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Mitigation of greenhouse gas emissions from households by urban woodland in Ibagué-Colombia

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Abstract: Trees are essential in the city to capture CO^2, and, at the same time, to contribute to the mitigation of climate change. Carbon storage and fixation in aboveground biomass was estimated in the urban woodland of Ibagué with a census from 2013-2016, and a new measurement of 15% on individuals in the 2019-2020 period. The number of trees of the main species required to mitigate emissions of greenhouse gases from households was estimated. Urban woodland captures about 3.81 Gg CO^2/year, which represents only 2,3% of the city emissions. The mitigation of 169.2 Gg CO^2/year of the city households would be achieved by having between 412,000 and 1.2 million trees of the most dominant species. Efforts based on green infrastructure to compensate urban emissions at municipal level must be coordinated with territory policies at large scales.

Keywords: Ecosystem services, environmental policy, fixation, storage, urban silviculture.

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Introduction

Environmental assets have strategic functions withing cities that look forward to being sustainable. Ecosystem balance between human internvention and care of their resources should be properly planned, because cities and their fast demographic expansion are the main generators of atmosphere pollutants contributing to climate change (GRIMM et al., 2008). Urban worldwide population increased from 751 million in 1950, to 4,2 thousand million in 2018. The regions with the most urbanization are North America, 82%; Latin America and the Caribbean, 81%; Europe, 74%; and Oceania, 68% (UNITED NATIONS, 2018). These nations have made different proposals to duly plan their development and fulfill their goals concerning climate actions. For example, the goal to contribute with a 20% reduction of the total greenhouse gas (GHG) emissions in Colombia for 2030 (IDEAM, 2012).

Ibagué, a city in the Colombian Andes area, moved from being a small city with 349,241 inhabitants in 1985, to an intermediate city with 492,524 in 2018 (DANE, 2018). This municipality is ranked eighth in population after Bogotá, Medellín, Cali, Barranquilla, Cartagena, Cúcuta, and Soledad. By extension, it shares the sixth place of the biggest cities in the country with Cúcuta (VILLANUEVA et al., 2016). On this context, some strategies for strengthening environmental management have been established, such as the urban trees census, and the Urban Woodland Silviculture Master Plan (Plan Maestro de Silvicultura del Arbolado Urbano), intending to estimate the role of urban trees in the mitigation of certain negative impacts caused by demographic level and poor management of its natual resources (FINDETER, 2018). Besides, in the Emerging and Sustainable Cities intiative (ESC), developed by the Interamerican Development Bank (IDB), an inhabitatnt of Ibagué has 6.7 m^2 of green area, which allows its categorization as a green city (FINDETER, 2018). However, this value does not reach the minimal recommeded by the WHO (0.5-1.0 ha/inhabitant with a distance equal or shorter than 300 m from their place of living), according to the United Nations Human Settlements (UN-HABITAT, 2018).

Baró et al. (2014), Charoekit and Yiemwattana (2016), Reynolds et al. (2017), Mohamed et al. (2018), and Lindén et al. (2020) have emphasized on the estimation of carbon reservoirs in urban woodlands and their mitigation of GHG emissions. This because perennial woody structure absorbs CO_2 and deposits it in biomass and soils as carbon (MCHALE; MCPHERSON; BURKE, 2007; TIMILSINA et al., 2014). CO_2 has considerably increased its concentration in atmosphere from the 280 parts per million (ppm) of pre-industrial era to the 411 ppm in 2019, corresponding to a 48%, from which, more than half has been produced in the last 50 years (NOAA, 2019). Urban trees provide different ecosystem services (ES), such as carbon sequestration. A mature tree can sequestrate 150 kg CO_2/year and, depending on the species and location in the city, can cool the air down between 2 and 8°C, increase urban biodiversity, regulate water flow and contribute to food and nutritional security (FAO, 2016). It plays an important role in the carbon volunteer global market as land use. The volume of compensation generated by these activities increased around 264% between 2016 and 2018, growing from 13.9 Mt

CO_2e to 50.7 Mt CO_2e, whereas the volume in all other types of compared compensations raised only 21% (DONOFRIO; MAGUIRRE; MERRY, 2019). These same authors claim that urban woodlands are in a category of predominant project as the world has realized that climate Solutions based on nature are feasible and available.

There have been few studies about urban woodland and ES offer in Colombia, (BORRERO, 2012; REYNOLDS et al., 2017; RODRIGUEZ, 2018; CORTES; MATIAS, 2019; RUANO, 2019). Besides, environmental measurements to mitigate emissions are limited to the use of technology available, energy efficiency and renewable energy actions (BARO et al., 2014). Likewise, those accountable for policy formulation ignore, to a great extent, the potential of green urban spaces to contribute to compliance of environmental goals, considering that environmental offer increases quality of new urbanistic development (ALCALDÍA MUNICIPAL DE IBAGUÉ, 2020).

