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Opportunities and Barriers to Composting in a Municipal Context: A Case Study in São José dos Campos, Brazil

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Abstract: The management of municipal solid waste (MSW) is a global challenge of a complex nature. The organic fraction of rapidly degrading MSW, which can be recycled via composting provided it is segregated at the source, is an incipient or non-existent practice in low- and middle-income countries. This study aimed to identify the barriers and opportunities for composting MSW based on the perception of local stakeholders through a qualitative and quantitative exploratory case study in the municipality of São José dos Campos (SP). The study identified and interviewed local stakeholders engaged in composting in the territory, surveying the local market for organic agricultural inputs. Education, infrastructure, and social influence were the main factors that led to the decision to start composting. For home composting, the efficiency of generated waste diversion is from 42% to 59%, and management difficulties at the beginning of the practice are recurrent. Engaging people is the main challenge of community initiatives and 32% ended their composting activities due to the COVID-19 pandemic. Vermicomposting can be an opportunity to value organic waste in the local market. The insights gleaned from the perceptions of local stakeholders provide valuable input for more effective planning within a municipal composting scheme.

Keywords: composting; local stakeholders; influencing factors; organic waste

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1. Introduction

Municipal solid waste (MSW) management is a global challenge of a complex nature, as it deals with environmental, social, and economic dimensions [1]. The world generation of MSW in 2016 was 2.01 billion tons. In 2050, it is expected to grow by 70% [2]. South Korea, Sweden, Japan, Netherlands, Switzerland, and Germany are countries rated as successful in managing their MSW. These countries have in common the development of efficient methods, solid political structure, long-term vision, education, the incentive to waste reduction, and a high level of segregation at the source [3].

Low- and middle-income countries have a high commitment to their municipal budget with MSW management, about three to five times more than high-income countries. In these countries, more than half of the MSW generated is putrescible solid organic waste (PSOW) [2], and segregation at the source is incipient or non-existent [3]. While some waste recycling programs have existed for decades, they lack adequate planning and a better-established institutional configuration. The idea that organic waste is considered 'no value' is the main barrier to its management [4].

Composting is a consolidated form of treatment to recycle PSOW [5] and is considered an efficient, ecologically correct, and economically viable technology [6]. Composting studies have focused on technology optimization and life cycle assessments, particularly in the USA, China, Spain, and India [7]. The social aspect is little explored, especially in Latin American countries.

In Brazil, MSW covers the waste generated in homes and urban cleaning activities. It may also include non-hazardous waste from commercial and service establishments at the discretion of municipal public authorities [8]. In 2020, the country generated 37.4 million tons of PSOW [9]; about 60% was disposed of in landfills [10], and only 0.9% was treated via composting [11].

By the year 2040, Brazilian municipalities are required to implement a plan for the valorization of PSOW, aiming to reclaim 13.5% of the PSOW from the overall mass of municipal solid waste (MSW) generated [9]. The responsibility lies within the municipal sphere to determine the most effective strategies to promote generator participation in composting within their respective areas [12]. However, public management faces political–administrative barriers, such as the lack of investment in the sector, lack of guidance and cooperation from the population [13], and managers' lack of knowledge about the subject [12].

Additionally, management impediments manifest in inadequate infrastructure, deficient planning of operational activities, and ambiguity in defining the responsibilities of the involved agents in the process [14]. These impediments influence the difficulties in operational processes, low quality of the raw material arising from the absence or failure of segregation in the generating sources, and devaluation of the compost in the market [15].

Based on these obstacles, it can be inferred that Brazilian municipalities lack support to promote the composting strategies and tools that integrate local stakeholders in the organic matter recycling chain. Studies focused on the local scope can arguably help managers in more assertive action plans and the development of partnerships for their promotion.

The planning of programs developed from the top-down [16] or based only on the vision of experts runs the risk of not considering the new insights arising from a community's perception of what motivates or inhibits behavioral change [17]. User participation in the pre-implementation phase was identified as a predictive factor for the system's success [18]. Even so, few interventions consider the vision of local stakeholders in system planning [17,19].

This research aimed to identify the barriers and opportunities for the economic and socio-environmental viability of composting in a municipal context. It is based on the identification and recognition of the motivations and limitations concerning the practice from the perspective of local stakeholders and the assessment of the potential local market for organic compost and similar products.

2. Methodology

This is exploratory qualitative and quantitative research [20] with a case study in the São José dos Campos municipality. Figure 1 presents the methodological design.

2.1. Study Area

São José dos Campos is a municipality located in São Paulo state, Brazil (Figure 2), with an industrial and technological profile [6] and 737,310 inhabitants [21], of which 97.9% live in an urban area and occupy 32.2% of the municipal territory [22].

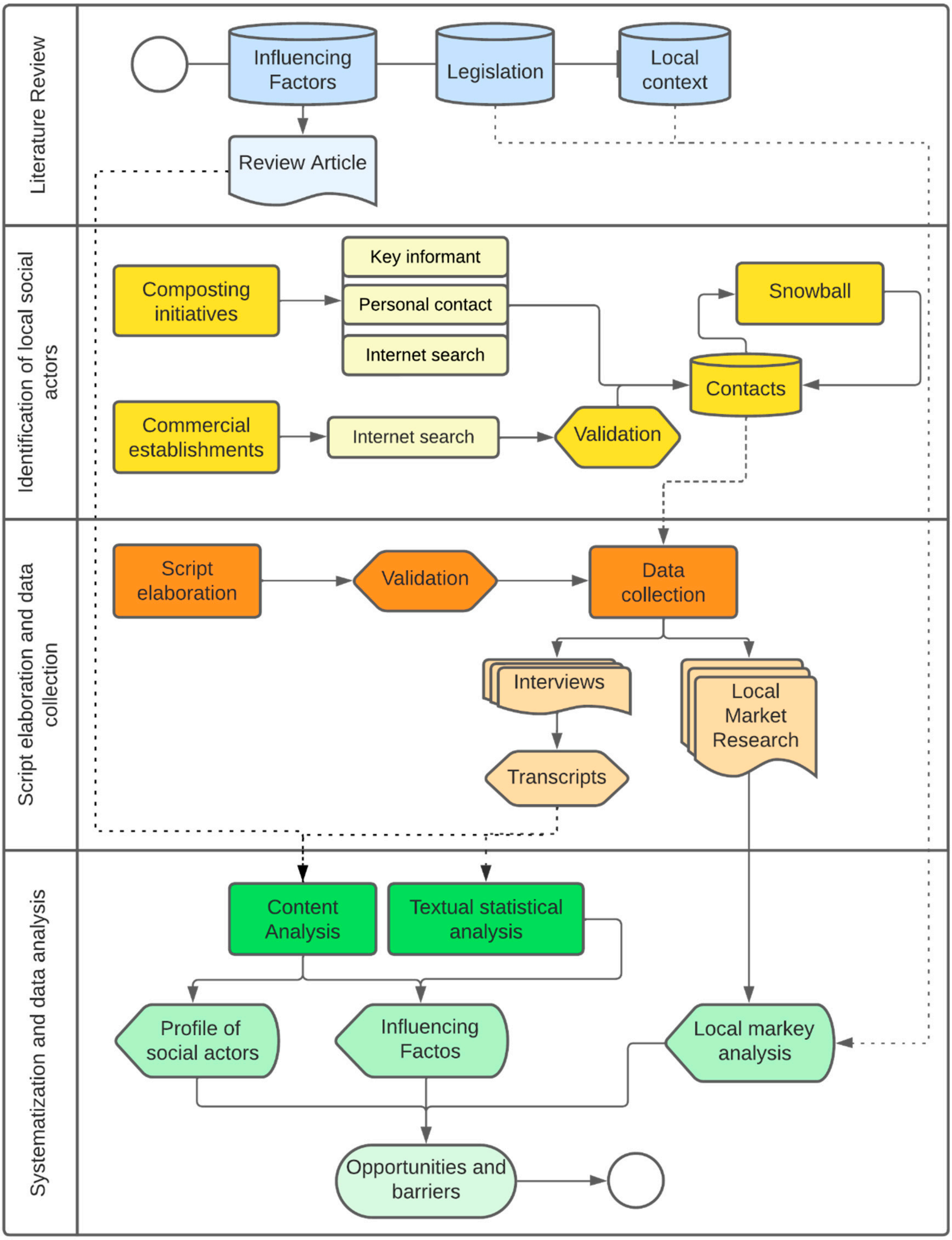


Figure 1. Methodological design of the research.

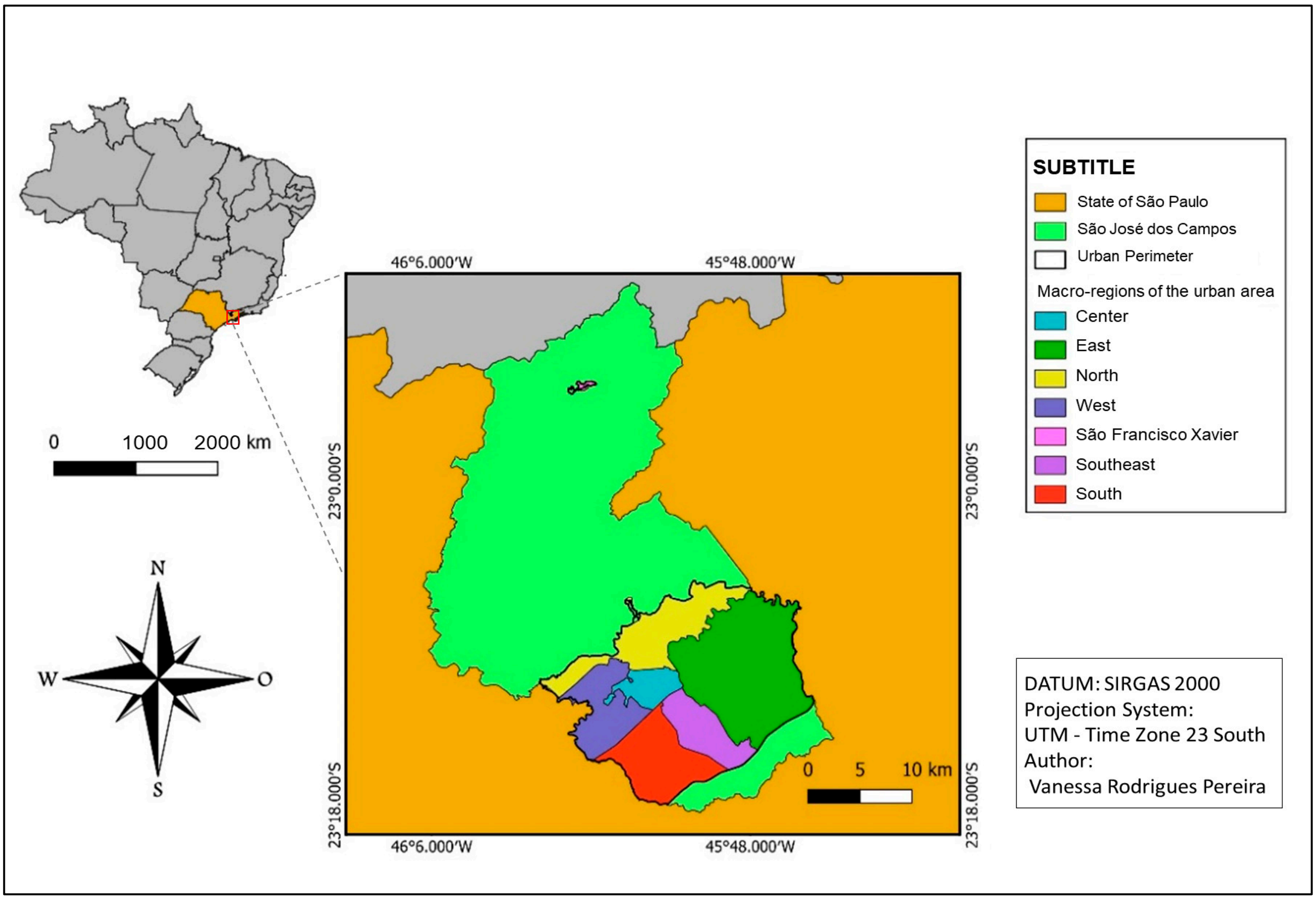


Figure 2. Location of the study area. Data source [23]. Prepared using QGis Software 3.16.11.

