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RECYCLABLE DOMESTIC SOLID WASTE IN FAMILY FARMS: A CASE STUDY IN SOUTHERN BRAZIL

RESÍDUOS SÓLIDOS DOMICILIARES RECICLÁVEIS NA AGRICULTURA FAMILIAR: UM ESTUDO DE CASO NO SUL DO BRASIL

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Abstract

Recycling domestic solid waste is a growing urban world demand; however, there are few studies about it in areas dominated by small farms, as in Brazil. To quantify the current composition of domestic rural waste, we monitored gravimetric composition of recyclable domestic solid waste and economic indicators in the homes of 31 family farmers in Southern Brazil for a period of 12 months. The annual expenditure average on domestic products was US $1,681.26 per family, which produced about 21 kg of waste.year^{-1}. This waste was divided into plastic (46.47%), paper and cardboard (27.18%), glass (13.28%), metal (8.58%), Tetra Pak© cartons (3.00%), mixed (0.98%) and polystyrene fractions (0.52%). A higher production of waste occurred in the months of December and August. Each resident was estimated to produce 405 kg of domestic solid waste over the course of their lives, and total domestic solid waste for all 31 farms was approximately 40 tons per year. We encourage municipal managers to determine the adequacy of the rural community storage system and transportation in accordance with different levels of production of recyclable household rural waste, especially for plastics.

Keywords: Family farming, Household waste, Solid waste management.

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Resumo

A reciclagem de resíduos sólidos domésticos é uma crescente demanda urbana mundial, no entanto, há poucos estudos sobre o assunto em áreas dominadas por pequenas propriedades rurais, como no Brasil. Para quantificar a composição atual de resíduos rurais domésticos, foi realizado o monitoramento da composição gravimétrica dos resíduos sólidos domésticos recicláveis e indicadores econômicos na casa de 31 agricultores familiares no Sul do Brasil por um período de 12 meses. A despesa média anual, sobre produtos domésticos foi de $1.681,26 por família, que produziu cerca de 21 kg de resíduos.ano^{-1}. Este resíduo foi dividido em plástico (46,47%), papel e papelão (27,18%), vidro (13,28%), metal (8,58%), caixas Tetra Pak© (3,00%), misturado (0,98%) e frações de poliestireno (0,52%). A maior produção de resíduos ocorreu nos meses de dezembro e agosto. Foi estimada uma produção de 405 kg de resíduos sólidos domésticos para cada residente, ao longo de suas vidas, e aproximadamente 40 ton. por ano de resíduos rurais sólidos domésticos para o total de 31 propriedades rurais. Nós incentivamos os gestores municipais a realizar adequação do sistema de armazenamento e transporte da comunidade rural, de acordo com os diferentes níveis de produção de resíduos domésticos recicláveis, especialmente para plásticos.

Palavras-chave: Agricultura familiar, Gerenciamento de resíduos sólidos, Lixo doméstico.

Introdução

Nowadays, a substantial effort is directed to control and treat urban solid waste, but little attention has been paid to rural wastes. Scientific articles on the qualitative and quantitative aspects of recyclable waste generation in the household and in family farms are rare. As rural communities depend less on locally produced agricultural products, waste generation is changing and current rural waste management systems are inadequate for these changes. Recent socioeconomic transformations in rural areas have altered household incomes to include inputs from various sources that are not derived from land use, such as retirement, pension, leases, donations and rentals. The diversification of income sources and the combination of agricultural and non-agricultural activities has enabled the rural population to raise their purchasing power and demand a wide range of consumer goods. Changes in consumption patterns resulting from the modernization of agriculture and urbanization increases the amount of household waste produced (LI et al., 2011ab). It also presents the potential to decrease consumption of agricultural product produced locally and increase waste associated with consumer goods imported into rural areas (BESSANT, 2006).