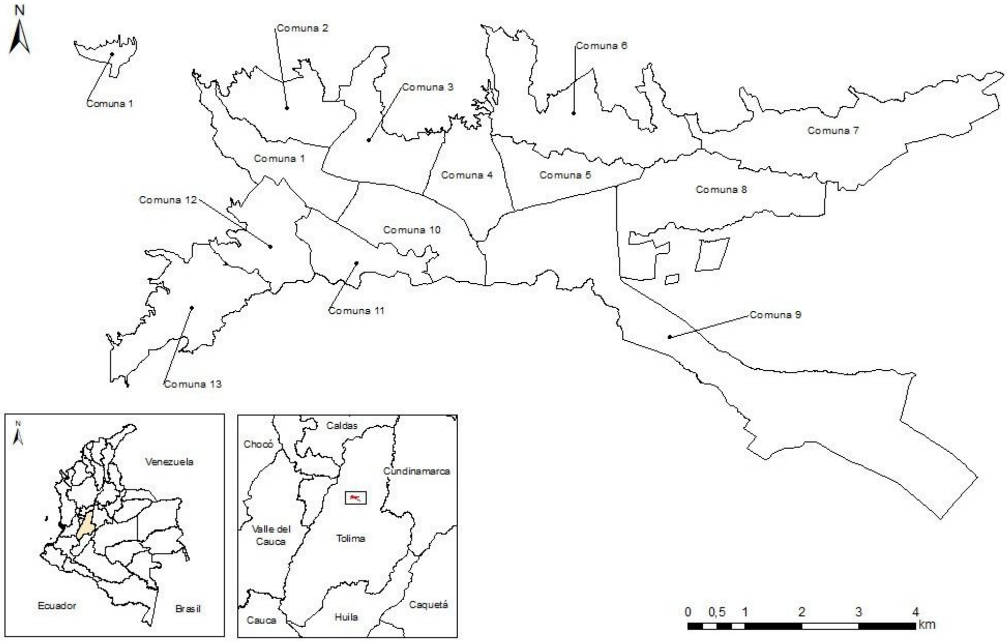
Carbon biomass in trees has noticeable differences among cities due to the prevalence of weather, history, its urbanization patter and composition of species (LÓPEZ et al., 2018; LINDÉN et al., 2020). Therefore, understanding structure, function and value of urban woodlands contributes to the decisions that improve human health and environment quality, and build joint solutions based on nature creating green jobs and economy (REYNOLDS et al., 2017; LINDÉN et al., 2020). This research assesses the role of urban woodland in aboveground carbon sequestration and mitigation of emissions in the residential area in the city of Ibagué. It also proposes strategies to mitigate such emissions, such as the design of local gevernance tactics based on scientific, ethical, and social criteria oriented to the sustainable development of the cities (IPCC, 2014).

Materials and methods

Area of study

The study was carried out in the urban area of the municipality of Ibagué, in the department of Tolima (4°15' – 4°40' N and 74°00' - 75°30' O), in the central part of the Colombian Andean region. The urban area of this city is divided into a mountainous and a plain part (CORTOLIMA, 2020). The first one sets in the coffee landscape with a temperature around the 18°C, while the lower areas are in a landscape of the Magadalena valley, characterized by an average temperature of 24°C (IDEAM, 2020). The urban area of Ibagué is classified as pre-montan wet forest (bh-PM) (IDEAM, 2020), it is at an altitude between 615 and 1285 m with a precipitation level between 1000 and 2000 mm/year, and especifically between 1400 and 1800 mm/year in the middle area. The city has an area of 1439 km^2, from these 2,4% belongs to the urban area divided into 13 districts *comunas* (Figure 1) and 445 neighborhoods (ALCALDÍA MUNICIPAL DE IBAGUÉ, 2020).

Figure 1 – Political–administrative division of Ibagué, Colombia



Source: Authors.

The municipality has a projection of 541,101 inhabitants for 2020 (DANE, 2018), where urban population would represent a 94.3-94.5% of the total (ALCALDÍA MUNICIPAL DE IBAGUÉ, 2016). Ibagué takes second place nationwide as a city with the largest green area per capita (6.7 m^2). The first one is Neiva with 7.5 m^2; followed by Valledupar, Cartagena, and Bucaramanga with 5.8, 4.6 and 4.5 m^2, respectively (FINDETER, 2018). Species of the urban woodland are part of the green infrastructure, and for their maintenance, permanent activities of mowing, pruning and felling (SALBITANO et al., 2017).

Sampling design

Selection of species to sample

The study took the census of 101394 urban trees as baseline, measured during three phases, under contracts No. 572 of 2013, No. 672 of 2014, and agreement No. 2095 of 2016 (Municipality) / 056 of 2016 (CORTOLIMA), performed among different institutions (CORTOLIMA et al., 2020). Database was refined considering trees with a trunk diameter at breast height (dbh) ≥ 10 cm, with a total of 55684 individuals. After that, total and relative basal area per species was estimated to identify the most dominant ones, selecting those which, as a whole, have an 80% of the basal area.

Dbh was re-measured to approximately 15% of individuals (7779 trees) of the most dominant species in all the city districts by the end of 2019 and beginning of 2020, taking into consideration the districts and the specific location of each tree (parks, sidewalks or pavement, as well as main and secondary streets).

