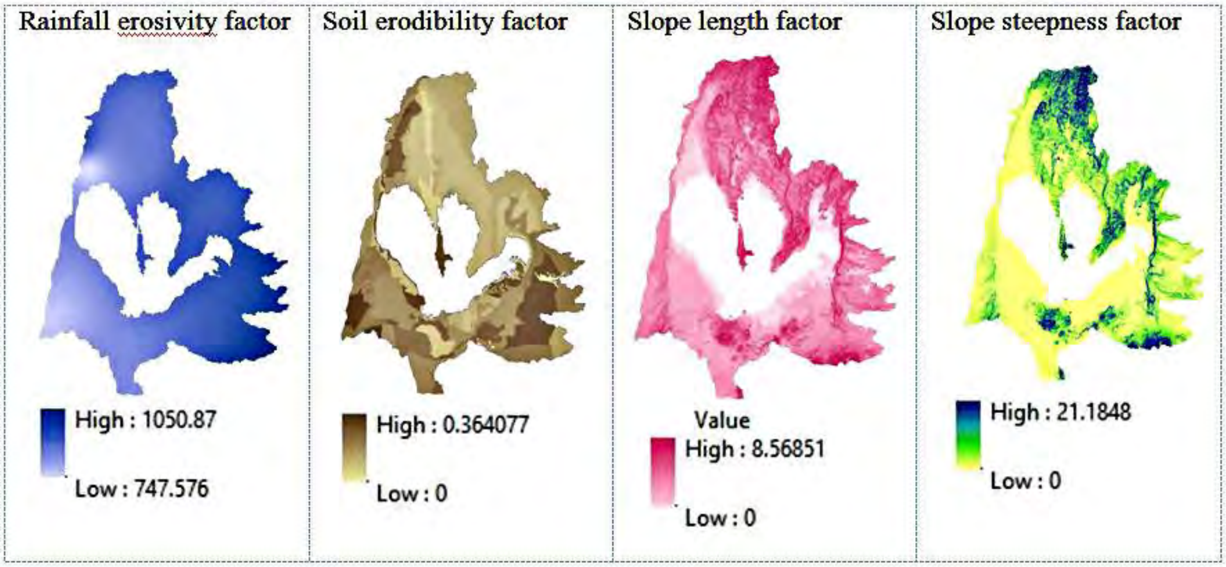


**Figure 2. The erosion modelling factor for SedNet modeling**

SedNet's scenario analysis capabilities were used to analyze the ecosystem service 'sediment retention,' i.e. avoided erosion. To analyze the amount of avoided sediments, all semi-natural and natural ecosystems, like closed and open forest, shrublands, grasslands and wooded grasslands were changed into bare lands in the model. The resulting amount of erosion and sedimentation was assumed to equal the avoided erosion and sedimentation, respectively, as a consequence of the presence of the vegetation. The effects on sediment loads and exports were analyzed by rerunning the model for this simulated scenario. Results of the normal condition were then deducted from the results of the simulated conditions to elucidate the avoided erosion service. Post processing of maps for each sub-watersheds were conducted in ArcGIS. Only 21 sub-watersheds where run using SedNet. The small watersheds of Angono, Caliraya and Taguig were not included in the analysis due to difficulty in getting good results in terms of stream definition. This will not have a significant impact on the overall results given that these stream contribute only a very minor part (<5%) to the overall sediment loading.

### 2.1.4 Method-Ecosystem Service Account: Flood Control

Flooding of houses and infrastructure within the Laguna de Bay region is an important economic issue. In most years, there are minor floods affecting part of the basin, but in case of major typhoons the area is subject to heavy flooding leading to losses of life as well as losses of houses and infrastructure. The last time this happened in 2009 when during the typhoon Ketsana (Ondoy) the water levels recorded around 13.8m lake level, and the damages in the Laguna de Bay region amounted to around 6 billion pesos (data LLDA, 2014).

The Laguna Lake is a crucial element in the hydrological system of the watershed. It acts as a retention basin, where water generated in the upper parts of the watershed is collected before it is discharged, through the relatively small Pasig River to the Manila Bay. Through the retention of water in the lake, the flood risk is mitigated. This is interpreted as the flood retention service of the lake, which has been analyzed, in physical and monetary terms, in this section of the report.

The flood retention service of the lake is defined as the capacity of the lake to store water that would otherwise have led to flooding of houses and infrastructure. The flood risk is imposed, in the Laguna de Bay watershed, from rain water collected in the lake through run-off from the 24 sub-watersheds draining into the lake, in particular during high rainfall events such as typhoons. The capacity to store water is defined as the water that can be stored in the zone between (i) the average water level in the beginning of the rainy season (July); and (ii) the water level at which the first houses along the lake are flooded. In between these two levels water can be stored without causing economic losses due to flooding. Note that the flood retention capacity is not related to the overall volume of water stored in the lake, the water level below the average beginning of the rainy season level is, on average, filled throughout the year and therefore not available as retention basin.

Based on the above, the retention service is defined as the zone between 11.5m and 12.5m[1] (see Figure 4). Over time, people have started living ever closer to the lake. Nevertheless, at present, there are very few houses in the lake area, if any, that are built below the 12.5 m level, given that this level experiences floods in most years. The flood retention service is affected by the inflow of sediments in the lake. Although the overall depth of the lake has not changed very substantially in the period 1997-2014, as explained in the previous section, sedimentation has affected the flood retention service because sediments were deposited by means of backfilling of the shores of the lake. On areal photographs, extensive sandbanks can be observed, where sediments were deposited close to the shore including in the zone between 11.5 and 12.5m.

The flood retention service was analyzed in a number of subsequent steps:

1. Analysis of the population density and number of houses in each 1m zone above the 12.5 m water level (12.5-13.5, 13.5-14.5, 14.5-15.5m). Population data were available for the years 2000 and 2010. These data have been interpolated, and the average annual growth rate in this period has been extrapolated to the period 2011-2014.

2. The average number of people per household is assumed to be 4.6 (PSA 2014; data for 2010). The number of houses per flood zone is calculated by dividing the number of people by 4.6. The average house price of a basic house in the flood zone is assumed to be 500,000 pesos. Note this is an estimate based upon expert judgement of the LLDA. Although PSA presents house prices, they are averages over a larger area. Since this area includes parts of the urban zone of Metro Manilla, as well as the well-developed area south of the Laguna Lake with relatively high house prices, these house prices were assumed to be unrepresentative for the houses built in the zones most prone to flooding, which are often illegally built, simple constructions. Consequently, the costs of flooding need to be interpreted with caution. Note also that the model is calibrated for the costs of the 2009 flooding. Based on this calibration, the costs of damages to infrastructure were assumed to be equal to around 25% of the damages to houses. Further research is needed to analyze both the costs of damages to houses in the flood zone, and the costs of infrastructure. Given the uncertainty attached to this monetary value, the value is not included in the summary account for policy makers.

3. The amount of damage caused by flooding is dependent upon inundation depth, the duration of the flood, the type of construction and materials used (wood, concrete, bricks, etc.) and the use of flood control measures. Based on past floods, inundation

[1] Water levels in this report are based on the LLDA reference system. 11.5m in this system corresponds to 1.5m above mean sea level.

depth and damage costs have been correlated (Figure 5) (Arias et. al. 2014). This analysis only considers damages to houses. Damage to infrastructure, crops and other properties were on average 25% of damage to houses during past flood events (LLDA, 2014). Therefore damage ratios were multiplied by a factor of 1.25.

4. A simple spreadsheet model was prepared in order to relate flood level, in each year, to damage costs. The outcomes of the model are illustrated in Table 2, which presents the model calculations of the damage costs of a 13.8m flood (the 2009 flood level). Note that the model also allows predicting flood damages as a consequence of flood levels in the future (by extrapolating population growth rates). When new census data become available population data can be updated in the model.

