 doi:10.1017/S1742170513000537

Innovation in urban agricultural practices: Responding to diverse production environments

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Accepted 6 December 2013 **Research Paper for Themed Content: Urban Agriculture**

Abstract

Although discussion of the role of urban agriculture in developing nations has occurred over the past decade, dialogue relating to urban agriculture in industrialized countries, including the United States (US) has only recently begun to attract significant attention. The unique factors that influence urban agriculture, including limited and non-traditional land access, use of reclaimed soils and alternative growing mediums, local legal and political environments, social and community-based missions, and involvement of non-traditional farmers, create a production system distinct from rural agricultural enterprises. In many cases, specific local environmental and external factors drive urban farms to develop unique innovations for space-intensive production systems, often creating a dominant paradigm for urban farming for a given location. Furthermore, non-production-related organizational goals are often the primary focus of urban agricultural operations, with the food production becoming a secondary objective. In order to address this information gap regarding the status of urban agriculture in the US, our project, centered at the University of Wisconsin-Madison, gathered data through site visits to and interviews of organizations in seven cities, examining how structural and strategic food system factors shape urban agricultural efforts. A broad range of operations are considered, including diverse business and production models based on both commercial and community-based management strategies and production in parking and vacant lots, warehouses, public land and peri-urban locations. Based on these observations, the unique innovations in space-intensive agricultural production that have arisen in response to urban food system factors are discussed. We conclude with an assessment of the most significant challenges continuing to face urban agriculture.

Key words: urban agriculture, urban farming, urban production, value-added, food systems, alternative agriculture

Introduction

Production of food in urban environments has been associated with a wide range of complementary benefits such as fostering community pride, engaging youth and volunteer workers, improving access to nutritious food and providing skill development for job training programs[1]. Despite interest in urban agriculture in the United States, research and discussion have focused largely on the role of community gardens and the social and political implications of the movement, with relatively little attention being paid to the unique commercial production aspects of farming in urban areas. The literature related to urban farming often emphasizes the social mission, such as educational programs, job training, social justice and community development[1]. Much of the examination of the land available for urban agriculture has focused on related local zoning and policy implications and does not address the impact on production factors[2]. A recent study by Wortman and Lovell addressing the issue of environmental contamination notes a general lack of research relevant to the non-social aspects of urban agriculture[3].

Urban agriculture varies widely in breadth, encompassing community and school gardens, food security efforts, educational projects and commercial farming ventures[4]. Goldstein et al.[5] provide a definition that captures the core of urban agriculture but also points to these varied forms: ‘Most broadly, urban agriculture refers to growing and raising food crops and animals in an urban setting for the purpose of feeding local populations. Cities choose to narrow and focus this definition in various ways, often categorizing urban agriculture as one or more of the

Table 1. Demographic characteristics and USDA Plant Hardiness Zone of cities included in research visits.

City	Boston, MA	Cedar Rapids, IA	Chicago, IL	Detroit, MI	Los Angeles, CA	Madison, WI	Milwaukee, WI
Total population[7]	609,942	126,306	270,0741	738,223	3,782,544	231,783	591,957
White[7]	56.7%	90.6%	46.4%	12.5%	54.4%	83.5%	49.9%
Black or African American[7]	27.8%	7.1%	34.1%	83.7%	10.5%	8.7%	41.3%
American Indian and Alaska Native[7]	0.8%	0.8%	0.6%	1.0%	1.1%	1.0%	1.7%
Asian[7]	9.7%	2.5%	5.9%	1.4%	12.5%	8.2%	3.9%
Native Hawaiian and other Pacific Islander[7]	0.1%	0.1%	0.1%	0.0%	0.3%	0.1%	0.1%
Some other race[7]	8.9%	1.7%	14.8%	3.4%	24.4%	1.7%	6.6%
Persons per square mile[8]	12792.7	1784.3	11841.8	5144.3	8092.3	3037.0	6188.3
Median household income (dollars)[9]	$51,739	$51,108	$47,371	$27,862	$50,028	$54,093	$35,851
Percent high school graduate or higher[10]	84.2%	95.5%	80.2%	77.1%	73.9%	94.5%	80.5%
Civilian labor force, unemployed[9]	7.0%	3.9%	8.0%	14.3%	6.9%	4.3%	8.2%
Percentage of people whose income in the past 12 months was below the poverty level[9]	21.4%	12.6%	21.4%	36.2%	20.2%	18.0%	27.0%
USDA Plant Hardiness Zone[11]	6b	5a	6a	6b	10b	5a	5b

