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Urban horticulture for sustainable food systems

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Agricultural progress over the past century has brought about such remarkable gains in productivity that food production now provides more than enough calories required to feed the global population. These gains were borne out of the increasingly technological food production system characterized by new synthetic inputs, crop varieties, and labor-saving technologies—culminating in the Green Revolution paradigm in the 1950–1960s. While the Green Revolution provided momentum toward achieving food security *via* calorie-rich foods, it did so at first without considering the negative environmental and health consequences. Owing to growing environmental concerns since the mid 1980s, the Green Revolution has been largely replaced by the Sustainability Revolution in most places or otherwise promoted (Welch and Graham, 2000; Pretty et al., 2018)—where agricultural still focuses on large-scale production but simultaneously aims to preserve crop productivity *and* a healthy resource base (land, soil, air, and water). However, even with the implementation of various agricultural practices borne out of the Sustainability Revolution, food production has not radically changed—it is only relatively more sustainable due to incremental advancements. Key issues have gone unaddressed, such as the underproduction of healthful foods, food insecurity gaps, the vulnerability to climate change, and disruptions of the food chain. Still, a radical new paradigm for food production is needed. Meeting the demand for food will be far more difficult in the coming decades due to the convergence of several complex challenges, such as the destabilizing forces of climate change on large-scale production (Bush and Lemmen, 2019); the fundamental mismatch between calorie-dense production and nutrient-dense requirements (Bahadur et al., 2018) (i.e., hidden hunger); the ever-widening gap between those who are food secure vs. insecure (Gundersen and Ziliak, 2018); the growing rural to urban migration (United Nations, 2018); and food chain supply disruptions. Finding alternative ways of meeting food demands that simultaneously provide healthy, environmentally, and socially sustainable food remains complicated and elusive.

A new look at an old concept: Urban horticulture

By 2050, nearly 70% of the projected 10-billion people will live in cities (United Nations, 2018)—a staggering metric, and one that cannot be ignored when envisioning a sustainable food future. Directly integrating food production into the fabric of urban environments is key component toward shaping a better Anthropocene (Boivin and Crowther, 2021). As such, considering the role of urban horticulture is crucial. Here, urban horticulture is broadly defined as the cultivation (in any form) of fruits, vegetables,

herbs, and ornamentals in urban environments (i.e., the region surrounding towns, cities, suburbs, or metropolises). Urban horticulture can provide diverse healthful foods (i.e., fruits and vegetables), inclusive and equitable food access (i.e., fill the gaps in urban food deserts), and environmental benefits (i.e., carbon sequestration). In recent years, it has received increased attention and its benefits are frequently promoted. Yet urban horticulture is not typically recognized as a mainstream agricultural sector; it is not typically regulated, monitored, or governed as a unique and independent sector of agriculture.

When evaluating the potential of urban horticulture, considering the lessons of the past is a good place to start. Some cities existed for millennia, demonstrating remarkable food resiliency and offering useful models for exploring solutions to present-day food system problems. For example, Maya cities shared a basic model for organizing urban landscapes where garden space was directly integrated into the urban fabric thereby forming "managed mosaics" or "garden cities" (Barthel and Isendahl, 2013). Reasons for why a "managed mosaic" arrangement conferred food resiliency are related to (i) the diversity of food provided by urban spaces, and (ii) the multitude of ecosystem services that are provided by urban horticulture, in addition to food provisioning. It is believed that the *balance* was more important in driving food security than adaptations to the environment alone, because it gave the city the resiliency to re-organize during times of crises (Barthel and Isendahl, 2013). Other enduring cities, like Byzantine Constantinople, demonstrated food resiliency during periods of supply cuts by shifting to urban agriculture and developing food and water storage systems (Barthel and Isendahl, 2013). When it comes to the ecosystem services provided by these urban managed mosaics, it was more than just provisioning that contributed to the city's food resiliency. The edible green spaces would have also provided a variety of different ecosystem services (i.e., supporting, regulating, and cultural)—many of which function as positive feedback to further support food production.

There are other more recent historical examples that demonstrate the importance of horticulture during times of crises. Namely, the victory gardens of the World Wars, the relief gardens of the Great Depression, and the garden metropolises in cities during economic collapses (Brown and Jameton, 2000; Siegner et al., 2018; Cruz-Piedrahita et al., 2020). Today, urban gardening is promoted as a tool to strengthen local food production in response to the food supply chain disruptions brought about by the pandemic (Lal, 2020). It appears that horticulture has consistently played an important role in food security and resiliency—and in more than one way.