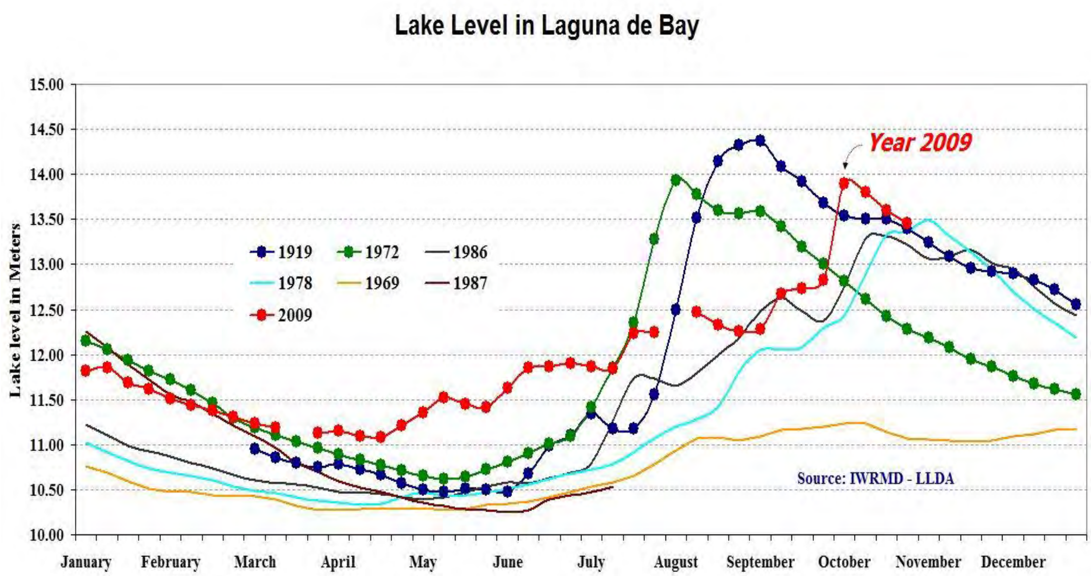


**Figure 3. Water levels in the lake in selected years with floods (source: LLDA)**

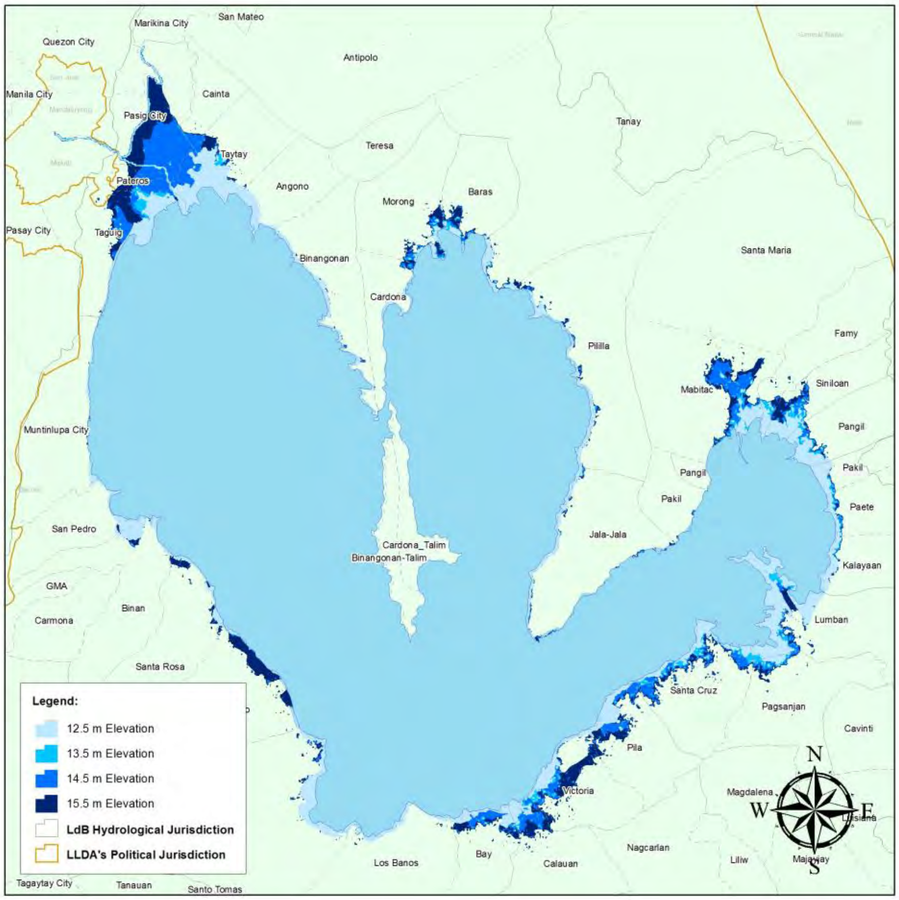


**Figure 4. Lake showing flood retention service vis a vis flood plain areas (2014)**

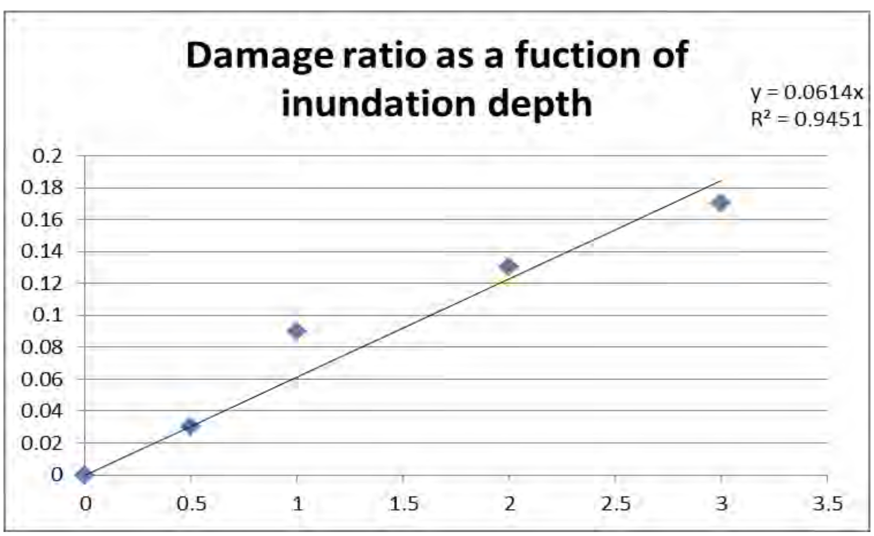


**Figure 5. Damage ratio as a function of inundation depth (based on Arias et. al. 2014)**

**Table 2. Damage costs of 13.8m flood in Laguna de Bay area**

| Year | Flood Height | Damage costs (billion pesos) |
|---|---|---|
| 1997 | 13.8 | 4.1 |
| 1998 | 13.8 | 4.2 |
| 1999 | 13.8 | 4.4 |
| 2000 | 13.8 | 4.5 |
| 2001 | 13.8 | 4.7 |
| 2002 | 13.8 | 4.9 |
| 2003 | 13.8 | 5.0 |
| 2004 | 13.8 | 5.2 |
| 2005 | 13.8 | 5.3 |
| 2006 | 13.8 | 5.5 |
| 2007 | 13.8 | 5.6 |
| 2008 | 13.8 | 5.8 |
| 2009 | 13.8 | 5.9 |
| 2010 | 13.8 | 6.1 |
| 2011 | 13.8 | 6.2 |
| 2012 | 13.8 | 6.4 |
| 2013 | 13.8 | 6.6 |
| 2014 | 13.8 | 6.7 |
| 2015 | 13.8 | 6.9 |

The value of the ecosystem service 'water retention' can be approximated by comparing flood levels with and without the water storage volume of the lake. In line with the assumptions above, at 12.5m it is assumed that there are no significant flood damages in the Laguna de Bay area. Would there be no water storage between 11.5 and 12.5m, then the water level could be expected each year to reach 13.42m in the rainy season. Due to the bathymetry of the lake shore, the flood level would rise with 0.92 instead of 1m[2].

