Article

Offsetting the Impact of CO$_2$ Emissions Resulting from the Transport of Maiêutica's Academic Campus Community

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Abstract: The authors aim to investigate the number of trees necessary to capture the CO$_2$ emissions from house–campus travelling, to and from the Maiêutica Academic Campus in the north of Portugal. A sample of the academic community was given an online survey in order to assess mobility practices. Based on the data collected, CO$_2$ emissions, as well as the number of trees necessary to mitigate these emissions, were calculated. The authors estimate that the total emissions resulting from house–campus commutes amount to 2937 tCO$_2$ year^{-1}. To mitigate this amount of carbon dioxide, 138 ha would be necessary to plant 96,539 trees, according to the species' respective CO$_2$ removal rates. The estimated tree area necessary to neutralize the community's mobility related CO$_2$ emissions is so high that other alternatives must be considered: a preferred use of public transportation, carpool system, online theoretical classes, rescheduling timetables, green roofs installation, and photovoltaic panels.

Keywords: CO$_2$ emissions; carbon sequestration; transports; academic campus

1. Introduction

1.1. The Emissions of CO$_2$ from Transports

The Earth is a planet with finite resources. Even though there is a decreasing tendency in the use of fossil fuels, increasing the preference for renewable energy sources, fossil fuels still represent 71% of the gross energy available in the European Union (EU) [1]. In Portugal, the transport sector still has one of the highest energy consumption rates (37.2%) of the total primary energy among other activity sectors [2]. This sector makes one of the most significant contributions to the increase of greenhouse gases, GHG (CO$_2$, CH$_4$, N$_2$O, HFCs, PFCs, SF$_6$, and NF$_3$). According to the European Environment Agency [3], transport accounts for 27% of the total CO$_2$ European emissions to the atmosphere. GHGs, due to anthropogenic emissions, are responsible for climate changes, in particular the temperature increase in the last 30 years [4]. To achieve the objectives set by the Paris Agreement, and keep the global average temperature increase well below 2 °C, the European Union (EU) defined performance requirements for new passenger cars. Firstly, Regulation (EC) No 443/2009 was published, setting the emission limit at 130 gCO$_2$/km and 95 gCO$_2$/km, for 2015 and 2020, respectively [5]; and more recently, with Regulation (EU) 2019/631, the bar of 95 gCO$_2$/km for 2020 was confirmed, and reductions for the following years were planned [6]. In 2020, the European Commission [7] put forward a goal to reduce 1990 values of greenhouse gases by a minimum of 55% by 2030. The escalation of the policies is due to the long period of time that key areas, like the transport sector, take to readjust, as the Commission pointed out. If these goals are not successfully implemented by 2030, the necessary adaptations to fulfil 2050 goals would have to happen at an unrealistically high speed. According to this document, "the transport sector had the lowest share of renewable energy in 2015, with only 6%. By 2030, this has to increase to around 24% through further

development and deployment of electric vehicles, advanced biofuels and other renewable and low carbon fuels as part of a holistic and integrated approach".

1.2. The Capture of CO_2 from the Atmosphere

According to the literature, the capture of CO_2 can be made with technology or with biomass [8]. Technology requires direct air capture and uses physical and chemical processes. As an example, CO_2 can be injected in geological strata, like old cold mines, oil wells, and saline aquifers [9–12]. However, this alternative comprises high costs and leakage risks [13].

Biomass resorts to the biological process of photosynthesis, a natural process of carbon capture by the trees, to remove CO_2 from the atmosphere [8,14–17], the alternative championed by the Kyoto Protocol [18].

Recently, some authors have studied different biomes or forest ecosystems' (tundra, rain forest, woodlots, etc.) capacity to capture carbon from the atmosphere [17,19], defining the carbon footprint parameter known as Average Forest Carbon Sequestration (AFCS). Other authors have been looking into specific trees' capacity to capture CO_2 [15,16]. Their method depends on the measurement of the trees' diameter and height. From that data, the tree's weight is estimated and multiplied by the factors 0.725, 0.50, and 3.6663 to estimate the tree's dry weight organic matter, amount of carbon, and CO_2 sequestered, respectively; finally, by dividing the result by the tree's, age, we get the annual amount of captured CO_2. Nevertheless, information regarding the annual amount of carbon dioxide removed by different tree species is still scarce.

