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Potential of carbon credits generation from organic waste composting of large generators: an alternative to the final disposal in sanitary landfills

Potencial de geração de créditos de carbono via compostagem de resíduos orgânicos de grandes geradores: uma alternativa à disposição final em aterros sanitários

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ABSTRACT

This study aims to measure the potential for reducing Greenhouse Gases by surveying the amount of methane avoided by a company that collects and processes organic waste from large generators through composting. The applied methodology was the avoidance of methane emissions through composting, from the Clean Development Mechanism, considering as a baseline the emissions of the Santa Rosa sanitary landfill, located in the city of Seropédica, state of Rio de Janeiro, Brazil. With data on the amount of organic waste composted by the company, the emissions of carbon dioxide equivalent (CO_{2eq}) were calculated, considering the standard emission factors established in the methodological instrument. The data show that the emission of 22,062 tons of CO_{2eq} was avoided, which corresponds to a reduction of 83.5% of CH_4 emissions, if the waste composted by the company were deposited in the Santa Rosa sanitary landfill. In terms of carbon credit, according to the calculation, this value would correspond to approximately 17 thousand euros annually (considering current values). Thus, the applicability of this study contributes as a scientific basis to assist decision-making and effectiveness of other composting projects, enabling greater reductions in emissions of Greenhouse Gases in the long term and adequacy to the future perspectives of carbon market development. At the same time, it contributes to the construction of alternative scenarios for mitigation and reduction of Greenhouse Gases emissions in Brazil and promotes sustainable waste management, as determined by the National Solid Waste Policy.

Keywords: greenhouse gases; methane; energy use; avoided emissions; CO_2 mitigation; carbon market; clean development mechanism.

RESUMO

O presente estudo tem o objetivo de mensurar o potencial de redução de Gases do Efeito Estufa por meio do levantamento da geração de metano evitada por uma empresa de coleta e do tratamento dos resíduos orgânicos de grandes geradores através da compostagem. A metodologia utilizada foi a *avoidance of methane emissions through composting*, do Mecanismo de Desenvolvimento Limpo, considerando como linha de base as emissões do aterro sanitário Central de Tratamento de Resíduos Santa Rosa, localizado em Seropédica, Rio de Janeiro. Com os dados de quantidade de resíduos orgânicos compostados pela empresa, foram calculadas as emissões de CO_2eq em função dos fatores de emissão padrão estabelecidos na ferramenta metodológica. Os dados mostram que se evitou que 22.062 toneladas de CO_2 equivalentes fossem lançadas na atmosfera, o que corresponde a uma redução de 83,5% das emissões de CH_4 que ocorreriam caso os resíduos compostados pela empresa fossem destinados à Central de Tratamento de Resíduos Santa Rosa. Contabilizando, em termos de crédito de carbono, esse valor corresponderia, atualmente, a aproximadamente 17 mil euros anualmente. Dessa forma, a aplicabilidade deste trabalho contribui como base científica para auxiliar a tomada de decisão e efetividade de demais projetos de compostagem, possibilitando ainda mais reduções de emissões de Gases do Efeito Estufa em longo prazo, bem como adequação às perspectivas futuras de desenvolvimento do mercado de carbono. Ao mesmo tempo, esperamos contribuir para a construção de cenários alternativos para mitigação e redução das emissões de Gases do Efeito Estufa no Brasil e promover a gestão de resíduos sustentável, como determinado pela Política Nacional de Resíduos Sólidos.

Palavras-chave: gases do efeito estufa; metano; emissões evitadas; aproveitamento energético; mitigação de CO_2; mercado de carbono; mecanismo de desenvolvimento limpo.

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Introduction

The main greenhouse gas in the solid waste treatment sector is methane (CH_4), a fuel gas resulting from the decomposition of the organic fraction of municipal solid waste in sanitary landfills and dumps (Jeswani and Azapagic, 2016).

According to the United Nations Environment Programme (UNEP), solid waste management is responsible for 5% of anthropogenic greenhouse gas (GHG) emissions on a global scale (Kaza, 2018). However, the sector has the potential to become one of the largest reducers of GHG emissions, because when waste is recovered and reinserted into the supply chain, emissions from the extraction and transportation processes of natural resources are avoided, positively affecting the entire production flow (UNEP and ISWA, 2015; Firmo et al., 2019).

