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A COMPARATIVE ASSESSMENT OF ECONOMIC AND ENVIRONMENTAL IMPACTS OF TWO SOLID WASTE MANAGEMENT SCENARIOS

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ABSTRACT
This work conducts a practical study in the city of Paraíba do Sul in Brazil, comparing two possible scenarios for Municipal Solid Waste (MSW) Management. The novelty of this work is in employing cost and sustainability indicators in the MSW management proposal, using the organic fraction of waste in a local composting process. Two scenarios are proposed; the first one is based on sending all MSW collected in the city to the new private landfill; and the second scenario is a novel model proposed in this work, involving the shipment of organic waste to a composting yard. The study analyzes different scenarios involving ten neighborhoods from the municipal core. The findings indicate a 19% monthly cost difference between the scenarios, with the second simulation being the most expensive. However, this additional cost could be offset by revenue from compost sales. Sustainability indicator scores suggest that the second scenario is the most environmentally favorable, primarily due to its technological simplicity, the low economic cost of the composting method, and the presence of selective collection and organic waste utilization.Such advantages stand out and the economic validation of the model for the context of cities with up to 50,000 inhabitants, in developing countries.

Keywords: Urban Solid Waste. Sustainability Landfill. Composting. Waste Management.

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INTRODUCTION

The Brazilian National Policy on Solid Waste (BNPSW) was established based on Federal Law 12,305/2010 [1], which requires environmentally sound disposal of solid waste in all Brazilian municipalities with more than twenty thousand inhabitants [2,3]. One of the biggest challenges for municipalities is to properly collect, recycle, treat, and dispose of the increasing volume of solid waste [4]. 2018). About 60% of Brazilian municipalities, especially small ones, still dispose of their urban solid waste improperly [5]. It is known that smaller municipalities do not have enough investments for good solid waste management, and many of them still have irregular open-air dumps as the main final destination [6]. There is thus a need for better solid waste management strategies in small urban regions, and possible policies to encourage reduction, reuse, and recycling, fostering sustainable waste management practices [7].

Some theorists of the 1960s coined the term “urban metabolism” to designate flows into and out of cities, as in a living organism [8]. In the 2000s, there was a second generation of scholars on this topic, relating it to concepts such as ecological footprint and circularity [9–11]. This second generation emphasizes the role of cities in the future of humanity, understanding that we will increasingly live within them and in conditions determined by them [9]. However, the current city model - production, consumption, and linear disposal - should not be in force. Priority should be given to the circular model, which, unlike the linear model, does not seek resources or transfer environmental impacts outside the physical limits of cities [11]. Hence, the concept of the “ecological footprint” of cities was born, that is the physical area that a given city demands in its search for resources, and for space to deposit its waste. Virtually, the footprints of existing cities already cover the entire planet [9]. The concepts of linearity and circularity in the city, on the other hand, refer to the inputs they need (water, energy, food), and the by-products they generate (pollution, solid waste, sewage). Planet Earth is an almost closed system, with solar energy being the only external resource to this system. Thus, the other resources that cities use to develop are planetary resources (water, fossil fuels, etc.). On the other hand, cities generate waste and pollution, and such products will remain on the globe, causing impacts to the cities themselves and their surroundings - immediate or not [9].

In a natural ecosystem, waste from one species is food to another, so matter and energy can circulate continuously [10]. A similar concept applies to urban areas, where converting waste into valuable resources fosters a circular urban metabolism. This process

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helps close the loops of water, materials, and energy, contributing to the development of sustainable communities. [12,13]. Hence, potential future alternatives that need to be explored include the stepwise reduction of landfilling by the introduction of composting [14,15], anaerobic digestion, and mechanical-biological treatment [16]. Sustainable waste treatment should be capable of recovering the raw material to conserve natural resources; this can be achieved through total waste utilization or recycling of all effluents generated in the treatment [17]. In this sense, composting of organic waste is one of the most advantageous techniques for the recovery of organic solid waste (OSW), mainly because it generates organic compost that can be made into an excellent organic soil conditioner compound fertilizer [18].

Composting of organic waste is a controlled process of transforming the organic waste into a conditioning compound (fertilizer), with the aid of microorganisms and temperature monitoring, which can happen aerobically or anaerobically [15]. In Brazil, the largest share (50% - 51.4%) of MSW is composed of organic matter [3,19]; however, composting is rarely used as a treatment technology, mostly due to issues of lack of public support, institutional vulnerability, political-administrative discontinuities and negative impacts on the neighborhood, such as bad smell and attraction of animals [20,21]. In 2008, only 3.8% of Brazilian municipals had access to composting plants and about 11.6% of municipalities sent municipal solid waste to recycling plants [7]. During agricultural harvests, several nutrients are removed from the soil (Nitrogen, Phosphorus, Potassium, Iron, etc.) that are not replanted by synthetic fertilizers. When the material generated by the composting process is used as fertilizer in the crops, these nutrients are returned to the soil, featuring an organic recycling model, which also promotes soil aeration and drainage, as direct advantages [22]. Massukado [23], in his experiment, visually compared the difference, in the cultivation of carrots and beets, with and without the use of organic compost vs. synthetic fertilizers, as shown in **Figure 1**.

Figure 1. Visual test to evaluate the performance of carrot and beet growth in an area without compost with synthetic fertilizer (on the left) and an area with the addition of organic compost (on the right) [23].

There are national researches that deal with the integrated management of solid waste in Brazilian cities, based on environmental and economic analyses [6,24,25]. The term "integrated" means not only disposing of the waste in a proper place for its environmentally correct final destination but also considering treatments and alternatives available to reduce the amount of material that will inevitably go to the landfill. The following are the environmental analyses [26]. Mersoni eande Reichert [27] evaluated the environmental performance of five MSW management scenarios for a Brazilian city with 32,000 inhabitants, using the Life Cycle Assessment (LCA) technique. Such scenarios integrated recycling, composting, anaerobic digestion, and incineration processes, compared to a base scenario that only considered landfills. All scenarios that included treatments such as composting performed better than the scenario that included only the final disposal in the landfill. The authors concluded, among other aspects, that the return of the material to the environment reduced the potential environmental impacts in the analyzed scenarios. To achieve this objective, an arrangement of technological alternatives for recycling the different types of MSW should be established on a case-by-case basis. To compare the benefits of different management systems, they suggest that stakeholders include economic and social criteria for the location, considering the premises of sustainable development. [27].

Marchi [28] developed a theoretical model for the Installation and Management of Solid Waste Disposal Equipment, aiming to offer a more comprehensive alternative than the technical-operational models, which are more widespread in the literature. The author stressed the importance of considering environmental and management aspects in studies of this type and concluded that city halls act in a technically correct way when implementing landfills in cities, but they end up becoming open-air dumps due to poor management. operational, lack of technically qualified personnel to operate the equipment, and lack of financial resources. Siqueira and Abreu [29] discuss the challenges of implementing the composting process in Brazilian cities, mainly due to the difficulty in separating organic waste from inorganic and tailings. The authors inform that the final quality of the compost is directly related to such segregation and that it must be done at the generating source. In addition, selective collection is also fundamental to the success of the system. The research reports that there was a widespread spread of sorting and composting plants throughout the country during the 1980s, which failed due to the lack of appropriate technical planning. Such an unsuccessful experience seems to be the cause of the low acceptance of composting as a solution to MSW among public managers. The work also analyzes the issue of selective collection in Brazilian cities in the last 20 years, informing that, when it exists, it is focused only on inorganic residues (paper, plastic, metal, etc.), and not on organic ones (food scraps and pruning), as the former are more commercially valued. Given the above, the authors warn of the idea of resuming composting along the same lines of centralization and without selective collection of organics, as an unsustainable model that extends the social and environmental interests of the municipalities [29].

