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Urban Cultivation and Its Contributions to Sustainability: Nibbles of Food but Oodles of Social Capital

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Abstract: The contemporary interest in urban cultivation in the global North as a component of sustainable food production warrants assessment of both its quantitative and qualitative roles. This exploratory study weighs the nutritional, ecological, and social sustainability contributions of urban agriculture by examining three cases—a community garden in the core of New York, a community farm on the edge of London, and an agricultural park on the periphery of San Francisco. Our field analysis of these sites, confirmed by generic estimates, shows very low food outputs relative to the populations of their catchment areas; the great share of urban food will continue to come from multiple foodsheds beyond urban peripheries, often far beyond. *Cultivation* is a more appropriate designation than *agriculture* for urban food growing because its sustainability benefits are more social than agronomic or ecological. A major potential benefit lies in enhancing the ecological knowledge of urbanites, including an appreciation of the role that organic food may play in promoting both sustainability and health. This study illustrates how benefits differ according to local conditions, including population density and demographics, operational scale, soil quality, and access to labor and consumers. Recognizing the real benefits, including the promotion of sustainable diets, could enable urban food growing to be developed as a component of regional foodsheds to improve the sustainability and resilience of food supply, and to further the process of public co-production of new forms of urban conviviality and wellbeing.

Keywords: catchment area; core/edge/periphery urban areas; environmental education; environmental justice; food/ecological/social sustainability; food hub; foodshed; food system

1. Introduction

There is a widespread resurgence in urban food growing. One sign of its popularity is the endorsement of political leaders. For example, Michelle Obama planted a garden in 2009 with the help of schoolchildren—the first White House plot since Eleanor Roosevelt's World War II Victory Garden. The rise in interest is also indicated by a change in the status of urban food growing: increasingly it is referred to as urban agriculture by academics [1] and others. As pointed out in the *New York Times*, it has become a bandwagon phenomenon: "In recent years, chefs, writers, academics, politicians, funders, activists and entrepreneurs have jumped on the hay wagon for urban agriculture" [2] (p. D1).

The designation as *agriculture*, rather than *gardening*, projects a new frame and a larger scale that raise research questions about urban food growing's output and sustainability. We address these questions based on three case studies: a community garden, a community farm, and an agricultural park. The study is exploratory and descriptive, and addresses only cities of the global North; the picture is quite different in the global South [3–5], which is home to 80% of urban croplands [6]. Furthermore,

the study does not consider the practice that some have advocated of growing food in underground chambers using artificial light [7], because it is a thermodynamic nonsense. Photosynthesis captures a tiny percentage of incident radiant energy; therefore, the energy used to illuminate plants grown underground is necessarily one to two orders of magnitude greater than the energy content of the plants. Allow for the inefficiencies in converting primary energy to light and the imbalance between the source and the product gets worse by typically a further order of magnitude. Growing food without daylight may have a role for mushrooms, which, traditionally and iconically, can be managed by keeping them in the dark and intermittently covering them in fertilizer, but not more generally and not for any main dietary constituent. Underground growing of photosynthesizing plants has no place in a serious discussion of sustainable food production, whether or not it is organic. As one researcher has commented: "why (does) it make sense to put a lot of intellectual activity and resources into something that negates the direct use of our one and only absolutely renewable resource—the sun—and totally replace it with artificial light?" [8] (p. 5).

There are compelling background reasons for the mounting interest in urban food growing. The world has a rising and increasingly urban population [9]. There will be 2 billion more people to feed by 2050, when around 70% of our population of 9 billion will be urban, compared to 50% today. This is projected to increase food demand from a growing and richer population by 2050. The extent of the increased demand is uncertain, but estimates range up to 70% more crop calories than produced in 2006 ([10] cited in [11]). Urbanization leads to loss of farmland [12]. Between 1970 and 2000 the land equivalent of Denmark was converted from farmland to urban settlement globally. The projection for 2000 to 2030 is the equivalent of Mongolia, 36 times the area of Denmark. Thus, at the same time that more food will be needed, less farmland will be available.

To exacerbate the problem, climate change is projected to result in farm yield loss [13,14]. Although there is debate around how large the loss may be, there is agreement that food security is one of the principal concerns humanity must address in the context of global climate change. For example, the United States, the world's third largest food producer and largest food exporter [15], projects its yield of major crops to decline by mid-century due to soil degradation, rising temperature, and precipitation extremes [14].

As a consequence of these global trajectories, agriculture faces the major challenge of increasing production levels substantially and doing so sustainably. Designating the upsurge in urban food growing as *agriculture* implies that increasing output in cities can contribute significantly to meeting these challenges. To avoid this implicit assumption, we propose the term *cultivation*.

There is also a foreground context for the rising interest in urban food growing: the environmental movement and related campaigns for organic, locally sourced, healthy, and sustainable diets. Community food growing evokes a cultural orientation different from that of traditional urban allotments and domestic gardens. Domestic gardening is a private and individual activity. Allotments are on common land but are allocated to individuals; they were institutionalized as compensation for the land clearances involved in the emergence of industrial agriculture in the late 18th and early 19th centuries in northwestern Europe [16]. In the United Kingdom, statutory allotment sites receive protection under the Allotment Act of 1925, although there are fewer safeguards for private and temporary sites [17]. Current urban food growing arose in the late 20th century, largely as neighborhood mobilizations to reclaim vacant and derelict lots in post-industrial cities of North America and Europe.

