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Biomass of a fragment of the montane seasonal deciduous forest the south Brazil

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Abstract: The objective the work was to quantify the biomass using the destructive method of a forest fragment located in the South of Brazil. The study was conducted in fragment of Montane Seasonal Deciduous Forest with approximately 55 ha, centered at the coordinates S 27°23'44" and W 53°25'59". For that, three plots of 12x12 m were installed. All plants with diameter at breast height (DBH) greater than 5 cm were identified at the species level. All trees with DBH>10 cm had the following information collected: DBH, total height (h), height at the morphological inversion point (MIP) and the diameter at 0%, 25%, 50%, 75% and 90% of the MIP height. As result, we verified that trees with DBH> 10 cm represent more than 90% of the total biomass (345.2 Mg ha^{-1}). The estimated biomass of leaf litter was 12.4 Mg ha^{-1}. The stock of dry aboveground biomass and litter for the study area was 380.5 Mg ha^{-1}.

Key words: Subtropical; Carbon sink; Vegetation.

Biomassa em fragmento de floresta estacional decidual montana no sul do Brasil

Resumo: O objetivo do trabalho foi de quantificar a biomassa em fragmento florestal localizado no sul do Brasil utilizando o método destrutivo. O estudo foi realizado em fragmento de Floresta Estacional Decidual Montana com aproximadamente 55 ha, centrado nas coordenadas 27°23'44" S e 53°25'59" O. Para isso, três parcelas de 12x12 m foram instaladas. Todas as plantas com diâmetro a altura do peito (DAP) superior a 5 cm foram identificadas em nível de espécie. As árvores com DAP>10 cm tiveram as seguintes informações coletadas: DAP, altura total (h), altura do Ponto de Inversão Morfológica (PIM) e as circunferências relativas a 0%, 25%, 50%, 75% e 90% da altura do PIM. Como resultado, verificou-se que as árvores com DAP> 10 cm representam mais de 90% da biomassa total (345,2 Mg ha^{-1}). A biomassa estimada de serapilheira foi de 12,4 Mg ha^{-1}. O estoque de biomassa seca acima do solo e serapilheira para a área de estudo foi 380,5 Mg ha^{-1}.

Palavras-chave: Subtropical; Sumidouro de carbono; Vegetação.

Introduction

Brazil has approximately 58% of its territory covered by natural and planted forests, of which 485.8 million hectares are of native forests (FAO, 2015).

In Rio Grande do Sul, seasonal forests cover about 13,865 km2, corresponding to 4.9% of the original area, and the seasonal deciduous forests (IBGE, 2012) account for most of this area: 11,762 km2 or 4.2 % (SEMA/UFSM, 2001).

In addition to economic importance, forests provide several environmental services, including sequestration and carbon storage in their biomass (FIORENTIN et al., 2015; RIBEIRO et al., 2009).

Currently, discussions on climate issues related to the increase of greenhouse gas (GHG) concentration, mainly carbon dioxide (CO_2), are of interest to researchers due to the role that planted forests exert in relation to biological fixation and removal of CO_2 in the atmosphere (SANQUETTA et al., 2014) and by CO_2 stored in natural forests (BALBINOT et al., 2017).

The correlation between the concentration of carbon dioxide (CO_2) in the atmosphere and the average temperature of the planet validates concerns about the impacts of increasing concentrations of greenhouse gases (GEG) on climate change (IPCC, 2006).

To understand the sequestration and storage of carbon in natural forests, a qualitative and quantitative analysis of the various biomass components of forest ecosystems is required (CALDEIRA et al., 2011).

Direct biomass determinations in the field are crucial factors in increasing the accuracy of carbon storage estimates, which can increase the number of forest projects for CO_2 capture (SOCHER et al., 2008; WRIGHT et al., 2004). In addition, local surveys are essential to increase the accuracy of estimates on a regional and global scale (NUNES et al., 2012), as well as for the implementation of the mechanism of reduction of emissions by deforestation and forest degradation (REDD) according to the UN climate convention (AVITABILE et al., 2011; CORTE et al., 2012).

Although in Brazil many studies have been carried out on the quantification and distribution of forest biomass in areas of tropical forests (RIBEIRO et al., 2009; AMARO et al., 2013; SOARES et al., 2016), studies on forest fragments are still needed, especially those distributed in subtropical areas.

In the absence of such investigations in fragments of deciduous montane forest in southern Brazil, our objective was to analyze the allocation of aboveground tree biomass in a fragment of deciduous montane forest in the city of Frederico Westphalen-RS.