Therefore, municipal solid waste (MSW) management plays a strategic role in policies on climate protection and implementation of a low-carbon economy, considering its potential for integration with several economic sectors (Reichert and Mendes, 2014; Jensen et al., 2017). The improvement of waste management can contribute about 15 to 20% to the reduction of total emissions, considering the entire life cycle of materials and the hierarchy in waste management (UNEP and ISWA, 2015).

The predominant component of MSW in Brazil is organic matter, which represents approximately 45% of the waste (ABRELPE, 2021). Of this amount, only 1.5% goes to composting units (Brasil, 2021). The vast majority of organic waste is destined for sanitary landfills and open dumps, which represents a waste of valuable resources, generation of greenhouse gases – as a result of the anaerobic digestion of these final disposal sites –, generation of leachate, and other environmental impacts (Jeswani and Azapagic, 2016; Sharma and Chandel, 2016). An important tool for the valorization of organic waste in Brazil is composting (Deus et al., 2017; Rodrigues et al., 2019), which consists of the controlled degradation of the organic fraction of solid waste in the presence of oxygen, producing organic fertilizer at the end of the process (Kiehl, 1998; Awasthi et al., 2020).

With the use of this technique, it is possible to reduce the amount of waste destined for sanitary landfills, the generation of leachate, and methane emissions to the atmosphere, as well as reducing the use of chemical fertilizers (Andersen et al., 2010; Jensen et al., 2016; Chen et al., 2020). Another relevant aspect for the valorization of this waste is the possibility of obtaining carbon credits with the valorization of organic waste (Andersen et al., 2012). Zago and Barros (2019) highlight the need to comply with the National Solid Waste Policy, which prioritizes recycling and treatment before disposal in sanitary landfills.

Sanchez et al. (2015) and Mortula et al. (2020) indicate that composting is one of the cheapest technologies to treat organic waste, consisting in a sustainable strategy and one of the technologies that can be employed in any scenario of solid waste management, including developed and developing countries. However, in Brazil, millions of tons of organic waste are still buried, burned, or disposed of in dumps due to the lack of knowledge of the potential to use this waste, as well as the negative impacts they cause when disposed of inappropriately (Zago and Barros, 2019) . Menezes et al. (2019) highlight that, considering the high incidence of organic waste in the gravimetric composition of MSW, in addition to the low percentage of recovery and treatment, the structure of selective waste collection must be reassessed to ratify a potential to be explored.

According to Jensen et al. (2017), the use of natural compounds implies better absorption of nutrients from the soil, reduced energy in the production of fertilizers and release of nitrous oxide into the atmosphere, in addition to increasing water retention in the soil. Polzer (2016) highlights the use of fertilizer generated in the composting process in urban green spaces such as squares, vegetable gardens, vertical gardens, and even green roofs.

Due to the environmental impacts arising from global warming and directly related to greenhouse gas emissions, policies were implemented to propose international trade cooperation actions to mitigate GHG emissions. This concern culminated in the creation of the carbon market, defined by Article 12 of the Kyoto Protocol, allowing the negotiation of carbon credits generated from the implementation of Clean Development Mechanisms (CDM) projects (UNFCCC, 2015; Diniz Oliveira et al., 2019).

CDM projects had bureaucratic characteristics, strict criteria, and high costs involved in their implementation (Godoy, 2013). Nevertheless, due to the trade of carbon credits generated, 344 projects registered with the CDM Executive Board were implemented in Brazil. Of these, 52 are sanitary landfill projects with biogas recovery to burn in flare or power generation (UNFCCC, 2020), promoting job creation, income, and technological development (IPEA, 2018). The total number of GHG emission reductions from Brazilian projects reached 379 million in December 2019 (Brasil, 2019; UNFCCC, 2020).

The CDM was incorporated into Article 6 of the Paris Agreement as a Sustainable Development Mechanism (SDM), strengthening the expansion trend of the carbon market, focused on shared interests of mitigation and sustainable development, without differentiation of groups or parties (Santos et al., 2017; Stua et al., 2022).

