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Assessing the Role of Watershed Areas in Mitigating Climate Change in the Philippines: The Case of the La Mesa Watershed

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Abstract

Tropical rainforests have a recognized potential for mitigating climate change by their natural absorption of CO_2, a greenhouse gas, from the atmosphere. The Philippines offers such areas that can serve as carbon sinks, among which is the La Mesa Watershed. With an area of 2,700 ha, the Watershed holds carbon stocks within its different land covers: tree plantations, brushlands, and secondary growth forests. They make up 64%, 3.1% and 4.2% of the total area, respectively.

A combination of primary and secondary data were used to determine the total carbon storage in the La Mesa Watershed. For tree plantations, various carbon pools were measured: tree biomass; understorey vegetation; litter/necromass; and soil. For brushlands and secondary growth forests, carbon storage was derived from the generated carbon density data of previous studies conducted in the Philippines.

Results revealed that the La Mesa Watershed currently has carbon stocks of 140 Gg C, the greater portion of which can be found in tree plantations (113 Gg C), followed by secondary forests (20 Gg C) and brushlands (6.97 Gg C). Carbon storage in the Watershed is expected to significantly increase once rehabilitation activities in the area are completed, that is when newly-established 1,000-ha tree plantation matures.

Key words : *carbon sink, biomass density, tree plantations*

INTRODUCTION

Climate change, more popularly known as global warming, is defined by the Intergovernmental Panel for Climate Change (IPCC) as a change in climate attributed directly or indirectly to human activity that alters the composition of the global atmosphere in addition to natural climate variability observed over comparable time periods (*Houghton et al., 1995*). This is brought about by the building up of greenhouse gases (GHGs) in the atmosphere. GHG's like carbon dioxide (CO_2), methane, nitrous oxide and chlorofluorocarbons absorb thermal radiation emitted by the earth's surface. Thus, rising concentration of GHGs in the atmosphere leads to global warming.

Tropical forests have great potential in mitigating global warming (*Trexler* and *Haugen 1994; Brown 1998; Frumhoff, et al., 1998*). Forests absorb CO_2 from the atmosphere during photosynthesis to make carbohydrates and other organic compounds for growth and metabolism.

In the Philippines, there are many potential areas that can serve as carbon sink (Lasco and Pulhin, 2000), among which is the La Mesa Watershed. Located in Novaliches, Quezon City and with an area of about 2,700 ha, its establishment in 1929 was primarily aimed at turning it into the main source of water for Metro Manila. Through time however, demand for water in the area has increased, making the watershed now only part of the entire network of water sources for the city.

The La Mesa Dam's proximity to major urban centers gradually led to its degradation. Vast forested areas were converted to farm lands by squatter families occupying the watershed area. Such massive conversion led to excessive soil erosion, increased runoff and siltation of the lake reservoir. To save the La Mesa Watershed from further degradation, the Metropolitan Manila Waterworks and Sewerage System (MWSS) commissioned the ABS-CBN Bantay Kalikasan Foundation to spearhead its rehabilitation. Large tracts of degraded lands were planted with various tree species to recover lost forest cover, which not only promotes local ecological stability but also enhances the global environmental services of forests, such as carbon sequestration.

Currently, no study has assessed the carbon stocks of the La Mesa watershed. The main objective of this study was to determine the amount of carbon stored in the La Mesa watershed. Specifically, it sought to:

- Determine the current aboveground and ground biomass of the different plantations in the La Mesa watershed;
- Determine the carbon content of various plant parts and the soil; and
- Determine the carbon density of the different land cover in the La Mesa watershed.

MATERIALS AND METHODS

Description of the Project Site

Biophysical Characteristics

The La Mesa watershed is situated in the city of Caloocan, San Jose del Monte, Bulacan and Rodriguez, Rizal. To date, the La Mesa Watershed is considered to be the only remaining forest inside the highly urbanized National Capital Region (NCR).

