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Estimation of the Carbon Biomass Stored in the Forest Ecosystem of the Billings Reservoir-SP

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Abstract: Global warming has become international concern, culminating with the ratification of the Kyoto Protocol which includes definitions and objectives of the sustainable development mechanisms and features that make it easier for the industrialized countries to jointly compensate for their polluting greenhouse gas emissions. São Paulo is a state known for its industrial development and distortion of the green areas in ecosystems associated with the Atlantic Forest biome. In the middle of this chaotic scenery lies the Billings reservoir in São Bernardo do Campo-SP, its forest ecosystem is the provider of numerous environmental services. Quantification of biomass (Bwood) of stems resulted in estimates of 113.73.ha-1, which corresponded to 56.87 tC.ha-1. The estimates obtained for the forest ecosystem of the reservoir can be used as a reference for the establishment of forest restoration projects under the under the sustainable development mechanism established the Kyoto Protocol.
Keywords: Environmental service, Atlantic forest, forest inventory, dendrometry.

Estimativa da Biomassa de Carbono Armazenada no Ecossistema Florestal do Reservatório Billings – SP

Resumo: O aquecimento global tornou-se preocupação internacional, culminando com a ratificação do Protocolo de Quioto, onde constam as definições e os objetivos dos mecanismos de desenvolvimento sustentável e possui procedimentos flexibilizadores, facilitando aos países industrializados compensar em conjunto suas emissões poluentes de gases do efeito estufa. São Paulo é um estado conhecido pelo desenvolvimento industrial e descaracterização das áreas verdes dos ecossistemas associados ao bioma Mata Atlântica. Frente a este cenário caótico está à represa Billings em São Bernardo do Campo-SP, seu ecossistema florestal é prestador de uma série de serviços ambientais. A quantificação da biomassa (Bmadeira) do fuste resultou em estimativas de 113,73 t.ha-1, o que correspondeu a 56,87 tC.ha-1. As estimativas obtidas para o ecossistema florestal da represa podem ser usadas como referência para o estabelecimento de projetos de restauração florestal, no âmbito do mecanismo de desenvolvimento sustentável, estabelecido no Protocolo de Quioto.
Palavras-chave: Serviço Ambiental, Mata Atlântica, inventário Florestal, dendrometria.

Estimación de La Biomasa de Carbono Almacenada en el Ecosistema Forestal del Embalse de Billings-SP

Resumen: El calentamiento global se ha convertido en preocupación internacional, culminando con la ratificación del Protocolo de Kioto, donde constan las definiciones y los objetivos de los mecanismos de desarrollo sostenible y tiene procedimientos flexibilizadores, facilitando a los países industrializados compensar conjuntamente sus emisiones contaminantes de gases de efecto invernadero. São Paulo es un estado conocido por el desarrollo industrial y descaracterización de las áreas verdes de los ecosistemas asociados al bioma Mata Atlántica. Frente a este escenario caótico está a la represa Billings en São Bernardo do Campo-SP, su ecosistema forestal es prestador de una serie de servicios ambientales. La cuantificación de labiomasa (Bmadeira) del fuste resultó en estimaciones de 113,73 t.ha-1, lo que correspondió a 56,87 tC.ha-1. Las estimaciones obtenidas para el ecosistema forestal de la represa pueden ser usadas como referencia para el establecimiento de proyectos de restauración forestal, en el marco del mecanismo de desarrollo sostenible, establecido en el Protocolo de Kioto.
Palabras clave: Servicio Ambiental, Mata Atlántica, inventario Forestal, dendrometría.

INTRODUÇÃO

Approximately 54.4% of Brazil's territory is occupied by forests (FLORESTAS DO BRASIL, 2015) and from this percentage, approximately 12.5% corresponds to the area of the Atlantic Rainforest Biome (SOS MATA ATLÂNTICA, 2015), stretching for 17 States of the federation, going from the state of Rio Grande do Sul to Rio Grande do Norte, ranging from the coastal regions, such as plateaus and hills of the interior.

In the state of São Paulo, the Atlantic Forest biome offers characteristic phytoecological formations constituted by forest ecosystems: Seasonal Semidecicual Forest and Dense Ombrophilous Forest. The latter features subdivisions in its phytophysiognomy, suffering variations according to the altitude range of relief where it is inserted. The divisions are: The Alluvial Lowlands, Submontane Forest, Montana and Alto-Montana (SOS MATA ATLÂNTICA, 2015).

According to RODRIGUES et al., (2017), in addition to this important set of forest ecosystems, the Atlantic Forest also covers other associated ecosystems such as mangroves, restingas, mixed Araucarias forestry and the altitude fields.

The biome stretched by more than 90% of the total area of the state of São Paulo, according to the annual balance sheet presented by the non-governmental organization SOS MATA ATLÂNTICA (2015), until the end of the 1990’s, approximately 15% of the area of this territory was still covered by native vegetation. The report of the institution demonstrates that the historical process of anthropic intervention has been happening since the discovery of Brazil and has been expanding over the centuries, due to some activities of economic development, such as exploitation of timber, agricultural and industrial activities. Another factor associated with the loss of vegetation is the unplanned urban growth, which in Brazil occurs mainly in areas that are covered by the biome (SOS Mata Atlântica, 2015).

According to INPE (2018), of the total Atlantic Forest, 23,548 hectar of vegetation were suppressed of which corresponds to 7% of its forest remains, safeguarded mainly in this areas of more difficult access, how to slopes of the Serra do Mar, considered unsuitable for agricultural practices. This territory has large forest spots adjacent to areas of high fragmentation (ARROMBA et al., 2012). The law Nº 11.428/2006 determines the area of protection of the biome for the 17 states of the federation, which corresponds to 38% of the Brazilian territory. Studies of the INPE (2018) point out that the whole area of Atlantic Forest had approximately 1,300,000 km² of extension, and now is reduced to 162,666 km², the equivalent to 12.4% of its original forest cover, as today has many uses, some of them being: the remaining forest, planted forests (mainly pinus and eucalyptus), pastures and agricultural crops of annual and perennial plants.

