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GHG emissions and removals of a federal institute campus from Brazil

Emissões e remoções de GEE no campus de um instituto federal no Brasil

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Abstract

There is a growing demand for institutions and organizations to adopt actions aimed at combating climate change and its impacts. The objective of this study was to carry out inventories of greenhouse gas (GHG) emissions and carbon removal by afforestation of the Nova Venécia Campus of the Federal Institute of Espírito Santo (IFES-NV), Brazil. Emissions from scopes 1 (stationary combustion, mobile combustion, fugitive emissions, and wastewater), 2 (electricity), and 3 (commuting to campus, work travel, and solid waste) were accounted for in 2019 based on the methodology proposed by the Brazilian GHG Protocol Program. The GHG emissions were then compared to the annual rate of carbon removal by trees growing on the campus to determine net emissions. In total, 1,148.878 tons of carbon dioxide equivalent (tCO_{2e}) were quantified. Commuting to campus was responsible for more than 93% of total emissions, demonstrating that it is necessary to neutralize and/or drastically reduce emissions from burning fossil fuels in places with a high number of visitors. Although the campus afforestation only neutralized the equivalent of 1.7% of total emissions in 2019, it was able to neutralize approximately 50% of emissions from scopes 1 and 2, which are the emissions most directly managed by the institution. For future studies, it is recommended to also quantify carbon removal by tree roots and soil, as these may represent an important carbon sink.

Keywords: GHG inventory; Carbon footprint; Climate change; Carbon offsetting; Educational institutions.

Resumo

É crescente a exigência para que instituições e organizações adotem ações direcionadas ao combate às mudanças climáticas e seus impactos. O objetivo deste estudo foi realizar os inventários de emissão de gases de efeito estufa (GEE) e remoção de carbono pela arborização do Campus Nova Venécia do Instituto Federal do Espírito Santo (IFES-NV), Brasil. Foram contabilizadas emissões dos escopos 1 (combustão estacionária, combustão móvel, emissões fugitivas e efluentes líquidos), 2 (energia elétrica) e 3 (deslocamentos residência-*campus*, viagens a trabalho e resíduos sólidos) em 2019 a partir da metodologia proposta pelo Programa Brasileiro GHG Protocol. As emissões de GEE foram então comparadas com a taxa anual de remoção de carbono pelas árvores do *campus* para determinação das emissões líquidas. Ao todo, foram levantadas 1.148,878 toneladas de dióxido de carbono equivalente (tCO_{2e}). Os deslocamentos residência-*campus* foram responsáveis por mais de 93% das emissões totais, demonstrando que é preciso neutralizar e/ou reduzir drasticamente as emissões advindas da queima de combustíveis fósseis em locais com elevado número de frequentadores. Embora a arborização do *campus* tenha neutralizado apenas 1,7% das emissões totais em 2019, ela foi capaz de neutralizar

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aproximadamente 50% das emissões dos escopos 1 e 2, que são as emissões mais diretamente gerenciadas pela instituição. Para estudos futuros recomenda-se quantificar também a remoção de carbono pelas raízes das árvores e pelo solo, pois esses compartimentos podem representar um importante estoque de carbono.

Palavras-chave: Inventário de GEE; Pegada de carbono; Mudanças climáticas; Compensação de carbono; Instituições de ensino.

INTRODUCTION

Climate change is the result of the action of greenhouse gases (GHG) that have been increasing in the atmosphere mainly due to human activities (Intergovernmental Panel on Climate Change, 2018). According to *The Global Risks Report 2022*, published by the World Economic Forum, climate change will be at the center of global concerns for the next decade. This concern is due to the environmental, economic, and social consequences that are already being felt around the world (World Economic Forum, 2022).

Due to the consequences and the scale of climate change, international discussions and policies are being adopted to reduce GHG emissions. In 2015, governments of 195 countries signed the Paris Agreement, which defined objectives related to climate change mitigation and adaptation (Grassi et al., 2017). Through its Nationally Determined Contribution (NDC), Brazil has committed to reducing 50% of its GHG emissions by 2030, compared to levels emitted in 2005, and has indicated a goal of achieving climate neutrality by 2050 (Brasil, 2022).

Internally, the Brazilian National Policy on Climate Change (PNMC) establishes the GHG inventory as one of its instruments for accounting for emissions and achieving national targets (Brasil, 2009). The GHG inventory is an indispensable tool for environmental management (García-Alaminos et al., 2022; Nagar et al., 2019; Yang et al., 2018). Through the inventory, the sources of GHG emissions and the amount of gases released into the atmosphere are mapped (Intergovernmental Panel on Climate Change, 2018). In addition to knowing the profile of emissions, there is the possibility of reducing costs, obtaining benefits, and strengthening the institutional image (Fundação Getúlio Vargas, 2009).

