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Amount of Carbon Store in the Species Ficus Soatensis and Tecoma Stans Established in the Locality of Puente Aranda, Bogotá D.C.

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The present study contributes to the mitigation and adaptation of climate change in the city of Bogotá, through of the valuation of carbon storage and the biomass of endemic species in the city, without use destructive methods. The mentioned information is necessary to scientifically show which roles these species play in the ecosystem and such allow us to define the good management of resources and to generate mechanisms in the long-term. To know the amount of carbon stored in the species Ficus soatensis and Tecoma stans settled in the locality of Puente Aranda, samples were taken from individuals of different diameter classes, of four tree components: trunk, bark, branches and leaves, and sent to the laboratory to be analyzed by the CHN test. The average carbon content for the two-species varied between 44.54% and 51.95% with an average of 47.23% and standard deviation of 2.84 in all tissues of the individuals analyzed. The carbon content accumulates differentially in the tissues of the individual; the highest value was obtained in the trunk of Tecoma stans and the lowest corresponds to the branches of Ficus soatensis. The percentages of Carbon content by species and by tissue found for Ficus soatensis were, in trunk 51%, branches 43%, bark 45% and leaves 46%; for Tecoma stans the results were 53% in trunk, 46.5% branches, 46.5% bark and 47.5% leaves. When comparing the carbon stocks in the biomass, using the specific concentration as a reference, with respect to the general carbon concentration for the species Ficus soatensis and Tecoma stans, it was found that there is a difference in the carbon content in the branches, since the one registered by the laboratory is greater than the one estimated in a general way. When evaluating the difference between the specific carbon reserves with the general carbon reserves, it can be evidenced that there is a significant difference in the case of the branches. Therefore, it is appropriate to consider this variation in carbon storage estimates, to reduce the margin of error when reporting results of this type.

1. Introduction

According to the National Center for Scientific Research of France (CNRS, 2006), the CO2 concentration currently exceeds 380 parts per million. Bogota is not alien to this reality, justly in the Capital District, CO2 discharges are emitted to the atmosphere contributed mainly by industrial activities, the automotive park, agricultural sector, and others. According to the to Environmental Secretary of Bogotá, the emission of C02 in Bogotá is equivalent to 1.89 tons' habitant per year, which totals 13,498,244.31 tons of CO_2eqGEI. The trees are one of the main components of the provision of necessary resources for humans. It's not just the biomass producing be a source of natural and infinitely renewable energy, but because they use the carbon dioxide that we throw away and in return, they produce the oxygen we need. Currently, the trees play a key role in our daily lives, since a wood whose chemical composition is mainly given by cellulose, hemicelluloses, lignin and pectins, serves as a raw material for many of the things we use (Goncalves et al., 2016; Sanchez Penalva et al., 2016). Likewise, it is noteworthy that trees have a fundamental participation in the uptake of atmospheric carbon dioxide, its assimilation, transformation, and accumulation in the form of biomass. The carbon is stored in several reservoirs such as leaves, stems, branches, roots, and necromass. Between 30% and 50% of the total amount of carbon absorbed by plants is used in metabolic processes and is returned to the atmosphere through the process of respiration (Amthor et al., 2001). The remaining carbon is fixed as organic matter and is defined as the net primary production (NPP). The ability of the plants to store carbon in the form of aerial biomass varies depending on the floristic composition, age and the population density of each stratum by plant community (Schulze et. Al., 2000). There is variability in the carbon content stored in trees as biomass, between 43% and 58% (IPCC, 1996), depending on the species and the tissue of the tree (Gifford, 2000). This variation is presented in terms of the quality of the site, climate, type of soil, the age of the trees and the method used in the determination of the carbon content (Cubero et al., 1999). To evaluate the carbon stored by trees, the literature recommends the use of a constant value of 50% which is assumed to correspond to the amount of this element present in the biomass. This value is used as a standard for all forest ecosystems (IPCC, 1996). This value has been recommended in cases where it is not available the local information, because of the difficulties involved in generating it. Some authors suggest that ignoring this variation in carbon concentration in the estimates of biomass reserves can introduce relative errors of -6.7% to + 7.2%. Of this range, 93% is attributed, first, to ignore the interspecific variation (Zhang et al., 2009), and second, to environmental variables, in addition to other factors such as growth factors (DAP) (Elias et al., 2003). To determine carbon stocks, the content of this element in the biomass is taken into account. This is estimated by the general carbon concentration (50% for woody tissues and 45% for non-woody) and using the specific carbon concentration for every tissue and every species. This condition includes interspecific and intraspecific variation and is the reference to which it is compared. It is important to note that the concentration of carbon varies between different tissues of the tree (Zhang, et al., 2009). This contribution presents the results of the estimation of carbon stored in the biomass of the species Ficus soatensis and Tecoma stans (the most distributed species in the locality of Puente Aranda), from the measurement of carbon concentration in the trunk, branches, bark and leaves of each species in the sample. The standard method to measure the CHN combustion in an elemental analyzer was used.