Jacobi and Besen [30] provide a Brazilian overview of the sustainability challenges for the management of MSW, informing that there is a growing investment by the federal government in infrastructure, with the construction of sanitary landfills and sorting and composting plants, among others. However, the national scenario highlights the responsibility and the need to commit local management (city halls) to more sustainable choices: both economically (low cost), and in the sense of technologies compatible with the municipal context in question. The authors reinforce the need to reduce waste in generating sources and to be disposed of in landfills, through a well-designed and agreed waste plan with society. They also highlight, in line with the PNRS, that landfill should not be seen as a final solution, but rather as an alternative to waste that is not subject to other previous treatments; and that incineration is not a good solution, from the point of view of environmental sustainability. Both cases can contribute to the harmful consumption patterns in force [30]. Finally, they comment that there is a “vicious circle”, based on economic interests in private contracts, which makes it difficult to abandon grounding systems. They then determine that the major challenge for MSW management is to reverse this logic, investing in the reduction of excessive waste generation, selective collection, and composting - to the detriment of the final destination in landfills. [30].

The theme of the Clean Development Mechanism (CDM) has been addressed with projects that reduce landfill participation in MSW management [31]. Prioritizing other types of waste treatment would be a smarter guideline for developing countries, which have not yet been able to massively implement WL [32]. The studies presented point to the need to reduce the volume of MSW to be sent to landfills through alternatives that prioritize the return of matter to the environment, in decentralized models.

Regarding the selection criteria, it should be remembered that in Brazil, around 50% of the MSW is organic [33]. As WL is a costly device with a short life span (20 years on average), composting appears to be a good strategy for reducing the amount of grounded

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MSW, especially through the UFSC Composting Method, which proposes the composting using passive aeration static windrows [34]. In addition, several studies present insights into the benefits of organic waste recycling through composting over the landfill, in terms of landfill life extension, compost product, and mitigation of greenhouse gases [34,35]. There are also surveys where economic analyses have been carried out.

Garré et al [36] carried out a feasibility study for a sorting and composting plant in the municipality of Pelotas, RS (320,000 inhabitants), establishing results that point to the economic viability of the model, in addition to socio-environmental advantages. The study's proposal is a large-scale plant that receives heterogeneous material - different from the studies directed at environmental analysis, previously presented. Gunaruwan and Gunasekara [37] carried out a comparative assessment of two composting plants in Sri Lanka, having concluded the technical and economic feasibility of both. The study indicates that the plants are not attractive to private investors, but they could receive government subsidies or improve their financial performance to become commercially viable. For one of the evaluated models, the authors believe that if the plant were less expensive and generated more compost production, it would enter a financially attractive limit. Specifically on this topic, the study makes it clear that the high capital invested is questionable, as it excludes the financial attractiveness of these plants. He also mentions that some local administrations seem to have been successful in the implementation and administration of composting facilities with much smaller investments. Finally, it indicates the possibility of using compost in networks of establishments that generate large amounts of organic waste, such as markets [37].

Wartchow et al [38] carried out a case study in the municipality of Ijuí, Rio Grande do Sul - which has about 83,000 inhabitants - comparing 4 scenarios for the management of household solid waste, using the Net Present Value (NPV) method. The scenarios considered different arrangements between composting and WL, or just WL. For scenarios that included composting, the authors chose the method that uses revolved windrows with air insufflation, and the solutions varied between sorting and composting plants or just composting (without sorting, with the use of segregated material at the source). The results showed that the scenario that presented the lowest NPV for the costs of MSW management was the one that established the composting of 45% of the waste considering the segregation of organic waste in the generating source (households). In addition to greater global efficiency, the authors highlighted 3 other financial advantages in this scenario:

reduced costs of transporting waste to the WL and also with treatment of leachate in the WL (by reducing the amount of material sent there), and savings on cleaning urban public health. [38].

Finally, the study by Pandyaswargo and Premakumara [39] is presented, which analyzed the cost-benefit of plants at different scales in developing Asian countries. All the plants studied had some type of financial support from governments, universities, and donor agencies. To construct the analysis, the authors evaluated four scenarios, the worst of which was the absence of any financial support. Throughout the study, relevant information is presented. The authors report, for example, that the chosen composting method directly influences the plant's operating costs: traditional windmills require more labor, while sophisticated technologies require greater electricity consumption - which can mean heavy costs in locations where energy costs more. Also worth noting is the information that all evaluated plants receive financial return through the sale of organic compost, and the smaller the scale of the plant, the greater the control over the final quality of the compost - which increases the market value of the compost. Finally, it was reported that the cost of transportation is highly significant in large-scale plants, which can make them unprofitable [39]. The results of the study showed that the medium and low-large-scale plants (51 and 200 t/day, respectively) obtained the best economic performances, to the detriment of the large and small-scale plants. However, the two small-scale plants evaluated proved financially viable, even though they offer low profitability. The authors indicate that in such cases, the government can play the role of provider of investment costs [39].

After analyzing the studies presented, it was concluded that composting - associated with a means of final disposal, such as a landfill - seems to be a good solution for waste management in small cities in developing countries. With only 2 exceptions [27,38], all the composting cases analyzed by the authors above are on a community scale (educational institutions, condominiums) or in large and medium-sized cities, such as São Paulo, Pelotas, and some foreign cities. Among the exceptions which evaluated cities between 32,000 and 85,000 inhabitants), the authors did not inform the composting method used or if it was a method with slightly more improved technology (windrows revolved with air insufflation) [27,38].

The literature review revealed a research gap regarding the potential to link landfills with a low-tech composting approach and decentralized implementation. This integration could enhance waste management strategies in Brazilian cities with populations of up to 50,000. Notably, around 80% of Brazilian municipalities fall within this population range. [40], so this is a relevant contingent to be considered as the focus of MSW policies. Consequently, to reduce environmental impacts, taking into account the premises of sustainability and the closing of the cycle of materials locally, the following hypothesis was launched: Analyze the probability of the association of Municipal Composting (under the UFSC Method in decentralized implementation) with the Landfill, as a way of improving strategies for waste management in small Brazilian cities.

To evaluate this hypothesis, this work aims to present a practical case study in the city of Paraíba do Sul, in the form of a comparative evaluation of two possible scenarios for Municipal Solid Waste (MSW) Management, one of which with the proposed association municipal composting with landfill, using economic cost and sustainability indicators. The novelty of this work is to apply the UFSC Method associated with the Landfill for small cities in Brazil. As landfill is an expensive and short-lived device (20 years on average), composting may be a strategy to reduce the amount of landfill MSW and extend its useful life. It is recognized that despite the inherent limitations of conducting a case study, the results will serve as a benchmark for Brazil to be applied in Brazilian cities with up to 50,000 inhabitants. The research presented here was motivated by the lack of practical studies on this theme.

