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SHORT COMMUNICATION - Conservation of Nature

Small Rural Atlantic Forest Remnants Might Store Significant Amounts of Carbon: An Example in Southeastern Brazil

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Abstract

Human activities in the tropics, particularly large-scale deforestation, significantly contribute to rising greenhouse gas emissions. The carbon storage capacity of the Atlantic Forest, specifically in seasonal forests, needs to be better understood. Therefore, we analyzed the aboveground carbon stock (AGC) in a semideciduous seasonal forest (SSF) remnant in southeastern Minas Gerais through comprehensive vegetation inventory and wood density sampling. The 20 species that counted for half of the total basal area corresponded to a surprising AGC of 58.05 $Mg.ha^{-1}$. The AGC found is similar to other studies in second-growth SSF, especially the ones with no recent record of human disturbance. However, besides the natural process of increasing AGC in forests over the years, long-term decreasing trends in other forest ecosystems in Brazil have already been reported. Future long-term studies are crucial to understanding how the forest carbon stock will respond to the ongoing environmental and climate change scenario.

Keywords: AGC, wood density, semideciduous seasonal forest, allometric equation.

Human activities in the tropical region cause forest fragmentation and habitat loss, primarily through agriculture and livestock expansion (Joly et al., 2014; Arroyo-Rodríguez et al., 2017). Deforestation significantly contributes to increasing greenhouse gas emissions, reinforcing the global climate change scenario (DeFries et al., 2007). Addressing this, sustainability policies like REDD+ and Clean Development Mechanisms (CDM) focus on mitigating emissions by sequestering carbon in trees and soil (Lederer, 2012; UNFCCC, 2023).

The accurate measurement of the aboveground biomass (AGB) is essential for determining the aboveground carbon (AGC) stored in wood (Chave et al., 2009). Although there is already information on the capacity of carbon stocks in the world's forest biomes (Pan et al., 2011; Heinrich et al., 2023), tropical regions, such as the Atlantic Forest domain, lack accurate AGB and AGC estimations due to their taxonomic complexity and difficulty in obtaining reliable field data, essential for the calculations of allometric models (Chave et al., 2014). Furthermore, field work in tropical regions is hard and challenging (de Lima et al., 2022).

To obtain the most accurate estimates of AGB and AGC in a forest, considering the wood density of all occurring species would be ideal. However, this is hardly achieved. The high richness and abundance of individuals within tropical forests and the high complexity of obtaining and processing wood samples are the main strains. Considering this scenario, the main approach to forest biomass and carbon estimations studies consists of using wood density values of the dominant species in the community (Brown et al., 1989; Baker et al., 2004; Saatchi et al., 2011; Flores and Coomes, 2011). However, most of the studies use wood density values from databases or literature, not considering that the wood density of a species may vary according to the different environmental and geographical factors that the species occur (Fearnside, 1997; Swenson and Enquist, 2007), leading to less accuracy of the AGB and AGC measurements in forests.

Little is known about the semideciduous seasonal forests (Atlantic Forest's largest remaining phytophysiognomy) capacity to store carbon, even more in the Zona da Mata of Minas Gerais (southeastern Brazil), which makes any carbon policy unfeasible. Some studies on carbon storage have been developed in this (Borges et al., 2020, 2021; Pyles et al., 2020; Costemalle et al., 2023) but consider secondary information for wood density from the literature database.

Here, we analyze the AGC stock of the tree component in a secondary forest remnant in the municipality of Ewbank da Câmara, Minas Gerais, based on the vegetation inventory and samples of wood density of the dominant species.

This study was carried out in a 30ha remnant forest in the NIASSA-UFJF (Núcleo de Integração Acadêmica para Sustentabilidade Socioambiental – Federal University of Juiz de Fora), a former livestock farm in the rural area of the municipality of Ewbank da Câmara – State of Minas Gerais (-21.581160, -43.568307). The studied area, now protected from direct anthropogenic disturbance, is a remnant of a second-growth forest, classified as a semideciduous seasonal montane Atlantic Forest (IBGE, 2012). Historically, the Atlantic Rainforest domain has a lengthy land-use background, mainly converting the natural forest landscape to agriculture and pastures (Coelho et al., 2022). As a second-growth forest, the studied remnant carries that background, and satellite images show that its form and area have been the same since the 80s. Moreover, according to local people's information, the forest stands for more than 50 years and was used by former farmers for low-impact activities such as minor selective logging and hunting until the '00s.

We established 30 random permanent plots (15 x 12 m) corresponding to 0.5 ha in the remnant. Within each plot, we measured the diameter at breast height (DBH) and height of all living trees with DBH ≥ 5 cm. Trees were collected and taxonomically identified using the Leopoldo Krieger Herbarium (CESJ-UFJF) collection. The phytosociological structure was analyzed according to Kent & Coker (1992) (Table 1).