The total area covered by the La Mesa watershed is around 2,700 ha. Based on 2004 estimates, the watershed has the following land uses (**Figure 1**): second growth forest (112 ha or 4.2%); tree plantation (1,717 ha or 64%); brushland (85 ha or 3.1%); built-up area (5 ha or 0.18%); and lake or eco-resort (782 ha or 29%). The second growth forest has been improved by Bantay-Kalikasan through planting indigenous tree species.

Old tree plantations were established in 1989 by the Manila Seedling Bank Foundation (MSBF). Most of the commonly used species include: Yemane (*Gmelina arborea* Roxb.), Auriculiformis (*Acacia auriculiformis* A. Cunn. ex Berth.), Mangium (*A. mangium* Willd.), Narra (*Pterocarpus indicus* Willd. forma *indicus*), Mahogany (*Swietenia macrophylla* King), Teak (*Tectona grandis* L.f.), Ipil-ipil (*Leucaena leucocephala* De Wit), Kaatoan bangkal (*Anthocephalus chinensis* (Lam.) A. Rich. ex Walp.) and Alibangbang (*Bauhinia malabarica* Roxb.).

In terms of topography, the watershed has mountainous slopes and hilly and rolling terrain. The area belongs to climatic Type 1 with distinct dry and wet seasons. On the average, La Mesa watershed receives around 2424 mm of rainfall every year. Maximum temperature in the area ranges between 26 °C to 37.8 °C while minimum temperature ranges between 18.5°C to 27.2°C. Average temperature is 27.8 °C.

Soils in La Mesa watershed falls within Novaliches series. It is acidic with pH of less than 5.5 and has texture of sandy clay to sandy clay loam.

Socio-Economic Conditions

As of the 1997 census, around 169 families are living within the La Mesa watershed. Through the years, the presence of these illegal settlers posed problems on the protection of the watershed. Settlers cut trees and cleared large areas of the watershed and converted these into agricultural farms. Such illegal activities eventually led to the degradation of the watershed, loss of biodiversity, occurrence of excessive soil erosion and low soil productivity.

Compounding this situation is the improper garbage disposal practices of the settlers, wherein garbage is either burned or simply thrown on the ground.

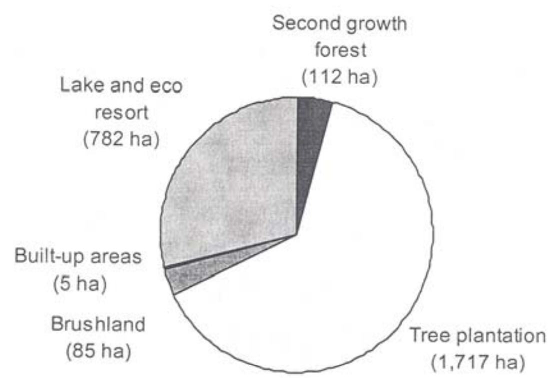

Figure 1. Land use distribution in the La Mesa Watershed (2004 estimate)

Biomass and Carbon Storage Determination

To assess the total amount of carbon stored in the La Mesa watershed, a combination of primary and secondary data were used. For secondary forests and brushlands, the total amount of carbon stored was determined using the generated carbon density data of studies previously conducted in the Philippines. For tree plantation sites however, ground measurements were obtained. Various carbon pools were measured: tree biomass, understorey vegetation, litter/necromass, and soil. In each of the tree plantation sites of the watershed, two sample plots measuring 5 m x 40 m were established. In areas that have trees with dbh > 30 cm (whether or not they are included in the sample plots established), additional 20 m x 100 m plots were laid out (**Figure 2**).

Tree Biomass

In determining tree biomass, the study used destructive sampling for trees measuring < 5 cm and non-destructive sampling for trees > 5 cm. In all the plots established, the following data were obtained: species name, diameter-at-breast-height (dbh) or stem diameter at 1.3 m above the ground, total height and height at first branch.