An analysis in the United Kingdom found that the "sense of community participation and empowerment . . . links examples of community gardening" [18] (p. 285). Community food growing can enhance the creation of locally specific social capital in urban areas. More recent studies of U.K. community food-growing schemes and networks have reinforced this point, and identified a wide range of associated social processes: for example, grassroots innovation and informal local research and development; demonstration projects; opening up debate with existing actors in food systems; and expanding the range of alternatives to established practices [19,20]. Involvement in community

food-growing is associated with opportunities for people "to engage more actively around issues of food, health, waste, community and environment" [19] (p. 31). Such findings underline a key point in our analysis: urban food-growing is primarily about cultivation of social skills, capabilities, and virtues that can contribute to sustainable urban living, rather than about major additions to food production. We describe this set of features as social sustainability services.

2. Methodology

In the context of this paper, *urban* refers to metropolitan areas—cities (core) with their nearby suburbs (edge) and distant exurbs (periphery). In this exploratory qualitative research into social contributions, we visited three field sites, representing a range of scales, social activities, and locations. Two of the sites exemplify common modalities of the new urban food growing: one very small inner city community garden ("The Garden", specifically Manhattan's West Side Community Garden) and one larger suburban farm ("The Farm", Sutton Community Farm on the outskirts of South London). The Garden was selected because an author was a member and had begun to study it in 2011. The Farm was selected because it had been the subject of recent research [21], including a Life Cycle Assessment (LCA); one author had worked on a similarly sized commercial market garden (known locally as a "smallholding") at that location some 50 years previously. The third case ("The Park", Sunol Agricultural Park near San Francisco) represents an emergent modality: a larger agricultural park in a peri-urban location; it was selected because it represented another variation in urban food growing in yet another metropolis. Two of the authors visited the Garden in 2012 and the Park in 2014. All three authors visited the Farm in 2013. Data collected through these field visits comprised observations, documentary and verbal information provided by informants, supplemented by archival data made available by informants and by online research. The principal informants were the President of the Garden, the Manager of the Farm, and the President of Sustainable Agriculture Education, parent of the Park. For the discussion in this paper, the primary qualitative data are supplemented by average estimates of potential production; see Section 4.

Urban cultivation's contributions to social sustainability require this kind of empirical scrutiny. One methodological tool available for this task is Life Cycle Assessment. LCA was originally developed to assess the environmental costs associated with the full supply chains delivering products and services, and has since been expanded to include the economic costs. For example, an LCA study of the suburban Farm included in this study [21] found that it could produce reductions in greenhouse gas (GHG) emissions as compared to supermarket food chains provided that the Farm concentrated on crops usually grown in heated greenhouses or flown in from warmer climates. Such niche crops are also the major sources of its income. However, while GHG emissions are one key indicator of environmental performance, they are only one of a suite of sustainability metrics that includes aspects not addressed by conventional LCA, including labor issues and social dynamics [22]. Another challenge facing sustainability research is identifying not just the dietary and GHG-reducing aspects of a mode of food production but also the social and ethical benefits. Production, distribution and consumption are to be seen not just as a one-way flow of resources from supplier to consumer, leaving impacts in their wake, but as a channel by which benefits can flow from the consumer (of food or land use) to other agents [23]. Adapting LCA to this kind of case represents a methodological challenge. The guidelines on social LCA [24] are still very much in the developmental phase [25] and are in any case directed at detecting social "bads" in international supply chains rather than the local social benefits that are among the drivers for urban cultivation. Further development of social LCA depends on the execution of case-by-case studies, using methods and approaches appropriate to the specific scope and scale.

The Garden, Farm, and Park cases illustrate that: "To be a viable alternative in cities and compete with other land uses, the justification for urban agriculture must include the ecological and cultural function these systems offer, in addition to the direct benefits of food produced" [26]. At the three sites examined here, the viability of the activity depends not just on inputs like imported compost but

also on consumers—of vegetable boxes delivered to the doorstep in the case of the Farm, of cultural programs at the Garden, and of farming educations at the Park. The social benefits, as counter-posed to the environmental and economic ones, of urban cultivation accrue mainly at a local level rather than being distributed along a supply chain; they are outside the familiar framework of LCA and can flow laterally to the residents of an activity's catchment area; e.g., in the form of educations. Therefore, the kind of field investigation carried out here will remain essential.

3. Results: The Three Cases

3.1. The Garden

The Garden emerged in the context of the massive 1970's Urban Renewal Program in the slums of post-industrial U.S. cities [27]. The City of New York evicted tenants and razed tenement buildings in much of Manhattan's Upper West Side, leaving brownfield land available for redevelopment and gentrification [28]. A high-rise condominium building was built on a site which included the future Garden and another was awaiting capital investment. In the meantime the site became a dump for abandoned automobiles and other urban detritus.

The dump site was transformed into a verdant garden in a spontaneous response by local residents to clean up a dangerous area in their midst that was also an eyesore. With construction imminent, the neighborhood was assisted in saving this open space by the local Community Board and the national Trust for Public Land. City government officials and real estate developers acquiesced, in part because community gardens enhance property values and thereby add to tax revenues—while also of course adding to value for property owners. In an analysis of community gardens established in New York City between 1977 and 2000, Voicu and Been found that "gardens were located on sites that acted as local disamenities within their communities . . . after opening gardens have a positive impact on surrounding property values, which grows steadily over time" [29] (p. 268). The City administered a "sunshine test" and approved the site as a garden, with two stipulations for becoming untaxed land: that it would be open to the public and would pay for its upkeep.