With the GHG inventory results, one of the alternatives to neutralize the emissions is the removal of atmospheric carbon dioxide (CO_2) through planting trees (Duffy et al., 2020; Intergovernmental Panel on Climate Change, 2018; Rocha, 2002). Forests capture CO_2 from the atmosphere in the photosynthetic process and store large amounts of carbon, playing a key role in the global carbon budget (Mohren et al., 2012). The quantification of carbon removed in urban trees provides estimates of offset carbon emissions (Ngo & Lum, 2018). Together with carbon retention, planting trees in urban areas brings benefits such as rainwater interception, air quality improvement, climate alleviation, as well as aesthetic and cultural values (McPherson et al., 2011; Nowak, 2019; Silva, 2019). The carbon removal through the planting of trees can be subtracted from gross emissions to generate a balance with net emissions (Fundação Getúlio Vargas, 2009).

According to Gamarra et al. (2019), educational activity is a complex system that presents a wide variety of processes and materials with environmental impacts. As the causes and impacts of global climate change become more evident, educational institutions are adopting important roles in climate planning, as is the case of the American College & University Presidents' Climate Commitment (ACUPCC), which brings together North American universities and colleges with the purpose of reducing their GHG emissions (Dyer & Dyer, 2017; Willson, 2010).

Despite the greater requirement for institutions and organizations to adapt to a reality focused on environmental issues, in Brazil there are still few initiatives to inventory GHG in educational institutions (Brianezi et al., 2014). The Federal Institute of Espírito Santo (IFES) is an example of an institution that has made progress in this direction. In addition to increasing the socio-environmental perception of the academic community, monitoring GHG emissions and removals makes it possible to quantify and identify the nature of the emissions, incorporating the results into the environmental management strategies of IFES.

Therefore, the objective of this study was to determine the GHG emission and removal inventories of the Nova Venécia Campus of the Federal Institute of Espírito Santo (IFES-NV) for the year 2019 and, if applicable, to propose the neutralization of net emissions.

MATERIAL AND METHODS

Description of the study site

IFES-NV is located on the banks of the Cricaré River, in the urban area of the municipality of Nova Venécia, Espírito Santo State (ES) (18°42'S and 40°24'W and altitude of 181 m), Brazil (Figure 1). With an area of 5.66 hectares (approximately 42% of built-up area), the campus was opened in 2008, and since then it has been dedicated to teaching, research, and extension activities. The green area of the campus corresponds to approximately 58% of the total area and is composed of native and exotic tree and shrub species. The IFES-NV has 554 students and offers technical, undergraduate, and graduate courses (data from 2019).

Figure 1. Geographic location of Nova Venécia Campus of the Federal Institute of Espírito Santo in the municipality of Nova Venécia, Espírito Santo State, Brazil.

According to the Köppen classification, the climate of the region is tropical with a dry winter (Aw), characterized by having a dry winter and a rainy summer. Annual average temperature and precipitation in Nova Venécia are 23.1 °C and 1,255 mm, respectively (Alvares et al., 2013). The predominant vegetation is formed by a special type of Atlantic Forest called Tabuleiro Atlantic Forest, where Dense Ombrophilous Forest predominates (Martins & Cavararo, 2012), with a high level of forest fragmentation (Mendes et al., 2022). The main type of soil is yellow oxisol (Cunha et al., 2016). The topography of the campus is predominantly flat, with small slopes in the areas close to the river.

Inventory of GHG emissions

The calculation of GHG emissions was carried out using the methodology of the Brazilian GHG Protocol Program for the base year of 2019. This methodology was adapted to the Brazilian context by the Center for Sustainability Studies of Fundação Getúlio Vargas and is compatible with the NBR ISO 14064-1 standards of the Brazilian Association of Technical

Standards (ABNT) and with the quantification methods of the Intergovernmental Panel on Climate Change (IPCC) (Fundação Getúlio Vargas, 2009).

Following the recommendations of NBR ISO 14064-1, the first step adopted for the preparation of the GHG inventory was to define the organizational and operational limits of the inventory (Associação Brasileira de Normas Técnicas, 2007). Thus, the organizational limit of the inventory was the IFES-NV and the operational limit was defined in accordance with the guidelines of the Brazilian GHG Protocol Program, classifying emissions into direct and indirect, and allocating them into three scopes. In scope 1, direct GHG emissions from sources that belong to or are controlled by the institution were accounted for. Emissions from stationary combustion, mobile combustion, fugitive emissions, and wastewater were included in scope 1. Indirect GHG emissions resulting from the generation of electricity consumed by the institution were considered in scope 2. In scope 3, indirect GHG emissions resulting from the institution's activities, but produced from sources that do not belong to or are not controlled by the institution, were accounted for. Emissions resulting from commuting to campus, work travel, and solid waste treatment were accounted for in scope 3.

In scope 1, stationary and mobile combustion was represented by the burning of cooking gas (LPG) used in the preparation of food in the canteen and by the use of fuels in the institution's vehicles. The number of fire extinguishers, air conditioners, refrigerators, and drinking fountains and their respective GHG emissions were surveyed to determine fugitive emissions. Subsequently, the amount of gas emitted into the atmosphere during the recharging and maintenance processes of these devices was quantified.

Still in scope 1, emissions from the generation of wastewater for 2019 were estimated using the average value of biochemical oxygen demand (BOD) measured by Crizel & Lara (2020) for gross wastewater at the Limeira Campus of the State University of Campinas (Unicamp). This estimate was performed with data from the literature due to the restrictions imposed by the COVID-19 pandemic in 2020 that prevented the BOD measurements being carried out in the field at IFES-NV. To calculate the amount of wastewater generated by the campus, 80% of the volume of water consumed was considered (return coefficient = 0.8), a value commonly adopted by the Brazilian water supply and sewage companies.

