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Impact of individual home-composting on the quantities of MSW collected

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ANNIE RESSE AND THIERRY BIOTEAU
Irstea Rennes
17 avenue de Cucillé
CS 64427
35044 Rennes Cedex

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Sommaire

Introduction

In September 2005, the Ministry of Ecology and Sustainable Development of France introduced a policy to reduce the mass of municipal solid wastes through recycling also to be applied to the organic fraction. Some municipalities have anticipated the creation of selective collection practices to recycle packaging, newspaper-magazines-fliers, as a first phase, and then as a second phase, the organic fraction of the solid waste stream. This program resulted in the wide use of home composting bins, within city suburbs and village. Between 2000 and 2007, the French agency for environment and energy, called ADEME, supported home composting through a large promotional campaign resulting in the installation of more than 900 000 units. As in other countries of Europe, 34% of the population in France is composting its organic waste (OW) to reduce the fraction of municipal solid waste (MSW) being landfilled (Indigo LH2, June 2008). In comparison, 25% of the Luxembourg population is practicing composting in 2001 (Administration of the Environment of Luxembourg, 2001), as opposed to 10% in Ireland in 2004 (EPA, 2009), and 35% in England in 2005 (DEFRA, 2007).

Representing about 30% of the municipal solid waste stream, kitchen and yard wastes can be recycled through home composting bins (ADEME, 2009). Several studies (Jasmin and Smith, 2003; ECCOVAL, 2012) report the annual composting of about 40 kg of kitchen waste and 80 to 100 kg of yard wastes. Nevertheless, it is difficult to correctly estimate the mass of composted biowaste (Rabeau, 2008), because the promotion of composting impacts production and quality of the recyclable collection (Mitaftsi and Smith, 2006; Resse and Langlois, 2008). Therefore, evaluating the complete diversion effect also requires the monitoring of the final compost usage (Read, Gregory and Philips, 2009), which can be accomplished through surveys among practitioners (Burnley, 2006).

Municipalities are increasingly interested in the true recycling of OW through home composting, considering that such practices aim at reducing waste collection and treatment, while still respecting health regulations. Several municipalities have monitored the composting activities with their region, but the mass balance complied was inconclusive or incomplete (Rabeau 2008, Resse and Langlois 2008). Furthermore, results cannot be compared because of the lack of standard evaluation method. To fill this gap and within the Européen Life+ Miniwaste project, the objective of the present study was to produce a standard evaluation method.

To finalize this protocol, an experimental phase was conducted within sectors of the city of Rennes, France, supporting the project, to evaluate two basic fluxes, kitchen and yard wastes, through two recycling method, in ground piles and in home composting bins. The project made use of the tools specified by ADEME, in its 2003 program, ‘Selective collection and treatment of household organic wastes – performance indicators for quality’. Therefore, three tools were applied on one test sector. The final objective was to compare the field testing results and propose an evaluation method for the domestic organic waste stream.

Methodology

The method consisted in conducting a survey valid for individual housing in order to evaluate the quantity of composted biowaste and to compare this quantity to the organic waste (OW) fraction garbaged by the community. The evaluation method is based on the results obtained by these tools and applied to a sector of the City of Rennes.

The tools developed are: (1) a household survey, (2) the monitoring of the quantities of organic waste composted by voluntary households, (3) the monitoring of the quantities of garbage collected by the municipality and its composition, (4) the use of geographic information system (GIS) for the consideration of yard waste. All these tools have been tested on the same sector between June 2010 and May 2011.

Household survey

Municipalities easily organize household survey to find out the waste management or behaviour in relation to certain waste, their satisfaction with the service offered, or their expectations. They such investigation realize by themselves or subcontract to a consulting firm. Under the project Miniwaste, the telephone survey was carried out by a consultancy firm (LH2). This firm also conducted the "National Survey of household management of organic waste" to ADEME under the National Plan of Support for Domestic Composting. Therefore, the results can be compared with those of the National Inquiry especially since the questionnaire takes a significant share of issues. Some 1000 households were surveyed by telephone, within a community of 4303 households living within individual homes. This survey characterized the families, their living conditions and their recycling practices (example: composting or garbaging) for kitchen wastes (fruit and vegetable peels, coffee grindings and tea bags, table scraps, meat, fish) and yard trimmings (grass, leaves, weeds). The questionnaire covers several aspects:

- The description of the household (age, occupation, number of people, status ...),
- The description of the home (yard area, the presence of an ornamental garden, a vegetable garden, lawn, hedges ...), presence of animals,
- Management practices of food waste (bin, fed to animals, pile composting, compost bin (purchased from the community or self-built) for fruit and vegetable peelings, remains of meat and fish, coffee, tea, bread remains, remains of meals, pasta ...),
- Management practices of yard waste (garbage, fed to animals, waste disposal, discharge, burning, mulching, pile composting, composting bin (purchased from the community or self-built) for yard waste, leaves, mowing , pruning, branches, weeds, plants with roots and soil),
- The description of the practice of composting: windrow composting, composting bin, volume, use of a grinder, the number of years of practice composting.

The main objective of the survey is to establish habits of households for the management of biowaste in a representative area of Rennes Métropole. In addition, the survey will also be used to form groups of households with different management practises. These managements have the main consequence that the quantities of kitchen waste are composted more or less importantly according to the management practiced.

The 303 completed surveys were classified based on their typology, considering their practice of composting or garbaging of OW. Four main categories were identified (Table 1):

- Recycled organic waste using a ground pile (Type 1- Pile).
- Recycled organic waste using a composting bin (Type 2-CB+), (CB for composting bin).

- Recycled fruit and vegetable peels using a composting bin (Type 3-CB-).
- Garbaging of organic waste (Type 4-NC) (NC for non-composting).

During the telephone survey, household correspondents were invited to take part in a preliminary study on composting. These households were classified as « volunteer households » or VH.

Number of Households	Type 1 « Pile »	Type 2 «CB+ »	Type 3 « CB-»	Type 4 «NC»
Not volunteering (NVH)	35	26	43	161
Volunteering to weight their biowaste composted (VH)	9	13	16	

Table 1: Telephone survey household characterization

Quantity of composted biowaste

Municipalities often make campaigns of weighing in the context of waste prevention. For this, they are seeking voluntary households. The goal is to raise awareness of the quantities of waste production and then to choose one or more actions to reduce the quantities. For biowaste management, composting is often proposed because it is easy to implement. Generally, the results are presented per household or per person.

Under the project Miniwaste, the weighing of composted biowaste was proposed at the moment of the survey. 38 VH were equipped with a fish scale, a small pail to weight kitchen wastes, a large bag to weight yard trimmings and a chart to record monthly organic waste composted. Monitored during one year, all VH weight the kitchen waste and yard trimmings recycled through composting, and compiled results were regrouped under the three categories of: Pile, CB+ and CB- (Table 2), in terms of total mass or mass per person.

The data will allow:

- Measure the quantity treated on a year by both the composting bin and pile,
- Calculate the distribution of the amount of food waste composted compared to that of the garden,
- Determine the variability of measured data,
- Determine the seasonal variation of waste composted,
- Specify the type of waste composted.