Understorey and Herbaceous Vegetation

Eight sampling frames measuring 1m x 1m were randomly laid-out inside the 5 m x 40 m sample plots. All herbaceous and woody vegetation with less than 5 cm dbh inside the frame were collected. Fresh weight of the samples were determined before they were oven-dried.

Litter

Inside the sampling frames used for measuring understorey and herbaceous vegetation, a 0.5 m x 0.5 m frame was established for litter collection. The total fresh weight of all the samples were taken after which about 300 grams was reserved for air-and oven drying. Samples were oven dried at a temperature of 80°C for 72 hours or until weights of the samples become constant.

Soil Organic Carbon

Composite soil samples for chemical analysis were collected within the 0.5 m x 0.5 m frames where the litter samples were collected, using a standard depth of 30 cm from the soil surface. These samples were placed in labeled plastic bags and transported to

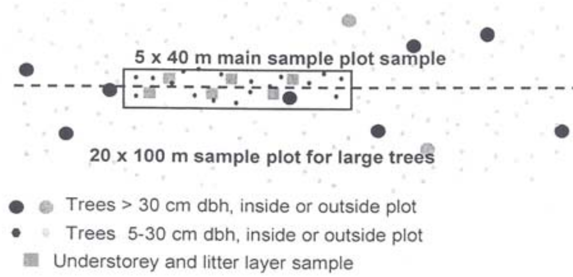

Figure 2. Sampling layout adapted from *Hairiah et al. 2001*

the laboratory and analyzed for organic matter content using the Walkley-Black method (*PCARR 1980*). Soil organic carbon (SOC) content of soil was estimated from the organic matter content values.

Soil bulk density was determined by choosing an undisturbed spot near the quadrat, removing the litter from the surface and carefully pushing into the soil a metal cylinder of known volume to a depth of 10-20 cm to represent the upper 0-30 cm soil layer. The extracted soil core was carefully placed in a labeled plastic bag. The collected bags of undisturbed soil cores were immediately sealed for later processing. The samples were immediately weighed in the laboratory and dried in an oven for 48 hours at ±102°C. The dry weights were recorded.

Bulk density was computed using the formula:

Bulk Density (g cm^{-3}) =
Dry weight of soil (g) / Volume of cylinder (cm^3)

The dry weight of soil and the equivalent C stock was determined using the following formula:

- Volume of 1 ha soil = 100m x 100 m x 0.3 m
- Weight of soil (Mg) = Bulk Density x Soil volume
- Carbon density (Mg ha^{-1})= Weight of soil x % SOC

Biomass Calculation

Tree biomass was calculated using the following allometric equation for tropical trees of the moist climatic zone (*Brown 1997*):

$$Y = \exp(-2.134 + 2.53 * LN(D))$$

(diameter range: 5-148 cm; n: 170; adjusted r^2=0.97)

where Y = tree biomass (kg) D = dbh (cm)

Biomass density values for understorey and herbaceous vegetation and standing litter were calculated using the following formula:

Total Dry Weight (kg m^{-2}) =

$$\frac{\text{Total Fresh Weight (kg) x Subsample Dry Weight (g)}}{\text{Subsample Fresh Weight (g) x Area of Frame (m}^2\text{)}}$$

Plant biomass was converted to the equivalent amount of carbon by multiplying by 45%, which is the average carbon content of plant tissue samples taken

from different areas in the Philippines (*Lasco et al. 2001*).

The total carbon stock of tree plantation is determined by summing up the contribution of the different C pools.

RESULTS AND DISCUSSION

Characteristics of Ecosystems Studied

The diameter of the various tree plantations studied ranges from 5 to 75 cm with an average of 21.62 cm (**Table 1**). Among the ecosystems studied, the Yemane plantation exhibits the widest diameter range (5-75 cm) while trees in the pure Mahogany plantation showed the most limited diameter range (5 -12 cm). In general, trees inside the sample plots are relatively small. Around 30% of the trees measure < 10 cm and about 34% have diameter of 10-30 cm. The remaining 36% have diameter of 31-75 cm, bulk of which are in the 31-40 cm diameter range.