With the advent of the Paris Agreement, in force since 2016, new opportunities for carbon credit generation arise, resulting from projects in the solid waste sector, as the 195 countries that signed the Agreement committed themselves to meeting voluntary emission reduction goals, with the aim of reducing carbon dioxide (CO_2) by 2030 and achieve carbon neutrality by 2050. To this end, the adoption of the composting technological route to treat the generated organic waste contributes to the reduction of greenhouse gas emissions and the generation of carbon credits, as organic waste is no longer disposed of in sanitary landfills and can be computed as avoided CO_2 emissions.

In addition to markets regulated by jurisdictions to meet the goals set by the Nationally Determined Contributions (NDCs), there are voluntary markets, which are sought after by companies that seek to meet environmental standards, but which can be audited by independent agencies (Mota, 2021). Both carbon credit markets have been growing, reaching values of approximately 50 euros in 2021 (ICAP, 2021).

Considering this context and aiming at strategic changes in reducing emissions in waste management, it is expected that the regulation of the carbon market will be a way to advance solid waste management in Brazil (van Elk et al., 2021), as companies and countries that have a goal of reducing waste emissions may be interested in buying carbon credits from projects in the solid waste sector (Stua et al., 2022). In this sense, large waste generators play an important role due to their responsibility in the collection and treatment of generated waste, and with the possibility of gains from the sale of carbon credits as a stimulus to comply with the legislation (Catorza, 2020).

Some countries have already launched their compliance markets. Among the most important ones are the markets from Europe, China, Germany, and in the state of California (Ricce, 2021). In Brazil, Bill No. 528 aims to establish guidelines for the regulated and voluntary carbon markets, with the creation of the Brazilian Emissions Trading System.

The objective of this study was to measure the potential for reducing GHG emissions and generating carbon credits by choosing the composting technique as an alternative to the disposal of organic waste in sanitary landfills, using as a case study a company from Rio de Janeiro that treats the organic fraction of solid waste from large generators and the methodology for calculating the CDM.

Material and Methods

For conducting the present study, a case study was carried out based on a company that collects and treats organic waste from large generators in the state of Rio de Janeiro, Brazil. The study consisted of surveying the amount of carbon that would be generated if the waste treated at the company was destined for the sanitary landfill of the city of Seropédica, called Santa Rosa. Carbon credits will be presented in euros, as the European market is one of the pioneers and most important carbon markets in the world.

Company for collection and treatment of organic waste from large generators

Based on the proposed objectives, a survey of companies collecting and treating organic waste from large generators in the state of Rio de Janeiro was carried out. The company in question was chosen for the study because it operates the composting process on an industrial scale, with the capacity to process 1,500 tons of organic waste per month, and also because it has data on its activity dating from up to ten years. Waste treatment is carried out in the municipality of Cachoeiras de Macacu, in the mountainous region of Rio de Janeiro, and the company operates using the Windrow Composting technique, in which aeration is passive and windrow turnover is mechanized. The waste treated at the company is transformed into organic fertilizer within 45 days, completing the cycle from the collection of waste from large generators to the composting process, compost production, cultivation, and marketing of organic foods by the company itself.

Clean Development Mechanism methodology: avoidance of methane emissions through composting

Estimations of methane reductions were performed using the Clean Development Mechanism (CDM) methodology: avoidance of methane emissions through composting (AMS-III.F.), version 12.0, which consists of avoiding methane emissions to the atmosphere by applying treatment measures for organic waste such as composting. Therefore, CH_4 emissions to the atmosphere are reduced and carbon credits are generated as a result, which can be explained by Equation 1:

$$ERy = BEy - PEy \tag{1}$$

Where:

ERy = reductions in CH_4 emissions in year y (tCO_2e/year);

BEy = CH_4 emissions at baseline in year y (tCO_2e/year);

PEy = CH_4 emissions by the composting project in year y (tCO_2e/year).

In this context, methane emissions from the sanitary landfill represent the baseline, while the application of waste destined to treatment with composting and its respective emissions constitute additionality (UNFCCC, 2016).

CH_4 emissions at baseline: Santa Rosa sanitary landfill, in Seropédica

The calculation of emissions at the baseline consists of estimating the amount of methane that would be generated if the organic waste collected by the composting company were destined for the Santa Rosa sanitary landfill, in the city of Seropédica, which is the business as usual of destination of solid organic waste in the study region.