In the territory, 0.81 kg/day of MSW per capita is generated and collected door-to-door in 100% of the urban area and at fixed points in rural areas. Of the MSW collected, 81% come from the so-called common collection, 12% from urban cleaning services, and 7% result from the selective collection. In the composition of materials from the common collection, 21.42% of dry waste is potentially recyclable, 57.15% is PSOW, and 18.22% is rejected [24]. As an estimation, in 2021, approximately 207 thousand tons of MSW were disposed of in landfills, of which about 100 thousand tons are PSOW.

2.2. Identification of Local Stakeholders

The identification of local stakeholders engaged in composting initiatives occurred between January and May 2021, based on the researchers' personal contact, internet search, and identification of key informants. From this initial relationship, during data collection, the snowball methodology was used between July 2021 and March 2022. The keywords used for the internet search were "composting" and "São José dos Campos", observing the results obtained from 2012 in order of relevance until rejecting ten subsequent results.

The identification of key informants (KI) occurred on three fronts where there were previous composting initiatives: public administration, non-governmental organizations (NGOs), and research institutions (RIs) in the study territory, contacting at least 20 KI in total. In public administration, the KIs that work directly and indirectly with the theme were investigated. It involved five sectors: Departments of Urbanism and Sustainability (SEURBS), Health, Education, City Maintenance, and URBAM—a municipal mixed economy company responsible for the management of MSW in the municipality. For NGOs and RIs, the following criteria were adopted: to be headquartered in São José dos Campos, to carry out an activity, or to have a qualified human resource related to solid waste management, environmental education, or agronomy.

Commercial establishments were identified using the Econodata® company prospecting platform [25], business and trade disclosure sites, and public consultation on government websites and agricultural product associations. A limit of 50 potential commercial establishments was adopted for the data collection, which should have an active government enterprises registry and economic activities within the scope. Only those who declared selling organic agricultural inputs were interviewed.

2.3. Preparation of Scripts and Data Collection

The semi-structured interview scripts aimed at the local stakeholders engaged in composting were prepared based on thematic axes, presented in Table 1, and adapted to the following contexts: home, institutional/community, and commercially oriented community (scripts in Supplementary Section S1). Four researchers previously validated them on the subject through pilot interviews and were approved by the ethics committee of the Institute of Sciences and Technology—Unesp (Opinion 5241652).

Table 1. Structure of scripts applied to composting initiatives.

Thematic Axis	Data to Be Collected
Identification	Time of existence of the initiative, neighborhood, sociodemographic data (only household)
Operating conditions	Model, the form of handling, frequency and average time spent on handling, an estimate of diverted waste and produced compost, type, and origin of raw material, problems in operation.
Resources	Destination of the compost, price (if sold), monetary expenses with implementation and/or operation, and level of perceived energy expenditure.
Motivations and Limitations	Factors for the decision to practice composting (triggers), motivational and inhibiting factors, strengths (community and commercial), and difficulties and discontinuity of the practice.

The number of interviews adopted in this study was 27, according to the recommendations for qualitative interviews [26,27]. Only those in which composting initiatives were active during the data collection and where the interviewee allowed the recording were considered for assigning the interviews. Information provided by the respondents who did not fit these conditions was also added to the project.

In commercial establishments, structured interviews were carried out with salespeople, by telephone, or with those available in the sector. Complementary data collections were carried out in the field by verifying the product packaging directly. The information investigated was the characteristics of the commercialized product, prices practiced, type of raw material used, the origin of suppliers, and the average sales per period (Supplementary Section S2).

2.4. Systematization and Data Analysis

The semi-structured interviews were transcribed and systematized in electronic Excel spreadsheets based on the content analysis (CA) [28,29]. The data were presented in a categorized manner in the Profile of the Composting Local Stakeholders and Influencing Factors of Composting Subchapters, which was identified based on the review by Pereira and Fiore [30]. Also, the quality data was triangulated with the descending hierarchical classification (DHC), performed using the IRAMUTEQ software (www.iramuteq.org) [31].

Barriers and opportunities were identified and summarized in a SWOT matrix, supporting the analysis of alternatives in complex decision-making [32], and were classified according to the pillars of sustainability, formed by the social, economic, and environmental dimensions [33,34].

3. Results and Discussion

Local stakeholders in composting were identified through 21 key informants (KIs), of which 71.4% (n = 15) responded, in addition to 6 personal contacts and 11 accessible contacts found on the internet. A total of 133 contacts were obtained, as shown in Table 2, of which 39 were active during the data collection and are categorized in Figure 3.

Table 2. List of contacts obtained in this case study.

Initiatives	Snowball	SEURBS	Total (%)
Active	28	11	29.3
Inaccessible	9	23	24
Discontinued	2	20	16.5
Inactive but intending to resume or start	7	-	5.3
Outsources composting (outside the municipality)	1	-	0.7
Potential (not contacted)	32	-	24

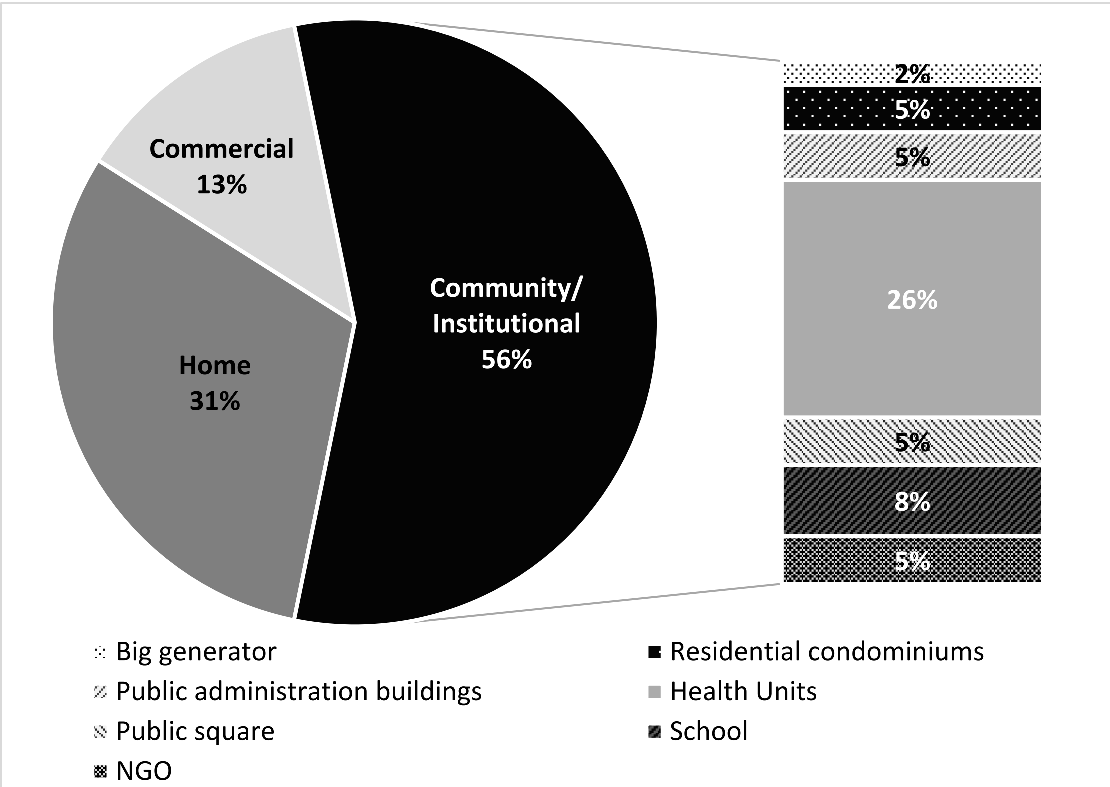


Figure 3. Active composting initiatives per categories.

A total of 60% of the contacts were reported by the local authority but were not included in the snowball sample (Supplementary Section S3) because there was no indication of a person being directly responsible. Only 28% of these initiatives were active at the time of this research. In the end, the data were collected from 12 households, 11 institutional and four commercial initiatives. Although the snowball sampling method does not allow for a representative sample of the target group [35], it was possible to map the relationships between the interviewees and identify promising multipliers for composting. Access to new initiatives was facilitated by the snowball method compared to the local authority's indication without direct contact.

3.1. Profile of Composting Local Stakeholders

Income and space availability are not determining factors for people who make home compost. One of the possible reasons for the low requirement regarding space availability may be the preference for composting in stacked boxes (worm farms or boxes with microorganisms), used by 66% of the respondents' home composters. The sociodemographic results are in Supplementary Section S4.

Figure 4 shows the models used by the initiatives surveyed in this study. Some initiatives used more than one composting model, details of which are given in Table 3.

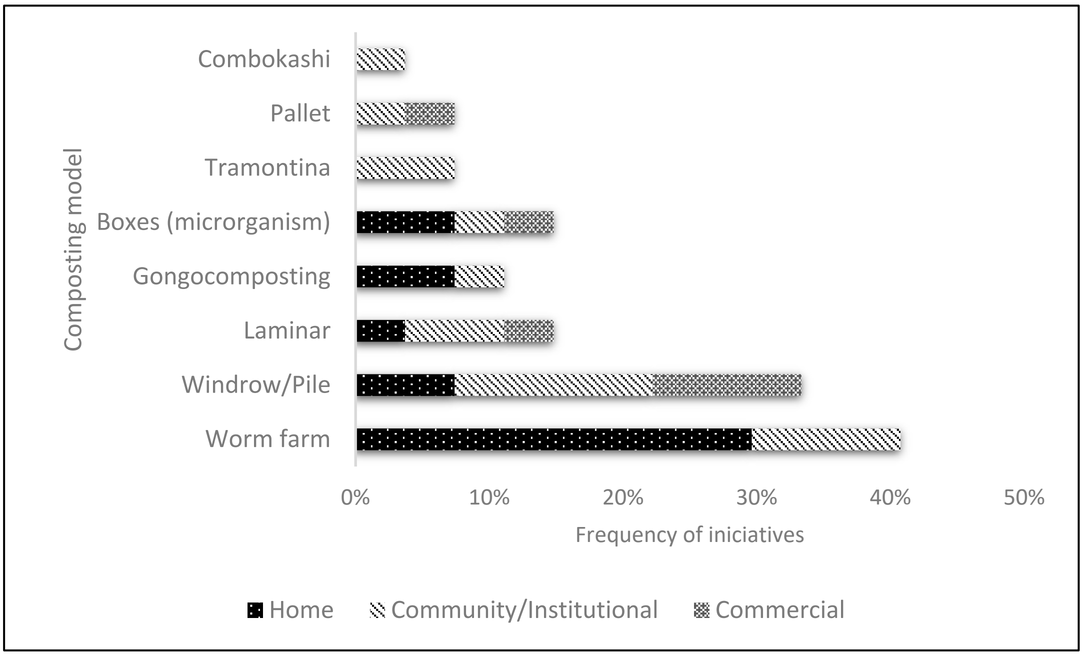


Figure 4. Frequency of composting models adopted by interviewees.

Table 3. Description of the composting models adopted by the interviewees.

Model	Description	Reference
Pile or windrow	The most traditional form of disposal in patios, reaching temperatures close to 65 °C.	[36,37]
Pallets or open boxes	They follow the same heating phases but are arranged in pre-molded and hollow wooden structures with a size of around one m^3.	[38]
Tramontina©	Hollow and collapsible commercial plastic compost bin for composting in the garden.	[39]
Combokashi or bokashi	Anaerobic method developed in Japan that degrades organic matter using efficient microorganisms, molasses, and water.	[40]
Laminar	It consists of disposing a layer of approximately 30 cm height of the residue directly on the soil with straw and covering it with another layer for natural decomposition. The site is used for planting after transforming the material into compost. The Lages method, developed by the Federal University of Santa Catarina, was one of the methodologies applied.	[41,42]
Worm farm (vermicomposting) and boxes with microorganisms	Worm farms and the box with microorganisms have the same structure as stackable and closed boxes. The difference is that the first uses Californian earthworms (*Eisenia andrei*) to consume organic waste, and the second does not.	[43,44]
Milicomposting	Biotransformation of cellulosic materials (vegetable waste, non-toxic cardboard) with woodlice (*Trigoniulus corallinus*).	[45]

Community composting uses a greater variety of models, which shows an ability to adapt the practice in different situations, depending on the number of people involved and the physical structure conditions typical for decentralized composting [46]. Overall, decentralized composting units have a processing capacity of up to 5 t/year [46], receive waste from nearby generators, and are usually simpler due to the smaller amount of material received [47].