Waste management in rural landscapes is a global issue in strong need of assessment and implementation of environmentally sound systems of management and dispersal. Domestic solid waste (common garbage and rubbish from household sources such containers used for food packaging, bottles, cans, disposables, newspapers and magazines, hygiene materials and cleaning products, etc.) such waste is commonly managed improperly, within rural areas characteristics such as low population densities in remote areas that increase logistic complexity of waste management programs. Improper disposal has contributed to contamination of water and soil and proliferation of diseases in rural areas (EL-HAGGAR, 2007; MIHAI, 2012; MIHAI and APOSTOL, 2012; HE, 2012; TIAN ET AL., 2012). The current household waste collect system for rural areas generally is insufficient for actual waste needs due to an underestimation of waste production. This under estimation results in a dispersed disposal of pollutant waste into the surrounding natural environment. Most rural studies quantifying waste generation were performed in small-town urban areas and countryside villages, but not specifically on family farms areas, very common in Brazil. Given the environmental and health related impacts untreated or improperly treated waste can have, it is imperative that the contributions of family farms zones to waste be quantified.

Approaches to waste management vary among countries, but often-current strategies and regulations do not adequately address the family farmer's communities. In China, the majority of rural residents separate waste components because of the value of recyclable materials (CHUNG and POON, 2001), with an average per capita waste production of 646.43g.day^{-1} (ABDULI et al., 2008), such practices could contribute greatly to waste reduction in rural communities. In the US, rural communities used to be usually subject to the same federal and state regulations regarding the generation of waste as urban communities (STOKOE and TEAGUE, 1995; JAKUS et al., 1997).

Participation of the non-governmental companies in solid waste management is still limited. Whereas, surveyed villagers of rural areas in Egypt estimate approximately 73% of solid waste is inappropriately released within their communities (EL-MESSERY et al., 2009). In Romania, most farms fail to recognize the importance of waste management because they assess the small-scale production of the family unit and do not consider the sum of all units within the rural community (CAPATINA and SIMONESCU, 2008).

In Brazil, the issue of solid waste management in rural areas has also been sparsely investigated. In Paraná State was reported 52 $g.resident^{-1}.day^{-1}$ of inorganic waste (MARTINS et al., 2009) in a rural community. Dias et al. (2007) reported that in other Brazilian rural community in Bahia State, waste was comprised of 64% organic matter, 17% plastic, metals, paper and glass, and 19% mixed. Compared to the estimated 11% plastics in Africa (EDJABOU et al., 2012) and 15% in Mexico (TABOADA-GONZALEZ et al., 2011) in the waste of small rural villages, Brazil is not alone in limited management capacity of waste management. There is a low efficiency in the Brazilian management of rural recycled solid waste from both a governmental and household perspective.

The Southwest territory of the state of Paraná, made up of 42 municipalities, is one of the most important regions of Brazilian family farms agriculture (NAVARRO, 2002), where the management of the property is shared by the family, and agricultural productive activity is the main source of income (MDA, 2018). In Chopinzinho-PR, 94% of rural establishments are family farmers (immigrants of Italian and German origin who produce mainly soy, maize, beans, wheat, milk, poultry and pigs), and as in the rest of Brazil, are mostly established in small properties of up to 50 ha (IBGE, 2006).

Finally, actual waste production is poorly quantified for many rural areas and this quantification is necessary to adapt waste management to the growing needs in a changing socioeconomic climate. Considering the importance of more research on household waste of family farming, we aimed to analyze the production of recyclable solid waste in a small family farms study case in Chopinzinho-PR, Southern Brazil, to investigate its production composition and contribute to the solid waste management proposals in rural communities.

Material and methods

Study area

This study was performed in the municipality of Chopinzinho, located at the geographic coordinates 25º 51’ 21” S and 52º 31’ 24” W in the southwest region of the Paraná State in Southern Brazil. The municipal area has 960 km^2 and a total population, according to the Brazilian Institute of Geography and Statistics (IBGE, 2011), of 19,679 inhabitants. Of these, 7,171 reside in rural areas in 2,113 households, representing 36% of the total population. The agricultural census of IBGE (2006) showed that the municipality has 1,937 farms, and of these, 86% are classified as family farms under Brazilian Federal Law 11326/2006 (BRASIL, 2006). The source of the local gross income is from the production of crops (maize, beans, soybeans and tobacco), poultry and livestock dairy cattle. Dairy production is present in most of the properties.

Gravimetric composition of the waste and relationship between spending and waste production

We surveyed 31 farm families selected from a student population that attends to the technical program of Environmental Management at a state institution called “Rural Family House” (RFH). These farm families were chosen as our sample unit because they supposed to be a fair representative of this community since this institution is broadly looked for the family farmers (that represents the majority in this rural municipality). The families had an average of 3.77 people per household (SD = 1.05). Students collected the recyclable household waste within their own homes for a period of one week (seven days) randomized within each month for 12 months (April 2010 to March 2011).