The survey provides information describing the voluntary households. Some items are averaged to obtain the characteristics of groups of volunteers (Table 2).

Households (VH)	Type 1 « Pile »	Type 2 «CB+ »	Type 3 « CB-»
Number of households	9	13	16
Persons per household	3,1	3,5	3,1
Average Age	51	50	52
Average garden area (m^2)	353	324	489

Table 2: Characteristics of the volunteer households conducting home composting

Information acquired in the survey (person, garden area) are used to calculate rates of composted waste per household and per person for each focus group:

- Production of kitchen and yard waste per household and/or per person (kg/year),
- Production of yard waste per garden area (kg/m²).

Wherever possible, the characteristics of groups of volunteer households will be replicated to build another panel of households: the non-voluntary households (NVH).

Quantity collected by the municipality

Municipalities often use the quantity collected on an area or a town as a mean to evaluate their actions to reduce waste. Generally, they compare the quantities before and after the implementation of the action in a given territory. This comparison ignores the many parameters that can influence the evolution of these quantities.

To obtain accurate data, the project Miniwaste benefited from the introduction of electronic measurement. All bins on the experimental area are equipped with a computer chip that identifies the amounts collected for each home. The individual amounts are then aggregated per group.

This monitoring operation required the establishment of 7 groups of households. Since VH often exhibit better behaviour, their results were validated by measuring the garbaged OW of NVH and VH households and comparing this against that of households not conducting composting. Overall, 7 groups of households were compared, as described in Table 3.

Households		Type 1 « Pile »	Type 2 « CB+ »	Type 3 « CB-»	Type 4 «NC»
NVH	Number of households People/household Average Age Average garden aera (m^2)	15 3,0 52 years 459 m^2	15 2,8 53 years 453 m^2	15 3,1 53 years 364 m^2	15 2,9 52 years 345 m^2
VH	Number of households People/household Average Age Average garden area (m^2)	9 3,1 51 years 353 m^2	13 3,5 50 years 324 m^2	16 3,1 52 years 489 m^2	

Table 3: The 7 experimental household groups

The weighing of quantities will lead to:

- Measure the production of household waste per household and per person of each household type,
- Determine the seasonal variation in waste production,
- Compare the quantities produced by types of households, i.e. voluntary households, composters, non-composters,
- Determine the amount of biowaste in the garbage from sample analysis.

The weekly monitoring of amounts due to the electronic weighing bins will also help:

- Check that the production measured at the time of characterising the garbage is representative of the season.

Composition of garbage

Municipalities choose the criteria of the composition of garbage as a way to decide what action have to be set up or evaluate the actions implemented according to the quantities present in the garbage. For this, they realize themselves the characterization of their waste or they subcontract to a consulting firm. Under the project Miniwaste, waste analysis was carried out by Irstea assisted by staff of Rennes Métropole. The standard procedure in France (XP X 30-408) was applied. Waste composition is established following 12 major categories (biowaste, paper, cartons, complexes textiles, sanitary textiles, plastics, fuels, glass, metals, incombustible, special wastes). The organic waste is composed of kitchen waste and yard waste. The other sub-categories analyzed identify recyclables (newspapers, magazines, advertisements, packaging cardboard-ELA-plastic-metal-glass). Analysis of garbage provides a composition in %.

As part of this project, the composition analysis provides information on the percentage of biowaste still present in the garbage. The objective is to compare the results from both the panel of VH and NVH because VH often exhibit better behaviour. Also, the garbage of VH is compared to those of NVH to evaluate the impact of composting on the composition of garbage. Finally, the garbage of 7 groups of households is analyzed separately (Table 4).

Households		Type 1 « Pile »	Type 2 « CB+ »	Type 3 « CB-»	Type 4 «NC»
NVH	Number of households Number of persons	15 45	15 42	15 46	15 43
VH	Number of households Number of persons	9 28	13 45	16 49	

Table 4: Characteristics of the seven groups of households for the composition of household waste

Analysis of household waste can:

- Measure the percentages of OW present in garbage and the proportion of both kitchen and yard waste,
- Calculate the quantities of OW into the garbage by associating it with waste production,
- Determine the seasonal variation of both kitchen and yard wastes contained in the garbage,
- Compare the percentages and quantities of OW into the garbage of VH and NVH,
- Compare the percentages and quantities of OW into the garbage of both composting and non-composting households.

Territory analysis to assess the quantities of green waste composted

Very few municipalities use the Geographic Information System (GIS) for analysis of their territory in the objective of a better management of household waste. However, the production of green waste is closely linked to the area covered by vegetation. Under the project Miniwaste, Irstea uses expertise developed over several years to implement its methodologies in the test sector of Rennes Métropole. The objective is to mobilize all sources of information in order to achieve the estimated stream of green waste at field scale. To do so, within the GIS, it is necessary to collect the following georeferenced data:

- Aerial photographs, 50cm pixel size preferred,

- Digitized cadastre,
- Address location of VH practicing composting.

The first step is to process the image by using remote sensing tools. Image Processing by "supervised classification" lead to the discretization of the selected area into 3 classes (built-up areas, lawns, hedges / trees). Image analysis is carried out by correspondence with a sample of pixels whose class is known. Then, this classification is overlaid to the cadastre, to get the surfaces in the 3 classes (trees, grass, buildings) for each cadastral parcel.

The resulting data correspond to surfaces (m^2) and can be gathered at the scale of a sector, or a wider territory. To transform this data into yield data (in kg/year), such data must be supplemented by other data (in kg/m^2.year) that are derived from either averages (local or national) or experimental tests. Under the Miniwaste project, option was chosen to obtain data through:

- The weighing carried out by voluntary households composting and placing green waste into civic amenity sites,
- The monitored quantities of green waste for all civic amenity centres obtained from the municipality,
- Characterizations of garbage for the quantities of green waste therein.

The objective in this part of the project is to:

- Compare the exact green area (grass + hedges / trees) of each weighing volunteer to the surface of the garden reported at the time of the survey,
- Determine a value of production per plant and per square meter using the weighing performed by voluntary homes. This ratio will then be used as a reference for an application to a wider area by integrating:
    - ♣ The typology of households depending on the method of management of green waste,
    - ♣ The classification of surfaces of garden,
- Calculate the total deposit of green waste and then determine the percentage of green waste composted at home and the one brought in civic amenity centres.

Results obtained with a single tool

The composting practises of households living in individual houses

The survey indicated that 48 % of households were conducting composting, which is under the average reported for the City of Rennes, France, of 57 % or for the France, of 55 % (households living in individual houses), established by the LH2 Survey group in its report « National survey on the management of domestic organic waste » financed by ADEME within its National Plan to Support Domestic Composting. Also, these households were found to differ in the way they conducted composting, as presented in Table 5.