No measurements were performed at the activity site of the sanitary landfill to monitor GHG emissions; hence, the calculations used standardized values, presented in the Project Design Document (PDD) of the Seropédica Sanitary Landfill — entitled *CPA-1: Recuperação do gás de aterro, geração de energia e distribuição de biogás da CTR Santa Rosa em Seropédica* [Landfill gas recovery, power generation, and biogas distribution from Santa Rosa sanitary landfill in Seropédica] — as well as standardized emission factors from the CDM Tool AM04 *Methodological tool: Emissions From Solid Waste Disposal Sites — Version 08.0* and updated according to the United Nations Framework Convention on Climate Change (UNFCCC) and the Intergovernmental Panel on Climate Change (IPCC) (UNFCCC, 2012, 2017a).

The CDM Tool AM04 was chosen because of the requirement to apply this tool to CDM projects that avoid the disposal of municipal solid waste in sanitary landfills, and consequently avoid GHG generation in these locations (Santos et al., 2017; UNFCCC, 2017a). Equation 2 presents the formula for calculating CH_4 emissions in sanitary landfills.

$$BE_{CH4, SWDS, y} = \varphi \cdot (1 - f) \cdot GWP_{CH4} \cdot (1 - OX) \cdot (16/12) \cdot F \cdot DOC_f \cdot MCF \ \Sigma^{y}_{x} = {}_1\Sigma_j W_{jx} . DOCj . e^{-kj (y-x)} . (1-e^{-kj}) \quad (2)$$

Where:

$BE_{CH4, SWDS, y}$ = baseline methane emissions during year y, with the disposal of organic waste in sanitary landfills, during the period from the beginning of the composting project activity until the end of the year y (t_{CH4});

φ = standard value for the correction factor to account for model uncertainties;

f = fraction of methane captured at the sanitary landfill and burned in flare, incinerated, or otherwise used;

GWP_{CH4} = global warming potential of CH_4;

OX = oxidation factor, which reflects the amount of methane from the landfill that is oxidized in the soil or other material that covers the waste;

F = methane fraction in landfill gas (volume fraction);

DOC_f = fraction of degradable organic carbon (DOC) that can decompose;

MCF = methane correction factor;

DOC_j = fraction of degradable organic carbon (by mass) in type-j waste;

K_j = decay rate of type-j waste;

$W_{j,x}$ = amount of type-j organic waste disposed of at the landfill in year x (tons);

X = year when the composting company began its activities;

Y = year for which methane emissions were calculated, considering the total time for degradation of all organic matter deposited until 2019.

Input data, emission factors, and equations were entered into Microsoft Excel spreadsheet software to perform the calculations and obtain the results, using the following values: φ = 0.9; f = 0.5; GWP_{CH4} = 28; OX = 0.1; F = 0.5; DOC_j = 0.15; K_j = 0.4; Wj,x = 78,053; X = 2007; Y = 2031 (UNFCCC, 2012, 2017a).

CH_4 emissions with additionality: composted organic waste

Additionality, in this context, consisted of measuring the CH_4 emissions that were avoided with the application of composting for the treatment of organic solid waste, avoiding the generation of large amounts of this GHG to the atmosphere.

The tool that enables to inventory GHG emissions from composting, required by the AMS-III.F. methodology, is the CDM Tool Methodological tool AM013: Project and leakage emissions from composting — Version 02.0 (UNFCCC, 2017b).

Measurements were not performed to monitor GHG emissions by composting *in loco*; therefore, the calculations were made using standardized values, presented in the CDM Tool AM013 (UNFCCC, 2017b) calculation tool, according to Equation 3.

$$PE_{COMPy} = PE_{ECy} + PE_{FCy} + PE_{CH4y} + PE_{N2Oy} + PE_{ROy} \quad (3)$$

Where:

PE_{COMPy} = emissions associated with the composting project in year y (tCO_2e/yr);

PE_{ECy} = emissions associated with electricity consumption in the composting project in year y (tCO_2 e/yr);

PE_{FCy} = emissions associated with fossil fuel consumption in the composting project in year y (tCO_2e/yr);

PE_{CH4y} = methane emissions in the composting project in year y (tCO_2e/yr);

PE_{N2Oy} = nitrous oxide emissions in the composting project in year y (tCO_2e/yr);

PE_{ROy} = methane emissions from the sanitary effluents in year y (tCO_2e/yr).