The Garden is located near the geographic center of New York City's Manhattan Borough. The land, 0.15 hectare, is governed by a board elected annually from its 300+ paid members. Membership is open to the public at a nominal annual fee. Only about 1/3 of the Garden's space is used to grow food. Gardeners work on raised beds of 2.8 m^2. Of the remaining garden space, 1/3 is devoted to horticulture and 1/3 is dominated by an amphitheater used for cultural productions.

Gardeners reported that they do not grow much food—enough vegetables to add to several meals a week over the harvest period. "I just grow some nibbles," one gardener said. Several informants related that growing food was not the main reason they gardened; rather, it was because they liked to garden. "I enjoy my green thumbs," one reported. Also, many gardeners said that they liked the cooperative aspects of the Garden and enjoyed its features—a quiet, safe, and green retreat amid the Manhattan skyscrapers.

The Garden depends on a steady replenishment of labor to take care of its three large compost bins and to keep public areas tidy, as well as to raise money. It requires about $75,000 annually to operate. The bulk of the money goes to maintain pavements, towards insurance, and to purchase gardening supplies and tools. The Garden has no paid labor. Finding volunteer labor has been a general problem for community gardens. The work required is skilled and this limits the available pool. The largest source of gardeners is women, mainly retirees. New York City's gardens have declined in number since the mid-1980s largely due to a lack of participation—many rely on only a few tireless souls [30].

The Garden provides a range of cultural programs that attract thousands of visitors who are potential sources of finance and labor. The programs include music, theatre, poetry, film, and arts and crafts presentations. The Garden's signature cultural event is its annual spring Tulip Festival, when some 12,000 blooming flowers attract visitors from around the world [31].

3.2. The Farm

The Farm comprises 2.9 ha, 1.4 of which are tilled. It lies in the Borough of Sutton at the southern edge of greater London, in what is termed the Green Belt in the U.K. planning system. It occupies greenfield land but the soil is very poor. Until the 20th Century lavender (*Lavandula*) had been grown on the site as it can thrive in poor soil. The land use was changed as part of the mid-20th century drive to increase food production in the United Kingdom and took advantage of labor from a nearby camp for prisoners of war. Fifty years ago, the smallholding was operated by a family who lived there; it depended on high value glasshouse crops, primarily salad vegetables and cut flowers sold via large wholesale markets in London, with high inputs that included horse manure. There are now 500 m^2 of polytunnels at the Farm, providing for year-round production, but it requires large inputs of compost, an expensive appetite for a non-residential farm with no manure-producing animals.

The Farm is London's largest community farm. It was started in 2010 with the blessing of Surrey County Council, the local government authority, which owns the land and collects ground rent. The Farm is a cooperative and plans to offer shares within its local community. Other examples of similar social enterprises engaged in scaling up urban food growing include *Urbivore* in Stoke [32], *Farmscape* in Los Angeles [33] and *Lufa Farms* in Montreal [34].

The Farm is not solvent and there are no plans to make a profit. The goals are to make it pay for itself and to become a platform for food growing activities in the local community; examples include providing gardening experiences to school children and to disabled people. However, because of the Farm's location and the lack of local public transport, a visit must be a planned event.

While salad crops are still the most profitable output, accounting for around 1/3 of income and only 1/7 of acreage, the produce is consumed more locally than 50 years ago. About 3/4 is distributed to retail customers in vegetable boxes; this scheme currently has 142 customers, with a capacity for 350. The remaining 1/4 is sold wholesale, largely to local restaurants and cafés. The demographics of vegetable box customers reflect the local residential area: they are largely middle class. Many are seasonal customers who grow their own vegetables and therefore buy much less in the summer. The Farm's unsold produce is collected by a local charity that makes soup from it. Its two major expenses are compost (purchased from a local municipal site), for which haulage is the principal outlay, and water for irrigation.

The Farm's manager is a university graduate who used to be a chef and became interested in food security issues. He has organized an apprentice scheme at the Farm. His view is that expertise in managing small scale farms is generally lacking in the United Kingdom. The Manager also organizes volunteer gardeners, some of whom are employees of local businesses which pay them as they work on the Farm as part of a Corporate Social Responsibility program.

Most of the Farm's tilled land is devoted to leaf crops but it has not applied for Organic Certification. The Manager said that its production is "based on organic principles" and is open to anyone who wants to come and see for themselves. The Farm uses a small tractor but most of its work is manual. The sole full-time employee is the Manager. A "sustainable farming" apprentice grower is paid for three days per week. One grower is paid for one day per week. The vegetable box scheme has one employee working 3.5 days per week to deal with customers, and two drivers are employed, each for one day a week. The total paid labor is equivalent to 2.7 full-time workers.

3.3. The Park

The Park is located in Sunol, an unincorporated former railway town in Alameda County in the San Francisco metropolitan area. Sunol's annual sunshine days are about twice the U.S. average. The Park is adjacent to a Water Temple, a well-known local feature commemorating the opening of a water supply system. The land is owned by the San Francisco Public Utilities Commission (a water supplier) and is managed by Sustainable Agriculture Education (SAGE). The Park was set up in 2006 with the mission to foster sustainable farming and public education programs while protecting natural resources. It rents the land and is currently home to six small-scale organic farming enterprises on

6.5 of its 7.3 hectares. The Park is an example of an incubator farm. One of its models is the Agriculture and Land-based Training Association in Salinas (a farming town 129 km south of the Park and not in the San Francisco metropolitan area), which pioneered a farmworker-to-farmer program. The Salinas program trains Latino farmworkers to take on farm management and operation. The Park aspires to do something similar but in an urban periphery setting. Its brochure states that: "AgParks are an innovative, scalable model that facilitates land access for beginning and immigrant farmers, local food provision for diverse communities, resource conservation, public education, and job training opportunities."