following: community gardens, commercial gardens, community supported agriculture, farmers' markets, personal gardens, and urban farms'. The focus of this paper will be on agricultural production efforts that are located within, or are closely proximate to, a metropolitan area and strive to produce food to be consumed in the same area. Primary attention will be given to projects producing at the commercial or community level rather than solely for personal household consumption.

Urban agriculture integrates a wide variety of production systems, ranging from models familiar to a typical rural farmer to techniques that push the limits of the definition of agriculture. This diversity includes both very high-tech approaches, such as nutrient film technology, and low-tech methods, such as planting into soil-filled recycled buckets. Although many aspects of urban agricultural production are similar to those of small-scale rural farms, several factors set it apart from traditional agricultural operations. Limited and non-traditional land access, use of urban soils and alternative growing media, unique legal and political environments, non-production-related missions and involvement of non-traditional farmers drive urban operations to develop unique innovations, including the development of production practices adapted to maximize space-intensive production systems.

This paper examines how food system factors shape urban agriculture, followed by a discussion of the space-intensive production innovations arising to respond to the challenges and opportunities of urban food systems. We conclude with an assessment of the most significant challenges confronting urban agriculture.

Methodology

This paper is based on research conducted during the first 3 years of the *Community and Regional Food Systems* research project funded by the United States Department of Agriculture National Institute of Food and Agriculture (award 2011-68004-30044) involving the University of Wisconsin-Madison, Growing Power, Inc., the University of Wisconsin-Extension and many community partners. The project focuses on the refinement and the validation of a 'Community and Regional Food System Framework' which characterizes the components of successful Community and Regional Food Systems[6]. As part of the project activities, site visits to urban agricultural operations were conducted within seven cities: Boston, MA; Cedar Rapids, IA; Chicago, IL; Detroit, MI; Los Angeles, CA; Madison, WI and Milwaukee, WI. Select project activities were also conducted in Minneapolis and St. Paul, MN. The cities were chosen to represent diverse geographical regions, local political factors and maturity of urban agricultural projects. Milwaukee, WI, Detroit, MI and Chicago, IL represent large, industrial Midwestern cities facing the challenges of post-industrial economic transition. Madison, WI and Cedar Rapids, IA were selected as smaller Midwestern cities that serve as a counterpoint to the first three large industrial cities but possess similar seasonality and climate. The inclusion of Boston, MA and Los Angeles, CA provided the experience of large coastal cities with different climatic, demographic and economic factors to compare to the Midwestern cities included in the study. See Table 1 for a comparison of the project cites.

Site visits were conducted over a 3-year period, from 2010 to 2013. At least one visit was made to each city, with some cities visited multiple times if a greater number of organizations and/or individuals were interviewed. Efforts were made to visit all of the urban agriculture projects within each city that were identified and that met the criteria of producing above a personal household scale. Table 2 provides a description of the interviewees.

Table 2. Name, location, business model structure and size of urban agriculture organizations included in the interview process conducted in 2010–2013.