The term PE_{ROy} was not considered for estimating GHG emissions, as the composting company does not treat sanitary effluents in its process. Conversely, the variables PE_{ECy}, PE_{FCy}, and PE_{N2Oy} were disregarded, in such a way that only CH_4 emissions between the composting process and methane emissions at the sanitary landfill (baseline) can be compared. Thus, it is possible to reduce Equation 3 to $PE_{COMP} = PE_{CH4}$.

According to the CDM Tool AM013, CH_4 emissions in the composting process can be estimated by finding the results for the term PE_{CH4}, using Equation 4 as follows:

$$PE_{CH4y} = Q_y \text{ x } EF_{CH4y} \text{ x } GWP_{CH4} \quad (4)$$

Where:

PE_{CH4y} = methane emissions in the composting project in year y (tCO2e/yr);

Q_y = amount of composted waste (78,053 t/yr);

EF_{CH4y} = methane emission factor (CH_4) per ton of composted waste in year y (0.002tCO2e/yr);

GWP_{CH4} = global warming potential of methane (CH_4) ($28tCO_2/tCH_4$).

The CDM Tool AM013 uses conservative values for emission factors, when it is not possible to guarantee the efficiency of the composting process; hence, it is important to carry out monitoring campaigns to obtain specific CH_4 emission factors for each project.

CH_4 emission reductions and carbon credits with aerobic composting

The amounts of GHG emission reductions attributed to a CDM project activity result in Certified Emission Reductions (CER) traded on the carbon market.

Based on the results of the calculations of the emissions at the baseline (Seropédica sanitary landfill) and the emissions from the composting process, it was possible to find the methane emission reductions with the application of composting for the treatment of the organic fraction of municipal solid waste. By Equation 5, the amount of CH_4 avoided when using aerobic composting for the treatment of organic waste was obtained; this will also be the value of GHG reductions to obtain carbon credits (CER).

$$CER_y = BE_y - PE_y \tag{5}$$

Where:
CER_y = Certified Emission Reductions of CH_4 in year y (tCO_2e/yr);
BE_y = CH_4 emissions at baseline in year y ($tCO_2e/year$);
PE_y = CH_4 emissions by the composting project in year y ($tCO_2e/year$).

The amount of CH_4 emissions avoided by composting was multiplied by the historical price values of the CER quotation during the period of activity of the composting company, and, thus, the values that could be acquired – if carbon credits were claimed – were found, as indicated in Equation 6. For the period after 2021, the value of the last quotation (€48.64) was considered. The values of the quotations of Carbon Credits used in the calculation were collected on the International Carbon Action Partnership (ICAP) platform (ICAP, 2021).

$$€CER = € \times CER \tag{6}$$

Where:
€CER = value obtained with CER in year y;
€ = value of Euro/tCO_2eq in year y;
CER = CH_4 emissions avoided in year y.

Results and Discussion

Data on the amount of composted organic waste are presented in Table 1 and concern the company's period of activity, from 2007 to 2019, when the last annual balance sheet was released, totaling 78,053 tons of organic waste treated throughout the period. This value will be the reference for the construction of the baseline and additionality scenarios.

In Table 1, the evolution of the amount of organic waste treated in the company is noteworthy, especially as of 2010, when the National Solid Waste Policy was enacted, considering that, from that moment on, there was greater demand for the correct disposal of organic waste.

According to the data obtained from the AMS-III.F. methodology, the composting company prevented 22,062 tons of CH_4 in equivalent CO_2 from being released into the atmosphere when performing the treatment of the organic fraction of waste from large generators in the state of Rio de Janeiro, which corresponds to a reduction of 83.5% in CH_4 emissions that would be generated at the Santa Rosa sanitary landfill; that is, for each ton of organic waste treated by composting, 283 kg CO_2eq are prevented from being released into the atmosphere.