The mass of waste diverted from the landfill, presented in Table 2, was calculated considering the respondents who knew how to inform each group. They are 83% (n = 10) for households, 64% (n = 7) for community/institutional composting, and 75% (n = 3) for commercially oriented composting. The per capita PSOW deviation of PSOW from landfill to home initiatives was estimated to range from 5.9 to 8.2 kg/month (calculated based on the number of people who benefit from the income and considering the PSOW density equal to 0.435 kg/L [48] when estimated by volume).

The compost production estimate (Table 4) was based on 62% of interviewees who knew how to respond. Only one community initiative weighed the compost produced, and the rest of the interviewees answered based on empirical or academic knowledge.

Table 4. Monthly waste mass diverted from the landfill and processed compost.

Home Composting (kg/Month.Home)			Community Composting (kg/Month)		
Reference	**Residue**	**Compost**	**Reference**	**Residue**	**Compost**
This study	13.58 to 18.84	3.36	This study	228.4 [a] 1870 [b]	60 [a] 772 [b]
[49]	11.6	-	[50]	168	-
[51]	15.52	-	[52]	862.6	-
[53]	10.5	-	[54]	15,000	5250

Subtitle: [a] n average for community/institutional composting initiatives; [b] average for commercially oriented community composting initiatives.

The estimate of the mass diverted from the landfill and the organic compost produced, based on the perception of the interviewees, are uncertain data since the amount of waste inserted in the systems and the percentage of reduction for the matured compost vary, depending on the type of food consumed [55].

The use of compost for one's own benefit is one of the main concerns in the practice of composting. In this survey, 96% of respondents use it personally or at the same composting site, as shown in Figure 5.

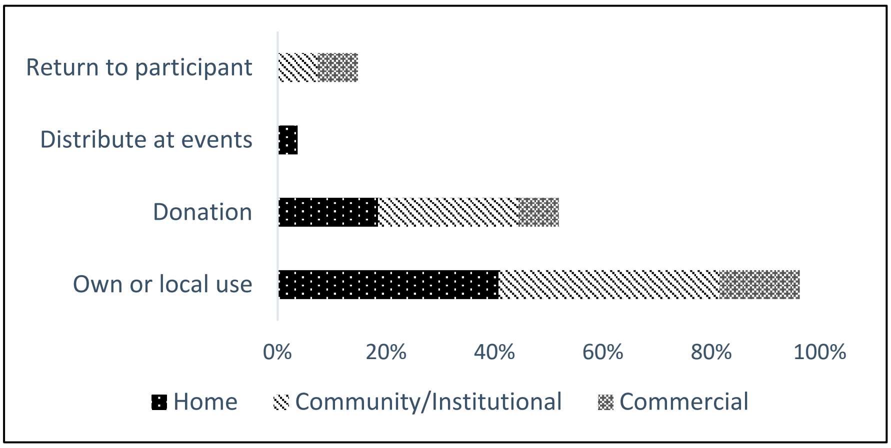


Figure 5. Forms of compost disposal.

According to the interviewees, compost donations are made to people close to the composting site or within the circle of relationships of those who compost. Not everyone donates the compost produced, but those who do are generally sought after, and none of the interviewees had their product refused. Others prioritize returning the fertilizer to those engaged in the management or segregation of waste to reward their participation.

Home composting had an efficiency of between 42% and 59% deviation concerning the waste generated when considering the estimate of 24.3 kg/month of MSW from the common collection and the percentage of 57.15% of PSOW in the composition of MSW of the municipality studied [21,56]. The value is close to other studies that evaluated the efficiency by direct measurements, 47% [57] and 77% [53].

Decentralized composting can reduce transportation costs, landfill fees, and the purchase of fertilizers [58] and increase landfill life. A home composting program expanded to the entire municipality studied would have the potential to save approximately USD 9700 per month in landfill fees or an equivalent to approximately 3% of the total budget expended on it ($Economy = 7.05\frac{\text{kg}}{\text{month}}.\text{hab} \times 10\% \div 24.3\frac{\text{kg}}{\text{month}}.\text{hab}$). The estimative considers the 10% population participation rate, suggested by Pai et al. [58], the estimated average deviation of PSOW of the households in this study, and the cost of USD 17.97 per ton with a landfill operation in the municipality studied in 2022 (verbal information (information provided by URBAM employee)).

In this study, 26% (n = 7) of the interviewees had no expenses with the implementation of composting, as shown in Figure 6. However, 66% (n = 8) of the households and 55% (n = 6) of the community/institutional local stakeholders claimed to have incurred expenses. Three households and one community initiative claimed to have costs of maintenance involving fuel, the purchase of dry matter, and/or a delivery service of material to the home. Expenses are occasional and account for, on average, USD 13.03 per year.

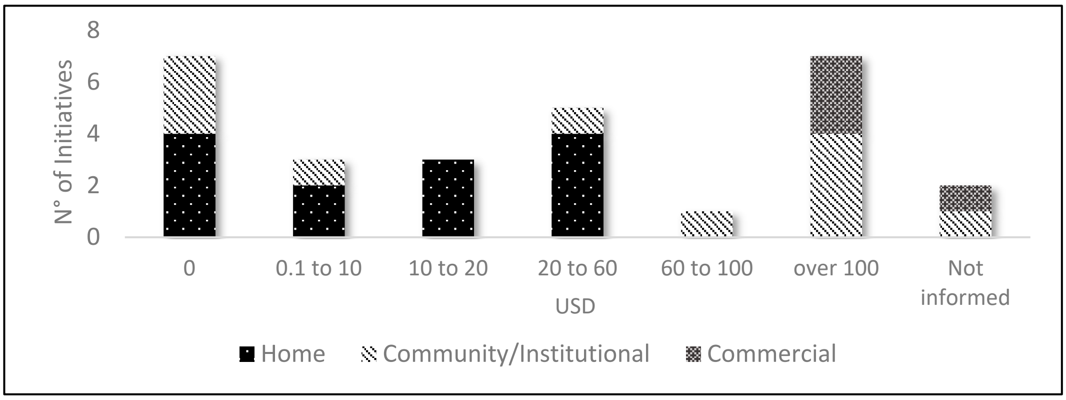


Figure 6. Expenses with the implementation of composting.

For commercial composting, two companies reported expenses with implementation alone, with an approximate average of USD 121.60. Another company said it spends around USD 485.00 to USD 585.00 monthly, involving maintenance costs. Table 5 summarizes the implementation expenses for the home and community initiatives measured in this research and presents similar case studies.

Table 5. Costs of implementing composting by scale level.

Scale	This Study	[58]	[59]
Home (USD)	21.48 (1)	34.63 to 230.87 (2)	57.06/t (2)
Community (USD)	86.77/t (1,3)	438.65/t (2)	160.30/t (2)

(1) Amount obtained in BRL and converted into USD (1 USD = 5.14 BRL) based on bcb.gov.br in September/2022. (2) Values corrected for inflation according to the CPI (Consumer Price Index). (3) Average for community/institutional composting for those who claimed to have implementation expenses.

The reported costs specifically cover the initial investment in equipment and infrastructure. Due to the diverse range of equipment involved, measuring the time duration proves challenging. To facilitate comparisons, we estimated the average cost per ton of waste diverted from community initiatives, assuming a twelve-month compost production period—which is considered the minimum expected durability. Notably, the lowest cost for compost production in this study is attributed to human labor (voluntary), with no consideration of expenses related to campaigns or government programs (which are non-existent in the municipality under investigation).

The effort encompasses the energy expended on activities directly and indirectly linked to composting, such as source separation, packaging, and handling. Figure 7 illustrates the perceived effort of interviewees, who provided their insights on a Likert scale, ranging from little to a lot at the extremes.

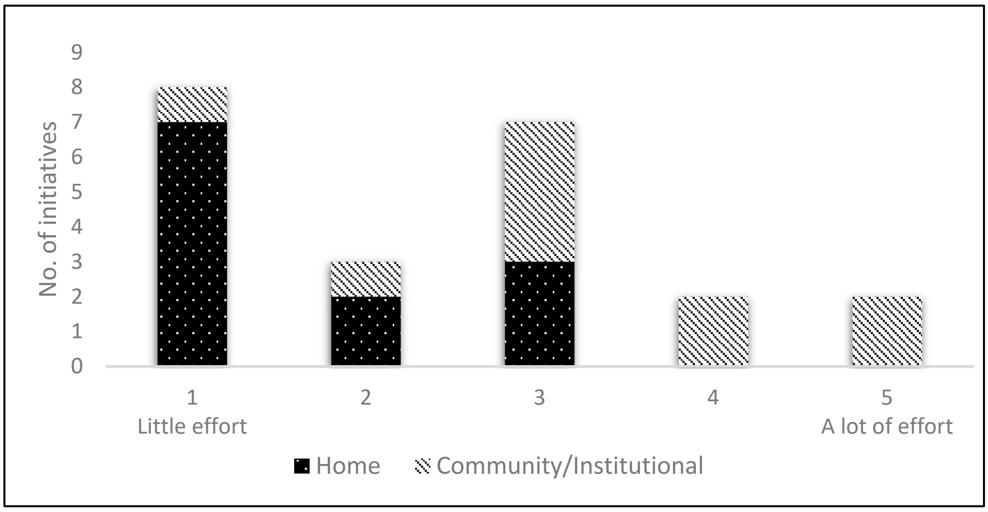


Figure 7. Level of perceived effort in composting activities on the Likert scale.

The greatest perceived effort for community composting activities also involves social issues (these elements configured non-operational difficulties and were detailed in item 3.2.9), as reported by Interviewee 14.

“Even mentally, you have to talk to people more and convince them, and then I think it’s a more exhausting process. It’s not just the day-to-day handling there because that’s not a problem for us, considering the volume we’re there. But we often cannot take a step further because I will depend on another structure.” (Interviewee 14).

Although it has not been a task foreseen in this work, some interviewees affirmed that the perceived effort at the start of the practice was more significant or may be related to incorporating the habit and the problems faced at the beginning. Figures 8 and 9 show the practice time of two groups of local stakeholders and the time spent with handling, respectively.

No clear correlations were observed between the perceived effort and time spent without handling (r = 0.178), segregated residue (r = −0.084), and years of practice (r = 0.137). According to some interviewees, the time dedicated to handling is often considered a rewarding activity. Notably, there was a correlation between work time, handling duration, and the amount of waste diverted from landfills (r = 0.679). Commercial initiatives engaging in activities that take less time (as depicted in Figure 8) may indicate the social perception of a potential new market niche.

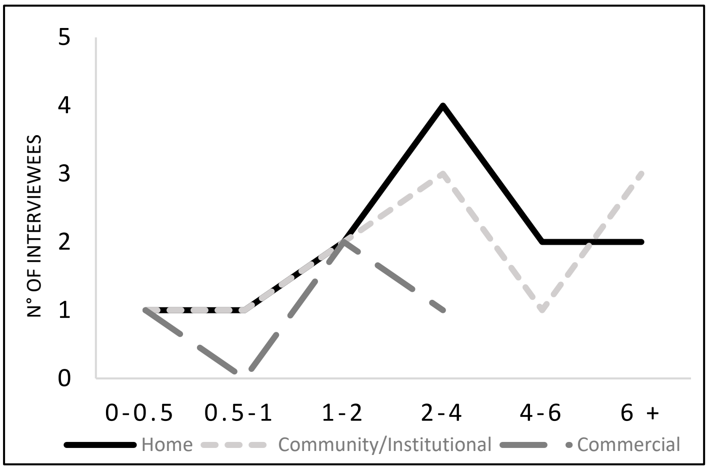


Figure 8. Composting practice time.

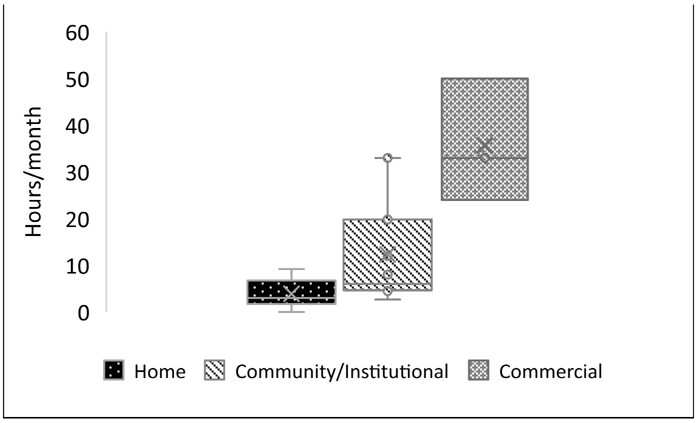


Figure 9. Work time expended with handling.