However, even facing an intense and historical process of deforestation, the Atlantic Forest biome has one of the largest biodiversity in the planet, with high concentrations of endemic species (BERGALLO et al., 2016) and a high level of degradation. Thus, it is possible to consider it as a hotspot, being the conservation of its natural resources of utmost importance to mankind.

The plants are autotrophicorganisms, they need of CO2 for the production of their food through the photosynthetic process, in woody plants the incorporation of a part of this carbon in the secondary xylem of plant is popularly known as wood (SILVA et al., 2017). There are methods that allow researchers to evaluate the concentration of carbon in woody plants, however in native forests these measurements are only estimated, for in a community there is not a single model of growth and morphotype, because it is a set of populations dependent on the ecological relationships (HENRY et al., 2011).

Carbon sequestration and storage is, among the many environmental services provided by forests, one of great importance. Especially in face of global warming's intensification (SILVA et al., 2017). The phenomenon mentioned above is cause by the increase of the concentration of greenhouse gases, especially carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O), from human emissions (SILVA et al., 2017).

In order to mitigate these impacts arising from the emission of greenhouse gases, the Kyoto Protocolwas created, as countries held as their paramountgoal the reduction of emissions of these gases in 5.0% during the period from 2008 to 2012, which corresponds to the first commitment period. The Protocol officially came into effect in February 2005 and brought three innovative mechanisms to ensure flexibility: Emissions trading, Joint Implementation and Clean Development Mechanism (CDM), by which it is possible to obtain the Certified Emission Reductions (CERS), which are one of the types of carbon credits. It is noteworthy that among these three mechanisms of flexibilization, only the CDM allows the participation of developing countries like Brazil, representing, therefore, a way for the country's participation in the recent and innovative carbon credits market (TORRES et al., 2013).

The state of São Paulo is included in the Atlantic Forest domain. The devastation of forests in this state is happening almost since the period of its discovery, drastically reducing their original vegetation coverage. Only 7.26% of the original area remains (TAVARES et al, 2012; FUNDAÇÃO SOS MATA ATLÂNTICA et al., 2011), it is vital that the green areas and woody species that still exist are preserved. Especially considering the various services that the forest ecosystem can provide., such as: maintenance of water resources, conservation and preservation of soils and the concentration of atmospheric carbon in forest fragments.

The city São Bernardo do Campo is located at the top of the Serra do Mar, the Atlantic Plateau, however in almost every area of Atlantic Forest in the region, it is possible to observe influxes of eucalyptus and pine trees, the livestock and agriculture also distort the Atlantic Forest site, in addition to the massive synthesis of real estate ventures.

Billings reservoir is one of the biggest and most important reservoirs of water in the Metropolitan Region of São Paulo. The West borders the watershed of the Guarapiranga reservoir, and South, Serra do mar. Its main rivers and streams are the Rio Grande or Jurubatuba. Located in a fishing region with an emerging spot of strong environmental interest, its area of the original forest is altered, when not completely deleted due to the deployment of real estate ventures or agriculture, in addition to the cultivation of Pinus sp., Eucalyptus sp. and Corymbia sp. For these reasons, even today, its humid areas of ecotone with rain forests and gallery forests, although quite affected by human activity, stand still as important floristic and faunistic elements of interest to conservationists, especially the flora (SOS MATA ATLÂNTICA, 2015).

Because of importance of the Billings reservoir for the state of São Paulo and the need for the preservation of its ecosystem, the objective of this work was to quantify biomass in m3 through the installation of 54 plots (UA) of 36 m2 arranged systematically in a forest fragment of 48,010.91 m2 encompassing a sampling area of 1944 m2, with the purpose of estimating the concentration of carbon in tC·ha-1 which is concentrated by the forest ecosystem of the dam.

MATERIAL E MÉTODOS

Characterization of the study área

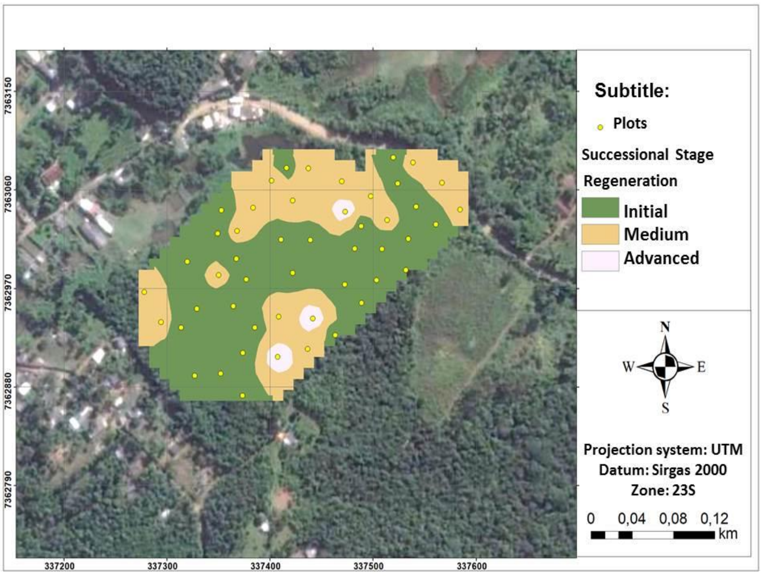

Figure 1 – Classification of successional stage of regeneration of the fragment and provision of sample units in the area of studies. Total area: 48,010.91 m^2.
Source: by the author himself.

The forest fragment is located in the area of influence of the Billings reservoir (Figure 1) in the municipality of São Bernardo do Campo, which is one of the largest and most important reservoirs of water in the Metropolitan Region of São Paulo.

The dam was conceived in the decades of 1930 and 1940 by engineer Billings, one of the employees of the formerenergy provider Light. Initially, the dam had the objective of storing water to generate electrical power for the hydroelectric plant Henry Borden in Cubatão.