2. Materials and methods

The study starts with the analysis of subsamples taken from 803 trees. Diameter classes and heights classified the individuals by the method of Sturges (1926) in order to obtain the plant material. Two samples for each individual by class, of the trunk, branches, bark and leaves components were taken. To extract the trunk samples a Pressler drill was used. To obtain bark samples a machete was used and to collect the foliage samples a pulley sling was used. The roots were excluded because of the logistical difficulties of sampling. A total of 44 samples belonging to 11 individuals were taken. For the determination of the specific weight, samples from the wood of the trunk between 5 and 10 cm3 were taken. It depended on whether the individuals present in the sampling, they had a diameter greater than 2.5, because this facilitated the extraction of the sample. The samples were taken at 1.3 meters above the ground. Weighing and conservation procedures for samples in the field and drying in the oven were carried out using the methods of Vásquez & Arellano 2012. The determination of Carbon, Hydrogen and, Nitrogen was carried out simultaneously and automatically in a CHN simultaneous automatic analyzer.

To determine the carbon content, the samples were pulverized in two hammer mills of blades for coarse and fine crushing, until passing mesh N°60 (sample size 0,250 mm), they were homogenized and packed with their respective label. The powdered samples were dried again to 105°C during 24 hours in the oven of the IGAC soils laboratory, in order to eliminate any rest of humidity. The determination of Carbon, Hydrogen, and Nitrogen was carried out simultaneously and automatically, burning a quantity sample (0,02g) in the middle of a pure oxygen stream to 950°C in a simultaneous automatic analyzer CHN. This method gives the total percentage present of C, H, and N, and included carbon of hydrogen carbonates of moisture and the water of hydration of silicates. The range of values obtained to C and H is from 0,01% to 100%, and for N is from 0,01% to 50%. The sensibility is 0,01% for the three elements and the Detection method for the C and H is infrared absorption analysis and for N is thermal conductivity.

3. Results and analysis

To evaluate the carbon content in the species of the study, the assumptions of normality by the Kolmogorov - Smirnov, and Shapiro-Wilk test were used. Based on these tests, it was determined that the carbon content data do not conform to a normal distribution. Therefore, a non-parametric one-way ANOVA analysis was performed using the Kruskal Wallis test. Through it, the significance of the differences in the medians of the carbon content between the four components of the woody individual (trunk, branches, bark and leaves), between the species Ficus soatensis and Tecoma stans and between the size of individuals according to their diameter classes were observed. The relationship between the carbon content measured in the individuals with other structural variables was evaluated by the Spearman correlation coefficient (R). The non-parametric

Mann-Whitney U test was applied. This test allows identifying differences between two populations based on the analysis of two independent samples, whose data have been measured at least on an ordinal level scale. The estimation of carbon stocks is carried out usually by multiplying the biomass and the carbon fraction in it. The normality analysis for the measured carbon percentage in the four tree components was performed. For this purpose, the following hypotheses were proposed:

Null Hypothesis (H0): The percentages of carbon (Trunk, Bark, Leaves, Branches) come from a normal population;

Alternative hypothesis (H1): The percentages of carbon (Trunk, Bark, Leaves, and Branches) do not come from a normal population.

Null Hypothesis (H0): The percentage of carbon content calculated in (trunk, bark, leaves, branches) does not vary in Ficus soatensis and Tecoma stans.

