Gardening the City: Addressing Sustainability and Adapting to Global Warming through Urban Agriculture

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Abstract: This article envisions urban agriculture as a solution to address global warming by decreasing the urban heat island effect while also addressing many other urban sustainability issues, such as multi-functionality, creating new commons, amenities and ecosystem services, reinventing urbanity, encouraging community building by growing local food, and enhanced water management. This article examines how urban design and planning can promote this solution to reconfigure more sustainable and resilient cities. A crucial aspect is that urban planning should evolve from its traditional prescriptive form to adaptive planning. An important point in adaptive planning is that anybody concerned should be associated with the decision-making process, which requires the involvement of citizens in the decisions that affect them.

Keywords: adaptive planning; participatory policies; sustainability; revegetation; urban agriculture; urban heat island; urban regeneration

1. Introduction

Based on their current design, urban areas are not adapted to global warming [1]. Many emerging risks of global warming are concentrated in cities, primarily because they have specific climate conditions that can be encapsulated in the notion of the urban heat island (UHI), which was first theorized by Luke Howard at the beginning of the 19th century [2]. He noted a temperature difference at night of +3.7 °C between inner London and the fringe of the agglomeration. Today, the adverse impacts of the UHI on cities are universally recognized, but this has not always been the case. In the middle of the 20th century, Franz Linke considered the UHI to have positive effects [3]. It was only at the beginning of the 21st century that the deleterious effects of the UHI became obvious, especially in relation to global warming. In 2003, mortality rates in urban areas of Western Europe increased significantly (+134%) during a summer heat wave with consistent temperatures of over 40 °C (Observatoire Régional de la Santé d'Île-de-France, 2003). This episode, which was followed by a second one in 2006, indicated that cities could very well be genuinely uninhabitable in the near future [4,5]. As a result, fighting UHIs—through decreasing their intensity or adjusting to them—became a key urban policy issue.

It must be borne in mind that UHIs are neither the cause nor the direct result of global warming. A UHI is the temperature difference between urbanized and close non-urbanized areas that have existed throughout historical time. Indeed, the anthropogenic heat production (traffic, residential and industrial heating, etc.) in cities is higher than in nearby rural areas, and besides the physical aspects of the urban landscape (canyon streets, dark materials such as asphalt or pavements) that contribute to trapping a consistent part of this heat, meteorological conditions (wind, humidity, sky view factor, radiation, precipitation, etc.) also result in the formation of the UHI [6,7]. The problem of the UHI lies in its magnitude, which has been steadily increasing in recent decades due to global warming [8,9]. Thus, the point is not to eradicate the UHI—which would be nonsense—but to decrease its magnitude to an acceptable level. Doing so can be tricky. As shown recently by Mojca Nastran, Milan Kobal, and Klemen Elere [10], there are huge differences in the UHI magnitude between cities according to their geographic position (in a somewhat counterintuitive way, longitude seems to have a stronger influence than latitude on its magnitude), the distance of the city to the sea, the type of land use (proportion of grey and green areas, forest, lawns or agriculture, etc.), and the type of planning policies (called planning families by the authors). In general though, we can consider three key policy levers to decrease the UHI [11]:

- The first consists of reducing anthropogenic heat emissions in the city, such as road traffic, residential and industrial heating and cooling, and industrial activities.
- The second addresses urban morphology. Indeed, canyon streets lined with buildings of similar size are heat retainers. In opposition to green land use, asphalt, concrete, and granite—all dark materials—act as heat sinks that store solar energy during the day and release it in the form of heat at night. Preventing canyon streets and favoring light reflecting materials reduces the amount of solar radiation absorbed and therefore reduces the UHI magnitude [12].
- The third concerns urban density. In dense urban areas, the UHI is more important than in lower density areas, and it has dramatic consequences. A report by the Italian city of Genoa shows a strong correlation between high urban density and increased mortality during heat waves [13]. The report recorded the number of deceased in relation to the characteristics of the urban fabric where the people died: green neighborhoods, suburban low-rise housing, dense urban centers, etc. In France, the Institut National de Veille Sanitaire (INVS) reached the same conclusion in a report after the summer heat wave of 2003 [14].

