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Article

Productivity and Efficiency of Community Gardens: Case Studies from the UK

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Abstract: The extensive and burgeoning literature on the productivity of urban farms and gardens is largely focused on measures of crop yield and resource use, with little offered to date on their contribution to social productivity and sustainability. This paper suggests that evaluation of urban agriculture should consider all types of resource consumption and productivity simultaneously. The research reported here used a citizen science approach to collect data from seven community gardens and one community farm in London, UK in the 2019 and 2020 growing seasons. The paper examines the many variables that impact the sites' overall performance, highlighting the complex nature and relationship between the many benefits and outcomes of urban farms and gardens. Data are presented on crop yield, equivalent fruit and vegetable portions, input use (including water and fertilizer), journeys made to the garden by volunteers, social benefits, and social outreach. Results show very mixed levels of crop and social productivity, depending on the organizational structure and agenda of the various sites included in the study. With no clear pattern emerging, this paper suggests that the evaluation of citywide productivity, often based on projections of small data samples, may not be reliable. By ensuring that training opportunities for volunteers are made available, higher resource efficiency as well as higher productivity could be attained.

Keywords: community garden; crop productivity; multifunctional urban agriculture; environmental efficient urban agriculture; social benefits

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1. Introduction

Increasingly, urban agriculture (UA) is viewed as a solution to build local resilience, with the debate on this practice now also focusing on its capability to strengthen resilience during crises. For example, there is literature that documents the benefits in terms of food supply and mental well-being that community gardens can provide in the post-earthquake recovery phase [1,2]. Other studies point to the rise in demand for food gardens during the first and second wave of the recent COVID-19 pandemic [3,4], the 2008 financial crisis and other economic downturns [5,6]. More generally, the literature recognizes the potential for UA to mitigate locally the consequences of environmental and climatic crisis [7,8], but UA benefits can go beyond those attained during emergencies. Barthel et al. [9] identify soil fertility, land availability and food access as some of the stressors that threaten the stability of global food production. Urban and peri-urban agriculture is the practice that can alleviate the pressure generated by such stressors, thereby contributing to the long-term health of critical global resources and supplies.

The extent to which UA connects with diverse local and global challenges demonstrates that food is not only a basic need but is also a catalyst for social and environmental improvement. It also contributes to upholding values of cooperation and environmental awareness. However, for this concept to be accepted, evidence must be generated of the wide range and scale of benefits that urban food production can simultaneously yield.

Studies presenting data on this wide range of benefits, rather than individual forms of productivity, are limited. Considering such a range in its entirety, however, is a key requirement if claims of sustainability are to be substantiated. Ascertaining precisely in what way and to what extent UA is resource-efficient can help improve this practice and strengthen its sustainability credentials. Likewise, measuring the several aspects of productivity can demonstrate the real multiple values of UA.

To provide evidence on the wide range of benefits generated by UA and contribute to the knowledge gap in this area, this study measured a diverse range of UA indicators in seven community gardens and one community farm in London. These include crop yield, equivalent fruit and vegetable portions, water consumption, fertilizer input, volunteer and growers' trips to the garden, social benefits and social outreach. The study's primary hypothesis is that the overall productivity of the community gardens when all activities are accounted for is considerable. It shows the obstacles to accurate data recording and collection. It also debates the reliability of data collected in community gardens and farms when they do not follow established protocols of production and distribution, such as those used in conventional agriculture.

Data were collected by farmers using citizen science methods between March and October 2019 and 2020. Results of the investigation show diversity in performance, with no clear common trend. However, disparities in productivity across the sample can be understood when analyzed against each garden/farm's main objective and organizational structure. This enables the identification of leverage points that can endow UA with higher efficiency. It also shows how diverse these UA projects are, and how problematic it can be to use data samples to predict food productivity at a city scale. This is because such samples cannot capture the, often extreme, disparities between UA projects. Following a literature review of studies illustrating several types of productivity and a methodology section, the results of the data collected are presented. These are subsequently discussed in a dedicated section.

2. Literature Review

To assess many of the claims concerning the value of UA, quantitative studies have been developed that measure UA productivity. These, together with qualitative investigations weighing UA social impacts in the areas of community-building [10], health [11], economy [12] and education [13,14], consolidate the evidence on the multiple productive potential of UA, albeit with contradictory results. For example, studies that focus on Boston, New York, London and Barcelona quantify potential crop production at between 17% and 89% of the local vegetable demand. City morphology, climate, geographical urban boundaries, and research methods all greatly influence the outcome of the evaluation [15–20]. Some of the studies on productivity are based on secondary data, but others using primary data show equally varied results. A range between 0.46 kg/m^2 and 1.96 kg/m^2 was measured in allotments and community gardens in Paris and Montreal [21], and a range between 1.99 kg/m^2 and 15.53 kg/m^2 in 13 gardens in Sydney, Australia [22]. In times of crisis, well demonstrated by the Second World War UK campaign Dig for Victory, policy and government interventions drove increased local fruit and vegetable production (described by [23] as "*Order and control*". This, however, resulted in the production of only 18% of the overall amount of fruit and vegetables needed [24]. Lovell [11] reminds us that in Shanghai, 60% of vegetables consumed are actually produced within the city.

Other recent UK studies come to similarly diverse conclusions. Nicholls et al. [25], in a study of allotments and urban gardens in Brighton, show that the average yield of these spaces is 1 kg/m^2. Using GIS and survey data from three UK cities, Grafius et al. [26] estimate that the spaces studied could meet the annual fruit and vegetable needs of 54,000 people, using the recommended "five a day" measure. Walsh et al. [27] used GIS and existing yield data to explore the potential fruit and vegetable production in urban green spaces, if used for food production across the UK. They found these have the potential to provide an upper limit of between 20.70 and 22.41 metric tons of fruit and vegetables. If achieved, this quantity would provide fruit and vegetables in excess of the daily recommended amounts for the population.

The manner in which measurements of crop productivity are recorded often vary and this can make comparisons difficult. A summary of some of these different approaches is shown in Table 1.

Table 1. A selection of approaches to measure UA crop productivity used in recent studies.

Source	This Study	Dobson et al. [28]	Wright [29]	Sustain [30]	Taylor [31]	Nicholls et al. [25]
Location	London, UK (*n* = 8 community gardens and farms)	UK Wide Allotments (*n* = 163 allotments)	Kirkham Prison Farm	London (mainly) (*n* = 89 2014 + 160 in 2013)	Rhode Island (US) (*n* = 4 experimental plots at Rhode Island University)	Brighton & Hove (UK) (*n* = 185 allotment-holders and home-growers)
Metric						
Kg/m^2	a	a		a	a	a
Economic Value				a	a	a
Production Quantity (heads)			a			
Weight	a			a		
Number of Portions (80g)	a			a		

Types of productivity other than food output have been measured using different indicators. For example, Ward et al. [32] quantified the potential of UA by calculating protein content. Guitart et al. [33] surveyed gardening practices of 50 community gardens in Brisbane to assess their "ecological viability" in terms of fertilizers, pest control, soil management and other indicators. Nicholls et al. [25], Newell et al. [34] and Evans et al. [35] highlight the contribution UA makes to biodiversity, insect populations and ecosystem services in allotments and UA spaces. UA social benefits have also been measured, for example, the contribution that gardening can make socially and through improved well-being in addition to its potential for building social connectedness and capital [36–38]. Based on a survey of more than 150 urban gardeners, Kirby et al. [39] identified mental well-being as the main benefit derived from UA, overtaking economic and educational impacts.

