

Supplemental Files

APPENDIX 1 - Municipal Solid Waste Management System (MSWMS) in the Four Case Studies

MSW management system in the municipality of Harmonia (State of Rio Grande do Sul) in 2019

The MSWMS in the Harmonia municipality is composed of collection, transport, sorting, and final disposal in a landfill. A private company, outsourced and contracted by the Municipality of Harmonia (PMH), is responsible for collecting, transporting, and sorting dry and wet waste. The collection of dry and recyclable waste occurs once a week, while wet and organic waste occurs twice a week. Bulky waste is collected once a month. The sorting centre is located in the nearby town of Tupandi, just 12 km from Harmonia. The contracted company also must dispose of the waste that was not reused, and because of that, it uses a private landfill in the city of São Leopoldo, which is located 40 km from Harmonia and 50 km from Tupandi.

The per capita waste generation in the city is only 0.405 kg/inhabitant/day (in 2019), well below the national average of 1 kg/inhabitant/day (SNIS, 2019). Through fieldwork and data provided by PMH, information on MSW's composition, generation, and management can be seen in Appendix 2.

Also, compared to the national average, on the gravimetric composition of waste - in which 50% is organic waste - it is noted that only 22% of the total MSW managed by the municipality of Harmonia is composed of organic matter.

Through fieldwork, it was possible to learn about composting in schools, restaurants, and homes in urban and rural areas, a fact that is mainly due to environmental education actions and local awareness and culture on the reuse of organic waste for vegetable gardens places for food production. Furthermore, through the interviews carried out with authorities and citizens, it was also possible to notice a certain naturalness about the importance of reusing waste, especially the organic fraction for the production of compost and food.

Environmental education activities occur in municipal schools in a transversal and interdisciplinary manner and through actions on commemorative dates, such as the World Day for the Environment, Water, Earth, etc. In 2019, the projects were developed with 375 students and 49 teachers from 4 schools in the municipal education network. In addition, social participation in municipal councils and public debates (such as public hearings and legislative sections) on local public policies are also fundamental aspects for cohesion and good results in the management of MSW in the municipality.

Through Figure A, it is possible to understand which initiatives are part of MSW Management in the municipality. Home composting (also known as garden and backyard composting) does not have its environmental and economic burdens considered within the MSWMS, as individuals support it and not by the public waste management service. Thus, as home composting is not included in the public waste management system, this activity has been considered an action of prevention, reduction, and non-generation of waste, as suggested and demonstrated by important studies in the area. Therefore, it can generate economic and environmental benefits for MSWMS, as seen in Chapter 4 - Table 2.