The waste management in the city of Paraíba do Sul, in the state of Rio de Janeiro is unsatisfactory. The city is located in the central region of the state, 138 km from the state capital, with a total area of 587.68 km², and an estimated population in 2016 of 42,737 people. The municipality has a largely rural area, but it is in its urbanized stretch (about 10 km²) where about 88% of the population concentrates [40]. The daily amount of MSW collected in the municipality is 23.5 tons per day since it is split into 0.55 kg per inhabitant per day when related to the population of the municipality. The gravimetric composition of the waste in the region where the city is located is 53.63% organic matter, 20.31% plastic, 16.08% paper, 2.84% glass, 1.74% metal, and 5.40% of other residues [41–43].

Costs for urban sanitation services in the city of Paraíba do Sul are high with the MSW management expenditure exceeding 13% of the total annual municipal expenditure amount [42]. The city lacks a Municipal Plan for Integrated Solid Waste Management (MPISWM) [44]; the process for the execution of the study is still in the bidding stage through the Paraíba do Sul Middle Committee. The municipality has only completed the

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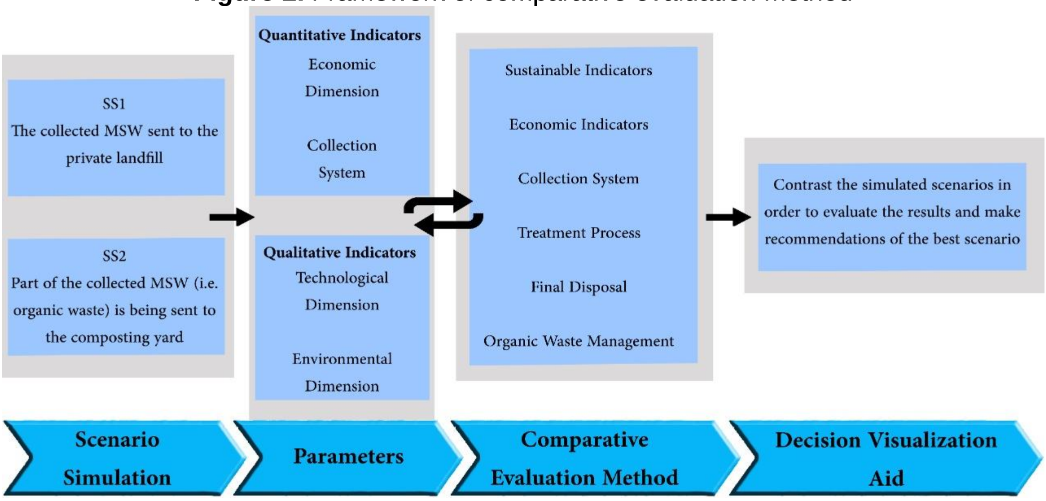
Municipal Basic Sanitation Plan (MBSP), but because it has more than 20,000 inhabitants, it must have the MPISWM independent of the MBSP [42]. After this brief description of the city of the case study, in the next section, an overview of the method adopted will be presented, followed by results, discussion, and conclusion.

COMPARATIVE EVALUATION METHOD

The methodology used in this work was quantitative and qualitative exploratory research, evaluating aspects of economic costs and strategies related to the sustainable development of the data collected. The quantitative research is based on the estimate of MSW generation (total and organic of large generators in tons per month), cost estimation for collection (conventional and selective to organic waste); and estimate of costs for final disposal and waste treatment (Landfill and Municipal Composting Courtyard). The qualitative research uses sustainability indicators, to evaluate the proposed scenarios of this research.

The comparative evaluation method will be applied to two scenarios simulated under quantitative and qualitative parameters. The quantitative parameters refer to the economic dimension and the collection system, and the qualitative parameters refer to the technological and environmental dimensions. Finally, both scenarios will be compared to evaluate the results and make recommendations for the best scenario, as can be noticed from the framework in **Figure 2**.

Figure 2. Framework of comparative evaluation method



Thus, the objective of this work is validate the hypothesis presented, through the evaluation of these two simulated scenarios of Solid Urban Waste Management for

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Brazilian cities up to 50,000 inhabitants, using economic cost indicators (for collection, treatment and final disposal) and sustainability (technological and environmental dimensions). It also aims to propose a complementary strategy to the landfill, given the urban scale of cities up to 50.000 inhabitants, and the possibility of a more sustainable treatment of MSW, using the composting of its organic fraction.

The first scenario evaluated - Simulated Scenario 1 - involves sending of all MSW collected to a Private Landfill (PL). The second scenario evaluated - Simulated Scenario 2 - involves sending of the segregated organic waste at source to a new composting yard, named “Municipal Composting Yard” (MCY). Such waste would only be collected from large generators, and would also include municipal pruning waste. The remaining MSW would be sent to PL. It is important to highlight two factors related to the successful application of the composting process at the municipal level, in Scenario 2: the MCY implementation model and the selective collection of organic waste previously segregated at the source of production (which are the major generators of organic waste, such as restaurants and fairs).

MCY will follow the decentralized deployment model, which is a model located close to generating sources and receives waste from a few groups (characterized by urban, institutional/corporate, community and / or domestic composting yards) [21],which has been proven to be the most efficient and long-lived in previous studies [21]. Thus, the yard will serve only some neighbourhoods of an intentional profile. The UFSC Composting Method was chosen for use in MCY because it works with previously segregated waste collected from large generators (restaurants, markets, fairs, etc. besides municipal pruning waste, abundant in the municipality). In this method, the windrows have a dry vegetal cover, which allows the passive aeration of the internal material and prevents the access of animals such as flies and rats, as shown in **Figure 3**. This means that the process is less expensive because it does not require constant material revolving, and more effective, as it avoids impacts on the neighborhood related to smell and attraction of animals - the responsibility for the closure of most composting units [21].

Figure 3. Composting windrows by UFSC Method [33]

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CASE STUDY: PARAÍBA DO SUL, RJ

The sample used in this research was composed of ten districts of the municipal headquarters of Paraíba do Sul, chosen due to they are located in the central nucleus of the municipality with high population density and because they have a great concentration of organic waste generators. This is a representative sample of the study universe, since most of the inhabitants are present at the municipal headquarters and, therefore, is where the largest portion of MSW is generated [45]. Next, the instruments, sources, and parameters of the research method for each of the quantitative and qualitative indicators, proposed in the evaluation of the scenarios simulated in this case study, will be presented.

QUANTITATIVE INDICATORS

Economic cost indicator - municipal solid waste generation estimates

Two estimates of waste generation were made: total MSW (heterogeneous) and OSW of large generators. To define such quantities, a survey of the area and population of the proposed neighborhood cut was carried out. To define the area and population of this section, data from the Territorial Development Master Plan of Paraíba do Sul were used. The total amount of MSW collected in this universe was estimated, in tons per day, based on the 0.55kg/inhab/day [41–43].