Scope 2 GHG emissions were calculated from the monthly electricity consumption of the campus. An average emission factor for electricity generation in the Brazilian National Interconnected System (SIN) in 2019 was used to quantify emissions (Ministério da Ciência, Tecnologia e Inovações, 2020).

In scope 3, emissions from commuting to campus were estimated by conducting a survey among people who were on campus in 2019. An online questionnaire through Google Forms was conducted among 93 people (66 students, 16 teaching staff and 11 administrative staff). Information was collected regarding the means of transport used, type of fuel consumed, year of vehicle manufacture, frequency of going to campus, and distance between the place of residence and the campus. Thus, the values found in the research were extrapolated to all those who frequented the campus in 2019, based on the data collected in Table 1. In the case of buses, it was necessary to classify them as municipal (buses for urban transport in Nova Venécia) and travel (buses from other municipalities).

Data on work travel (scope 3) were collected through the System for Concession of Daily Rates and Tickets (SCDP) of the Brazilian Federal Government, used by IFES-NV. Journeys undertaken for scientific and academic purposes in buses, planes, or in private vehicles with reimbursement of expenses were considered. Google Earth Pro software was used to measure the distances traveled on the routes taken. Work journeys in the institution's vehicles were accounted for in scope 1.

In the same way as in the wastewater category, due to the restrictions imposed by the COVID-19 pandemic, emissions from the treatment of solid waste were estimated from a study carried out at another Brazilian university. Based on the study carried out by Carvalho et al. (2017), the amount of solid waste produced by IFES-NV was estimated, as well as its gravimetric composition, based on the number of people who were on campus in 2019. As the IFES-NV performs selective waste collection, only the part of the waste destined for landfill was considered for the emissions calculation.

Data from the categories of the three scopes were then applied using the calculation tool of the Brazilian GHG Protocol Program, version 2021.0.1. Each kind of greenhouse gas was converted into its carbon dioxide equivalent (CO_{2e}) according to the warming potential provided by the IPCC. Thus, the calculation of all greenhouse gases was summarized and the tool provided the emission values by GHG, category and scope. Biogenic CO_2 emissions were accounted for and provided separately, as they are considered as being neutral.

Inventory of carbon removal

In order to quantify carbon removal, an inventory of the campus trees was carried out, in which all trees with a diameter of the trunk with bark greater than 5.0 cm were identified and measured. Diameter measurement was performed at a height of 1.30 meters above ground level (DBH), using a diameter tape. The total height (Ht) of each tree was measured using a *Haglöf* EC II clinometer and using a 30 m measuring tape.

The estimation of the total carbon (TC) stored in the aboveground biomass of the trees was made based on the model of Schumacher (1933), adjusted by Brianezi et al. (2013), to estimate the carbon present in the afforestation of the main campus of the Federal University of Viçosa (UFV). The equations fitted by Brianezi et al. (2013) for non-palm trees (1) and palm trees (2) are as follows:

$$LnTC = -0.906586 + 1.60421 * LnDBH + 0.37162 * LnHt \quad (1)$$

$$LnTC = -4.46988 + 1.99082 * LnDBH + 1.06420 * LnHt \quad (2)$$

Where: Ln = naperian logarithm; TC = estimated total carbon, in kg; DBH = diameter at breast height (1.30 m), in cm; Ht = total height of the tree, in m.

Based on the values of TC and age of the trees, the annual rate of carbon removal was calculated, in kgC $year^{-1}$. The ages of the trees planted from 2008 onwards were obtained through planting records and using sequential satellite images of the Google Earth Pro software. For trees planted before 2008, age was estimated by dividing the individual volume (in m^3), calculated according to Silva (2019), by the average annual increase in volume (IMAv, in m^3 ind^{-1} $year^{-1}$), since there are no planting records and satellite images with good resolution prior to 2008 (year of inauguration of the campus). The IMAv values per species determined by Silva (2019) in the urban afforestation of the municipality of Viçosa, Minas Gerais State, were considered, and an average value was used when there was no IMAv value for a particular species on the campus. The stored carbon values were converted into CO_{2e} through multiplication by the factor 3.6667, which corresponds to the molecular conversion factor from carbon (C) to carbon dioxide (CO_2) (Intergovernmental Panel on Climate Change, 2006).

Balance of carbon emissions and removals

The balance of carbon emissions and removals (in tCO_{2e}) in 2019 was obtained by comparing GHG emissions and the annual rate of carbon removal on the campus. Based on the result of the carbon balance, it was possible to evaluate the need or not of neutralizing emissions through the planting of trees.

RESULTS AND DISCUSSION

It is estimated that IFES-NV was visited by 3,785 people in 2019 (Table 1). The average annual attendance on campus was 208.67 days for regulars (students, teaching staff, administrative staff, outsourced employees, and service employees) and 9.76 days for visitors.

The estimated number of visitors was composed mostly of people who participated in projects and extension courses and events held on campus in 2019.