Comparing flood damage costs at 12.5m with those of 13.42m therefore provides an indication of the monetary value of the water retention service of the lake, based on the avoided damage costs from floods. At 12.5m the damage costs are assumed to be zero, and at 13.42m the damage costs are modelled to be 4.2 billion pesos (in 2015). Hence the value of water retention (i.e. flood control) can be estimated to represent 4.2 billion pesos per year. However, this value is strongly dependent upon the assumptions made. On one hand, a conservative estimate, since the water storage also reduces the flood levels during years with extremely high water levels, as in the case of the 2009 typhoon. On the other hand, this value may be an overestimate since in reality people may move out of the 12.5 to 13.42m flood zone in case the present water storage in the lake would not be possible. A consideration here is that many of these people have few places to go, they settled in the flood prone zones of the lake because of a lack of alternative places to build a dwelling.

Hence, the value of 4.2 billion pesos per year should be interpreted with caution. It is an approximation of the value of this service only, and given the lack of experience with valuing

---

2 Based on: (water volume at 12.5m – water volume at 11.5m)/(water volume at 13.5 – water volume at 12.5m) = (4.1-3.1)/(5.2-4.1) – these are rounded values in million $m^3$

flood control further discussion is needed before this, or alternative value estimates, can be considered sufficiently robust for monetary ecosystem accounting. Recognizing that further discussion is needed on how the flood control service can best be valued, we chose not to include this indicator in the summary account for policy makers.

## 3. Results and Evaluation

### 3.1 Watershed Land Use/Cover Change

**Land cover in 2003**. In 2003, industrial and urban/built up areas covered 7.9% of the basin or about 30,469 ha (see Figure 6 and Table 3). Built-up areas are mostly concentrated at the western portions of Laguna Lake and the six sub-basins with the highest concentration of urban sprawl are Manggahan, Marikina, Muntinlupa, Sta. Rosa, Binan and Taguig sub-basins.

A large portion of the land cover, approximately 91,245 ha or 24% is covered by Annual Crops and 57,704 ha is Perennial Crop including rice fields, coconut plantations, fruit trees, piggery/poultry/livestock raising and other agricultural activities. The agricultural areas are concentrated in the southern area of the region, particularly in the towns of Laguna Province and some portions in Rizal Province. Rice farming and farming of various crops are observed bordering the level lands of Laguna de Bay, which are evident in the towns of Pakil, Pangil, Siniloan, Famy and Sta. Cruz in Laguna Province. Sugarcane is the most important crop in the following areas: Calamba, Cabuyao and Sta. Rosa in Laguna Province; Sto. Tomas and Tanauan in Batangas Province; and Carmona in Cavite Province. In the marshlands of the coastal areas, fishponds and duck farms/"balut" production can be observed. The mountainous northeastern, eastern and southern areas, many of which used to be forestlands, are used for coconut, banana and fruit production.

Forest cover represented by Closed Forest (1.1% or 4,350 ha) and Open Forest (5.5% or 21, 504 ha) constitutes the remaining forest ecosystems. The closed forest areas, including primary and secondary forest, are mainly located in the northeastern and eastern parts of the region, with a few patches in the southwestern section. The primary forest holds stands of dipterocarp trees such as *lauan, apitong, manggachappui* and *yakal* while the secondary forests are often places that have been planted to reforestation tree species such as mahogany, *gmelina, falcata* and *ipil-ipil* or have been naturally occupied by other tree species such as bamboos and palm trees.

The shrub land area covers 65,049 ha or 17% while the open/barren area comprises 1,152 ha or 0.3% of the total watershed area of the Laguna de Bay Basin. The grasslands and bushlands are located close to the forested areas in the northern, eastern and southern sections of the region. Except for the barelands, the grassed areas are utilized for grazing. Many of the grazing areas, however, are below the 18-percent slope which by law should be relegated only to urban and agricultural uses. Grazing is only allowed in the 18 to 50-percent slopes, along with mining and production forestry or silviculture. Slopes above 50 percent should, by law, be used strictly only for protection forest (Table 3 below). These land use limits are more accurately delineated at the sub-watershed level, hence the need to also plan the whole region at the level of each of the 24 sub-watersheds comprising the region. The grasslands areas in the region are dominated by cogon (*Imperata cylindrica*) and talahib (*Saccharum spontaneum*) whose immature shoots are used as animal feeds. In other cases, more palatable pasture grasses such as Kudzu, Para Grass and Guinea Grass are purposely planted to produce more healthy livestock.

**Table 3 Land cover composition by slope category**

| Land Cover 2010 | Slope in meters, (ha) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Unclassi-fied | 0 to 3 | 3 to 8 | 8to 18 | 18 to 30 | 30 to 50 | 50 and above | Grand Total |
| | Area in hectares | | | | | | | |
| Annual Crop | 117 | 23,651 | 10,265 | 13,426 | 1,774 | 1,466 | 1,593 | 52,291 |
| Built-up | 345 | 23,517 | 13,892 | 20,126 | 5,784 | 1,520 | 504 | 65,687 |
| Closed Forest | | 1,555 | | 10 | | 315 | 952 | 2,831 |
| Fishpond | | 51 | | 25 | | | | 76 |
| Grassland | 1 | 938 | 1,177 | 4,904 | 794 | 3,987 | 4,682 | 16,482 |
| Inland Water | | 91,111 | 731 | 1,049 | 816 | 312 | 906 | 94,924 |
| Mangrove Forest | | 1 | | | | | | 1 |
| Marshland/Swamp | | 2 | 2 | | | | | 4 |
| Open Forest | 2 | 2,271 | 291 | 1,630 | 673 | 4,511 | 11,389 | 20,768 |
| Open/Barren | 1 | 105 | 84 | 327 | 26 | 69 | 93 | 707 |
| Perennial Crop | 98 | 3,873 | 7,516 | 18,703 | 4,047 | 4,668 | 4,830 | 43,734 |
| Shrubs | 478 | 3,122 | 2,621 | 13,330 | 12,178 | 12,276 | 19,647 | 63,652 |
| Wooded grassland | 76 | 1,445 | 1,410 | 8,842 | 506 | 5,692 | 8,881 | 26,853 |
| **Grand Total** | **1,118** | **151,641** | **37,990** | **82,371** | **26,598** | **34,816** | **53,476** | **388,011** |

The water bodies cover about 23% or 89,517 ha which include the Laguna Lake itself and other inland waters such as seven crater lakes, Tadlak lake, Caliraya reservoirs and other marshy areas or wetlands within the region. Note that there are differences in water areas in the 2003 and 2010 maps, which may be related to a different timing of the remote sensing images on which the maps are based, and to the different resolution of the images (as discussed above).