To identify and select the large generators of OSW, a survey was made in the municipal register of companies and the survey of the areas of such establishments, in m² - information that was used to estimate the amount of waste generated. According to [46], the main generators of OSW are restaurants, snack bars, juice shops, fruit and vegetables, markets, producers of food for delivery, and hotels.

The amount of OSW generated in the selected establishments was derived from COMLURB [47], which indicates the following estimates: 0.70 litres/day/m² for stores, hotels, and inns and 1.00 liter/day/m² for restaurants, snack bars, and the like. The quantities found in liters refer to the heterogeneous residue and were converted from volume to weight, using the PROSAB index [48], which defines the average density of 300 kg/m³ for the newly collected MSW. To define the compostable quantities, the heterogeneous quantities were multiplied by 0.50, since the organic fraction is about half of the total waste, by weight [33].

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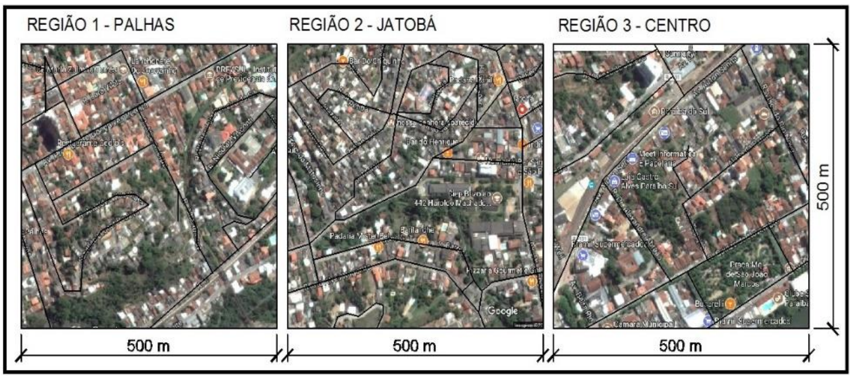
Economic Cost indicator - collection cost estimates

Two estimates of collection costs were made: cost of conventional collection and cost of selective collection of organics from large generators. Such estimates are composed of: vehicle fuel consumption and employee salaries. To produce maps with the collection routes [46], Google Maps digital system, with its Routes and Markers functionalities, was used to identify the relevant travel routes.

For the average fuel consumption of the vehicles, the collection vehicles and the distances to be covered in both types of collection were defined: for conventional collection, the compacting truck with a capacity of 19m³ - corresponding to 5.7 t of waste [48] was adopted, while for selective collection, a truck with an open body model Ford F-4000 was simulated [45]. Two types of distances (km/month) were defined for each type of collection: distance D1, referring to the logistics of waste already collected up to its final destination; and distance D2 - referring to home-to-home collection. In the conventional collection, D1 is the distance between the urban center of Paraíba do Sul and Três Rios Private Landfill (TRPL); in the selective collection, D1 is the distance between the urban center and the MCY. The distance D2 was the same in both collections: to define it, three regions of the proposed neighborhood cut were mapped, and the mileage of its streets was measured using the AutoCAD software.

Regions with different street patterns were chosen to reach an average representative of the spatial profile. Each region has 0.25 km², and the average of the 3 regions is 2.9 km of streets - so, by means of a rule of 3, 1 km² is equivalent to 11.6 km of streets (**Figure 4**). From the 3 regions, the others were estimated by the total area of each neighborhood, as shown in table 1. Thus, there is an estimated D2 of 113 km of streets to be traveled by conventional and selective collection trucks.

Figure 4. Maps of the 3 regions chosen in the proposed neighborhood section, to define the mileage of the collection routes



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To calculate fuel consumption, Lino's (2009) estimate was used: 0.433 L/km. Diesel oil used in trucks cost about R $ 3.254/L in November 2017, in the Paraíba do Sul region - a value defined from the average between the values of the cities: Rio de Janeiro, Sapucaia and Teresópolis, available on the National Petroleum Agency [49].

Collectors 'and drivers' salaries were estimated through [50]: R $ 478.73 and R $ 500.00, respectively - and adjusted according to the National Consumer Price Index (INPC) [51]. The current minimum wage in 2017 (R $ 937.00) was used for adjusted values below this.

In Scenario 1, conventional collection is simulated once a day, except for Sundays (average of 28 days/month), performed by four employees in each truck.

In Scenario 2, in addition to conventional collection (in the same way as described for Scenario 1), selective organic collection is simulated, also under an average of 28 days/month, but by two employees in each truck. In this scenario, the use of 50 L plastic drums to simulate OSW in generating sources is simulated. Full bombs will be offered for collection and emptied at the MCY. At the time of collection, empty canisters will be delivered to the generators, configuring a cycle of containers that are not disposable and will be purchased by the generators - not comprising costs for the management of municipal MSW.

It is noteworthy that the model proposed for Scenario 2 contemplates the segregation of organic waste from the others, to be carried out by the large generators before offering them for collection - thus not composing any cost for the administration of the system (city hall).

Economic Cost indicator - final disposal and waste treatment cost estimates

Final disposal and treatment costs were estimated based on three definitions: Costs for final disposal at TRPL; Costs for MCY implementation and monthly operation; and Monthly revenue from marketing the compost.

To determine the costs of the final disposal at TRPL, the amount of R $ 54.25 /t, as described in the National Solid Waste Plan [44], was corrected, according to the Broad Consumer Price Index (IPCA), in November 2017 [51]. For Scenario 1, all generated MSW was considered. For Scenario 2, in the monthly calculation of the generation of heterogeneous waste, the generation of organics from the large generators was subtracted.

To determine the costs of implementing the MCY, the UFSC Method was first defined under the Decentralized Implementation / Management Model, according to its suitability for the proposed case study. The costs of implementing the MCY were estimated globally, in reais (R$), through manuals and similar case studies [46], and corrected according to the Broad Consumer Price Index
(IPCA) [51].

MCY's monthly operating costs were estimated in a unitary manner, taking into account employee salaries and fixed operating costs. MMA [46] indicates the need for only one professional - Revirador de Leira -, according to the demographic parameter closest to this study. Such reference was used, considering the need for two more employees: an Administrative Assistant and a Yard Assistant. The employees' salaries described in the document - R $ 1,041.01, R $ 1,163.71, and R $ 612.00, respectively [46] - were adjusted according to the National Consumer Price Index (INPC) [51]- November 2017 for fixed operating costs, the water and energy consumption values of the MCY were estimated, according to CAOPMA [52] - namely: R $ 150.00 per month, referring to the sum of both. For inflation adjustment, the General Market Price Index “IGPM” was used in November 2017.

Determining the revenue from the commercialization of the compost, the quantity generated was first estimated. According to MMA [46], "for each kilo of waste delivered to the unit, [produces] half a kilo of compost". Thus, the calculated estimate of OSW received at the MCY was multiplied by 0.5. According to a survey in the local market, the average price of 1 kg of compost is R$ 15.00. It was decided to simulate a price below the market value, to promote the local closing of the OSW cycle, selling to small farmers in the region.

