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# Recycling local organic waste in peri-urban horticulture: a case-study in the Parisian region

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## *Abstract*

In France, there is a growing demand of locally produced vegetables from urban consumers. Meanwhile, cities and their peri-urban areas are a source of organic wastes (OW) that can be recycled as amendment or fertiliser in agriculture. Our research objective was to investigate the current and prospective uses of OW by market gardeners and fruit growers in three peri-urban areas near Paris (France). We carried out semi-structured interviews with thirty market gardeners and/or fruit growers to study their current fertilisation practices and their perception regarding the potential use of diverse OW available (or probably available in the future). It turned out that the most common OW were green waste compost and horse manure, used mainly as soil amendment. Besides, most farmers used commercial organic fertilisers. Farmers' perception regarding the potential use of biowaste compost was good, as well as for shredded green waste. However, the farmers were more reluctant to use digestate from biowaste anaerobic digestion and human urine, although they would be suitable OW for the substitution of commercial fertilisers (thanks to a high N availability). This reluctance was mainly explained by sanitary risks, legal barriers, logistic problems or fear of consumer perception. We showed that for farmers, OW had to be considered not only for their fertilisation or amendment role but also for other farming objectives such as mulching. The rates of OW application greatly varied among farmers but were higher than what was usually applied in field crops in Paris region. Based on these figures, we extrapolated the required acreage to recycle all composted organic wastes from private households at the scale of the Ile-de-France (Paris) region. This showed that market gardening and fruit production could play a significant role in recycling OW from cities at the regional level.

**Keywords:** Market gardening, fruit growing, peri-urban agriculture, circular economy

## INTRODUCTION

There is a growing demand of locally produced fruits and vegetables from French consumers which local authorities claim to support by developing territorial food projects (Dedinger et al., 2021). As 80% of French population now lives in urban areas (Costemalle, 2020), the vast majority of consumers are city dwellers. The cities, apart from being a pool of consumers, are also a source of organic waste (OW) such as organic household waste, green waste, excreta or horse manure in urban areas with numerous equestrian facilities (Moinard et al., 2021). Instead of being incinerated, these OW can be shredded, composted or digested and recycled as amendment or fertiliser in agriculture. The use of OW as amendment in agriculture is known to improve soil properties and fertility and to increase

soil carbon and organic matter (OM) levels. Valorisation of OW can also help to reduce the quantities of mineral fertiliser applied in fields (Noirot-Cosson, 2016; O'Connor et al., 2021) and thus avoid their energy-consuming production or mineral resource depletion (Herrera et al., 2022).

Recycling OW from cities is not an emerging activity as it was one of the main ways to maintain soil fertility in previous centuries, e.g. during 19<sup>th</sup> century in Paris area (especially for market gardening (MG))(Barles, 2018) or during the Edo period (1600-1868) in Japan (Brown, 2013). With the emergence of mineral fertiliser, recycling OW from cities soon became depreciated. Today, it could help to close the loop of OM and nutrients and thus preserve the nutrient and carbon levels within the soils.

The potential recycling of OW in field crops have already been highlighted in the Versailles plain (agricultural area near Paris)(Moinard et al., 2021) but little information has been gathered regarding the recycling of OW in market gardening or fruit growing (FG). Nevertheless, these types of crops generally have high nutrient needs and imply low organic matter return to soil (Neuweiler and Krauss, 2017). Thus, the hypothesis was made that the potential recycling of OW in MG and FG could be high. In that respect, our main objectives were to study and quantify current fertilisation practices of market gardeners and fruit growers in three peri-urban areas near Paris and to understand their perception regarding the potential use of diverse OW available.

## MATERIAL AND METHODS

### Study area

Three peri-urban areas in the south-west of Paris have been studied: the Versailles plain, the Triangle Vert and the Saclay plateau (Figure 1). These areas are 10 to 50 kilometres away from Paris. Their perimeters are defined by the boundaries of the cities involved in three local associations, whose goals are to maintain and promote agriculture in these areas where urbanisation is expanding quickly. Thanks to proximity between cities and fields in these areas, organic wastes are potentially highly available for agriculture.