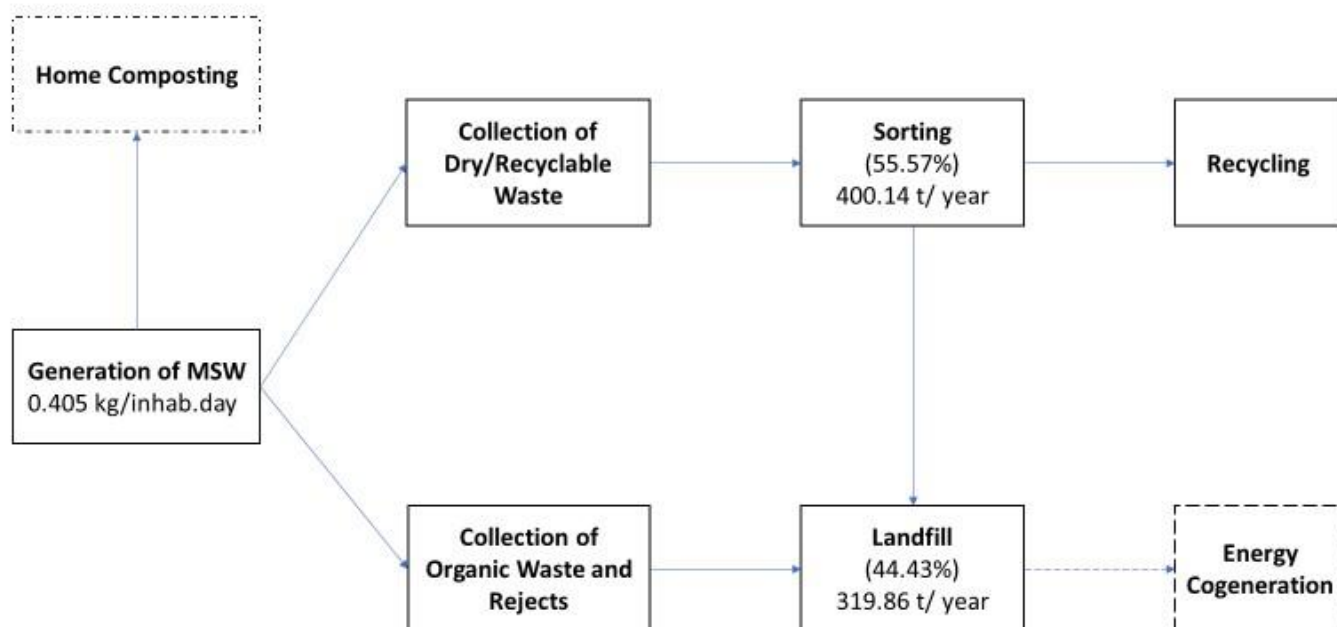


Figure A: MSW management system in the municipality of Harmonia (State of Rio Grande do Sul) in 2019.

MSW management system in the municipality of São Paulo (State of São Paulo) in 2019

The MSWMS in the municipality of São Paulo is divided into two contractual and management models. First, through a Public Service Concession Contract, two companies provide the services of collection, transport, and final disposal in a landfill, in addition to the selective collection of household waste (HHW). Here, companies must send recyclable materials to the two Mechanized Sorting Centres (MSC) and the manual sorting centres, operated by cooperatives.

In 2019, the city of São Paulo had 24 cooperatives (approximately 900 waste pickers) and over 1,400 self-employed waste pickers registered with the Municipal Urban Cleaning Authority (AMLURB). In addition, there were also another 30 cooperatives not authorized by the municipal government and an estimated 10 to 12 thousand informal waste pickers (Paes et al., 2021a).

Through the Service Provision Agreements, another six companies were responsible for Waste from Public Cleaning (PCW), consisting of selective collection of organic waste from the street market and sending it to 5 composting units, pruning, and weeding. Also, the collection and disposal in the landfill of debris, sweeping residues and waste of the drainage system, removal of waste discarded in inappropriate places, dead animals, and expired food.

Figure B shows the main activities of the MSW Management System – comprising the generation, collection, transport, sorting, treatment, destination, and generation of co-products – in addition to the quantities generated and managed by the municipality of São Paulo. The gravimetric composition of the MSW can be seen in Table B.

Based on these data and information, it is also possible to observe the large amount of dry (recyclable) and wet (organic) waste that the selective collection, sorting, and composting system could reuse. Only 0.4% of organic waste was recovered in 2019, while more than 40% was sent to landfills. Concerning dry and recyclable waste, only 1.7% was recovered by the formal selective collection and sorting system, while more than 25% of paper, plastic, glass, and metals were also buried.

However, it is possible to stand out important initiatives on innovation in the city, such as i) the two MSC, with a processing capacity of up to 250 t/day each, which were operating at only a quarter of their capacity; ii) the composting projects, which through the selective collection of organic waste from the street market and processing in five composting yards, produced 3,700 tons of compost in 2019 and; iii) the cogeneration of electricity from methane generated by the decomposition of organic matter in two landfills that the city sent its waste, with installed capacities of 8MW and 29MW. The methane use projects also generate carbon credits for the city, sold through auctions and destined for the Municipal Environmental Fund. The third landfill, which only receives PCW, had a methane-burning plant and was in the process of environmental licensing for the biogas plant for energy use with an estimated installed capacity of 2.5MW.