The city São Bernardo do Campo has a warm climate and temperate climate. There is significant rainfall throughout the year, even the driest month there is plenty of rainfall. According to the Köppen Geiger and the climate is classified as Cfb (LUCHIARI et al., 2012). In São Bernardo do Campo, the average temperature is 17.8°C, the average annual rainfall is 1524 mm. The difference between the precipitation of the driest month and the rainiest is 190 mm. Throughout the year the average temperatures vary 6.5 °C. The hottest month of the year is

February with an average temperature of 20.9°C. July has an average temperature of 14.4°C, this was the lowest mean temperature, precipitation in the month of July is 44 mm, this being the driest month. The wettest month was January, with an average of 234 mm.

The forest fragment located in the Taquacetuba Road, in the Taquacetuba neighborhood, under the inscription 624700708000, in the Alto-Tietê's basin area, specifically in the sub-basin of the Billings reservoir. The main access roads to the location of the project are by the highway of Imigrantes and by Mário Covas Beltway, so it is in an important and privileged geographical position. In accordance with the environmental process N 59.602/2017, the fragment has 3 stages of succession: initial, medium and advanced, the largest portion of the successional stage corresponding to the 'initial' stage.

Sample Design and Analysis

From 10 December until 23 December 2017, 54 quadratic sampling units (6x6 m) were demarcated in the area of the venture, totaling 1944 m2 of sample area (Figure 1) the fragment studied has a total area of 48,010.91 m2, the field team catalogued all the botanical species existing in the quadratic plots of 36 m2, theymade these plots with tape and string. Within each quadratic plot they were collected arboreal species with CAP greater than or equal to 5 cm, and estimated the height and the radius of the canopy of sampled individuals. The quadrats were marked with striped tape. The vertex closest to the access to the sampling unit was georeferenced using a GPS with an accuracy of 3 meters under vegetation cover. The individuals were collected and catalogued in the herbarium of the laboratory of forage plants of UFRJ at the Instituto de Zootecnia and stored at the Laboratory of Environmental Mapping of UFRRJ (LAMAGEDENASA).

The simple random sampling is the fundamental process of selection from which to derive all other sampling procedures, aiming to increase the accuracy of estimates and to reduce the costs of the survey (RIBEIRO et al., 2009).

The simple random sampling is the best method for presentation of the theory of sampling, because it allows estimating the sampling error. The selection of each sampling unit must be free of any choice and totally independent from the selection of the other sample units. The equation for the calculation of the sample sufficiency in simple random sampling is shown below (HUSCH et al.1982) (Equation 1):

$$n=N\times S^2\times t^2/(N\times(E\times \bar{x})^2+S^2\times t^2 \quad (1)$$

Where:

n = number of parcels to be raised;

N = total number of samples possible in the area;

t = value of probability distribution ($t_{0.10}$, with n-1 GL);

$\mathbf{S^2}$ = variance of the parameter evaluated;

$\bar{x}$ = average

E = Error (10%) and X=Average of the parameter evaluated.

The following are defined the symbols to identify the variables of the Community:

The sample sufficiency was calculated on the basis of the parameter number of adult individuals, in view of the interest of the evaluation of the quantification of biomass in m^3 and quantification of carbon stored in the $tC.ha^{-1}$ of plants with CAP above or equal to 5 cm.

For the analysis of total biomass by species and botanical family we used the volumetric equation of CETEC (1995) which is used by other authors (RIBEIRO et al., 2009), Atlantic Forest vegetation (equation 2):

$$Vt=0.00007423\times DAP^{1.707348}\times Ht^{1.16873} \quad (2)$$

Where:

Vt= total volume of the bole;

DAP = 1.30 m above the ground;

Ht = total height of each stem.

The estimate of the bole biomass was performed using the non-destructive method, depending on the impossibility of using the destructive method, due to restrictions of legal orders and operational. Thus, it was evaluated only the biomass of the stem and not other forest compartments, such as branches, leaves, bark and lianas.

The indirect method for quantification of biomass is based on the use of empirical relationships between biomass and other variables in the tree (DBH, total height etc.) (CETEC, 1995), these relations expressed by means of statistical models (SILVA et al., 2017). One needs to be cautious with its implementation, in order to avoid significant error in the calculation of biomass: a careful analysis of the situations of field (ex. hollow trees) and the sample is representative of the area (SILVA et al., 2013).

This method is often considered a more accurate alternative than the direct method, since in the latter, the information obtained usually come from parcels of small size, in a small number and selected intentionally, usually in areas that are more representative of the whole (BROWN et al., 1989). Such conduct could introduce errors of biased estimates, which may lead to over- or underestimation of the average biomass of the forest evaluated.

Considering the use of non-destructive method, we performed the selection of species with secondary xylem in the area (CETEC, 1995). Then, we obtained the values of basic density for each lignified species selected, based on existing studies (LORENZI, 2014; IBAMA, 2014). To determine the basic density of species not identified (Indet), we collected bodies of evidence, using a Pressler probe. The collections were always carried out in the morning, in order to avoid possible variations of the values of which could be caused by changes in water potential and perspiration after noon and the samples were stored individually in a plastic bag sealed until laboratory measurements. Synthesized the methodology for determining the basic density of the wood in the lab, as it is instructed in the norm ABNT NBR 11941 NBR11941, as for deceased individuals, we used an average value of the bodies of evidence sampled.

The basic density values obtained, already converted into Ton.m^{-3}, it was calculated the average basic density (d) of all the mature forest, weighted by the value of coverage, according to Equation 3:

$$d=\sum_{i-=1}^{n} 〚Db_i\times\left(\frac{VC_i}{\sum_{i-=1}^{n} VC_i}〛\right) \quad (3)$$

Where:

n = number of selected species;

Dbi = basic density of the ith species selected, in Ton.m^{-3}; and

VCi = average value of coverage of the i-th species with secondary xylem.

The biomass of wood present in the stem of each tree was estimated by multiplying the average wood basic density by volumes of the stems (equation 2), according to Equation 4:

$$B_{wood}=d\times\bar{x}\times Vt \quad (4)$$

Where:

B = biomass of the stem, in Ton;

d= average basic density of the wood, in Ton.m^{-3}; and

Vt = total volume estimated de Stem, in m^3.