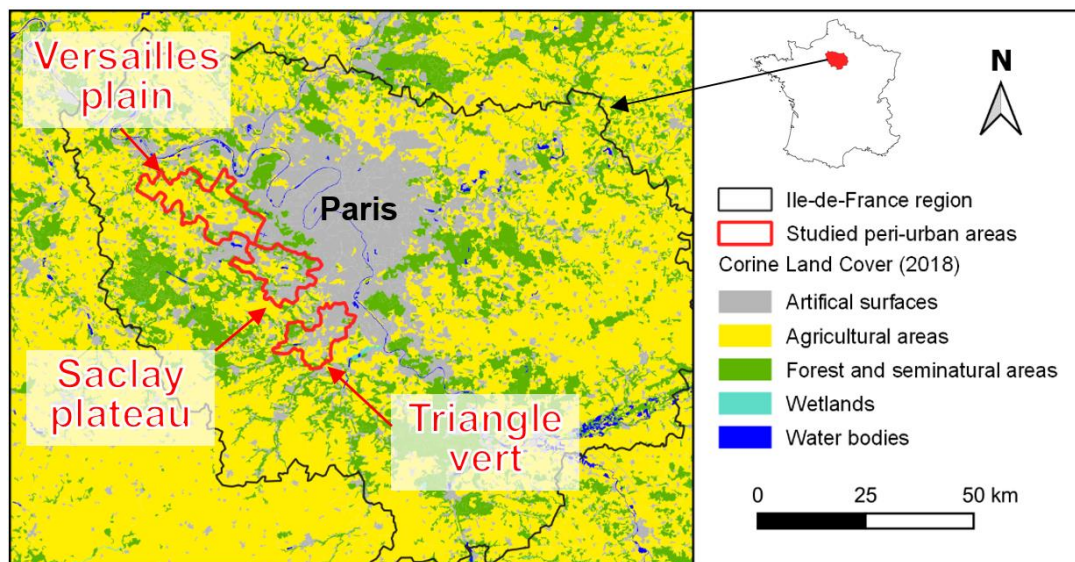


Figure 1. Location of the three studied peri-urban areas in Ile-de-France (Paris) region

In the Versailles plain, the Saclay plateau and the Triangle Vert, agriculture is quite preserved considering their closeness to Paris. These areas are located in the Ile-de-France region, which is the most populated area in France (12 million inhabitants). Ile-de-France covers a surface of 1,2 million ha and 564,000 ha of this surface is dedicated to agriculture

which is mainly devoted to field crops and where animal husbandry is not well developed (except for equestrian facilities) (Pignard et al., 2021). The selected areas have more UAA dedicated to MG and FG than in the rest of Ile-de-France region (Table 1), making them interesting to investigate for our research on this topic.

Table 1. Agricultural land in the studied areas compared to Ile-de-France area

Studied areas	Ile-de-France	Versailles plain	Saclay plateau	Triangle Vert
Total surface (ha)	1,201,200	23,217	15,607	4,859
Total Utilised Agricultural Area* (UAA) (ha) (% of total surface)	563,965 (47%)	12,156 (52,4%)	3,724 (23.9%)	1,491 (30.7%)
UUA dedicated to MG and FG** (ha) (% of total agricultural land)	3,789 (0.7%)	298 (2.5%)	100 (2.7%)	113 (7.6%)

\* Data from the French Land Parcel Identification System and Agreste for Ile-de-France figures

\*\* Data from interviews with farmers of the studied areas and their websites

### Semi-structured interviews

On the studied areas, there were fifty market gardeners and/or fruit growers. Semi-structured interviews were conducted with thirty of them in order to investigate their current and prospective use of OW. A variety of MG and FG systems have been investigated to get a full picture of existing practices to maintain soil fertility.

The interview guide was organised the following way:

- 1- A general part to describe the farm of the interviewee (creation date, legal status, type of crops, marketing channel, certifications, cropping practices, etc.)
- 2- A part focused on fertilising and mulching practices with a specific point on the use of OW. The reasons of these practices were particularly investigated. For non-users, their reluctance to use OW was explored.
- 3- A last part investigating the farmers' perception of different types of OW available in the explored areas. To do so, OW were presented to farmers using fact sheets with agricultural, sanitary and legal information. Farmers were then asked if they would use it in their farm or not (three answers possible: "Yes, I would use it", "Yes, but under certain conditions", "No, I won't use it").

### OW presented to farmers

Seven OW available (or probably available in the near future) on the studied areas were selected to be presented to the interviewed farmers (ramial chipped wood (RCW), compost from green waste, compost from biowaste, digestate from biowaste, cattle manure, horse manure and fertilisers from human urine). Even though cattle manure is not strictly speaking an urban waste, it was available on the three studied areas and has been selected in order to be compared to horse manure. In France, spreading digestate from anaerobic digestion on MG surfaces is not allowed but it was considered as an important OW to investigate since it has a rich content in nutrients and it is made from biowaste highly available in urban areas. Human urine being a high potential and intensively discussed prospective fertiliser (Martin, 2020), it was also selected to be presented to farmers.