Table 1. Phytosociological parameters and wood density of the 20 dominant species in the seasonal Atlantic Forest at Ewbank da Câmara, Zona da Mata, Minas Gerais State, Brazil. BA = basal area ($m^2.ha^{-1}$); AD= absolute density; RD= relative density (%); AF = absolute Frequency; RF = relative frequency (%); ADo= absolute dominance; RDo= relative dominance (%); IV= importance value; WD_{mean} = mean wood density ($g.cm^{-3}$).

Species	BA	AD	RD	AF	RF	ADo	RDo	IV	WD_{mean}
Lacistema pubescens Mart.	1.029	184	14.7	22	4.00	2.06	5.88	24.67	0.39
Piptadenia gonoacantha (Mart.) J.F.Macbr.	0.751	10	0.80	5	0.90	1.50	4.29	6.00	0.43
Sorocea guilleminiana Gaudich.	0.72	91	7.31	15	2.72	1.45	4.16	14.20	0.48
Tachigali vulgaris L.G.Silva & H.C.Lima	0.709	20	1.60	9	1.63	1.42	4.05	7.30	0.38
Platypodium elegans Vogel	0.554	7	0.56	7	1.27	1.10	3.16	5.00	0.56
Xylopia brasiliensis Spreng.	0.532	53	4.26	1	2.90	1.06	3.04	10.21	0.48
Ocotea bicolor Vattimo-Gil	0.491	35	2.81	14	2.54	0.98	2.80	8.16	0.45
Inga laurina (Sw.) Willd.	0.478	12	0.96	7	1.27	0.95	2.7	4.97	0.52
Casearia sylvestris Sw.	0.477	24	1.92	13	2.36	0.95	2.73	7.02	0.42
Xylopia sericea A.St.-Hil.	0.466	28	2.25	8	1.45	0.93	2.66	6.37	0.46
Cecropia hololeuca Miq.	0.455	5	0.40	4	0.72	0.910	2.60	3.73	0.37
Lamanonia ternata Vell.	0.437	3	0.24	3	0.54	0.87	2.50	3.28	0.50
Didymopanax morototoni (Aubl.) Decne. & Planch.	0.399	16	1.28	12	2.18	0.79	2.28	5.75	0.29
Tovomitopsis paniculata (Spreng.) Planch. & Triana	0.352	22	1.76	7	1.27	0.70	2.01	5.05	0.38
Guapira opposita (Vell.) Reitz	0.33	27	2.17	8	1.45	0.66	1.91	5.53	0.31
Matayba elaeagnoides Radlk.	0.30	17	1.36	10	1.81	0.60	1.74	4.92	0.31
Miconia urophylla DC.	0.303	46	3.6	10	1.81	0.60	1.73	7.25	0.40
Machaerium nyctitans (Vell.) Benth.	0.280	13	1.04	8	1.45	0.56	1.60	4.10	0.50
Protium heptaphyllum (Aubl.) Marchand	0.263	7	0.5	5	0.90	0.52	1.50	2.97	0.38
Cupania vernalis Cambess.	0.254	28	2.25	11	2.00	0.50	1.45	5.70	0.38
Total	**9.606**	**648**	**52.**	**194**	**35.27**	**19.21**	**54.89**	**142.2**	-
Other taxa	7.893	596	47.9	356	64.72	15.78	45.10	157.7	-
General total	**17.49**	**1244**	**100**	**550**	**100**	**34.99**	**100**	**300**	-

To assess the aboveground carbon (AGC) of the forest, we initially obtained wood density data for the species with higher basal area (BA) and importance value (IV). The selected species, corresponding to >50% of total BA and IV, had one to three tree individuals sampled based on absolute density. Palms, tree ferns, unidentified, or pending identification species were excluded, and the next identified species in ranking replaced them. AGB calculations excluded these taxa as well.

We analyzed wood density following Pérez-Harguindeguy et al., (2013). We used an increment borer (model Haglöf Sweden) inserted at 1.30 m DBH on the tree trunk to a depth equal to half the diameter to obtain the sample. Afterward, we sealed the hole to prevent timely contamination after the procedure.

We determined the saturated volume for each wood sample using the water displacement method. We dried the samples at an average temperature of 100°C for 72 hours to obtain the dry mass. To calculate the wood density value ($g.cm^{-3}$) per species, we divided the dry mass value by the saturated volume.

For the AGB calculation, we used the global allometric equation proposed by Chave et al., (2014) for tropical forests:

$$AGB_{est} = \exp[-1.803-0.976E+ 0.976ln(\rho) +2.673ln(D)-0.0299[ln(D)]^2]$$

In which ρ is the wood density of each species, and D represents the diameter at the breast height of the individual. All the AGB values obtained for the individuals were summed and extrapolated to the community in $Mg.ha^{-1}$. As AGC concentration of the different parts of a tree is generally assumed to be 50% of the AGB (Brown, 1997), we multiplied the AGB value by 0.5 and obtained the estimation of AGC stored for the forest remnant.