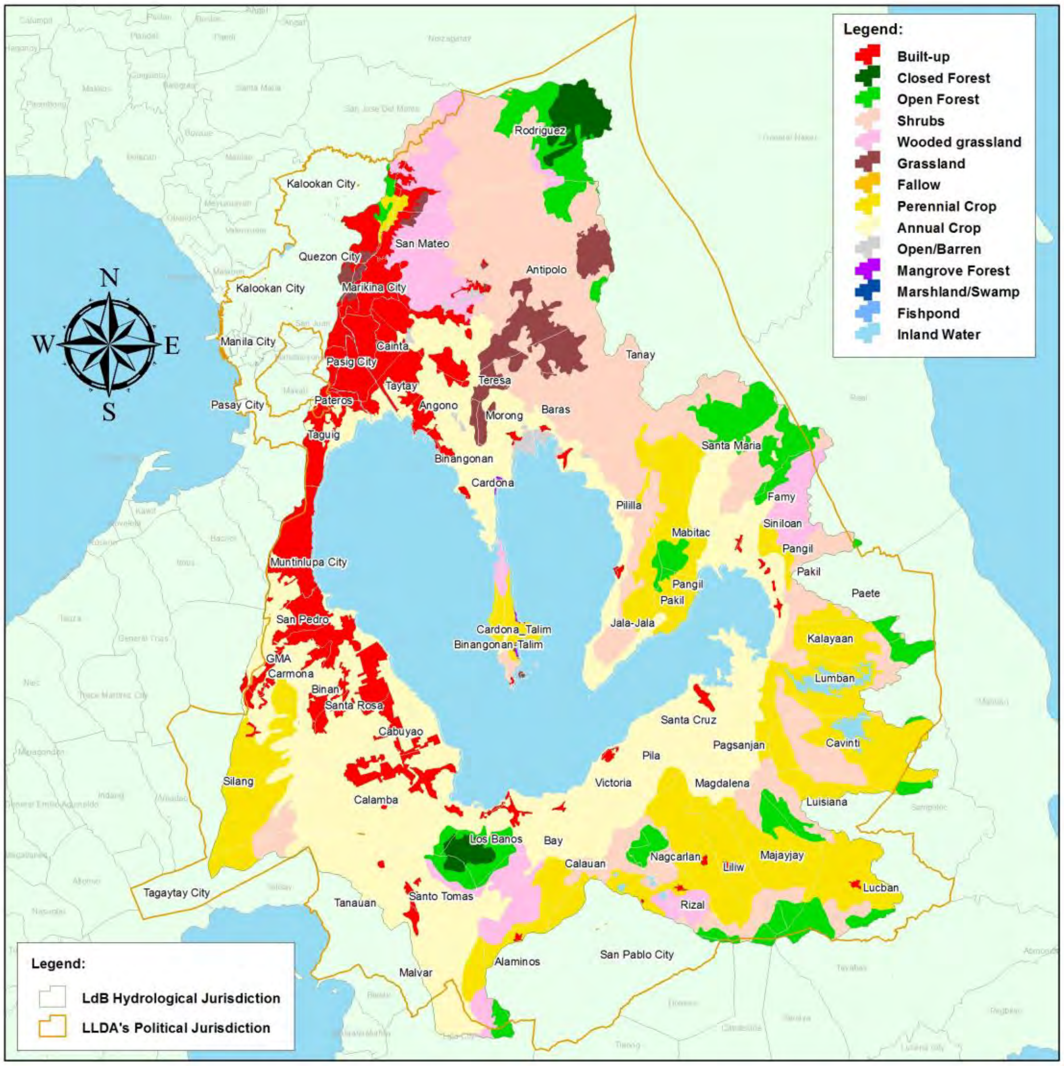


**Figure 6. Land Cover by Watershed, 2003.**

**Land Cover in 2010**. The Land Cover classification of 2010 captures spatial units more accurately, especially small portions of land cover, due to its 10-meter image resolution backed-up with ground validation. From the 2010 land cover map of the Laguna de Bay Basin, it can be derived that forest cover represented only 6% of the basin, including Closed Forest (2,831 ha or 0.7%) and Open Forest (5.9% or 20,768 ha), see Figure 3.4 and Table 3.1. Among the twenty-four (24) sub-basins of the Laguna de Bay Basin, the highest forest cover (closed and open forest) in 2010 remains to be found in Marikina with 7,307 ha, followed by Pagsanjan with 2,966 ha and Los Banos sub-basin with 2,946 ha.

Built-up areas amount to 17% or 65,687 ha is the highest, mangrove forest with only a hectare is the lowest. Marikina being the largest sub-basin of the Laguna de Bay Basin also occupies the largest built-up areas with 9,530 ha. This is followed by Manggahan, Santa Rosa, San Cristobal, and San Juan sub-basins with 7,264 ha, 7,042 ha, 5,896 ha and 4,710 ha, respectively. Considerable built-up areas can also be found in the cities and towns of Santa

Rosa, San Juan and San Cristobal sub-basins where large number of industries, residential areas, and other commercial establishments are emerging.

Agricultural land including areas planted with Annual Crops and Perennial Crops are mostly concentrated in agricultural based sub-basins such San Juan, Pagsanjan, Calauan, Pila, and Sta. Cruz sub-basins. These sub-basins are planted with agricultural products such as rice, corns and some roots crops. In terms of Annual crops, San Juan sub-basin is the largest and covers 8,858 hectares, followed by Pagsanjan with 5,698 ha and Pila with 4,724 ha. Perennial crop are largely situated in Pagsanjan (6,670 ha), Calauan (6,689 ha) and Sta. Cruz (5,648 ha) sub-basins.

Large areas of shrubs are also noticeable in sub-basins of Marikina (17,916 ha), Pagsanjan (12,901 ha) and Sta. Maria (6,759 ha). Wooded grasslands and grassland areas are largely situated in Marikina sub-basins with 7,145 ha of wooded grasslands and 7,192 ha grasslands. Followed by Sta. Maria sub-basin with 5,049 ha wooded grasslands and 775 grassland areas. Interestingly, Sta. Rosa sub-basin has 1,403 ha grassland areas but without areas occupying wooded grasslands category. San Cristobal sub-basin also contributes to the total grasslands areas with 1,955 ha of grassland and 199 ha of wooded grasslands.