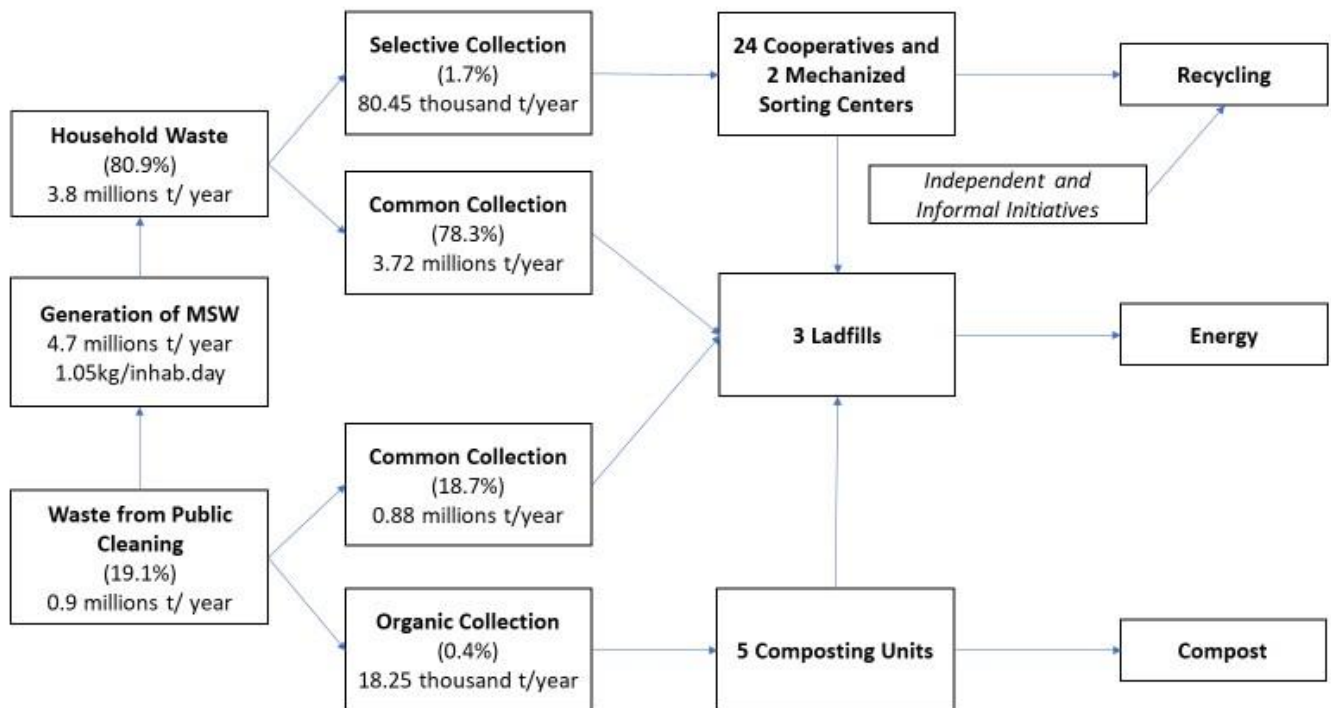


Figure B: MSW management system in the municipality of São Paulo (State of São Paulo) in 2019.

MSW management system in the municipality of Ibertioga (State of Minas Gerais) in 2019

The MSWMS in the municipality of Ibertioga comprises the activities of collecting, transporting, and disposing of waste to the Sorting and Composting Unit (SCU), which has the facilities of the sorting, composting, and landfill plants, as shown in Figure C. The city hall of Ibertioga carries out the entire operation of the MSWMS. The collection of dry and recyclable waste takes place once a week (Fridays), as well as wet waste (Mondays) and tailings (Wednesdays). Employees of the city hall itself also carry out the operation of SCU. In 2019, the sorting, composting, and landfill plants received an approximate volume of 27.6%, 39.8%, and 32.6%, respectively, as shown in Figure and Table C, reaching 67.4 % of reuse. In addition, the city hall itself sells recyclable materials. Most of them are sent to the municipality of Juiz de Fora, while Ibertioga uses compost to produce vegetable gardens and seedlings within the SCU.

In the state of Minas Gerais, it was possible to diagnose and understand the important role played by the state government, which has been supporting and working in collaboration with the municipalities through technical and financial support. Through financial support, we highlight the resources destined for the construction of Sorting and Composting Units and the remuneration of the municipalities that present good MSW management indicators (through the transfer of state tax). Also, the project known as the "recycling fellowship" directly remunerates associations and cooperatives of waste pickers. Furthermore, through technical support, stands out the partnership between the State Secretariat for the Environment and Sustainable Development (SEMAD) and the Social Policy Management Institute (Gesois), which has been training municipalities for the installation and operation of SCU, creation of consortia and management of cooperatives and association of waste pickers. There is also a partnership agreement between SEMAD and the Public Ministry to guide city halls on the correct management of MSW.