2. Vegetating the City Decreases the Urban Heat Island Effect

Many modeling studies show that a more efficient way of reducing the magnitude of the UHI is either by increasing the albedo of the urban surfaces or by developing vegetated areas. Plant leaves transpire into the air the water that their roots draw from the ground, and this water vapor has a cooling effect [15]. It is a phenomenon called evapotranspiration. When the air temperature exceeds 25 °C, most of the deciduous trees in a temperate climate initiate evapotranspiration. A single tree can evaporate into the air up to 4000 liters of water per day. Even when considering that wind mixing and heterogeneous urban morphology may limit the effects of evapotranspiration [16], the shading due to the tree canopy absorbs subsequent portions of solar radiation, which limits ground level warming [17]. Thus, the combination of shading and evapotranspiration can drastically reduce the UHI magnitude, as shown by Nicole Müller, Wilhelm Kuttler and Andreas-Bent Barlag [18]. Stephan Pauleit and Friedrich Duhme were the first to determine—in the city of Münich—that a 10% increase in the vegetated surfaces of shade-providing trees with a high rate of evapotranspiration resulted in a decrease in temperature of 1 °C in a radius of 100 m [19]. In the same vein, Emmanuel Boutefeu demonstrated that by developing a wooded park of 100 m^2 within a city block bordered by buildings 15 m in height, he could lower the air temperature by 1 °C on a 100 m stretch of the adjacent canyon street [20]. Since then, many researches have confirmed the cooling effect of deciduous urban trees, be it in Münich [21] or in other places, such as high latitude cities [22], Chinese cities [23], or African cities [24].

To be perfectly accurate, this cooling effect must be nuanced according to the type of trees. In a study of 70 European cities during the heat wave in 2006, it appeared that the green areas composed of coniferous forest did not reduce the UHI [25]. This result was confirmed by other studies in Poland [26], and in the USA [27]. In contrast, deciduous and mixed trees helped to decrease the UHI magnitude. Nonetheless, green areas may be excellent natural air coolers, provided that the right type of revegetation is planted. Essentially, the largest temperature differential due to revegetation was observed:

- In the vicinity of large, deciduous wooded parks that included a river, a decrease in temperature of 1 °C to 7 °C was recorded [28]. For the same global surface, it appears that larger green patches with high edge density are more efficient in decreasing the UHI than several smaller patches, which places emphasis on the type of planning policies [29,30].
- Green facades and green roofs show substantial cooling benefits. Above green roofs, the air temperature is substantially lower than above blank roofs during a summer sunny day (22 °C instead of 41 °C, which is a mitigation of 18 °C) [31].

It follows that an elegant, efficient, and inexpensive way—compared with energy efficient building technologies—to address the UHI is revegetating the city. However, creating parks and foresting the existing green areas is an initiative that quickly reaches its limits, especially in dense urban centers where unbuilt places are scarce. Only brownfields and former industrial wastelands can potentially be used, as with the Community Forest Trust in the United Kingdom [32]. Even then, due to real estate demand, there is a high pressure to build on these derelict lands in dense urban areas instead of foresting them. Thus, other types of revegetation must be imagined. One option consists of planting street trees differently. In Buenos Aires, instead of aligning the trees along the sidewalk in the traditional way, they are arranged in an unevenly spaced quincunx pattern [33]. Moreover, suitable species adapted to local growth conditions (plane trees and lindens, but also Palo Borracho (Drunken Stick), Tipa or Gomero tree) are haphazardly mixed, as are ages and heights. This arrangement results in a magnificent urban landscape, in addition to its efficiency in reducing the UHI. In a smaller way, sidewalks at the foot of buildings could host flowerbeds, creepers, and pergolas to create shade and help draw air through the surrounding buildings while also diminishing the UHI. The Greater London Authority closed many dead-ends, backstreets, lanes, and alleys to traffic to create community gardens and kitchen gardens [34]. Zurich City Hall offered their citizens the opportunity to green, as they wish, vacant spaces at the foot of buildings, and under street trees [35]. By doing so, the inhabitants took ownership over the city's public space while reducing the UHI.