Merchantable height of the tree plantations ranges from 0.75-22.5 m with an average of 5.97 m. More than half (53%) of the trees have a merchantable height of 1-5 m. Total height in the watershed ranges from 2.75-32 m. Average total height of trees inside the sample plots is 13.69 m.

Aboveground Biomass- and Carbon Density of Tree Plantations

Table 2 shows the biomass density of the various tree plantation species in the La Mesa watershed. Biomass produced by the eleven types of tree plantations in the La Mesa watershed ranges from 16-161 Mg ha^{-1}. Among the tree plantations examined, Kaatoan Bangkal exhibited the largest biomass while the pure Mahogany plantation had the lowest biomass. The relatively small biomass contained in the pure Mahogany plantation can be attributed to the small trees present in the sample area, which only have diameters ranging from 5-12 cm. In contrast, the Kaatoan bangkal plantation has larger trees with dbh measuring 13-42 cm.

On the average, biomass density of the tree plantations studied is 71 Mg ha^{-1}. This value is significantly lower than the average biomass density of 26 tree plantation species previously studied in the Philippines, which is 116 Mg ha^{-1}. The slow biomass accumulation of the tree plantations in the La Mesa watershed can be attributed to both environmental and human factors. It is likely that the watershed is frequently disturbed by human activities since the area is near the city center. *Lugo and Brown (1993)* emphasized that the higher biomass values are often associated with less human or natural disturbances.

A large percentage of the total biomass accumulated by the tree plantations is contributed by the trees. For instance, in the Kaatoan bangkal plantation, around 97% of the total aboveground and ground biomass is contributed by the trees while 94% is supplied in the Alibangbang, Auriculiformis, and Ipil-ipil plantations. These results are consistent with the findings of earlier studies conducted in various ecosytems. For instance, *Guillermo (1998)* found that in a secondary forest in Mt. Makiling Forest Reserve in Laguna, Philippines, trees generated 79 % of the total biomass while *Lasco et al. (1999)*, in a study of a natural forest in the PNOC Geothermal Reserve in Leyte, found 93 % as the share of the trees in the total biomass per hectare of the area. Other studies validate the major contribution of trees in biomass accumulation: 82% from mossy forest in Mt. Makiling Forest Reserve, Laguna (*Lasco et al. 2000*); 90% from a multistory agroforestry system in Mt. Makiling Forest Reserve, Laguna (*Zamora, 1999*); 90% from mossy forest in Pagbilao, Quezon (*Lasco et al. 2000*); 82% from the pine forest in Baguio City (*Lasco et al. 2000*); 85% from the tree plantation in Nueva Ecija (*Lasco et al. 2000*); 81% from the secondary forest in the Subic Bay Metropolitan Authority, Subic Zambales (*Lasco et al. 2001*); 91% from secondary forest in the Mt. Makiling Forest Reserve, Laguna (*Lasco et al. 2004*); 78% from the old growth forest in Atimonan, Quezon (*Lasco et al. 2001*); 98% from the secondary forest in Agusan del Sur (*Lasco et al. 2000*); 82% from the Dipterocarp plantations and 85% from the Mahogany plantations in the Mt. Makiling Forest Reserve (*Racelis, 2000*); 99% from the secondary forest in Mt. Makiling Forest reserve (*Juarez 2001*); and 89% from the secondary forests in Isabela (*Pulhin 2003*).