Figure 1 shows the GHG emissions that would be generated at the Santa Rosa sanitary landfill in Seropédica (baseline), the emissions generated during the composting process, and the emission reductions over time (additionality).

Regarding the possibilities of earning revenues from carbon credits, the results estimated values higher than €422,000, the currency used in carbon market transactions in the European market, as shown in Figure 2.

Table 1 – Amount of organic waste composted in the company under study.

Composted organic waste (food waste)	
Year	Wj,x (Tons)
2007	2,500
2008	3,110
2009	3,470
2010	4,010
2011	5,140
2012	5,220
2013	6,010
2014	6,580
2015	7,070
2016	7,430
2017	8,020
2018	9,303
2019	10,190
Total	78,053

Source: Catorza (2020).

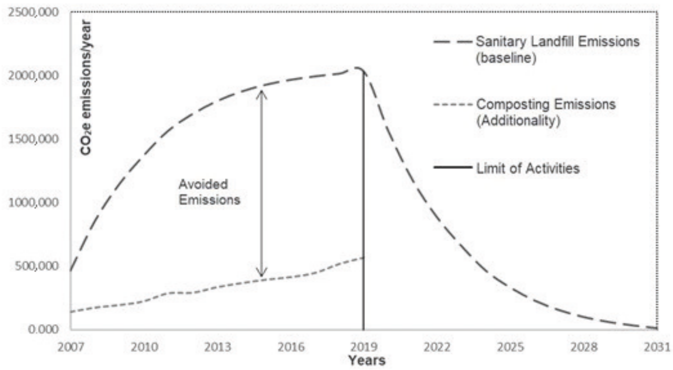

Figure 1 — CO_2 emissions at baseline and with additionality.

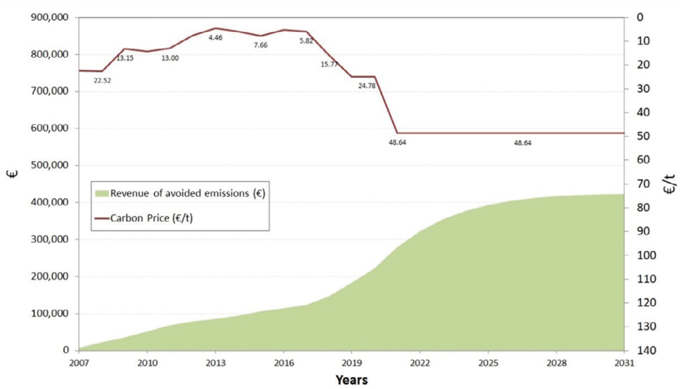

Figure 2 — Carbon credit revenues during the project lifetime.

It should be noted that the identified methane emissions resulting from composting could be even lower, as the default emission factor (2 $Kg.Mg^{-1}$), defined in the calculation tool for obtaining carbon credits through aerobic composting in CDM projects, is deemed conservative (UNFCCC, 2017b). Thus, when applying specific emission factors available in the technical literature, such as the emission factor developed by Inácio (2010) for composting (1.2 $Kg.Mg^{-1}$), the reduction of total CH_4 could reach 90%. However, the calculation tools indicate that, when there are no measurement campaigns at the site of activity, the emission factors defined in the tool itself should be used (UNFCCC, 2017b). Data on emission factors in composting can be found in Amlinger et al. (2008) and Jensen et al. (2017).

Therefore, it is possible to identify that, even with small changes and variations in the values and parameters of the used formulas, significant impacts can be generated.

The results show that the development of composting as the main form of final disposal of organic waste is essential for the management of low carbon waste and the achievement of national and global goals for reducing GHG emissions and, most importantly, for the success of the containment strategies of global warming (Jeswani and Azapagic, 2016; Mortula et al., 2020). The gain from the use of this technological route does not only refer to large-scale composting plants; composting plants for industrial kitchens, condominiums, shopping malls, and other small and medium scale generators are equally advantageous (Lima Júnior et al., 2017).

The valuation of organic waste can help solving serious environmental problems such as soil degradation, erosion, and climate change. Both cities and companies and agriculture widely benefit from considering their organic solid waste as a precious "resource," converting it into fertilizer and/or energy, creating jobs, and contributing to the reduction of the costs of its disposal (Zago and Barros, 2019). Despite the numerous advantages of recycling organic waste, there are difficulties, including in countries with high recycling rates, such as European countries and the United States of America, because technologies are not always economically feasible and there are difficulties inherent in the collection of organic waste that is not contaminated (Abramovay et al., 2013).