In the face of optimistic projections of potential food production, the overall contribution of UA can be perceived as modest if the productive capacity of each incremental benefit is measured in isolation. The reasons for this perception stem from the limited quantities of food currently produced when compared to conventional agriculture. However, it is often because these spaces support a wide range of activities that food production is not prioritized. Some food gardens are not managed with a professional approach to optimize processes and outputs. In a review of LCA studies, Dorr et al. [40] found that food gardens that sell their produce may be more productive than those that do not. Considering the scale of UA practices, which—although growing—are for a large part not commercially competitive, job creation may be still limited [41] and highly variable depending on the socioeconomic conditions of urban areas [17]. Health care and well-being service commissioners increasingly recognize the value of social prescribing [42], including community farms and gardens as providers of nature-based therapies [43–45], yet in the UK, social prescribing is sometimes poorly funded [44], operating with different delivery models and measuring impact differently [46], making it difficult to upscale. It is in fact the aggregate impact of all these outputs (food, employment, well-being and more) that makes UA unique and valuable. With some studies suggesting that UA can be resource-intensive and generate a higher impact on the environment than conventional agriculture [47,48], it is important to consider that in UA, inputs (i.e., resources) generate not only material (i.e., food) but also immaterial outputs.

3. Materials and Methods

One of the difficulties of presenting a composite measure of the multiple benefits of UA is the lack of data on each indicator, ranging from physical inputs through to social outputs from each garden included in any study. The FEW-Meter project, on which this paper draws, set out to do just that, collecting a full range of data types from a panel of contributing gardens, using citizen science methods, over an extended period.

The FEW-Meter (Food–Energy–Water) project was a 5-country study funded through the call Sustainable Urbanization Global Initiative (SUGI)/Food-Water-Energy Nexus (SUGI), jointly established by the Belmont Forum and the Joint Programming Initiative Urban Europe. FEW-Meter investigated the use of energy, water and other resources on case study farms and gardens in five countries (UK, US, Poland, France and Germany). Data were gathered over two growing seasons (2019 and 2020) to model the resource flows of urban agriculture, allowing the identification of methods to improve efficiency on the farm and also at a city scale (see [49]).

Garden/farm recruitment—In the UK, London was selected as the case study city because of connections made through the partner organization Social Farms & Gardens. In consultation with the University of Kent, the latter organized a meeting in London in early 2019 to recruit urban farms and gardens to the project. As a result of this meeting, five gardens joined the project in February 2019. A further four gardens were recruited through personal contact with community gardens. One of the gardens experienced challenges in collecting the data required by the study and so dropped out quite early on in the process. Those gardens approached at the London meeting or via personal contact who chose not to be a part of the project were put off mainly due to one of two reasons. Some were afraid of the perceived scale of data collection required. Others believed that the formal measuring and collection of harvest data was contrary to the philosophy of the garden, which was focused more on the unencumbered production and distribution of fruit and vegetables.

Data collection—Having identified the initial volunteer farms and gardens, a first visit was made by the project team from the University of Kent to further explain the objectives of the project and to supply the necessary documentation for data collection. This largely consisted of a paper handbook that required participants to record the quantity of water and other inputs used in the garden/farm, the weight of produce harvested and its destination, the distance that volunteers traveled to work in the garden and the number and type of social activities taking place at the site. Participants were instructed on how to complete the handbook, including how frequently to collect and record data. The correct method for using the water meter was also explained. A further visit was made to each garden initially to measure the physical infrastructure present to feed into the LCA analysis that formed a part of the FEW-Meter project.

Following these initial two setup visits, regular visits were made to the gardens to monitor data collection over the course of the 2019 growing season. This season was interpreted as being between 1 March and 31 October to allow for uniformity of the data collection period between study countries. When the COVID-19 pandemic struck in early 2020, some gardens closed their activity or decided they could not commit to a second year of data collection. Contact with the 5 gardens that continued collecting data switched to online methods, with one garden submitting its data by post.

Regardless of the basic induction provided as mentioned above, each garden adopted its own method for data recording. Three supplied the spreadsheet that they would normally use to record water use and harvest data for their own records. Two developed a spreadsheet specifically for the project, which they then emailed to us. One recorded the data on a whiteboard in the garden, of which they then sent photos on a weekly basis. One recorded the data in a paper diary at the garden, which the project team took photos of during 2019. Two recorded the data in the paper handbook that the team delivered to the garden on the first visit. Likewise, data were recorded at different time intervals, with some measuring harvests daily and others weekly.

In addition to the data requested in the project handbook, a survey was also undertaken of garden volunteers asking about their motivations for visiting and working in the garden and the benefits they perceived as a result of their participation. This survey was supplied to garden managers, who were asked to pass on paper copies to volunteers. Respondents were thus self-selected, and the research team did not control the number of questionnaires completed. The number of forms returned by each garden varied from zero, where there were no volunteers working, to 14 at one community garden, with 48 forms completed in total. Table 2 provides a profile of the case studies—which have been anonymized—in terms of objectives of their activities, type of outreach activities running in parallel with food production, and the destination of food harvested. These data are key for an interpretation of the performance of each project, which is documented in the following section and discussed in Section 5.

Table 2. Profile of the case studies.