To collect the waste, the recyclable material generated was stored in plastic bags. We separated the waste material according to type – plastic, paper and cardboard, metal, glass, Tetra Pak© multilayers cartons, polystyrene, textiles, mixed, rubber and mixed – and then weighed each fraction on a precision balance. The waste gravimetric composition (weight of different materials found) was compared by an analysis of variance followed by a Duncan's test (α= 5%).

The data obtained from the seven days of sampling within the month were extrapolated by the number of days of each month. The average production of recyclable solid waste was was then categorized into four seasons (spring: Sep 21th – Dec 20th; summer: Dec 21th – Mar 20th; fall Mar 21th – Jun 20th; winter: Jun 21th – Sep 20th). We used a Chi-square test (α= 1%) for the statistical analysis of the seasons. The financial records for each household were evaluated monthly calculating the total purchases of food, hygiene materials and cleaning products. Purchases were used to estimate the influx of consumer products that would become the components of recyclable solid waste on farms. To determine whether spending and waste production were correlated; we used a Pearson's test.

Waste production versus socioeconomic indicators

We used a questionnaire in March 2011 to obtain information on the diversity of income generating strategies from family production systems during the survey period. The results of this pre-research provided the gross product, intermediate consumption, depreciation, divider of the value added and the agricultural and non-agricultural incomes. Thus, the total income of all properties was obtained by the sum of all incomes, whether agricultural (discounted the gross product of all property expenses) or other income (amount of financial resources from retirement, wages, rents, pensions, donations and social public programs for state income). Additionally, we calculated the area used for crops at each property. Using the value of the different sources of agricultural and non-agricultural incomes, the "Income Diversification Index" (ID), proposed by Andrade (1995) was calculated to check the concentration of family income: $ID = 1/\Sigma fi^2$, where Fi represents the fraction of the total gross income as a percentage from the income type i (i = number of income types of the property). As the ID approaches one, the farm becomes less diversified. Thus, the medium ID is composed of a *specialists* group, in which families have a below average ID, and a diversified group, in which the families have an ID greater than or equal to the average.

Finally, each one of the following economic variables was compared to the production of recyclable waste for each property: average monthly consumer spending, average rate of income diversification, average total income, average farm income, average "others income" and average crop area. After dividing the properties into two groups – Group 1: below the average waste production and Group 2: above the average waste production – we analyzed these two groups by the economic variables mentioned above. For the statistical analyzes we used a Chi-square test (α = 5%).

Waste production and the rural household distance to the urban downtown

The distance between the rural households and the urban downtown (where is located the supermarkets) was evaluated using personal information provided by the families that showed the most commonly used path. The paths were stratified into classes of distances traveled to relate them with the levels of waste production. We verified, statistically, if there was significant variations in waste production by a Chi-square test (α= 5%), and the correlation between the distance of the households and waste production was calculated using a Pearson's test.

Results and discussion

Gravimetric composition and relationships between spending and waste production

There were substantial differences in total recyclable solid waste weight among months of the year, and December 2010 (2,242.14 g) and August 2010 (1,934.13 g) had the the highest waste production (Table 1). Greater waste production in December is likely related to the end of the year holidays, when families consume a greater quantity of consumer goods (food, hygiene and cleaning products, drinks and gifts). While there were monthly differences in waste production, there were no seasonal patterns in these rural households.

We estimated an average family had a monthly recyclable solid waste production mass of 1,722.34 g equating to an annual expense of $1,681.26 (US) per family with homogeneous spending throughout the year. Each family spent $140.11 (US) monthly on average. The waste production was not significantly correlated to the monthly expenses, indicating that higher spending on the consumer goods surveyed in this study did not translate to larger volumes of waste.

Table 1: Production of rural household recyclable solid waste and monthly expenses between April 2010 and March 2011 in Chopinzinho (PR), Brazil.