Material and Methods

Study area

The paper was developed in a forest fragment with approximately 55 ha located at Frederico Westphalen, RS, Brazil (Figure 1). The area represents an altered primary succession fragment of the montane seasonal deciduous forest, characterized by the selective cut of high-value species. The altitude of the fragment ranges from 520 to 550 m (s.n.m.m.). The area climate type is Cfa (Humid subtropical climate in the Köppen-Geiger classification), with an average annual rainfall of 1700 mm, well distributed along the year. The average temperature 23ºC (ROSSATO, 2014). The soils of Frederico Westphalen are classified as aluminoferric oxisol (SANTOS et al., 2013).

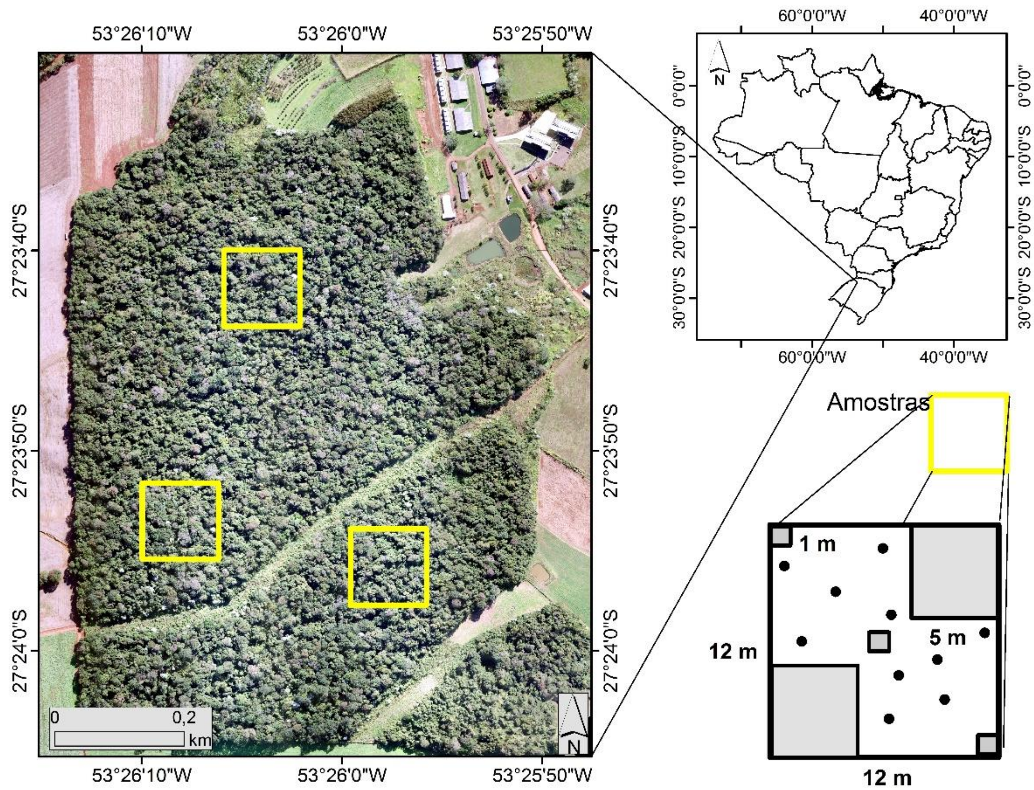

Figure 1. Location of the study area demonstrated in aerial image of the three sample plots (VANT Matrice 100 X3 camera) dated May 23, 2018 (true color composition). Diagram showing the distribution of the subsampling units within the plot.

Sampling and quantification of biomass

Were installed three sampling units of 12 x 12 m (144 m^2) (Figure 1), in which every individuals from stratum 1 (E1), with diameter at breast height (DBH; at 1.3 m) ≥ 10 cm, were felled and identified. All sampled trees were identified at a species level, and the following information were collected: DBH; total height; height of the morphological inversion point (MIP) and; the circumference at 0%, 25%, 50%, 75% and 90% of the MIP height.

In the field, the green biomass components were separated in bole with bark, thick branches (diameter ≥ 5 cm), thin branches (diameter ≤ 4,9 cm), leaves and miscellaneous (vines, lianas, bromeliads). Samples of each component were collected for determination of the dry weight. For the thick and thin branches, samples were taken from several diameters along the canopy layers. Leaves were collected in several points of the canopy. Tree discs were taken from half the height of the bole. From these discs, the bark was separated from the wood, obtaining a bark factor for the bole.