Approximately 80% of the respondents reported composting or having initiatives in place for at least one year, while limited data were available on the population's participation time in community projects exceeding two years. Table 6 contrasts the active time of the initiatives in this study with the population's participation time in source segregation for community composting and volunteering compared to other initiatives.

Table 6. Composting involvement time.

Involvement Time (Months)	This Study	[54]	[60]	[52]
	%			
0–6	11.1 (n = 3)	27	17	37
6–12	7.4 (n = 2)	13 *	6	13
12 +	81.5 (n = 22)	60 **	77	50

* Range of 0.5 to 1 year, according to the original study. ** Range between 1.5 to 3.5 years for the original study.

Overall, the lowest observed percentage between 6 and 12 months across various studies highlights the fragility in the continuity of composting practices or participation in composting schemes. The higher rate of activities after one year is influenced by project duration and influx, masking dropouts during this period. Given that those who remain over one year are more likely to continue in the project, it is suggested that adhesion campaigns should be consistent within the first 12 months to solidify composting schemes [60]. Additionally, government incentives and training programs can further encourage and support this practice.

As reported by the interviewees, the composting time varied from 1 to 12 months, with 50% indicating that the process takes 3 to 4 months, aligning with similar findings in other community composting case studies ranging from 2.5 to 5 months [61–63]. The processing time aligns with Kiehl's assertion that compost stabilization occurs between 1 and 2 months, maturing between 3 and 4 months [36]. Variations depend on the initial conditions like particle size and the carbon/nitrogen ratio [36], as well as physicochemical parameters throughout the process, such as the pH and moisture content [64]. However, this study did not delve into verifying these parameters or assessing the quality of matured compost, as it was beyond its scope.

3.2. Influencing Factors

The factors influencing composting are motivators (opportunities) and inhibitors (barriers). Among the motivating factors are the trigger factors, which led to the decision to start composting. Figure 10 presents the influencing factors and triggers identified in this study and those reported by Pereira and Fiore [30]. In this study, the factors were centered on the experiences of the social actor and not on the initiative, except when two actors discussed similar factors related to the same initiative. In this case, this factor was considered only once.

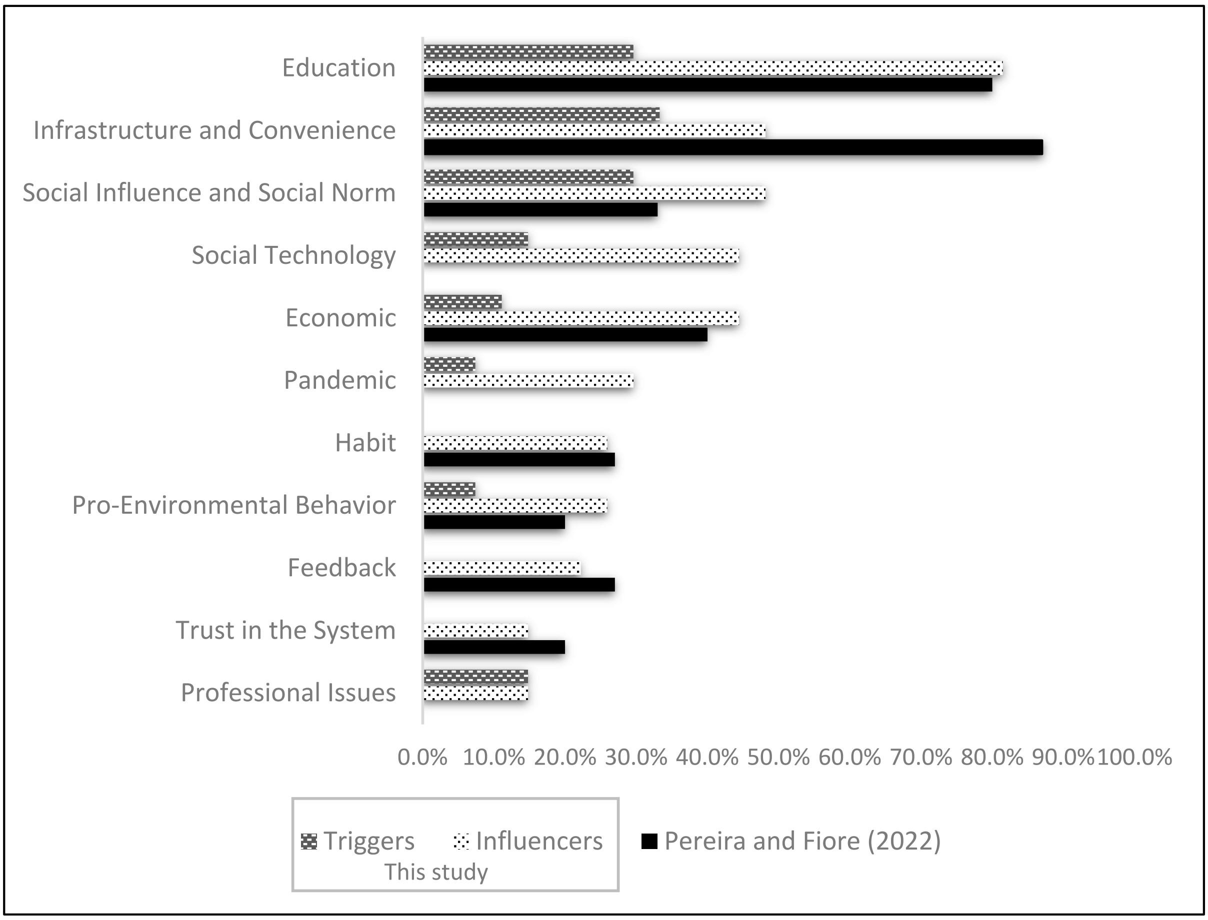


Figure 10. Influencing factors associated with stakeholders involved in composting schemes (Pereira and Fiore (2022) [30]).

Trigger factors (Table 7) were obtained based on personal experience or the history of the initiative provided by the interviewee. These factors are not necessarily exclusive to the practice and only functioned as a trigger for the decision to compost. In total, 61% of the expertise cases covered two or more trigger factors.

In essence, insights from the interviews revealed three distinct categories—professional issues, social technology, and the impact of the COVID-19 pandemic—adding nuances beyond those previously reported by Pereira and Fiore [30]. Professional issues pertain to the conditions in which one's job directly or indirectly fosters a connection with composting. Social technologies, in turn, drive community-based social transformations [65], encompassing values such as collaboration, sustainability, empowerment, knowledge dissemination, human-nature connection, and community support for projects.

Table 7. Trigger factors in the decision to practice composting.

Trigger Factors	Subcategories	Total %
Infrastructure and Convenience	Compost bin gain	33.3
	Excess vegetable residue on the property	
	Need for fertilizer	
Education	Workshop and courses	29.6
	Internet search	
	Academic education	
Social Influence and Social Norm	Sensitization through close person	29.6
	Exchange of information between peers	
	Inspiration from other initiatives	
	Everyday experience	
Social Technology	Entrepreneurship	11.1
	Sustainable School	
	Foster collaborative culture	
	Food safety education	
Professional Issues	Set an example as an influencer of the practice	11.1
	Problems with waste generated in the work environment	
Economic	Reduction of expenses with destination	11.1
	Reduction of expenses with the purchase of fertilizer	
	Financial return with the sale of service or compost	
Pro-Environmental Behavior	Take an interest in environmental issues	11.1
	Concern about waste disposal	
Pandemic	-	7.4

The COVID-19 pandemic, treated separately due to its unique impact, led to changes in people's routines, resulting in a reduction in food waste [66]. This reduction was attributed to improved food planning and preparation [67], increased available time, and a heightened awareness of waste consequences [68]. However, in community and institutional settings, the overall decrease in people's movement or the absence of individuals to maintain management adversely affected many initiatives. In this case study, 32% of the discontinued initiatives had to close due to pandemic-related challenges. Descriptions and details of the other influencing factors are in Supplementary Section S5.

3.3. Operational and Non-Operational Difficulties

The operational difficulties identified in this study, presented in Figure 11, refer to problems related to system management, which involve infrastructure issues and a lack of technical knowledge.

In the initial stages of home composting, half of the interviewees faced operational challenges, with issues like fruit fly infestations, earthworm escapes, or deaths, and unpleasant odors, all linked to insufficient humidity and oxygenation conditions. Ultimately, 25% of the home composters continue to grapple with the discomfort caused by fruit flies as the lone persisting problem.

Conversely, operational challenges were uncommon for community and commercially oriented initiatives, with only two instances reporting initial problems with flies and rats. Within these groups, primary operational hurdles centered around low maintenance due to time or personnel constraints and employee turnover. Recurrent difficulties in these contexts, identified through interviews, were associated with non-operational factors, including social and socioeconomic challenges.

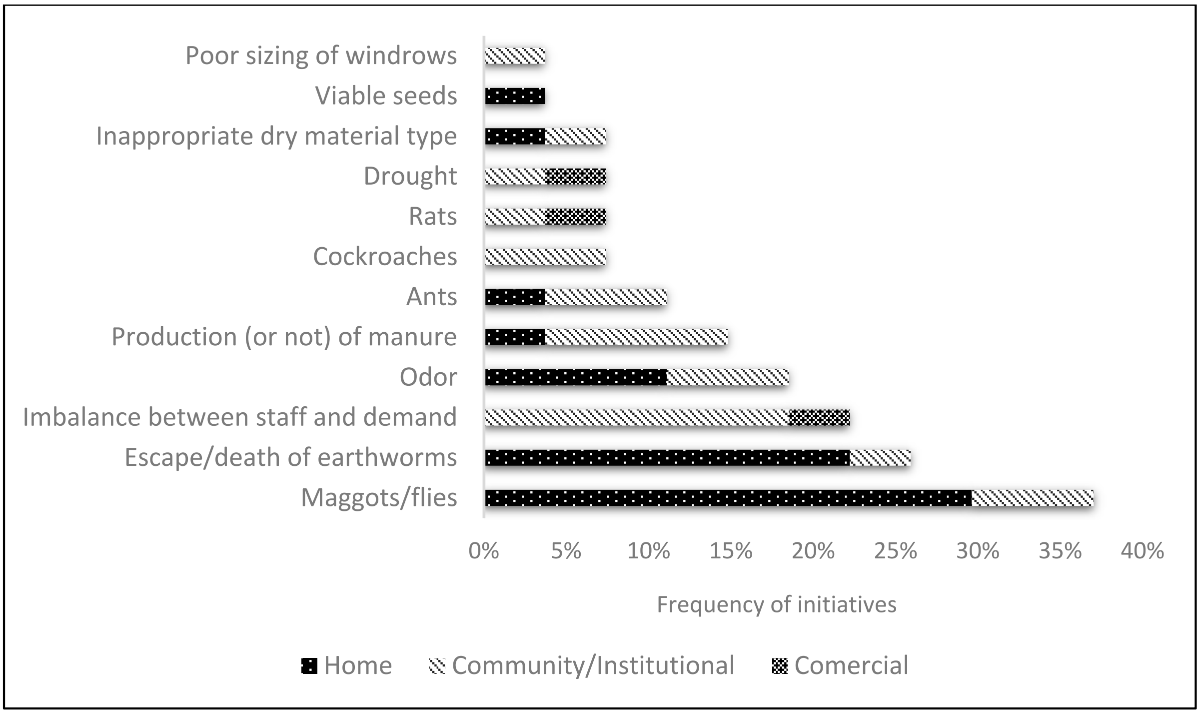


Figure 11. Operational difficulties per kind of initiatives.

Mobilizing new participants poses a significant challenge, particularly among those perceiving the activity as 'dirty' or resisting direct contact, associating composting with handling inconveniences like odor and undesirable animals. Another hurdle lies in the lack of recognition of post-segregated organic waste (PSOW) collection and treatment as a service subject to payment, leading to the disregard and undervaluing of the logistical and composting process costs.

Additional reported problems include material theft in public spaces, challenges in assigning responsibilities to individuals already occupied with other primary duties in institutions, and difficulties in composting all generated waste due to the volumetric limitations of compost bins. Trust in the system is also questioned due to insufficient investments, support, and dialogue between the government and the population, along with the organization of one-off events or initiatives lacking continuity with ongoing efforts.

3.4. Textual Statistics Analysis

Descending hierarchical classification (DHC), shown in Figure 12, was performed in the respondents' native languages with a correspondent translation in Supplementary Section S6. For the interpretation of the classes, the first most relevant words resulting from each class were considered.

The analysis of word classes allows us to infer the most prevalent factors in this study, namely education, infrastructure, and social influence, without delving into their intricacies.