QUALITATIVE INDICATORS

This paper presents a qualitative analysis of the proposed scenarios applied to sustainability indicators, mainly related to the circularity of materials, the generation of employment and income, the increase of landfill life, and the prioritization of local solutions based on the previous research of Santiago et al. [53]. Traditionally, six dimensions of sustainability are often assessed, namely: politics; technology; economic and financial; environmental and ecological; knowledge dimension (environmental education and social mobilization); and the dimension of social inclusion [53]. The applicability of indicators of the Political and Economic dimensions would be difficult to apply as the evaluation of two

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simulated scenarios for waste management were developed in the municipality and not for the country.

The indicators proposed in the Knowledge and Social Inclusion dimensions do not apply to this research, as they relate to specificities within the MSW theme that are not being addressed in this study - such as aspects related to environmental education and inclusion of recyclable waste pickers. Thus, the present research adopts specific indicators of the Technological and Environmental/Ecological dimensions, as shown in **Table 1** and **Table 2**; in the technological dimension, all indicators are used as I2a, I2b, I2c, and I2d. In the environmental and ecological dimension, only the indicators related to solid waste described below will be employed: I4d, I4e, I4f, I4g, I4h, and I4j.

Table 1. Matrix Pattern of Sustainability Indicators to MSW–Technological Dimension [45,53,54]

Dimension	Key question	Indicator	Description	Score
Technological	Does this observe the principles of appropriate technology?	(I2a) Employs local manpower	All phases of solid waste management	5
			Collection and administration	3
			Only collection	1
		(I2b) Maintenance of the equipment made locally	All phases of solid waste management	5
			Only transport	2
			External maintenance	1
		(I2c) Reuse technology with low energy consumption, non-trailer patents, and royalties; easy handling; employs local manpower	Comprises all items	5
			Only low energy consumption and non-trailer royalties and patents	3
			Non-attendance	0
		(I2d) Specific collector vehicle appropriate in terms of capacity, size for local generation needs	Yes (only for this function)	5
			Yes (also used in other municipal functions)	2
			Non-attendance	0
		MAXIMUM SUBTOTAL		20

Table 2. Matrix Pattern of sustainability indicators to MSW – Environmental/Ecological Dimension [45,53]

Dimension	Key question	Indicator	Description	Score
Environmental / Ecological	Minimal environmental impact?	(I4a) Collection efficiency	91 to 100%	5
			31 to 90%	2
			< 30%	1
		(I4b) Population satisfaction with public collection (periodicity/frequency/schedule)	> 70%	5
			30 to 70%	3
			< 30%	1

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		(I4c) Existence of public cans	In the whole urban area, in places where people move	5
			Only in the downtown of the municipal core	2
			Does not have cans	0
		(I4d) Existence of selective collection in the city	Yes	5
			In the deployment phase	3
			Does not exist	0
		(I4e) Coverage of selective collection in the city	The whole city	5
			The whole urban area of the city	4
			Exclusively in some neighborhoods of the urban area	1
		(I4f) Existence of places for the voluntary offer of segregated waste	Serves more than 50% of the population	5
			Serves less than 50% of the population	3
			Does not have	0
		(I4g) Rate of recovery of the recyclable materials Recovery rate of recyclable materials	Above 10,1%	5
			Between 5,1 and 10%	3
			Up to 5%	1
		(I4h) Recovery of organic waste	Above 30%	5
			Between 5,1 and 30%	3
			Up to 5%	1
		(I4i) Municipal solid waste generation *per capita (kg / person / year)*	< 307	5
			Between 307 and 376	3
			> 376	1
		(I4j) Licensed Landfill / Licensed Controlled Dump	Yes	5
			In the licensing process	2
			Not licensed or dumping ground	0
		(I4l) Existence of landfill to inert waste (construction and demolition waste)	Yes, with reuse	5
			Yes, only to disposal	2
			Does not have	0
		(I4m) Number of clandestine waste places / total extension of roads in km	Neither	5
			0,1 to 0,4	3
			≥ 0,4	1
		(I4n) Is there a recovery of degraded areas by waste?	Wholly	5
			Partially	3
			Non-attendance	0
		MAXIMUM SUBTOTAL		65

RESULTS

After exposing the method applied in the case study city, the results will be presented to test the hypothesis of this work.

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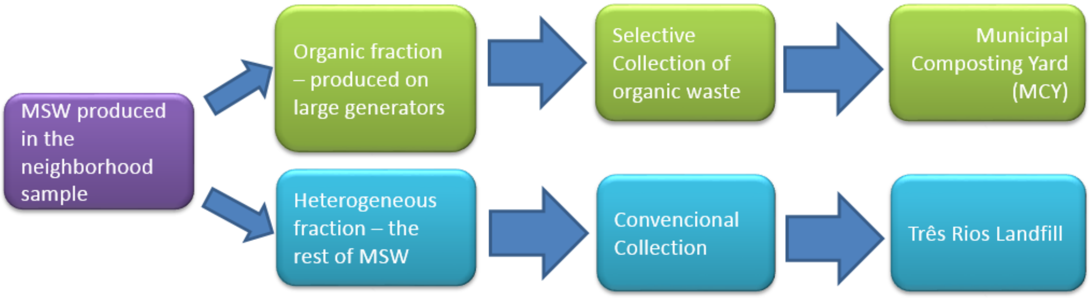
SCENARIOS PRESENTATION

Scenario 1 contemplates sending all MSW to TRPL. **Figure 5**, demonstrates the flowchart for this scenario.

Figure 5. Scenario 1 flowchart [45]

Scenario 2 is a model in which the organic fraction of large generators would be sent to a municipal compost yard, and the other MSW would continue to be sent to TRPL, as shown in **Figure 6**. Inorganic MSW and hazards would be sent to the Três Rios landfill, as there is neither the technical capacity nor the financial resources to treat locally or give an environmentally appropriate final destination for these types of waste.

Figure 6. Scenario 2 flow chart [45]



Economic Cost Indicator - municipal solid waste generation estimates

The ten neighborhoods contemplated in the proposed spatial cutout make up the continuous urban fabric of the municipality. They are: "Bela Vista", "Brocotó", "Centro", "Cerâmica D'Angelo", "Grama", "Jatobá", "Lavapés", "Niagara", "Palhas" and "Parque Morone", as presented in **Figure 7**. The neighborhoods "Limoeiro", "Liberdade", "Santo Antônio" and 'Fernandó", despite being in the same urban spot on the map, have morphological characteristics or boundaries that make them stand out from the others, such as the presence of a highway or the accentuated relief [55].

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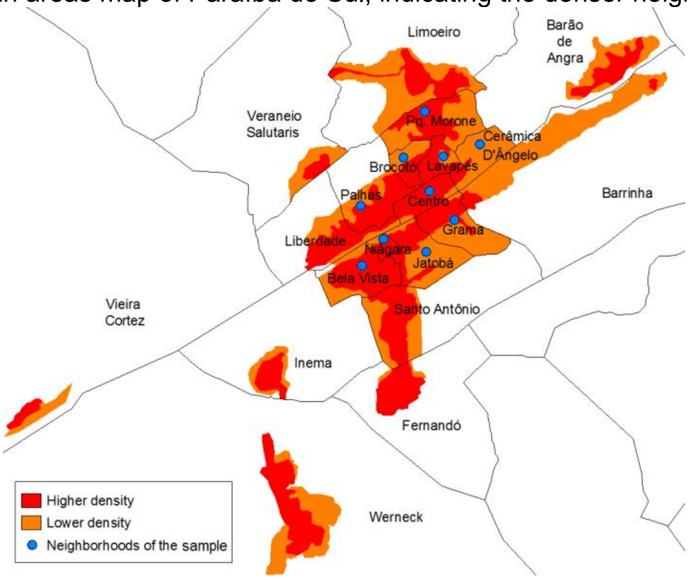
Figure 7. Urban areas map of Paraíba do Sul, indicating the denser neighborhoods [45]



As described in the Territorial Development Master Plan of Paraíba do Sul, 88% of the municipal population of Paraíba do Sul is concentrated in densely populated urban areas [41–43]. Being the total population (100%) of the municipality of 42,737 inhabitants, the percentage of 88% results in 37,608 inhabitants. From this demographic data, and from the sum of all areas, 37,608 people live in 9.68 km².