	Type 1 « Pile » %	Type 2 «CB+ » %	Type 3 « CB-» %
Composted kitchen wastes			
Fruit and vegetable peels	80	100	100
Food wastes	30	100	0
Coffee grindings, tea bags	80	93	82
Egg shells	80	79	82
Orange, citrus fruits	60	79	59
Meal /Fish	0	36	0
Bread	30	36	18
Seafood, shellfish	10	29	12
Yard trimmings			
Grass	60	86	76
Tree leaves	60	36	53
Cutting	60	57	24
Faded Plants/flowers	80	86	71
Weeds	60	50	35
Vegetable yard wastes	30	21	47

Table 5: Percentage of households composting their organic waste

Generally, households using pile composting (Pile) were less inclined to recycle kitchen waste than those using composting bins (CB+), as also confirmed by the group LH2 finding that from 42 to 46 % of households used kitchen waste when composting in piles as compared to 57 to 70 % when composting in bins. Also, CB+ households compost more organic wastes than CB- households. As for yard trimmings, differences were not so obvious. The LH2 study reported a higher percentage of households composting grass with the compost pile, (56 %) as compared to the bin (44 %). In the present study, the percentage of households composting grass with the compost pile reached 60 % as compared to the bin at 76 %.

Accordingly, the telephone survey proved to be an effective (economical and fast) mean of obtaining information on composting practices from a large number of households. Composting was found to be well accepted by household with owners of over 35 years of age. However, two parameters indicate that the sample is not representative of the population in the surveyed sector. The number of interviews is:

- Overrepresented in the population equipped with a composter provided by Rennes Métropole. The response rate was 27% while the rate of equipment is 13%,
- Underrepresented for the households less than 39 years. The rate of interviews was 13% for this category while the number of households under 39 years on the sector is 29%.

So, using the results obtained in the investigation must take into account characteristics.

Furthermore, the telephone survey verified other statistics such as the number of persons per household, but was not able to estimate the mass of organic waste composted.

Composted organic waste as reported by volunteer households

After a year of monitoring, the number of households decreases from 38 households to 21 households still involved in the project. The results obtained in this work show that motivation is difficult to maintain, hence the need to focus on shorter duration. If the implementation of this action is maintained, it is suggested to reduce it to 6 months and to begin preferably before summer. This period would then cover three seasons without affecting the Christmas and New Year and the school summer vacation.

The one year study produced the following average yearly mass of composted organic waste per household: 253 kg for « Pile », 306 kg for « CB + » and 278 kg for « CB- ». Table 6 compares these quantities per person or square meter (Table 8). The number of living person per household and the garden area is obtained thanks to survey. If there were no initial investigation, it is necessary to obtain the information from each household concerned by the project.

	Type 1 « Pile »		Type 2 « CB+ »		Type 3 « CB- »	
	kg/person	kitchen wastes %	kg/person	kitchen wastes %	kg/person	kitchen wastes %
Summer (June, July, Aug.)	19,5	57	29,2	55	16,2	61
Autumn (Sept., Oct., Nov.)	20,1	71	26,8	79	42,0	30
Winter (Dec., Janu., Fev.)	19,4	75	23,2	79	16,9	66
Spring (March, April, Mai)	24,6	50	19,0	74	22,3	39
Total (kg/person.year)	83,6	62	98,2	71	97,7	43

Table 6: Summary of organic waste composted according to the seasons

The statistical analysis of the date reveals that households « Pile » and « CB+ » conduct composting regularly throughout the year. But, in November one household « CB- » was composted many yard trimmings. Over half of the households loaded their composting bin or ground pile with 75 % kitchen waste and 25 % yard trimmings. Each household exhibited different management practices. The amount of biowaste composted was not proportional to the number of persons per household (Table 7). Furthermore, fruit and vegetable peels, coffee grindings and tea bags and egg shells are the most frequently composted wastes. Yard trimmings are not so frequently composted in the bin as compared to the ground pile

kg /household/month	« Pile »	« CB+ »	« CB-»
2 people	17 to 34	15 to 19	6 to 39
3 people	15 to 41	5 to 20	5 to 35
4 people		15 to 44	11 to 14
5 people	9 to 12		28 to 30

Table 7: quantities of waste composted according to the number of people in household

So it is not appropriate to classify voluntary households according to the number of people in homes.

Figure 1 illustrates the mass of food waste composted by households: the mass for group CB+ is most important, as compared to only 40 kg for group CB- composting only fruit and vegetable peels. When using a ground pile as opposed to composting bins, households tended to compost as much biowaste. Biowaste composting of 40 to 70 kg/person/year correspond to the values reported by other studies, such as that of the ADEME report on the «Evaluation of domestic composting policies » by RDC Environment (2004), and « Local communities and garbage reduction » also produced by ADEME.

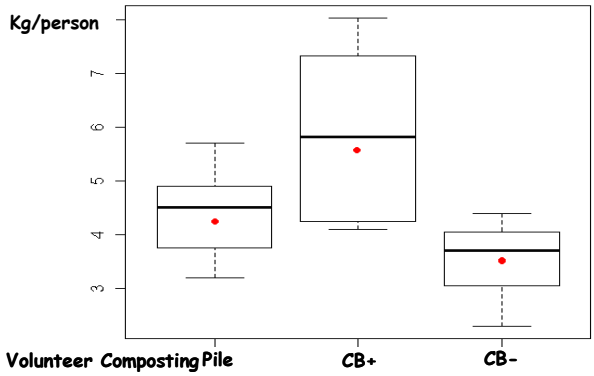


Figure 1: Quantities of food waste composted per month

kg/inhab.year	Kitcheen wastes composted
Pile	**60 kg**
CB+	**70 kg**
CB-	**45 kg**

Table 8: average quantities of food waste composted

Grouping the households into 3 groups seems appropriate considering that each group composts a different mass of biowaste according to the practises declared in the survey. Also results of garbage composition shows that the garbaged OW was lower for those VH as compared to the other households (NVH and NC).

The amounts of yard waste were measured by households with known surfaces with preliminary questionnaire (Table 9). For this waste, weighing by the home seems more delicate and difficult. Weights and volumes are larger and less regular resulting in difficulties to have accurate and reliable data.

g /m².year	« Pile »	« CB+ »	« CB-»
Composted	301	499	321
Civic amenity	265 to 437	318 to 476	302 to 423

Table 9: quantities of yard waste from voluntary households

The average amounts from homes type "pile" and "CB-" are equivalent, but lower than the type "CB +". Quantities brought to civic amenity centres do not appear very different. The data collected allow us to examine whether the surface of the garden is a factor influencing the choice of the composting practice (Table 10).

Garden aera (m²)	« Pile »	« CB+ »	« CB-»
<300 m² 300 à 399 m² 400 à 599 m² >600 m²	40 % 60 %	54 % 15 % 31 %	24 % 18 % 41 % 18 %
Median area	339 m²	239 m²	500 m²

Table 10: Distribution of volunteer households according to the surface of the garden and the method of composting

The pile composting is also practiced on small gardens contrary to common belief. CB + composters have smaller gardens and compost more of their green waste.

Residual organic fraction in the garbage

For each season and in terms of kg/person.year, the mass of residual wastes garbaged is presented in Table 11.