Location	Entity	Brief description	Approximate acreage
Boston, MA	Allandale Farm	Commercial	130, 30 cultivated, 20 rural
	City Growers	Commercial	1, several parcels
	Groundwork Somerville	Non-profit	< 1, plus several school gardens
	Needham Neighborhood Farm	Commercial, CSA	4.5 (rural), plus several urban backyards
	ReVision Urban Farm	Non-profit	< 1, 2 parcels
	The Food Project	Non-profit	40, several parcels including 31 rural acres
Cedar Rapids, IA	Feed Iowa First	Non-profit, provides food grown on corporate campuses to hunger relief efforts	5
	Matthew 25	Non-profit, community development ministry	2.5, several contiguous urban lot parcels
Chicago, IL	Growing Home	Non-profit, transitional job training	10 (rural) and several urban parcels
	South-side Education and Economic Development System (SEEDS), Rosebud mini-farm	Community effort	< 1
	The Plant	Commercial business incubator	2.2
	The Urban Canopy	Commercial rooftop farm	< 1, included in The Plant acreage
Detroit, MI	Detroit Black Community Food Security Network, D-Town Farm	Coalition of organizations and individuals	7
	Earthworks Urban Farm	Non-profit, produce supports Capuchin Soup Kitchen	7, several parcels
Los Angeles, CA	CSU Expo Farm	Non-profit	< 1
	EVO Farms	Commercial, aquaponics consulting	< 1
	Growing Home	Commercial	< 1
	John Muir School Garden	School garden	< 1
	Little Farm Fresh	Commercial backyard farm	< 1
	Silver Lake Farms	Commercial	< 1
	The CityFarm	Commercial	< 1
	The Growing Experience	Non-profit on public housing land	4.5
	Whisper Farms	Non-profit, aquaculture, education	< 1
Madison, WI	Troy Gardens	Non-profit, under umbrella of land trust	5
	Voss Organics	Commercial	< 1
Milwaukee, WI	Alice's Garden	Non-profit, community and educational plots	2
	Fondy Food Center (Farm and Market)	Non-profit, leases plots primarily to immigrant farmers	80 (rural), rented as several small farm parcels
	Growing Power	Non-profit, education, aquaponics, microgreens, and field production	300 (mix of urban and rural parcels)
	Hunger Task Force	Non-profit, supplies emergency food system	150 (rural)
	Sweet Water Organics	Commercial/foundation hybrid, aquaponics, no longer operating	< 1
	UW-Extension-Milwaukee, Organic Learning Center	Governmental, educational	< 1
	Victory Gardens	Non-profit, community, and educational focus	1.5 plus community raised bed program
	Walnut Way	Non-profit, community development	Several vacant lots throughout neighborhood
Minneapolis & St. Paul, MN	Growing Lots	Commercial	2.5, 2 rural
	Stone's Throw Urban Farm	Commercial	2, 16 parcels

Table 3. Guidelines and example questions for the interviews.

Organizational structure	- What are your organizational goals? - How are decisions made (production specific; other)? - What types of programs do you offer (including production, education)
Land access and suitability	- How much land is available to you suitable for agricultural production? - How has land been acquired? Under what terms?
Crop selection	- What do you grow and why? - Are animals raised as part of this operation?
Infrastructure	- Is irrigation available? - What equipment is available? - Are season extension facilities such as hoophouses or greenhouses available and used?
Fertility	- Is soil tested? - How is fertility managed? - Do you rotate crops or use fallow, cover cropping strategies?
Pest and disease control	- What are the pests of concern in each crop, and which is most difficult to manage in your current production/crop schemes? - How are pests and disease managed? - Where do you get information about this topic?
Labor and business models	- Who manages the farm? - How many employees? What is the business structure?
Harvest and post-harvest	- What practices or equipment are used for harvesting? - What post-harvest handling practices are in place? - How is food safety addressed?
Production outputs	- Do you measure yield? - Record-keeping: how do you keep track of inputs, yield and economics? By hand, electronically, etc.?
Market access	- What market channel is food sold/distributed through? - How many people are fed through this model? - Do you collect data on sales or distribution volume?
Teaching and learning	- Where is information obtained? - What information/knowledge relative to production would improve your operation? - What outreach programs do you offer?