For the cut-off neighborhoods, the sum of occupied areas is 4.61 km². From this and the previous data (37,608 people live in 9.68 km²), a rule of three was used to define the population of the cutout neighborhoods, obtaining the population of 17,910 inhabitants in the cutout neighborhoods. Thus, the area studied in this case study has 4.61 km², and its respective population is 17,910 inhabitants [45].

From the data of 0.55 kg / inhab / day, and the total population of the spatial area (17,910 inhab.). There is a production of 9.85 t/day of MSW in the analyzed neighborhoods, which becomes 305, 4 t/month [41–43]. It is important to remember that, in Scenario 1, all this production will be displayed in TRPL. In Scenario 2, this value will be lower, when subtracting the organic fraction of the large generators.

The document obtained from the Municipal Register of Companies, in March 2017, organizes companies by activity categories and makes their addresses available. 12 categories/activities were selected as major generators in this case study. From the sum of establishments, we have that the total of large organic SR generators contemplated in this research is 95 establishments.

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Estimating the production of organic waste to be sent to the MCY, the procedure described in Method was carried out, which relates the generation of waste to the areas and functions of the establishments - according to COMLURB [47]. **Table 3** shows the sum of the areas of establishments by category, followed by the total production of waste in the category, and finally the total generation of MSW in all categories.

Table 3. Areas and total production of heterogeneous waste from large generating establishments in Paraíba do Sul

Property category	Area (m²)	MSW production (litres/day)
Com. Retail. Of horticultural products	734	513,80
Com. Retail. Vegetables	86	60,20
Com. Retail. Merc. In general, with predominance. Food	668	467,60
Prov. Prepared food for companies	72	72
Hotel	4166	2916,20
Snack bar	1686	1686
Snack bars, tea houses, juices and similar	2323	2323
Mini Market	342	239,4
Alimony	262	262
Pizzeria	401	401
Restaurants and similar	2346	2346
Supermarket	1947	1362
Total heterogeneous MSW of all categories (liters/day)		12650,10
Cubic meters to kilograms (density MSW = 300 kg / m³)		3.795 kg

The organic fraction was calculated according to the procedure described in Method, reaching an estimated production of 1.9 t/day of OSW in the large generators, which converts to 58.9 t/month - the amount of OSW that will be sent to the MCY, in Scenario 2. The amount of heterogeneous waste to be sent to TRPL in Scenario 2 is 7.95 t/day, which converts to 246.5 t/month.

Cost indicator - collection cost estimates

Table 4 shows the number of compactor trucks to meet the estimate of total MSW generation in the cutout for collection in the chosen neighborhoods. It also presents the distances D1 and D2, fuel costs, and costs of employee salaries. The number of employees for conventional MSW collection was defined in this way: 3 collectors and 1 driver per truck, totaling 6 collectors and 2 drivers.

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Table 4. Estimated costs of conventional MSW collection

Total MSW	9,85t/day
Compactor truck capacity	19m³ (5,7t)
Number of compacting trucks	2
D1 (km / month)	17.8 km per trip x 4 71.2 km / day in total x 28 days 1,994 km / month
D2 (km / month)	113 km / day for 28 days D2 = 3,164 km / month
D1 + D2	5,158 km / month
Monthly fuel cost	*average consumption of 2,233 L/month* value of diesel per liter (R$ 3.254) approximate amount R $ 7,500.00 / month
Monthly salary cost (8 employees)	R $ 7,532.46 / month
Total cost	R $ 15,032.46 / month

Table 5 shows the number of trucks needed for the selective collection of organics in the 95 large establishments. It also shows the distances D1 and D2, fuel costs, and costs of employee salaries. The location chosen for the installation of the MCY is on a road at an appropriate distance from the urban core. The distance from the MCY to the cutout neighborhoods (D1) is about 3 km. The number of employees for conventional MSW collection was defined in this way: 1 collector and 1 driver per truck, totalling 2 collectors and 2 drivers.

Table 5. Estimated costs of selective collection of MSW

MSW	1.9t / day
Capacity of the Ford F-4000 model truck with open body measures 6.5m x 2.5m	96 50L drums per trip 1.44t capacity of waste per trip
Number of compacting trucks	2
D1 (km / month)	3 km per trip x 4 12 km / day in total x 28 days 336 km / month
D2 (km / month)	113 km / day for 28 days D2 = 3,164 km / month
D1 + D2	3,500 km / month
Monthly fuel cost	average consumption of 1,515 L / month value of diesel per liter (R $ 3.254) approximate amount R $ 5,000.00 / month
Monthly salary cost (4 employees)	R $ 3,784.46 / month
Total cost	8,784.46 / month

Cost indicator - final disposal and waste treatment cost estimates

Table 6 presents the costs for the final disposal of waste at the landfill, in Scenario 1 and Scenario 2. The corrected value in November 2017 was R$ 92.15 /t.

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Table 6. Final disposal cost in TRPL - Scenario 1e Scenario 2

Scenario 1 cost		Scenario 2 cost	
Total amount of MSW	305.4 t / month	Total amount of MSW	246.5 t / month
Value of MSW / t	92,15/t	Value of MSW / t	92,15/t
Approximate total amount	R $ 28,500.00 / month	Approximate total amount	R $ 23,000.00 / month

For the present case study, the value of Jardim (1995), corrected in November 2017: R $ 85,340.00, was used, approximating the value of R $ 90,000.00. **Table 7** shows the operating costs of the MCY - reference values corrected in November 2017.

Table 7. Estimated costs for operating the MCY. Adapted from MMA [46] and CAOPMA [52]

Items		Reference value (R$)	Corrected amount (R$)
Water and energy bills		150,00	222,53
FUNC.	Windmill turner	1.041,01	1.619,68
	Administrative assistant	1.163,71	1.810,59
	Yard Assistant	612,00	952,20
Total corrected (approximated)			4.605,00 (R$ 5.000,00)

Based on the estimated amount of OSW received at the MCY (58.9 t / month), multiplied by 0.5, there is an estimated production of 29.4 t / month of compost. The value of R $ 2.00 was stipulated for the commercialization of the 1 kg bag of compost produced at MCY - a value well below that raised in the local market (R $ 15.00 / kg). Then, there is an estimated monthly revenue of R $ 58,800.00, which can be rounded up to R $ 55,000.00 / month. Finally, **Table 8** presents a summary of all cost indicators.