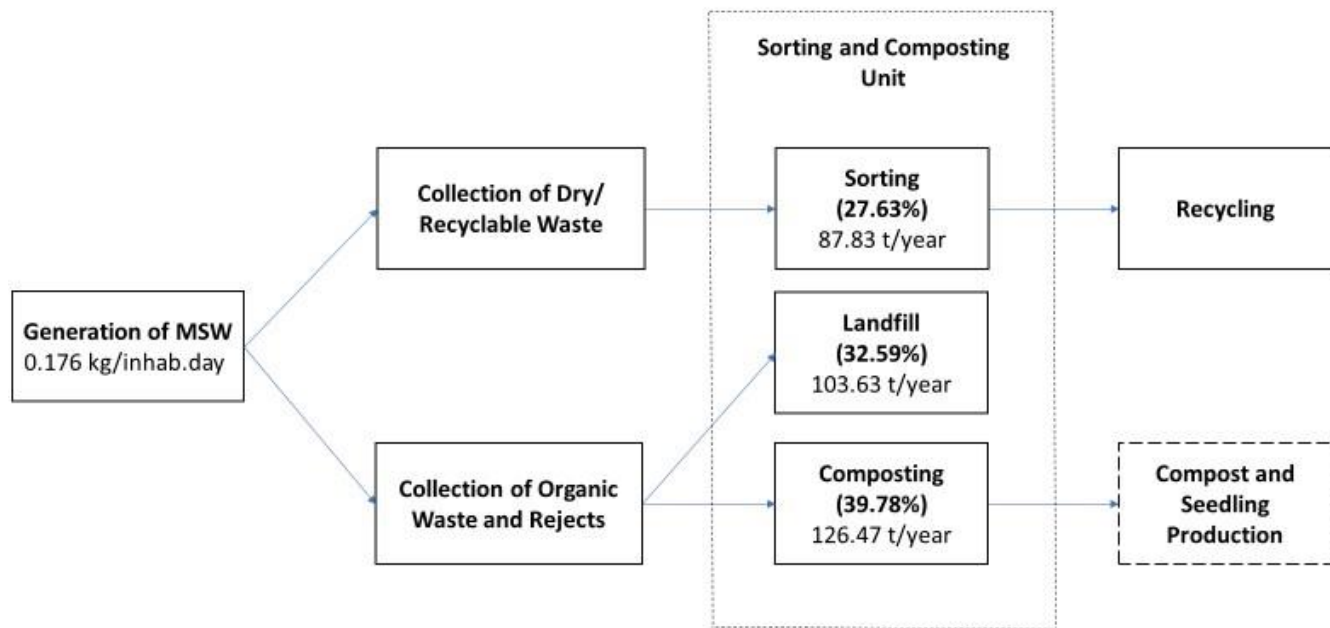


Figure C: MSW management system in the municipality of Ibertioga (State of Minas Gerais) in 2019.

MSW management system in the municipality of Carauari (State of Amazonas) in 2019

The MSWMS in Carauari city is composed of the collection, transport, and final destination of waste to a landfill (both steps operated by the city hall itself), in addition to the informal work of waste pickers (in the urban area) and reuse of organic and recyclable waste (in rural and forest areas) (Figure D). According to the National System of Information on Sanitation data, of the 62 municipalities in the state of Amazonas, only Carauari, Manaus, Novo Airão, Parintins, and Presidente Figueiredo have landfills (SNIS, 2019).

In 2014, there were initiatives to build an association of recyclable material collectors in the city; however, only two waste shipments were sent to Manaus (approximately 20t each). The local government estimates that every 03 months (with 11 t each trip), around 44 t/year are sent to Manaus, even without proper formalization by the waste pickers. In 2017, the municipality collected and sent 1,700 tons of waste to the landfill.

The collection of waste only serves the urban population (21,707 inhabitants), representing 76.7% of the municipality's total population (28,294). Therefore, 23.3% (6,587 inhabitants) who live in 52 communities do not have access to public waste management services and have been developing autonomous alternatives for waste management.