Our food system is more than just production; it encompasses all the aspects related to feeding and nourishing people, including growing, harvesting, postharvest handling and storage, processing and manufacturing, transporting and distributing, and consuming food. The functioning of these aspects is supported by a variety of inputs, institutions, infrastructure, and services; outcomes are also shaped by diets and cultural practices. Food connects people to the natural world (land, water, and climate)—and in doing so, human health and nutrition is not only fundamentally associated with the natural world, but also to our impacts on it. Moving forward, we should strive to holistically support the functioning of all the aspects of the food system, as well as the connections to the natural world. I propose that it is the *multifunctionality* of urban horticultural ecosystem services that, when viewed together, form a sound framework for evaluating the performance of sustainable food systems; these functions should be considered as integral parts of the wider food system (Figure 1).

Sustainability borne out of the multifunctionality of urban horticultural ecosystem services

Provisioning services

The production of edible plants and green landscapes in urban environments directly provides foods, but the key is to produce nutrient-dense foods as opposed to calorie-rich staples. In provisioning nutrient-dense foods—namely fruits and vegetables—horticulture has the potential to better match food production with nutrient requirements and thereby address "hidden hunger" deficits. Of the remarkably few studies that have quantified horticultural production in cities, promising results have emerged. For example, if all available land/space within a developed city was cultivated, urban horticulture could provide at least 15% and up to 122% of the demand for fruit and vegetables by a city's population (Edmondson et al., 2020; Grafius et al., 2020; McDougall et al., 2020). Home gardening is believed to be one of the most effective interventions in improving nutrition (Berti et al., 2004); households involved in gardening are found to have better access to food, a more diverse diet, and eat more vegetables than households not involved in gardening (Zezza and Tasciotti, 2010). Despite the small-scale nature of individual gardens in or near cities, collectively, the total amount of food produced can be considerable (with yields comparable to or higher than rural large-scale conventional farms; Nicholls et al., 2020). If contemporary cities planned for and implemented a "managed mosaic" design for food production, then cities could exert power to influence the global food system toward one that is more nutritious, sustainable, and equitable.

Urban horticulture can take *many* forms (unlike most conventional/commercial large-scale food production systems), thereby offering several different frameworks toward the same goal of food provisioning. Beyond commercial production, these include home gardens, allotment growing, communal growing or community gardens, community-support agriculture, vertical

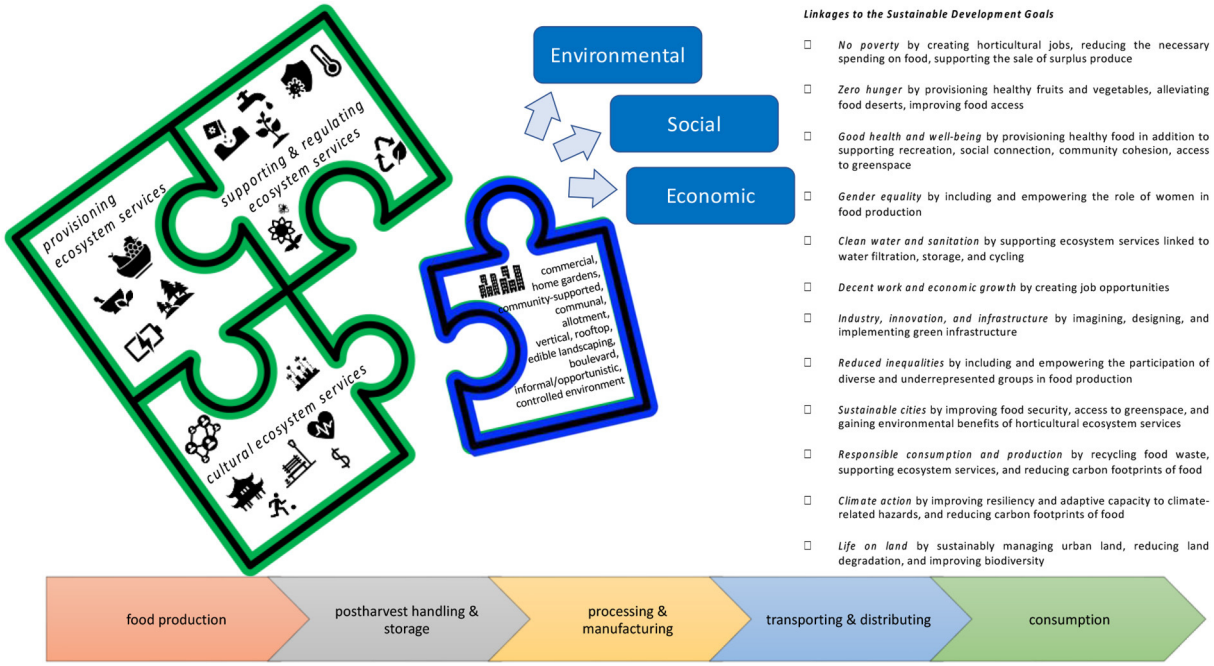

FIGURE 1
The multifunctional ecosystem services provided by horticulture (outlined in green), if directly integrated into urban environments (outlined in blue), may offer hope toward the environmental, social, and economic dimensions of a sustainable food system and contribute to several sustainable development goals.

agriculture, edible landscaping, rooftop gardening, boulevard gardening, informal/opportunistic urban agriculture, controlled environment agriculture. Such variable ways of producing food in cities might offer a degree of functional redundancy when it comes to the overall provisioning services.