The carbon stored in the bole biomass was estimated by means of the multiplication of the estimates of biomass obtained by factor 0.5, considering that the dry biomass contains approximately 50% of carbon (RIBEIRO et al., 2009). Then, the stock of carbon was extrapolated to tons per hectare.

RESULTADOS E DISCUSSÃO

Were measured in 553 trees (622 stems), distributed in 26 families, 49 taxa identified up to species or genus, and only 5 could not be identified because of the impossibility of collection by the height and density of the canopy. Of this total, fifty-four (54) individuals were dead. For the calculation of the sample sufficiency in simple random sampling, met a n= 45.65 sample units (U A) for the total area of 48,010.91 m^2 (N=54; S^2= 24.40531; S= 4.94 plants; Std. Error= 0.67 plants; CV = 42.89 %; an estimate of the total population= 57.613092; CI= 12±1.12 plants per hectare), so the allocation of 54 plots of 36 m^2 was sampled more than representative for this work, it can be concluded that the sampling was sufficient.

Table 1 – List of species sampled in the sample units.

N	Family	Species	Ind.	Stems	G (m²)	Height x-bar (m)	Qnt. Plot
1	Euphorbiaceae	*Alchornea sp.*	12	13	0.053991	9.38	8
2	Euphorbiaceae	*Alchornea triplinervia* (Spreng.) Müll.Arg.	6	6	0.030035	7.5	5
3	Annonaceae	*Annona sp.*	1	1	0.001912	5	1
4	Asteraceae	*Baccharis oreophila* Malme	10	10	0.042693	5.25	6
5	Meliaceae	*Cabralea canjerana* (Vell.) Mart	1	1	0.002037	5	1
6	Salicaceae.	Casearia sylvestris Sw.	9	10	0.046483	6.1	7
7	Urticaeae	*Cecropia glaziovii* Snethl.	1	1	0.019107	11	1
8	Clethraceae	*Clethra scabra* Pers.	43	49	0.396869	7.47	22
9	Clusiaceae	*Clusia criuva* Cambess.	24	35	0.177858	6.81	12
10	Polygonaceae.	*Coccoloba glaziovii* Lindau	7	7	0.064569	7	4
11	Sapindaceae	*Cupania oblongifolia* Mart.	3	8	0.031284	7.31	3
12	Cyatheaceae	*Cyathea* cf. *Corcovadensis* (Raddi) Domin	21	21	0.102577	15.49	8
13	Myrtaceae	*Eucaliptus*sp	2	2	0.209551	19	1
14	Myrtaceae	*Eugenia* glazioviana Kiaerskcf	1	3	0.006802	8	1
15	Myrtaceae	*Eugenia pruniformis* Cambess.	1	1	0.012104	11	1
16	Myrtaceae	*Eugenia uniflora* L.	1	2	0.065969	8.5	1
17	Arecaceae	*Euterpe edulis* Mart	9	9	0.032119	3.43	5

18	Rubiaceae	*Faramea tetragona* Müll.Arg.	6	6	0.020873	6.75	1
19	Moraceae	*Ficus elastica* Roxb.	2	2	0.011539	6.25	1
20	Asteraceae	*Gochnatia polymorpha* (Less.) Cabrera	2	3	0.175604	11.5	2
21	Nyctaginaceae	*Guapira opposita* (Vell.) Reitz	3	3	0.043418	6.67	3
22	Meliaceae	*Guarea macrophylla* Vahl	3	3	0.01052	6.17	3
23	Annonaceae	*Guatteria australis* A.St.-Hil	6	6	0.01656	5.84	3
24		1 Indet	1	1	0.013377	11	1
25		2 Indet	1	1	0.019894	7	1
26		3 Indet	1	1	0.004584	7	1
27		4 Indet	1	2	0.044699	9.5	1
28		5 Indet	1	1	0.016114	10	1
29	Bignoniaceae	*Jacaranda puberula* Cham	2	3	0.00193	6.67	2
30	Lauraceae.	*Endlicheria sp.*	2	2	0.010968	7.25	2
31	Sapindaceae	*Matayba intermedia* Radlk	4	8	0.233703	13.69	4
32	Celastraceae	*Maytenus sp.*	1	1	0.020698	10	1
33	Melastomataceae	*Miconia cinnamomifolia* (DC.) Naudin	26	30	0.121853	4.95	15
34	Melastomataceae	*Miconia cubatanensis* Hoehne	8	8	0.098415	8.44	4
35	Melastomataceae	*Miconia fasciculata* Gardner	19	23	0.076209	5.05	11
36	Melastomataceae	*Miconi a*sp.	1	1	0.014037	8	1
37		**Dead**	54	60	0.389364	4.55	28
38	Myrtaceae	*Myrcia multiflora (Lam.) DC.*	1	1	0.003026	7.5	1
39	Myrtaceae	*Myrcia sp.*	1	1	0.014714	8	1
40	Myrtaceae	*Myrcia sp2.*	1	1	0.0023	6.5	1
41	Myrtaceae	*Myrcia splendens* (Sw). DC	21	22	0.012252	6.38	12
42	Myrsinaceae	*Myrsine aff. Balansae* Mez Otegui	21	22	0.101511	6.42	15
43	Myrsinaceae	*Myrsine coriácea* (Sw). R.Br. Ex Roem. & Schult	6	7	0.04442	6.64	6
44	Myrsinaceae	*Myrsine gardneriana* A.DC.	2	2	0.02038	8.5	2
45	Lauraceae.	*Nectandra grandiflora* Nees	3	3	0.01582	5.77	3
46	Lauraceae.	*Nectandra sp.*	2	2	0.012323	6.5	2
47	Lauraceae.	*Nectandra sp2.*	1	1	0.004584	7	1
48	Lauraceae.	*Ocotea aff. nítida* (Meisn.) Rohwer	1	1	0.004029	8	1
49	Lauraceae.	*Ocotea odorifera* (Vell.) Rohwer	3	3	0.009995	6.67	1
50	Peraceae	*Pera glabrata* (Schott) Poepp. Ex Baill.	2	2	0.004615	6	2
51	Pinaceae.	*Pinus sp.*	5	5	0.422914	14.8	4
52	Asteraceae	*Piptocarpha axillaris* (Less.) Baker	6	6	0.086509	7.67	5
53	Asteraceae	*Piptocarpha sp.*	1	1	0.004974	8	1
54	Myrtaceae	*Psidium cattleianum S*abine	8	10	0.038149	6.15	7
55	Myrtaceae	*Psidium* sp.	10	10	0.026889	4.5	3
56	Rubiaceae	*Psychotria sp.*	1	1	0.00179	5	1
57	Rubiaceae	*Psychotria suterella* Mull. Arg.	1	1	0.002037	3	1
58	Rubiaceae	*Psychotria vellosiana* Benth.	2	2	0.006724	5.5	2
59	Rubiaceae	*Bathysa gymnocarpa* K. Schum.	2	2	0.008157	6	2