Aboveground biomass and carbon estimation

Aboveground biomass of the trees was estimated using the general allometric model by Chave et al. (2005), which considers dbh and basic wood density (Equation 1), those value used was 0.45 g/cm³ (ALVAREZ et al., 2011). Carbon was estimated multiplying by 0.47, the default carbon fraction recommended by the IPCC (2007) for tropical areas.

Equation 1

$$B = \rho * exp(-1{,}499 + 2{,}148 * Ln(\text{dap}) + 0{,}207 * Ln(dap)^2 - 0{,}0281 * Ln(dap)^3$$

Where:

B: Biomass (kg/tree)

ρ: Basic density (g/cm³)

dbh: Diameter at breast height (cm)

Carbon sequestration was estimated based on the annual periodic increment (API), considering the increase in carbon storage between measurements divided by the time between them (JUAREZ, 2014). Carbon fixation values were changed to CO_2e, and using the stoichiometric factor of 3.67 (IPCC, 2007). Based on carbon storage in the census measurement (2013-2016), in the re-measurement (2019-2020), and the carbon fixation rate of trees re-measured, the fixation rate for the entire urban woodland was estimated. In this case, it was assumed that there is a close relationship between storage and carbon fixation in urban trees (ZHAO, 2010).

Estimation of GHG emissions from urban households in Ibagué and its possible mitigation

Information of emissions was obtained from Sierra estimates (2020), which was based on the use of fossil fuels and electricity in the residential sector of the city of Ibagué. The total number of households in each socioeconomic stratum (ENERTOLIMA, 2018) was considered for estimating emissions in the city. The estimation of the number of trees needed to compensate emissions, as a mitigation measure, was carried out using carbon fixation rates of the 15 most sequestrating species of urban trees Ibagué.

Statistical Analysis

A descriptive analysis was performed, and the *Pearson* correlation coefficient between carbon storage and fixation was estimated for all species and for the most dominant species of the urban area. Subsequently, a non-parametric *Kruskal-Wallis* variance analysis was performed to estimate differences of GHG emissions in households between different socioeconomic strata. In addition, comparisons in emissions between pairs of strata were made with the *Dwass-Steel-Critchlow-Fligner* test. *Jamovi* software was used for statistical analyses.