While nominally in a metropolitan area, the Park is remote: there are no significant sources of laborers nearer than Pleasanton, 8 km to the northeast. The land was a hay field until it was taken over by SAGE, which acts as a non-profit intermediary between the farmers and the water utility. It collects rents and other charges from farmers and arranges a supply of irrigation water. It also maintains Organic Certification and permits for chickens. SAGE promotes mutual learning among the farmers, and implicitly tries to screen out any who are not serious or competent.

The soil of the Park is thin clay and very arid—not unlike the soil at the Farm, but much drier—so plentiful irrigation is essential. Compost must be applied at least annually to condition the soil and to ensure water retention. Aphid infestation is a particular problem. Organic practices are *de rigueur* so there is no input of synthetic fertilizers or pesticides. There is no access to grid electrical power.

About 2000 schoolchildren visit the Park annually, mainly from Oakland, also in Alameda County and about 25 km away. The children are aged 10–12 and are largely from low-income families; 60% are on their school district's Free & Reduced Meals Plan. SAGE tries to charge $2 per head as a contribution towards payments to the water utility but do not always succeed. SAGE also helps schools find grants towards the cost of bussing children.

A young and aspiring farming couple have been at the Park since March 2014, initially on 0.4 ha but now on 0.8 ha—the Happy Acre Farm. One was previously a manager at a farmer's market; the other had worked on an organic farm. The couple used their first season to learn the ropes; *i.e.*, what could successfully be grown and what was to be avoided—for example, not growing crops when "bugs" would seriously attack them. The first task was to remove the Bermuda grass (*Cynodon dactylon*) that covered the site. They did this by an undercutting technique taught by a local specialist who is something of a farming guru. They were greatly helped by another farmer; he taught them husbandry practices, introduced them to customers, and gave them some seeds. The couple emphasized that contact with more experienced farmers is one of the benefits at the Park.

The couple plan to keep themselves by farming but not to employ anyone, at least in the short term; in any case they recognize that finding laborers is problematic and expensive. They plan to augment income from produce by selling processed goods such as jellies and preserves and by running classes on making such goods. The couple plan to grow arugula (or rocket: *Eruca sativa*) on a rotation of three crops per year, hoping that this intensity of production will enable them to live off the land. They also plan to introduce chickens for their eggs and meat. The chicken paddock will be moved around to fertilize the soil, subject to SAGE regulation of how long land must be left fallow between keeping chickens and growing food on it.

Happy Acre Farm has been distributing produce to restaurants. In 2015, following a break of several months when they were not farming, the couple started a box system with the help of the Community Supported Agriculture program. This program, modeled on that developed in Switzerland and Japan in the 1960s, was adopted by the U.S. Department of Agriculture in the mid-1980s as a vehicle to help low income farmers find capital, labor, and dependable markets [35]. Associations of individual consumers pledge to financially support one or more local farms, sharing the risks and benefits of food production with growers. This particular farming duo will do the distribution themselves, using their own truck. They have targeted Oakland as a market and are hoping to distribute to neighborhood hubs from which individual consumers will collect produce. They have already spent about $25,000 on their enterprise for insurance, seeds, tools and transport fuel. They pay SAGE $2,000 per annum

per acre for land rent and water. They buy compost from a supplier recommended by SAGE and plan on paying about $150 for 5 tons of compost per acre per annum.

3.4. Comparing the Three Cases

All three sites are nominally within the metropolitan areas of very large cities. The Garden is the most centrally located, followed by the Farm and then the Park, the most outlying. The Garden is an example of an inner city brownfield site co-opted for social benefits; it is completely dependent on volunteer labor and contributions. The Farm is an example of a low-productivity greenfield site that has been transmuted into a social enterprise with some income for a paid work force. The Park is an incubator farm that collects rent from aspiring farmer-entrepreneurs. While the Garden supplies its own compost, the Farm and the Park must haul in large quantities. The Garden's relatively low water needs are supplied by a sufficiently damp microclimate but the Farm and the Park must import large quantities of irrigation water.

All three sites have outreach educational programs for their local communities. While the Garden has several schools a short walk away, children visiting the Farm and the Park must be transported. The Garden gets a large number of walk-in users and provides a sizeable cultural program, while the Farm and the Park produce considerably more food. The Garden can be described as place-based because it is embedded within a neighborhood, while the Farm and the Park are interest-based as their service areas are rather large districts [36].

The three cases illustrate the core-edge-periphery trinity of urban form, with the Garden being 8 km from its urban center (seat of the central city's government), the Farm 16 km, and the Park 32 km. The core encompasses a built-up, high-density center; the edge encompasses the city-to-suburb transition area; the periphery, the suburb-to-exurb transition area. Both population density and land value decline with distance from the center. Thus, the proportion of land available for growing food increases with distance from the core; at the same time fewer people have access to the land and distribution to consumers requires longer delivery journeys. In addition to residential density, cultural diversity declines with distance from city cores in these three metropolitan areas. The diversity includes the largest pool of potential urban gardeners: poor immigrants with farming experience.

4. Results: Food Production

4.1. Food Production Metrics

The food growing potentials of the Garden, the Farm, and the Park are shown in Table 1, estimated using average data for metric tons produced per hectare [37] rather than the actual outputs of the three sites. For these estimates, the sites are assumed to be devoted to fruit and vegetable production, although all three currently grow some flowers for aesthetic, commercial, and pollinating purposes.