Reading begins with the upper row, forming two major groups: classes 2 and 3, pertaining to education and social issues, and classes 1, 4, and 5, relating to operational concerns.

Class 2 is linked to environmental education, encompassing the experiences tied to educational spaces and individuals. The represented actions involving verbs delineate processes of knowledge exchange, dissemination, and the associated energy costs. The educational environment emerges as a pivotal space in individual development, contributing to the construction of pro-environmental behavior and fostering social influence. It also serves as a crucial avenue for driving the social and cultural changes necessary for ensuring the viability of the system.

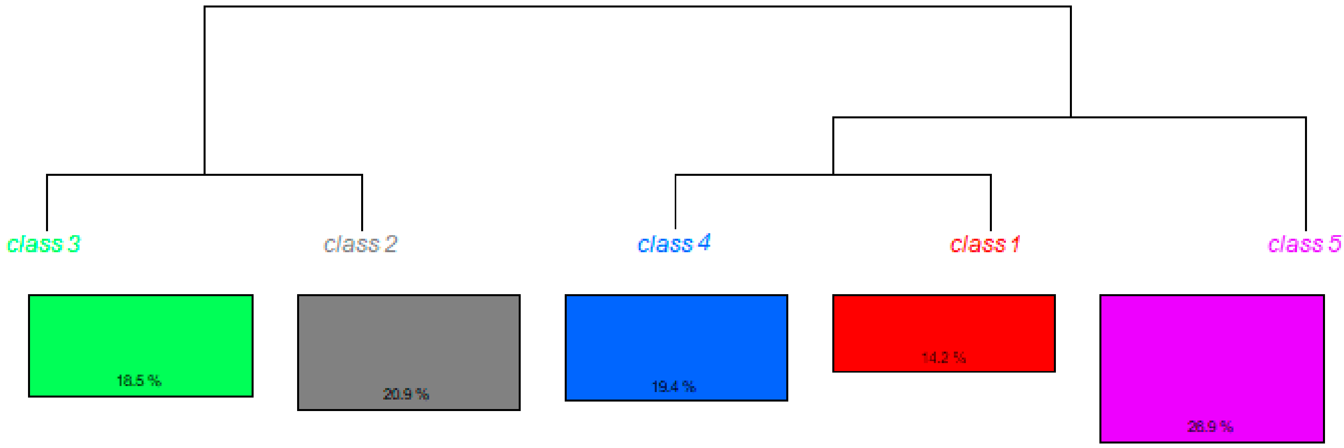


Figure 12. Descending hierarchical classification.

Class 3 encapsulates education in terms of awareness-raising and infrastructure, underscoring the role of public authorities in waste management and the performance of the private sector. This class also evidences the acknowledgment of local stakeholders with the mention of them, emphasizing their vital role in collaboratively constructing a composting system.

Class 4 revolves around handling activities and composted materials, standing out as the class with the highest number of verbs, with the most relevant word being an action verb. Class 1 represents the phase following waste processing, also interpretable as the perceived benefit. Class 5 addresses the operational challenges in the process, encompassing the control and parameters of composting. It holds the highest frequency of occurrence, underscoring its significance compared to other themes in the study.

3.5. Local Market

Out of the 50 potential trading establishments identified, 32% were found to retail some types of organic agricultural inputs. Concerning these establishments, 4% lacked a responsible person available for an interview during the data collection phase of this research. Consequently, information on product packaging was consulted. Furthermore, 34% of the establishments asserted that they did not sell the product under scrutiny in the study, and an additional 32% were not accessible for survey purposes.

The organic-based agricultural inputs identified in the study area were classified by the establishment and/or suppliers as topsoil, earthworm humus, cattle manure, chicken manure, substrate, soil conditioner, organic fertilizer, organic compost, and peat. Among the establishments consulted, those not selling topsoil offered organic compost. According to Brazilian legislation, organic fertilizers are considered as manure, peat, earthworm humus [69], and organic compost [70], which can also be used as a soil conditioner and substrate ([71] apud [70]).

Interviewees mentioned the number of sales only for the most commercialized products, emphasizing topsoil. Table 8 presents the characteristics of the most recurrent products in the researched establishments.

The average weekly sale for the 10 kg package was 17.25 units, and for the 20 to 25 kg package, 45 units. However, this was reported as one of the most sought after; the most offered by the establishments were 5 kg and 10 kg. This difference is probably because small establishments without larger packages are available for selling the product. Figure 13 presents the average price per kilo of products sold in packages of 2 kg to 5 kg and sold in 80% of the establishments covered in this study.

Table 8. Establishments' quantity per product offering.

Supply and Demand of Organic Compost	Product				
	Topsoil	Humus	Substrate	Cattle Manure	Organic Compost
No. establishments	14	11	10	7	5
No. suppliers	16	10	9	9	4
Weight of most wanted packages (kg)	10–12 20–25	2	20–25	2–3	25

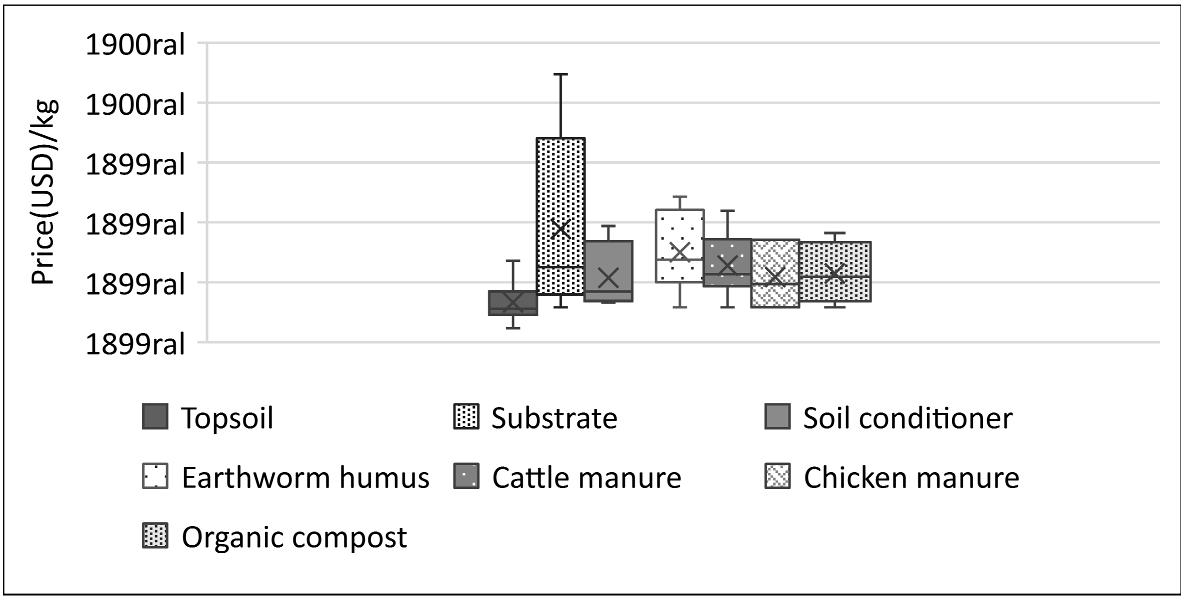


Figure 13. Price per kilogram of organic products.

Companies providing post-segregated organic waste (PSOW) collection and treatment services, with plans to sell organic compost in the future, propose an average price approximately 30% higher than soil conditioner and organic compost and 60% higher than local topsoil prices. To enhance the chances of local market acceptance, the PSOW organic compost needs to be perceived by the population as offering greater added value compared to competing products or priced more competitively against substitute products available in the local market.

Studies indicate there is a low acceptance of organic compost by peri-urban farmers in São José dos Campos, who prefer agricultural inputs or any other types of fertilization to those made through composting [72]. In the metropolitan region of Vale do Paraíba (MRVP), 69% of farmers use chemical fertilizer, 68% animal manure, 28% vegetable compost, and 4% humus [73]. Promoting home composting emerges as a viable strategy to boost population acceptance. Home composting offers local use without the need for extensive logistical infrastructure, and users have insight into the production process, making it feasible, even in confined spaces.

Agriculture assumes a central role in any local circular economy strategy. Its practice in urban environments can contribute to a low-carbon economy and enhanced food safety, provided precautions are taken to prevent contamination by pollutants [74]. Additionally, access to locally produced food proves strategically valuable during crises [75], such as the COVID-19 pandemic. According to [73], the MRVP exhibits areas with good or moderate suitability for olive cultivation.

In Brazil, establishments that sell or produce fertilizers, correctives, or substrates for plants must be registered with the Brazilian Ministry of Agriculture, Livestock and Food Supply (MAPA). In this study, only 52% of suppliers and 25% of establishments were registered in May 2022. Table 9 shows the price per kilogram, verified in this study, of products based on suppliers with and without MAPA registration.

Table 9. Average price per kilogram of products.

Certification Condition	Topsoil	Substrate	Soil Conditioner	Humus	Cattle Manure	Organic Compost	Peat	Chicken Manure
	Average Price (USD/kg)							
Registered in MAPA	0.46	1.08	0.54	1.10	0.94	0.76	0.31	-
No MAPA registration	0.28	0.39	-	0.50	0.54	0.33	-	0.54

This research reveals that, in the local market, products lacking registration with the MAPA are, on average, about 50% cheaper than registered products. It is important to highlight that registration ensures that a product has undergone an agronomic efficiency assessment process and meets the quality conditions required by MAPA [76]. However, no studies explored the impact of MAPA registration on the product's competitiveness in the market.

Vermicompost presents an opportunity to enhance the value of post-segregated organic waste (PSOW) in the local market, as evidenced by this research, which indicates that the price of earthworm humus ranks among those with the highest added value. Furthermore, as per national legislation, humus generated and processed naturally, without the addition of chemical products, may be exempt from registration when used for personal purposes or sold directly to the final consumer, provided it adheres to specific legislation regarding the usage requirements and safe application [77,78].

Compared with organic compost, vermicompost offers greater moisture retention capacity in the soil [43], improves the diversity and stability of the bacterial community in the ground [79], provides higher levels of nutrients [80,81], with higher percentages of total nitrogen and phosphorus [82], has better availability quality [83], and can reduce GHG emissions by 23 to 48% if feeding under ideal conditions [84]. Vermicomposting can reduce levels of toxic metals and break them down into non-toxic forms [85]. Furthermore, humus generated through vermicomposting can be used immediately after production [84], and the process is adaptable for small spaces, making it suitable for home contexts.

Despite the potentialities compared with compost, vermicomposting is ten times less studied than composting for treating PSOW [82]. There are few studies on the viability and sustainability of vermicomposting for urban waste management and the socioeconomic impact of the practice and use of the product in agriculture [86]. Research investigating such issues can contribute to the appreciation of PSOW.

This research identifies 21 suppliers of various organic inputs, along with 2 others not identified. Only two suppliers are headquartered in the municipality of São José dos Campos, while eighteen are scattered across other cities in the state of São Paulo, and one is located in the state of Minas Gerais, as indicated in Figure 14.