1.3. Universities' Role in Keeping Sustainable Practices

There has been an increasing focus on many organizations' and institutions' sustainable development and environmental management. According to Ferrer-Balas et al. [20], it was the 5th Environmental Management for Sustainable Universities (EMSU) International Conference, held in Barcelona, Spain in October of 2008, that led universities to rethink how they were dealing with the matter of sustainability.

In June 2012, in Rio de Janeiro, Brazil, on the occasion of the United Nations Conference on Sustainable Development, chancellors, presidents, rectors, deans, and leaders of higher education institutions and related organizations all signed the "Commitment to Sustainable Practices of Higher Education Institutions" pledging to a series of actions, among which was to green the campuses by reducing the environmental footprint, encouraging more sustainable lifestyles [21].

Universities in Europe, such as the Norwegian University of Technology and Science [22], the Technical University of Madrid [23], or the University of Castilla La-Mancha [24] are pursuing the goals of sustainability, estimating carbon footprints, and making inventories of carbon emissions. In Britain, there is a Higher Education Carbon Management (HECM) program aimed at helping universities to set up a carbon management plan, forecasting and targeting carbon emissions and sequestration [15]. However, most of these works, when they mention transportation-related carbon footprint normally refer to the service industry, as is the case with Larsen et al. [22], Alvarez et al. [23], and Gómez et al. [24] from the Norwegian University of Technology and Science, the University of Madrid, and the University of Castilla-La Mancha, respectively.

Gibassier et al. [25] consider the climate vulnerability and the future carbon accounting a social issue; because of that, as faculty members and university students alike are part of the most educated sector of the population on matters of sustainability practices, they should be the ones to educate the remaining population and contribute to climate change prevention.

Portugal, in the Ministers' Cabinet Resolution n° 53/2020 [26], reaffirmed its commitment to achieving carbon neutrality by 2050, proposing to reduce its greenhouse gas (GHG) emissions by 85% to 90% relative to 2005 values. Among the many greenhouse gas emission reduction sectorial goals is a 40% reduction in the transport sector's emissions.

1.4. Maiêutica Academic Campus

Maiêutica is a higher education cooperative in the city of Maia, near Oporto, in the north of Portugal. The academic campus of Maiêutica started to be built in February 1995 on the cooperative grounds, and since then it has undergone several expansions, currently occupying 7 ha. Currently, there are two institutions on campus, the University of Maia and the Polytechnic Institute of Maia. Together, they serve a population of 4378 individuals: 4000 (91.4%) students, 313 (7.1%) professors and research staff, and 65 (1.5%) administrative and service staff. The academic community mainly comes from the metropolitan area of Porto (75%), while 20% come from frontier districts and just 5% from the rest of the country.

1.5. Goals

This is one of the few studies carried out on CO_2 emissions resulting solely from the academic community's commute. As was mentioned, some universities' or higher education schools' carbon footprint papers can be found in the literature, but there is very little information regarding academic communities' transport-related emissions.

In this paper, the authors aim to calculate the academic community's carbon emissions, as it concerns house–campus travelling (round trip), to and from the Maiêutica Academic Campus; determine the number of trees necessary to capture the CO_2 emissions resulting from those travels; inform the community about their contributions to their mobility-related carbon footprint; offer suggestions for more sustainable mobility strategies; and contribute to achieving the target set by the Portuguese government of reducing transport-related emissions, increasing awareness to this problem.

2. Methods

2.1. Samples and Procedures

An online survey was designed to collect data about transportation to and from the campus. The survey was specifically developed for this investigation and pre-tested before application. The questionnaire had thirteen questions, twelve of which were closed: number of trips done to campus per week, use of car, distance done by car (round trip in km), mean number of car occupants, fuel type, car age, usage of metro, distance done by metro (round trip in km), use of train, distance done by train (round trip in km), use of bus, and distance done by bus (round trip in km). Additionally, there was an open question regarding the use of other means of transportation. The target population of this study consisted of a community of 4378 individuals working or studying at the Academic Campus of Maiêutica. Data collection was conducted in April 2019, and during this period, two emails were sent to the community calling for answers to the survey.

The link to the questionnaire was sent to all institutional emails, and the answers allowed the distribution of the respondents' profile according to professor (or researcher), student, or administrative (or service) staff. Data treatment was developed using IBM SPSS Statistics software, version 25, International Business Machines Corporation, New Orchard Road, Armonk, New York 10504, USA.