### Interview analyses

The interviews were qualitatively analysed thanks to NVivo and Excel programs. Quantitative data were also gathered such as the current quantities of various spread OW in MG and FG, which helped us to estimate the required surfaces to recycle all organic waste from household in Ile-de-France. To do so, the following input were considered: 900,000 t of organic waste from household produced each year in Ile-de-France (including green waste from household) (Conseil Régional d'Ile-de-France, 2019), the hypothesis that

composting reduces by one third the initial biowaste volume (Mallard et al., 2005) and the median volume of compost used in MG and FG determined by interviews.

## RESULTS

### Profile of market gardeners and fruit growers interviewed

Farmers had 0 to +20 years of seniority, with 40% of them with less than 5 years. This was consistent with the recent development of small-scale vegetable farms by new entrants in the area (Pignard et al., 2021). 47% (n=14) of the farmers interviewed were certified in organic farming and 40% (n=12) used conventional farming methods, which is representative of the total population studied. Four farmers reported that, even though they did not have organic farming certification, they did not use any pesticides and declare that their practices were more sustainable than the ones required for organic certification. Crop types of each interviewed farmers are presented in table 2. Different surveyed farming systems imply different agricultural surfaces, from 0.12 ha to 50.5 ha with a median of 4.5 ha. Different types of marketing mode were encountered: zero level channel only (n=24), wholesale market (n=3) or a combination of both (n=2).

Table 2. Crop types of interviewed farmers

Crop type	Number of farmers (%)
Market gardening only	12 (40%)
Fruit growing only	2 (7%)
Market gardening and small fruits	3 (10%)
Market gardening and fruit growing	5 (17%)
Market gardening with cereals	1 (3%)
Cereal production and vegetable crops	5 (17%)
Aromatic and medicinal herbs	2 (7%)

### Current fertilizing and mulching practices of investigated farmers

Among the thirty interviewed farmers, 28 of them added organic matter to their soil through a large variety of OW or commercial organic fertilisers (Fig. 2). Their main reasons were to offset the export of crops, to increase the level of organic matter of the soil and to improve soil porosity, soil health and its fertility in the long run. Some of them used organic waste as mulch in order to keep humidity and to reduce weed competition. Only two of them used mineral fertiliser.

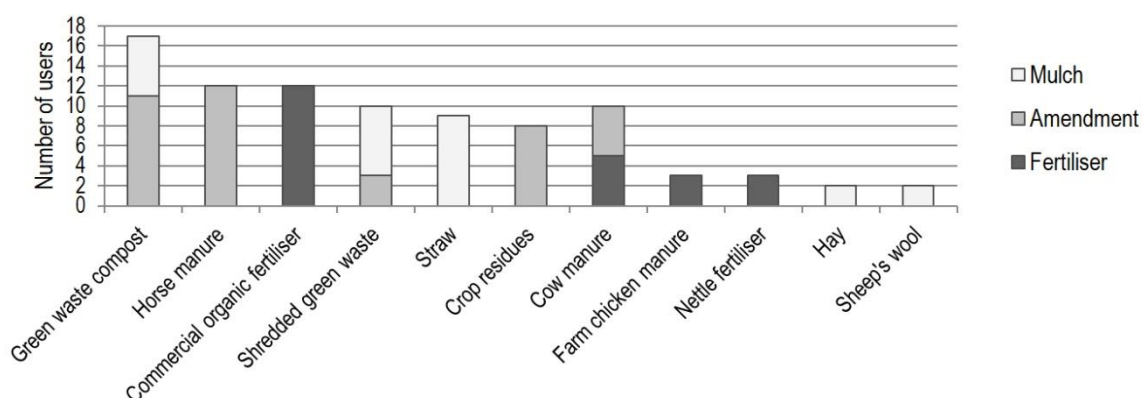


Figure 2. Organic wastes and fertilisers applied, number of users and their use

The following products have been mentioned by only one user and are not presented in Figure 2: biowaste compost (fertiliser and mulch), brewer's spent grain (amendment), cardboard (mulch), castor cake (fertiliser), commercial chicken manure (fertiliser), dry leaves (mulch), guano (fertiliser), ground coffee with mycelium (amendment), miscanthus mulch (mulch) and sheep manure (fertiliser and amendment).