Table 1. Regulars and visitors of the Nova Venécia Campus of the Federal Institute of Espírito Santo in 2019.

Regulars/visitors	Number
Technical course students	305
Undergraduate students	193
Graduate students	56
Teaching staff	55
Administrative staff	46
Outsourced employees (cleaning, maintenance, and security)	24
Service employees (canteen)	5
Visitors (events, courses, projects, etc.)	3,101
Total	**3,785**

A total of 1,148.878 t of CO_2 equivalent (tCO_{2e}) was calculated through the GHG inventory, distributed across the three evaluated scopes (Table 2). The gases emitted in the evaluated categories were carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and hydrofluorocarbons (HFCs). Scope 3 emissions accounted for 96.59% of total emissions, while scope 1 and 2 emissions accounted for 1.28% and 2.13%, respectively. The carbon emission per capita of IFES-NV in 2019 was 0.304 tCO_{2e}/person. This value is similar to that found for the Pontifical Catholic University of Rio de Janeiro (PUC-Rio), Gávea Campus (0.294 tCO_{2e}/person) (Carvalho et al., 2017) and lower than those reported for educational institutions in developing countries: National University of Colombia, Medellín Campus (0.432 tCO_{2e}/person) (Cano et al., 2022), Universitas Pertamina (0.516 tCO_{2e}/person) (Ridhosari & Rahman, 2020), University of Talca, Curico Campus (0.946 tCO_{2e}/person) (Vásquez et al., 2015), Autonomous Metropolitan University, Cuajimalpa Campus (1.075 tCO_{2e}/person) (Mendoza-Flores et al., 2019), National Autonomous University of Mexico, Engineering Institute (1.466 tCO_{2e}/person) (Güereca et al., 2013), and The University of Cape Town (4.009 tCO_{2e}/person) (Letete et al., 2011).

Table 2. Emissions in metric tons of CO_2 equivalent (tCO_{2e}) for the different gases inventoried in scopes 1, 2, and 3 in Nova Venécia Campus of the Federal Institute of Espírito Santo in 2019.

GHG	Emissions (tCO_{2e})		
	Scope 1	Scope 2	Scope 3
CO_2	10.245	24.506	1,042.837
CH_4	0.875	0	31.050
N_2O	0.298	0	35.760
HFCs	3.307	-	0
PFCs	0	-	0
SF_6	0	-	0
NF_3	0	-	0
Total	**14.725**	**24.506**	**1,109.647**

Scope 1 emissions represented a small share of total emissions (1.28%) (Table 3). The fact that stationary combustion was represented only by the burning of LPG and the number of institution's vehicles is low (2 vehicles) explains the low values of stationary and mobile combustion, respectively. The small use of CO_2-based fire extinguishers and the low contribution of wastewater also help to explain the small contribution of scope 1 to total emissions. Despite the low GHG emissions in the wastewater category (0.825 tCO_{2e}), it is important that the campus seeks an alternative with the government for the correct disposal of its wastewater, which has been discharged untreated into the Cricaré River. Additionally, awareness campaigns have been carried out for the campus community on reducing water consumption and avoiding waste.

Table 3. Emissions in metric tons of CO_2 equivalent (tCO_{2e}) for the different categories inventoried in scopes 1, 2, and 3 in Nova Venécia Campus of the Federal Institute of Espírito Santo in 2019.

Category	Emissions (tCO_{2e})		
	Scope 1	Scope 2	Scope 3
Stationary combustion	3.974	-	-
Mobile combustion	6.607	-	-
Fugitive emissions	3.319	-	-
Wastewater	0.825	-	-
Electricity consumption	-	24.506	-
Solid waste	-	-	27.650
Work travel	-	-	7.586
Commuting to campus	-	-	1,074.411
Total	**14.725**	**24.506**	**1,109.647**

Emissions from the generation of electricity consumed by the institution (scope 2) were also quite low due to the recent replacement of the campus air conditioners by more economical models and the role of trees around the buildings in mitigating the effects of heat (Table 3). Afforestation considerably reduces electricity consumption by air conditioners by reducing solar radiation on the walls and roofs of buildings (Donovan & Butry, 2009; Ko, 2018). Additionally, there are a high number of hydroelectric sources in the Brazilian energy matrix (Lima et al., 2020). A different situation was found in the GHG inventory carried out in 2017 at the University of Pittsburgh (USA), where the need for space heating and the presence of more than 96% of non-renewable sources in the energy matrix contributed to the institution's main source of emissions being purchased electricity (49%) (Bilec & Ketchman, 2017).

Commuting to campus was responsible for 93.52% of total emissions (Table 3). The carbon emissions determined in this category were similar to the results of another related study carried out by Carvalho et al. (2017) in Gávea Campus of the PUC-Rio, where the main source of GHG generation (98% of total emissions) was related to commuting between the campus and the residences of the estimated 20,000 people who frequented PUC-Rio daily in 2011. Other studies in educational institutions also showed that the mobility of the campus community was the activity that most influenced total emissions (Cano et al., 2022; Gonçalves & Pozza, 2016; Mendoza-Flores et al., 2019; Varón-Hoyos et al., 2021). These findings demonstrate that it is necessary to neutralize and/or drastically reduce emissions from burning fossil fuels in places with a high number of visitors.