Household			June	October	January	March
Volunteer (VH)	Composting	1-Pile	99	91	108	120
		2- CB+	82	65	63	57
		3- CB-	47	91	77	90
Non volunteer (NVH)		4- Pile	107	117	139	92
		5- CB+	119	123	110	99
		6-CB –	61	67	71	75
	Non composting	7- NC	148	138	154	156

Table 11: Mass of residual households wastes (kg/person.year)

Despite a wide range of values from 47 to 156 kg/person.year, resulting from the limited number of households studied, some interesting results can be observed:

- Volunteer households (VH) composted more biowaste, and garbaged less residual wastes;
- There is a much higher amount of residual wastes when composting is not practiced;
- The production of residual wastes does not vary with seasons within the 7 groups of households.

The weekly monitoring of each home involved in the project allow the comparison of the above 4 production points (one per season) with the average measurements throughout the year thanks to the weighing equipment installed on the garbage bins (Figure 2).

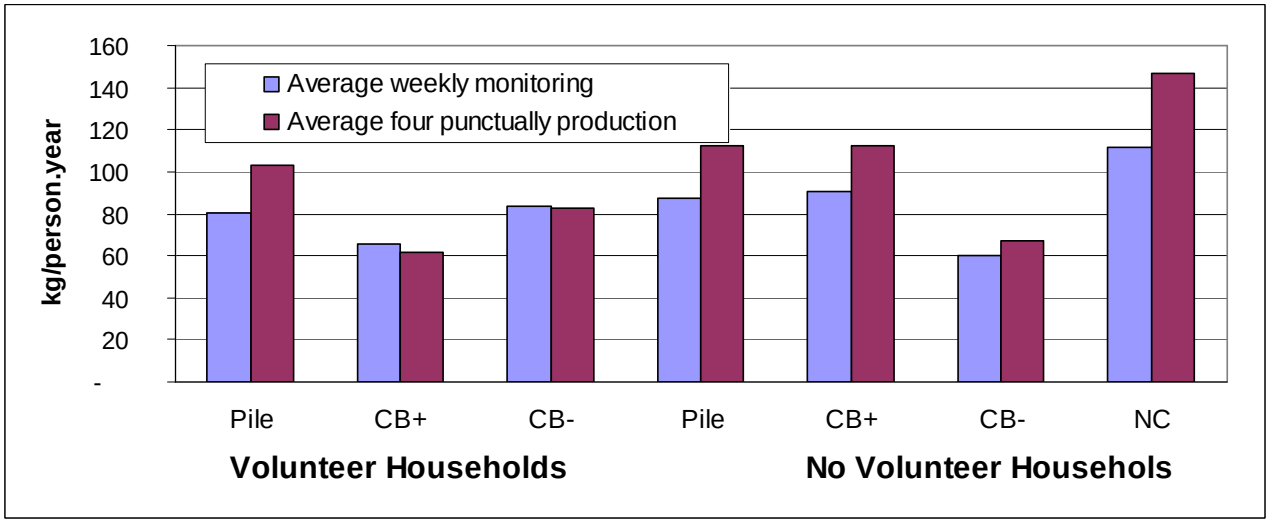


Figure 2: Comparison of residual wastes quantities according to the two monitoring methods performed

The average four individual measures tend to give higher values than the average yields obtained by the weekly monitoring. This is easily explained by the fact that the measures are systematically chosen excluding holiday periods, weeks of holidays, etc. Therefore, it is always set in the worst case for the production of household wastes. On this suburban area, the average yields are much lower than the national values and those announced by Rennes Métropole. The weekly monitoring of garbage valid point measured productions.

The monitoring of the quantities can be made punctually to obtain a representative value of annual production. It is nevertheless advise to replicate several times that monitoring (one per season) to certify the measured amounts. Also, monitoring show that the productions are lower for composting households compared to non-composting. So these two populations shall be separated and independently be monitored when it is desired to assess the impact of composting.

The composition of garbage collected by the municipality

The composition of garbage is analysed for each group and for four seasons. Figure 3 shows the average composition of garbage.

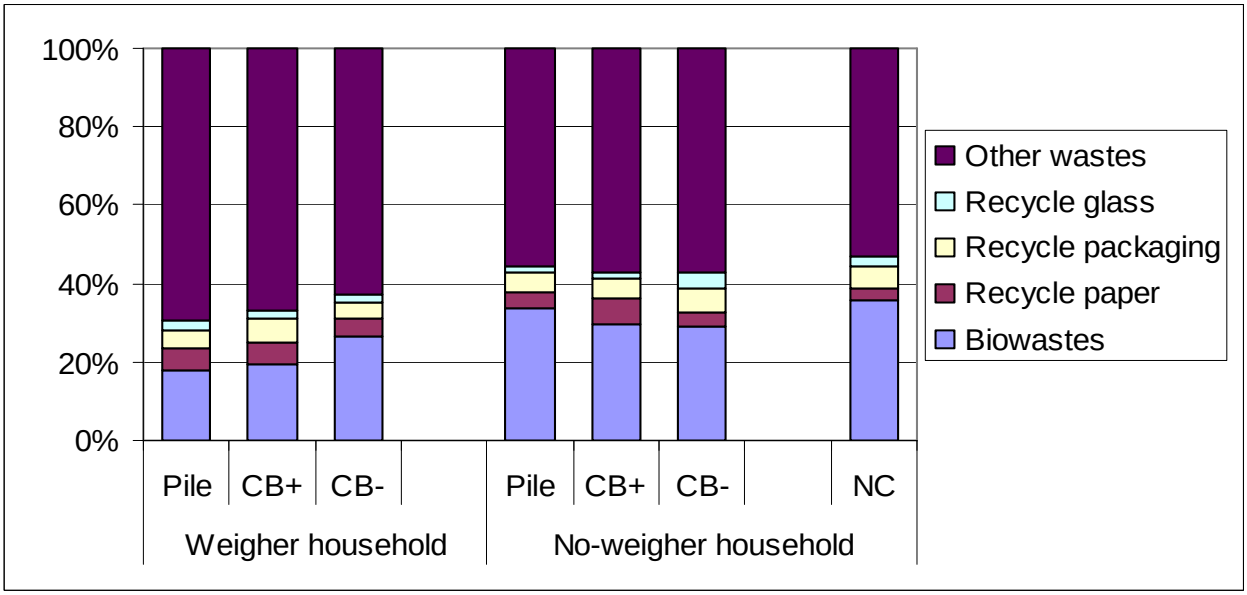


Figure 3: Average composition of garbage per group (%)

Within garbage, recyclable varies from 8 to 20%. Statistical analysis of results shows:

- That there is no significant variation between the four seasons,
- That there is no significant difference in the papers & packaging between groups,
- There is less packaging recyclable in VH garbage.

Within the garbage, OW varies from:

- 13 to 35% for VH,
- 22 to 39% for composting households,
- 31 to 39% for non-composting households.

Figure 4 presents the mass of OW for each group, and each four seasons. The percentage of OW is presented in terms of percentage of wet mass.