Generally speaking, people are very demanding of the greenery nearby to the place where they live or work, rather than remote large parks, as shown by a CERTU survey in the French city of Lyon [36]. That is the reason why revegetation is an essential component of the program Nouveaux Quartiers Urbains, in Paris [37]. This revegetation program takes the form of community gardens, promenades, and green roofs. The point is to ensure that nature will permeate the whole urban fabric. Such a network should greatly improve urban resilience by reducing the UHI, provide ecosystem services such as walking and leisure activities, and create productive agricultural land within the city (community gardens and kitchen gardens). Thus, Parisian revegetation promotes urban multi-functionality as a means of addressing both global warming and sustainability issues. Indeed, combating UHIs should not lead decision-makers to overlook the other dimensions that make a city sustainable—or at least livable—or not. The aim is to integrate the social demand for fostering nature in the city, economic concerns (simple and cost-efficient solutions, what smart technical devices are not necessarily useful), social justice and inclusiveness, access to ecosystem services, and ecological concerns (biodiversity, air and water quality, etc.) [5]. For example, revegetation can also reduce the impact of heavy rains related to global warming by occupying low-lying and steep areas. It helps to downsize water runoff, and the remaining excess water percolates through the soil of the low-lying green areas [38]. Consider the case of New York City. Since 2011, the Green Infrastructure Grant Program of the city's DEP (Department of Environmental Protection) has provided funding to many urban agriculture projects to simultaneously address both the UHI and flood hazard. The program promotes so-called "blue roofs" that hold rainwater and progressively release it into the sewage system, "green streets" for stormwater management, and turning derelict lots and rooftops into kitchen and community gardens. Overall, this experience fosters the creation of productive land within the city (micro-farms and edible gardens) and also generates social and health advantages. A 2010 report from the New York City Department of Parks and Recreation [39] stated that these strategies were—by far—a more cost-efficient option than the conventional approach, which was based on "grey infrastructure" to deal with flood hazard, and provided vital ecosystem services that helped to diminish the UHI [40]. Such an approach is not the whim of rich cities in wealthy countries. In Argentina, the city of Rosario promotes the conversion of stream banks into farming plots, changing traditional roofs into green roofs to reduce flood risk, the development of urban agriculture in public squares and places, streets and avenues, motorways, railways, and shoulders, all in an effort to reduce the UHI and strengthen local communities [41]. In that spirit, developing urban agriculture may be the right choice to address UHI issues.

3. Using Urban Agriculture to Green the City Has Many Benefits

Urban gardens, agricultural lands, street and fruit trees, parks and forests may decrease solar radiation, increase evapotranspiration and consequently lower temperatures through evapotranspiration and shading [42]. Naturally, urban agriculture's cooling effect must be nuanced according to factors such as the type of climate, the type of cultures, and the local agricultural traditions. For example, in Western and Northern Europe, cities with a higher share of agricultural land see a reduced UHI magnitude, but it may not be the case in some Mediterranean cities [10]. The reason for this is probably different albedos and evapotranspiration rates, which depend on the type of plants and how they are grown, and structural differences in the configuration of the agricultural land [10]. This means that developing urban agriculture to decrease the UHI is not a panacea that may be applied anywhere and anytime. Context is essential, as we will see now. However, even in some situations where there is no huge impact on the UHI, urban agriculture can still help build more sustainable, resilient, and livable cities (reducing runoff, creating ecosystem services, building social cohesion, etc.).

Many authors—such as Tidball and Krasny, or Dubbeling [43,44]—consider that urban agriculture may reduce drastically the UHI effect and contribute to building more resilient communities and sustainable cities. More generally, urban agriculture can be a cornerstone to turn derelict lands and brownfields into urban amenities, into a common good that can help reduce the effect of the UHI. Besides, fostering urban agriculture initiatives in these abandoned places can bring people together and ignite social innovation, as with the city of Montreuil sous Bois, a Paris suburb. There, in approximately the same vein as the Nouveaux Quartiers Urbains, an urban program envisions the preservation (Montreuil is already covered with 23 ha of farming land, mainly *murs à pêches*—literally peach walls [45]) and the development of urban agriculture in connection with two parks (Parc des Beaumonts and Parc Montreau). Eventually, this urban agricultural development will occupy more than 20% of the district area. It will take the form of *murs à pêches* and community gardens, crossed by public transportation (a line of tram), and lanes and an alley (called "rues vertes"—green streets) where people can wander around [46].