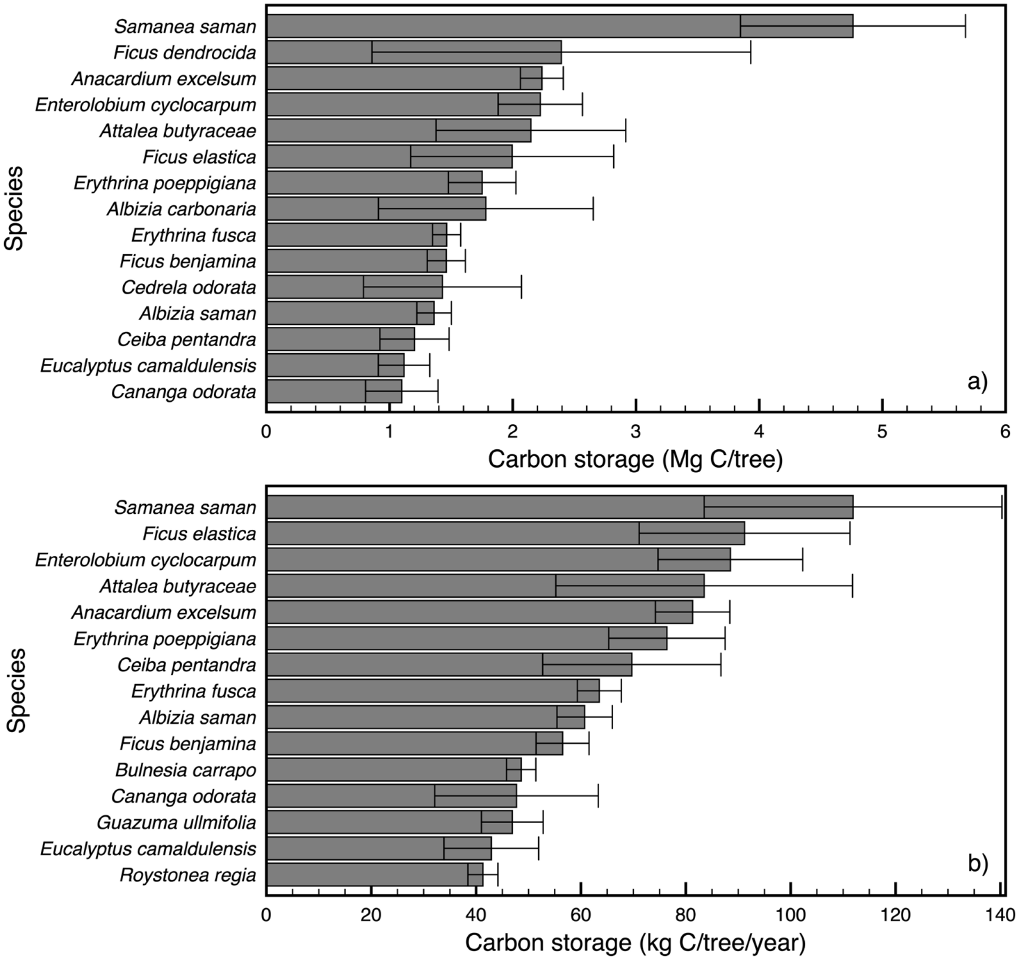
Results

Carbon storage in aboveground biomass of urban trees varied between 10.6 kg and 10.2 kg Mg C/tree, with an average 402 ± 9.5 kg C/tree. The most outstanding species in carbon storage is *Samanea saman* (Jacq.) Benth (samán), with 4.8 ± 0.9 Mg C/tree, doubling *Ficus dendrocida* Kunth (caucho – rubber tree) in storage, which stores 2.4 ± 1.5 Mg C/tree (Figure 2a). The rest of the 13 most important species concerning carbon, have a storage between 1.1 ± 0.3 and 2.3 ± 0.2 Mg C/tree, values exceeded between two and three times by *S. saman* (Figure 2a).

Rates of carbon fixation in the most dominant species of urban trees are between 0.15 and 394.2 kg C/ tree/year with an average of 23.6 ± 0.4 kg C/tree/year (Figure 2b). *S. saman* shows the highest fixation rate (111.9 ± 28.4 kg C/tree/year), followed by *Ficus elastica* (ex. Hornem) (caucho de la india - india rubber tree), and *Enterolobium cyclocarpum* (Jacq) (orejero), with 91.2 ± 20.1 and 88.4 ± 342.0 kg C/tree/year, respectively. Carbon fixation rates of all other species decrease between 5 and 8 kg C/tree/year, from 83.5 ± 28.3 kg C/tree/year in *Attalea butyracea* (Mutis LF), W. Boer (corozo), to *Roystonea regia* (Kunth) o.f Cook (palma real - royal palm tree) with 41.3 ± 2.8 kg C/tree/year (Figure 2b).

Among the most representative species, according to tree statutes of the city of Ibague (MOLINA, 2008) due to their storage and carbon fixation rates, stand out: *Erythrina fusca* Lour. (cachimbo), with 1.5 ± 0.1 Mg C/tree - 63.5 ± 4.2 kg C/tree/year, *Erythrina poeppigiana* (Walp) O.F. Cook (cambulo) with 1.8 ± 0.3 Mg C/tree - 76.3 ± 11.1 kg C/tree/year, *Anacardium excelsum* (caracolí) with 2.2 ± 0.3 Mg C/tree - 81.1 ± 7.1 kg C/tree/year, *Ceiba pentandra* (L.) Gaertner (ceiba) with 1.2 ± 0.3 Mg C/tree - 69.7 ± 17.0 kg/tree/year, and *S. saman* with 4.8 ± 0.9 Mg C/tree - 111.9 ± 28.4 kg C/tree/year (Figure 2ab). Another native and abundant species in Ibagué is *Tabebuia rosea* (Bertold) D.C. (ocobo), which showed a fixation rate of 25.5 ± 2.3 kg C/tree/year (Figure 2). Within the introduced species, stand *Cedrela odorata* (cedro amargo) native from Asia with 1.1 ± 0.3 Mg C/tree - 47.7 ± 15.6 kg C/tree/year; *Eucalyptus camaldulensis* Dehn (eucalipto - eucalyptus) from Australia with 1.1 ± 0.2 Mg C/tree - 42.9 ± 9 kg C/tree/year; *Ficus benjamina* L. (caucho benjamín) with 1.5 ± 0.2 Mg C/tree - 56.5 ± 5.0 kg C/tree/year; and *F. elastica* (caucho – rubber tree) from India with 2.0 ± 0.8 Mg C/tree - 91.2 ± 20.1 kg C/tree/year (Figure 2).

Figure 2- Carbon storage and fixation rates of the most dominant perennial woody species of urban trees in Ibague, Colombia, 2019 – 2020