Understorey and litter on the other hand share a very small percentage on the total aboveground and

Table 1. Stand characteristics of tree plantations in the La Mesa Watershed

Species	Diameter Range (cm)	Average Diameter (cm)	Height Range (m)		Average Height (m)	
			Merchantable Height	Total Height	Merchantable Height	Total Height
Yemane	6 - 63	31.24	1.8 - 14	4.5 – 24	7.36	15.57
Kaatoan bangkal	13 - 42	28.21	3 – 22.5	8 – 25	12.74	16.70
Alibangbang	5 - 30	12.60	0.85 – 13	3.5 – 24	3.70	9.64
Mangium	10 – 37	30.02	2 - 11	6 – 16	5.15	11.38
Auriculiformis	7 - 49	31.16	1.75 – 16	6 – 32	7.31	22.05
Mahogany – Mixed Stand	5 - 75	30.32	1 - 8	2.75 - 25	3.63	13.23
Mahogany - Pure Stand	5 - 12	7.42	1.5 –6	5 – 10.50	3.66	7.59
Ipil-ipil	5 - 21	11.94	1 - 8	5 – 18.70	3.79	10.80
Teak	6 - 32	11.78	0.75 – 10.68	4.7 – 12.7	2.45	8.75
Narra – Pure Stand	5 - 18	9.46	0.75 – 5	3.5 – 16	2.56	7.60
Narra – Mixed Stand	5 - 30	12.58	1.5 - 19	4.5 – 26	4.58	13.23
AVERAGE	22.56		5.97	13.69		

Table 2. Aboveground biomass pools of tree plantations in the La Mesa Watershed

Species	Biomass Density (Mg ha^{-1})			
	Tree	Understorey/ Herbaceous	Litter	Total
Yemane	92.58	1.71	2.44	96.73
Kaatoan bangkal	155.85	1.75	3.08	160.68
Alibangbang	74.24	2.14	2.63	79.01
Mangium	60.03	1.47	3.52	65.02
Auriculiformis	74.98	1.65	3.41	80.04
Mahogany – Mixed Stand	55.54	1.13	3.45	60.12
Mahogany - Pure Stand	12.93	1.07	2.28	16.28
Ipil-ipil	64.85	1.60	2.48	68.93
Teak	53.14	1.11	2.86	57.11
Narra – Pure Stand	26.93	1.35	2.65	30.93
Narra – Mixed Stand	61.74	1.42	3.34	66.5
Average	66.62	1.49	2.92	71.03

ground biomass. In most tree plantations studied, they contribute only around 4-6% of the total biomass.

Similar to the trend observed in the biomass density, Kaatoan bangkal is found to have the highest aboveground carbon density. The results indicated that the higher the biomass produced by a pool, the higher is the amount of carbon stored and the higher the percentage contributed to the total carbon stored. The results obtained from this study are consistent with the results of the studies conducted by *Sampson et al. (1993)*, *Guillermo (1998)*, *Sales (1998)*, *Lasco et al. (1999)*, *Juarez (2001)*, *Zamora (1999)*, *Lasco et al. (2000)*, *Racelis (2000)*, *Lasco et al. (2001)*, *Andrada (2003)*, *Orpia (2003)* and *Pulhin (2003)*. These findings are also consistent with the regression analysis conducted by *Zamora (1999)*. Zamora found that at 5 % level of significance, there was very strong positive correlation between the amount of biomass produced and the amount of carbon produced.

Soil Carbon Density of Tree Plantations

Aside from the biomass, soil is also a significant sink and source of carbon (*Bouwman 1989* as cited in *Lugo and Brown 1993*). It has the longest residence time among organic C pools in the forest (*Lugo and Brown 1993*). The soil component can also contain as much carbon as vegetation (*Watson et al. 2000*). Results of previous studies conducted in the Philippines reveal that more than 50% of the total carbon stored by forests is contained in soil. *Lugo and Brown (1993)* mentioned that capacity of the soil to store soil organic carbon is influenced by a number of factors: (1) mean annual precipitation; (2) degree of forest disturbance; and (3) extent of land use change. *Birdsey (1992)* also reports that conversion of forests to agriculture production reduces soil carbon content by 40%.