Also in scope 3, emissions from work travel and solid waste were accounted for (Table 3). Air travel (54.24%) and car travel (40.32%) for scientific and academic purposes were the main contributors to emissions reported in the work travel category. Actions such as replacing the use of private cars with buses for work journeys and greater use of video conferencing can reduce emissions in this category. The solid waste generation on campus in 2019 was estimated at 57.279 t. On the basis of this estimate, 36.659 t of solid waste (64.00%) were destined for sanitary landfill and 20.620 t (36.00%) were sent for recycling. The projected CH_4 emissions from the solid waste were 1.106 t (27.650 tCO_{2e}) and correspond to 2.41% of total emissions. Recycling resulted in an emissions reduction of 54.350 tCO_{2e} (66.28%), which reinforces the importance of proper management of the waste generated by the institution. Furthermore, recycling contributes to the reduction of energy and water consumption in the manufacture of new products and minimizes environmental pollution (Cudjoe et al., 2021). For work travel, 7.586 tCO_{2e} were calculated, which corresponds to 0.66% of total emissions.

Biogenic CO_2 emissions were calculated separately and resulted in 183.734 tCO_{2e}, distributed in scopes 1 (0.70%) and 3 (99.30%). These emissions came mostly from ethanol and biodiesel present in the composition of fuels and were accounted for separately as they do not have an additional impact on the concentration of CO_2 in the atmosphere (Fundação Getúlio Vargas, 2009). Biogenic CO_2 emissions are considered neutral for global warming because they result from the transformation of biological carbon stocks originated from the removal of CO_2 from the atmosphere through the photosynthetic process (Liu et al., 2019).

In the forest inventory, 330 individual trees of 66 different species were measured. The mean DBH and height of trees were 22.8 cm and 7.43 m, respectively. *Mangifera indica* L. (11.21%), *Enterolobium contortisiliquum* (Vell.) Morong (6.06%), *Acacia mangium* Willd. (5.15%), *Cenostigma pluviosum* (DC.) Gagnon & G.P.Lewis (5.15%), and *Peltophorum dubium* (Spreng.) Taub. (5.15%) were the species observed in greatest numbers. The trees present on the campus were responsible for storing 327.519 tCO_2 in their aboveground biomass. The annual rate of carbon removal was 20.026 tCO_{2e} $year^{-1}$. Comparing the annual removal rate with the total value of emissions in 2019, a negative carbon balance of -1,128.852 tCO_{2e} (net emissions) was verified, with afforestation on the campus responsible for neutralizing 1.74% of total emissions. This was exactly the percentage of carbon sequestration (1.74%) by trees at the Medellín Campus of the National University of Colombia (Cano et al., 2022). Different mitigation results were found by Brianezi et al. (2014), who determined the balance of GHG emissions and removals from the main campus of UFV. It was reported that the afforestation (branches and roots) of the main campus of UFV was responsible for neutralizing 4.24% of the emissions in a year, disregarding the emissions from livestock.

Considering only scope 1 (direct emissions) and scope 2 (electricity), the carbon stored in the aboveground biomass of afforestation was able to neutralize 51.05% of emissions. These values demonstrate the importance of conducting the carbon removal inventory and promoting the conservation and expansion of campus afforestation, as well as seeking alternatives to reduce current emissions. However, very few initiatives have evaluated the carbon removal inventory and subtracted it from the GHG inventory in educational institutions (Brianezi et al., 2014; Cano et al., 2022). Although not evaluated in this study, the stock of carbon in tree roots and in the soil (up to one meter deep) can considerably increase the rate of carbon removal at IFES-NV.

For the neutralization of net GHG emissions, the planting of tree seedlings was proposed considering a store of 180 kg of CO_2 per tree (branches and roots), over a 30-year horizon (Alves, 2014). Regarding the recommendation of the total number of seedlings to be planted, there was an increase of 20% to compensate for possible losses due to mortality after planting (Alves, 2014). Thus, 7,526 seedlings of native species should be planted to fully neutralize the campus carbon emissions in 2019. Given this number, each person who was on campus in 2019 should plant two seedlings to promote total neutralization of emissions. It is recommended that the seedlings be planted on the campus and in public areas of the city of Nova Venécia, with the selection of species from lists of potential species for carbon offsetting described by Morais Junior et al. (2019), Silva (2019), and Morais Junior et al. (2020).

The GHG inventory allows institutions to calculate GHG emissions and define plans and strategies for reducing and mitigating the emissions surveyed (García-Alaminos et al., 2022; Intergovernmental Panel on Climate Change, 2018). The results of the IFES-NV GHG inventory should be used to define environmental management strategies aimed at reducing quantified emissions, especially in scope 3. As with other educational institutions, this study is also an important initiative to increase the socio-environmental awareness of the academic community of IFES-NV and encourage the search for solutions to combat global warming. In this context, Findler et al. (2018) emphasize that higher education institutions have the ability to shape the mindset of future decision makers in business, academia, and politics. Therefore, educational institutions should be considered in the context of prevention and mitigation of climate change and act as an example and multiplier of knowledge related to this emergent issue.