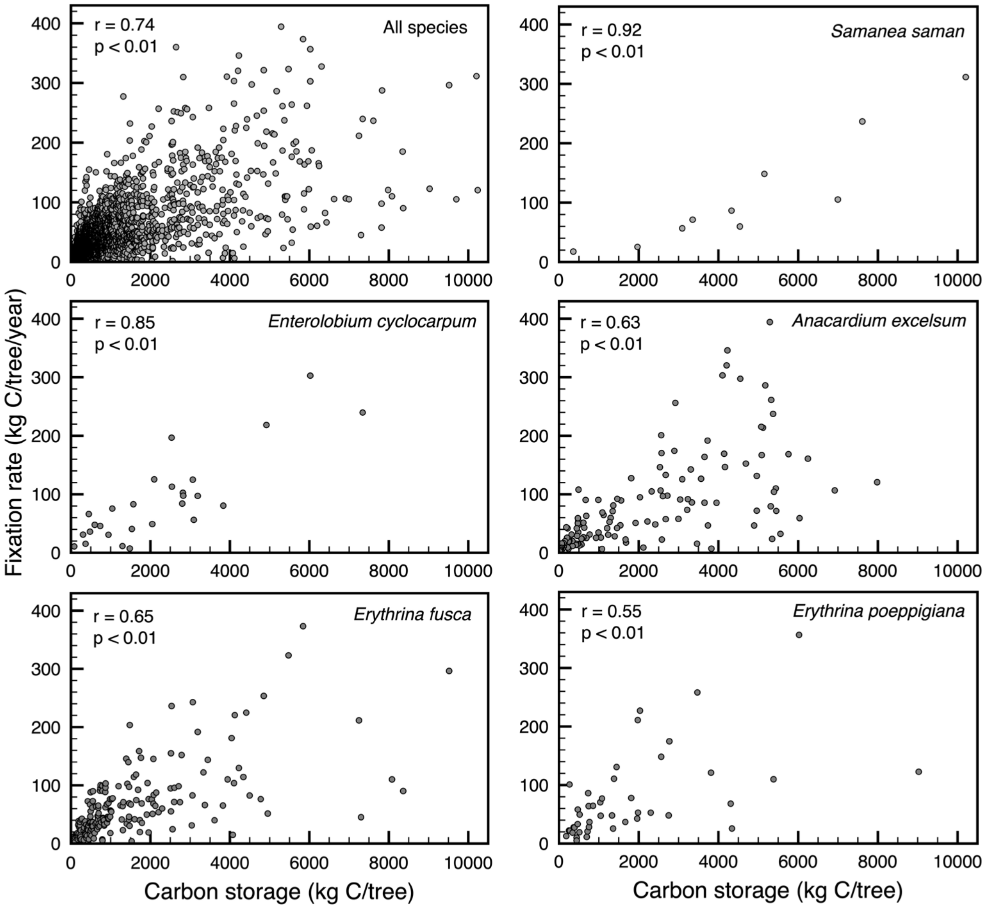


Values correspond to the average, and error bars represent the standard error of the mean.

Source: Authors.

An acceptable correlation between carbon storage and fixation in aboveground biomass of all species was found (r = 0.74; p <0.01) (Figure 3). For *S. saman*, and *E. cyclocarpum*, *Pearson* correlation coefficient between storage and carbon fixation was even greater than in the rest of the main species analyzed (r = 0.92 r = 0.85, respectively). These stadigraphs confirm that models that estimate carbon fixation based on their storage, which in turn depends on their dap, may be developed. In contrast, in the other species, the correlation was not as acceptable (0.55 <r <0.63) (Figure 3).

Figure 3 - Pearson correlation coefficient (r) between carbon storage and fixation rates in aboveground biomass of the most dominant perennial woody species of urban trees in Ibagué, Colombia, 2019 – 2020.



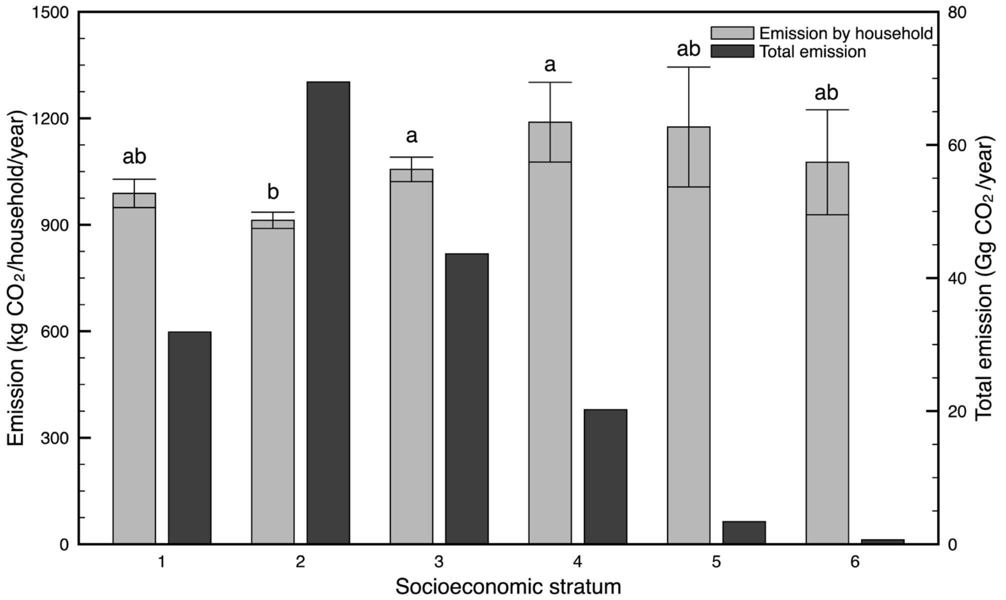
p: probability. Source: Authors.

GHG Emissions from households in Ibagué

Statistical differences ($p < 0{,}05$) were detected in emissions per household in the city of Ibague among socioeconomic strata, which vary between 912.0 ± 40.0, and 1,189 ± 112 kg CO_2/home. Stratum 2 had lower emissions, which were statistically different ($p < 0.01$) only with the strata 3 and 4; the other comparisons of strata pairs were statistically similar ($p > 0.05$) (Figure 4). A total emission of 169 Gg CO_2/year in the homes of the city was estimated, finding differences between strata, where the greatest emissions are recorded in stratum 2 with 69 Gg CO_2/year, while stratum 6 contributes only with 0.6 Gg CO_2/year. Stratum 1 contributed with 18.8% of total emissions, unlike stratum

2, with 41%, and falling to stratum 3, which accounted for 26%, followed by strata 4, 5, and 6 with 11.9, 2.0 and 0.3%, respectively (Figure 4).