Date	Average weight per Family (g)	Production per capita (g)	Spending per family (US$)[1]
January 2011	1,702.87 (bc)	451.69	150.38
February 2011	1,757.40 (bc)	466.15	153.49
March 2011	1,596.58 (bc)	423.50	149.53
April 2010	1,714.71 (bc)	454.83	134.21
May 2010	1,450.59 (c)	384.77	139.71
June 2010	1,766.81(bc)	468.65	134.90
July 2010	1,670.01 (bc)	442.97	134.87
August 2010	1,934.13 (ab)	513.03	130.92
September 2010	1,762.67 (bc)	467.55	135.11
October 2010	1,651.41 (bc)	438.04	127.42
November 2010	1,428.81 (c)	378.99	128.56
December 2010	2,242.14 (a)	594.73	162.16
Total	20,678.13	5,484.90	1,681.26
Overall average	1,722.34	457.08	140.11
Standard deviation	213.15	56.77	11.09
Coefficient of variation	5.91	-	-
P > F	0.003	-	0.478

(*) Means that are not followed by the same letters differ ($P < 0.05$). The currency conversion used was from August 2, 2013, in which US $1 was equivalent to R$2.2855 (Real = present-day currency of Brazil).

The monthly production of rural household recyclable solid waste was 457.08 g.inhabitant^{-1} (Table 1). Martins et al. (2009) recorded a higher monthly production of 1,560 g of recyclable solid waste per capita in a rural settlement in Luiziânia (State of Paraná) of six families studied for 65 days (August to October 2007), most likely because of a methodological error that promoted an over-estimate of the glass component.

In our study, the recyclable solid waste annual production was 20,678.13 g.family^{-1}, and the annual per capita production was 5.48 kg (Table 1). It seems very little compared to the average annual *per capita* gathering of recyclable solid waste in urban Brazil was 8-10 kg and 20 kg in Southern Brazil (SNSA, 2011), values higher than the average recorded in our study (5.48 kg). This is most likely related to the urban population's different dietary habits from rural populations. In the European Union urban areas, Blumenthal (2011) reported an average annual production rate of recyclable materials per capita of 118 kg, an increase of 159% in the last 15 years. These values are much higher than in Brazil and are also most likely related to dietary habits, income, urbanization and possibly to a greater seasonal effect on consumption in these Northern hemisphere countries.

On the other hand, considering that the life expectancy for the Brazilian state of Paraná (IBGE, 2011) is 73.8 years, we estimated that each resident will produce 404.79 kg of waste over their lifetime. Additionally, we estimated an annual production of 39,332.65 kg for the entire rural area of Chopinzinho (PR). These records point to a concerning environmental liability when these values are multiplied by 10, 20, 30 or more years because most of these rural wastes are inappropriately managed.

In our study, a large concentration of rural households solid waste was represented by plastic (800.72 g), followed by paper and cardboard (468.38 g), glass (228.79 g) and metal (147.93 g), which differ significantly from each other (Table 2). Plastic is almost half the total (46.47%), most likely because of its use in packaging. Recycled and waste thermoplastics are major components of global municipal solid waste (ASHORI, 2008; AL-SALEM et al., 2009; YANG et al., 2012). The multilayer category and "mixed" were sequential after the metals. In the “mixed” category we observed numerous light bulbs and batteries. Batteries are not frequently consumed in rural areas, but they have a great potential to release heavy metals into the environment (YIDONG et al., 2011). It was not detected a notable presence of electronic waste. Finally, polystyrene was detected in limited quantities, but it maintains a high potential effect on the environmental.

Table 2: Gravimetric composition of recycled household waste from 31 family farms in the municipality of Chopinzinho (PR), Brazil. April 2010 to March 2011.

Material	Monthly average mass (g)	Monthly mass per capita (g)	Ratio to total (%)	Cumulative ratio (%)
Plastic	800.72 (a)	212.39	46.47	46.47
Paper and cardboard	468.38 (b)	124.24	27.18	73.65
Glass	228.79 (c)	60.69	13.28	86.93
Metal	147.93 (d)	39.24	8.58	95.51
Tetra Pak© cartons	51.66 (e)	13.70	3.00	98.51
Mixed	16.81 (e)	4.46	0.98	99.48
Polystyrene	8.93 (e)	2.36	0.52	100.00
Total	1,723.22	457.08		
Coefficient of variation (%)	5.91			
PR > F	0.0001			

(*) Means that are not followed by the same letter differ ($P < 0.05$).