Garden/Farm	Cultivated Area (m^2)	Total Harvest 2019 (kg)	Primary (a), Secondary (b) and Tertiary (c) Objectives	Educational Activities (E) and Community Activities (C)	Food Destination/Sales Channel
CG1 is located in Central London and aims to improve the mental and physical well-being of residents and local groups. It offers sports facilities, a community hub, room hire for activities, a café and a food growing space.	144	205	(a) Community cohesion and development (b) Environmental remediation (c) Food production	(E) Gardening demonstration/training Environmental lessons Hydroponics workshops (C) Volunteer day Community meals	Sold Donated to food bank Used in own restaurant
CG2 is a community garden attached to a North London leisure center. It uses the space around the building for productive and educational purposes, strengthening the environmental and social sustainability of the center by increasing the local biodiversity and giving volunteers the opportunity to improve their well-being through gardening. The food grown is cooked in the local cafeteria. It uses permaculture methods.	297	1132	(a) Food production (b) Environmental remediation (c) Education	(E) School visits Environmental and food lessons Bee courses Woodcraft (C) Cultural events, garden/farm tours, festivals/parties Community meeting Community outreach—well-being day	Used in own restaurant
CG3 is a community garden within a large social housing estate in East London. It is located next to the community center and mainly attracts the estate's residents, although it is open to volunteers from all over London.	100	145	(a) Food production (b) Community cohesion and development (c) Education	(E) N/A (C) Festival/party Open Squares Weekend	Distributed to volunteers, sold or donated Farm stand Restaurants

Table 2. *Cont.*

Garden/Farm	Cultivated Area (m^2)	Total Harvest 2019 (kg)	Primary (a), Secondary (b) and Tertiary (c) Objectives	Educational Activities (E) and Community Activities (C)	Food Destination/Sales Channel
CG4 is a charity and a community garden within an allotment site in Hertford. It supports adults with learning disabilities and mental health issues through gardening. The produce is also used in the café, which employs some of the volunteers with disabilities	452	566	(a) Community cohesion and development (b) Public health (c) Food production	(E) Environmental lessons, other educational activities Willow weaving (C) Community meetings, volunteer days Open allotments	Distributed to volunteers Sold Used in own restaurant
CG5 is located within one of the most famous London parks. It aims to inspire people to grow food whilst providing advice on organic methods of cultivation. It is open to the public and the food is distributed to volunteers or donated. It runs several educational activities	324	161	(a) Public health (b) Environmental remediation (c) Education	(E) Volunteer day, festivals/parties Open day with book signing (C) N/A	Distributed to volunteers
CG6 has moved several times across the neighbourhood where is located. It is a moveable garden with the educational mission to connect people with nature. It offers a growing space and many other facilities for community activities, including workshops, room hire and a café.	137	26	(a) Education (b) Community cohesion and development (c) Food production	(E) Environmental lessons School visits Gardening and cooking training Talks Bee days (C) Community meals and meetings Family Saturday	Used in own restaurant
CG7 is in South London, within a local park which includes a playground and a community shed. It grows food for educational purposes and hosts workshops and training events,	76	69	(a) Environmental remediation (b) Education (c) Food production	(E) Environmental lessons Gardening demon-stration/training School visits Sessions for elderly adults in care Summer holiday club (C) Festivals/parties Drop-in gardening sessions	Distributed to volunteersSold Farmgate sales
CF1 aims to grow food that is good for people and the planet. It is deeply connected with the local communities. In a few years, it has become a fully fledged farm selling the food produced while helping local people learn about food, promoting health and well-being, and increasing local food supply.	9200	14,673	(a) Food production (b) Community cohesion and development (c) Education	(E) School visits Cooking and food lessons Gardening training (C) Cultural events, festivals/parties Garden/farm tours Community meetings Games nights Annual members meeting Tree planting events	Produce boxes Restaurants

4. Results

The results of the data collection are presented below, with key findings highlighted and further discussed in Section 5.

4.1. Crop Yields

Crop productivity was measured as an aggregate yield of all crops grown over the cultivated surface area (kg/m^2—see Figure 1). This aggregate measure does not allow comparability with conventional agriculture productivity, which is usually given for individual crops. No clear pattern emerges from the crop productivity data. In the sample, four gardens sell their harvest to clients or use it to prepare meals in their own restaurant, and four share it amongst volunteers and sell part of the harvest (Figure 2). It could be assumed that economic motivations lead to higher productivity. The most productive gardens are in fact selling their produce, but there is a significant gap between the top two productive gardens (CG2—3.81 kg/m^2; CF1—1.59 kg/m^2) which is probably related to a more intensive use of cultivated space of the former. CG1, CG4 and CG6 operate with models that are similar to CG2. However, CG1 and CG4 distribute part of their produce amongst volunteers, thus not selling the entire harvest. In addition, at CG4, gardeners supervise adults with learning disabilities in their gardening activities. CG6 grows on a very small surface area, in only one greenhouse, with an internal space that is not used intensively.

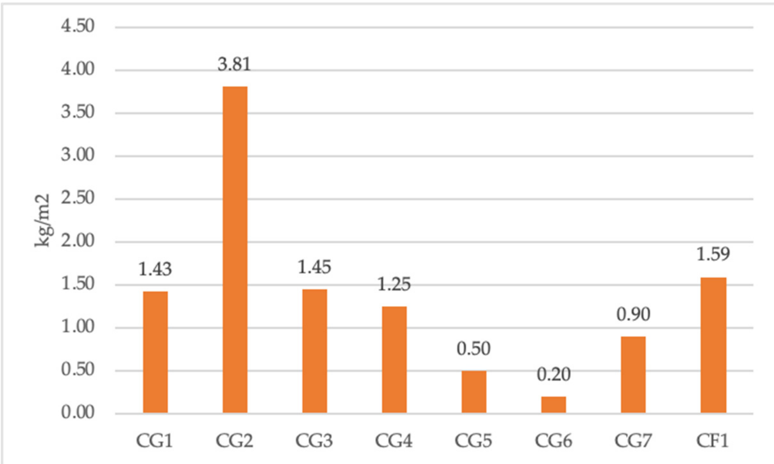


Figure 1. Crop productivity of 7 community gardens and 1 city farm measured in kg/m^2 of cultivated surface area.

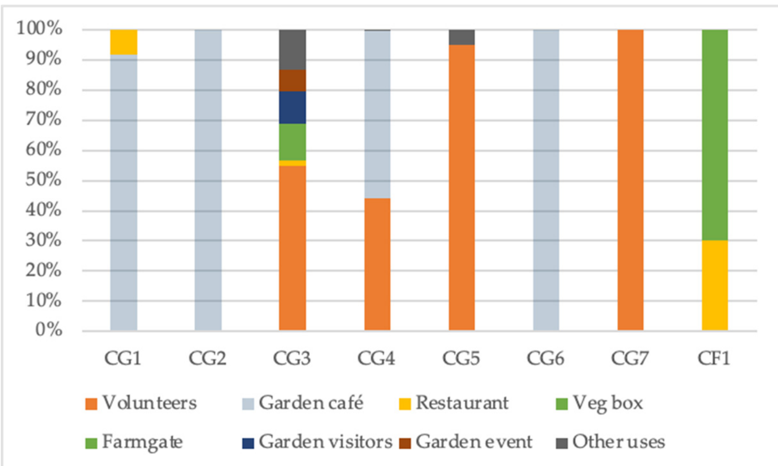


Figure 2. Destination of food for each garden.