Table 8. Summary of cost indicators

Summary of cost indicators			
	description	Quant. / Order of Greatness	unit
1	Estimated total MSW quantity	305,4	t/month
	GG organic fraction quantity estimate	58,9	t/month
	Estimated quantity RSU (-) organic fraction GG	246,5	t/month
2	Conventional collection cost	15.032,46 (15.500,00)	R$/month
	Large organic selective collection cost ger.	8.784,46 (9.000,00)	R$/month
3	Final disposal cost AS for Scenario 21 (all MSW)	28.142,61 (28.500,00)	R$/month
	Final disposal cost AS for Scenario 2 (MSW except organic GG)	22.714,97 (23.000,00)	R$/month
	MCY deployment cost	85.340,00 (90.000,00)	R$
	Monthly MCY operation cost	4.605 (5.000,00)	R$/month

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	Estimated revenue from marketing the compost	58.800,00 (55.000,00)	R$/month

QUALITATIVE INDICATORS – MATRIX TECHNOLOGY

For indicator I2a, “Uses local labor”, both scenarios scored 3 points, referring to the collection and administration phases. As the other phases of MSW management may require specialized labor - which is not always found in the city - it was decided to mark only these two. For MCY technical management, for example, it is important to have a professional or consultant who specializes in soil and composting techniques. Also the shipment of waste to a WL outside the municipality, by itself, already characterizes external agents. It is noteworthy that waste collection management is currently performed by an outsourced company, but in both scenarios, it is simulated that the city assumes this service.

The second indicator, I2b, “Equipment maintenance performed locally”, scored 5 for both SS, referring to all management phases, since the equipment used is simple and its maintenance is easily found in the city.

Indicator I2c, “Energy-efficient reuse technology, not linked to payment of patents and royalties; easy handling; employs local labor”, did not score any points for Scenario 1 as it does not foresee any reuse technology. For Scenario 2, it scored 5 points, because the utilization model proposed in the simulation (UFSC Composting Method) includes all the described items.

Finally, indicator I2d, “Capacity-specific and size-appropriate collection vehicle for local generation needs”, scored 5 points for Scenario 1 as the conventional collection truck (compactor) is for single use only. MSW management. For Scenario 2, the indicator scored 2 points, as the organic pickup truck (open body) could be used for other municipal functions. Thus, the total score of the Technology Matrix was 13 and 15, respectively for Scenario 1 and Scenario 2.

Environmental and ecological matrix

The indicators I4a, I4b, I4c, I4i, I4l, I4m, and I4n do not apply to the scenarios simulated in this paper, namely: “Collection efficiency”; “Satisfaction of the population regarding collection”; “Existence of public dumps”; “MSW generation per capita”; “Existence of landfill for inert waste”; “Number of clandestine waste points”; and “There is the recovery of areas degraded by waste”, respectively.

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For indicator I4d, “Existence of selective collection in the municipality”, Scenario 1 did not score points, as this scenario does not provide for this solution. Scenario 2 scored 5 points, referring to the full existence of selective collection.

Indicator I4e, “Scope of the selective collection in the municipality”, also did not score for Scenario 1, as it does not apply. Regarding Scenario 2, it scored 1 point, since the collection of organics serves only some neighborhoods of the urban area.

For indicators I4f, “Existence of points for voluntary disposal of segregated waste”, and I4g, “Recovery index of recyclable materials”, neither scenario scored, as these solutions were not foreseen in either simulation.

In indicator I4h, “Organic waste recovery”, there was no score for Scenario 1. For Scenario 2 there were 3 points, referring to the alternative “Between 5.1% and 30%” of recovery. It is estimated that the total organic waste generated in the municipality is 11.7 t / day since the overall total (heterogeneous MSW) is 23.5 t / day [42] and the organic fraction represents on average 50%. of the total [33]. Thus, the amount of organic waste defined in the case study to be sent to MCY composting (1.9 t/day - referring to the large generators of the cut-off neighborhoods) represents 16.2% of the total 11.7 t/day.

Finally, indicator I4j, “Licensed sanitary and controlled landfill”, scored 5 points in both scenarios, as both simulations predict the use of the TRPL.

Thus, the total score of the Environmental / Ecological Matrix was 5 and 14, respectively for Scenario 1 and Scenario 2. **Table 9** below summarizes the sustainability indicators for each scenario.

Table 9. Summary of Sustainability Indicators

SUMMARY OF SUSTAINABILITY INDICATORS				
DIM.	Item	Description	Score Scenario 1	Score Scenario 2
TECHNOLOGICAL DIMENSION	I2a	Local Manpower	3	3
	I2b	Maintenance of equipment made locally	5	5
	I2c	Reuse technology with low energy consumption, non-trailer royalties; easy handling; employs local manpower	0	5
	I2d	Specific and appropriate collector vehicle	5	2
ENVIRONMENTAL / ECOLOGICAL DIMENSION	I4d	Existence of selective collection in the city	0	5
	I4e	Coverage of selective collection in the city	-	1
	I4f	Existence of places for voluntary offer	0	0
	I4g	Index of the recovery rate of recyclable materials	-	-

	I4h	Index of the recovery rate of organic waste	-	3
	I4j	Licensed Landfill / Licensed Controlled Dump	5	5
		TOTALS	18	29

DISCUSSION

From the data obtained, the monthly cost of PMPS [55] for the collection and final disposal of its waste is approximately R $ 44,000.00 for Scenario 1; and approximately R $ 52,500.00 for Scenario 2. **Table 10** below shows a comparison of real and percentage values for the simulated scenarios 1 and 2.

Table 10. Comparison in absolute and percentage values, between the economic cost indicators for Scenario 1 and Scenario 2

Economic Cost Indicators	Scenario 1 **Values (R $)**	Scenario 2 **Values (R $)**	**Percentage observations**
Collection (s)	15.500,00	24.500,00	*Scenario 2 58% more expensive than Scenario 1*
Final Disposal at the Landfill - RS heterogeneous	28.500,00	23.000,00	*Scenario 2 19% cheaper than Scenario 1*
MCY Treatment - RS Organic GG	--	5.000,00	*Scenario 2 only*
TOTALS	44.000,00	52.500,00	*Scenario 2 19% more expensive than Scenario 1*

The difference between the monthly costs between Scenario 1 and Scenario 2 was only R$ 8,500.00, or about 19%, with Scenario 2 being the most expensive. This value is considered low in the scope of the municipal management of MSW, however Paraíba do Sul is a small municipality, which has few resources. Thus, such investment could be required in a program to promote sustainable development initiatives, or in CDM projects - since Scenario 2 includes the composting system.

It is noteworthy that the MCY proposed in this case study would cost approximately R $ 90,000.00 to be implemented in Paraíba do Sul. Such cost is only about one-fifth of the estimated value for the annual relocation of Green ICMS in the city: R $ 449,522.91 [42]. This resource could be required by PMPS [55] in the first year of the destination of the city's waste to TRPL.

Thus, the MCY could be implemented and start operating the following year, generating savings of approximately R $ 5,500.00 / month in the disposal of waste in the TRPL - a value that could be used to finance the monthly operation of the MCY itself (estimated at R $ 5,000.00 monthly).