Figure 4- CO_2 Emissions of urban households in Ibagué, Colombia, 2018



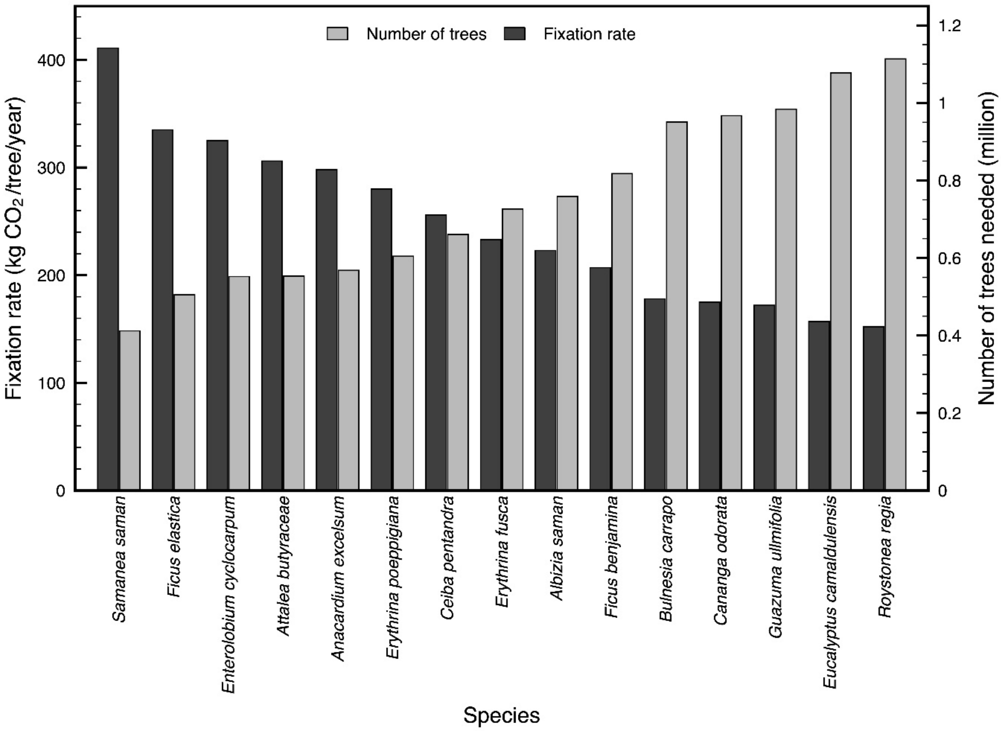
Values correspond to the average, and error bars represent the standard error of the mean. Different letters indicate statistical differences ($p < 0.05$).

Source: Authors.

GHG Mitigation of emissions by urban trees

A carbon fixation rate of 1.04 Gg C/year was estimated in aboveground biomass for all urban trees in Ibagué, which means 3.81 Gg CO_2/year, showing that these green areas can capture and mitigate only 2.3% of total emissions from households in the city. The complete compensation of emissions from Ibagué households requires 412,000 *S. saman* trees, considering that this species has an average foxation rate of 411 kg CO_2/tree/year, unlike *Roystonea regia*, which has a carbon fixation rate of 152 kg CO_2/tree/year that requires 1.1 million trees to compensate these emissions (Figure 5). For *T. rosea*, the tree badge of Ibagué, about 1.8 million trees would be required to mitigate these emissions.

Figure 5. Number of trees of the most dominant species of urban trees needed to mitigate emissions per household in the city of Ibagué, Colombia, 2018-2020



Source: Authors.

Discussion

Heterogeneity of species and the specific characteristics from each one of them show their CO_2 absorption capacity, especially *S. saman*, a determining species to mitigate GHG by urban trees of Ibagué by having the biggest carbon storage and sequestration values. It should be noted that carbon sequestration is takes place mostly during the development of the trees. Then, as years pass, when trees have reached their full maturity, they capture only small amounts of CO_2 required for soil respiration and theirs. Thus, it is not important how much carbon they capture immediately, but how much carbon they capture and fix throughout their lives (AGUDELO, 2009).

In this current study, *E. fusca* highlighted by storing 1.5 Mg C/tree, which contrasts with findings of Rodriguez (2018), who estimated 8.0 Mg C/tree in Envigado and Medellin, Colombia. Although the results are dissimilar, possibly due to age differences of the trees, the potential climate change mitigation of this species in urban forests of the country is evinced. Another outstanding species in carbon storage and fixation was *F. benjamina* with 1.5 Mg C/tree and 56.5 kg C/tree/year, respectively. Similar results were found in the study by Cortes and Matias (2018) in Parque Los Fundadores in the city of Villavicencio-Colombia, estimating a 0.48 Mg C/tree storage.