The productivity of CG3, CG5 and CG7 varies from 0.2 to 1.45 kg/m^2. Their focus on providing social support to local groups may be detrimental to crop productivity, but it is difficult to explain the differences between the most and least productive. We looked at the share of cultivated area over the entire surface available as an indicator of efficiency (in land use and by extension, maximization of yield), but this was not linked to productivity either. CG5 cultivates 62% of its land and produced 0.5 kg/m^2, and CG3 cultivates 31% of its land area and produced 1.45 kg/m^2.

As an average, all gardens and farms produced 1.59 kg/m^2, which is within the range of crop yields reported in a wide array of studies (for example, [50,51]). It is, however, below the 1.8 kg/m^2 average reported by Dobson et al. [28] on a large sample of allotments. Of course, community gardens and allotments are different UA types, for which meaningful comparisons are elusive.

We collected 2020 data from five gardens only, as three either closed due to COVID-19 or declined to collect data for a second year (see Figure 3). The pandemic greatly limited access to the gardens by the volunteers and staff and hence activities and operation. In all gardens except CG4 (possibly because volunteers—adults with learning disabilities—were not allowed to travel to the garden and cultivate their own beds), production increased substantially, although the destination of food changed. For example, CF1 had to reorganize their delivery system to cope with an increase in demand for vegetable boxes from individual households. CG7's productivity leaped from 0.9 kg/m^2 in 2019 to an exceptional 4.6 kg/m^2 in 2020. Due to their program of social activities including many workshops with school children, in 2019 some of the crop harvested may not have been recorded as children were allowed to pick their own. During the lockdown, this activity stopped, and the community garden was tended only by the lead grower and occasionally one volunteer. The food grown was entirely redistributed to those in need. CG4 and CG1 restaurants were closed, and crops harvested redirected to local groups and soup kitchens. This shows that productivity can increase substantially as a consequence of a change in context (e.g., a crisis) and program (i.e., the interruption of social activities detracting time from and focus on food production).

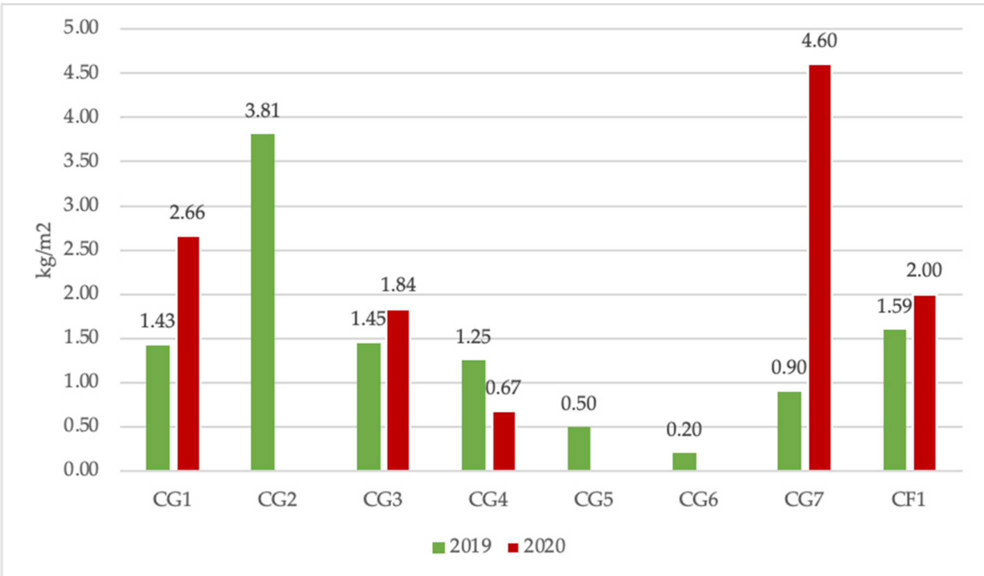


Figure 3. 2019 and 2020 crop productivity of 7 community gardens and 1 city farm measured in kg/m^2 of cultivated surface area (in 2020 CG7 increased the cultivated surface area from 76 to 100 m^2).

Total yield in the 2019 growing season from the spaces in the study was 16,979 kg. Using the UK government's "five-a-day" recommendation [52], it is estimated that the spaces in this study would have provided 213,700 portions of 80 g in the 2019 growing season (see Table 3). Based on this figure, these spaces have the potential to provide the daily fruit and vegetable requirement of 42,447 people for just one day. Each square meter under cultivation provided, on average, the equivalent of 19.88 portions of fruit and vegetables. Sustain [30], using data from 2013 and 2014, suggests a quantity of six portions produced per m^2. Samples analyzed included 160 and 89 food gardens, respectively, but in both years productivity was averaging approximatively 0.5 kg/m^2, much below the average productivity of our sample (1.59 kg/m^2). This explains the difference in portions between this and Sustain's study. Alternatively, the sample size used by Sustain (189 spaces) is larger, and as such may provide a better reflection of the "portion productivity" of such farms and gardens. It is also much more varied, including allotments, community gardens and other smaller growing spaces.

Table 3. Total number of portions produced per garden in 2019.

Garden/Farm	Total kg Produced 2019	Total Growing Area m^2	Total kg/m^2	Total Number of 80 g Portions	Total Number of 80 g Portions per m^2
CG1	205	144	1.42	2562	17.75
CG2	1132	297	3.81	14,150	47.63
CG3	145	100	1.45	1812	18.13
CG4	566	452	1.25	7075	15.63
CG5	161	324	0.5	2012	6.25
CG6	28	137	0.2	350	2.50
CG7	69	76	0.91	862	11.38
CF1	14,673	9200	1.59	183,412	19.88
Total	16,979	10,730		212,237	
Mean			1.59		19.88
SD			1.09		13.66

Table 3 presents mean and standard deviation values for crop productivity and portions produced: 75% of values fall within 1 SD of the mean, but this is based on a very small, skewed sample.

4.2. Water Use

Two gardens showed substantially higher water consumption (431 and 489 L/m^2—see Figure 4), whereas the others ranged from 115 to 211 L/m^2. For water, too, the measurement is given as an aggregate, not distinguishing between each crop's water requirement. Predominantly, this is municipal water, with only CG2, CG4, CG5 and CG6 self-reporting the use of rainwater harvested for irrigation. In cities, rainwater harvesting has the potential to greatly increase the environmental efficiency of horticulture. In our sample, only CG2 is using a large quantity of rainwater. CF1 and CG4's location, however, is peri-urban, with limited rooftop surface area available for water collection on their land. Also, CG2 is the only garden that has a building associated with it that has a large roof surface area from which water can be collected.

The behavior of growers and their knowledge of horticulture and sustainability could be a factor influencing the levels of water use. Observation and informal conversations with the lead growers suggested low awareness about issues related to water use and optimal irrigation patterns. Observation and informal reports of volunteers excessively irrigating growing beds were common. Many growers run sessions with young students and other local groups. Irrigation is part of these sessions and excessive, uncontrolled water use can happen. Hence, the environmental efficiency of our sample of gardens can be negatively impacted by the community and educational activities that are at the core of these projects.