Alternative hypothesis (H1): The percentage of carbon content calculated in (trunk, bark, leaves, branches) varies in Ficus soatensis and Tecoma stans, with a level of significance (alpha) $\alpha = 5\% = 0.05$

The Wilcoxon rank test was carried out in order to compare the general carbon stock based on the content approximation (50% for woody tissues and 45% for non-woody tissues), against the stock of the specific carbon content determined by laboratory samples. Thus, the following hypothesis were proposed:

H0: The specific carbon stock does not differ from the general carbon stock.

H1: The specific carbon stock differs from the general carbon stock. Level of significance: 5%

Using the Kolmogorov-Smirnov test we evaluated the carbon content expressed as the percentage of the dry biomass. The information can be seen in Table 1.

Table 1: Carbon content (%) measured in Tecoma stans and Ficus soatensis species in the locality of Puente Aranda

Component	Minimum	Maximum	Mean	Standard Deviation.
Trunk Carbon	47.70	56	51.95	2.83
Bark Carbon	42.20	49.90	46.09	1.98
Leaves Carbon	41.90	53.20	46.33	3.23
Branches Carbon	37.20	48.30	44.54	3.33

The Shapiro-Wilk normality test determined that, for the percentage of trunk carbon of the two species, there are two of the observed data oscillating between 47.5% and 48.75% carbon, three between 50% and 51.25%, one between 51.25% and 52.5%, two between 52.5% and 53.75% and three between 55% and 56.25%. In the case of the percentage of carbon in the bark, the test shows that one of the observed data oscillates between 42% and 44% of carbon, four between 44% and 46%, four between 46% and 48% and two between 48% and 50%. Likewise, for the carbon data in the leaves, one is between 40% 40% and 42%, two between 42% and 44%, three between 44% and 46%, three between 46% and 48%, one between 48 and 50% and one between 52% and 54%. Finally, the test shows that for the percentage of carbon in branches, there is one of the observed data oscillating between 36% and 38% of carbon, one between 40% and 42%, three between 42% and 44%, one between 44% and 46%, three between 46 and 48% and two between 48% and 50%. According to the previous results and taking into account that the values of significance for Ficus soatensis and Tecoma stans are greater than the proposed level of significance of 0.05, the Null Hypothesis is not rejected. Then, it can be inferred that the percentages of carbon in trunk, leaves, branches and, bark for Ficus soatensis as for Tecoma stans, come from a normal distribution. Although the samples have a normal distribution, it was necessary to apply the Mann–Whitney U test, for the differences in the percentages of carbon measured in the laboratory since the sample size is small. When comparing the carbon contents between the two species, the alternative hypothesis is confirmed in which the percentage of carbon content calculated in trunk, bark, leaves, branches varies in Ficus soatensis and Tecoma stans, with a level of significance (alpha) $\alpha = 5\% = 0.05$.

Regarding the average contents of trunk carbon, the p-value (asymptotic significance (bilateral)), is equivalent to 0.045, therefore, the null hypothesis is rejected, that is, the percentage of carbon calculated in trunk varies between Ficus soatensis and Tecoma Stan.

On the other hand, the average carbon contents of the branches have an error of 0.018 and it is also proved that the percentages of Carbon content of the branches are different between Ficus soatensis and Tecoma stans. In the box-and-whisker plots (figures 1 and 2), shows that there is a significant difference between the percentage of carbon content calculated for trunk tissue and branches in the species Ficus soatensis and Tecoma stans. Figures 1 and 2 show that the percentages of carbon of the species Tecoma stans have an average higher than the Ficus soatensis. On the other hand, in the percentage of trunk carbon, no atypical data are found in any of the two species.

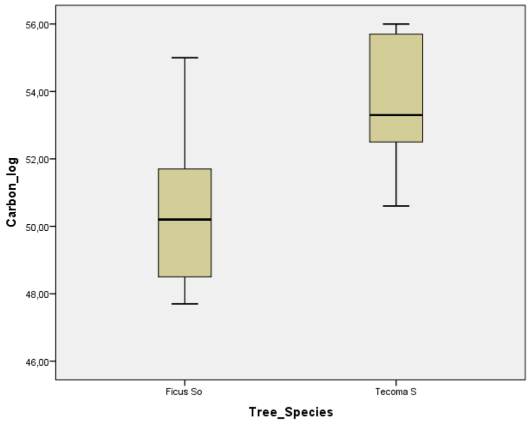

Figure 1: Difference in the carbon content of the trunk between Ficus soatensis and Tecoma stans.