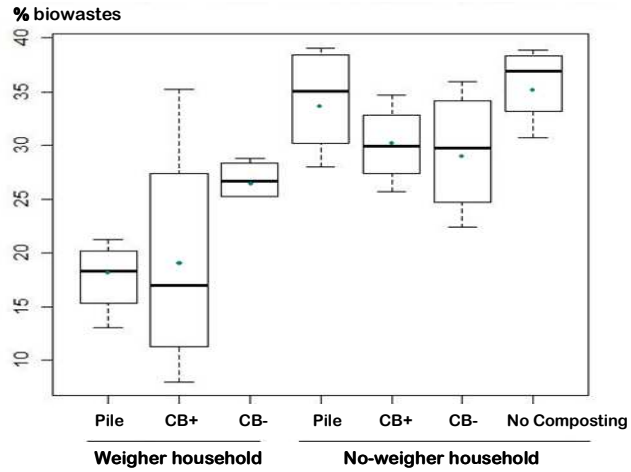


Figure 4: Percentage of residual organic waste or biowaste in the garbage of households

For the VH (volunteer households), there are differences among groups:

The percentage of organic waste found in the garbage is significantly lower for:

- The « Pile» volunteer group versus the other households using a ground pile for composting;
- The « CB+» volunteers versus the households using piles but not in the volunteer group,
- The « Pile» and « CB+» volunteers versus those not practicing composting.

The percentage of biowaste does not vary significantly from once season to another within groups of households.

The OW made up of 85 % food waste because Rennes Métropole has a strong policy against accepting yard trimmings within its garbage.

The gardens of composting households

From the analysis of aerial photography in combination with cadastral parcels, the total area and the detail (lawn and tree/ hedge) are determined for every voluntary household. An average is calculated per group in order to facilitate comparisons (Table12).

garden areas (m^2) of the VH	Pile	CB+	CB-
Median	339	239	500
Average	303	317	465
Standard deviation	90	158	199
Tree/hedges	137	134	175
Lawns	75	84	147

Table 12: average areas of parcels from VH (obtained through GIS analysis)

Results obtained by the combination of several tools

The quantities of organic waste collected in the garbage (tools: monitoring of the quantities + composition of waste + survey)

Table 13 illustrates that the garbage of VH had 8 to 22 kg/person.year as compared to the other composting households (NVH) with 15 to 37, and the other non composting households with 40 kg /person.year. Furthermore, fruit and vegetable peels were found in the garbage of all households, contrary to the telephone survey.

Household			June	October	January	March	**Average**
VH	Composting	1-Pile	7,8	15,5	12,7	18,8	**13,7**
		2-CB+	9,2	11,6	21,5	4,5	**11,7**
		3-CB–	10,2	18,4	16,5	21,1	**16,5**
NVH		4-Pile	35,8	30,1	36,6	32,4	**33,7**
		5-CB+	28,1	31,1	30,3	26,4	**29,0**
		6-CB–	17,7	18,0	22,4	15,2	**18,3**
	Non-composting	7-NC	42,8	45,8	37,4	38,9	**41,2**

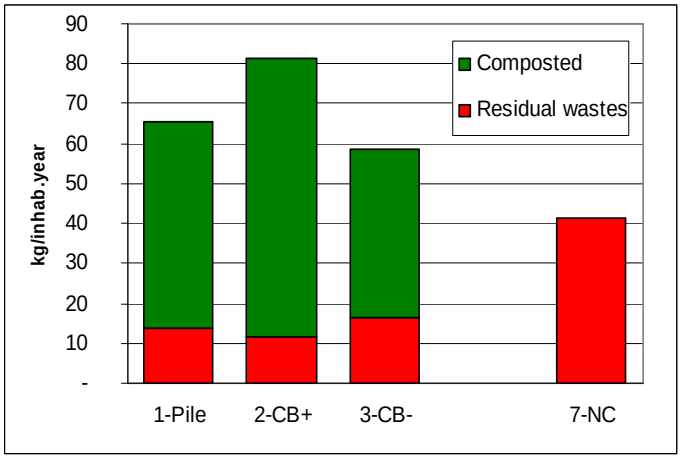
Table 13: Mass of food waste found in household garbage (kg/person.year)

Garbage composition and mass both show that food waste is more limited when composting is practiced, a measure which proved valued in this study.

While the garbage analysis provided relevant information, it is not necessary to retain it as the percentages are not significantly different for VH and NVH. However, the different amounts between composting households and non-composting households warrant keeping the accurate measurements of garbage quantities for such both types.

Mass balance of the waste quantities in Volunteers Households (tools: weighing survey + waste composition)

Knowing the quantities weighed by households and having analyzed their residual household waste separately allows obtaining a mass balance of food waste (Figure 5) as well as for garden wastes (Figure 6).

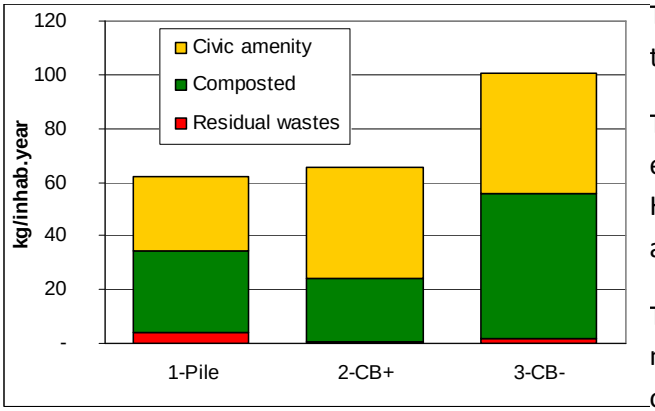


The graph shows that 70% of kitchen waste is composted by VH composters. For these households, the performance of composting kitchen waste is equivalent to the collection of papers and packaging.

However, VH composters have more kitchen waste compared to Non composters. Therefore, the implementation of a compost bin in that last type of households will not have the same incidence on the amounts diverted because they have less food waste.

Figure 5: Assessment of kitchen wastes depending on management practiced by households

The amounts of yard waste are unrelated to the number of people in the home as well as the practice of composting. However, the act of expressing quantities of yard waste per capita allows for an assessment of the waste according to the different streams. This especially enables to preview place of green waste composting for different categories of VH (Figure 6).



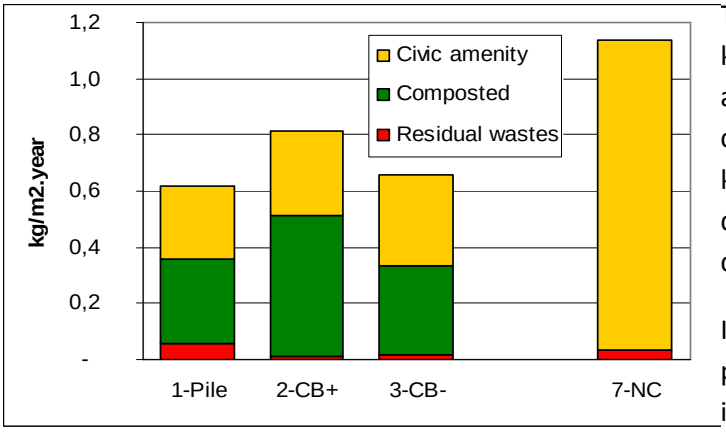
There is little yard waste in the garbage compared to other streams.