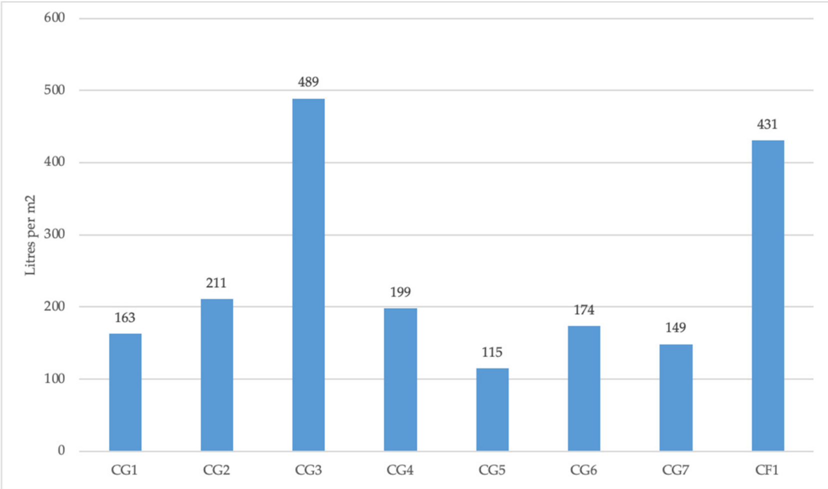


Figure 4. Water use in 2019 per site.

4.3. Fertilizer and Insecticide

All gardens—except for CG6, which did not gather data on fertilizers or insecticide—reported organic methods of cultivation (see Figure 5). No garden mentioned use of synthetic insecticide, but rather they relied on natural methods of pest control, such as ash on the soil around crops for slug prevention. CF1, the only farm/garden operating at a commercial scale, referred to using organic pest control methods.

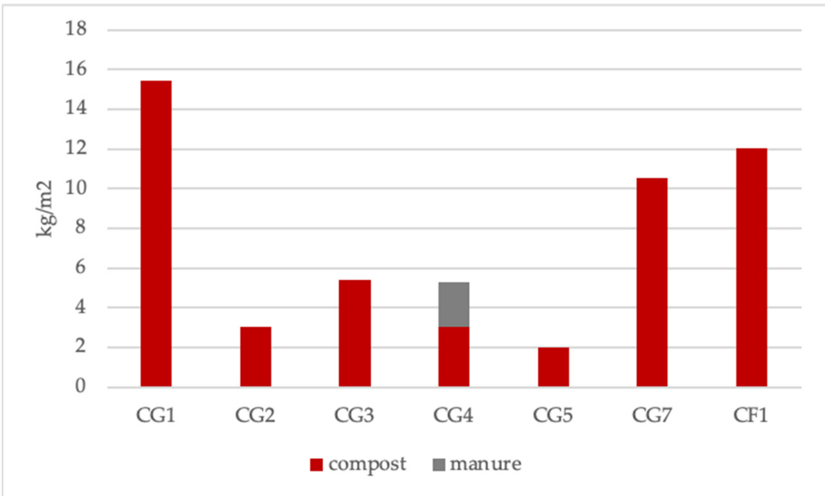


Figure 5. Soil amendments in 2019 per site.

Many gardens produced compost locally, although all gardens bought certified organic compost by local suppliers. The application of compost as soil amendment varies greatly depending on the soil composition, horticultural techniques, and more. Raised beds often require regular additions of organic matter and topsoil to maintain nutrient levels. One garden did not report (although applied) soil amendment. Four gardens applied between 2 and 5 kg/m^2 of compost (with CG4 the only garden applying a mixture of compost and manure). The first year of production for CG7 was 2019, and their raised beds were newly built and filled almost entirely with compost and topsoil coming from external sources, hence their higher level of compost use compared to other gardens. It is difficult to explain the higher quantities of compost for CF1 and CG1, although the former possibly follows intensive cultivation logic and thus with high levels of soil enrichment.

A summary chart is given below (Figure 6), with crop productivity and inputs (water and soil amendments) for each garden. Gardens are split into two groups: those with food production as their primary objective (CG2, CG3 and CF1) and those whose primary objective is social. Patterns do not clearly emerge, although water consumption seems to be lower for the latter group and much higher for those prioritizing food production. Patterns of use for soil amendments, as mentioned above, cannot be identified.

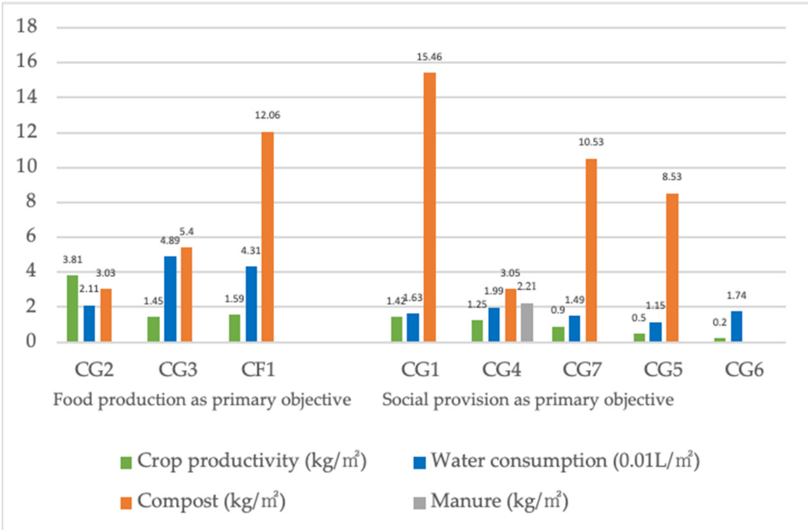


Figure 6. Summary of crop productivity, water consumption and compost/manure use. **NB:** Water consumption metric is divided by 100 to reduce bar lengths.

4.4. Energy and Trips to the Garden

All gardens used only manual tools except CF1. Most food gardens were part of an organization with a broad program of initiatives supporting the well-being of local groups. Each community garden has a community hub containing working equipment (e.g., computers and photocopy machine), a kitchen (e.g., electric hobs and other cooking equipment) and other appliances. Hence, these community gardens are consuming energy for activities not directly related to growing food. Exceptions are CG2 and CF1, the former owning a drying machine to dehydrate herbs harvested from their beds and sold to their restaurant and the latter using tractors and other fuel-operated machines. Due to the inexistent or very low requirements for energy, we decided to consider gardens energy-free. CF1, however, in 2019 used 200 L of kerosene for flame weeding, 205 L of burning oil, 610 L of diesel to operate their tractors, and 5 L of engine oil.