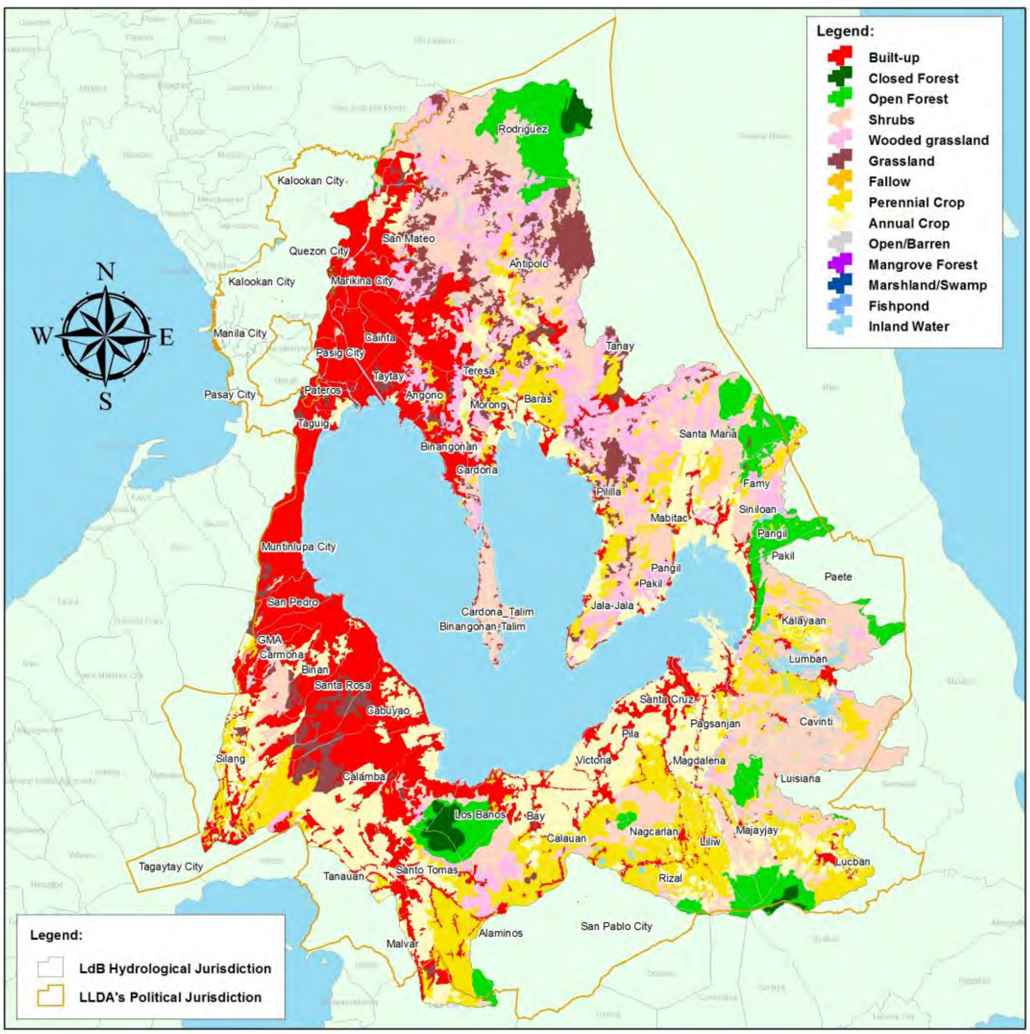


**Figure 7. Land Cover by Watershed, 2010**

**Land cover change between 2003 and 2010**. Comparing 2003 and 2010 land cover (Table 4), built-up areas more than doubled in this period (representing an average annual growth of more than 11%). This reflects the rapid development and change of land use in the region; lands have been converted, mostly by private owners, for industrial/commercial and residential purposes. There is also an increase in areas of grassland (8,190 ha) and wooded grassland (8,225 ha). On the other hand, open forest areas decreased by 3% and closed forests by 35% in this period. The decrease in forest areas may be attributed to rampant forest degradation and remaining shifting cultivation in upland areas of the Laguna de Bay Basin. Forests in the region has been subjected to deforestation in past decades. Between the mid 1940s and mid 1990s, forest cover decreased from about 53 percent to 8 percent. Deforestation rate in the region was highest in the 1970s because of logging. Expanding urban areas, poverty and unregulated trading of forest products have contributed to the degradation of the watershed and the region.

There is also a marked decrease in agricultural areas in this period, of on average about 35% in the Laguna de Bay Basin. Specifically, annual crop decreased by about 43% or 38,953 ha while Perennial crop decreased by 24% or 13,970 ha. The last patches of mangrove forest virtually disappeared in the lake basin in this period, declining from 94 ha in 2003 to 1 ha in 2010. The last remaining mangroves can be found in the intersection of Laguna Lake and Pasig River.

Overall, land cover change in the period 2003-2010 has been very rapid. Analyses are ongoing for the year 2014 to see if this trend has continued.

**Table 4. Comparison of Land Cover of 2003 and 2010 by Watershed, area in hectares**

| Land Cover | Land Cover 2003 | | Land Cover 2010 | | Change in Land Cover | | |
|---|---|---|---|---|---|---|---|
| | Hectares | Share of Land Cover | Hectares | Share of Land Cover | Change in Hectares | % Change Land Cover | % Change in Share of Land Cover |
| Annual Crop | 91,245 | 24% | 52,291 | 13.5% | -38,954 | -43% | -10.0% |
| Perennial Crop | 57,704 | 15% | 43,734 | 11.3% | -13,970 | -24% | -3.6% |
| Built-up | 30,469 | 8% | 65,687 | 16.9% | 35,218 | 116% | 9.1% |
| Open/Barren /fallow | 1,160 | 0% | 707 | 0.2% | -453 | -39% | -0.1% |
| Shrubs | 65,049 | 17% | 63,652 | 16.4% | -1,397 | -2% | -0.4% |
| Grassland | 8,292 | 2% | 16,482 | 4.2% | 8,190 | 99% | 2.1% |
| Wooded grassland | 18,628 | 5% | 26,853 | 6.9% | 8,225 | 44% | 2.1% |
| Marshland/Swamp | - | | 4 | 0.0% | | | 0.0% |
| Open Forest | 21,504 | 6% | 20,768 | 5.4% | -736 | -3% | -0.2% |
| Closed Forest | 4,350 | 1% | 2,831 | 0.7% | -1,519 | -35% | -0.4% |
| Mangrove Forest | 94 | 0% | 1 | 0.0% | -93 | -99% | 0.0% |
| Inland Water | 89,517 | 23% | 95,000 | 24.5% | 5,407 | 6% | 1.4% |
| **Total** | **388,011** | | **388,011** | | | | |

The land account clearly illustrates the major land cover change in the basin in the period 2003-2010. There is rapid urbanization and industrialization in the lake region in particular in the Greater Metro Manila area in the northwest and in the western and southern portions of the lake. The spread and location of residential subdivisions are characterized by unplanned urban sprawl. This involves, among others, the conversion of agricultural lands to residential uses, and the construction of new settlements close to the lake shore, in the zone that is vulnerable to flooding.

The forest cover has undergone a very rapid decline in the same period. All mangrove forest (except one 1-ha patch) disappeared, and closed forest decreased with 35%. Remaining forests are found, in particular, in the Makiling Forest Reserve and Sierra Madre mountain ranges, but even in these areas illegal settlements have been established. These remaining forest areas should be preserved as they maintain the ecological balance of the lacustrine region. In addition, there are still many parts of the region that should be reforested by law (P.D. 705) and these are the above-18-percent slopes and above-1000-meter elevations that are seen particularly in the Sierra Madre Mountain foothills in Rodriquez, San Mateo, Antipolo, Tanay, Pagsanjan and Sta. Cruz. The typhoons Ondoy and Pepeng flooding catastrophes in 2009 were wake-up calls to the need to immediately reforest the denuded foothills especially of the northern Marikina and the southern Sta. Cruz-Pagsanjan sub-watersheds. A protected zone is the 42.4 $km^2$ Makiling Forest Reserve (MFR) in Los Baños which is preserved as a wildlife sanctuary, pool for genetic diversity, and training laboratory for the advancement of scientific knowledge on natural resources. In addition, as a natural resource the MFR also provides irrigation, industrial and domestic water as well as electric power to the surrounding communities—the latter resource being provided by the Makiling-Banahaw Geothermal Power Plant.

This report began with the assertion that an understanding of the implications of changes in land cover and land use is a fundamental part of planning for sustainable development and ecosystems of Laguna de Bay Basin. Through the processing of data and information, we have provided how the development of land accounts can contribute to knowledge and understanding in this important area. For instance, the accounts can inform on recent efforts at land conversion that may not be aligned with development plans or planning laws, enabling better enforcement of such regulations. Of considerable importance for policy relates to conversion of forest lands. For example, a question for policy makers is if legally classified forest lands with longstanding claimants be converted to Alienable and Disposable Lands, in other words if existing, but not legal land use should be allowed and legalized or if the land should be reverted to forests. These and other policy issues require regular updates of land account.

The land cover maps are used in ecosystem accounting in a number of ways. First, they provide useful information by themselves in support of policy making, as described above. Second, they are a basis for calculating the supply of ecosystem services (see e.g. Remme et al., 2015). Regulating services, for example, require the modelling of ecological processes that generally depend upon, among others, land cover. This is illustrated in this account with the calculation of sedimentation control by vegetation. One of the most important input datasets for calculating this service was land cover.

Further development of land accounts should continue to obtain basic information on the availability and usability of land resource to provide planners and users with adequate basis for facilitating the orderly development and wise usage of this vital resource. We therefore recommend that land accounts should be regularly updated, and be incorporated in the watershed-based or regional planning process. This requires an ongoing collaboration with NAMRIA to provide datasets for land cover and land use comparison on a regional up to micro-watershed level.