Green waste compost and horse manure were the most applied OW. Unlike green waste compost, biowaste compost being less developed was almost not used by market gardeners and fruit growers. Commercial fertilisers (fertilisers industrially processed and purchased) were also frequently used. Including commercial chicken manure, feather meal, guano and castor cake, 70% of interviewed farmers declared to use commercial fertilisers at least once a year. 19 out of 21 users also applied OW on their farm and 17 declared that commercial fertilisers were used as a supplement of fertilisation in addition with OW. Some of them wished to do without these commercial fertilisers but considered that it was not possible if they wanted to reach a sufficient production. Among the non-users of commercial fertiliser (n=9), seniority median was 2.5 years and their UAA was between 0.12 ha and 2.5 ha (except for one with 20 ha) which represented the lowest range of surface in our sample. Six of them were certified organic and three others declared not to use any pesticides. Quantities of OW varied a lot among users, ranging from 9.5 t.ha<sup>-1</sup>.year<sup>-1</sup> to 100 t.ha<sup>-1</sup>.year<sup>-1</sup> for green waste compost and from 5 t.ha<sup>-1</sup>.year<sup>-1</sup> to 33 t.ha<sup>-1</sup>.year<sup>-1</sup> for horse manure (Fig. 3). Fruit growers that did not have a market gardening activity were not using green waste compost.



Figure 3. Quantities of horse manure and green waste compost applied by farmers

Quantities of green waste compost varied depending on the way it was used. Higher quantities were applied when green waste compost was used in order to increase soil organic matter level. Lower doses were applied when the goal was to maintain soil fertility. Quantities of green waste compost applied were high in comparison with the one used with commercial organic fertilisers (0.4 t.ha<sup>-1</sup>.year<sup>-1</sup> to 4 t.ha<sup>-1</sup>.year<sup>-1</sup>) that have a higher content of N, P and K and a higher price. Quantities of OW applied could not be related to any specific type of market gardener or fruit grower. Neither the farming methods (conventional, organic, etc.) nor the UAA had a specific influence on the amount of OW used in our sample.

### Interviewed market gardeners and fruit growers perception of OW

Farmers' perception regarding the potential use of green waste compost and biowaste compost was predominantly good, as well as for RCW, horse manure and cow manure. However, the farmers were more reluctant to use biowaste digestate from anaerobic

digestion and human urine, although they would be more suitable for the substitution of commercial fertilisers (thanks to a high N availability) (Fig. 4). Advantages and disadvantages mentioned by the farmers during the interviews were summarised in table 3.

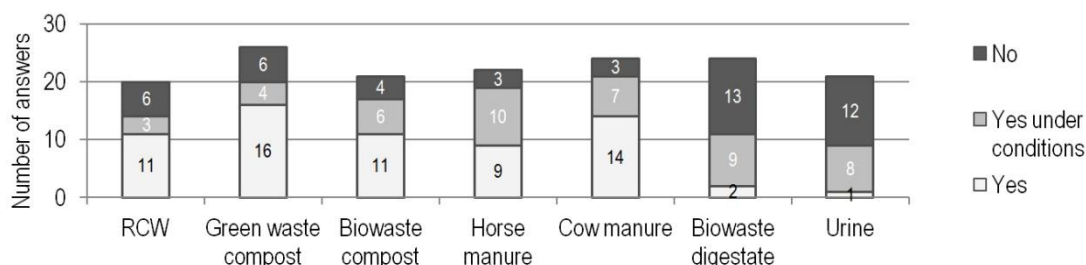


Figure 4. Perceptions of interviewed farmers in the studied areas about the possible use of OW in their farms

Table 3. Advantages and disadvantages of OW perceived by interviewed farmers

OW	Advantages mentioned	Disadvantages mentioned
RCW	Enhances soil mychorrization, improves soil OM level, mulch easier to use than straw	Fear of potential nitrogen immobilisation, soil acidification and slow decomposition, supply difficulties
Green waste compost	Easily available, maintains soil OM level, long term fertility, can be used as seedbed	Plastic pollution, potential nitrogen immobilisation, the feeling that it doesn't improve soil quality
Biowaste compost	Similar to green waste compost, avoids biowaste incineration	Similar to green waste compost
Horse manure	Easily available, maintains soil OM, long term fertility, trust in horse manure due to the historical use	The possible presence of antibiotics or pathogens, logistic problems: difficult delivery or spreading
Cow manure	Perceived as richer in NPK than horse manure, maintains soil nutrient and OM levels	Limited availability, concern about presence of antibiotics or pathogens, logistic problems
Biowaste digestate	High N availability, can avoid N immobilisation when used with other products richer in C	Smell and aspect, difficulties to spread a liquid product, fear of sanitary risks, few experiments in market gardening, low OM levels, some farmers against anaerobic digestion
Urine	High nutrients availability, can avoid N immobilisation when used with other products richer in C	Fear of hormones or pharmaceutical residues, concern about consumer perception, high pH, logistic problems: difficult storing and spreading