The amount of composted green waste is equivalent to those placed in civic amenity sites. Households composting in a pile also go to the civic amenity sites but their quantities are lower.

The low number of households in each typology makes it difficult to interpret results. For example, one of the homes “CB-” placed at one time lot of waste in the compost bin so that the aggregate numbers are larger compared to other categories.

Figure 6: Assessment of yard wastes depending on management practiced by households

The data obtained under the Miniwaste project allow establishing an assessment of the production of yard waste per m² of VH homes. These data can be correlated to the average yields obtained at the scale of the civic amenity centers of Rennes Métropole (Figure 7).



The aggregate numbers for VH (0.6 to 0.8 kg/m².year) are smaller compared to the average production of green waste in the civic amenity sites of the territory (1.1 kg/m².year). This can be explained by the difficulty of weighing the green wastes despite the material provided.

In this analysis, we considered the global practice of composting but not the individual surface of the garden. However, the categories of garden surfaces can be a discriminant factor.

Figure 7: Assessment of yard wastes depending on management practiced by households (in kg/m².year)

For this, we must identify each garden area and assign to it the amount of yard waste composted. It is only possible for VH who weighed their yard waste.

Production of yard wastes depending on the area of the garden (tools: weighing household + GIS)

The data collected from VH coupled with the determination by GIS of the surfaces covered by vegetation aims to find the most representative production rate of the quantities composted per m² of the home (Fig 8).

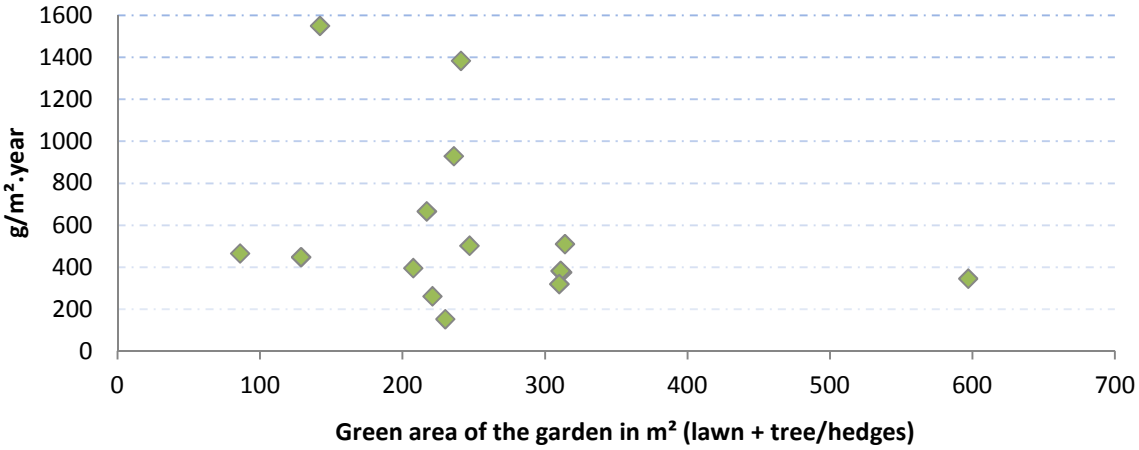


Figure 8: Green waste composting (in g/m².year) depending on the garden area of the household parcel

The data presented in Figure 8 are highly variable and need to be reinforced by additional data. A choice of splitting the results at the surface of 300 m² is justified by previous studies conducted by Irstea in other territories.

Currently, the study indicates a production of green waste composted at home of:

- 0.48 kg/m².year for gardens less than 300 m² with 0.51 kg/m².year for pruning and 0.32 kg/m².year for mowing,
- 0.37 kg/m².year for areas larger than 300 m² with 0.21 kg/m².year for pruning and 0.14 kg/m².year for mowing,
- A median of 0.45 kg/m².year was calculated for all the 15 samples with a median of 0.40 kg/m².year for pruning and 0.30 kg/m².year for mowing.

Choice between two tools to get the same data or equivalent

The origin of waste really composted by volunteers compared to the survey results (tools: weighing campaign + survey)

In addition to the measured weights, households indicated the origin of the waste placed into the compost. The results obtained are reported in Table 14.

% households	« Pile »	« CB+ »	« CB-»
Peeling of fruit and vegetable	88	87	88
Coffee grounds, tea bags	82	85	70
Egg shells	65	89	64
Orange, citrus fruits	49	58	30
Piece of Bread	26	48	25
Tree leaves	23	27	36
Yard wastes	29	14	19
Grass	29	14	11

Table 14: Deposit rate of waste destined to composting

The peels of fruits and vegetables, coffee, tea bags and egg shells are the most commonly composted, for all households. Waste from pruning and lawn mowing are less frequently placed in the compost bin compared to the category "Pile". These results are compared with data obtained in the survey for those same homes. By matching with the declarative survey, it appears that many households are composting food waste as indicated in the survey. So it does not seem necessary to acquire this information by two different actions. However, for yard waste, the results are lower than in the survey. Several reasons can be cited such as forgetting to weigh and record the weights, due to the difficulty of weighing bulky or heavy materials.

The real area of the VH garden compared to their declaration (tools: GIS + survey)

The average results obtained by both methods (survey and GIS) are shown in Table 15.

% households	1-Pile	2-CB+	3-CB-
Number households	10	14	19
Average area (m^2) from GIS analysis	303	316	465
Average area (m^2) from survey	353	379	489

Table 15: average area for each group in function of the method of acquisition

The areas obtained by GIS are more accurate but also require more resources. It is difficult for the household to respond accurately on their areas and to distinguish cadastral and garden area. Therefore, the surfaces reported in the survey are higher by 5 to 17% compared to the GIS. Nevertheless, the accuracy of the data acquired during the survey appears sufficient. However, the capabilities of GIS allow:

- Know the green surfaces producing two different types of waste (mowing, pruning),
- Work at several levels (sector, zone of influence of civic amenity centers, overall territory).

Proposal of an evaluation methodology

The results obtained in the territory of Rennes Métropole suggest separating the stream of kitchen waste and those from the garden.

Percentage of kitchen waste diverted through home composting

The potential stream of kitchen waste is calculated by the following equation:

Gistot_DC = (DCcomp * %PC) + ((OMR_DC_C*%PC)+(OMR_DC _NC*(100-%PC))/100

Where:

Gistot_DC: total deposit on the study area (kg / person.year)

DCcomp: Quantities of kitchen waste composted by households (kg/composting-person.year)

%PC: Percentage of practice of composting (%)

OMR_DC_C: amount of kitchen waste in the garbage from households that practice composting (kg/composting-person.year)

OMR_DC_NC: amount of kitchen waste in the garbage from households that do not practice composting (kg/non-composting-person.year)

Then the percentage of kitchen waste diverted from the total stream through home composting (%DCcomp) is given by:

% DCcomp=(DCcomp * %PC) / Gistot

The quantity of kitchen waste diverted per year is given by:

%DCcomp x Gistot_DC x PHI/100

Where:

PHI: total population in individual housing

For the implementation of each term, it will be useful to refer to Table 17.