2.2. Estimation of Carbon Emissions

Because some of the respondents commute on their way to campus and back, the weekly carbon emission was determined by adding the various to and from mobility-related emissions of every participant, according to the following equations

$$CE_{week} = N \times \sum_{i=1}^{n} (\frac{d_i}{y_i} \times E_i). \tag{1}$$

$$D = \sum \frac{d_i}{y_i} \tag{2}$$

where:

CE_{week}—carbon emission per week (g CO_2) per respondent,

N—number of trips done to campus per week,

d_i—partial distance in a given transportation i (km)

y_i—number of occupants in a given car ($y_i = 1$ for other transports),

E_i—transport i's average carbon emission (g CO_2/km), and

D—campus–home and home–campus total distance for each participant (km)

Cars' carbon emissions were based on the values on Table 1. Account was taken of the type of fuel and the age of the vehicle. In instances of car sharing, CO_2 emission was divided by the number of passengers as shown in Equation (1).

Table 1. Car emissions of CO_2 by fossil fuel usage and age.

Car	Average Carbon Emission (E_i) (gCO_2/km)	Source
Age > 10 years old		
Gasoline	207	[27,28]
Diesel	197.9	[27,28]
LPG	164.7	[28]
5 ≤ Age ≤ 10 years old		
Gasoline	156.6	[28]
Diesel	151.2	[28]
LPG	137	[28]
Vehicles < 5 years old		
Gasoline	128.5	[28,29]
Diesel	126.9	[28,29]
LPG	98.3	[28]
None (electric)	52	[30]

For collective means of transportation (subway, train, and bus), the carbon emission estimate was based on Table 2 and, in this case, values corresponded to individual passengers.

Table 2. Public transport emissions of CO_2.

Public Transport	Average Carbon Emission (E_i) Per Passenger (gCO_2/Km)	Source
Metropolitan	40	[31]
Train	26.4	[32]
Bus	82	[33]

*2.3. Estimation of Trees Needed to Capture CO_2*

The Portuguese Forest Management Regional Program [34] identifies, for every Portuguese region and sub-region, the forest species that should be protected, in accordance with their high economic, heritage, and cultural value, their relationship with the region's history and culture, their scarcity, and their role in habitat support. The maritime pine (*Pinus pinaster*), the eucalyptus (*Eucalyptus globulus*), the Portuguese oak (*Quercus faginea*), the Pyrenean oak (*Quercus pyrenaica*), the holm oak (*Quercus rotundifolia*), and the cork oak (*Quercus suber*) are among the species whose protection should be prioritized in the region of the Maiêutica Academic Campus.

Considering the mild, dry climate of the region, and taking into account the data presented by Bernal et al. [17], reporting a 95% confidence interval, the removal rate, in $tCO_2 \cdot ha^{-1} \cdot year^{-1}$, for the above mentioned species are: pine 7.6 ± 2.0; eucalyptus 37.9 ± 5.5; and oak 5.3 ± 3.5. In order to determine the area necessary for planting these trees, a mean tree density of 700 stems per hectare was assumed, as observed by Crowther et al. [35] for a Mediterranean forest.