### Extrapolation of required acreage to recycle all composted organic wastes from private households

Considering the median amount of green waste compost applied by interviewed farmers (Fig. 3), we made the hypothesis that every market gardener and fruit grower of Ile-de-France could use 30 t.ha<sup>-1</sup> of biowaste compost each year. This was a high-case scenario as market gardeners did not necessarily all used compost. Considering this hypothesis, 10,000 ha of MG and FG land would be required to recycle all organic waste from private household in Ile-de-France (900,000 t of organic waste, i.e., 300,000 t of compost). This represented 2.6 times as much land as the current MG and FG surfaces but only 1.8% of Ile-de-France agricultural land (Pignard, et al. 2021; Agreste, 2020). Thus, market gardening and fruit production could play a significant role in recycling OW from city households at the regional level.

## DISCUSSION

This study was based on semi-structured interviews which provided the main reasons of the use of OW and helped farmers to give their free opinion concerning the several presented OW. However, due to the period of the interviews between May and July 2021 (peak production in MG and FG and Covid-19 restrictions), some farmers did not have much time, which altered the amount of information gathered for some of them. Despite that, we have been able to interview thirty market gardeners and fruit growers out of fifty on the studied areas and this sample can be considered as representative of the studied population.

Extrapolation of required acreage to recycle OW from private households was based on the high-case scenario of every market gardener and fruit grower using 30 t.ha<sup>-1</sup>.year<sup>-1</sup> of compost, yet we must keep in mind that only 13 farmers out of 30 declare to use green waste compost and that they were not all necessarily interested in changing from green waste compost to biowaste compost. Even if relevant to increase soil organic matter, we can also wonder whether applying 30 t.ha<sup>-1</sup>.year<sup>-1</sup> does not bring nutrients in excess and what are the potential soil, air and water pollutions associated (Small et al., 2019).

The extrapolation calculation was also based on the figure of 900,000 tonnes of OW from households available but the collection of these OW is not well developed. However, specific collection of OW is supposed to increase in the future (Conseil Régional d'Ile-de-France, 2019).

In the studied areas, the main OW used in MG and FG were: green waste compost and horse manure. These OW were the most available resources on the areas and were also the most used OW in field crops (Moinard et al., 2021). Farmers used these OW as amendment to increase the soil fertility in the long term, as classically pointed out by several authors (Hijbeek et al., 2019; Paul et al., 2017), but also as mulch for green waste compost which was less commonly reported. The labour for spreading OW and their contamination were often cited by farmers as disadvantages to the use of OW, which were also classically reported in the literature (Hijbeek et al., 2019; Paul et al., 2017). Market gardeners used more commercial organic fertilisers than cereal producers, possibly because the share of fertilisation costs in market gardening was lower than in field crops thanks to a higher productivity per hectare (Lecuyer et al., 2013). Market gardeners also applied more green waste compost (30 t.ha<sup>-1</sup> each year) than cereal producers (20-30 t.ha<sup>-1</sup> every three-four years) (unpublished data) but less mineral fertilisers.

This area-specific study can be transposed to other agri-urban areas with similar characteristics, namely: an agricultural land close to a large city with field crops as main culture, market gardening being not highly developed and very little animal husbandry.

The replacement of commercial fertilisers by OW, in particular biowaste digestate and human urine that are rich in N, P and K elements, could be possible if acceptability by farmers is improved and if laws are changed. To do so, it will be necessary to prove the safety of these OW, especially regarding the potential presence of plastics, pharmaceutical residues, pathogens and heavy metals. Communication about these OW could be a way to improve acceptability by farmers (Paul et al., 2017; Selvaggi et al., 2021) but also by consumers. Field experiments done by market gardeners interested in OW could be a lever to demonstrate the agronomic benefits of these products, and to mitigate the feeling of some farmers that their agricultural fields serve as urban waste outfall. A last important lever to increase the use of OW by farmers is to facilitate their access to these products e.g. by providing them better information on which OW are available locally.

## CONCLUSIONS

The following conclusions can be drawn from the study:



- A large majority of interviewed market gardeners and fruit growers applied OM at least once a year in their fields.
- The most commonly used OW in MG and FG in the three studied areas are green waste compost and horse manure, but a diversity of OW are applied.
- Biowaste compost, such as green waste compost, RCW and animal manure are well perceived, contrary to biowaste digestate and human urine.
- To prove the safety of these OW, to facilitate their access and to communicate about it with general public would be great ways to improve their acceptability in MG and FG.
- Knowing the quantities of applied green waste compost, market gardening and fruit production could play a significant role in recycling OW from city household at the regional level.

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