60	Euphorbiaceae	*Sapium glandulosum* (L.) Morong	4	4	0.00992	11.13	4
61	Anacardiaceae.	*Schinus terebinthifolia* Raddi	19	23	0.257813	6.79	12
62	Styracaceae	*Styrax lancifolius* Klotzsch ex Seub	1	3	0.015231	7	1
63	Arecaceae	*Syagrus Romanzoffiana* (Cham.) Glassman	6	6	0.147465	7.75	6
64	Melastomataceae	*Tibouchina mutabilis* (Vell.) Cogn.	118	128	1.632466	7.43	38
65	Sapindaceae	*Toulicia Laevigata*ra dlk	4	4	0.008165	6.38	3
66	Cannabaceae	*Trema micrantha* (L.) Blume	1	1	0.020698	13	1
67	Rutaceae	*Zanthoxylum fagara* (L.) Sarg	2	2	0.077811	10.5	2
68	Rutaceae	*Zanthoxylum rhoifolium* Lam.	1	1	0.002578	6.5	1
		Total	**553**	**622**	**5.660578**	**7.74**	**315**

Source: by the author himself.

The most representative family was Myrtaceae with 16.13% of the 553 individuals in 54 sample units (Table 1), followed by Lauraceae with 9.68% and Rubiaceae and Melastomataceae, both with 8%, all these species representative of the environment of Atlantic Forest, however individuals in the family Fabaceae were not sampled within the 54 sample units.

The rate of bifurcation of the community forestry analyzed was 12.48%, while the bifurcation may be associated with adverse environmental impacts as the insolation and damage the structure of trees (SILVA et al., 2013; SANTOS & VALCARCEL, 2011), the bifurcation can also be associated with sunshine and fires, however, the species that contributed most to the rate of bifurcation was *Clusia criuva* Cambess., which has naturally high rates of bifurcation, a characteristic auto-ecological of the representatives of the family Clusiaceae. From the diametric structure drafted, it was found that the community forestry (Figure 2) showed a tendency to a J-inverted, as, the higher number of individuals found in the smallest diameter classes, which is a typical behavior of multianeforests (SILVA et al., 2017).

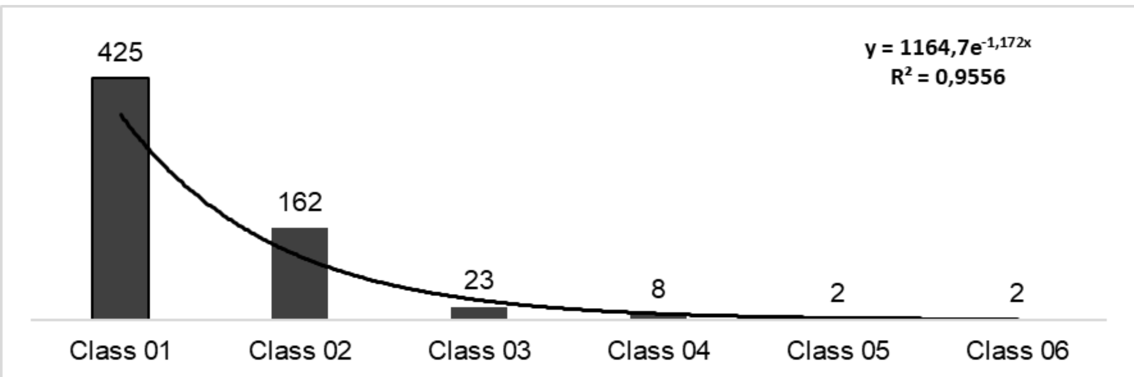

Figure 2 – Distribution of frequency per class of Dbh of trees measured
Source: by the author himself.

The heights of the trees measured in the inventory were distributed in three (3) classes with amplitude of stratum: lower, middle and upper. Distributed in accordance with Resolution Nº 1/1994 of the Environment National Council (CONAMA), in which the lower strata concentrated trees with up to 5.2 m, the middle stratum of trees that had the height exceeding 5.2 m until the height of 14.5 m and the upper stratum of trees with height greater than 14.5 m. According to Martins, 1991, estimates of the heights of individuals shrubs and trees can provide important information for both the interpretation of vertical structure of the forest as an aid in understanding the dynamics of populations that compose it. According to the analysis of estimated heights of 553 trees (Figure 3), 202 are in the lower strata (<5.2 m), 393 are in the middle stratum (>5.2 and <14.5 m) and 27 are located on the upper stratum (> 14.5 m), indicating an environment of regeneration and with recruitment of new individuals in each stratum of the forest ecosystem.

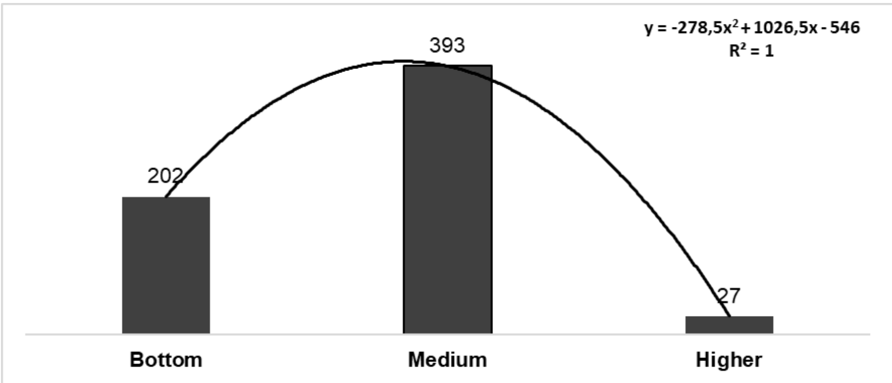

Figure 3 – The vertical structure of the forest ecosystem.
Source: by the author himself.