The forms of urban agriculture initiatives are diverse. Thus, to understand the role of urban agriculture in reducing the UHI while making the cities more sustainable, it is necessary to be more specific. Urban agriculture refers to growing and distributing edible plants in both public (parks, vacant lots, abandoned interstitial areas, flower beds, traffic islands, etc.) and private (terraces, roofs, indoor gardens, etc.) places of a city [47]. It generally takes the form of micro-farms, allotment gardens, also known as kitchen gardens, community gardens, and street gardening [48,49].

The impact of urban agriculture on the UHI relies on the location of the city as well as the topography and local characteristics of the climate [50,51]. However, the aims of urban agricultural initiatives depend on the geographic, economic and social situation of the city. In many urban areas of Central and South America, Africa or South East Asia, urban agriculture is essentially a food security issue, related to the fight against poverty and malnutrition [52,53], even if the examples of Kathmandu or Bobo-Dioulasso show an emerging concern and other dimensions [54]. The situation is quite different in European cities [55], which are our main concern in this paper, as well as North American cities [56], or Japanese cities [57]. In these regions, many official urban agricultural projects result from "greening" agendas created under the umbrella of the *Green New Deal*, which aims to address global warming and the financial crises rather than food issues, as mentioned by Tim Jackson [58].

In most other cities, the landscaping aspect and the recreational dimension are highlighted. In all these cases, urban agriculture is regarded as a way of improving quality of life and enhancing urban landscapes. In so-called "Northern" cities, urban agriculture is not so much about food [59], yet it was not always that way. In Europe, growing vegetables in the city was a common practice in the 19th and 20th century. Fresh and cheap food augmented the diet of the lower classes in expanding industrial European cities. Local companies within the policy framework of industrial paternalism, and local authorities within social policy initiatives, provided lots for kitchen gardening [60].

In any event, all these different urban agricultures—whatever their form, their goal, and their means (food production, ecosystem services and amenities, support for community engagement)—share significantly common features: the size and shape of the field plots, the informality, the ability to create or foster neighborhood relations, etc. [61]. Gardening appears to be a very effective way to foster community building [62,63], to involve marginalized social groups in the social fabric [64,65], and to reduce urban fragmentation [66,67].

Indeed, urban agriculture, whatever its purpose, is becoming increasingly recognized as the expression of a renewed relationship between citizens and their city [68]. Well beyond the interest in responding to the urban challenges related to global warming and to ecology-related issues, many authors have shown how urban agriculture can create trust relations between different actors through genuine participative processes that mobilize the creative potential of citizens [69,70]. In this sense, urban agriculture can be considered one of the city's crucial seedbeds for creative innovation, and encourage the transition to sustainable development [71,72].

4. Developing Agriculture in the City Also Means Evolving toward Adaptive Planning

Within a city, farmers, gardeners, and their neighbors share more than just fence lines. The urban agriculture projects that have mushroomed since the end of the twentieth century often contribute to reshaping urban landscapes, and even the whole urban fabric [73,74]. Many examples in Europe show how urban agriculture initiatives help experiment with alternatives to traditional urban life. Sometimes, they create a new commons by bringing people together and reinventing urbanity via dialogue—and sometimes by confrontations—between farmers, gardeners, private actors, local authorities, neighbors, and other inhabitants [75–77].

In France, *La Fournillière*—a former squatted wasteland of more than 3 ha in the city of Nantes, turned into a huge and extremely pleasant farming land—is an example of co-management between a neighborhood and city planners [78]. In the mid-seventies, gardeners progressively squatted this wasteland. There were more than 70 illegal squatting gardeners at the beginning of the nineties, when the Nantes' city council finally decided to develop a park on the lot. Unexpectedly, the gardeners spontaneously united their forces and organized to impose their views on the municipality. They claimed their right to be involved in the decision-making process. They negotiated hard with the local authorities, and eventually the Nantes' city council decided to support a new project designed by the gardeners, and abandoned its own. This new project is a park organized around islets of grouped gardening plots, entwined by pedestrian lanes and alleys. There is a visitor center and the center of the park houses an ecomuseum dedicated to waste and material recycling in gardening, sorting and composting [79]. Another example is the *Parco delle Energie* neighborhood community in Rome, Italy. Urban gardeners and cultural associations transformed a derelict park into garden lots through an innovative governance process that helped to create an ecosystem service in the very center of Rome (resulting in cleaner air, a lower UHI, green amenities, fresh food), which succeeded in enhancing the social and urban fabric [80]. These cases illustrate how urban agriculture is prone to foster agreements for the co-management of green areas, where gardeners, neighbors, or citywide associations—such as the *Libere Rape Metropolitane* (Free Metropolitan Beetroots) in Milan [81]—provide practical support to local authorities and obtain in return decision-making power on urban affairs [82,83].