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In Scenario 2, the sale of compost could generate an average monthly revenue of R $ 55,000.00, an amount that fully covers the costs of waste management in Scenario 2 (R $ 52,500.00). Recalling that this total of R $ 52,500.00 does not consider significant costs, related to the depreciation of equipment, taxes, charges, etc. It is believed that a feasibility study would establish a final value around 30 to 40% higher. Even so, the sale of the compost would bring relevant revenue to be considered in the financing of the system.

In this sense, it is believed that the local market would be able to absorb the amount of compost produced in the MCY since there is great agricultural demand in the region and much of the soil is eroded due to the monoculture of coffee in the 19th century.

Regarding the sustainable indicators applied in this study, the difference of 11 points more for Scenario 2 leaves no doubt about what is the best scenario in the environmental context. We highlight the technological simplicity and the low cost of the method indicated for composting, as well as the existence of selective collection and the utilization of organic waste, as the biggest advantages of Scenario 2 in this sense.

It is also worth mentioning the carbon savings contemplated by the local practice of composting - especially if the compost is commercialized also locally. The use of the compost in local agriculture, to the detriment of synthetic fertilizers, may encourage the cultivation of organic foods in the region, closing the cycle of organic materials. Finally, it is highlighted that the costs not included in the calculations of this case study - namely: depreciation of equipment and trucks, fees, taxes, charges and employee benefits - would not make a significant difference in the comparison between the scenarios. This is because, if included, they would only be added to both scenarios, so that the final difference would remain virtually unchanged. As this work is not a feasibility study, it was not considered appropriate to detail such costs.

The case study presented in this article corroborates the authors of the researched bibliography, in the sense of considering other MSW treatments before the final disposal, as a sustainable strategy for municipal management, aiming at lower environmental impacts [27,28,30,38,39].

The present work reinforces the recommendations of Mersoni and Reichert [27] and Marchi [28], by suggesting that managers take into account environmental and social factors when making decisions about the MSW management model to be implemented in the municipalities, and highlighting that the problem of waste does not seem to be solved by just disposing of it inexpensive landfills.

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In this sense, it is emphasized that the technological simplicity of the proposed composting model for the case study in Paraíba do Sul (UFSC Method) contributes to success in the local context - which can be replicated in several small Brazilian cities. This idea was worked on both by Marchi [28] when commenting on the abandonment of landfills due to a lack of technical capacity and financial resources, and by Jacobi and Besen [30], who highlight the need for commitment by city halls and the technological adequacy of management solutions of MSW.

Also in terms of the operating costs of the composting units, it is interesting to keep it simple, as in the proposed case study. Thus, Pandyaswargo and Premakumara [39] and Wartchow et al [38] reported, and the second study showed savings of 50% in the implementation and operation of simpler plants - which receive segregated material at the source (only compost) - to the detriment of the most complex - that receive heterogeneous waste (sorting and composting).

Regarding the selective collection of organic waste, it is interesting to note that every city has large generators, such as fairs and restaurants - establishments that can easily separate the materials for disposal, offering only organic to the selective collection. The case study presented contributes in this sense, offering a quantitative overview of the generation of OSW in a section of a small Brazilian municipality. The work meets the studies of Gunaruwan and Gunasekara [37], Wartchow et al [38], Pandyaswargo and Premakumara [39], and Siqueira and Abreu [29] that indicate the receipt of segregated waste at the generating source, for efficiency and success of composting units.

Regarding the quantitative assessment (costs), it is recommended to carry out feasibility studies for the implementation and operation of yards or small composting plants, such as the MCY simulated in the case study. The success of similar alternatives seems to point to a favorable path [37,39], but this article did not aim to detail the costs, requiring a more complete and cautious study, which also includes the demand for organic compost in the region - to find out if the model is viable and profitable.

Despite this, it is worth mentioning two factors presented by Pandyaswargo and Premakumara [39] that contribute to the possible success of the strategy adopted in the present case study (the MCY that serves only some neighborhoods in Paraíba do Sul). They are the scale of the unit and the transport. The authors concluded that the smaller the scale, the greater the control over the final quality of the compost - which increases its

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market value; in addition, they reported that transportation costs are very significant at larger plants.

CONCLUSIONS

This paper sought to offer subsidies to a complementary alternative to landfills, which was validated by sustainability indicators, with huge environmental gains: the composting of the MSW organic fraction. It was intended to highlight the importance of considering other solutions before the disposal of waste in landfills by the municipality. The novelty of this work is in including the UFSC Method in a decentralized municipal compost yard for a city with less than 50,000 inhabitants, as well as validating the MSW management proposal by using part of the organic fraction employing sustainability indicators. As landfill is an expensive and short-lived device (20 years on average), in these terms, composting may be a strategy to reduce the amount of landfill MSW. The use of this tool can be adopted as a sustainable development strategy for small municipalities, empowering the decision-making process. It is noteworthy that this project was the first place in the third edition of the Good Environmental Practices Project Competition held by the Paraíba do Sul Middle Committee, in 2018. The contest was intended to disseminate and reward good ideas and successful initiatives. This action is part of the project bank of the CBH-MPS Project Office for possible replication in the municipalities of the Middle Paraíba do Sul basin. It is expected that alternatives such as this may be considered by municipal managers in the future.

This research also collaborated to demonstrate that the sustainable gains of the simulated scenario that contemplated composting were undeniable. Moreover, their costs were not as high as those of the scenario that disregarded such a solution, as common sense might suppose. This result underlies the rationale for considering sustainable alternatives in MSW projects, even though there are few financial resources available. It is understood that market adaptation to sustainable solid waste practices is still necessary in order to acquire the technical capacity to respond to new challenges in the sector. However, this factor cannot prevent the application of such practices in the municipalities - especially the small ones, which have much to gain by adopting sustainable development strategies. There is a challenge to encourage municipalities to invest more and more in the selective collection and composting, thus reducing the amount of material to be sent to landfills and this work certainly sought to offer a new point of view in this regard. Also, the relevance of composting for society at large is noteworthy to foster local and organic agriculture and to

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close the cycle of organic materials. Such materials would otherwise be sent to a landfill or dump where they would impact the environment rather than benefit it. In addition to being valued through composting, they can also generate revenue from the sale of compost. There is an urgent need for a more systemic understanding of the management of MSW in Brazilian cities. As highlighted by Pandyaswargo and Premakumara [39], managers believe that they can be convinced they can change their strategies based on information about the socioenvironmental benefits of composting.

Thus, as an innovation, the proposal to use a low cost composting method, which uses passive aeration static windrows in a decentralized deployment model, being supplied only with waste previously segregated in large generating sources, is a means of achieving efficiency in the context of Brazilian cities up to 50,000 inhabitants who do not have an effective MSW management model. However, this work has some difficulties in obtaining data on the subject of composting organic waste and on MSW. These data are not publicly disclosed and a special request and a delay in obtaining them are required. Hence, more detailed evaluations on the management of composting yards are indicated as a future recommendation by comparing private models against the municipal management of this portion of MSW. Another indication for new works would be the investigation of the existence of demand for organic compost in the central region of Rio de Janeiro state, to evaluate the real possibility of local closure of the organic waste cycle.

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