### 3.2 Aquatic Condition Account: Change in Lake Bathymetry

The results are shown in the two figures below. Various model runs were conducted using different interpolation technique to establish overall lake depth based on the sample points, and these consistently show that there has been a small reduction in the lake volume in the period 1997 to 2014 (<5%). The main patterns of change is that the deeper parts of the lakes became somewhat deeper (1 to 2 cm) over time, in particular in the western and central part of the lake (compare Figures 8A and 8B). However the periphery of the lake became shallower, in particular in areas close to where rivers drain into the lake. Noticeable is the decrease in 10.5 m lake surface area, which can be attributed to sedimentation (and land reclamation, often following sedimentation on areas where there has been a particular build up in sediments). Overall it appears as if the overall volume of the lake to contain water and to drain water to the Pasig channel has not markedly changed in this period, but that the lake volume between 10.5 and 12.5m water level has decreased, due to backfilling of the lake with sediments deposited nearby river outlets in the lake. The likely impact of shallowing of the periphery and decreasing water volume retention is increasing flood frequency in flood plains of the lake if the capacity of the Pasig River channels, the only outlet of the lake, is reduced. The TWG is presently reviewing the estimates to refine the results. The bathymetry measurements have to be made more frequent than what is already done (1997 and 2014) if this will be linked to the water and flood accounts.


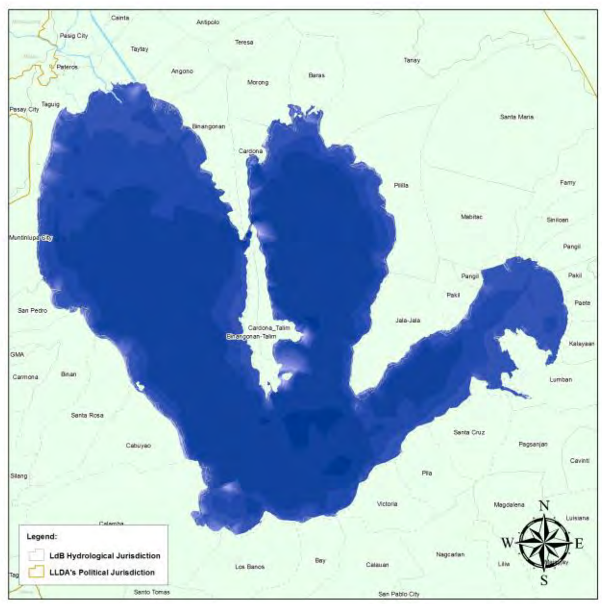


**Figure 8A. Lake depth in 1997** **Figure 8B. Lake depth in 2014**

### 3.3 Ecosystem Service Account: Soil Erosion Control

The total area of the 24 sub-basins analyzed is 2,741 square kilometers. Under normal conditions, the total sediment generated using 2010 land cover is 2,011 kilo tons of sediment per year. The highest contributing sub-watersheds are Sta. Maria, Los Banos, St. Cruz, Pagsanjan and Marikina (see Table 5). Under simulated conditions sedimentation rate increased to 6,885 kilo tons of sediment per year. Simulated conditions entails all natural and semi natural ecosystems including close and open forest, shrublands, grasslands, and wooded grasslands being converted to bare lands. Figure 9**Error! Reference source not found.** presents the 21 sub-watersheds and their corresponding suspended sediment yields.

The ecosystem service of closed forest, open forest, shrubs and wooded grasslands in terms of avoided erosion was then calculated to be 4,874 kilo tons of sediment per year. This was calculated by deducting the results of the normal conditions and simulated conditions.

**Table 5. Contribution of sediments by seven sub-watersheds under present and simulated conditions**

| **Sub-watershed** | **Area (km2)** | **Sediment generated under 2010 land cover (KT/Y)** | **Sediment that would be generated under bare land cover** | **Ecosystem service (avoided erosion)** |
|---|---|---|---|---|
| Units | square kilometer | kilo tons per year | kilo tons per year | kilo tons per year |
| Muntinlupa | 44 | 2 | 3 | 1 |
| Mangahan | 88 | 13 | 27 | 14 |
| Sta Rosa | 120 | 16 | 50 | 34 |
| Binan | 91 | 17 | 146 | 129 |
| Jala-Jala | 86 | 29 | 46 | 17 |
| San Juan | 73 | 44 | 86 | 42 |
| San Cristobal | 204 | 46 | 259 | 213 |
| San Pedro | 140 | 48 | 79 | 31 |
| Pangil | 47 | 50 | 148 | 98 |
| Pililia | 56 | 51 | 61 | 10 |
| Calauan | 41 | 58 | 256 | 198 |
| Tanay | 163 | 73 | 167 | 94 |
| Morong/Baras | 54 | 82 | 137 | 55 |
| Siniloan | 122 | 99 | 112 | 13 |
| Pila | 93 | 119 | 256 | 137 |
| Sta Maria | 205 | 139 | 524 | 385 |
| Los Banos | 103 | 141 | 252 | 111 |
| Sta Cruz | 149 | 157 | 785 | 628 |
| Pagsanjan | 319 | 296 | 1154 | 858 |
| Marikina | 543 | 531 | 2337 | 1806 |
| **TOTAL** | **2741** | **2011** | **6885** | **4874** |

Key: /1 assuming that all closed forest, open forest, shrubs and wooded grasslands would be converted to bare land

The highest sediment yielding sub-watersheds under current land cover conditions are Marikina, Pagsanjan and Sta. Cruz. Based from the evaluation of land account analysis, these areas included several highly denuded areas, the majority of which are within 18 degrees and higher in slope. These watersheds are dominated by shrublands, grasslands, wooded grasslands, perennial and annual crops.

Sediments produced by each of the sub-watersheds cause siltation deposited along the shorelines of the lake, especially along the northwest and southeast parts of the bay. The location of the five major watersheds with the highest sedimentation rates coincides with the shorelines that have displayed sediment deposition similar to the findings of the bathymetry model. Silt deposition along the lake shoreline causes natural land reclamation leading to further encroachment of human settlers along the lake shoreline. This in turn decreases the water retention of the lake causing a higher risk of flooding.