For the analysis of biomass (VT), in 1944 m^2 of Area Studies, we quantified 36.99 m^3 of timber, so for each hectare of woody area of the Billings reservoir a quantification of 190.28 m^3 is expected.

The families that have greater expression of biomass (Vt) in m^3 (Figure 4) are: Melastomataceae (10.71 m^3), Euphorbiaceae (4.15 m^3) and Myrtaceae (3.91 m^3).

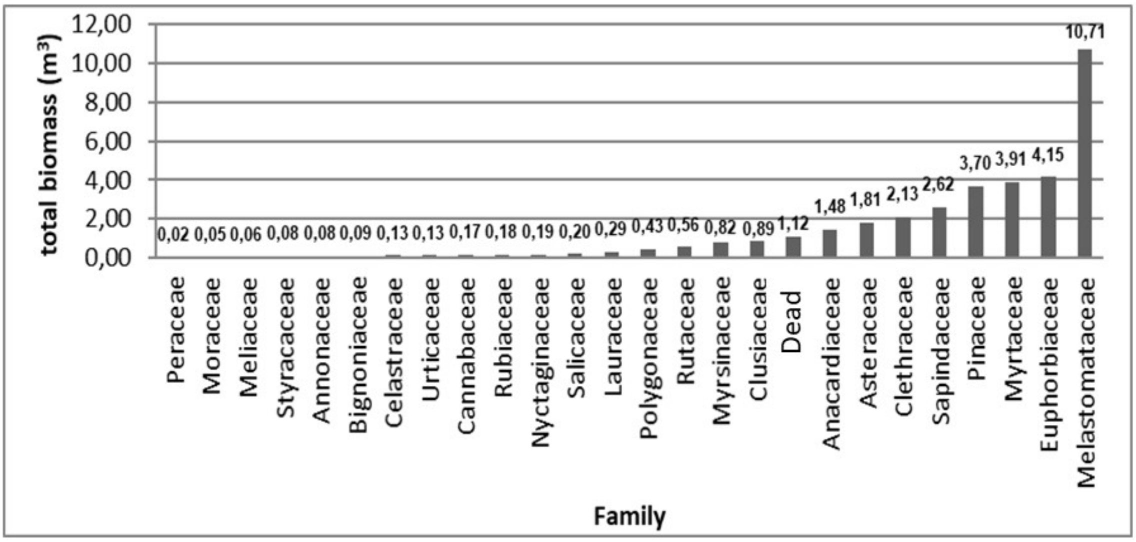

Figure 4 – Total biomass (m^3), by the botanical family sampled.
Source: by the author himself

Of the 69 species selected, the most representative in biomass (m^3) was *Tibouchina mutabilis*, which alone represents about 33% of biomass in the forest community analyzed.

Table 2 – Volume m^3 per forest species sampled in community forestry.

N	Species	Density ton/m³	Vt (CU)	Dr (%)	VC
1	*Alchornea* sp.	0.44	3.19	2.17	1.562
2	*Alchornea triplinervia* (Spreng.) Müll.Arg.	0.49	0.164	1.085	0.808
3	*Annona* sp.	0.63	0.00743	0.181	0.107
4	*Baccharis oreophila* Malme	0.45	0.17	1.808	1.281
5	*Bathysa gymnocarpa* K. Schum.	0.64	0.035	0.362	0.253
6	*Cabralea canjerana* (Vell.) Mart	0.69	0.00784	0.181	0.108
7	Casearia sylvestris Sw.	0.84	0.204	1.627	1.224
8	*Cecropia glaziovii* Snethl.	0.41	0.133	0.181	0.259
9	*Clethra scabra*Pers.	0.53	2.13	7.776	7.393
10	*Clusia criuva* Cambess.	0.83	0.891	4.34	3.741
11	*Coccoloba glaziovii* Lindau	0.89	0.434	1.266	1.203
12	*Cupania oblongifolia* Mart.	0.67	0.175	0.542	0.548
14	*Endlicheria* sp.	0.58	0.0612	0.362	0.278
15	*Eucaliptus* sp	0.61	2.57	0.362	2.032
16	*Eugenia* glazioviana Kiaersk cf	0.67	0.0451	0.181	0.15
17	*Eugenia pruniformis* Cambess.	0.81	0.0902	0.181	0.197
18	*Eugenia uniflora* L.	0.85	0.189	0.181	0.673
20	*Faramea tetragona* Müll.Arg.	0.52	0.107	1.085	0.727
21	*Ficus elastica* Roxb.	0.52	0.0493	0.362	0.283
22	*Gochnatia polymorpha* (Less.) Cabrera	0.76	1.06	0.362	1.732
23	*Guapira opposita* (Vell.) Reitz	0.35	0.193	0.542	0.655
24	*Guare amacrophylla* Vahl	0.79	0.0474	0.542	0.364
25	*Guatteria australis* A.St.-Hil	0.59	0.0753	1.085	0.689
26	1 Indet	0.49	0.09828	0.181	0.209
27	2 Indet	0.51	0.08132	0.181	0.266
28	3 Indet	0.52	0.02326	0.181	0.131
29	4 Indet	0.48	0.2469	0.181	0.485
30	5 Indet	0.5	0.103	0.181	0.233
31	*Jacaranda puberula* Cham	0.58	0.0871	0.362	0.198
32	*Endlicheria* sp.	0.63	0.0612	0.362	0.278
33	*Matayba intermedia* Radlk	0.61	2.4	0.723	2.426
34	*Maytenus*sp.	0.79	0.128	0.181	0.273
35	*Miconia cinnamomifolia* (DC.) Naudin	0.57	0.448	4.702	3.427
36	*Miconia cubatanensis* hoehne	0.63	0.627	1.447	1.593