However, collaborative action in urban policies is anything but obvious. One of the main challenges is integrating bottom-up processes of knowledge, data collection, and top-down agency [84]. This issue can be embodied in two questions: How can a planner know enough about the lives of local people to propose the best possible policies? How is a community motivated—or not—to collect its local information and communicate it in a way that can help planners? The example of the public water points in the city of Pune, India, developed by Luis Bettencourt, raises the following issue: How is it possible for a planner to determine how many public water points should be created in a neighborhood [85]? From the inhabitants' point of view, short distance and easy maintenance is essential, as well as minimal waiting time, which calls for many points forming a dense network. Such a choice presents a collateral interest: smaller groups use every point, which fosters a stronger sense of responsibility. However, how does the planner know how many points are not too many? They must learn it from the communities themselves. The inhabitants are the only ones who know the real limits—not the administrative limits—of the communities and of the neighborhoods. They will give the information only if they perceive that it is in their best interest to do so, and if they feel they will have a seat at the decision-making table. This type of urban planning entails trust, as well as knowledge issues [86]. In other words, everyone concerned by sustainability issues should be involved in the process of decision-making [87]. Common people have values and knowledge that are out of reach of experts, scientists, or elected representatives, and they may prove essential to designing effective policies [88].

Including urban agriculture in urban policies will require shifting from traditional prescriptive planning to what can be called adaptive planning [89], which is a process that requires involving citizens in decisions that affect them via an active engagement in the city design, rather than via a mere consultation on already existing proposals. It means integrating values and knowledge from different stakeholders, in a context of high uncertainty and no "blueprint solutions", which is tricky [90]. Adaptive planning also modifies the rules of the eternal game between what the authorities—whatever their form—try to impose on the social fabric, and what the social fabric imposes on the authorities, through deception or force, confrontation or bargaining [91].

Embedding all of the actors' needs and values through a collaborative approach has a big consequence: it is impossible to develop "silver-bullet" solutions. The solutions must always depend on the characteristics of the local communities. They are typically place-based and it is crucial to build solutions that adapt to the local characteristics [92]. As it has been mentioned previously, the type of urban agriculture that can be developed in a city not only depends on the local agricultural practices, topography or climate characteristics, but also—even more—on the local society and its values. It is therefore essential to locally determine what is a good environment for the communities involved, when trying to address the sustainability–justice nexus: One in which the improvement of environmental conditions stricto sensu (water quality, air, biodiversity, prudent use of resources, land, and energy, etc.) will lead to improved living conditions. One in which technical devices and ecological processes will lead to new lifestyles.

5. Discussion and Conclusions

Urban agriculture appears as an effective means to address global warming—by reducing the effects of UHIs and reducing flood risks for example—while also fostering urban transitions to sustainability in many ways, such as creating new commons, amenities, ecosystem services, reinventing urbanity and encouraging community building by growing local food, etc. It makes a lot of sense to promote the development of urban agriculture in interstitial areas, wastelands, brownfields of former industrial sites, rooftops, derelict parks and squandering soils, since one among the many challenges of sustainability should be making better use of what is already there [93].

Since urban agriculture can help reconfigure more sustainable and resilient cities, it can thus be considered one of the main seedbeds for innovation. To do so, urban policies should evolve from the traditional prescriptive form of planning to adaptive planning, examples of which we have seen in the different cases mentioned in this article. A crucial point in adaptive planning is that anybody concerned should have a seat at the decision-making table. By involving all the inhabitants, and not only the elected officials, developers and city planners, in the definition and implementation of these policies, the decision-making process becomes a matter of collective decision [94]. It is a matter of collective ownership and participatory joint-construction [95].

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