Although some species such as *A. excelsum* and *F. elastica* have great benefits in climate change mitigation, it is important to consider that they generate high risks in public spaces, because of infrastructure damage (MOLINA, 2008; CORTES; MATIAS, 2018). In contrast, Molina (2008) recommended species such as *E. fusca*, *C. pentandra*, *S. saman*, and *S. poeppigeana* for strengthening the ecological structure of Ibagué, which showed important benefits on their carbon sequestration and climate change mitigation. In Villavicencio (Colombia), Prieto and Garzon (2007) agreed to recommend species such as *E. poeppigeana* and *C. pentandra* for strengthening the main ecological structure, because they are optimal for soil conservation, erosion control, and recovery of degraded lands because they have a high capacity to fix nitrogen to the soil. These benefits make cities economically and environmentally sustainable (FAO, 2016).

In the selection of the most beneficial tree species for urban trees must be considered, in addition to carbon fixation, the offer of other ES such as shade supply, beautification of the city and air pollution mitigation. Native species produce food for fauna, especially birds and small mammals such as bats and squirrels, and a wide variety of insects, so native species not only comply with ornamental and environmental aspects, but also with ecological (PRIETO; GARZÓN, 2007).

GHG emission estimates from households in Ibagué showed that there was no effect of the socioeconomic status. This may be due to two factors in the upper strata: first, to the increased use of equipment, but probably more energy-efficient, such as efficient appliances, high-end cars and energy-saving bulbs (SCOTUS; SÁNCHEZ; PÉREZ, 2016); and second, the members of these households consume more foods that do not require cooking or are prepared outside the home (BELALCAZAR; TOBAR, 2013; GROVE, VILLA, 2016).

Balance between household emissions and CO_2 fixation rate allows suggesting that urban trees can mitigate only a small proportion of GHG emissions. In this balance, it is necessary to look for additional alternatives, as mentioned by the World Health Organization, which states that cities must meet a minimum surface of green areas between 0.5 and 1.0 ha/inhabitant with a distance lower or equal to 300 m away from their residence, as described in UN-HABITAT (2018), and non-compliance with this rule in the city is evident in this research.

Assuming that Ibagué acquires the recommended area per inhabitant, carbon sequestration by urban trees could significantly increase. The small extension of green areas in urban zones of the city is possibly because these are concentrated in the highest strata; whereas in many streets and avenues of the city center and in the lower strata, there is a deficit of urban trees, caused by rapid population growth and poor planning of green areas (MOLINA, 2008).

Lindén et al. (2010) estimated storage in parks built in Helsinki (Finland) at 25 Mg C/ha, important information for planning urban green areas. Mohamed et al. (2018) conducted extensive research of vertical vegetation systems in tropical climate, beyond urban forests, and showing the benefits of adapting the natural environment into the urban, built in an eco-friendly way, considering its carbon sequestration potential and climate change mitigation. Reynolds et al. (2017) estimated the total storage of the public urban public woodland in the metropolitan area of the Aburrá Valley (Colombia) at 103820 Mg CO_2, with a net sequestration of 2.9-5.3 Gg CO_2/year, a value comparable to the 3.81 Gg CO_2/year estimated in the current study. Differences can be caused by the zone of the study area, involving differences in the number of trees, additionally, Reynolds et. al (2017) also included biomass belowground.

Trees in urban areas have other benefits in the fight against climate change, such as preventing CO_2 emissions indirectly through energy saving in buildings for heating and cooling (NOWAK, CRANE, 2002). Therefore, in this research, it is likely that the contribution of urban trees to mitigate climate change is underestimated, but it solves several questions, including the notorious carbon storage and fixation rates difference among species. The estimation of the number of trees needed to mitigate CO_2 emissions from households in the city of Ibagué would help in the plans of Ibagué green city strategy, and it is a tool for future infrastructure decisions, since there are few planning strategies for land use, highly affecting the green areas of cities (FAO, 2016).

A proposal for mitigation of emissions from households in the city, is the extension of public urban trees as public policy. Depending on the tree species to be used, from 412,000 to 1.1 million trees may be required. The strategies to neutralize emissions must be a priority, as the city had more than 199,357 vehicles and motorcycles in 2019, which are determining in the air quality (ALCALDÍA MUNICIPAL DE IBAGUÉ, 2019). Also, the fact that the unplanned urban growth in the last 16 years has resulted in a total loss of 244.5 ha and the disappearance of 58 forest units in the urban area of Ibagué is highly relevant (DIAZ, 2019). This problem was also evident in the global urban tree cover, where a reduction of 26.7 to 26.5% between 2012 and 2017 was recorded (NOWAK; REENFIELD, 2020). The prevailing idea claims that the progress made by climate science is a solid foundation for the development of public policies, reinforce or implement new governance strategies, with goals aimed at local scenarios, based on scientific foundations. Additionally, all political sectors must work together without keeping any interest in any sector (LEZAMA, 2014).

The use of clean technologies should be promoted and adopted, considering the use of solar panels for public lighting and solar water heaters, stimulating consumption of energy-efficient technology (GUTMAN, 2007; BARTON, 2009; ANDRADE et al, 2013; SANCHEZ, REYES, 2015). Also, energy saving must be encouraged, replacing refrigeration equipment that is over 10 years old, disconnecting devices without immediate use, avoiding the standby mode in appliances, reducing the use of air conditioning and other devices with high energy consumption (LACKNER, 2012; MINMINAS, 2016). It is important to develop strategies of smart mobility to reduce GHG emissions in the city and improve the air quality (ZAMUDIO, 2016), share vehicles in urban and rural areas, use greener transportation forms and, as a vision for the future, change the public transport system with a more efficient and sustainable one, with fewer emissions, especially in intermediate cities like Ibagué (UDDIN, 2012).