Waste from rural and agro-extravist communities – Carauari (Amazonas)

Regarding the waste from communities located on the banks of the Juruá River (in the municipality of Carauari), the generation in these rural communities can reach 0.5 kg/person/day. 90% of these wastes are organic matter, used mainly to feed animals or generate compost, together with forest residues. Inorganic/dry solid waste (10%) is reused (e.g., glass and plastic packaging), burned, or improperly dumped in open places (Paes et al., 2021a, 2021b).

Considering the rural population of 6,569 inhabitants (in 2019), waste production in these communities could reach 1,200 t/year. As infrastructure services are practically non-existent in this rural context, this generation of waste can have serious negative impacts on the health of the population, especially concerning the inadequate management of hazardous waste, such as batteries, light bulbs, and oils, among others (Paes et al., 2021a, 2021b).

The fieldwork identified some initiatives that are already being developed.

An example is the reuse of waste from the agroindustry that produces andiroba and murumuru oils for a cosmetics company with great relevance in the national economic scenario. In 2019, this initiative involved approximately 1,200 families in seed collection within two conservation units: the Sustainable Development Reserve (RDS) of Uacari and the Extractive Reserve (Resex) Médio Juruá.

After the collection by these families, the seeds are processed in the agroindustry with the potential to process 36 tons/year of oils. Approximately 2 tons of waste is generated for every ton of product, giving the potential for some 20 tons in 2019. For example, the communities were reusing fruit peels in the forests in home gardens. At the same time, the oilcake (approximately 70% of the waste, or in this case, 14 t/year) was being processed and turned into soap for local use.

Pirarucu fishing and management have also proved to be a great ally in conservation projects, recovery of endangered species, and community development. Every year, the communities of the Juruá River have benefited, on average, 1,500 fish (up to 100 kg each) that generate waste from the viscera, an average of 5 kg per fish. For this case, there are also alternatives for processing these wastes, which, added to cassava flour and murumuru almonds, can produce feed for turtles, which were also endangered species and are currently included in community management projects (Paes et al., 2021a, 2021b).

Within all this context and complexities, alternatives that can integrate waste management with rural and agro-extractive communities' productive and subsistence activities are presented as important tools for mitigating environmental impacts and generating important social and economic benefits. The wastes that the communities cannot reuse, such as some recyclables and hazardous, could be sent to remanufacturing, recycling, and landfill industries.