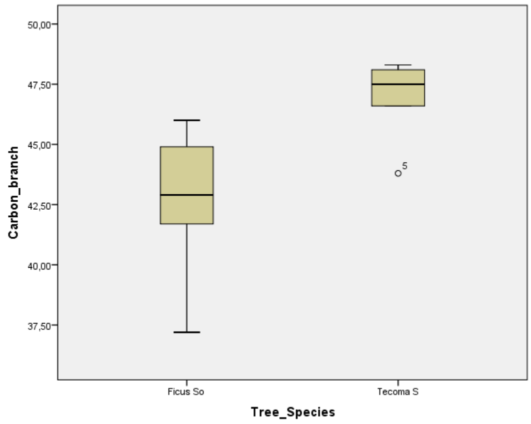

Figure 2: Difference in the carbon content of the branches between Ficus soatensis and Tecoma stans

Regarding the percentage of carbon in the branches, an atypical data of Tecoma stans corresponding to the class V diameter is recorded (equivalent to 43.8%). With regard to the percentage of carbon in the bark, the p-value equal to 0.067 is observed, in relation to the percentage of carbon in the leaves, there is an error of 0.144, for which the null hypothesis is not rejected. That means in the percentage of carbon calculated in bark and leaves there is no a significant difference between Ficus soatensis and Tecoma stans. This can be seen in figures 3 and 4, which show that the percentages of carbon of the species Tecoma stans have an average higher than that of Ficus soatensis. With respect to the carbon results in the bark, no atypical data are found in any of the two species. On the other hand, in the values of carbon in leaves, there are an atypical data in Tecoma stans, corresponding to the variation of the class VI diameter equal to 41.9%.

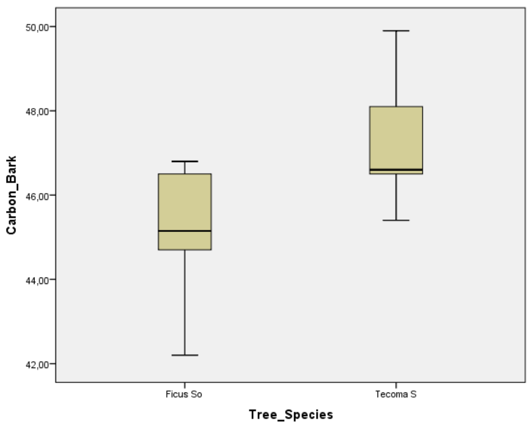

Figure 3: Difference in the carbon content of the bark between Ficus soatensis and Tecoma stans.

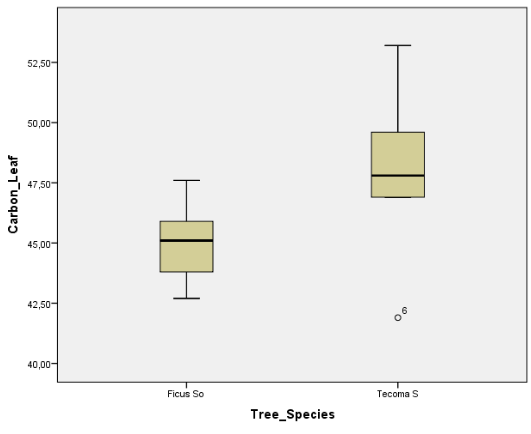

Figure 4: Difference in the carbon content of the leaves between Ficus soatensis and Tecoma stans

Significant differences were found in the carbon content according to the individual's tissue. The trunk is separated from the other tissues by presenting the highest carbon content and the branches presented the lowest value. When comparing the carbon stocks in the biomass, using the specific concentration as reference, with respect to the general carbon concentration for the species Ficus soatensis and Tecoma stans, it was found that there is a difference in the carbon content in the branches. This is because the value