For urban areas in Brazil, the primary composition of recyclable solid waste, according to Consoni et al. (2010), is 39% paper and cardboard, 22% plastic, 19% glass, 10% metals, 3% Tetra Pak© cartons, 3% mixed and 13% residues. In the data obtained in rural areas, the reversal of the first two items is noted. The urban area, probably because of its habits, presents paper and cardboard first; while in rural areas, plastic is first. As for glass, metals and Tetra Pak© cartons, the same waste composition pattern is noted for both the urban and the rural areas.

All materials derived from plastic, paper and cardboard, glass, metal and Tetra Pak© cartons measured in this gravimetric analysis are suitable for recycling in municipal waste management units. Exception are for polystyrene, light bulbs and batteries, which require special procedures for recycling and should be referred to their respective factories or facilities with environmental authorization to treat these materials as according to the Brazilian Federal Law 12305/10 ("National Plan on Solid Waste") that includes the “reverse logistic” (BRASIL, 2010).

The variation in the mean mass of the solid waste components that were recycled in the different seasons indicated that plastic, metal, polystyrene and the average monthly production of recyclable waste did not have a statistically significant variation during this period (Table 3). However, for paper and cardboard (χ^2_c= 12.36), glass (χ^2_c= 53.84), Tetra Pak© cartons (χ^2_c= 13.02) and mixed (χ^2_c= 30.54), there was a significant variation in production throughout the seasons, indicating that the larger production of paper and cardboard takes place in the summer, of glass in the spring, of Tetra Pak© cartons in the summer and of mixed (including light bulbs and batteries) in the fall.

Table 3: Monthly average production of recycled solid waste components in rural households by season. April 2010 to March 2011.

Material	Fall (g)	Winter (g)	Spring (g)	Summer (g)	Average (g)	χ2c (α = 1%)
Plastic	796.32	852.21	818.30	736.04	800.72	8.94
Paper and cardboard	426.35	505.65	435.08	506.46	468.38	12.36*
Glass	152.43	238.27	307.86	216.59	228.78	53.84*
Metal	172.40	122.26	150.61	143.87	147.28	8.67
Tetra Pak© cartons	52.60	40.05	41.15	72.29	51.52	13.02*
Mixed	31.76	19.99	15.00	0.24	16.74	30.54*
Polystyrene	12.18	7.31	6.12	10.13	8.93	2.49
Monthly average	1,644.04	1,785.74	1,774.11	1,685.62	1,722.77	8.22

(*) Data with significant difference ($P < 0.01$).

Waste production versus socioeconomic indicators

The average rate of diversification and the average area of crops showed no significant difference with respect to the overall mean of the variable (Table 4). The waste average production (χ^2_c= 65.64), average monthly expenses (χ^2_c= 7.75), average total income (χ^2_c= 8,267.00), average agricultural income (χ^2_c= 8,615.10) and average of “other incomes” (χ^2_c= 279.44) presented significant differences regarding the overall means of each variable.

Table 4: Index of diversification of income, total gross income, agricultural income, "other incomes", crop area, monthly financial value of household consumption *versus* average monthly waste production. Group 1: below the average waste production (15 families); and Group 2: above the average waste production (16 families).

Material	Group 1	Variable average	Group 2	χ2c (α = 5%)
Average waste production (g)	1,243.31	1,722.34	2,233.31	65.64*
Monthly average expenses (US$)1	123.89	140.11	154.54	7.75*
Index of diversification	2.76	2.50	2.22	0.05
Average total income (US$)1	9,027.67	13,872.52	19,040.36	8,267.00*
Average agricultural income (US$)1	6,820.25	11,280.04	16,037.13	8,615.10*
"Other incomes" average	2,207.42	2,594.48	3,040.85	279.44*
Average crops area (ha)	13.76	14.82	15.97	0.16