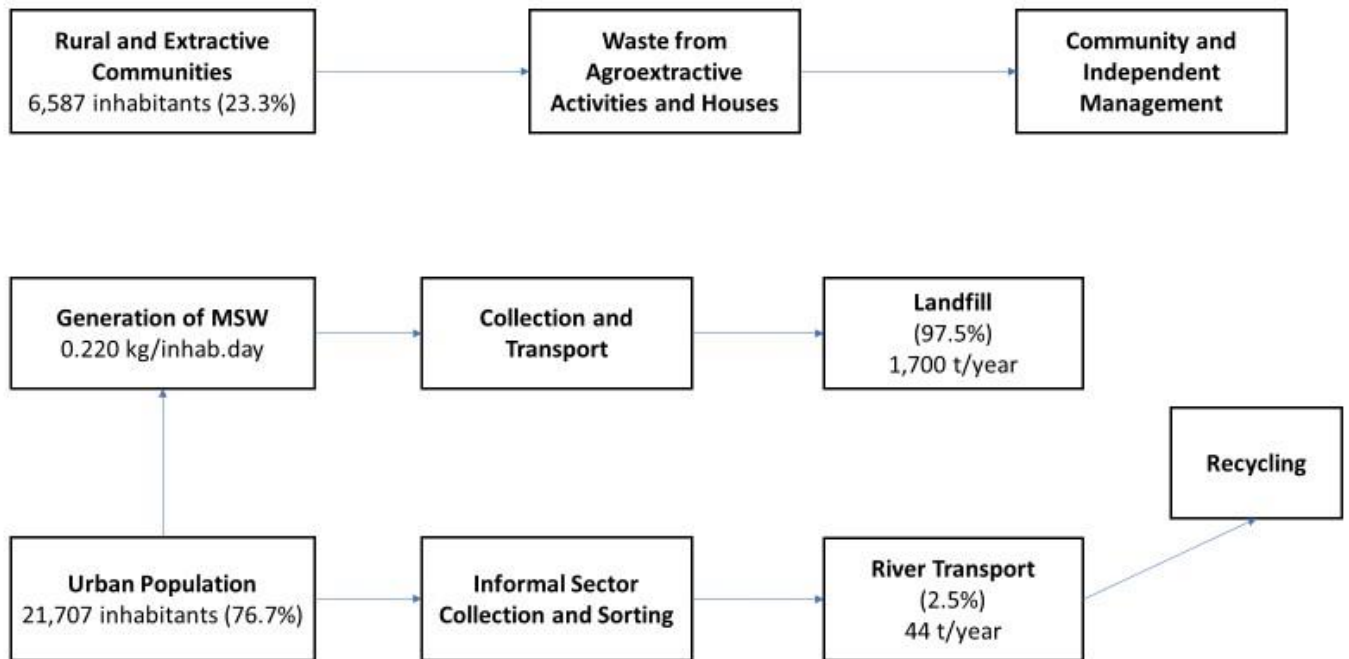


Figure D: MSW management system in the municipality of Carauari (State of Amazonas) in 2019.

APPENDIX 2 - MSW composition of the 4 municipalities

Table A: Amount of MSW Generated and Managed in the Municipality of Harmonia in 2019.

Type of Waste and Treatment/Destination	%	t / year
Paper / Cardboard	15.4%	110.78
Plastics	12.8%	92.32
Metals	10.3%	73.85
Glasses	5.1%	36.93
Electronics / Furniture / etc	4.3%	30.87
Others	7.7%	55.39
Total for Recycling	55.6%	400.14
Organic Matter	21.7%	156.07
Rejects	22.8%	163.79
Total for Landfill	44.4%	319.86
Total MSWMS	100.0%	720.00

Table B: Amount of MSW Generated and Managed in the Municipality of São Paulo in 2019.

Type of Waste	%	t / year
Organic Matter	41.0%	1,925,393.41
Paper / Cardboard	10.5%	492,629.95
Plastics	10.8%	507,672.09
Glasses	1.9%	90,252.82
Metals	2.3%	109,055.49
Others	14.4%	678,175.53
Subtotal HHW	80.9%	3,803,179.29
Others	18.7%	880,259.75
Organic Matter ¹	0.4%	18,250.00
Subtotal PCW²	19.1%	898,509.75
Total MSW	100.0%	4,701,689.03

Table C: Amount of MSW Generated and Managed in the Municipality of Ibertioga 2019.

Type of Waste	%	t/ year
Paper / Cardboard	12.8%	40.58
Plastics	8.8%	28.03
Metals	1.7%	5.51
Glasses	4.3%	13.71
Others	0.0%	-
<i>Total Recyclables (Sorting)</i>	27.6%	87.83
<i>Total Organic (Composting)</i>	39.8%	126.47
<i>Total Rejects (Landfill)</i>	32.6%	103.63
Total	100.0%	317.93

Table D: Amount of MSW Generated and Managed in the Municipality of Carauari in 2019.

Type of Waste	%	t/ year
Organic Matter	46.8%	816.2
Paper / Cardboard	17.9%	312.2
Plastics	16.1%	280.8
Glasses	1.1%	19.2
Metals	2.0%	34.9
Others	16.1%	280.8
Total	100.0%	1.744.0

Source: SNIS, 2019; Brasil, 2011.

APPENDIX 3 – Content addressed in the semi-structured interviews

Items and aspects to be analyzed, understood, and correlated in fieldwork

1- Political, Social, and Institutional Aspects

1.1. Political Aspects

- ✓ Existence of laws, plans, and strategic programs, such as Environmental Education Policies, Basic Sanitation Plans, Municipal Plans for Integrated Solid Waste Management, Climate Change Policies, etc.
- ✓ Does the city hall have partnerships for the development of environmental actions? If yes, how is this partnership carried out?
- ✓ The city hall has already received resources for the development of environmental actions.
- ✓ Coordination between agencies and institutions (sectoral policies and other government levels).
- ✓ Action and coordination between the public, social, and private sectors.

1.2. Social Aspects

- ✓ Political and social leaders dedicated to environmental issues.
- ✓ Social participation in the planning and control of activities (audiences and public consultations/municipal councils).
- ✓ How do users, service providers, and society participate?
- ✓ Does the municipality have a municipal environmental council? Is it consultative or deliberative, and what is the frequency of council meetings?
- ✓ What are the councils that act on the subject of MSW?
- ✓ The municipality has a municipal fund linked to the environment.