CONCLUSIONS

The GHG inventory of the IFES-NV allowed, for the first time, to know the nature of its emissions and to quantify them by categories. The emission and removal inventories will help the IFES-NV to establish strategies and actions to reduce and neutralize GHG emissions, resulting in environmental benefits on a local and global scale, as well as potential economic benefits. As a way to reduce the emissions from the mobility of the campus community (about 94% of total emissions), the IFES-NV should develop initiatives to encourage the use of public transport and vehicles that do not emit GHGs, in addition to the greater use of ethanol as fuel in cars and motorcycles. Awareness campaigns are important to reduce the consumption and wasting of water and electricity, which will lower emissions in scopes 1 and 2.

Although the afforestation of the campus was responsible for neutralizing only a small portion of the total emissions, it was able to neutralize more than half of the emissions most directly managed by IFES-NV (scopes 1 and 2). This reinforces the importance of promoting the conservation and expansion of the campus afforestation. For future studies, it is recommended to quantify the carbon removal by tree roots and soil, as these may represent an important carbon sink.

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REFERENCES

Alvares, C. A., Stape, J. L., Sentelhas, P. C., Gonçalves, J. D. M., & Sparovek, G. (2013). Köppen's climate classification map for Brazil. *Meteorologische Zeitschrift*, *22*(6), 711-728. http://dx.doi.org/10.1127/0941-2948/2013/0507.

Alves, E. B. B. M. (2014). *Mudanças climáticas: Percepção do produtor, balanço de carbono em propriedades rurais e neutralização de evento da Universidade Federal de Viçosa* (Master's thesis). Departamento de Engenharia Florestal, Universidade Federal de Viçosa, Viçosa.

Associação Brasileira de Normas Técnicas – ABNT. (2007). *NBR ISO 14064-1: especificação e orientação a organizações para quantificação e elaboração de relatórios de emissões e remoções de gases de efeito estufa*. Rio de Janeiro: ABNT.

Bilec, M. M., & Ketchman, K. J. (2017). *Greenhouse gas inventory of University of Pittsburgh for FY 2017*. Pittsburgh: University of Pittsburgh.

Brasil. (2009, 29 de dezembro). Lei nº 12.187, de 29 de dezembro de 2009. Institui a Política Nacional sobre Mudança do Clima - PNMC e dá outras providências. *Diário Oficial da República Federativa do Brasil*, Brasília. Retrieved in 2021, September 1, from http://www.planalto.gov.br/ccivil_03/_ato2007-2010/2009/lei/l12187.htm

Brasil. (2022). *Acordo de Paris. Contribuição Nacionalmente Determinada – NDC*. Retrieved in 2022, October 1, from https://www.gov.br/casacivil/pt-br/assuntos/comite-interministerial-sobre-mudanca-do-clima/arquivos-cimv/item-de-pauta-3-paris-agreement-brazil-ndc-final-1.pdf

Brianezi, D., Jacovine, L. A. G., Soares, C. P. B., Castro, R. V. O., & Basso, V. M. (2013). Equações alométricas para estimativa de carbono em árvores de uma área urbana em Viçosa-MG. *Revista Árvore*, *37*(6), 1073-1081. http://dx.doi.org/10.1590/S0100-67622013000600009.

Brianezi, D., Jacovine, L. A. G., Soares, C. P. B., Gonçalves, W., & Rocha, S. J. S. S. D. (2014). Balanço de emissões e remoções de gases de efeito estufa no campus da Universidade Federal de Viçosa. *Floresta e Ambiente*, *21*(2), 182-191. http://dx.doi.org/10.4322/floram.2014.017.

Cano, N., Berrio, L., Carvajal, E., & Arango, S. (2022). Assessing the carbon footprint of a Colombian university campus using the UNE-ISO 14064–1 and WRI/WBCSD GHG Protocol Corporate Standard. *Environmental Science and Pollution Research International*, 1-17. In press. PMid:35962170. http://dx.doi.org/10.1007/s11356-022-22119-4.

Carvalho, J. P. A. F., van Elk, A. G. H. P., & Romanel, C. (2017). Inventário de emissões de gases de efeito estufa no campus Gávea da PUC-Rio. *Engenharia Sanitaria e Ambiental*, *22*(3), 591-595. http://dx.doi.org/10.1590/s1413-41522017155865.

Crizel, M. G., & Lara, A. C. (2020). Avaliação da eficiência de uma estação de tratamento de efluentes instalada em uma universidade federal: questão de gestão ambiental. *Revista Brasileira de Meio Ambiente*, *8*(3), 54-70.

Cudjoe, D., Wang, H., & Zhu, B. (2021). Assessment of the potential energy and environmental benefits of solid waste recycling in China. *Journal of Environmental Management*, *295*, 113072. PMid:34144431. http://dx.doi.org/10.1016/j.jenvman.2021.113072.