The trees and/or shrubs with 5 < DBH < 10 cm were classified as stratum 2 (E2). For E2 were installed two sub plots of 5 x 5 m (25 m^2), inside the 144 m^2 parcel (Figure 1), where all the plants were separated into the components wood (formed by branches and bole) and leaves. The stratum 3 (E3) was collected in the same sub-parcel and included the plants with DBH ≤ 5 cm and highest than1.3 m. These materials were separated into wood and leaves. The stratum 4 (E4), was composed by every living plant with total height up to 1.3 m found in three 1 x 1 m (1 m^2) parcels (Figure 1). These components were weighted by using a dynamometer, with capacity for 500 kg (minimum 0.5 kg, error ± 10 g).

To obtain the leaf litter data, ten samples randomly distributed were collected in each parcel, using a 25 x 25 cm (0.0625 m^2) template. All green samples were weighted and put in a greenhouse (60 ºC) until they reached constant weight.

Results and discussion

In the extract E1 were found 33 trees (Table 1), belonging to 24 species and 14 botanical families. Twelve trees of five species were found in the stratum E2, mainly by Gymnanthes *concolor* Spreng and *Eugenia schottiana* O. Berg. In E3 a total of 63 plants (small trees and shrubs) of 10 species were found, such as *Eugenia schottiana* (n=25), *Hybanthus* sp. (n=9), *Gymnanthes concolor* (n=8) and *Sorocea bonplandii* (Bill.) W. C., Burger, Lanjouw and Boer (n=8). In total, 45 trees with DBH between 5 and 72.2 cm were sampled. For E4, there was no identification of species because in this extract were sampled countless individuals from several species and growth types (buds from tree and shrub species, herbaceous, trailing plants, etc.), that is, all living plants within the stratum standard.

Table 1. Dimensions and weight of the biomass of trees DBH> 10 cm according to the different compartments considered in Frederico Westphalen, RS, Brazil.

P	A	Species	H (m)	HPI (m)	DBH (cm)	Biomass (kg)						
						F	GG	CA	GF	FO	MI	Total
1	1	*Trichilia claussenii* C.DC.	11.1	7.6	14.0	46.9	0.0	4.3	9.9	1.8	0.0	62.9
	2	*Trichilia elegans* A. Juss	9.1	4.3	10.3	11.1	1.0	1.1	9.8	0.3	0.0	23.3
	3	*Gymnanthes concolor*	6.4	3.4	10.8	12.9	1.1	1.1	13.8	2.9	0.0	31.8
	4	*Trichilia catigua* A. Juss	14.6	6.5	20.8	156.3	101.0	15.8	126.0	12.8	0.0	411.9
	5	*Eugenia rostrifolia* D.Legrand	10.5	6.7	10.4	31.5	1.6	2.8	7.3	2.4	0.0	45.6
	6	*Chrysophyllum gonocarpum* (Mart. & Eichler) Engl.	10.4	4.9	12.4	27.4	7.5	3.3	12.2	2.0	0.2	52.6
	7	*Chrysophyllum marginatum* (Hook. & Arn.) Radlk.	16.3	11.1	25.8	128.0	43.9	13.0	16.0	4.3	6.2	211.4
	8	*Nectandra megapotamica* (Spreng.) Mez.	12.9	6.8	33.3	299.3	98.5	24.1	23.3	5.6	0.0	450.8
	9	*Chrysophyllum marginatum* (Hook. & Arn.) Radlk.	16.2	5.7	19.7	95.0	122.8	7.5	34.8	7.3	3.1	270.5
	10	*Cedrela fissilis* Vellozo	22.9	6.6	48.5	351.1	472.8	49.0	65.8	23.3	101.9	*1063.9*
	11	*Campomanesia xanthocarpa*	16.4	7.7	22.0	124.7	51.1	3.7	46.0	8.3	0.7	234.5
	12	*Chrysophyllum marginatum* (Hook. & Arn.) Radlk.	21.3	15.0	36.2	522.3	158.1	36.9	60.4	9.3	21.0	*808.0*
	13	*Machaerium stipitatum*	20.3	10.8	72.2	1057.4	412.6	38.0	102.4	12.4	97.3	*1720.1*