3. Results

3.1. Sample

A total of 490 individuals answered the survey: 174 professors and researchers (56% of the total teaching staff), 254 students (6% of the total student community), and 62 administrative and service staff (95% of the group). Figure 1 shows the distribution of transportation used on a round home–campus trip. Only 7.8% of the respondents make the trip by foot or bike (Others).
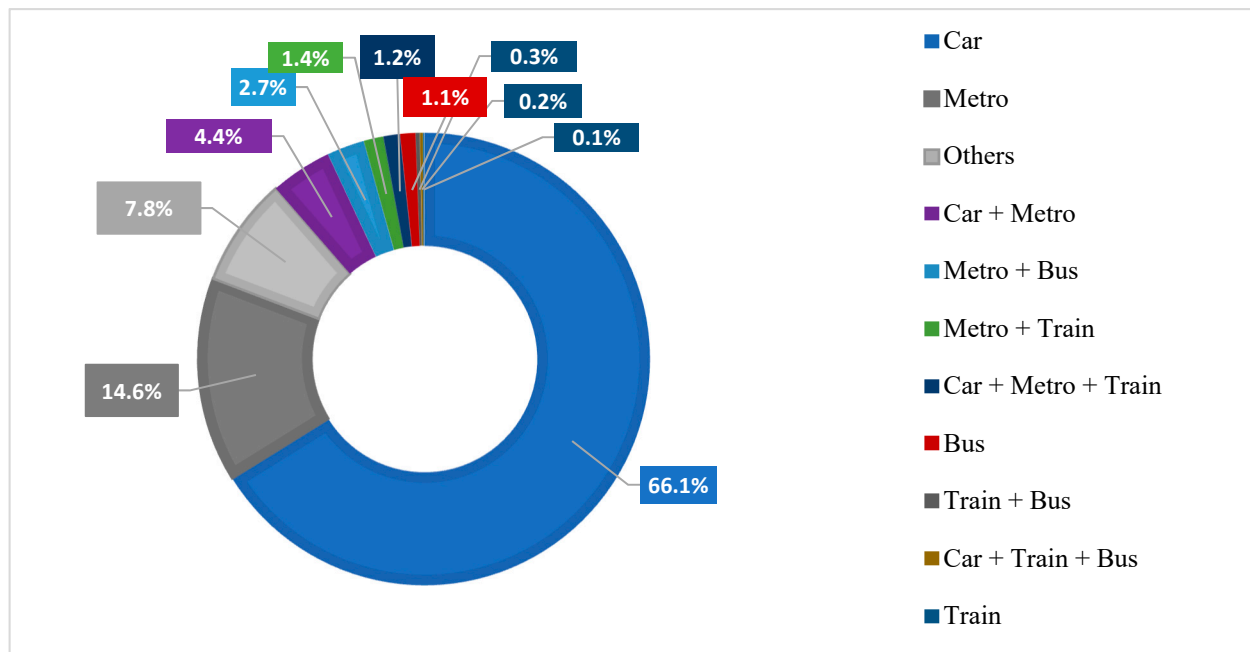
Figure 1. Distribution of transportation used on a round home–campus trip.

Only taking into account vehicle drivers and passengers, choice distribution for this trip by group, professors and researcher staff, students, and administrative and service staff, is shown on Table 3. As can be observed, the car is the preferred type of vehicle used by all three campus community groups, while students resort to public transportation the most.

Table 3. Transports used in house–campus trip by each group from the Maiêutica Academic Campus community.

Group	Percentage of Group Individuals by Used Vehicle:			
	Car	Metropolitan	Train	Bus
Prof Res. Staff	94.4%	5.1%	0	0
Students	52.8%	34.6%	5.6%	7.0%
Adm. Ser. Staff	85.5%	14.5%	0%	0%

Table 4 shows the 95% confidence interval for the distance travelled by each academic community group in a round house–campus trip for each type of vehicle.

Furthermore, we can see that the majority of cars (87.3%) hold only a single passenger, the driver him/herself. From those who resort to a car for transportation, only 4.2% of the professors group, 22.5% of students, and 11.3% of administrative and service staff surveyed carpool. Moreover, 79.1% of carpool rides carry only 2 passengers.

Table 4. Average distance travelled in a round trip and associated uncertainty (CI95) by type of transportation.

Group	Distance Travelled According to Transport (km/trip)							
	Car		Metro		Train		Bus	
	Mean	Half CI95	Mean	Half CI95	Mean	Half CI95	Mean	Half CI95
Teacher R. Staff	46.1	11.2	14.4	9.7	-	-	-	-
Students	39.7	4.5	25.0	3.6	42.1	13.3	19.7	7.7
Adm. S. Staff	30.7	6.0	37.1	13.8	-	-	-	-

Looking at fuel usage, we can see that 68.5% are diesel-fuelled, 29.1% are gasoline-fuelled, 1.6% are LPG, and only 0.8% run on no fuel (electric).

Table 5 shows the participants' average car age, indicating that the professors and researchers staff group drives the newest cars, while students drive the oldest, over 10 years old.

Table 5. Car age distribution among the three groups: professors and research staff, students, and administrative and service staff.

Car Age (Years)	Prof. R. Staff	Students	Adm. S. Staff
age $\leq$ 5	40.7%	23.8%	28.3%
5 < age $\leq$ 10	32.3%	25.2%	39.6%
age > 10	26.9%	51.0%	32.1%

3.2. CO_2 Emission Estimate

The amount of CO_2 emitted for the transportation of all three groups pertaining to the Maiêutica Academic Campus was determined as described in the methodology section, taking all factors into account. In order to estimate the annual carbon emissions (CE_y), the statistics for campus attendance in the last five years were consulted. Registered data allowed us to conclude that the professors, students, and administrative staff groups travel 37, 32, and 48 weeks per year, respectively.