We sampled 1244 trees with a total basal area of 17.50 $m^2.ha^{-1}$ and density of 2888 $ind.ha^{-1}$. We found 174 morphospecies distributed in 51 families and 85 genera. The 20 species that counted for 54.88% of the total basal area and 52.00% of the relative density are represented in Table 1.

The aboveground biomass (AGB) estimated for the forest remnant was 116.11 $Mg.ha^{-1}$, corresponding to an aboveground carbon (AGC) of 58.05 $Mg.ha^{-1}$. The AGC estimated in our study was similar to other studies in second-growth semideciduous seasonal forests of Minas Gerais state (Table 2). Especially the ones with a similar background and no recent record of human disturbance (Torres et al., 2013; Gaspar et al., 2014; Silva et al., 2018). Moreover, our AGC estimation was higher than in studies carried out in forest edge and second-growth forests with a recent record of human disturbance (Ribeiro et al., 2010; Da Rocha et al., 2019; Coelho et al., 2022) (Table 2). However, our carbon stock was remarkably lower than that Coelho et al. (2022) found in an old-growth semideciduous seasonal forest in the Rio Doce basin. High AGC in old-growth forests is expected since these systems have a long time to grow and gain secondary slow-growth species that store more carbon in their structure. Early successional stage forests and recently disturbed forests are mainly composed of fast-growth pioneer species that store less carbon with their short life cycle and life strategy (Guariguata & Ostertag, 2001; Villa et al., 2019; Coelho et al., 2022).

Table 2. Carbon stock in the seasonal Atlantic Forest at Ewbank da Câmara, Zona da Mata, MG, and comparison with other seasonal forests at Minas Gerais State, Brazil. *References: [1]Ribeiro et al. (2010); [2]TORRES et al. (2013); [3]GASPAR et al. (2014); [4]SILVA et al. (2018); [5]ROCHA et al. (2019); [6]COELHO et al. (2022).

Locality*	Carbon stock ($Mg.ha^{-1}$)	Methodology	Area disturbance background
Ewbank da Câmara	58.05	Allometric equations (AGC) using WD collected from the study species	Secondary forest with low-impact activities in the past 50 years
Viçosa[1]	19.50	Allometric equations of tree volume using WD from specific bibliography	Former pasture in 30 years of natural regeneration
Viçosa[2]	46.76	Local allometric equations using the biomass of tree branches	Former pasture; selective logging, eucalyptus plantation, 20 years of natural regeneration
São João Evangelista[3]	58.91	Allometric equations of tree volume using WD from specific bibliography	Information not described by the authors
Itutinga[4]	55.91	Biomass allometric equations using WD collected from the study species	No record of recent human disturbance
Viçosa[5]	45.43 (forest edge) 63.71 (forest interior)	Local allometric equations using the biomass of tree branches	Information not described by the authors
Rio Doce Basin[6]	130.70 (old-growth) 18.20 (secondary)	Allometric equations (AGB) using WD from global database	Old-growth: remnant inside the Rio Doce State Park, protected since 1962 Second Growth: areas previously occupied by plantations, with at least 30 years of land use

Nevertheless, the carbon stock in our study is representative of medium successional stage second-growth forests, and with its growing and developing perspective over the years, we expect an income in its biomass and carbon stock (Torres et al., 2013; Gaspar et al., 2014). However, we should see this carbon increment trend with parsimony. Although there is a tendency for carbon increase throughout the successional process in secondary forests, recent studies have shown a decline in long-term carbon sink in the Amazon secondary rainforests due to droughts, causing climate-induced tree mortality (Brienen et al., 2015; Hubau et al., 2020). In the Atlantic Forest domain, Maia et al. (2020), analyzing 32 seasonal forest sites monitored between 1987 and 2020, found a long-term decline in the carbon sink, and the driest and warmest sites have already moved from carbon sinks to carbon sources. On the other hand, Ferreira et al. (2023) highlight that AGB and carbon stocks can potentially increase in large fractions across the Atlantic Forest domain in the next few decades. The value of 58.05 $Mg.ha^{-1}$ stored carbon we found for the forest was surprising for a secondary small Atlantic Forest remnant. Although it has been around 50 years without considerable anthropogenic disturbance, it carries the background of the tremendous secular destruction of the region. Furthermore, the remnant can be used as a reference for carbon policies, such as REDD+ and CDM. However, in the current global warming scenario and climate change, long-term studies must be conducted in the studied forest over the coming decades to investigate its trends in carbon stocks, gains, losses, and net carbon sink.

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