Table 3 presents the soil organic carbon densities of the different plantations in the La Mesa watershed. Carbon density ranges from 30 Mg ha^{-1} to 43 Mg ha^{-1} and an average of 35 Mg ha^{-1}. Among the eleven plantations studied, Auriculiformis has the highest soil carbon density while mixed Mahogany contains the lowest soil carbon density.

Total Carbon Density

Figure 3 shows the total carbon densities of the various tree plantations in the watershed. Total carbon density ranged between 40 Mg ha^{-1}-106 Mg ha^{-1} with an average of 66 Mg ha^{-1}. Kaatoan bangkal plantation has the highest carbon density (106 Mg ha^{-1}) while Pure Mahogany plantation has the lowest (40 Mg ha^{-1}).

A large percentage (about 50-70%) of the total carbon density was found in the soil, while the small percentage were contributed by the understorey and litter (2.25%).These results are consistent with the findings of similar studies conducted. *Lasco et al. (1999)* found that 59 % of the total carbon stored in the secondary forests in Leyte was contained in soil. *Guillermo (1998)* and *Aguiero (2002)* reported that carbon stored in the soils of the secondary forests in Mt. Makiling Forest Reserve in Laguna were at 52 % and 57 %, respectively.

Total Carbon Storage of the La Mesa Watershed

To estimate the total amount of carbon stored in the La Mesa watershed, the area under each land use in the watershed is multiplied with the total carbon density estimate for each land use. Carbon contained in the brushlands and second growth forests were estimated using data derived from previous studies. For brushlands and second growth forests, carbon density values of 65.91 Mg ha^{-1}and 1 80 Mg ha^{-1}, respectively were used.

Results reveal that the secondary forests contain a total of 20 Gg of carbon while brushland areas have 6.97 Gg C. Adding these values to the total carbon stored in the tree plantations (113 Gg) inside the watershed, the total amount of carbon contained in the La Mesa watershed is 140 Gg. Tree plantation areas have the most amount of carbon stored as they cover a large portion of the watershed while built-up and lake areas are devoid of stored carbon as these land uses are assumed not to contain trees (**Figure 4**).

As of 2000, the total carbon emission of Metro Manila amounts to 23,403 Gg CO_2 *(Ajero 2003)*. The

Table 3. Soil carbon densities of the various tree plantation species

Species	Soil Organic Carbon Density* ($Mg\ ha^{-1}$)
Yemane	36.75
Kaatoan bangkal	35.19
Alibangbang	41.66
Mangium	41.57
Auriculiformis	42.79
Mahogany – Mixed Stand	30.14
Mahogany - Pure Stand	34.65
Ipil-ipil	33.42
Teak	32.95
Narra – Pure Stand	32.59
Narra – Mixed Stand	30.85
AVERAGE	**35.37**

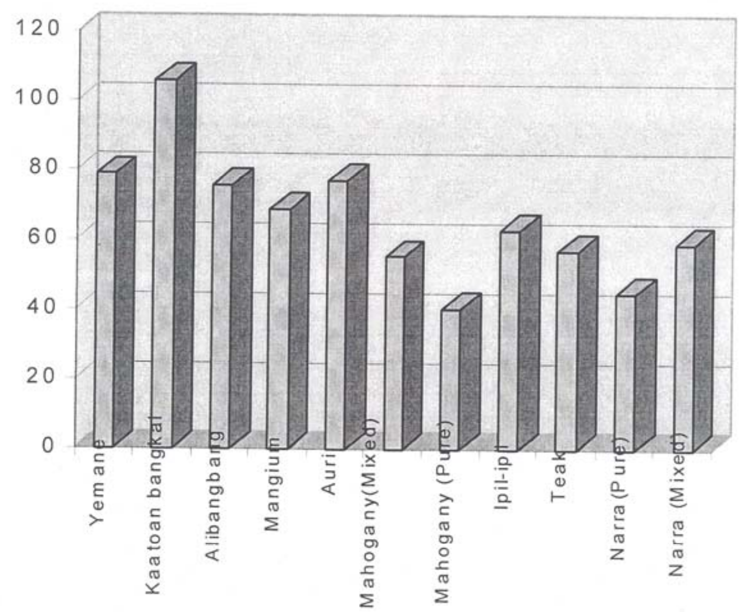

Figure 3. Density of various tree plantation species in the La Mesa Watershed.