		Parcel biomass (kg)	13.7	7.1	23.8	2863.9	1472.0	200.6	527.7	92.7	230.4	5387.3
2	1	*Machaerium stipitatum* (DC.) Vogel	18.6	7.8	23.7	108.5	91.0	4.9	42.3	2.5	104.9	354.1
	2	*Eugenia rostrifolia* D. Legrand	27.4	10.4	22.4	250.1	135.2	24.7	44.8	7.5	105.0	*567.3*
	3	*Nectandra megapotamica* (Spren g.) Mez.	18.0	10.6	22.8	161.9	33.4	12.3	33.8	11.2	0.0	252.6
	4	*Syagrus romanzoffiana* (Cham.) Glassman	17.4	13.4	22.0	321.8	16.8	0.0	0.0	19.9	0.0	358.5
	5	*Erythrina falcata* Benth.	7.4	4.8	10.7	8.9	0.0	2.2	0.9	0.0	0.6	12.6
	6	*Apuleia leiocarpa* (Vogel) J.F.Macbr.	19.2	15.0	11.7	79.8	2.0	6.5	11.3	1.2	0.0	100.8
	7	*Nectandra megapotamica* (Spreng.)	16.8	5.8	28.0	153.7	160.0	11.8	43.3	15.4	0.8	385.0
	8	*Apuleia leiocarpa* (Vogel) J.F.Macbr.	21.3	13.8	23.6	310.6	82.4	28.8	57.9	2.8	0.0	*482.5*
	9	*Parapiptadenia rígida* (Benth.) Brenan	25.2	10.7	58.9	1320.6	856.7	88.1	173.0	9.7	21.3	*2469.4*
		Parcel biomass (kg)	19.0	10.3	24.9	2715.9	1377.5	179.3	407.3	70.2	232.6	4982.8
3	1	*Guarea macrophylla* Vahl	5.9	2.6	10.4	11.4	4.7	0.9	7.1	1.5	4.8	30.4
	2	*Sorocea bonplandii* (Baill.) W.C. Burger	9.7	5.9	12.8	35.7	4.8	3.1	14.8	4.2	12.3	74.9
	3	*Cordia ecalyculata* Vell	14.7	6.1	23.9	104.2	62.9	19.7	14.4	5.8	22.6	229.6
	4	*Apuleia leiocarpa* (Vogel) J.F.Macbr.	18.2	11.4	17.6	112.0	51.6	8.6	24.5	4.5	5.7	206.9
	5	*Apuleia leiocarpa* (Vogel) J.F.Macbr.	13.3	8.5	15.6	79.3	14.0	4.5	313.6	7.5	0.3	419.2
	6	*Tetrorchidium rubrivenium* Poepp. & Endl.	21.7	11.5	40.9	405.3	134.0	33.5	42.7	12.7	0.0	628.2
	7	*Alchornea sidifolia*	15.9	2.0	34.5	85.6	457.2	5.4	50.3	17.4	18.2	*634.1*
	8	*Myrocarpus frondosus* Allemão	20.2	11.8	39.2	734.1	308.4	55.0	133.5	20.6	0.0	*1251.6*
	9	*Picrasma crenata* (Vell.)	11.3	5.6	16.2	43.0	1.0	4.0	2.6	0.1	0.0	50.7
	10	*Casearia sylvestris* Sw.	15.3	8.5	21.7	138.3	41.3	12.3	20.8	5.8	40.4	258.9
	11	*Tabebuia cassinoides* (Lam.) DC.	20.3	12.4	39.0	463.4	102.2	21.0	27.2	16.2	126.0	*756.0*
		Parcel biomass (kg)	15.1	7.8	24.7	2212.3	1182.2	168.2	651.6	96.4	230.2	4540.8
Average measured biomass						180.4	93.3	12.7	36.7	6.0	16.0	345.2

P = parcel; A = Tree; F = Bole biomass; GG = Thick branches; CA = Bark; GF = Thin branches; FO = Leaves; MI = Miscellaneous

The biomass values determined per sampling unit were estimated in tons per hectare to facilitate the comparison with other ecosystems (Table 2). The same procedure was done for the leaf litter (LL). The dry biomass stock aboveground of all vegetable strata was 368.2 Mg ha^{-1} and the leaf litter 12.4 Mg ha^{-1}. The whole biomass was 380.6 Mg ha^{-1}. Analyzing the distribution of stock among the strata, it is evident the importance of E1, which represents 345.3 Mg ha^{-1} (90,7%) of all the biomass aboveground, that is, all trees and other plants in the forest plus the leaf litter, represent the remaining 9.3%. This fact makes clear that, in this type of study, the trees with DBH above 10 cm are the component of the forest ecosystem that should get more attention from the researcher when the objective is biomass quantification.