Together with electricity, another factor that we measured was trips to the garden (see Figure 7). This is all the more relevant in a city such as London, where volunteers and growers may cover long distances to reach the gardens, with connected fuel, energy consumption and overall environmental impact. Within the paper handbook distributed to gardens, respondents were asked to report the number of journeys made per week by growers and volunteers as well as the method of transport used (which in some cases was multiple (e.g., underground and bicycle) and the distance covered. Responses were provided for 80 attendees, the number for each garden being random and varying in size (CG7 did not return any questionnaires). It cannot, therefore, be indicative of the actual pattern of trips to each garden, although results suggest that the geographical location relates to the choice of means of transportation. In fact, unsurprisingly, the two gardens located in London's peripheral area and in Hertford (within the London metropolitan area) show the highest share of car trips. Bicycles are used intensively in only three gardens (CG3, CG7 and CG2). Underground, and to a lesser extent bus, are used in many gardens. Walking is scarcely undertaken, except for CG3, which is located within a big social housing estate where many of the volunteers reside, and CG5, which is in one of the largest parks in central London, well connected through bus and underground routes. Overall, results suggest that volunteers behave responsibly in traveling. Cars, the most carbon intensive means of transportation on the road [53], are used only when gardens are not accessible through public transport routes and to transport adults with learning difficulties to CG4.

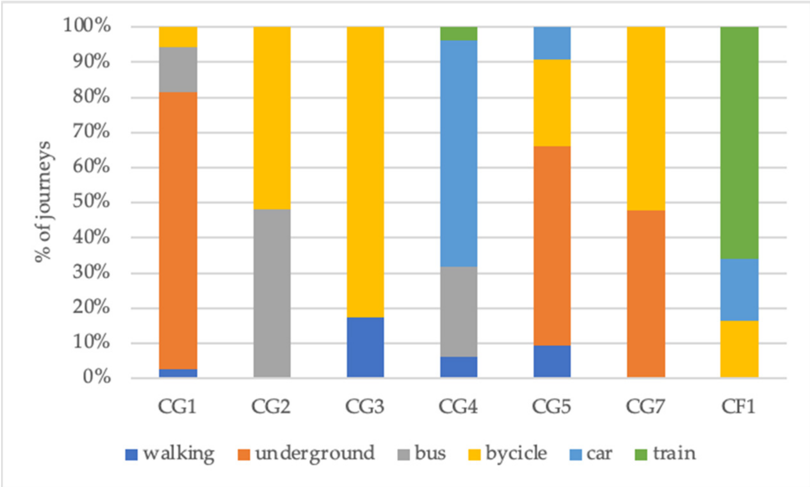


Figure 7. Trips to the site by mode of transport.

4.5. Social Impact

To demonstrate that the resources used in each garden do not generate only food but also social benefits, we conducted a survey to identify the perceived outcomes connected to gardening: 48 questionnaires were returned by growers and volunteers from 7 gardens. The profile of those who returned their questionnaire can help frame their responses. Figure 8 shows age, status and education of the people surveyed. A conspicuous share of this sample is below 25 (15%) and between 26 and 45 years old (31%), 31% are employed, 10% are studying, only 11% are unemployed, and 67% hold a university degree. Additionally, 28 of the responses received (58%) identified as female, 19 (39%) as male and just 1 (2%) not specified. In short, educated, young or middle-aged people with a job or studying are well represented within this sample.

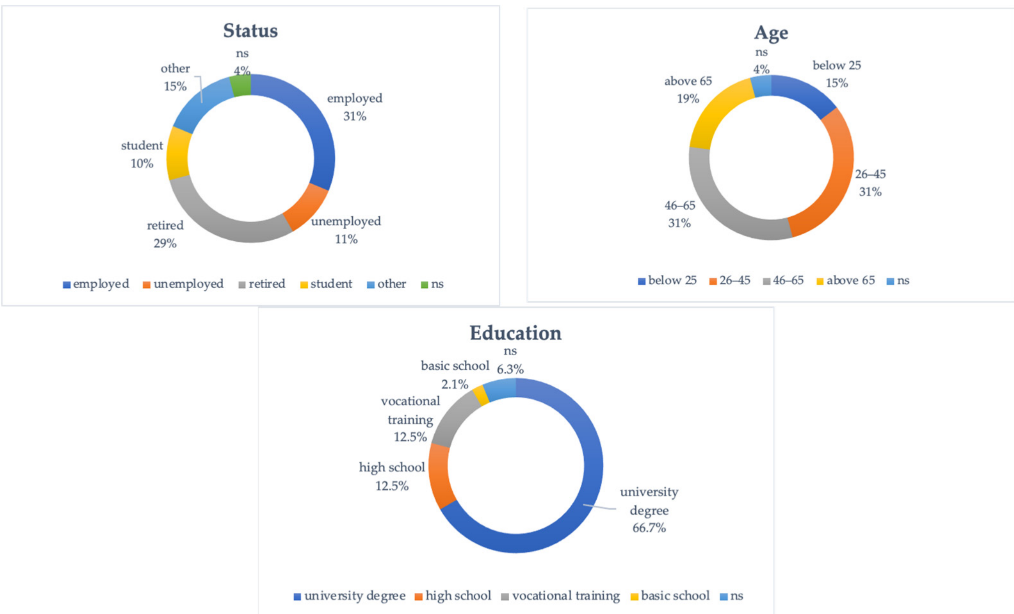


Figure 8. Age, status and education composition of the volunteers and gardeners sample surveyed (n = 48) N.S. = not specified.

Figure 9 shows that 60% or more of the respondents believed that being outdoors, improving the environment and the community context, are very important benefits, followed by mental and physical benefits and learning about food (about 50%). Access to fresh food, thereby increasing the opportunity to improve the quality of diets, learning new skills (i.e., job creation) and economic savings were perceived as weaker drivers. The latter was believed to be very important by only 15% of the respondents. It is possible that responses may change with a different socioeconomic composition of the group surveyed.