The implementation of carbon market, where the forestry sector and change of land use are important in voluntary carbon market projects is added, because of the materialization of new demand sources, and the volume of compensations generated. Between 2016 and 2018, commercialization of these activities increased from 13.9 Mt CO_2e to 50.7 Mt CO_2e, as the world requires credible and available climate solutions that can be executed in the present (DONOFRIO; MAGUIRE; MERRY; ZWICK, 2019). The average price of carbon during 2018 in the world ranged between U$3 and U$6/Mg CO_2e, with an average of U$2.6/Mg CO_2e for Latin America and the Caribbean (HAMRICK; GALLANT, 2018). This voluntary or strict compliance strategy adopted by countries that buy or sell carbon bonds has allowed a higher appropriation of individual, business, and government environmental care. A small sample of this is that, for 2019, Colombia has assigned a value of 16,422 COP/Mg CO_2e (U$ 5/Mg CO_2e[1]) (SFC, 2020), as a domestic tax to gasoline and diesel (DIAN, 2019).

Conclusions

The research estimated that there is variation in carbon storage fixation among the most dominant perennial woody species of urban trees in Ibagué. Correlation between carbon fixation and storage in these species could allow, in more detailed studies, the development of models that estimate fixation based on storage, which is an important tool for monitoring this ecosystem service in cities.

Urban woodland fixes around 3.81 Gg CO_2/year, which represents only 2.3% of emissions in the city. Mitigation of 169.2 Gg CO_2/year from households would be achieved by having between 412,000 and 1.2 million trees of the most dominant species in the city of Ibague. This indicates the need to increase urban tree plantations, in addition to enhance the diversity of native species properly established and managed to avoid phytosanitary problems or damage to the structure of public services or asphalts of road networks. There should also be work on replacing the use of electricity and fossil fuels with alternative energy sources. These mitigation strategies would support the plans of Ibagué, as a green city strategy.

Recommendations

Carbon storage estimates in urban trees may have errors due to the use of general biomass models, which do not consider the characteristics of handling this type of trees, such as continuous pruning. The development and validation of general models for specific application under these conditions is recommended.

Studies about the impact of urban trees in microclimatic conditions would be an ideal component for a wider vision of their benefits concerning climate change and climate variability. Green city policies, like those of Ibagué, require more detailed studies such as this current, a reason why funding research and development of goods practice should be a key element. Likewise, environmental education programs for the population and support to reduce energy consumption and the resulting greenhouse gas emissions are required.

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[1] Value estimated by taking the average TRM for Colombia during 2019 (3282.39 COP/USD).

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SciELO

Mitigação de emissões de GEE de famílias por árvores urbanas em Ibagué-Colômbia

Luis Miguel Acuña-Simbaqueva
Hernán J. Andrade
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São Paulo. Vol. 24, 2021

Artigo Original

Resumo: As árvores são essenciais nas cidades para capturar CO^2 e, por sua vez, contribuem para mitigar as mudanças climáticas. O armazenamento e fixação de carbono de biomassa acima do solo na floresta urbana de Ibagué foram estimados com um censo em 2013-2016 e uma re-medição de 15% dos indivíduos em 2019-2020. O número de árvores necessárias para as principais espécies foi estimado para mitigar as emissões domésticas de gases de efeito estufa. As árvores urbanas fixam cerca de 3,81 Gg de CO^2/ano, o que representa apenas 2,3% das emissões da cidade. A mitigação de 169,2 Gg CO^2/ano das residências da cidade seria alcançada com entre 412 mil e 1,2 milhão de árvores das espécies mais dominantes. Os esforços baseados em infraestrutura verde para compensar as emissões urbanas no nível municipal devem ser coordenados com políticas territoriais em escalas amplas.

***Palavras-chave*:** Armazenamento, fixação, política ambiental, serviços ecossistêmicos, silvicultura urbana.

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Artículo original

Resumen: Los árboles son indispensables en las urbes para capturar CO2, y a su vez, contribuir a mitigar el cambio climático. Se estimó el almacenamiento y fijación de carbono en biomasa arriba del suelo en el arbolado urbano de Ibagué con un censo del 2013-2016 y una remedición del 15% de los individuos en el período 2019-2020. Se estimó el número de árboles requeridos de las principales especies para mitigar las emisiones de gases de efecto invernadero de los hogares. El arbolado urbano fija cerca de 3,81 Gg CO2/año, lo que representa solo el 2,3% de las emisiones de la ciudad. La mitigación de 169,2 Gg CO2/año de los hogares de la ciudad se lograría teniendo entre 412 mil y 1,2 millones de árboles de las especies más dominantes. Los esfuerzos basados en infraestructura verde para compensar la emisión urbana a nivel municipal deben coordinarse con políticas territoriales a escalas amplias.

***Palabras-clave*:** Almacenamiento, fijación, política ambiental, servicios ecosistémicos, silvicultura urbana.

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