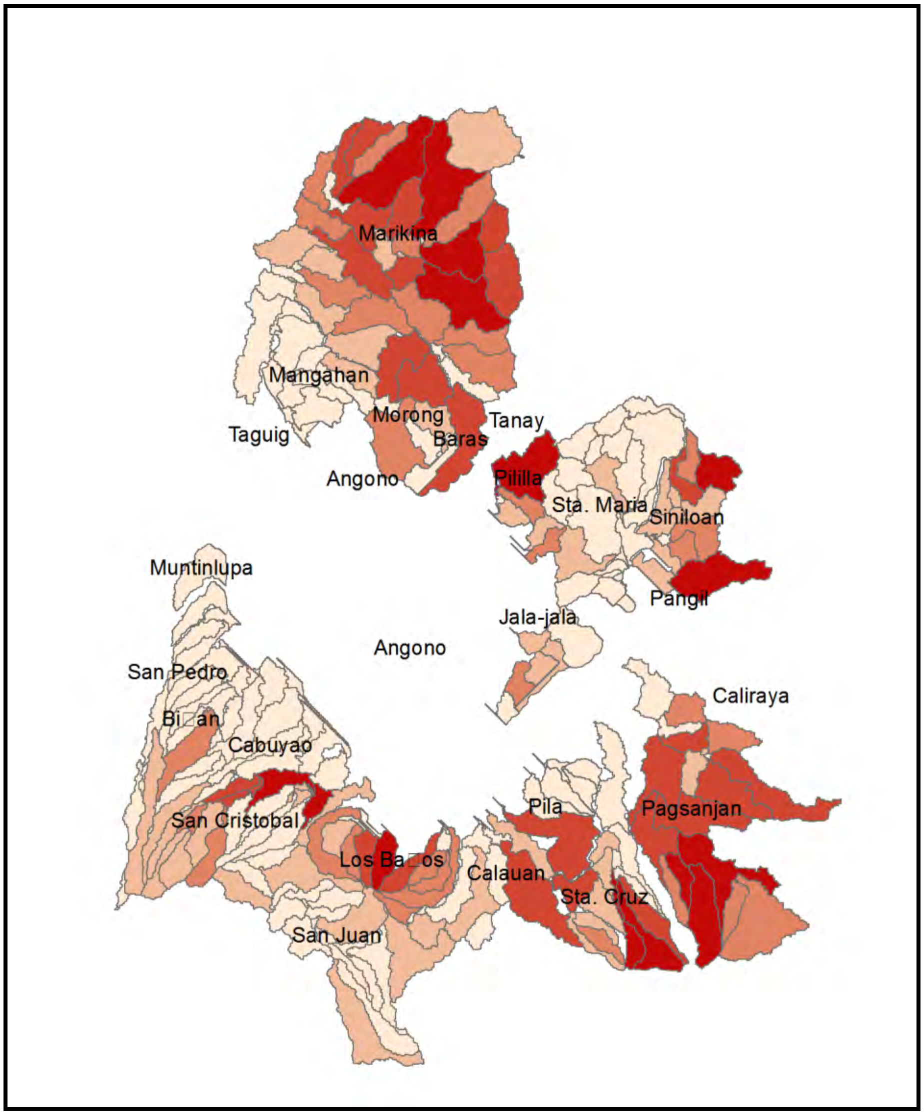


**Figure 9. Map showing the Total Suspended Solids (kilo tons per year) for the 21 major sub-watersheds of the Laguna de Bay Watershed**

Despite the current state of the ecosystem, the semi-natural and natural ecosystems are still capable of preventing 4,874 kilo tons of sediment per year from being deposited along the shorelines of the Laguna Lake Basin. With this information, efforts should be made in protecting these natural and semi-natural ecosystems to prevent further degradation that would hasten the siltation along the shoreline as well as shallowing of the lake.

*In terms of data quality, there were several limitations to the followed approach:*

- Land cover was only available for 2003 and 2010 hence no calculations for 2014 can be presented. 2003 was excluded from this account due to time limitations.
- Limited availability of current climatic data (in particular a deficiency of rainfall data).
- Limited availability of streamflow data.

Hence, the results of this account should be interpreted with some caution. Nevertheless, the relative erosion rates generated in the different parts of the basin are well represented, hence the map shows priority areas for soil and water conservation measures.

### 3.4 Ecosystem Service Account: Flood Control

The analysis provides a number of insights that are relevant for policy making. First, the analysis shows that the flood risks in the lake zone have substantially increased since the last major typhoon in 2009, because of an increasing population in the lake shore. The model indicates that, would the same flood level of 13.8m occur today, the flood damages would be 6.9 billion pesos. Importantly, these calculations do not include the loss of lives. Typhoon Ketsana (Ondoy) in 2009 caused not only 6 billion pesos in material damages but also the loss of 104 lives. Depending upon the emergency response strategies designed and implemented in the Laguna de Bay area since 2009 it needs to be considered that flood impacts are only increasing with current increases in population density. Climate change may increase these problems in the future, due to both potential increases in extreme events and sea level rise making drainage from the lake to Manila Bay even harder.

The model developed for the account forecasts a specific number of houses that would be flooded in each municipality around the lake for any given flood level, which could be helpful for updating emergency response plans. Given the importance of flooding, a flood risk map was produced to show a potential additional policy application of the Ecosystem Accounting approach. The maps clearly indicates the areas where population density of people at risk from flooding (and particular care is needed in terms of emergency response including evacuation plans), and the potential economic damages of floods are highest.

The modelling approach would also be useful to analyze the effects of the proposed water levee (dyke) in the southwestern part of the lake. Since this reduces the size of the overall flood plain of the river it is likely to lead to increased flooding in other parts of the lake. The magnitude of the flooding in other parts has not been predicted in this account but could easily be done once the (potential) design of the structure is available.

A flood risk map was derived using the number of households within the flood plain areas up to 14.5m lake level or 4.5 meter above sea-level (MASL), which correspond to the worst flood event recorded in history (in 1919). In other words, flood risks were visualized spatially by calculating the effects of a 14.5 m flood for the shore of Laguna Lake.

Demographic data in the various sections of the flood plain came from the Philippine Statistics Authority. The number of households affected was plotted per municipality and dot density was used to come-up with the number of flood-affected households per hectare (HH/ha). This output was used, in combination with flood damage cost parameters from the model specified in Annex 4 and 6 to generate the potential flood damage cost map in pesos per hectare or Pesos/ha.