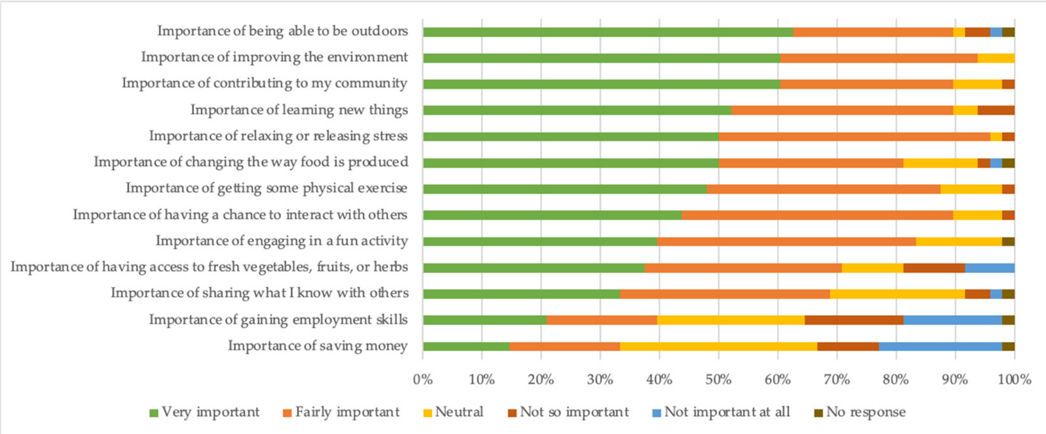
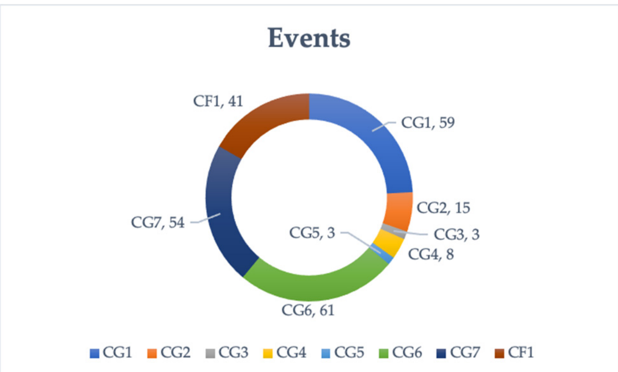


Figure 9. Benefits from gardening as perceived by volunteers.

Generally, community gardens and farms conflate growing and social engagement activities, and in doing so, they are hubs for socialization and education. Some have made their social engagement program a priority. Table 1 confirms this view, with CG1 and CG4 reporting community cohesion as their primary objective, and CG6 reporting education and community cohesion as primary and secondary objectives. To test this claim, we asked our eight gardens to self-report the number of events organized between March and October 2019 and the number of participants (see Figure 10). Four gardens had a remarkable engagement program, with events organized over 8 months ranging from 41 to 61. Cultivated land in CG6 (61 events) and CG1 (59 events) occupies only a small portion within the community garden, with open spaces, sheds or community hubs designed to host events and the restaurant representing an important point of attraction for the local communities. The other four gardens organized fewer events, albeit with considerable participation. For example, CG3 organized 3 events with a total of 314 participants. On the whole, the 8 gardens ran 244 events with 4660 participants, which can be seen as a remarkable result in terms of outreach and impact generated on local communities.



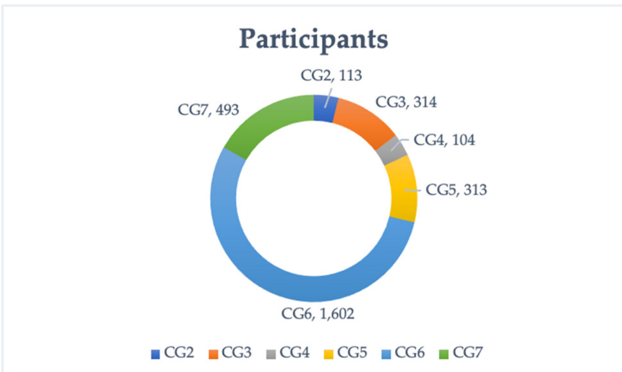


Figure 10. Events and participation in the case study sample.

5. Discussion

The diverse levels of productivity and resource use presented in this paper reflect the complex nature of our case studies and of UA generally. Such diversity is difficult to analyze and interpret, although it can be explained by considering the specific characteristics of each project. The difficulty in understanding the reasons behind each project's performance and recognizing patterns of productivity corresponding to—for example—UA types raises questions about appropriate methodology for estimating the overall UA productivity and resource efficiency. If each project is an anomalous case and its performance significantly influenced by factors external to horticultural skills and techniques, then how can general citywide projections of UA productivity be reliable? Also, if UA productivity is multifaceted (e.g., food, well-being and education) and resources used are many (e.g., water, fuel for trips and soil enhancers), how do we establish overall whether each project is successful? How can we link performance on multiple fronts to diverse hindering factors? These questions are complex, and further research is needed. In this study, we can offer a glimpse of the causes that may determine variations in food or social benefit productivity.

As noted, it can be assumed that the objective of selling crops grown is a driver for higher productivity, and the organization of labor and means of production is designed accordingly, but such a relationship (profit–productivity) does not clearly manifest across all our case studies. CG2, CG3 and CF1 set food production as their primary objective. These are the most productive projects in our sample. However, CG3 sells produce mainly to residents of the social housing estate in which they are located, at a self-determined price. Only CF1 and CG2 are organized to sell their usable harvest commercially, the former through a vegetable box scheme and the latter to the café run by the leisure center hosting the community garden. CF1 is a community farm, directed by a group of urban growers with experience in horticulture. However, CG2 uses its growing space more efficiently, with the highest yields per square meter, more than doubling CF1′s level of productivity (1.59 kg/m^2 and 3.81 kg/m^2, respectively). Reasons for this may be diverse, including crop choice and the period of data collection recorded. Lettuce and similar crops (the crops cultivated by CG2) grow fast and enable multiple harvests within the same growing season, and are space efficient (i.e., planted at a close distance); other crops such as those typically included in the vegetable box sold by CF1 (e.g., tomatoes, carrots and string beans) generate one harvest per year only. In our study, harvest records do not include winter months. A year-round record would probably reduce the gap between the two case studies since CG2 does not grow much food in the winter months, whereas CF1 does. Another reason may be related to the cultivated land area, with CF1 using about 1 ha (about one third of their farmland) and CG2 a surface of about 300 m^2 only. Reduced space availability may be a driver for higher crop density. Also, CF1′s total harvest is presumably determined by their clients' demand. In fact, production increased in 2020 because of a higher number of households registering for the vegetable box scheme. Calculated on the 2020 harvest, their productivity is 2 kg/m^2.

As with CG2, CG1, CG4 and CG6 use their produce in their cafés, although, compared to CG2, their productivity is lower. In these three projects, the food produced either is not entirely taken by their cafes (CG4 distributes a share of food grown to volunteers) or other activities and organizational issues affect the recorded productivity. CG6 (only 0.2 kg/m^2) grows in a greenhouse only, with its surface area not entirely used for cultivation, thus having low space efficiency. CG1 hosts many workshops with produce being picked by people involved in such activities (e.g., young students during workshops) and not recorded. These three case studies share a strong focus on providing social support to local groups, which may be one of the reasons for relatively low crop productivity, especially for CG6. In fact, all three show a strong record of social engagement activities compared to CG2, with CG6 the garden with lowest food productivity being the one most committed to social engagement activities when the number of participants is considered (n = 1602). CG6 and CG1 organized the most events (n = 61 and n = 59, respectively). These figures may offer clues for explaining lower levels of productivity although they may not be the most appropriate to indicate the real impact of social engagement, which relates to the profile of participants, their needs, and the purpose of the activities in which they engage. Lunch meetings at CG1, for example, are usually attended by groups needing to socialize, who may otherwise be NHS funded or paying to attend a similar gathering elsewhere to fend off depression, loneliness or anxiety. Instead, CG6's events focus primarily on education and training.