Percentage of yard waste diverted through home composting

First, a total production of yard waste can be estimated by:

Gistot_DV = [(SJ * %PC * P) + [(OMR_DV_C*%PC) + (OMR_DV_NC*(100 - %PC))] * NBF*NBmoyHF] /100 + (QDech)

Where :

Gistot_DV: total deposit on the study area (kg/year)

SJ: Overall area of garden from individual housing (m²)

%PC: Percentage of practice of composting

P: result of the weighings of composted yard waste (kg/m².year)

OMR_DV_C: Amount of yard waste in the garbage from households that practice composting (kg/composting_person.year)

OMR_DV_NC: Amount of yard waste in the garbage from households that do not practice composting (kg/non_composting_person.year)

NB: Total number of households on the study area

NBmoyHF: Average number of persons per household

QDech: Total amount of green waste deposited in civic amenity centers (kg/an)

Then, the percentage of green waste diverted from the total production through home composting (%DVcomp) is given by:

% DVcomp = (SJ * %PC * P) / Gistot

The quantity of garden waste diverted per year is given by:

%DVcomp x Gistot_DV/100

For more details about each term, refer to Table 17.

The proposal for this evaluation is planned for areas where the garbage are collected door to door once or several times a week. Two protocols are proposed to conduct an evaluation of home composting in an area. Indeed, all situations do not require an accurate assessment. In some cases an estimate may be sufficient. In this project, some results were found to be reinforced, suggesting that it is not necessary to acquire this result systematically. Some tools have also shown their limits and deviance. Tools appear more essential than others. The organization of these tools will be based on two approaches referred as:

- **Simplified assessment to get an estimate,**
- **Advanced Assessment on a small area and extrapolation.**

Tools to implement depend on the type of assessment (Table 16). When the tool is not needed, average values are proposed.

	Simplified assessment	Advanced Assessment
1-Survey	YES	YES
2- Cadastral parcels of individual houses	YES	YES
3- Weighing by households	NO	YES
4- Monitoring quantities of garbage	YES	YES
5- Characterization of garbage	NO	YES
6-GIS + aerial Photographs	NO	YES

Table 16: recommended tools depending on the choice of evaluation

The methodology is presented in the form of a summary table (Table 17) for the two assessment methods.

Table 17: Sequence of actions required for each assessment method.

<table>
<tr><th></th><th>Simplified assessment</th><th>Advanced Assessment</th></tr>
<tr><td>1-Survey, enables the evaluation of the percentage of home composting (%PC)</td><td colspan="2">-Choosing a representative area of 1000 homes from individual housing,
-Establish the questionnaire,
-Plan to solicit homes to weigh if this action is chosen,
-Accompanying the questionnaire by an official letter,
-Distribute questionnaires with a prepaid envelope for return,
-Exploit returns based on the following criteria:
<table>
<tr><td></td><td colspan="3">VH</td><td></td></tr>
<tr><td>% of replies</td><td>Pile or self-built compost bin</td><td>CI+</td><td>CI-</td><td>NVH</td></tr>
<tr><td>Age of people :
<39
39 à 54
55 à 64
>65</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Average number of person per home</td><td></td><td></td><td></td><td></td></tr>
</table>
<table>
<tr><td>Area of the garden</td><td>VH</td><td>NVH</td></tr>
<tr><td><300 m^2
>300 m^2</td><td></td><td></td></tr>
<tr><td>Average</td><td></td><td></td></tr>
</table>
Information from the investigation indicates the percentage of households practicing composting. A percentage of the types of composters (CI +, CI-, pile) may also be derived from the survey. It may be useful to obtain a percentage of composting practice with a differentiation according to the surface of gardens, in order to apply these percentages at point 6 in the case of the advanced evaluation, to apply a different percentage to those different classes of garden areas. The sample can also be adjusted to reflect the age of the population.</td></tr>
</table>

<table>
<tr><th></th><th>Simplified assessment</th><th>Advanced Assessment</th></tr>
<tr><td>2- Cadastral parcels, enables the evaluation of the total surface of individual housing (SJ)</td><td>Use of the files: cadastral parcels and digitized buildings.
Under spreadsheet (Excel), select the lines with the identifier "individual home". The account of selected lines gives the number of households in the individual houses (NBF).
Then sum the columns representing the areas of these two files.
Then, perform the operation:
Total area of the garden (SJ) = Total area of parcels - Total area of buildings</td><td>Perform the same operation as in beside column but with an overlying operation carried out through GIS analysis. The result is the production of a geographic file of the gardens. After overlapping this geographic file with the result of image processing, it will be possible to know the lawn and hedge surfaces, geolocated at garden level.</td></tr>
<tr><td>3-Weighings from volunteer households, enables evaluation of home composting quantities (DCcomp)</td><td>Use the average data :
<table><tr><th></th><th>Composted kitchen waste (kg/person.year)</th></tr><tr><td>Pile
CI+
CI-</td><td>60
70
45</td></tr></table>The yard waste is composted as much as kitchen waste in the best case. See point 6 for the estimation of quantities.

Note that these average date where obtained for the studied area on Rennes Métropole and may be different elsewhere</td><td>Contact volunteer homes and distribute experimental materials for the weighing survey.
Submit six months of weighing survey between January and June.
Gather the results of weighing according to the management of food waste (pile, CI + and CI-).
Express the results in kg/composting_person.year for kitchen waste
<table><tr><th></th><th>Composted kitchen waste (kg/composting_person.year)</th></tr><tr><td>Pile
CI+
CI-</td><td></td></tr></table>Express the results in kg/person.year for yard wastes, useful in point 6
<table><tr><th>Area</th><th>pruning</th><th>mowings</th><th>Sum</th></tr><tr><td><300 m²
>300 m²</td><td></td><td></td><td></td></tr><tr><td>Average</td><td></td><td></td><td></td></tr></table></td></tr>
</table>

<table>
<tr><th></th><th>Simplified assessment</th><th>Advanced Assessment</th></tr>
<tr><td rowspan="2">4- Garbage quantities, enables the differenciation of Garbage quantities from households practicing composting and from households who do not practice composting</td><td colspan="2">From the survey, separate “composting” and “non-composting” homes.
Choose a number of households in each type taking into account the average production of garbage.
Determine the number of people concerned from the survey</td></tr>
<tr><td>Weigh bins, and if it is not possible, measure the volume of garbage from the bins submitted to collection during one week in October.
Production is determined by applying a ratio of 85 kg/m^3
Calculation of production express in kg/person.year for both composting and non-composting homes.
<table>
<tr><td>kg/person.year</td><td>Compo-sting homes</td><td>Non-composting homes</td></tr>
<tr><td>garbage</td><td></td><td></td></tr>
</table>
</td><td>Weigh bins, and if it is not possible, measure the volume of garbage each season from the targeted households
Production is calculated by the use of the density that is determined during characterization by matching "Quantities collected" and "volume".