registered by the laboratory is greater than the estimated in a general way. For the other tissues in all diameter classes, the carbon content is similar, since they present slight variations.
The results of the Wilcoxon rank test revealed that in the cases of the carbon reserve of leaves, bark and trunk the null hypothesis is accepted since the level of significance is found p = 0,241; p = 0.203 and p = 0.260, respectively. This means that the carbon reserves specific for bark, leaves, and trunk do not differ from the general carbon reserves. As for the reserve of carbon in branches as the value obtained for p = 0.005, the null hypothesis is rejected, so the reserve of carbon specific for branches differs from its general carbon stock.
The average carbon contents in the analyzed individuals of the two species of this study fluctuated between 37.2% and 56%, with an average of 47.23% and a standard deviation of 2.84, in all tissues. This value is significantly below the 50% suggested by the Intergovernmental Panel on Climate Change. These values are similar to that found by Sierra et al. (2007) in Porce, Colombia, which mentions an average carbon content of 46%, and by Lozano (2012), which recorded carbon content of 45.16% in the region of Córdoba, Colombia.
The percentages of Carbon content by species and by tissue found for Ficus soatensis were, in trunk 51%, branches 43%, bark 45% and leaves 46%; for Tecoma stans the results were in trunk 53%, branches 46.5%, bark 46.5% and leaves 47.5%. According to Gifford, (2000), the concentration of carbon in a tissue depends on the proportion of compounds with high content of this element, such as lignin, and compounds that do not contain it, such as inorganic minerals. Thus, in similar studies, different results have been concluded, such as the case of research carried out in Quercus humboldtii oak in the Andes of Colombia, developed by Higuera & Martinez, (2006), where it was found that after the trunk, the branches were the greater capacity for carbon capture.
In another study elaborated by Yerena in the thorn scrub in Mexico, it was found that Cordia boissieri bark presented the lowest value of carbon (39.62%) and the leaves of Acacia schaffneri the largest with 50.14%.
In a research elaborated by Vásquez (2012), in forest plantations of Córdoba, it is recorded that the highest content of Carbon is in the trunk (46.05%), while the branches and leaves reached average values of (44.72 % and 45.52%) and the bark presented the lowest value (44.39%). A comparison was made between the estimates of the carbon reserves in the biomass using the specific concentration as a reference with respect to the general carbon concentration for the species Ficus soatensis and Tecoma stans. The results show that there was a difference in the content of carbon concentration in the branches. Moreover, the results which were recorded by the laboratory are greater than the general estimation. For the rest of the tissues in all the diametric classes, the carbon content is similar since it has slight variations. The above can be seen in the table 2.

Table 2. Difference of carbon content reserves

Species	SPECIFIC CARBON RESERVES					GENERAL CARBON RESERVES				DIFERENCE			
	Diameter classes	Bark	Leaves	Branches	Trunk	Bark	Leaves	Branches	Trunk	Bark	Leaves	Branches	Trunk
Ficus soatensis	I	1,1	0,56	0,97	2,19	1,07	0,53	0,44	2,18	0,04	0,03	0,53	0,02
Ficus soatensis	II	5,34	3,66	7,69	9,28	5,29	3,59	3,46	8,98	0,05	0,07	4,23	0,31
Ficus soatensis	III	10,28	7,04	17,81	17,07	10,31	7,23	8,02	17,07	-0,02	-0,19	9,8	0
Ficus soatensis	IV	16,11	10,97	27,72	24,66	15,49	10,99	12,47	25,43	0,62	-0,02	15,24	-0,76
Ficus soatensis	V	16,63	12,7	33,84	31,94	17,73	12,61	15,23	29,04	-1,1	0,08	18,61	2,9
Ficus soatensis	VI	12,18	8,21	22,33	19,29	12,26	8,65	10,05	20,22	-0,08	-0,44	12,28	-0,93
Tecoma stans	II	1,63	0,93	1,89	3,19	1,57	0,89	0,85	2,99	0,05	0,04	1,04	0,20
Tecoma stans	III	5,39	3,48	9,07	9,23	4,86	3,28	4,08	8,29	0,53	0,20	4,99	0,94
Tecoma stans	V	10,54	8,67	20,85	17,51	10,45	7,33	9,38	17,30	0,09	1,34	11,47	0,00
Tecoma stans	VI	6,70	4,90	12,05	11,43	6,47	4,44	5,42	10,88	0,23	0,45	6,63	0,54