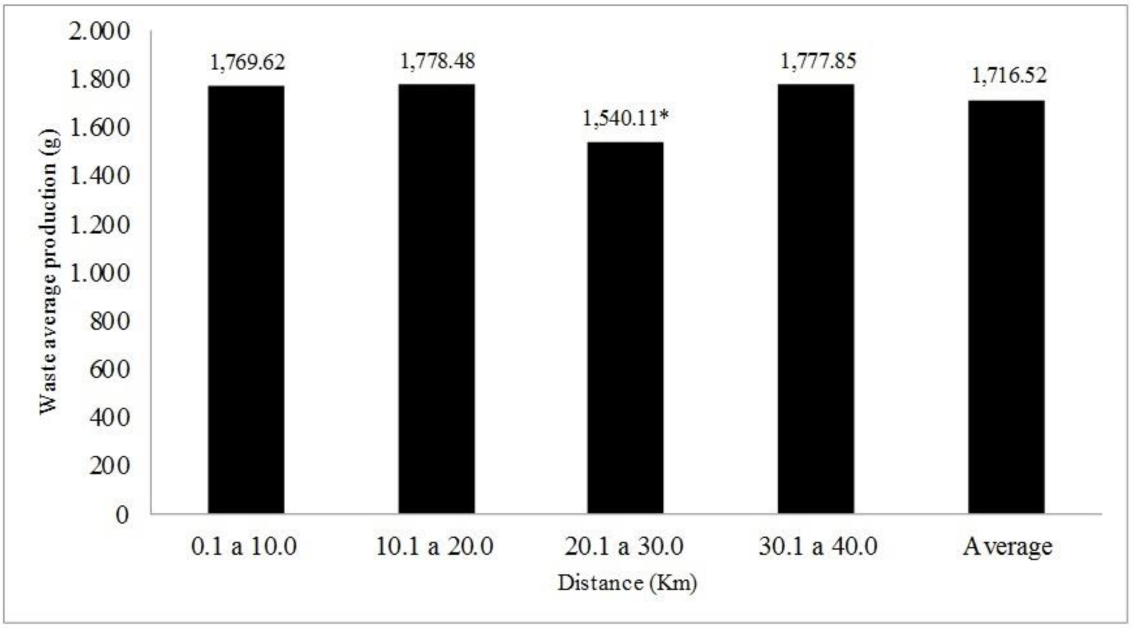
(*) Data with significant difference ($P < 0.05$). [1] The currency conversion used was from August 2, 2013, in which US $1 was equivalent to R $2.2855 (Real = present-day currency of Brazil).

Group 2 (above the average waste production) statistically displayed not only a higher production of waste but also higher incomes and expenses than Group 1 (below the average waste production). Therefore, these variables can explain the difference in waste production among the families. This was not true for the Index of diversification and crops area.

Waste production and rural household distance to the downtown

Analyzing the waste production in relation to the distance between the properties and the urban downtown (grocery stores nucleus), there was a significant variation (Chi-square test α 5% = 18.12) only for the 20-30 km distance, possibly influencing the logistics of waste management specifically in this range (Figure 1).

Figure 1: Waste average production in households with different distance ranges from the properties to the urban downtown. April 2010 to March 2011. *Data with significant difference (p < 0.05).



Some alternatives to address this geographic issue is to use intermunicipal cooperation (BEL and MUR, 2009) or on-site methods for the treatment of solid waste generated in the remote rural areas, where transportation costs are prohibitive (LI et al., 2011b). On the other hand, although the distant properties 20-30 km from the commercial centers have had an average lower, above 30 km waste production remained as properties with distance less than 20 km, i.e., there appears not to be a significant relationship between productions *versus* distance. Hypothetically, it could be related to the type of agricultural production that could provide a certain independence of these properties in relation to go shopping.

Conclusions

The data presented indicate a considerable use of manufactured products, most likely associated with changing eating habits in rural areas. With the purchase of new products that were previously produced by family subsistence, a large generation of recyclable waste is potentially generated on rural properties.

Each family farm spent almost two thousand dollars annually on household products. For families with higher incomes, there was a higher spending and increased waste production. Thus, monitoring the growth of household income can be an option to estimate the production of recyclable solid wastes produced in rural households.

The annual production of the farms in the studied town was approximately 40 tons. Each farm resident will produce approximately 405 kg of domestic solid waste over the course of their lives. The gravimetric composition of the waste, unlike the urban pattern, showed a large amount of plastic, followed by paper and cardboard.

Seasonally, a higher production of paper and cardboard occurred in the summer, glass in the spring, Tetra Pak© cartons in the summer and mixed (mainly composed of light bulbs and batteries) in the fall. With this information, an improved method can be planned for the collection of waste. However, biannual studies are recommended to ensure the long-term presence of these seasonal patterns.

We encourage municipal managers gather samples to adjust the transportation and storage systems to better suit the different levels of waste production. Finally, there are few studies on this subject, necessitating future studies relating socioeconomic and consumption aspects with the production of solid waste in rural areas to consolidate activities of waste integrated management in small family farms.

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