Table 1. Annual potential fruit and vegetable production of the Garden, Farm, and Park [1].

	Garden	Farm	Park
Growing area (hectares)	0.05	1.42	6.48
Potential production (kilograms) [2]	535	16,264 [3]	69,336
Persons per day fed [4]	4	111	475

[1]: Assumes one harvest per annum for field crops; [2]: Yield figure is 10.7 metric tons/ha from Garnett [37]; [3]: Includes two annual harvests from polytunnels, which account for 7% of output; [4]: Based on a consumption level of 0.4 kg, the minimum recommended by WHO [38].

The World Health Organization recommends the consumption of at least 0.4 kilograms of fruit and vegetable per day in a healthy diet [38]. This is also a reasonable proxy for a sustainable plate, needed to "provide good nutrition" [39]. The "healthy" and "sustainable" plates both focus on higher portions of fruit and vegetable and lower portions of meat than are common in "Northern" diets.

Using that minimal standard, the Garden can provide fruit and vegetable for four persons per day, the Farm for 111 persons, and the Park for 475 persons. This represents just "nibbles" of food for two reasons. Firstly, the recommendation of the U.K. National Health Service is that fruit and vegetables comprise 1/3 of a plate. At least as yet, none of the three sites produces any of the food comprising the remaining 2/3 of the plate, including grains, milk and dairy, meat and fish. Secondly, the food output does not approach serving a substantial portion of even fruit and vegetables for the populations of the sites' catchment zones. These catchment zones comprise the areas from which the Garden, Farm, and Park draw the largest share of their members/customers/tenants/visitors, and in which they provide social sustainability services.

Comparison of the food production of the three sites as compared to their catchment area populations reveals a very low per-person output. The Garden's output would provide fruit and vegetables for just 0.002% of the residents of its Upper West Side district (within a radius of 2.1 km), and just 0.02% of the residents of its immediate neighborhood (within a radius of 0.3 km) consisting of two of the 23 census tracts on the Upper West Side. The Farm's output would provide for only 0.06% of the residents of its district (within a radius of 2.4 km—Sutton borough) and just 0.24% of the residents of its immediate neighborhood (within 0.8 km—the suburb of Carshalton). The Park's production would provide for just 0.03% of its district's population (within 24 km—Alameda County) and only 0.1% of the residents of its neighborhood (within 12 km, consisting of its surrounding six suburban cities). Looking at this data from another perspective, it would take over 4500 gardens to provide the fruit and vegetable components of their diet for the people in its immediate neighborhood; over 400 farms and over 1000 parks to do the same.

Thus the three cases—Garden, Farm, and Park—illustrate the problem of scale facing urban food production. Other studies reflect a similar pattern: very low current output and low potential output, relative to the provision of healthy plates. Within London, current production is estimated as 1–2% of potential output; full potential output would still represent only 18% of current fruit and vegetable consumption [37]. Studies of other cities show comparable results: Cleveland [40], Detroit [41], New York City [42], Oakland [43] and Oxford [44]. These six urban areas grew an average of 2–3% and have an (unweighted) average maximum projected output of 20% of the fruit and vegetables consumed by their inhabitants. However, these figures are based on uniform distributions of consumption across urban populations; if urban produce is consumed by specific groups, the benefits may be more significant (see below).

There is wide variation among all seven urban sites, a finding that underscores the value of a case-by-case analysis of urban food growing. A major source of variation is between successful cities such as London, New York, and San Francisco, and distressed cities such as Detroit and Cleveland. The latter cities have considerably more available land; in Detroit, "abandoned houses, vacant lots and empty factories make up about a third" of the landscape [45] (p. 47) and therefore it demonstrates the highest level of potential production.

In reality, reaching the potential outputs will have to overcome some daunting conditions and issues. Cities struggle today to maintain their current green spaces. In London, the area of domestic gardens, which comprise 25% of the land upon which fruit and vegetables would be grown, is declining: between 1998 and 2008 it fell by 12% while the area of hard surfacing increased by 26%, largely paved over for car parking [46]. Land availability is but one example of an imposing array of structural challenges to scaling up urban food production. Globally, the land area used to produce just the vegetables in a healthy or sustainable diet is equivalent to about 3/4 of all urbanized land [47]. It is evident that there is not nearly enough arable land in urban areas to produce more than a small portion of the fruit and vegetables consumed by their residents. Of course, this leaves the remaining 2/3 of the sustainable plate unaccounted for.

More Food Production?

What are the possibilities of creating more urban food growing land by utilizing brownfield sites and by converting green spaces to food production? Both options have major drawbacks. With regard to brownfield sites, the condition of the soil is questionable. For example, a study of lead contamination in Oakland sites found a high level of variability that must be considered when undertaking food growing [43]. With regard to conversion of green spaces to food growing, there are issues of competition in supporting sustainability: these spaces already provide for carbon sequestration, urban cooling, and biological diversity. Any land use change to food production will have an uneven profile with regard to its environmental costs and benefits [48].

One solution proposed for the lack of arable urban land is vertical farming, or "*z*-farming" for zero acreage [49,50]. However, there are major sustainability obstacles for high-rise farming, including the inputs of energy for artificial lighting to grow plants away from windows (see earlier comments on underground farming, which are also relevant here) and the industrial fertilizers needed to optimize yields from hydroponic production [51]. These inputs add substantially to the environmental impacts: findings from a recent life cycle study indicate that "vertically grown produce has a carbon footprint that is much higher than conventionally grown produce" [52] (p. 76).