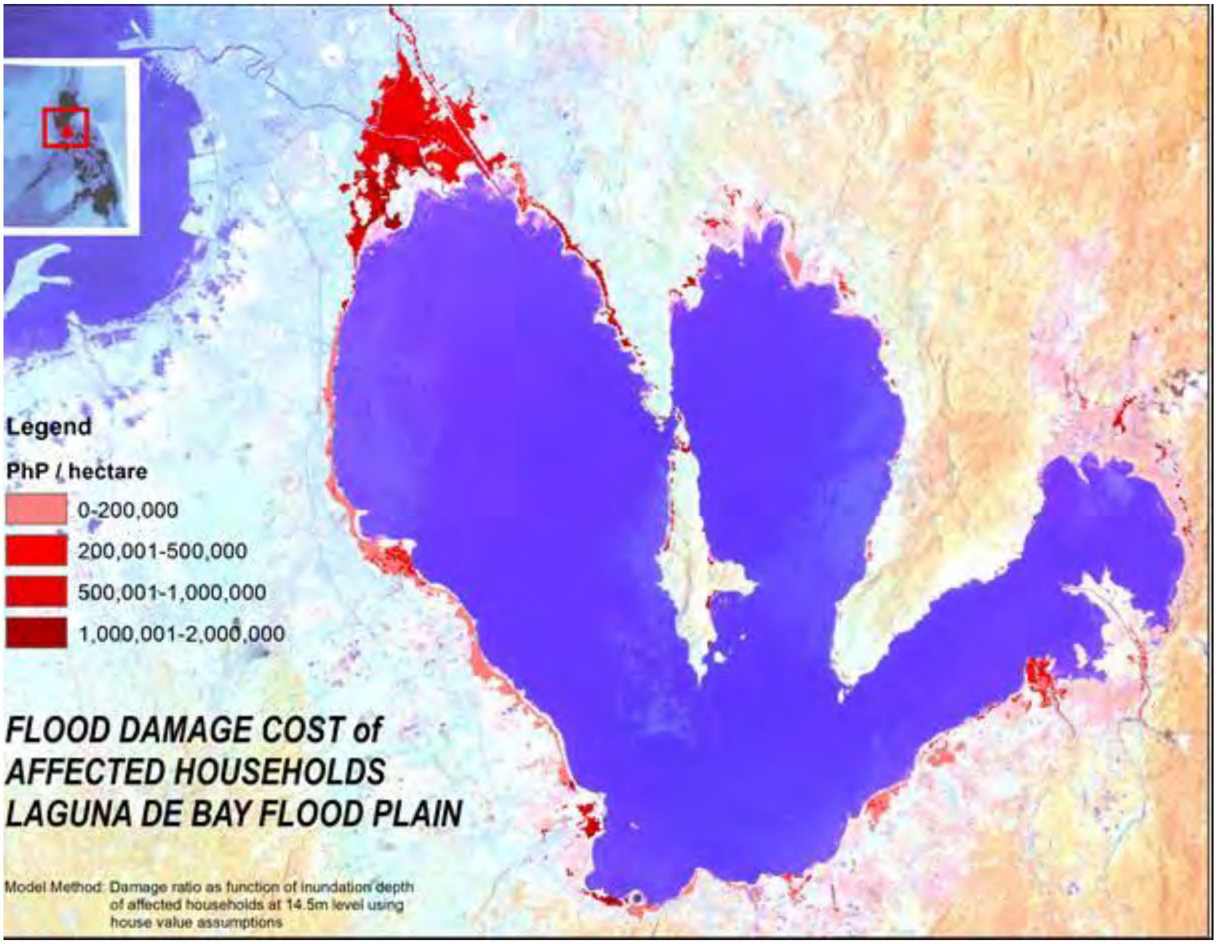


**Figure 10. Flood risk expressed as potential damage costs (in pesos per ha).**

## 4. Synthesis and conclusions

### Policy implications and recommendations to policy makers

There are several potential policy uses of the accounts. First, the need for specific policy interventions can be identified on the basis of rapid declines in specific environmental components. For instance, the accounts show the very large urban sprawl, including in highly flood prone areas and forest zones, and a lack of connectivity of households to sewage systems. Both aspects merit priority action by policy makers to avoid progressively increasing environmental risks in the future. Second, the accounts show areas where specific policy interventions should be, as a priority, carried out. For example, the accounts show which zones are responsible for the generation of sediment into the lake, and should therefore be prioritized for protection of remaining forest cover. Third, the accounts provide a benchmark for assessing the effectiveness of policy interventions, in two ways: through a comprehensive and long term monitoring system, and through the spatial information set that allows identifying different trends in areas that may be affected in a different way by policy interventions (e.g. closed forests inside and outside protected area boundaries).

The specific policy uses of the accounts have been discussed in a major stakeholder workshop held in October 2015. Feedback from the stakeholders was that the integrated information set is highly useful to support policy making and implementation in the area. A critical issue is however that many of the decisions on land management affecting the lake (including the establishment of houses, and land conversion) are made by local governments. Hence, it is critical that the information in the accounts is shared with the local government units, not only through a one off workshop but also through a continued process of information sharing. Specific policy relevant findings are briefly described below:

1. The population density has increased very rapidly in the Laguna de Bay basin in the last decades. For instance, the population in the municipalities immediately adjacent to the lake increased with 29% between 2003 and 2010, from 6.7 to 8.6 million people. This poses a number of major challenges in dealing with, amongst others, infrastructure development needs, dealing with sewage and waste, flood control

2. The Laguna Lake plays a major role in preventing flooding in the Metro Manila area. The lake acts as water storage reservoir, and explicit recognition of this service and appropriate management including ensuring the outflow capacity of Pasig river is required. In the absence of water storage, flood risks would be considerably higher for the around 9 million people living in flood risk zones. Hence, it needs to be ensured that the capacity of the lake to retain water during cyclone events is maintained, by avoiding increasing urbanization of the flood prone zones, and by reducing sediment loading in the lake through protection of the watersheds.

3. A major issue has been that people are settling and building houses ever closer to the lake shore. In case of new hurricanes, these people would be at immediate risk to lose their lives and properties. For instance, if a flood level equal to the 2009 flood level would be repeated in 2015, floods would affect 166,000 houses (instead of 146,000 in 2009) and damage costs would amount to an estimated 7 billion pesos (instead of 6 billion pesos in 2009). Given that significant number of people are living in the different flood risk zones (Annex 5 presents details for each flood zone and municipality), and that this number is still increasing, there is an urgent need to ensure that no further settlement in the two most risk prone zones (<2 meters above lake level) takes place.

4. In order to reduce flood risks, it is also urgently needed to rehabilitate the shorelines of the lake. Preferably, some of the mangrove cover would be restored (virtually all mangrove has been lost in the lake in last 15 years). The mangroves would contribute to flood control, would serve as nursery area supporting capture fisheries in the lake, and would act as sediment trap reducing siltation rates in the lake.

5. Management of the slopes and uplands of the Laguna de Bay basin is essential in maintaining the long term viability of the lake as water storage reservoir. Sedimentation is leading to a backfilling of sediments, which reduces the water storage capacity (significant part of the sediments are deposited in the zone that contributes to flood control, i.e. the zone between 11.5 and 12.5m water level in the lake). Maintaining forest cover is essential to reduce sedimentation.

6. An issue not yet considered in the account is that forest vegetation also acts as buffer, storing water during high rainfall events and gradually releasing this water over time. Hence the forests also provide a flood control service. It needs to be examined if this can be included in the next phase of the account.

7. There is a need to carefully consider the effects of the proposed land reclamation project in the southwestern part of the lake on flood risks in the other parts of the lake. There is a risk that land reclamation would reduce the water storage service of the lake. This could potentially lead to an increase in flood risks for people living in other parts around the lake during typhoons, in particular in the northwestern part (which includes the urban zones of Metro Manila) depending upon how large the area of reclaimed land will be. It is therefore recommended to analyze these flood risks, verify if these risks are significant or not, and if they are significant, to consider them in the design of the land reclamation project. The models developed for the Ecosystem Account can be used for this.

8. Management of the natural resources of Laguna Lake is increasingly challenging due to strong increases in population and economic activity. Yet, maintaining the natural resource base of the area (including but not limited to water, fish, flood control, cropland, forests) is essential for people to live and economic activities to grow. A pro-active approach is required to understand how the Laguna Lake's resources are changing over time, how demand for these resources increases over time, how ongoing degradation of the resources is affecting people, and how trade-offs in natural resource management can be handled based on comprehensive information on costs and benefits of different environmental management options. Hence, it is recommended that the accounts will also be produced in the future, with regular updates for example every 2 or 3 years. Given that these accounts have been developed by the LLDA this should be feasible.

9. There is a need for continuous data collection and improvement of the data included in the accounts. For instance, there is a need to verify and update the assumed costs of residential dwellings constructed in the flood zone and the damages of floods to infrastructure, the efficiency and connectivity of households to septic tanks, the inflow of inorganic pollutants in the lake, to assess the 2014 land cover etc. It is recommended for LLDA to develop a strategy and priority listing for improving data quality in the accounts.

## References


Edens, B. & Hein, L., 2013. Towards a consistent approach for ecosystem accounting. *Ecological Economics*, 90, pp.41–52. Available at: http://www.sciencedirect.com/science/article/pii/S0921800913000840 [Accessed September 3, 2014].

Kinsey-Hendersona, A., Prosser, I. & Posta, D., 2003. SubNet – Predicting Sources of Sediment at Sub-catchment Scale Using SedNet. *MODSIM Conference, Townsville*. Available at: http://www.mssanz.org.au/MODSIM03/Volume_02/A11/06_Henderson.pdf [Accessed April 10, 2015].

Laguna Lake Development Authority, 2014a. Laguna de bay: existing lake uses. Available at: http://www.llda.gov.ph/index.pesos?option=com_content&view=article&id=110&Itemid=476

Philippine Statistic Authority 2015, Census of Population released August 2016

United Nations, 2014. *System of Environmental-Economic Accounting 2012*, Experimental Ecosystem Accounting

WAVES, 2013. Country brief. Available at: https://www.wavespartnership.org/en.

Wilkinson, S.H. & Chen, S.Y., 2004. SedNet user guide: Client Report, CSIRO Land and Water, p.96.

World Bank.2004. Philippine Environment Monitor 2004. http://siteresources.worldbank.org/INTPHILIPPINES/Resources/16-38-BrownEnvt.pdf