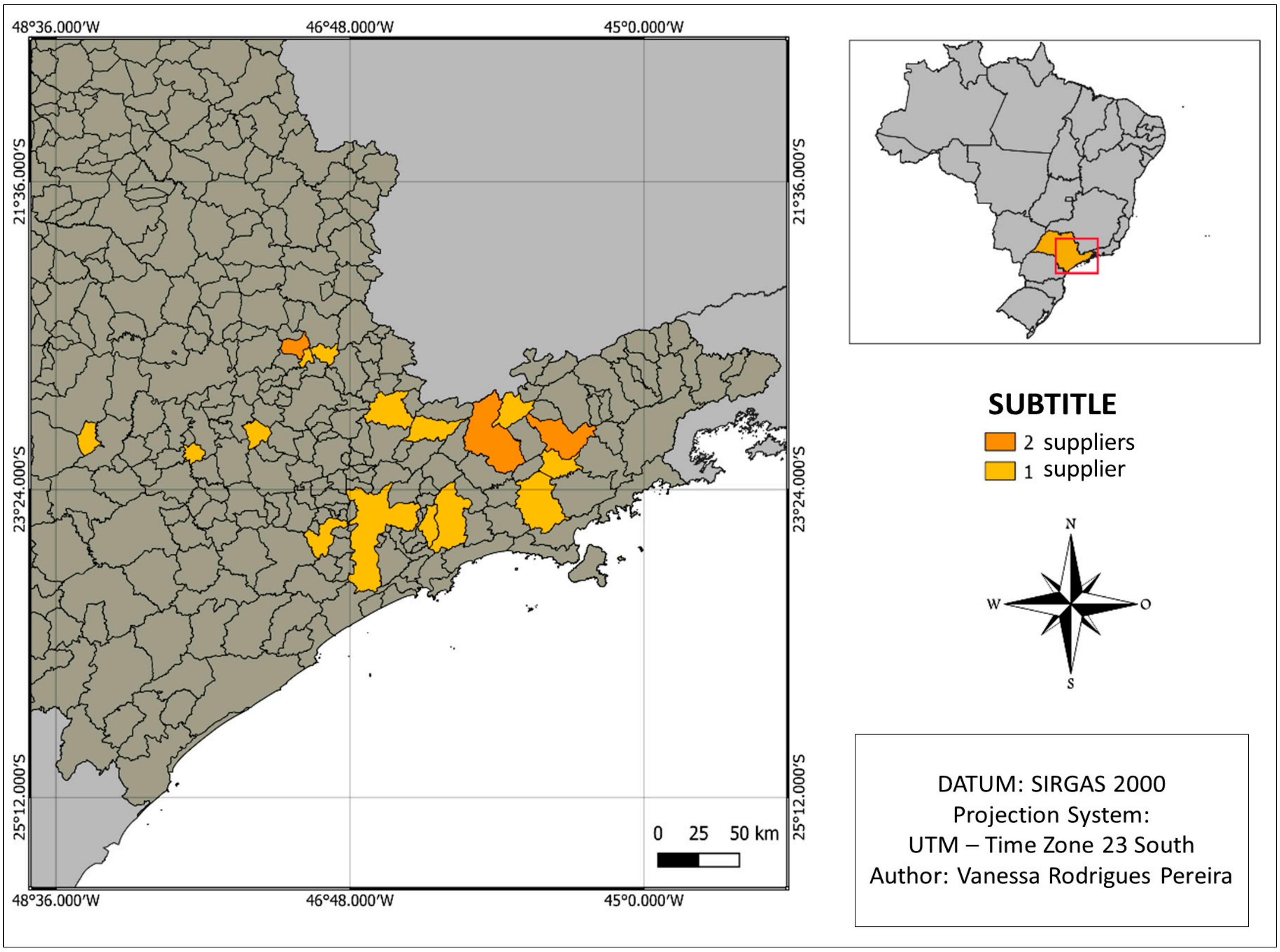
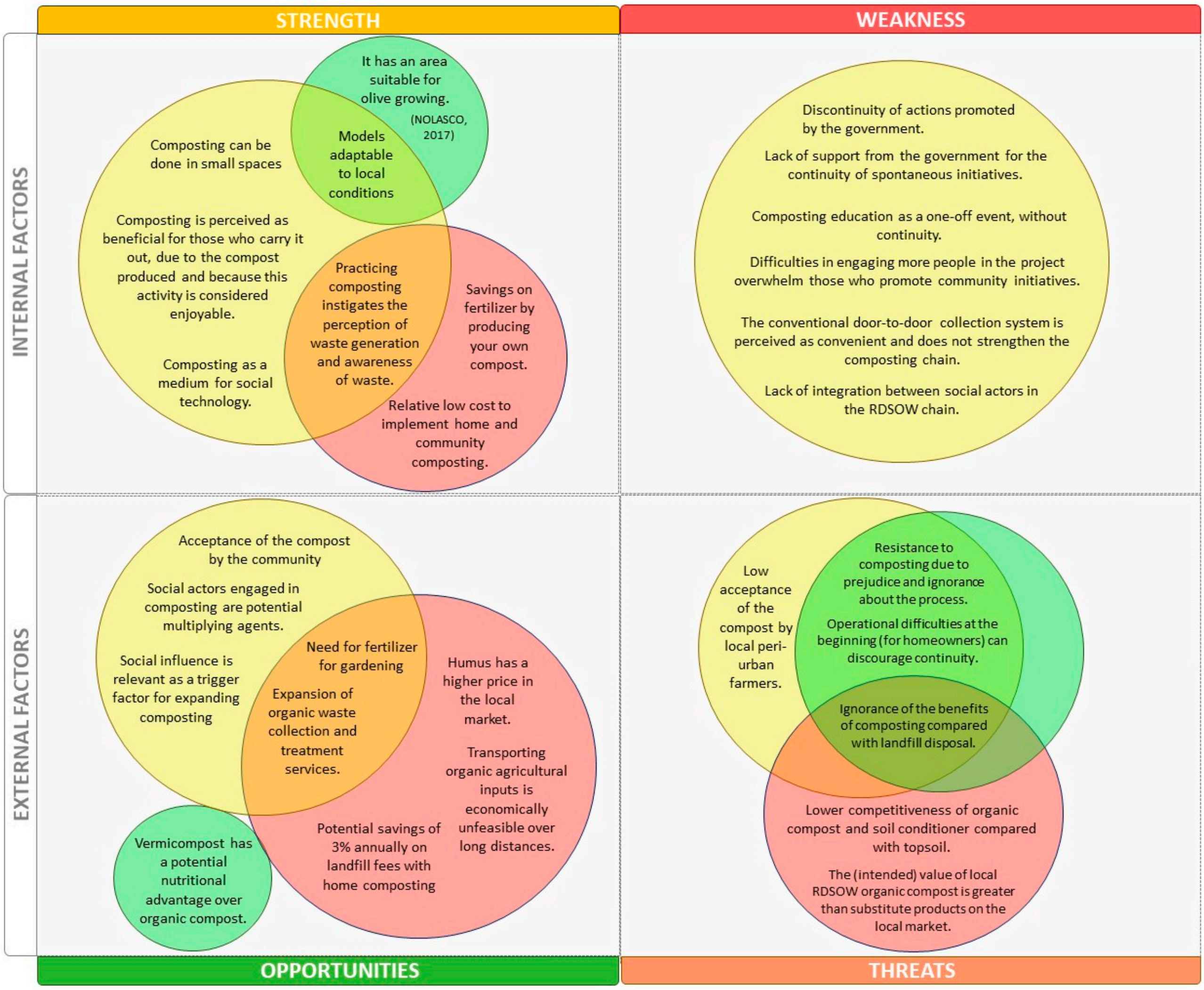


Figure 14. Location of suppliers of products offered by commercial establishments. Data source [87].

This research found that 80% of the suppliers are located within a radius of 200 km from São José dos Campos, and the longest route is approximately 670 km. Given the low value of agricultural products relative to their volume, transportation costs exert a significant impact on the overall price [88], making traveling long distances unfeasible. For mineral fertilizers, the transportation cost represents around 60% of the price composition [89]. There are no available estimates regarding the maximum economically viable distance for transporting organic fertilizers in the Brazilian market.

3.6. Opportunities and Barriers

The yet-unexplored potential of PSOW compost production in Brazil holds significant promise for urban and peri-urban food production across Brazilian municipalities [90]. Gathering local information on the availability of waste, strategic locations for processing the material, and potential consumers is crucial for consolidating this market and the segregation at the source of the PSOW. Figure 15 presents a SWOT matrix outlining the primary opportunities and barriers to composting in a municipal context, as identified in this study, categorized into social, economic, and environmental dimensions.



Note: social dimension; economic dimension; environmental dimension.

Figure 15. Matrix SWOT.

The matrix mainly explores the social and economic aspects since the panorama reached is limited to the vision of the sectors of the PSOW chain consulted in this study, the local stakeholders that carry out the composting, the market offer, and the secondary data from peri-urban farmers. Although the environmental dimension is rarely mentioned, it is already well explored in LCA studies [91,92] and circular economy studies of PSOW [93]. In the same way, the technical aspect was not a previous intention for this work, which focused only on the three dimensions of sustainability, highlighting that the technical aspect is equally important. Future studies may explore the quality of the compost produced in a local context to complement this topic.

The findings from this study suggest a profile akin to that of developing countries, where initiatives are spearheaded by local stakeholders [94] that persist even with low institutional support [95] and limited collaborative interaction among the intersectoral actors involved in the PSOW chain [94]. Hence, it is reasonable to extrapolate the main observations to similar territorial contexts, emphasizing the importance of considering local specificities.

This study also highlights the need to create mechanisms that ensure the effective contribution of the local stakeholders involved in the composting chain in the participatory processes of waste management. This strategy may enhance consistent cultural changes supporting the transition from the current linear chain to a circular chain, as reported by Ddiba et al. [94]. Despite the current low participation, it is understood that the local government can serve as a catalyst for structuring the network of local stakeholders in composting. This can be achieved through strategies that not only ensure the chain's continued operation but also minimize the need for long-term government intervention.

4. Conclusions, Insights, and Limitations

4.1. Conclusions

This research delves into the motivating factors for local stakeholders engaging in composting in the context of the low performance of the local government in institutionalized composting schemes. It highlights the importance of considering the perception of these actors to unveil latent opportunities and barriers that may not always be recognized by the government. Using the snowball methodology was adequate to facilitate access to the interviewees, ensuring greater adherence than contact compared to direct contacts without explicitly indicating the responsible person for composting.

The key results from this research include:

- Education, infrastructure, and social influence were determining factors in the decision to start composting.
- Operational difficulties at the beginning of the process for home composting and non-operational challenges for community and commercial composting are recurrent.
- Interviewees perceive trust in public authorities as low and mention a lack of support, dialogue, and one-off activities as insufficient to promote the practice.
- Space availability is not a determining factor for home composting.
- The efficiency of generated waste diversion is from 42% to 59% for home composting.
- There are potential savings of 3% annually on landfill fees with home composting.
- In the current scenario, the economic value of organic compost from MSW's rapidly degrading organic fraction is not very competitive compared to substitute products.
- Products with MAPA registration are 50% more expensive than those supplied without registration.
- Vermicompost could be a potential commercial product for PSOW appreciation.

4.2. Insights and Limitations

The data collection in this research is consistent with the objectives of exploratory studies, i.e., to obtain preliminary information for the proposition of hypotheses and suggestions for new studies [20]. In this sense, the following recommendations can contribute to the planning of composting systems in other territories and paths for future research:

Adequate information in the initial phase of the composting practice and an understanding of inherent processes is crucial for continuity. In this sense, it is recommended that the production of materials is oriented to the main operational difficulties identified for beginner composters and the creation of a collaborative support network for guidance to clarify doubts. This network can be built in partnership with more experienced composters to act as advisors and provide feedback, given that new practitioners understand the dynamics of the process.

Due to the sample size limitation, it was impossible to carry out statistical data treatment. Also, this study is limited to the perceptions of the targeted public that practices composting. For future research, it is recommended to enlarge the number of interviewees in quantitative research and to broaden the scope to a general sample of the population in the territory. In this way, it will be possible to identify who are the potential composters, what is the level of knowledge of the population, and what are the potential sites and composting models most suited to the local reality.

Market research and the flow of organic fertilizer and its substitute products in other territories can clarify the functioning of the current fertilizer logistics system and contribute to new insights that make the commercialization of PSOW organic compost economically viable.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su16083359/s1. References [96–100] are citied in the Supplementary Materials.