The remaining case studies (CG5 and CG7) do not sell their food and are driven by health-related, environmental and food security purposes. It is worth considering that once converted into fruit and vegetable portions per day, the total harvest of all the case studies between March and October translates into 212,237 portions. This represents a modest contribution to alleviate food insecurity locally, yet seen from this angle, community gardens could constitute an alternative option to food banks, offering fresh produce in a restoring environment. Such an option would require higher levels of crop productivity and a different organizational structure.

The nonprofessional nature of these gardens may also explain differences in harvest. Many studies report the steady growth of public interest in UA over the last two decades, particularly in the popular press and with the continued growth of the Sustainable Food Places movement in the UK [54]. This also resulted in a diversification of objectives, models and activities with which each project operates. To make sense of such diversity and establish a UA typology, Krikser et al. [55] propose three main types of UA (self-supply, sociocultural and commercial), with other types resulting from the several possible combinations between the three main ones (e.g., a mixture of sociocultural and commercial and a mixture of self-supply and commercial). In fact, the reality is more faceted and fragmented, particularly for those projects that combine horticulture and community engagement. Their operational models are influenced by their agenda, social capital, funds and resource availability, local policies and more. This variety is both an asset and a limitation; it makes a large share of the UA sector function as a living lab in which social innovation is experimented with, together with food production approaches and distribution systems. However, such diversity is also lacking policy recognition and professional accreditation. Community gardens and city farms are rarely recognized in policy as service providers. As such, they do not rely on established models endorsed by local authorities, and there is no accredited figure of urban farmer. As a result, community gardens are ambiguous entities, halfway between community associations and third-sector organizations, providing a public service but not being recognized as such and often overlooked for their capability to deliver on their stated objectives.

This is changing: a case in point is the recently formed AFAUAP (Association Française d'Agriculture Urbain Professionelle—http://www.afaup.org; accessed on 30 September 2022). Another one is the Mayor's Office for Urban Agriculture in New York City (https://www1.nyc.gov/site/agriculture/index.page; accessed on 5 October 2022), advising the mayor and the council about UA-related issues. GARDENISER is a European training program for garden organizers (i.e., managers) in community gardens and farms in which attendants learn about the necessary skills for this new professional figure (https://gardeniser.eu/en; accessed on 12 October 2022). However, many UA practitioners do not have relevant prior experience. Hence, lack of professional training and public recognition may also be reasons behind erratic levels of productivity and resource efficiency within the case study sample. Gardens with social objectives as their primary goal may not perceive training as a necessary component of their programs, and yet such training is fundamental to higher resource efficiency and sustainability, perceived as imperative by these projects. Providing effective induction to volunteers, although difficult because of limited available resources, should perhaps become embedded in a garden's community and educational goals. Likewise, the multiple objectives that each community garden sets in its agenda can be difficult to attain because they require specific managerial skill sets.

Water consumption is also erratic. Except for CG3, whose water use can be explained by incorrect water meter readings or unwise and uncontrolled use of water, CF1 and CG2 are the most water-intensive. It can be assumed that this is related to the commercial production objective and, for CF1, to the large use of polytunnels that cannot be irrigated through rain. The other five gardens recorded a range of water use from 115 to 199 L/m^2. CG4 (199 L/m^2) may not always use the water wisely because of the inexperience of their volunteers, but the variation of the remaining projects cannot be easily explained.

On a positive note, all case studies claimed that no synthetic fertilizer or insecticide was used. For this input too, variations are difficult to explain. The first year in which CG7 operated was 2019: the construction of raised beds may have required large amounts of compost and topsoil. CF1′s commercial farming activities may have led to over-enrichment of the soil. In comparison CG2′s compost use is modest.

Trips are rarely considered in environmental impact estimates for UA although they could considerably increase carbon footprints. CG4 and CF1 show the highest share of car use. This relates to their peri-urban location, and for CG4 the particular status of volunteers who may require private transport. The two case studies with a higher share of underground use are near underground stations. The obvious but logical conclusion is that careful planning and correct land allocation is necessary to achieve higher environmental efficiency of UA practices.

A final reflection on methodology concerns citizen science methods, which are particularly relevant when the research is developed in a context in which data are difficult to gather in a structured way. The size and number of agricultural projects within a city (small dimensions–high number) and the lack of a census make it difficult to conduct rigorous data collection. Reliance on growers to collect data becomes necessary with drawbacks and limits. It is useful to consider such limits from the onset on future citizen science-based UA research projects. They include that reliable collection of input use and harvest data can be dependent on staff who are often volunteers or already on overstretched contracts. Comments were made that suggested there may have been occasions when data recording was forgotten or incomplete. Some gardens in the current study had a high volume of volunteers passing through to attend various group activities. Not all of these could be relied upon to record water or harvest data. Some commented that children would pick fruit from stems and these data were not recorded. In addition, where the project team supplied some gardens with a meter to record water use, some volunteers were not able to operate this and recorded incorrect data. Sometimes volunteers would water parts of the garden without recording water use or use of water for social activities (e.g., to fill a paddling pool) that may have been included as garden use. Lastly, staff turnover at gardens was an issue: where the person agreeing to join the study subsequently left, the team were dependent on their successor agreeing to collect the necessary data. Staff holidays were also often left uncovered in terms of data collection. All these factors make the collection of complete and reliable data difficult and offer lessons to others attempting similar studies in UA settings.

6. Conclusions

The contribution of this paper to the UA research debate is to document the several aspects of productivity that community gardens and farms can deliver, their resource efficiency, and the barriers in recording productivity data, especially when using citizen science methods, with consequences for the reliability of any evaluation. The sample used for this study is very small and as such findings are inconclusive. As referred to in Section 4, the sample for this study is not sufficiently large to draw robust statistical conclusions, and further data collection and sharing and integration of data sets will benefit the sector. That said, the data gathered and the analysis developed provide a mixed picture, suggesting that community gardens and farms are very productive when all types of benefits are considered. This confirms the hypothesis formulated at the onset of the study, but not always when the focus is solely on crop productivity. Reasons for the latter include a focus on social benefits, detracting from time and effort dedicated to food growing, and a lack of relevant skills that could be addressed with relevant training opportunities. Some case studies can be inefficient in their resource use, but this varies considerably, a feature confirmed in a study of 72 UA spaces across Europe [56]. A list of limits influencing the reliability of data can be useful for future projects and provide further evidence of the issue that UA is still a practice needing advancement (organizational, technical and managerial) and policy recognition for invaluable social and resilience support.

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