Thus, we calculated the sample's carbon emission for the whole year of 2019 (Table 6). Dividing each group's CO_2 emissions by the group's respective size in the sample (n), we get the individual's average CO_2 emission. The teachers group exhibited the highest average of CO_2 emissions by individual (2.66 ton/year), while the students were the lowest individual emitters (0.51 ton/year).

Table 6. Estimate of the annual CO_2 emissions by the different groups and by individual.

Group	Sample		Individual	Community (Population)		
	n	Emission (tCO_2 year^{-1})	Emission (tCO_2 year^{-1})	n	Emission (tCO_2 year^{-1})	Emission (%)
Prof. R. Staff	174	463	2.66	313	833	28.4
Students	254	129	0.51	4000	2.031	69.1
Adm. S. Staff	62	70	1.13	65	73	2.5
Total	490	662		4378	2937	

Assuming that each group maintained the same pattern, that is, the same number of trips per week and choice of transportation, we calculated the CO_2 emissions of the whole Maiêutica academic community released to the atmosphere. Globally, campus community travel account for 2937 t CO_2 being emitted every year.

3.3. Number of Trees Needed to Capture CO_2

As mentioned in the methodology section, the most common and indigenous trees in the Portuguese territory are the pine, the eucalyptus, and the oak. Taking into account the

values observed by Bernal et al. [17] for the CO_2 removal rate of each of these species, the required area, in hectares, to capture all of the CO_2 emitted by the campus community's annual travels is presented in Table 7. Assuming the value of 2937 tons CO_2 year^{-1}, and a single species planted, the total area required could vary between 77 hectares and 554 hectares. Considering that the tree density for a Mediterranean forest as stated by Crowther et al. [35] is of 700 stems per hectare, the number of trees necessary for each species varies from 53,900 to almost 387,800.

Table 7. Area and number of trees from a given species necessary to capture the annually emitted CO_2 by the campus community's travel.

Species	Removal Rate [1] (tCO$_2$ year^{-1})	Required Area (ha)	Number of Trees
Pine	7.6	386	270,200
Eucalyptus	37.9	77	53,900
Oak	5.3	554	387,800

[1] Bernal et al. (2018).

Given that these three native species might appear simultaneously in the same forest, according to the official percentages of each species provided by the Portuguese Institute of Nature and Forest Conservation [36], the number of necessary trees and respective area was determined, assuming they were all simultaneously present (Table 8).

Table 8. Number of trees and respective area occupied by the three species simultaneously.

Species	% Coverage [2]	Required Area (ha)	Number of Trees
Pine	49.1%	67.7	47,390
Eucalyptus	45.6%	62.9	44,030
Oak	5.3%	7.3	5110
Total		137.9	96,530

[2] ICNF (2019).

Thus, close to 138 hectares would be necessary to plant the three tree species so as to compensate for the campus community's travel emissions.

Despite the reforestation support funds made available by the 2020 Portuguese Regional Development Plan, the acquisition of such extensive plots of land and the planting of all the trees necessary to compensate for campus community travelling is not economically viable for any educational institution.

Results show that campus reforestation is impracticable and cannot be the only CO_2 mitigating policy; thus, other initiatives must be in order.

4. Discussion

Even though there are papers concerning universities' CO_2 emissions, as is the case with the KIWI University of New Zealand [15], the School of Forestry Engineering Technical University of Madrid [23], and the University of Castilla-La Mancha [24], the CO_2 values assessed generally include energy, waste, procurement, and travel; and in some cases, "travel" includes not only academic community's mobility but also all the travelling implicated in the purchase and delivery of services and equipment, hindering an estimation comprising solely house–campus travelling (round trip) emissions. Larsen et al. [22] is an example of a study presenting an estimate for the Norwegian University of Technology and Science's carbon footprint as it regards to students and employees' travelling. This university, with seven faculties, has a total of 20,000 students and 5500 employers, reporting 16% of their general tCO$_2$ emissions from 2009 resulting directly from such travelling. Thus, an estimate can be made pointing at 2.7 tCO$_2$ year^{-1} per employee and 0.74 tCO$_2$ year^{-1} per student. These values are similar to those established for the Maiêutica Academic

Campus: 2.6 tCO$_2$ year^{-1} per person for professors and research staff; 0.51 tCO$_2$ year^{-1} per person for students; and 1.13 tCO$_2$ year^{-1} per person for administrative and service staff.