Cunha, A. M., Feitoza, H. N., Feitoza, L. R., Oliveira, F. S., Lani, J. L., Cardoso, J. K. F., & Trindade, F. S. (2016). Atualização da legenda do mapa de reconhecimento de solos do estado do Espírito Santo e implementação de interface no geobases para uso dos dados em SIG. *Geografares*, *2*(22), 32-65. http://dx.doi.org/10.7147/GEO23.12356.

Donovan, G. H., & Butry, D. T. (2009). The value of shade: estimating the effect of urban trees on summertime electricity use. *Energy and Building*, *41*(6), 662-668. http://dx.doi.org/10.1016/j.enbuild.2009.01.002.

Duffy, C., O'Donoghue, C., Ryan, M., Styles, D., & Spillane, C. (2020). Afforestation: replacing livestock emissions with carbon sequestration. *Journal of Environmental Management*, *264*, 110523. PMid:32250923. http://dx.doi.org/10.1016/j.jenvman.2020.110523.

Dyer, G., & Dyer, M. (2017). Strategic leadership for sustainability by higher education: the American College & University Presidents' Climate Commitment. *Journal of Cleaner Production*, *140*, 111-116. http://dx.doi.org/10.1016/j.jclepro.2015.08.077.

Findler, F., Schönherr, N., Lozano, R., & Stacherl, B. (2018). Assessing the impacts of higher education institutions on sustainable development: an analysis of tools and indicators. *Sustainability*, *11*(1), 59. http://dx.doi.org/10.3390/su11010059.

Fundação Getúlio Vargas. (2009). *Guia para a elaboração de inventários corporativos de emissões de Gases do Efeito Estufa (GEE).* São Paulo: FGV.

Gamarra, A. R., Herrera, I., & Lechón, Y. (2019). Assessing sustainability performance in the educational sector. A high school case study. *The Science of the Total Environment*, *692*, 465-478. PMid:31539963. http://dx.doi.org/10.1016/j.scitotenv.2019.07.264.

García-Alaminos, Á., Gilles, E., Monsalve, F., & Zafrilla, J. (2022). Measuring a university's environmental performance: a standardized proposal for carbon footprint assessment. *Journal of Cleaner Production*, *357*, 131783. http://dx.doi.org/10.1016/j.jclepro.2022.131783.

Gonçalves, P. B., & Pozza, S. A. (2016). Inventário de gases de efeito estufa no campus 1 da Unicamp em Limeira, SP. *Blucher Engineering Proceedings*, *3*(2), 576-583. http://dx.doi.org/10.5151/engpro-eneeamb2016-qa-004-4819.

Grassi, G., House, J., Dentener, F., Federici, S., Elzen, M., & Penman, J. (2017). The key role of forests in meeting climate targets requires science for credible mitigation. *Nature Climate Change*, *7*(3), 220-226. http://dx.doi.org/10.1038/nclimate3227.

Güereca, L. P., Torres, N., & Noyola, A. (2013). Carbon footprint as a basis for a cleaner research institute in Mexico. *Journal of Cleaner Production*, *47*, 396-403. http://dx.doi.org/10.1016/j.jclepro.2013.01.030.

Intergovernmental Panel on Climate Change – IPCC. (2006). *Guidelines for national greenhouse gas inventories*. Hayama: IGES.

Intergovernmental Panel on Climate Change – IPCC. (2018). Summary for policymakers. In V. Masson-Delmotte, P. Zhai, H. O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor & T. Waterfield (Eds.), *Special report: global warming of 1.5°C*. Geneva: IGES.

Ko, Y. (2018). Trees and vegetation for residential energy conservation: a critical review for evidence-based urban greening in North America. *Urban Forestry & Urban Greening*, *34*, 318-335. http://dx.doi.org/10.1016/j.ufug.2018.07.021.

Letete, T., Mungwe, N. W., Guma, M., & Marquard, A. (2011). Carbon footprint of the University of Cape Town. *Journal of Energy in Southern Africa*, *22*(2), 2-12. http://dx.doi.org/10.17159/2413-3051/2011/v22i2a3208.

Lima, M. A., Mendes, L. F. R., Mothé, G. A., Linhares, F. G., Castro, M. P. P., Silva, M. G., & Sthel, M. S. (2020). Renewable energy in reducing greenhouse gas emissions: reaching the goals of the Paris agreement in Brazil. *Environmental Development*, *33*, 100504. http://dx.doi.org/10.1016/j.envdev.2020.100504.

Liu, W., Zhu, Q., Zhou, X., & Peng, C. (2019). Comparative analyses of different biogenic CO_2 emission accounting systems in life cycle assessment. *The Science of the Total Environment*, *652*, 1456-1462. PMid:30586830. http://dx.doi.org/10.1016/j.scitotenv.2018.11.039.

Martins, L., & Cavararo, R. (2012). *Manual técnico da vegetação brasileira: sistema fitogeográfico, inventário das formações florestais e campestres, técnicas e manejo de coleções botânicas, procedimentos para mapeamentos* (2nd ed.). Rio de Janeiro: IBGE.

McPherson, E. G., Simpson, J. R., Xiao, Q., & Wu, C. (2011). Million trees Los Angeles canopy cover and benefit assessment. *Landscape and Urban Planning*, *99*(1), 40-50. http://dx.doi.org/10.1016/j.landurbplan.2010.08.011.