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References

1. Deus, R.M.; Bezerra, B.S.; Battistelle, R.A.G. Solid waste indicators and their implications for management practice. *Int. J. Environ. Sci. Technol.* **2019**, *16*, 1129–1144. [CrossRef]
2. Kaza, S.; Yao, L.; Bhada-Tata, P.; Van Woerden, F. *What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050*; World Bank: Washington, DC, USA, 2018. Available online: https://openknowledge.worldbank.org/handle/10986/30317 (accessed on 10 May 2021).
3. Sondh, S.; Upadhyay, D.S.; Patel, S.; Patel, R.N. A strategic review on Municipal Solid Waste (living solid waste) management system focusing on policies, selection criteria and techniques for waste-to-value. *J. Clean. Prod.* **2022**, *356*, 131908. [CrossRef]
4. Kharola, S.; Ram, M.; Goyal, N.; Mangla, S.K.; Nautiyal, O.P.; Rawat, A.; Pant, D. Barriers to organic waste management in a circular economy. *J. Clean. Prod.* **2022**, *362*, 132282. [CrossRef]
5. Fernández-González, J.M.; Diaz-Lopez, C.; Martin-Pascual, J.; Zamorano, M. Recycling organic fraction of municipal solid waste: Systematic literature review and bibliometric analysis of research trends. *Sustainability* **2020**, *12*, 4798. [CrossRef]
6. Awasthi, S.K.; Sarsaiya, S.; Awasthi, M.K.; Liu, T.; Zhao, J.; Kumar, S.; Zhang, Z. Changes in global trends in food waste composting: Research challenges and opportunities. *Bioresour. Technol.* **2020**, *299*, 122555. [CrossRef] [PubMed]
7. Xu, M.; Yang, M.; Xie, D.; Ni, J.; Meng, J.; Wang, Q.; Wu, C. Research trend analysis of composting based on Web of Science database. *Environ. Sci. Pollut. Res.* **2021**, *28*, 59528–59541. [CrossRef] [PubMed]
8. Brasil. Lei no12.305 de 2 de Gosto de 2010. Presidência Da República. Institui a Política Nacional de Resíduos Sólidos; Altera a Lei No 9.605, de 12 de Fevereiro de 1998; E Dá Outras Providências. Diário Oficial Da União, Brasília DF, de 03 de Agosto de 2010, P. 2.; Diário Oficial [Da União]. 2010. Available online: https://www.planalto.gov.br/ccivil_03/_ato2007-2010/2010/lei/l12305.htm (accessed on 19 May 2022).
9. Brasil; Ministério do Meio Ambiente; Secretaria de Qualidade Ambiental. Plano Nacional de Resíduos Sólidos—Planares [recurso eletrônico], coordenação de André Luiz Felisberto França, Secretaria de Qualidade Ambiental, Carlos Roberto Vieira da Silva Filho, Associação Brasileira de Empresas de Limpeza Pública e Resíduos Especiais—Abrelpe. 2022. Available online: https://portal-api.sinir.gov.br/wp-content/uploads/2022/07/Planares-B.pdf (accessed on 19 May 2019).
10. ABRELPE. Associação Brasileira de Limpezas de Limpeza Pública e Resíduos Especiais. Panorama dos Resíduos Sólidos no Brasil. 2021. Available online: https://abrelpe.org.br/panorama-2021/ (accessed on 19 May 2019).
11. SNIS. Ministério do Desenvolvimento Regional. Secretaria Nacional de Saneamento. In *Sistema Nacional de Informações sobre Saneamento: Diagnóstico Temático Manejo de Resíduos Sólidos Urbanos*; SNS/MDR: Brasília, Brazil, 2021. Available online: http://www.snis.gov.br/downloads/diagnosticos/rs/2020/DIAGNOSTICO_TEMATICO_VISAO_GERAL_RS_SNIS_2021.pdf (accessed on 19 May 2022).
12. Siqueira, T.M.O.D.; Assad, M.L.R.C. Compostagem de resíduos sólidos urbanos no estado de São Paulo. *Ambient. Soc.* **2015**, *18*, 243–264. [CrossRef]
13. Fehr, M.; Arantes, C.A. Making a case for recycling biodegradable municipal waste. *Environ. Syst. Decis.* **2015**, *35*, 483–489. [CrossRef]
14. Gonçalves, A.T.T.; Moraes, F.T.F.; Marques, G.L.; Lima, J.P.; Lima, R.D.S. Urban solid waste challenges in the BRICS countries: A systematic literature review. *Rev. Ambiente Água* **2018**, *13*, e2157. [CrossRef]

15. Simas, A.L.F.; Silva, W.L.C.; Tajiri, C.A.H.; Nader, F.A.S.; Alegre, M.F.R.; Scatena, G.K.; Oliveira Mello, I.; Filho, J.V.M.; Santa Inez, J.R.M. *São Paulo. Plano de Resíduos Sólidos do Estado de São Paulo 2020*; Secretaria de Infraestrutura e Meio Ambiente: São Paulo, Brazil, 2020. Available online: https://smastr16.blob.core.windows.net/home/2020/12/plano-resi%CC%81duos-solidos-2020_final.pdf (accessed on 24 June 2022).
16. Machado, R.C.; Cunha, S.K. From urban waste to urban farmers: Can we close the agriculture loop within the city bounds? *Waste Manag. Res.* **2022**, *40*, 306–313. [CrossRef]
17. Sewak, A.; Kim, J.; Rundle-Thiele, S.; Deshpande, S. Influencing household-level waste-sorting and composting behaviour: What works? A systematic review (1995–2020) of waste management interventions. *Waste Manag. Res.* **2021**, *39*, 892–909. [CrossRef] [PubMed]
18. Díez, E.; McIntosh, B.S. A review of the factors which influence the use and usefulness of information systems. *Environ. Model. Softw.* **2009**, *24*, 588–602. [CrossRef]
19. Kim, J.; Rundle-Thiele, S.; Knox, K. Systematic literature review of best practice in food waste reduction programs. *J. Soc. Mark.* **2019**, *9*, 447–466. [CrossRef]
20. Yin, R.K. *Estudo de Caso: Planejamento e Métodos*, 5th ed.; Bookman: Porto Alegre, Brazil, 2015.
21. IBGE. Instituto Brasileiro de Geografia e Estatística. Estimativas da População Residente com Data de Referência 1° de Julho de 2021. Available online: https://cidades.ibge.gov.br/brasil/sp/sao-jose-dos-campos/panorama (accessed on 24 June 2022).
22. PMSJC. *São José em Dados 2016—Informações Sobre a Cidade de São José dos Campos*; Prefeitura Municipal de São José dos Campos: São José dos Campos, Brazil, 2016.
23. PMSJC. Geosanja. 2022. Available online: https://geosanja.sjc.sp.gov.br/ (accessed on 6 June 2022).
24. PMSJC. *Urbam Conclui Estudo Sobre Lixo em São José*; Prefeitura Municipal de São José dos Campos: São José dos Campos, Brazil, 2018. Available online: https://www.sjc.sp.gov.br/noticias/2018/setembro/27/urbam-conclui-estudo-sobre-o-lixo-em-sao-jose/ (accessed on 20 January 2020).
25. Econodata. Plataforma de Prospecção de Empresas. Available online: https://www.econodata.com.br/consulta-cnae (accessed on 1 February 2021).
26. Yin, R.K. *Pesquisa Qualitativa do Início ao Fim*; Penso Editora: Porto Alegre, Brazil, 2016.
27. Marshall, B.; Cardon, P.; Poddar, A.; Fontenot, R. Does sample size matter in qualitative research?: A review of qualitative interviews in IS research. *J. Comput. Inf. Syst.* **2013**, *54*, 11–22. [CrossRef]
28. Bardin, L. Análise de Conteúdo. *Lisb. Edições* **1977**, *70*, 225.
29. Moraes, R. Análise de conteúdo. *Rev. Educ. Porto Alegre* **1999**, *22*, 7–32.
30. Pereira, V.R.; Fiore, F.A. Fatores influenciadores da segregação de resíduos orgânicos na fonte geradora para a viabilização de sistemas de compostagem. *Eng. Sanit. E Ambient.* **2022**, *27*, 643–652. [CrossRef]
31. Camargo, B.V.; Justo, A.M. Tutorial Para Uso do Software IRAMUTEQ. Universidade Federal de Santa Catarina Brasil [Internet].[Santa Catarina]: UFSC. 2013. Available online: http://www.iramuteq.org/documentation/fichiers/tutoriel-en-portugais (accessed on 2 February 2022).
32. Helms, M.M.; Nixon, J. Exploring SWOT analysis–where are we now? A review of academic research from the last decade. *J. Strategy Manag.* **2010**, *3*, 215–251. [CrossRef]
33. Mensah, J. Sustainable development: Meaning, history, principles, pillars, and implications for human action: Literature review. *Cogent Soc. Sci.* **2019**, *5*, 1653531. [CrossRef]
34. Janker, J.; Mann, S.; Rist, S. Social sustainability in agriculture–A system-based framework. *J. Rural Stud.* **2019**, *65*, 32–42. [CrossRef]
35. Vinuto, J. A amostragem em bola de neve na pesquisa qualitativa: Um debate em aberto. *Temáticas* **2014**, *22*, 203–220. [CrossRef]
36. Kiehl, E.J. *Fertilizantes Orgânicos*; Agronômica Ceres: São Paulo, Brazil, 1985; p. 492.
37. Onwosi, C.O.; Igbokwe, V.C.; Odimba, J.N.; Eke, I.E.; Nwankwoala, M.O.; Iroh, I.N.; Ezeogu, L.I. Composting technology in waste stabilization: On the methods, challenges and future prospects. *J. Environ. Manag.* **2017**, *190*, 140–157. [CrossRef]
38. Jouhara, H.; Czajczyńska, D.; Ghazal, H.; Krzyżyńska, R.; Anguilano, L.; Reynolds, A.J.; Spencer, N. Municipal waste management systems for domestic use. *Energy* **2017**, *139*, 485–506. [CrossRef]
39. Tramontina. Compostagem Plástica. Manual de Uso e Manutenção. 2016. Available online: https://assets.tramontina.com.br/upload/tramon/imagens/MUL/78295254MNP001.pdf (accessed on 21 September 2022).
40. Higa, T.; Parr, J.F. *Beneficial and Effective Microorganisms for a Sustainable Agriculture and Environment*; International Nature Farming Research Center: Atami, Japan, 1994; Volume 1.
41. Schwengber, J.E.i; Schiedeck, G.; Gonçalves, M.M. Compostagem laminar–uma alternativa para o manejo de resíduos orgânicos. In *Comunicado Técnico 169*; Embrapa: Brasília, Brazil, 2007.
42. Güttler, G. Acúmulo e Perdas de Nutrientes Durante a Compostagem de Resíduos Orgânicos Diretamente Sobre o Solo Com Cultivo de Hortaliças. Ph.D. Thesis, State Santa Catarina University, Florianópolis, Brazil, 2019.
43. Singh, R.P.; Singh, P.; Araujo, A.S.; Ibrahim, M.H.; Sulaiman, O. Management of urban solid waste: Vermicomposting a sustainable option. *Resour. Conserv. Recycl.* **2011**, *55*, 719–729. [CrossRef]
44. Gajalakshmi, S.; Abbasi, S.A. Solid Waste Management by Composting: State of the Art. *Crit. Rev. Environ. Sci. Technol.* **2008**, *38*, 311–400. [CrossRef]