Table 2. Distribution of the dry biomass above the soil and leaf litter (Mg ha^{-1}) in a fragment of the Seasonal Deciduous Forest Montana

Parcel	E1						E2		E3		E4	LL	TOTAL
	F	GG	GF	CA	FO	MI	DC	FO	DC	FO			
1	198.9	102.4	36.6	13.9	6.4	16.0	19.6	1.6	4.1	0.8	3.6	13.8	417.6
2	188.6	95.7	28.3	12.5	4.9	16.2	12.6	0.7	13.2	2.1	0.3	10.6	385.5
3	153.6	82.1	45.2	11.7	6.7	16.0	3.0	0.5	4.9	0.7	1.2	12.7	338.3
Average	180.4	93.4	36.7	12.7	6.0	16.1	11.7	0.9	7.4	1.2	1.7	12.4	380.6
Standard deviation	23.7	10.3	8.5	1.1	1.0	0.1	8.3	0.6	5.0	0.8	1.7	1.6	39.9
IC 95%	180.4 ±26.9	93.4 ±11.7	36.7 ±9.6	12.7 ±1.3	6.0 ±1.1	16.1 ±01	11.7 ±9.4	0.9 ±0.7	7.4 ±5.7	1.2 ±0.9	1.7 ±1.9	12.4 ±1.8	380.5 ±45.1
%*	47.4	24.5	9.6	3.3	1.6	4.2	3.1	0.2	1.9	0.3	0.4	3.3	100
%**	90.7						3.3		2.3		0.4	3.3	100

*percentage of the component of each stratum in relation to the total of the biomass; ** percentage of each stratum in relation to the total of the biomass. Where: F= Bole biomass; GG= Thick Branches biomass; GF= Thin Branches Biomass; CA= Bark biomass; FO= Leaves biomass; MI= Miscellaneous biomass; CG= Stem and branches biomass.

The strata E2, E3 and E4 represent, when summed up, 22.9 Mg ha^{-1} of biomass. This biomass is equivalent to 1.8 times the one found on the leaf litter, which is 12.4 Mg ha^{-1}. Such comparison makes clear the importance of leaf litter in the carbon studies. In addition, the quantification of dead wood on the soil may be considered to improve the stock accuracy.

Another component that has shown to be significant in the composition of biomass storage was the miscellaneous of plants (vines, lianas, lichens, bromeliads, etc.) that live supported or on the trees with DBH > 10 cm. This component happened only in stratum E1 and represented 16.1 Mg ha^{-1}. This component has 2.7 times more biomass than the leaves (6.0 Mg ha^{-1}) of the trees from E1, equivalent double the biomass of leaves of strata E1, E2 and E3, which is 8.1 Mg ha^{-1}.

Papers that evaluate the biomass of vines and lianas separately are rare, among them Brun et al. (2005) studied the Seasonal Deciduous Forest (Santa Tereza – RS) and found values of 14.6 Mg ha^{-1} in secondary succession forests in advanced stage and 7.8 Mg ha^{-1} in secondary succession forests in medium stage. Understanding the representativeness of the biomass associated to the miscellaneous is crucial for the qualification of indirect methods of biomass estimates, based on optical orbital sensors (ASNER e MARTIN, 2012; BALL et al., 2015; PHILLIPS et al., 2002).

On Table 3 presents a comparison with the data from Brun et al. (2005) who worked in a SDFM in Santa Tereza-RS and Vogel et al. (2006), who studied the SDFM in Itaara-RS, both with very similar methodologies. The tree stratum comprehends the trees with DBH > 10 cm, the shrub stratum comprehends all the plants with more than 1.3 m in height and DBH < 10 cm and the herbaceous stratum comprehends all the plants smaller than 1,3 height.