Rooftop gardens are another fashionable initiative that does not stand up to examination as a serious contribution to sustainable food production—as distinct from "green roofs," which can play a role in helping to mitigate urban heat islands [53]. Self-evidently, the area available for rooftop cultivation is strictly limited. Rooftop greenhouses are difficult to integrate into the waste management and recycling systems of their buildings [54]. Furthermore, roofs do not provide pavement level viewing and open access; in the absence of access to people other than the residents of the building, they cannot provide the social sustainability services of cultivation at ground level (see below).

In the end, the hope that urban food production might produce enough food to support the population within its borders is a utopian goal. The greatest opportunity for urban areas to reach a higher level of food security lies in the next tier of available land that is beyond the urban periphery: the broader region that is still largely rural. For example, in 2009–2010, 57% of London's consumption of fruit and vegetables was grown in the rural hinterland beyond its urban and peri-urban zones [55].

However, even assuming a full development of the broader foodshed region, it will still be necessary to bring in food, including cereal grains and exotic foods, frequently internationally traded. These imports are determined on a national case basis. For example, the United Kingdom's imported exotics include bananas, citrus fruits, coffee and tea. While our ancient ancestors ate only what they could find by walking within a hunter-gatherer food system, we humans of the Anthropocene have global-range appetites met by industrial-scale production and transport of agricultural products.

5. Results: Sustainability Services

5.1. Ecological Sustainability

Like all urban green spaces, the Garden, Farm and Park make contributions to ecological sustainability—by providing natural habitats, improving soil quality, reducing soil erosion, and mitigating the city heat island effect [17,53,56]. They may also reduce the runoff loss of rainwater exacerbated by the concreting over of cities and their environs [17]; this is significant where, as in London, a principal aquifer lies below the city.

In some respects, food growing plots may contribute more than other urban green spaces to ecological sustainability. However, a locally sensitive design is crucial in maximizing their potential. For example, Kulak *et al.* [21] carried out an LCA of the same Farm examined here. They found that reductions in greenhouse gas emissions are gained from an appropriate choice of local crops that can substitute for foods with high carbon footprints. Such crop prioritizing for sustainability also can be applied to broader multi-foodshed areas, as has been done for New York State [57].

Another way in which food growing may outperform other urban green spaces is that it shelters more biological diversity through its wide variety of flora—agricultural and horticultural. A key component of this diversity is the presence of bees to pollinate plants. The Farm in Sutton has three hives tended by a volunteer keeper and is close to woodland and commercial hives, while marigolds and other flowers are grown to encourage pollination. The Park in Sunol grows wild flowers and is serviced by bee colonies in its semi-rural locale. Despite being in the middle of a large city, the Garden in New York City has a good supply of bees from hives on nearby roofs and wild colonies in nearby Central Park [58]. Thus, all three sites support bee populations by providing a diversity of flora, paralleling the practice of spacing ribbons of flowers amidst mono-crop fields in rural areas.

5.2. Social Sustainability

Although its contribution to dietary provision will always be slight, urban food growing can contribute to two other components of social sustainability: environmental justice and public health. Both are needed now more than ever—environmental justice because of dramatically widening inequalities [59] and public health because of the new obesity epidemic [60]. There is abundant evidence of the ways in which urban green spaces contribute to physical, psychological, and social health [17,61–68], and growing evidence of their contributions to environmental justice. With regard to public health, gardening provides easily accessible opportunities for physical, mental, and social well-being. Growing food is a physical pursuit. Its physicality ranges from the fine motor involvement of cutting flower stems to the aerobic gross motor tasks of turning compost. While gardening promotes physical health, it also "has been observed to be a way to relax and release stress" [61] (p. 28). Finally, all types of urban green space provide natural locales for people living in densely-populated built environments. Access to nature can be a form of therapy, allowing for solitude, serenity, and reflection. This has been found to be related to mental health by mitigating a psychological nature deficit disorder [65].

With regard to environmental justice, urban food growing appears to produce more than just "nibbles of food" for some socially excluded sub-groups. One study shows that it can make a significant contribution to the tables of low-income immigrants from agricultural backgrounds [69]. Another study shows that it can make a substantial input to improving the diets of low-income persons with high rates of obesity and diabetes and with limited sources of fresh produce [70]. However, these are special cases, in which volunteer and experienced gardeners had convenient access to free plots of arable land, whereas this access is not usually available to low-income residents of cities in the global North.

Even a very small food growing space can contribute to environmental justice. An apt example is the half-acre Brook Park Community Garden in the Mott Haven neighborhood of the Bronx borough, one of the poorest communities in New York City. It employs a dozen teenage boys with criminal records to grow serrano peppers (*Capsicum annuum*), working under court orders as an alternative to incarceration. Their small stipends come from the profits from selling the garden's "Bronx Greenmarket Hot Sauce" [71].

However, it is in education, rather than environmental justice or public health, that the Garden, the Farm and the Park make their most impressive contributions to social sustainability. The inter-generational principle of sustainability relies on ecological education. The Garden reserves six plots for schoolchildren who participate in an ecology learning module during which they grow vegetables. As a follow-up to their experiences, children and their teachers have constructed several raised beds in their schoolyard. In New York City, the number of registered school-based gardens has multiplied six-fold [72]. (It is noteworthy that most of the adult participants in the Garden have had previous gardening experience, many in their childhoods.) The Farm operates a funded school program, the Green Grub Club, in which pupils and staff, after school, grow, cook and eat vegetables. In addition, 16 students and their caretakers from a local school participate in a sponsored Disabled Farming Assistance program.