45. de Sousa Antunes, L.F.; Correia ME, F.; da Silva, D.G. Millicomposting: Composting based on the use of diplopods aiming at the production of organic substrates. *Rev. Em Agronegócio E Meio Ambiente* **2020**, *13*, 1019–1038. [CrossRef]
46. Bortolotti, A.; Kampelmann, S.; De Muynck, S. Decentralised organic resource treatments–classification and comparison through extended material flow analysis. *J. Clean. Prod.* **2018**, *183*, 515–526. [CrossRef]
47. Siqueira, T.M.O.D.; Abreu, M.J.D. Fechando o ciclo dos resíduos orgânicos: Compostagem inserida na vida urbana. *Ciência E Cult.* **2016**, *68*, 38–43. [CrossRef]
48. Adhikari, B.K.; Barrington, S.; Martinez, J.; King, S. Characterization of food waste and bulking agents for composting. *Waste Manag.* **2008**, *28*, 795–804. [CrossRef]
49. Cox, J.; Giorgi, S.; Sharp, V.; Strange, K.; Wilson, D.C.; Blakey, N. Household waste prevention—A review of evidence. *Waste Manag. Res.* **2010**, *28*, 193–219. [CrossRef]
50. Gillespie, A.; Halog, A. Community-Scale Composting Initiatives in South-East Queensland and Beyond: A Review of Successes, Challenges and Lessons for a Pilot Project on Karragarra Island, southern Moreton Bay. *Circ. Econ. Sustain.* **2022**, *3*, 305–319. [CrossRef]
51. Reynolds, C.J.; Mavrakis, V.; Davison, S.; Høj, S.B.; Vlaholias, E.; Sharp, A.; Dawson, D. Estimating informal household food waste in developed countries: The case of Australia. *Waste Manag. Res.* **2014**, *32*, 1254–1258. [CrossRef] [PubMed]
52. Carvalho, G.M.D. Compostagem Urbana: Estudo de Caso do Projeto Reciclorgânico. Bacharelor's Thesis, Universidade de São Paulo, São Paulo, Brazil, 2021.
53. Vázquez, M.A.; Soto, M. The efficiency of home composting programmes and compost quality. *Waste Manag.* **2017**, *64*, 39–50. [CrossRef] [PubMed]
54. Abreu, M.J.D. Gestão Comunitária de Resíduos Orgânicos: O Caso do Projeto Revolução dos Baldinhos (PRB). Master's Thesis, Capital Social e Agricultura Urbana. de Ciências Agrárias, Universidade Federal de Santa Catarina, Florianopolis, SC, Brazil, 2013.
55. Walling, E.; Trémier, A.; Vaneeckhaute, C. A review of mathematical models for composting. *Waste Manag.* **2020**, *113*, 379–394. [CrossRef] [PubMed]
56. Urbam. Urbanizadora Municipal. Estudo de Caracterização Gravimétrica São José dos Campos—SP. 2018. Available online: https://www.sjc.sp.gov.br/media/34209/apresentacao-urbam-caracterizacao-gravimetrica-sjc-2018.pdf (accessed on 4 July 2022).
57. Fehr, M. The management challenge for household waste in emerging economies like Brazil: Realistic source separation and activation of reverse logistics. *Waste Manag. Res.* **2014**, *32*, 32–39. [CrossRef] [PubMed]
58. Pai, S.; Ai, N.; Zheng, J. Decentralized community composting feasibility analysis for residential food waste: A Chicago case study. *Sustain. Cities Soc.* **2019**, *50*, 101683. [CrossRef]
59. Adhikari, B.K.; Trémier, A.; Martinez, J.; Barrington, S. Home and community composting for on-site treatment of urban organic waste: Perspective for Europe and Canada. *Waste Manag. Res.* **2010**, *28*, 1039–1053. [CrossRef] [PubMed]
60. Karkanias, C.; Perkoulidis, G.; Moussiopoulos, N. Sustainable management of household biodegradable waste: Lessons from home composting programmes. *Waste Biomass Valorization* **2016**, *7*, 659–665. [CrossRef]
61. Chiabi, L. Ciclo Orgânico: Um Empreendimento Social, de Compostagem Comunitária e Gestão de Resíduos. Bachalor's Thesis, Universidade Federal do Rio de Janeiro, Rio de Janeiro, Brazil, 2017.
62. Takahashi, Y.; Nomura, H.; Yabe, M. Modeling home composting behavior toward sustainable municipal organic waste management at the source in developing countries. *Resour. Conserv. Recycl.* **2019**, *140*, 65–71. [CrossRef]
63. Keng, Z.X.; Chong, S.; Ng, C.G.; Ridzuan, N.I.; Hanson, S.; Pan, G.T.; Lam, H.L. Community-scale composting for food waste: A life-cycle assessment-supported case study. *J. Clean. Prod.* **2020**, *261*, 121220. [CrossRef]
64. Li, Z.; Lu, H.; Ren, L.; He, L. Experimental and modeling approaches for food waste composting: A review. *Chemosphere* **2013**, *93*, 1247–1257. [CrossRef]
65. Duque, T.O.; Valadão, J.D.A.D. Abordagens teóricas de tecnologia social no Brasil. *Rev. Pensamento Contemp. Em Adm.* **2017**, *11*, 1–19. [CrossRef]
66. Borghesi, G.; Morone, P. A review of the effects of COVID-19 on food waste. *Food Secur.* **2023**, *15*, 261–280. [CrossRef]
67. Principato, L.; Secondi, L.; Cicatiello, C.; Mattia, G. Caring more about food: The unexpected positive effect of the COVID-19 lockdown on household food management and waste. *Socio-Econ. Plan. Sci.* **2022**, *82*, 100953. [CrossRef]
68. Iranmanesh, M.; Ghobakhloo, M.; Nilsashi, M.; Tseng, M.L.; Senali, M.G.; Abbasi, G.A. Impacts of the COVID-19 pandemic on household food waste behaviour: A systematic review. *Appetite* **2022**, *176*, 106127. [CrossRef]
69. MAPA. *Instrução Normativa nº 61, de 8 de Julho de 2020. Estabelece as Regras Sobre Definições, Exigências, Especificações, Garantias, Tolerâncias, Registro, Embalagem E Rotulagem dos Fertilizantes Orgânicos e dos Biofertilizantes, Destinados à Agricultura*; Ministério da Agricultura, Pecuária e Abastecimento: Brasília, Brazil, 2020.
70. Bersan, J.L.M.; Kelmer, G.A.R.; de Almeida, J.R. Avaliação da qualidade nutricional de composto orgânico produzido com resíduos provenientes de composteiras domésticas. Revista Brasileira de Meio Ambiente 2022. pp. 240–258. Available online: https://revistabrasileirademeioambiente.com/index.php/RVBMA/article/view/1164 (accessed on 19 May 2022).
71. Ruellan, A. Olhares convergentes para o solo. *Cad. De Desenvolv. E Meio Ambiente* **1995**, *2*, 109–118.
72. Costa, S.; Marinelo, S. O visível e o invisível da agricultura urbana em São José dos Campos, SP. *GOT Rev. De Geogr. E Ordenam. Do Territ.* **2019**, *16*, 99. [CrossRef]

73. Nolasco, C.L. Demanda e abastecimento de hortaliças na microrregião de São José dos Campos, Brasil: Implicações para a segurança alimentar e desenvolvimento sustentável no contexto das mudanças globais. Ph.D. Thesis, Instituto Nacional de Pesquisas Espaciais, São José dos Campos, Brazil, 2016.
74. Ferreira, A.J.D.; Guilherme, R.I.M.M.; Ferreira, C.S.S. Urban agriculture, a tool towards more resilient urban communities? *Curr. Opin. Environ. Sci. Health* **2018**, *5*, 93–97. [CrossRef]
75. Altieri, M.A.; Nicholls, C. Urban agroecology: Designing biodiverse, productive and resilient city farms. *Agro Sur* **2018**, *46*, 49–60. [CrossRef]
76. ABREFEN. Associação Brasileira dos Produtores de Remineralizadores de Solo e Fertilizantes Naturais. *Rev. Novosolo* **2022**, *2*, 6–9. Available online: https://abrefen.org.br/category/ed2-revista-novo-solo/ (accessed on 19 May 2022).
77. Brasil. Decreto Federal nº 8.384, de 29 de Dezembro de 2014. Altera o Anexo ao Decreto nº 4.954, de 14 de Janeiro de 2004, Que Aprova o Regulamento da Lei nº 6.894, de 16 de Dezembro de 1980, Que Dispõe Sobre a Inspeção e Fiscalização da Produção e do Comércio de Fertilizantes, Corretivos, Inoculantes ou Biofertilizantes Destinados à Agricultura. 2004. Available online: https://sistemasweb.agricultura.gov.br/sislegis/action/detalhaAto.do?method=consultarLegislacaoFederal (accessed on 19 May 2022).
78. Brasil. Decreto Federal nº 4.954, de 14 de janeiro de 2.004. Regulamenta a lei nº 6.894, de 16 de Dezembro 1980, Que Dispõe Sobre a Inspeção e Fiscalização da Produção e do Comércio de Fertilizantes, Corretivos e Inoculantes Ou Biofertilizantes Destinados à Agricultura, e dá Outras Providências. 2014. Available online: http://sistemasweb.agricultura.gov.br/sislegis/action/detalhaAto.do?method=recuperarTextoAtoTematicaPortal&codigoTematica=1229184 (accessed on 19 May 2022).
79. Srivastava, V.; Squartini, A.; Masi, A.; Sarkar, A.; Singh, R.P. Metabarcoding analysis of the bacterial succession during vermicomposting of municipal solid waste employing the earthworm Eisenia fetida. *Sci. Total Environ.* **2021**, *766*, 144389. [CrossRef] [PubMed]
80. Ndegwa, P.M.; Thompson, S.A.; Das, K.C. Effects of stocking density and feeding rate on vermicomposting of biosolids. *Bioresour. Technol.* **2000**, *71*, 5–12. [CrossRef]
81. Hammermeister, A.M.; Astatkie, T.; Jeliazkova, E.A.; Warman, P.R.; Martin, R.C. Nutrient supply from organic amendments applied to unvegetated soil, lettuce and orchardgrass. *Can. J. Soil Sci.* **2006**, *86*, 21–33. [CrossRef]
82. Ducasse, V.; Capowiez, Y.; Peigné, J. Vermicomposting of municipal solid waste as a possible lever for the development of sustainable agriculture. *Agron. Sustain. Dev.* **2022**, *42*, 89. [CrossRef]
83. Suthar, S. Vermicomposting of vegetable-market solid waste using Eisenia fetida: Impact of bulking material on earthworm growth and decomposition rate. *Ecol. Eng.* **2009**, *35*, 914–920. [CrossRef]
84. Panda, A.K.; Mishra, R.; Dutta, J.; Wani, Z.A.; Pant, S.; Siddiqui, S.; Bisht, S.S. Impact of Vermicomposting on Greenhouse Gas Emission: A Short Review. *Sustainability* **2022**, *14*, 11306. [CrossRef]
85. Jain, K.; Singh, J.; Chauhan, L.K.S.; Murthy, R.C.; Gupta, S.K. Modulation of flyash-induced genotoxicity in Vicia faba by vermicomposting. *Ecotoxicol. Environ. Saf.* **2004**, *59*, 89–94. [CrossRef] [PubMed]
86. Lohri, C.R.; Diener, S.; Zabaleta, I.; Mertenat, A.; Zurbrügg, C. Treatment technologies for urban solid biowaste to create value products: A review with focus on low-and middle-income settings. *Rev. Environ. Sci. Bio/Technol.* **2017**, *16*, 81–130. [CrossRef]
87. IBGE. Instituto Brasileiro de Geografia e Estatística. Downloads. Available online: https://www.ibge.gov.br/geociencias/downloads-geociencias.html (accessed on 24 June 2022).
88. De Lima, L.M.; Péra, T.G.; Caixeta Filho, J.V. Implicações da Política Nacional de pisos de frete do transporte rodoviário na logística de fertilizantes No Brasil. *Rev. Bras. De Transp.* **2022**, *2*, 158–205. [CrossRef]
89. Pereira, A.A.; Oliveira, M.A.; Leal Júnior, I.C. Custo de transporte e alocação da demanda: Análise da rede logística de uma produtora brasileira de fertilizantes nitrogenados. *J. Transp. Lit.* **2016**, *10*, 5–9. [CrossRef]
90. Secretaria Especial de Assuntos Estratégicos. *Plano Nacional de Fertilizantes 2050*; SAE DF: Brasília, Brazil, 2021.
91. Bernstad, A.; la Cour Jansen, J. Review of comparative LCAs of food waste management systems–current status and potential improvements. *Waste Manag.* **2012**, *32*, 2439–2455. [CrossRef] [PubMed]
92. Morris, J.; Matthews, H.S.; Morawski, C. Review and meta-analysis of 82 studies on end-of-life management methods for source separated organics. *Waste Manag.* **2013**, *33*, 545–551. [CrossRef]
93. Paes, L.A.B.; Bezerra, B.S.; Deus, R.M.; Jugend, D.; Battistelle, R.A.G. Organic solid waste management in a circular economy perspective–A systematic review and SWOT analysis. *J. Clean. Prod.* **2019**, *239*, 118086. [CrossRef]
94. Ddiba, D.; Andersson, K.; Koop, S.H.; Ekener, E.; Finnveden, G.; Dickin, S. Governing the circular economy: Assessing the capacity to implement resource-oriented sanitation and waste management systems in low-and middle-income countries. *Earth Syst. Gov.* **2020**, *4*, 100063. [CrossRef]
95. Aguilar, M.G.; Jaramillo, J.F.; Ddiba, D.; Páez, D.C.; Rueda, H.; Andersson, K.; Dickin, S. Governance challenges and opportunities for implementing resource recovery from organic waste streams in urban areas of Latin America: Insights from Chía, Colombia. *Sustain. Prod. Consum.* **2022**, *30*, 53–63. [CrossRef]
96. Edgerton, E.; McKechnie, J.; Dunleavy, K. Behavioral determinants of household participation in a home composting scheme. *Environ. Behav.* **2009**, *41*, 151–169. [CrossRef]
97. Mckenzie-Mohr, D.; Smith, W. Fostering sustainable behavior: Community-based social marketing. CBSM. 2009. Available online: http://www.cbsm.com/pages/guide/introduction (accessed on 20 June 2022).
98. Weatherly, J.N.; Miller, K.; McDonald, T.W. Influência social como controle de estímulos. *Psicologia IESB* **2009**, *1*, 93–107.

99. Knickmeyer, D. Social factors influencing household waste separation: A literature review on good practices to improve the recycling performance of urban areas. *J. Clean. Prod.* **2020**, *245*, 118605. [CrossRef]
100. Manomaivibool, P.; Srivichai, M.; Unroj, P.; Dokmaingam, P. Chiang Rai Zero Waste: Participatory action research to promote source separation in rural areas. *Resour. Conserv. Recycl.* **2018**, *136*, 142–152. [CrossRef]