The "my car" culture is still too strong; it is necessary that we abandon the idea of the car as a symbol of consumption and status and start thinking about mobility as a social and environmental question. The results are clear regarding the percentage of CO$_2$ emissions, and other GHGs, due to the community's favourite medium of transportation, the car. Our sample's average number of passengers per car, 1.2 passengers/car, is lower than the Environment Portuguese Agency asserts, 1.6 passenger/car [2]. By looking at Table 6, we can see that a teacher emits five times more CO$_2$ than a student due to the choices he/she makes regarding his/her type of transportation.

For the good of the future, a change in mentality is imperative, namely in choosing a collective means of transportation or other less polluting alternatives. In the last two decades, we have witnessed the rise of new ways to use one's car, aiming mainly at reducing traffic, parking problems, and environmental abuse: car sharing and carpooling. Car sharing, a similar concept to time sharing for housing, has even more economic advantages, with less buying, maintenance, and insurance expenses than environmental ones. Carpooling is a more environmentally attractive concept. This system uses a private or company car to drive more than one passenger, later rotating the cars between the participants. The benefits are evident: reducing fuel and maintenance expenses, reducing the number of cars in circulation, reducing travelling time with less traffic, decreasing stress and tiredness, and alleviating parking problems and, as a consequence, very significantly, pollution. In fact, a study conducted in a service company in Italy showed that a reduction of CO$_2$ through a carpooling system could vary between 22% and 28% [37]. Recently, another study in the coastal area of Espinho (Portugal) estimated that carpooling could lead to a reduction in carbon emissions of between 25% and 30% [38]. There are, today, international projects focused on this carpooling system (www.compartir.org, accessed on 28 April 2021). A similar app, managed by the Students Association and/or the Maiêutica Administration, promoting connections between people taking the same route, might gather more supporters.

Looking at the results showing how many hectares and trees are necessary, it is not economically viable to neutralize community-related emissions of CO$_2$ solely by resorting to a tree planting strategy. Concurrently, green roofs could be installed atop the campus buildings, planting mainly herbaceous plants and small bushes, thus allowing thermal isolation of the building and CO$_2$ capture.

Another option would be the assembly of photovoltaic panels, whose renewable energy production would counter-balance the emission of CO$_2$ associated with the community's mobility.

Organizational policies like online theoretical classes and schedule replanning so as to reduce the necessity for round trips would be yet another option.

The need for a culture of sustainability integrated into educational and research programs has already been pointed out by some authors [23,39]. From an educational and academic point of view, the institution could develop a course, open to all degrees, where circular economy, the carbon footprint, and all the more pressing environmental questions of today could be approached, so as to appeal to the academic community and the surrounding civil society.

The present study did not consider such factors as driving behavior, vehicle configuration and traffic conditions, or side winds, rain, and road grade, which may have significant effects in fuel consumption in real-world driving [40].

It would be interesting in the future to inquire whether the installation of environmentally sustainable university housing, close to campus, would show a significant impact in carbon emission reduction.

5. Conclusions

The Maiêutica Academic Campus releases 2.937 tonnes of CO_2 to the atmosphere, per year, due to community trips. Most of these emissions come from students as they represent the largest sector of the community (91.4%) even though, individually, they are the lowest emitters at 0.51 ton $year^{-1} \cdot individual^{-1}$.

To compensate the total CO_2 emissions, native species such as pine, eucalyptus, or oak should be planted. However, according to our calculations, 270,200, 53,900, or 387,800 trees, respectively, would be necessary. These results are interesting because for eucalyptus, 77 ha is enough, which is significantly less than for pine, 386 ha, and extremely less than the 555 ha required for oak. For the planting of the three species simultaneously, using the proportions indicated by the Portuguese Institute of Nature and Forest Conservation, 138 hectares are needed, and, in total, 96,530 trees would need to be planted.

Facing the number of hectares and trees necessary for neutralizing the carbon dioxide emissions, it is clear that it is not viable to implement this as an isolated solution, for several reasons. As such, the authors suggest a broader range of solutions, namely: more frequent use of collective transportation; green roofs installation and photovoltaic panels; online theoretical classes and schedules' replanning; and a new app for carpooling.

The value we obtained pertaining to the number of trees necessary to mitigate the community's carbon dioxide emission shows us how far we are from solving the environmental problem the world is facing. The decision makers, the politicians, and the community in general should look at this work, reflect, and make decisions more in accordance with the preservation of the planet.

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