37	*Miconia fasciculata* Gardner	0.63	0.286	3.436	2.391
38	*Miconia*sp.	0.63	0.0706	0.181	0.214
39	Dead	0.5	1.12	9.765	8.322
40	*Myrcia multiflora (Lam.) DC.*	0.60	0.0176	0.181	0.117
41	*Myrcia*sp.	0.60	0.0734	0.181	0.22
42	Myrcia sp2.	0.60	0.0118	0.181	0.111
43	*Myrciasplendens* (Sw). DC	0.63	0.636	3.797	2.007
44	*Myrsine aff. Balansae* Mez Otegui	0.57	0.497	3.797	2.795
45	*Myrsine coriacea* (Sw). R.Br. Ex Roem. &Schult	0.57	0.208	1.085	0.935
46	*Myrsine gardneriana* A.DC.	0.57	0.113	0.362	0.361
47	*Nectandra grandiflora* Nees	0.61	0.0701	0.542	0.411
48	*Nectandra*sp.	0.66	0.0587	0.362	0.29
49	*Nectandra*sp2.	0.66	0.0232	0.181	0.131
50	*Ocotea aff. nitida*(Meisn.) Rohwer	0.47	0.0243	0.181	0.126
51	*Ocotea odorifera* (Vell.) Rohwer	0.51	0.0503	0.542	0.36
52	*Pera glabrata* (Schott) Poepp. Ex Baill.	0.63	0.0223	0.362	0.222
53	*Pinus* sp.	0.40	3.7	0.904	4.188
54	*Piptocarpha axillaris* (Less.) Baker	0.62	0.547	1.085	1.307
55	*Piptocarpha sp.*	0.62	0.0291	0.181	0.134
56	*Psidium cattleianum* sabine	1.12	0.195	1.447	1.06
57	*Psidium* sp.	0.96	0.09	1.808	1.142
58	*Psychotria* sp.	0.53	0.00703	0.181	0.106
59	*Psychotria suterella* Mull. Arg.	0.53	0.00432	0.181	0.108
60	*Psychotria vellosiana* Benth.	0.38	0.0272	0.362	0.24
61	*Sapium glandulosum* (L.) Morong	0.40	0.792	0.723	0.449
62	*Schinus terebinthifolia* Raddi	0.93	1.48	3.436	3.995
63	*Styrax lancifolius* Klotzsch ex Seub	0.59	0.0765	0.181	0.225
65	*Tibouchina mutabilis* (Vell.) Cogn.	0.66	9.28	21.338	25.089
66	*Toulicia laevigata* radlk	0.90	0.422	0.723	0.434
67	*Trema micrantha* (L.) Blume	0.40	0.173	0.181	0.273
68	*Zanthoxylum fagara* (L.) Sarg	0.75	0.544	0.362	0.868
69	*Zanthoxylum rhoifolium* Lam.	0.54	0.01303	0.181	0.113
	Total	40.64	36.99531		

Source: by the author himself.

The quantification of biomass of wood (B) resulted in estimates of 113.73.ha^{-1}, which corresponded to 56.87 tC.ha^{-1} carbon stock in the forest studied. The representativeness of forest inventory runs, it is incorrect to say that these are the estimation of biomass and carbon stored in the forest ecosystem of the Billings reservoir.

Table 3 – Average values (X) ̄of the variables measured per plot; average estimates of biomass of STEM ($t.ha^{-1}$) and carbon ($t.ha^{-1}$) of the forest per plot and successional stage of each plot analyzed.

Parcels	G(m^2)	DAP(cm)	stature(m)	radius of cup(m)	biomass(m^3)	C ($t.ha^{-1}$)	phase
1	0.006094	8.57	5.56	2.13	0.02415	0.007217	Page
3	0.007514	9	6.74	1.35	0.0434	0.012969	Page
4	0.015629	11.33	6.4	1.75	0.08804	0.026308	Average
5	0.013122	11.46	3.5	0.83	0.01528	0.004566	Average
6	0.014691	12.46	7.91	1.75	0.06925	0.020693	Average
7	0.0057	8.07	5.5	1.09	0.02341	0.006995	Page
8	0.007127	8.84	4.89	1.07	0.02355	0.007037	Page
9	0.048863	19.91	9.5	2.41	0.3183	0.095115	Average
10	0.025425	17.19	10	2.33	0.1625	0.048558	Average
11	0.003673	6.57	4.3	0.83	0.01234	0.003687	Page
12	0.005511	8.11	4.5	1.65	0.01778	0.005313	Page
13	0.009618	10.4	8.16	2.41	0.05037	0.015052	Average
14	0.02677	18.46	8.5	2.6	0.1314	0.039265	Average
15	0.006019	8.28	6.28	1.46	0.02774	0.008289	Page
16	0.005109	7.76	5.38	1.66	0.01964	0.005869	Page
17	0.003288	6.37	4.69	1.64	0.01103	0.003296	Page
18	0.003858	6.71	9.15	2.02	0.03301	0.009864	Page
19	0.038141	21.64	10.5	2.25	0.2297	0.068639	Advanced
20	0.006118	8.09	5.87	1.97	0.029	0.008666	Page
21	0.019908	15.6	9.5	3.33	0.1252	0.037412	Average
22	0.041097	17.26	11.58	2.44	0.4635	0.138503	Average
23	0.008535	9.55	6.4	1.84	0.03979	0.011890	Page
24	0.02981	18.67	10	2.84	0.1865	0.055730	Average
25	0.00473	7.38	5.17	1.32	0.01847	0.005519	Page
26	0.004635	7.48	10	1.25	0.03673	0.010976	Page
27	0.004652	7.4	6.92	1.8	0.02423	0.007240	Page
28	0.018239	8.7	2.4	0	0.007749	0.002316	Page
29	0.008387	9.99	7.43	1.58	0.04692	0.014021	Page
30	0.014019	12.73	6.35	2.37	0.05124	0.015312	Average
32	0.012758	11.94	11.06	2.75	0.1141	0.034095	Average
33	0.004584	7.63	6.5	1.8	0.02129	0.006362	Page
34	0.006828	8.91	4	0.76	0.0212	0.006335	Page
36	0.055993	23.44	9.16	4.5	0.323	0.096519	Advanced
37	0.022707	12.89	7.75	1.54	0.2339	0.069894	Average
38	0.010021	10.42	9.75	2.13	0.0707	0.021127	Average
40	0.007009	9	4.5	0.94	0.01947	0.005818	Page
41	0.01204	8.75	7.25	1.5	0.03058	0.009138	Page
42	0.031143	15.69	8.79	2.53	0.2595	0.077544	Average
43	0.000897	9.44	5.87	2.26	0.04116	0.012299	Page
44	0.007993	8.36	6.84	2.25	0.06422	0.019190	Page