At each visit, the project team members conducted a standardized interview based on a pre-established list of questions developed by the project team (Table 3). The questions were designed to gain an understanding of the production techniques, farm and organizational management, and the overall organizational goals. All of the farm visits included an interview with the field manager as well as a site visit to the farm to provide observational data with respect to the production scope and the techniques.

The interview content was analyzed by using both *a priori* categorization, based on the themes addressed in the interview question list, and the emergent categories. The relative importance of these codes was then used as criteria for the selection of relevant food system factors and innovations[12]. Themes with the highest frequencies across interviews are addressed in this paper as either food system factors or innovations. For the purpose of this work, a 'food system factor' was defined as a force not directly linked to food production that nonetheless shaped production decisions. 'Innovations' were defined as responses to food system factors that resulted in novel production practices, including a novel application of an existing practice.

Urban Agriculture as Defined by Food System Factors

Land access and tenure

The development of urban agricultural enterprises is strongly influenced by access to land. Although land access and tenure are limited in many cases, significant urban land resources can be available at low or no cost. Land access has wide-ranging implications for the enterprise, including the ability to make capital investments, crop selection, labor force and market access. In addition to land tenure, local land-use practices, policies and prices can influence the viability of an operation.

The availability and affordability of urban land can vary tremendously, not only among but also within cities. Many urban agricultural projects are established in the 'blighted' areas of cities, characterized by the availability of inexpensive or free land. However, access to 'free' land often comes with stipulations and the terms of use may hinder the ability of the organization to manage their operation effectively, particularly with respect to future organizational growth. This is exemplified by the case of City Farm in Chicago, IL, which has been forced to relocate their production operations several times as the vacant land initially made available by the city began undergoing other redevelopment plans. When the redevelopment plans move forward, the project relocates operations to a different vacant plot awaiting redevelopment, forcing the organization to continuously rebuild. The periodic moving and rebuilding of gardens resulting from unstable land tenure necessitates the investment of a significant amount of staff time and the development of new community relations. Despite the resulting organizational challenges, City Farm sees a positive side to these circumstances, as the new locations have offered the opportunity to expand into new spaces, contributing to growth in organizational capacity.

Ease of access to urban land for food production, both with respect to cost and tenure, may be impacted by personal relationships as much as financial resources. Many well-networked growers or organizations are offered more land than they can utilize, while other less well-networked groups within the same city struggle to find adequate space. EVO Farms of Los Angeles, CA and Needham Neighborhood Farm of Needham, MA tell similar stories of expressing the desire to build urban farms and becoming inundated with offers of backyard space from neighbors, including from many community members not associated with the organization. For the farms and the organizations entering the urban agricultural landscape, land access is not straightforward and can vary even within the same city. When the land in question is publicly owned, it may be difficult for a less well-connected organization to acquire the land and may engender conflict among groups competing for similar resources. This has been particularly pronounced in Detroit, where many organizations reliant on land provided by the city perceive inequities in land distribution and the process by which land is designated to urban agricultural entities. However, land accessed through social connections often lacks the long-term security characteristic of more formal land acquisitions, as agreements based on personal relationships are at risk if the partners in those relationships disappear.

Strong neighborhood relationships are another social factor critical to the success of the farms included in this study, both to successfully access land and contributing to conflict avoidance. Strong neighborhood support can assist in overcoming zoning and policy obstacles and minimize on-site vandalism. Examples of strong neighborhood connections contributing to the success of an operation were seen at: Community Services Unlimited, Los Angeles, CA; Allandale Farm, Brookline, MA and ReVision Urban Farm, Boston, MA. Conversely, complaints from neighbors can limit activities that can be carried out on urban land, particularly when agriculture is not expressly allowed by zoning ordinances, as at Growing Power, Milwaukee, WI and Silver Lake Farms, Los Angeles, CA. The restrictions resulting from these complaints may burden growers with additional management and labor requirements, such as requiring that work associated with noise or smells be completed at specific times. In more extreme circumstances, operations may be shut down completely.