Calculation of production express in kg/person.year for both composting and non-composting homes.</td></tr>
<tr><td>5- Characterisation of garbage, enable the evaluation of kitchen and yard wastes (OMR_DC et OMR_DV)</td><td>Use the mean value in the "national campaign to characterize household and similar waste in France" valid for 2007
<table>
<tr><td>OW</td><td>% of garbage</td></tr>
<tr><td>Kitchen waste
Yard waste</td><td>22,8
4,7</td></tr>
</table>
Apply this average value to the production of garbage (point 4) for the production of OW expressed in kg /person.year for each waste category and for both composting and non-composting homes.
Production of yard waste transformed into kg/m².year.
Calculate an average production in kg/person by multiplying the production of composting households by the percentage of composting practice and by adding the production of "non-composters" by the percentage of non-composting practice. Then, multiply the obtained per person production by the average number of person at home and then by the total number of households in individual housing (point 2) and divide by the total garden area (point 2).</td><td>A characterization campaign of garbage in October for both composting and non-composting homes.
Targeted homes identical to those chosen for the weighing campaign of composted waste.
Procedure XPX 30-408, for all categories and subcategories of OW and recyclable
Results expressed as%
<table>
<tr><td></td><td>Composting homes</td><td>Non-composting homes</td></tr>
<tr><td>Kitchen waste
Yard waste</td><td></td><td></td></tr>
<tr><td>Papers
Recyclable packaging
Glass</td><td></td><td></td></tr>
</table>
Results calculated in kg/person.year by applying the production of garbage (kg/person.year) obtained in step 4 for each category of waste and for both composting and non-composting homes.</td></tr>
</table>

		Production of yard waste transformed into kg/m².year. Calculate an average production in kg/person by multiplying the production of composting households by the percentage of composting practice and by adding the production of "non-composters" by the percentage of non-composting practice. Then, multiply the per person production obtained by the average number of person at home and then by the total number of households in individual housing (point 2) and divide by the total garden area (point 2).

<table>
<tr><th></th><th>Simplified assessment</th><th>Advanced Assessment</th></tr>
<tr><td>6- Green areas evaluated through GIS analysis, enable the evaluation of yard wastes from composting and non-composting homes (P)</td><td>Use the total area of gardens established in section 2.

Determine the coverage factor that is the percentage of vegetation per parcel by going on site to evaluate it (70% in Rennes, Nancy to 80%) and apply it to the surface of households to estimate the average green area per home.

Use the percentage of practice of composting as determined in item 1.

To estimate the quantities of green waste composted, apply an average value of 0.45 kg/m² to the total green area of composting homes.

Obtain the annual production of yard waste brought in civic amenity sites on the territory. Production in kg/m².year is obtained by dividing the total production measured in civic amenity sites by the total area of gardens estimated in Point 2, modulated by the coverage factor.

Consider the quantities of green waste in the garbage calculated in the point 4.
The total deposit is the sum of the composted quantities, those placed in civic amenity sites and those placed into the garbage.

The percentage of composted waste is the ratio of composted quantities by the total deposit.</td><td>Use the total area of gardens established in section 2.

Analyze aerial photography of the studied area to extract lawn and tree hedges in order to obtain the total green area from individual housing.

Use the composting practice rate of as determined in point 1 by separating, if possible, the upper and lower garden surfaces of 300 m².

For the estimation of the composted quantities, apply ratios obtained through weighing from VH (obtained in point 3 and expressed in kg/m².year). Apply this ratio to vegetated surfaces of homes concerned. If the image analysis assess only vegetation without distinguish the type of vegetation, the values entered in the last column of the table below should be used.

<table><tr><td>Garden area</td><td>Pruning</td><td>Mowings</td><td>Sum</td></tr><tr><td>< 300 m²
> 300 m²</td><td></td><td></td><td></td></tr><tr><td>Average</td><td></td><td></td><td></td></tr></table>Otherwise, apply to surfaces < 300 and > 300 m², the percentage of composting practice obtained in point 1 to assess a global stream diversion from home composting, in kg

Obtain the annual production of yard waste brought in civic amenity sites on the territory, taking into account, if necessary, the zone of influence of the different civic amenity centers. This task is achievable through network analysis capabilities available in GIS tools, allowing considering the road system. Production in kg/m².year is obtained by dividing the total production measured in civic amenity sites by the total area of the green areas concerned and estimated in Point 2.</td></tr>
</table>

		Consider the quantities of green waste in the garbage calculated in the point 4. The total deposit is the sum of the composted quantities, those placed in civic amenity sites and those placed into the garbage. The percentage of composted waste is the ratio of composted quantities by the total deposit.

Conclusions

Conducted among 300 households, the present project used several tools to analyze the impact of home composting on the organic fraction of garbage. The method allowed for the sub grouping of households into three categories, based on their compost management practices: composting households which volunteered to weight their composted biowaste (VH); composting households which did not volunteered weighing their composted biowaste (NVH), and non composting households (NC). Surveying the households by telephone initially brings additional information pertaining to the number of person within the household. Nevertheless, this initial survey does not provide information as to the mass of biowaste composted.

During the telephone survey, volunteer households were found and these participated by weighing the biowaste composted. The biowaste weighing process demonstrated that both households using ground piles and composting bins recycled about the same amount of waste. In the project, the experiment demonstrated that weighing and determining the fraction of garbaged residual organic fraction produced the same results as weighing the biowaste fed to the composting systems. Therefore, this biowaste weighing activity is not necessary when conducting an evaluation if the garbage is well monitored. Furthermore, when asking households to weight their composted biowaste, the volunteers are generally more adept composters than those who do not volunteer. Finally, the mass of biowaste produced did not vary with seasons. In conclusion, a standard method for the determining of the impact of composting on biowaste recycling requires basically a periodic weighing of the garbage produced. As a result, only 2 groups can be discriminated, those composting and those garbaging their biowaste.

GIS was used to study garden areas of homes that have weighed their waste placed in composting. The results obtained indicate ratios of composted yard waste according to the size of the garden and the type of vegetation (hedge, lawn). Unlike kitchen waste, the classification of households according to their garden areas is more relevant than their way of composting. Results differ for two distinct classes of gardens, with substantial variability of the weighing results for the first category (<300 m).

The mass balance achieved through this Miniwaste project, compared to other studies, such as that conducted within the Greater City of Nancy, France, validates the standard method developed to evaluate the impact of composting. The quantities of composted kitchen waste depending on the method of composting should not necessarily be evaluated. Instead, average values can be used. The use of GIS for assistance in obtaining the ratios of composted yard waste may be considered but could also be replaced by the use of a survey, using the areas declared by the households. Then, to extrapolate the results to a wider area, the use of GIS is becoming essential in the case of an “advanced assessment”. The simplified assessment” of composted yard waste relies on both measures and averages. Tasks to achieve are a survey and the determination of the quantities of garbage from both composting and non-composting homes.

The averages pertain to the amount of kitchen waste composted based on the type of home composting system used and the percentage of residual organics in the garbage. For yard waste, the use of cadastral data and the areas declared by the surveyed households then allow to apply average ratios. Then, it is possible to evaluate, at a lower cost, impact of composting.

This simple and economical standard method will be further validated by the other partners of the Miniwaste project.

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Irstea – centre de Rennes
17 avenue de cucillé
CS64427
35044 Rennes cedex
tel. +33 (0)223482121
fax +33 (0)223482115
www.irstea.fr