45	0.008666	9.16	6.89	1.99	0.05081	0.015183	Page
46	0.003858	6.74	5.81	1.3	0.01779	0.005316	Page
47	0.00391	6.96	6.38	1.67	0.01994	0.005958	Page
48	0.006005	8.3	5.32	1.21	0.02234	0.006676	Page
49	0.003716	6.61	3.78	0.86	0.009817	0.002934	Page
50	0.053702	20.9	8.4	2.3	0.1829	0.054654	Advanced
51	0.006878	9.03	6.08	1	0.02711	0.008101	Page
60	0.007095	9.23	4.92	1.35	0.02449	0.007318	Page
61	0.009028	9.07	7.35	1.9	0.05589	0.016701	Page
71	0.009691	10.66	7.5	1.67	0.05111	0.015273	Average
72	0.000322	10.9	6.78	1.7	0.0724	0.021635	Average
77	0.005231	7.98	3.67	1.3	0.01243	0.003714	Page

Source: by the author himself.

The population parameters of mature forest (Table 3), in turn, are in accordance with the submitted in Resolution Nº 1/1994 of the Environment National Council (CONAMA), for forests in the initial stages and medium, according to SILVA et al. (2018) forests, more young people tend to use more carbon than the ripe, it is noteworthy that the forest ecosystem of the Billings reservoir presented large densities of species *Tibouchina mutabilis*, *Cyathea* cf. *Corcovadensis* and *Euterpe edulis*, these last two species do not produce secondary xylem, as already mentioned above, it is therefore important to use other methods of measurement of biomass and carbon storage in non-lignified plants, preferably non-destructive methods, once that the species *Euterpe edulis* is considered threatened according the state of São Paulo resolution and the species *Cyathea* cf. *Corcovadensis* is of great importance for anurofauna, being an important micro-habitat for the region.

The estimation of biomass and carbon found were similar to studies in which they obtained estimates of stem biomass without bark of Ribeiro et al. (2009), which counted 319 tree species, belonging to 177 genera and 60 families. The quantification of biomass (B_{wood}) of the stem bark resulted in estimates of 166.67.ha^{-1}, for a carbon stock of 83.34 tC.ha^{-1}, in a mature forest in Viçosa, MG according to Resolution Nº 29/1994 of the Environment National Council (CONAMA).

For a volumetric study on a fragment of Atlantic forest in the municipality of Queimados-RJ, SILVA et al., 2017, quantified 26.28 tC.ha^{-1} for an initial forest.

For studies performed in the Amazon Biome we have: SANTOS et al. (2018), in a study in mature forest in central Amazonia, acquired estimates of biomass (B_{wood}) of the bole wood with bark ranging between 299.60 and 29.46. tC.ha^{-1}, with a mean of 327.8 ± 41.9. tC.ha^{-1}. SALDARRIAGA et al. (1988), in a study on ecological succession in the Amazon region, found wood biomass (B_{wood}) of the stem in four stands of mature forests ranging between 107 and 145. $tC.ha^{-1}$.

In general it is noticeable that the results found for estimates of wood biomass (B) and carbon stored above ground in the Amazon Biome, provided higher values for this study, as well as for the study by RIBEIRO et al. (2009), both in the Atlantic Forest biome, but in general the great abundance and frequency of species *Cyathe a*cf. *Corcovadensis* and *Euterpe edulis*, which do not have secondary xylem may have contributed negatively to the values of biomass and carbon storage found in this study, suggesting that the values mentioned, are still higher than those described here, however the forest ecosystem of the Billings reservoir has proven to be extremely helpful in the carbon sequestration and storage, benefiting the society and the environment.

For carbon credits to be credible, three technical tasks must be fulfilled: biomass estimation of the forest ecosystem, management of large amounts of spatial data and assessment of forest degradation (HAJEK et al., 2011). The Estimation of carbon stock in the forest ecosystem of the Billings reservoir has met all these criteria can be used as a reference for the establishment of projects of restoration/reforestation projects under the sustainable development mechanism, agreed upon in the Kyoto Protocol, and generate the so-called carbon credits.

The estimate of the carbon stock can be used as a reference for the establishment of projects of restoration/reforestation projects under the sustainable development mechanism, agreed upon in the Kyoto Protocol, and generate the so-called carbon credits. As the Atlantic Forest is a hotspot of biodiversity, many are the actions of forest restoration carried out in its ecosystems, therefore a biome of priority to conservation and environmental preservation, the recovery of degraded areas becomes relevant to have the proper generation of environmental services, the fragment in question must be the focus of actions that maximize the succession and the conservation of biodiversity, which could be liable for the establishment of carbon projects.

CONCLUSÃO

Considering the importance of the Billings reservoir for the state of São Paulo and the need for the preservation of its ecosystem, this study estimated the biomass (B_{wood}) of $113.73.ha^{-1}$ m^3 through the installation of 54 plots (U A quadratic) of 36 m^2 arranged systematically in a forest fragment of 48.010.91 m^2 covering an area of 1944 m^2, which corresponded to 56.87 $tC.ha^{-1}$of carbon stock in the forest studied.

Carbon stock estimation can be used as a reference for the establishment of degraded area recovery projects under the sustainable development mechanism established in the Kyoto Protocol and to generate so-called carbon credits. The importance of this is highlighted for the Atlantic Forest, due to the large number of degraded areas that this biome possesses, which could be establishment of carbon projects.

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