As for carbon credit revenues, the amounts represent an average of €17 thousand per year, which can be used to purchase equipment, improving infrastructure, vehicles, and human resources, thus boosting the operation of the composting company, promoting greater customer reach, greater amount of organic waste collected and treated, reduction of GHG emissions, and revenues from carbon credits, in addition to a more sustainable and circular waste management.

Composting projects can be developed with the aim of achieving higher revenues when considering carbon credits, which can enable small-scale and decentralized projects, which, in the absence of credit mechanisms and government incentives, would be unfeasible. Within this context, it is possible to improve the management of organic waste, avoiding greater environmental impacts with the improper disposal of waste, as well as promoting the valorization of organic waste with the aid of carbon markets (Galgani et al., 2014; Paiva et al., 2015; Torres et al., 2016).

New circular business models that seek the valorization of organic waste are essential to the success of public policies in the waste sector. Considering this scenario, there must be incentives for these ventures, as determined by the National Solid Waste Policy (PNRS in Portuguese), as they provide an environmental service by avoiding the impacts related to CH_4 emissions and leachate generation – which would occur if organic waste were not correctly treated (Firmo et al., 2019; Rodrigues et al., 2019) — as well as promoting cost reduction with the disposal of organic matter in sanitary landfills (Polzer, 2016; Zago and Barros, 2019).

In this sense, the continuity and evolution of the carbon market may represent a competitive advantage for waste treatment ventures aimed at CER revenues, considering that, according to a study carried out by the University of Maryland (Edmond et al., 2019) on the economic potential of Article 6 of the Paris Agreement, the regulated carbon market can reach US$250 billion annually by 2030.

No monitoring campaigns were carried out during the activities of the composting company and, therefore, the CDM Tool AM013 conservatively considers CH_4 and N_2O emissions in its standard emission factors (UNFCCC, 2017b).

The development and application of research to define optimal aeration rates, maintenance of oxygen and water contents through defined operating procedures, while studying the variation in GHG emissions during the composting stages, allows determining a specific emission factor for composting projects on an industrial scale, and thus contribute as a scientific basis to greater use of composting as a technological route for treating organic waste, aiming at low carbon waste management.

Conclusion

In this study, the authors estimated CO_2eq emissions that were avoided when composting was used to treat organic waste from large generators collected and treated by a medium-sized company. The methodology applied in the research was the AMS-III.F., and, through the calculation tools of the MDL, AM04, and AM013, the baseline and additionality were calculated. The results showed that the treatment of organic waste by composting processes has the potential to prevent 22,062 tons of equivalent CO_2 from being released into the atmosphere, taking as a reference scenario the waste disposed of at the Santa Rosa sanitary landfill. This value corresponds to 283 kg CO_2eq for each ton of composted waste.

The amount of emission reduction recorded in carbon credits, considering the value in euros, represents an average revenue of 17 thousand euros per year for the company. These values may be more significant with the expansion of the carbon market and the prospect of increasing the value of carbon credits in regulated and voluntary markets, as a consequence of the regulation of Article 6 of the Paris Agreement at the 2021 United Nations Conference on Climate Change (COP26), in Glasgow, Scotland.

The costs related to fees and other investments required in the accreditation and validation process of the composting company's processes were not considered to calculate the revenues found with carbon credits. It should be noted that these represent considerable investments and should be analyzed beforehand.

Thus, the applicability of this study contributes as a scientific basis to assist decision-making and effectiveness of other composting projects, enabling greater reductions in GHG emissions in the long term and adequacy to the future perspectives of carbon market development. Furthermore, this article can contribute to the construction of alternative scenarios for reducing GHG emissions in Brazil and promoting sustainable waste management, as determined by the National Solid Waste Policy.

Authors' contributions:

Catorza, C.F.: Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Writing — original draft. Van Elk, A.G.H.P.: Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Project Administration, Writing — review and editing, Supervision, Validation, Visualization. Passos, L.H.S.: Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Software, Writing — review and editing.

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