With the diverse avenues leading to land access, farms often operate on non-contiguous lots dispersed throughout a city. Urban traffic congestion can make a distance of even a few miles impractical, resulting in significant employee and volunteer time spent driving from site to site. As a result, farm managers may be restricted to infrequent visits to specific farm sites. With fewer site visits, a pest or disease outbreak may go unchecked, and irrigation and harvest timing may be compromised. To alleviate these issues, efforts to concentrate the locations of growing areas are beneficial. Some farms have found that limiting production to one or two crop types on a given parcel of land allows for more efficient management and more effective crop rotation (Growing Power, Milwaukee, WI; Needham Neighborhood Farm, Needham, MA; Stone's Throw Urban Farm, Minneapolis and St. Paul, MN; and Food First Iowa, Cedar Rapids, IA).

Other land-use arrangements may be contingent on the organization fulfilling other requirements, such as maintaining additional decorative garden beds. This is the case at Su Casa, a Catholic Worker community in Chicago providing production space to Growing Home, and Silver Lake Farms in Los Angeles, which provides landscaping in return for farm space. Although such arrangements require that labor be expended outside of the core mission of food production, the increased land access and enhanced community relationships can be worthwhile tradeoffs.

Many urban growers have addressed the limitations of urban land access by acquiring larger acreages of rural land, allowing a greater scale of food production. The market and community development opportunities of the urban site combined with the increased produce volumes provided by rural acreages allow urban agricultural operations to better supply markets. Growing Power, Milwaukee, WI; Growing Home, Chicago, IL; Fondy Food Center, Milwaukee, WI; Needham Neighborhood Farm, Needham, MA; Growing Lots, St. Paul, MN and The Food Project, Boston, MA all integrate rural land use into their production operations.

Unstable land tenure and regulatory limitations have important implications for an urban farm's choices regarding crop selection, soil building and capital investment. Without guaranteed access to land for multiple years, growers are forced to focus on annual crop production rather than livestock or perennial crops, which generally require longer-term investments and greater infrastructure. The lack of animal husbandry (whether due to lack of land tenure, policy limitations or personal choice of growers) in urban agriculture has consequences for farm sustainability and food security, limiting potential fertility sources for crops and protein sources for communities.

Farm infrastructure

Urban growers often face unique challenges regarding the construction and the purchasing of farm infrastructure. Infrastructure development, if allowed on a site, requires significant financial and labor investments. Unstable land tenure may limit the ability to obtain a return on a capital investment. Inability to install relatively routine farm infrastructure, such as water lines, greenhouses, hoophouses, wash and pack sheds, or even tool storage sheds impacts the crop choices and market outlets available to growers. In some cases, growers have developed creative approaches to gain access to needed infrastructure, such as partnerships with other farms and business with greenhouse space, water supplies and cold storage.

In urban areas where most growers rely on raised beds or imported soil, the growing media needed for production also becomes a limiting infrastructure factor that is difficult to transport in the face of relocation caused by uncertain land tenure. Start-up investment in raised beds, compost, mulch and soil amendments is the single largest expense for many urban growers.

Zoning and regulatory restrictions on urban land use can impact urban farming operations. City Farm in Chicago, IL and Troy Gardens in Madison, WI have both dealt with building restrictions on their property. As a result, these operations have been forced to find creative solutions to grow crops without the on-site use of hoophouses, greenhouses or toolsheds that many farms would consider indispensable. Groundwork Somerville (Somerville, MA) has faced similar restrictions on their ability to build infrastructure. By establishing a garden on city-owned land that will be developed within the next 10 years as a transit station, the farm operates under an agreement with the city that prohibits permanent changes to the site. To circumvent this limitation, the organization has built raised garden beds by layering mulch and soil atop the existing pavement and has worked with a local high school to design and build a modular storage shed and rainwater catchment system that will be moved to the future site upon garden relocation.