4. Conclusions

In this way, the storage of carbon in the aerial biomass of the species Ficus soatensis and Tecoma stans in the locality of Puente Aranda, varies according to the species and tissue of the individual, whether trunk, bark, branches or leaves. When assessing the difference between the specific carbon stocks (trunk, leaves, bark, and branches by species) that take into account the variation of the intraspecific and interspecific carbon concentration with the general carbon stocks that omit these variations, it can be evidenced that there is a significant difference in the case of branches. Therefore, it can be said that the variation of the interspecific and intraspecific concentration of this element directly affects the estimates of the total stocks of this element. Then it is appropriate to take into account this variation in the carbon storage estimates, in order to reduce the margin of error when reporting results of this type. The information differentiated by species and component of the individual obtained in this study constitutes a useful tool for estimating the carbon stocks in the forest plantations of the city, since it allows the use of specific carbon contents, although more samples must be evaluated to increase the degree of precision. It was found that there is a difference in the carbon content of the branches of the Ficus soatensis and Tecoma stans species since the registered by the laboratory is greater than the estimated in a general way.

References

Amthor J. S., Baldocchi, D. D., 2001, Terrestrial Higher-Plant Respiration and Net Primary Production. In: Terrestrial Global Productivity, Past, Present and Future, Eds. J. Roy, B. Saugier and H. Mooney, Academic Press, 32.

Cubero J., Rojas S., 1999, Fijación de carbono en plantaciones de Gmelina arborea, Tecoma grandis y Bombacopsis quinata. Tesis de Licenciatura, Universidad Nacional. Heredia, Costa Rica, Escuela de Ciencias Ambientales.

Elias M., Potvin C., 2003, Assessing intra- and inter-specific variation in trunk carbon concentration for 32 neotropical tree species, Canadian Journal of Forest Research, 33, 1039-1045.

Gifford R., 2000, Carbon contents of above ground tissues of forest and woodland trees. Canberra: Australian Greenhouse Office, National Carbon Accounting System, Technical Report, 22, 17.

Goncalves A.P., Cruz A., Sales J., Souza M., Silva F., Guimaraes D., Mattedi S., Jose N., 2016, Achivement and characterization of cellulose nanowhiskers of palm (elaeis guineensis) and bromelia fibers (neoglaziovia variegate), Chemical Engineering Transactions, 50, 403-408.

Higuera D., Martinez E., 2006, Sequestration and storage capacity of carbon in the canopy oak trees and their epiphytes in a Neotropic Cloud Forest, Colombia. Lyonia, 11, 945-958.

Sanchez Penalva P, Neto F., Aparecida De Lucca E., Masarin F., 2016, Particle size influence on the chemical composition from waste eucalyptus in the processing for industrial production of cellulose pulp, Chemical Engineering Transactions, 50, 337- 342.

Schulze E. D., Wirth C., Heimann M., 2000, Managing forest after Kyoto. Science 289 (5487), 2058-2059.

SDP., 2009, Secretaría Distrital de Planeación, Diagnóstico de los aspectos físicos, demográficos y socioeconómicos, <http://http://www.sdp.gov.co/portal/page/portal/PortalSDP/ciudadania/Publicaciones%20SDP/PublicacionesSDP/16puente_aranda.pdf> accessed 04.02.2017.

Segura M., 1999, Almacenamiento y fijación de carbono en Quercus costaricensis, en un bosque de altura en la cordillera de Talamanca, Costa Rica. Heredia (Costa Rica): Tes. Lic. Cs. Forestales, Universidad Nacional, p 127.

Sierra C., Del Valle J., Orrego S., Moreno F., Harmon M., Zapata M., Colorado G., Herrera M., Lara W., Restrepo D., Berrouet L., Loaiza L., Benjumea J., 2007, Total carbon stocks in a tropical forest landscape of the Porce región, Colombia. Forest Ecology and Management, 243, 299-309.

Sturges H., 1926, The Choice of a Class Interval, Journal of the American Statistical Association, 21, 65-66.

Vásquez, Arellano., 2012, Estructura, biomasa aérea y carbono almacenado en los bosques del sur y noroccidente de Córdoba, Colombia Diversidad Biótica XII. La Región Caribe De Colombia, Editorial Códice Ltda. (Bogotá), 963 – 961.

Yerena J., 2011, Carbon concentration in the above-ground biomass in the Tamaulipan Thornscrub, Revista chapingo Serie Ciencias Forestales y del Ambiente, 17, 238-291.