1.3. Institutional Aspects

- ✓ The municipality has an established environmental agency, and how the agency responsible for the management of MSW within the prefecture is characterized. The municipal institution is divided/shared with another agency?
- ✓ The municipality carries out selective collection, treatment, and/or other forms of reuse of MSW.
- ✓ MSW management data are available and reliable.
- ✓ Available technical solutions and skills, motivation, and qualification of staff.
- ✓ Knowledge about technological advances and good practices related to waste management.
- ✓ Changes in strategic positions/jobs.
- ✓ Knowledge of leaders about the situation of SGRSU, support from municipal authorities, and priority of politicians to issues related to MSW.
- ✓ Regulations and controls by the municipal/ state/ federal government.
- ✓ Coordination and cooperation between users and service providers.
- ✓ Environmental education actions (formal and informal)? If yes, how and in which areas the actions are developed?
- ✓ There are initiatives focused on climate change issues in the municipality.
- ✓ Adequate infrastructure (such as roads and vehicles) and technologies (such as facilities and equipment).
- ✓ How is the recycling production chain in the region?

2- Environmental Aspects - Climate Change

- ✓ MSW composition and generation data.
- ✓ Forms of Transport (km traveled and tons transported).
- ✓ Ways of Treatment and Final Disposal of MSW.

3- Economic Aspects - Operating and Investment Costs

- ✓ Total expenses or costs (operating and investment) per ton transported and treated.

Appendix 4 - Data on the locations, periods of fieldwork, and positions of the interviewees

Locations	Periods of fieldwork	Positions/ Jobs
Harmonia (State of Rio Grande do Sul - Brazil)	August 19 to 23, 2019	<ul style="list-style-type: none"> • Secretary of Agriculture and Environment • Secretary of Finance and Administration • 3 External Consultants • 1 Agricultural Technician • 1 School Director • 1 Pedagogical Coordinator • 2 residents and 3 entrepreneurs (who are active in local political discussion and decision-making processes)
Ibertioga (State of Minas Gerais - Brazil)	October 28th to November 1st, 2019	<ul style="list-style-type: none"> • Secretary of Agriculture and Environment • Municipal Mayor • Counter • Environmental technician • Municipal Solid Waste Manager at the State Secretariat for the Environment and Sustainable Development (SEMAD-MG)

São Paulo (State of São Paulo - Brazil)	Due to the size of the city and the research host institution being in the same municipality, fieldwork took place throughout 2019	<ul style="list-style-type: none"> • Director of Planning and Development at the Municipal Waste Management Authority (AMLURB) • AMLURB Financial Administrative Manager • AMLURB Planning, Standards, and Regulations Manager • Information and Research Manager at AMLURB • Coordinator of Organic Waste Projects and Composting Yards at AMLURB • Responsible for managing contracts with AMLURB and waste pickers Cooperatives • Career employee with extensive experience in various AMLURB political administrations • Visits to 3 cooperatives of Recyclable Material Collectors and Interviews with the 3 Presidents of the cooperatives • Monitored Technical Visits to the 2 Landfills where the city sends MSW; to the 2 Mechanized Sorting Plants and 2 Composting Yards.
Carauari (State of Amazonas - Brazil)	September 9th to 16th, 2019	<ul style="list-style-type: none"> • Municipal Secretary of the Interior and Environment of the City Hall • Environmental Advisor at City Hall • President, Treasurer and Project Coordinator of the Association of Rural Producers of Carauari (ASPROC) • President of the Juruá Institute (AM) • 5 community leaders

In addition to interviews, technical visits, and fieldwork, the data was also verified with the following official national publications:

IBGE – Instituto Brasileiro de Geografia e Estatísticas, 2019. Cidades. [Brazilian Institute of Geography and Statistics, 2019. Cities] Brasília.
<http://www.cidades.ibge.gov.br> Accessed 05.03.2020.

SNIS - Sistema Nacional de Informações em Saneamento Básico, 2019. Sistema Nacional de Informações em Saneamento Básico: diagnostico do manejo de resíduos sólidos (National system of information on sanitation: solid waste management inventory). <http://www.snis.gov.br/diagnostico-residuos-solidos>
 Accessed 07.12.2020.