Mendes, L. J., Milagre, J. C., Morais Júnior, V. T. M., & Coswosk, G. G. (2022). Forest cover analysis of a highly fragmented basin in northern Espírito Santo State, Brazil. *Scientia Forestalis*, *50*, e3928. http://dx.doi.org/10.18671/scifor.v50.32.

Mendoza-Flores, R., Quintero-Ramírez, R., & Ortiz, I. (2019). The carbon footprint of a public university campus in Mexico City. *Carbon Management*, *10*(5), 501-511. http://dx.doi.org/10.1080/17583004.2019.1642042.

Ministério da Ciência, Tecnologia e Inovações – MCTI. (2020). *Fator médio - inventários corporativos*. Retrieved in 2021, November 10, from https://www.gov.br/mcti/pt-br/acompanhe-o-mcti/sirene/dados-e-ferramentas/fatores-de-emissao

Mohren, G. M. J., Hasenauer, H., Köhl, M., & Nabuurs, G. J. (2012). Forest inventories for carbon change assessments. *Current Opinion in Environmental Sustainability*, *4*(6), 686-695. http://dx.doi.org/10.1016/j.cosust.2012.10.002.

Morais Junior, V. T. M., Jacovine, L. A. G., Alves, E. B. B. M., Torres, C. M. M. E., Faustino, I. S., França, L. C. J., Rocha, S. J. S. S., Simiqueli, G. F., Silva, L. B., & Cruz, R. A. (2020). Growth and survival of potential tree species for carbon-offset in degraded areas from southeast Brazil. *Ecological Indicators*, *117*, 106514. http://dx.doi.org/10.1016/j.ecolind.2020.106514.

Morais Junior, V. T. M., Jacovine, L. A. G., Torres, C. M. M. E., Alves, E. B. B. M., Paiva, H. N., Cruz, R. A., & Zanuncio, J. C. (2019). Early assessment of tree species with potential for carbon offset plantations in degraded area from the southeastern Brazil. *Ecological Indicators*, *98*, 854-860. http://dx.doi.org/10.1016/j.ecolind.2018.12.004.

Nagar, P. K., Sharma, M., Gupta, S., & Singh, D. (2019). A framework for developing and projecting GHG emission inventory and preparing mitigation plan: a case study of Delhi City, India. *Urban Climate*, *28*, 100462. http://dx.doi.org/10.1016/j.uclim.2019.100462.

Ngo, K. M., & Lum, S. (2018). Aboveground biomass estimation of tropical street trees. *Journal of Urban Economics*, *4*(1), 1-6. http://dx.doi.org/10.1093/jue/jux020.

Nowak, D. J. (2019). The atmospheric system: air quality and greenhouse gases. In M. H. P. Hall & S. B. Balough (Eds.), *Understanding urban ecology* (pp. 175-199). Cham: Springer. http://dx.doi.org/10.1007/978-3-030-11259-2_8.

Ridhosari, B., & Rahman, A. (2020). Carbon footprint assessment at Universitas Pertamina from the scope of electricity, transportation, and waste generation: toward a green campus and promotion of environmental sustainability. *Journal of Cleaner Production*, *246*, 119172. http://dx.doi.org/10.1016/j.jclepro.2019.119172.

Rocha, M. T. (2002). O aquecimento global e os instrumentos de mercado para a solução do problema. In C. R. Sanquetta, L. F. Watzlawick, R. Balbinot, M. A. B. Ziliotto & F. S. Gomes (Ed.), *As florestas e o carbono*. Curitiba: UFPR.

Schumacher, F. X. (1933). Logarithmic expression of timber-tree volume. *Journal of Agricultural Research*, *47*(9), 719-734.

Silva, V. F. (2019). *Neutralização de carbono: adaptabilidade e desenvolvimento de espécies florestais no ambiente urbano* (Master's thesis). Departamento de Engenharia Florestal, Universidade Federal de Viçosa, Viçosa.

Varón-Hoyos, M., Osorio-Tejada, J., & Morales-Pinzón, T. (2021). Carbon footprint of a university campus from Colombia. *Carbon Management*, *12*(1), 93-107. http://dx.doi.org/10.1080/17583004.2021.1876531.

Vásquez, L., Iriarte, A., Almeida, M., & Villalobos, P. (2015). Evaluation of greenhouse gas emissions and proposals for their reduction at a university campus in Chile. *Journal of Cleaner Production*, *108*, 924-930. http://dx.doi.org/10.1016/j.jclepro.2015.06.073.

Willson, R. (2010). Beyond the inventory planning for campus greenhouse gas reduction. *Planning for Higher Education*, *39*(1), 18-29.

World Economic Forum – WEF. (2022). *The global risks report 2022*. Retrieved in 2020, November 10, from https://www3.weforum.org/docs/WEF_The_Global_Risks_Report_2022.pdf

Yang, D., Xu, L., Gao, X., Guo, Q., & Huang, N. (2018). Inventories and reduction scenarios of urban waste-related greenhouse gas emissions for management potential. *The Science of the Total Environment*, *626*, 727-736. PMid:29358143. http://dx.doi.org/10.1016/j.scitotenv.2018.01.110.

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