The Park, like the Garden and the Farm, operates environmental education programs for school pupils. In an increasingly important aspect of education, the Park also provides a rare learning opportunity for urban young people to start farms. Increasing urbanization has progressively reduced the number of persons with farming knowledge. In 2012, the average age of U.S. farm operators was 58.3 years, up 1.2 years from 2007 and, continuing a 30-year trend, the number of beginning farmers was down 20% from 2007 [73]. This loss of farming expertise threatens both food security and climate change resilience. The Park addresses both, by inhibiting the conversion of farmland to settlement and by training a new generation of aspiring farmers. SAGE specializes in conserving peri-urban food growing based on the model of the European Association of Peripheral Parks, *Fedenatur,* used, for example, in Barcelona, Lille and Milano. The Sutton Farm addresses the same issues on a smaller scale by providing a sustainable farming apprenticeship program.

Informal education is also part of urban cultivation. For example, whether the land-limited Garden should grow food or flowers is a subject of continuing debate. There are four parties to the debate. Foodists make an environmental justice argument for converting flower plots to vegetables in order to shorten the queue for beds (now a year's wait) and to provide more opportunity for low-income persons to grow food. Ornamentalists make an aesthetic point about the beauty of flowers and gardening's social psychological rewards, which constitute a public health benefit. Pragmatists make an economic argument that flowers attract people who then contribute money and labor to the Garden. Ecologists make a sustainability case for the biological diversity added by flowers and the bees that depend on them.

A latent result of the Garden's debate is its contribution to the ecological knowledge of its participants. Gardeners hear from each other about some of the complexities of flora production and its relationship to sustainability. This communal learning is an example of the synergies that exist between ecological and social sustainability [74] and supports the argument here that small inner-city plots mainly have social value. The communality is a basis for the development of social capital rooted in its use value.

Growing food is both a physical and a mental activity. It simultaneously involves an active mind and body; thus, it is an embodied experience [75,76]. For this reason, it may have more learning impact in a person's life than do other environmental education activities. Communal learning takes place in urban food growing through a sharing of ecological observation and monitoring by gardeners [77]. There is also experiential learning, which can stimulate change in individual lifestyles. For example, food growers may gravitate to healthier diets (with more vegetables) and they may also take up sustainable practices such as composting. A good number of the Garden's members regularly carry food waste from their apartments to its compost bins, whether or not they have plots to tend.

6. Discussion

6.1. Urban Cultivation and Its Future

The estimates in Table 1 indicate that urban food growing in the global North does not now, and likely will not in the future, make more than a trivial direct contribution to food security. There is significant growth potential, with wide variations in the upper limits of production based on local circumstances, but urban food production can at best supply a limited proportion of some components of the diet of urban populations. There are strong structural factors that constrain production. The fundamental limitation is a lack of arable land. Field cultivation is simply beyond the land capacities of urban agglomerations. Cities can produce a small portion of the fruit and vegetable consumption of their residents but they lack the potential to grow the basic food of humanity—cereal grains, which are the stuff of the "staff of life." Cereals supply over half of the dietary energy of the human population [78] and large rural fields will remain the venue for their efficient production. Research indicates that peak economic efficiency is achieved in production units of 160–325 ha for soybean and 325–490 ha for corn ([79] cited in [80]).

Cities are places where great numbers of people live in small areas; they do not contain the expanses of ground level land fully exposed to the sun needed for field crops. Instead of food growing being the goal, it is more realistic to cast it as a secondary gain. This reasoning underlies our suggestion that cultivation rather than agriculture is the appropriate designation for urban food growing: cultivation better captures the sensibility as well as the output of this activity. Agriculture combines two Greek roots: *agros* for field and *cultura* for cultivation. As compared to agriculture, cultivation covers a range of etymological meanings beyond food production, including education and development, all of which are insufficiently recognized in the contemporary enthusiasm for urban food growing.

As to the future, the differences among the three sites of this study illustrate a dilemma for urban cultivation. The Garden is too small to provide a significant food output but has a high social amenity value due to its location and accessibility. The Farm is large enough to provide marketable food and some jobs, but its location makes its social value educational rather than amenity-based. The Park is too remote to provide for general environmental education (in a sustainable way) but the same remoteness allows for large tracts of land suitable for providing specialized farming educations. Given the demand and price for land in successful cities such as London, New York City and San Francisco, the distinction between urban and peri-urban and the demand for urban land are likely to persist although the pressures are currently mitigated in distressed cities like Detroit. At least for the present, being in the Green Belt provides a measure of protection against encroaching development for the Farm. The same can be said of the Park, although its relative remoteness already provides some measure of protection. Additionally, cultivable land can be generated by integrating it into urban new build and re-build plans. A study in Waterloo, Ontario, found that about half the land in its suburbs had the potential to support cultivation [81]. However, as we have indicated, assuring the land is not contaminated and can be sustainably converted from lawns to gardens is a formidable task.

6.2. A Systematic Scaling of Urban Cultivation

Despite scaling and sustainability obstacles, there is space available to continue the increase of food growing across urban areas—parcels of varying sizes of affordable and arable land. This growth should strive to meet local, national, and global sustainability standards, not only for its food production but also with regard to its ecological and social dimensions. These sustainability assessments will be better served if they take a systems perspective of urban food growing, with links among sites in the core, edge and periphery [80]. Such a system can connect diverse willing and able growers and consumers to accessible sites of arable land. Recognizing that urban and peri-urban cultivation play different roles in foodsheds suggests a different approach to land distribution: planning and regulation on a regional or ecosystem basis.