Supporting and regulating services

Ecosystems (and yes, this includes *urban* ecosystems) are supported by underlying natural processes such as nutrient cycling, water cycling, soil formation, climate, and photosynthesis; are regulated by natural phenomena such as pollination, decomposition, water filtration, erosion and flood control, carbon storage; and contribute to climate regulation *via* temperature control, evapotranspiration, and greenhouse gas emissions. Due to anthropogenic disturbances in cities, urban environments were long considered to have poor supporting and regulating services (Jim, 1998). However, recent studies are challenging this assumption. Urban horticultural soils (especially gardens) can be highly fertile; have greater soil biological diversity, nutrients, and organic carbon contents compared to rural or non-horticulture urban soils (Vauramo and Setälä, 2010; Edmondson et al., 2012, 2014; Tresch et al., 2018; Ziter and Turner, 2018; Bouzouidja et al., 2021; Dobson et al., 2021). Under the assumption that anthropogenic soils are highly degraded, these findings might be surprising; but, on the other hand, it is not entirely unexpected. There can be a reciprocal relationship between the gardener and the soil (a give and a take). Gardeners are often known to carefully tend the soil by adding compost or mulch, extending their growing seasons with covers (thereby extending living cover and carbon inputs), growing a diversity of species that contribute to the carbon dynamics of the soil and support biological diversity. Well-designed gardens support pollinator diversity (Nicholls et al., 2020) and water flow/storage (Chen et al., 2014). Overall, soil fertility and biological diversity, together with pollinator services and water cycling, point toward a robust capacity for urban horticulture to support and regulate the natural processes needed for food production and ecosystem functioning.

For our food system to become more sustainable, we must better understand externalities, the desired *and* undesired effects, trade-offs, and the unknowns. For example, certain gardening practices can have negative or unknown ecological effects (i.e., groundwater pollution, nutrient loading, and greenhouse gas emissions; Perrin et al., 2015; O'Riordan et al., 2021) and exposure to contaminants remains a widespread concern in urban environments—a risk that can be compounded by systemic inequities and warrants further study.

Cultural services

Urban horticulture not only provides food and environmental services, but also cultural services such as beneficial health outcomes, wellbeing, local job opportunities,

recreation, a sense of being, and social inclusion (Brown and Jameton, 2000; Berti et al., 2004; Camps-Calvet et al., 2015)—together, forming a social safety net that enhances community resilience and response capacity in times of crises. As we struggle with the SARS-CoV-2 pandemic, urban horticulture is once again being sought after to support the wellbeing of communities (Kleinschroth and Kowarik, 2020). The pandemic, food chain supply issues, commodity cost increases, catastrophic fires, droughts, and floods have only exacerbated already considerable social inequalities by impacting marginalized groups much harder. While urban horticulture will not resolve the root of these issues, it offers promise to help improve food security and justice for all, social inclusion, and economic opportunities.

Is the road toward a sustainable food future lined with gardens?

Although no replacement for large-scale agriculture, urban horticulture offers a resourceful strategy to help feed the world in more environmentally, socially, and economically responsible ways. Urban horticulture can contribute to several of the United Nation's 17 Sustainability Development Goals (United Nations, 2018)—and although some are similarly shared with large-scale agriculture, other linkages are unique to urban horticulture (Figure 1).

Despite the promise that urban horticulture represents, moving theory into practice is challenging. The potential for urban horticulture is more limited by urban planning for green spaces than by production itself—as garden space is not typically a major city design factor. Are cities and citizens willing to imagine and implement cityscapes with food production front and center? Indeed, some are: over 200 cities have signed the Milan Food Pact committed to making urban areas more food resilient, sustainable, and equal, and nearly 1,000 cities worldwide have committed to ambitious climate action plans. These numbers are promising, but to significantly impact the global food system, urban horticulture must be seriously implemented at a larger scale.

Instead of incrementally improving the sustainability of agriculture as we know it, a more systemic change is needed. Urban horticulture and its associated ecosystem services offers a promising strategy toward transforming the global food system; hence, should be considered much more seriously, intentionally, and widely. To improve the global food system, the practice of urban horticulture must be accompanied by strong and sustained public policies to support its regulation, monitoring, and governing. As more people chose to live in cities and as cities expand, these urban environments have the potential to play an increasingly significant role in the global food system, presenting leaders with the opportunity to shape a more sustainable food future. Solutions can be found by assimilating horticulture within urban planning and design projects, and action should seek to maximize all dimensions of horticultural ecosystem services. Through the lens of ecosystem services, urban horticulture offers hope for a more sustainable food future.

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Conflict of interest

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