Table 3. Biomass distribution (Mg ha^{-1}) above the soil in different studies with the Seasonal Deciduous Forest Montana in RS

Forest	No. of parcels	Trees					Shrubs		Her.	TOTAL
		F	G	CA	FO	MI	CG	FO		
Prim. Altered	3[3]	180.4	130.1	12.7	6.0	16.1	19.1	2.1	1.7	368.6
Sec. 70[1] years	12[4]	91.0	102.4	11.4	5.1	-	-	-	-	210.0
Sec. 53[2] years	3[5]	82.6	47.8	10.6	3.5	7.8	4.2	0.3	0.7	157.6
Sec. 33[2] years	3[5]	51.1	22.0	0.8	2.3	14.6	3.5	0.2	0.9	102.3

[1]Vogel et al. (2006); [2]Brun et al. (2005) consider all the thick, thin and dead branches, and, for the data of this paper, the thick and thin branches, without considering the dead branches. Where: F= Bole biomass; G= Branches; CA= Bark; FO= Leaves; MI= Miscellaneous; CG= Stem and branches. [3]12 x 12 m parcels, being closed cut; [4] 10 x 10 m parcels, an inventory was made of them and 20 trees were taken and distributed among the diameter classes; [5] 10 x 10 m parcels, with close cut.

It is observed that the trees with DBH > 10 cm (E1) represent 90.7% of the aboveground biomass. Analyzing all the strata, we can see that they correspond to 96.75% of the aboveground biomass (with the exception of the leaf litter). In this study, the sum of the weight of the branches (GG+GF) represents 130.1 Mg ha^{-1} (35.3% of the total biomass, with the exception of the leaf litter). Adopting a similar methodology (branches were considered from a morphologic inversion point), Brun et al. (2005) reported close results for medium and advanced stage forest (30.3% and 21.5%, respectively).

Studies developed in the ecosystem of the Montana Mixed Rain Forest (WATZLAWICK et al., 2012) showed that the average biomass stored by the forest was 250.90 Mg ha^{-1}, from this 104.17 Mg ha^{-1} of organic carbon, corresponding to 41.52% of the total biomass. In the Alluvial Mixed Rain Forest Socher et al. (2008) a total aerial biomass of 195.51 t/ha was obtained. The approximate dry biomass was 170 t/ha, wherein the portions that most contributed to this value were wood (52.84%), thick branches (35.19%) and thin branches (5.12%). The portions that less contributed were fruits and seeds, with 0.001%, and others (flowers, buds etc.), with 0.003%.

Torres et al. (2013), in a study in a fragment of a semi deciduous forest (altered secondary forest with the presence of exotic species), found for the aboveground biomass of the tree species the estimation of 80.41 t ha^{-1}, and regarding the leaf litter, the forest fragment presented a medium biomass equivalent to 11.57 t ha^{-1}.

To better exemplify the importance of E1 (trees with DBH> 10 cm), the stock of biomass FEDM was elaborated in Table 1. In her contains the values of total height (H), height of the morphological inversion point (HIP) and DBH, as well as the biomass determined for all the trees sampled in each of the compartments considered, namely Bole, Thick branches, thin branches, Bark, Leaves and Miscellaneous.

After analyzing Table 1, we could select the three largest trees of each plot. These trees would represent 66.1%, 70.6% and 58.2% of the total weight of each one of the parcels 1, 2 and 3, respectively. That is, in average, they correspond to 65% of the weight in the E1 stratum, and approximately 58% of the biomass of the studied forest. These results suggest that the biggest individuals should be carefully inspected. Also the distribution of the aboveground biomass points out that the trees with big diameter must be carefully analyzed because a few individuals can represent more than half the whole biomass of the forest. This way, in order to avoid estimate errors for great areas, it is necessary to concentrate efforts in this fraction of the forest.

It is possible to see the importance of secondary forests in the removal of atmosphere carbon, occurring slower for a longer period because the storage of biomass can triple between the initial and advanced stage (Table 3). This long storage period is precisely a positive aspect of natural forests because this preservation of biomass storage dampens the variations of anthropogenic emissions.

This fact highlights the importance of the application of REDD++ (reduction of emissions by deforesting and forest degradation, with its conservation and management sustainable) in native forests as tools to balance the stocks of carbon, and, consequently, mitigate the climatic alterations, having incentives for the non-taking down of forests, conserving and expanding the forest coverage, forest sustainable handling and recovery of the degraded areas. Moreover, REDD++ includes areas with sustainable agriculture and the preservation of existing natural resources.

Conclusions

The aboveground biomass is distributed in four strata: E1 345.2 Mg ha-1; E2 12.7 Mg ha-1; E3 8.6 Mg ha-1; LL 3.3 Mg ha-1 and E4 1.7 Mg ha-1.

Stratum E1 represents more than 90% of above-ground biomass of the entire forest. The total stock of dry above-ground biomass and leaf litter was 380.5 Mg ha-1.

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