Foodshed is a concept that was developed by Hedden [82] in his 1929 book: "*How Great Cities Are Fed*". Hedden contrasted foodsheds with watersheds by noting that water flows depend on natural land elevations while food movements are based in economic markets. The term was reintroduced by Getz [83] in a 1991 article on permaculture. More recently it was used to describe "the geographic areas that feed population centers" [84] (p.1). One part of the foodshed is the urban nexus of core, edge, and periphery. The three sites examined here illustrate the wide variations in access to land, to people, and to sustainability benefits that exist in a metropolitan area across these three zones (see Table 2).

Table 2. Schematic for the coordination of a potential urban cultivation system.

			Access to		**Sustainability Benefits**		
Site	**Scale**	**Area**	**Land**	**People**	**Food**	**Ecological**	**Social**
Garden	micro	core	very low	very high	very low	very low	very high
Farm	meso	edge	low	high	low	low	mod-erate
Park	macro	periphery	moderate	moderate	moderate	low	low

One type of facility, the food hub, may be well placed to coordinate these variations to best advantage. Food hubs are urban facilities that engage in aggregation (which can include growing), preparation, distribution, and marketing of food. They tend to be social enterprises that make small profits and receive benefits (including tax relief) from local government [85]. Food hubs are proliferating rapidly—over 60% of those in a U.S. national study had begun operation in the last five years [86]. From that survey, the three most common food hub customers are restaurants, small grocery stores and school food services. About 3/4 of their customers live within 160 km. Food hubs are usually sited in the moderately dense urban edge. They are possible lynchpins in local food systems because they are best positioned to reach an entire urban nexus efficiently—inward to the core and outward to the periphery. There is potential for the network of food banks—a response to economic hardship and hunger in towns and cities in the United Kingdom and United States in recent years—to evolve into a system of food hubs that could offer not only access to affordable food but also services concerning nutrition, healthier living and urban cultivation. A U.S. initiative, the Healthy Food Bank Hub [87], is a case in point. We suggest that the food hub innovation is an important field for further research on sustainable urban cultivation.

7. Conclusions

The three cases examined here provide a new perspective on the current widespread enthusiasm for urban food growing. While structural limits will prevent urban food growing from becoming urban agriculture (at least in cities of the global North), there is a strong case to be made for it on the grounds of its contributions to social sustainability. Urban agriculture can produce little more than "nibbles" of food but it can contribute "oodles" of social sustainability services [19,20]. Identifying the real benefits enables some forms of urban cultivation, most obviously underground or "vertical" farming, to be recognized as no more than "magical realism." Realistic assessment leads to a basis for promoting urban cultivation as part of the physical and social structure of urban areas, and highlights a potentially important systemic role for Food Hubs.

To assess the real role of urban cultivation, we should perhaps be looking at food provision differently. If the food system is recognized as involving produce supplied by oligopolistic intermediaries (retailers) from ever more consolidated primary producers (industrial scale farmers), many parallels with *energy generation and distribution* become apparent, suggesting a need for reforms to promote sustainability and, in particular, resilience [88]. Urban cultivation is a local phenomenon, the base level in a *food system approach* ([89] cited in [90]). Its unique grassroots activities contain and incubate adaptive, flexible possibilities for social sustainability services whose effects can extend throughout food systems.

What if we actively promoted food hubs to produce some food but primarily as vehicles to promote the social dimension of sustainability, with sub-stations in residential areas (allotment tillers, keen back garden food growers, and community gardeners) acting as the equivalent of a localized energy grid? As with decentralized or community energy, the aim would not be to achieve self-sufficiency and grid independence, except at the margins, but instead to boost system-wide resilience via redundancy, diversity and storage–and also to generate social benefits, such as local collaboration and trust, healthier lifestyles and grassroots innovative capacities.

As for boosting sustainable food production, enhancing food security depends on surmounting an inventory of difficult challenges: (a) reducing waste, which accounts for up to 1/3 of production through the food chain [91]; (b) shifting crops away from animal feeds and biofuels to human foods, which can increase global calorie availability by up to 70% [92], and at the same time shifting to sustainable plates on the consumption side [93–96]; and (c) adopting sustainable intensification practices in which productivity is raised without increasing environmental impact and without using more land [5]. The looming food security threat will not be tempered by the limited amount of food that can be grown in urban areas. Nevertheless, urban food growing can play a small but significant role in evolving a sustainable food system by contributing both to reducing waste and to

the adoption of sustainable plates—through the provision of environmental, dietary, and farming education, for example.

While this study is limited to just three cases, the results indicate some useful areas for further research, particularly in exploring the role of urban food growing in contributing to social sustainability services. Science has provided the basic ecological metrics needed to specify parameters for sustainable food security. The present gap in our knowledge is an understanding of the processes and practices necessary to develop the corresponding parameters within social structures—society has been the neglected child in the sustainability family. Urban cultivation provides a potentially informative vehicle for assessing the value and scope of social sustainability services and their synergies with ecological sustainability and food production. The success of assessment depends on the development of empirical measures of "soft data," positive services such as environmental education. This form of assessment requires a different approach from the "hard data" approach of conventional environmental LCA, focused on negative impacts, and suggests a direction in which social LCA should be developed.

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