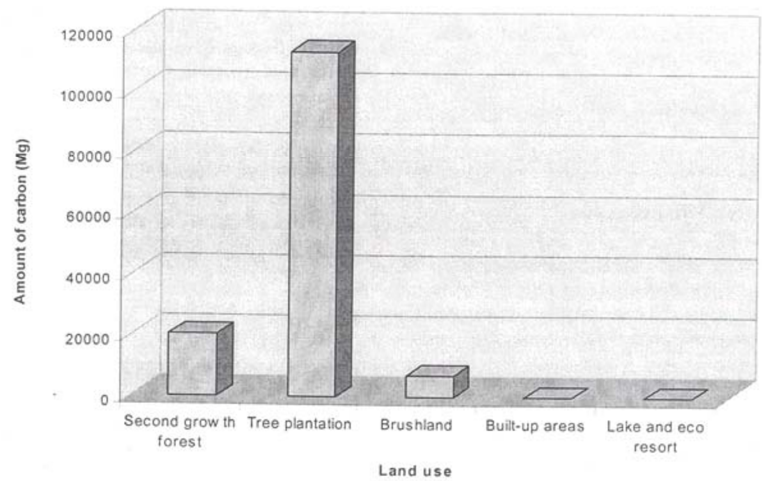

Figure 4. Carbon stored in the different land uses in La Mesa Watershed

major sources of this emission are: energy sector (9,053 Gg); transportation (11,847 Gg); waste (2,220 Gg); and agriculture (283 Gg). At its current condition, the La Mesa watershed can absorb around 514.87 Gg CO_2 or 2.2% of the Metro Manila's total carbon emission. The percent carbon absorbed by the watershed is expected to increase as newly established tree plantations mature and as brushland areas are planted with trees. It is worthy to note that in 1999, around 1,000 ha of the La Mesa Watershed area have begun to be developed into tree plantations. Thus, more carbon is expected to be absorbed through time.

Aside from the carbon benefits, protecting the La Mesa watershed will also provide other environmental benefits. These co-benefits include promotion of biological diversity, prevention of soil erosion, improvement of the soil quality and increase of infiltration capacity of the soil. Forests provide habitats to various species of plants and animals, thus ensuring that the area is covered with trees will certainly promote biodiversity. Also, forests prevent occurrence of excessive soil erosion since the canopy of the trees intercept and absorb the kinetic energy of the raindrops while the presence of litter layer in the forest floor prevents detachment and transport of soil particles during downpour. The forest also enriches the soil through litterfall and litter decomposition. Based on estimates, more than 80% of the nutrients taken by the trees from the soil are returned to the soil through litterfall and decomposition. Finally, forest improves the infiltration capacity of the soil because of the presence of the litter layer. The litter layer improves the physical properties of the soil by increasing its pore volume and decreasing its bulk density.

CONCLUSION

Based on the results of the study, the La Mesa watershed has the potential to store a substantial amount of carbon. Currently, total carbon storage in the watershed is estimated at 140 Gg, a greater portion of which can be found in tree plantations (113 Gg C), followed by secondary forests (20 Gg C) and brushlands (6.97 Gg C). If continuous protection and rehabilitation of the watershed is undertaken, its ability

to store more carbon will be enhanced and will help in the absorption of a portion of the carbon emissions of Metro Manila. Aside from the carbon benefits, protection of the La Mesa watershed will also provide other environmental benefits such as increased biodiversity, decreased occurrence of excessive soil erosion, improved soil quality and increased infiltration capacity.

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