Land suitability: water, siting and soil

Important physical characteristics of potential urban farm sites include soil quality, drainage, land-use history (particularly as it impacts soil contamination in urban contexts), access to water, and the surrounding built and natural environment. Adequate hours of full sunlight for successful crop production require the absence of tall buildings, trees or other structures blocking the garden, and can be significant barriers in finding suitable urban land.

Access to a reliable water supply, often achieved through a municipal connection or rainwater catchment systems, can also limit the site selection of urban agricultural production. Many urban growers do not have access to water on their own site and rely on neighboring sources. Most organizations pay either a flat fee or install a separate sub-meter to monitor water more precisely, often at a more expensive residential rate rather than a lower agricultural rate. Growers that do not have the benefit of a neighbor willing to share a water source may rely on nearby hydrants or transport buckets from a residence elsewhere in the city, as seen at Stone's Throw Urban Farm, Minneapolis and St. Paul, MN; The CityFarm, Los Angeles, CA and Groundwork Somerville, Somerville, MA. These alternative sources can be time-consuming and inconvenient, resulting in under-watered crops and, in some cases, non-compliance with city policy.

In addition to access to light and water, urban farms also are influenced by siting challenges unique to the urban environment. Many urban sites are susceptible to vandalism, ranging from passersby picking produce to destroying crops, smashing truck windows, overturning tractors and even stealing whole hoophouses to be sold for scrap metal. Using the concept of 'eyes on the street,' many growers find that strong neighborhood support and a highly visible location are the best defenses against vandalism (The Food Project, Boston, MA; Community Services Unlimited, Los Angeles, CA and Matthew 25, Cedar Rapids, IA). Troy Community Farm in Madison, WI has incorporated pick-your-own components into their CSA market explicitly to draw farm members to the otherwise secluded areas of the farm with the intention of fostering greater community watchfulness in areas where vandalism has been a problem.

In order to make these projects accessible to a diverse group of people, including low-income individuals and youth, proximity to public transportation is an important siting question. Many urban agriculture projects have an explicit goal of serving low-income and traditionally underserved populations[13], which is more effectively achieved through close proximity to public transportation routes. Proximity to public transportation may also be important in maintaining a labor force, involving community members or attracting customers.

The quality of the soil enters into the siting decisions, and finding sites with acceptable soil quality can be a significant challenge for urban agriculture operations[3]. Comprehensive testing for contamination on a large number of plots can be expensive and may provide inadequate or incomplete data, as contamination may be extremely localized and heterogeneous[14]. Furthermore, if contamination is found, remediation can be prohibitively expensive and concerns about the long-term impacts and the liability issues may lead to the prohibition of questionable land for agricultural production. Owing to the soil contamination concerns in Milwaukee, city policy requires that all of the gardens on land 'under the control, supervision or ownership of the city' use raised beds[15].

Complete remediation of contaminated soil is complex, with highly variable costs and potential legal issues[16]. A few examples exist where remediation has been paid for by the US Environmental Protection Agency Brownfield Program (Growing Home, Chicago, IL and The Food Project, Boston, MA). Far more commonly, farms create a new growing medium for crop production by importing a combination of wood chips, soil or compost. Given the tendency for urban agriculture to grow in imported soils, raised beds and pots, the evaluation and the optimization of soil tilth become more complicated. A suboptimal soil structure may pose management questions not directly addressed by the existing research aimed toward traditional agricultural enterprises.

Legal and political environment

Zoning and regulatory limitations have a significant impact on nearly all of the aspects of urban farming operations, including siting, production, infrastructure, access to materials and marketing[4]. A wide variation exists in the regulatory statutes allowing agricultural production activities. As a result of the increasing frequency of urban agricultural activities, many cities have begun to include language specifically addressing urban agriculture in their zoning and planning documents[17]. In many cases, these changes are intended to be supportive of agriculture but may result in the creation of additional regulatory and licensing barriers. The results of such changes are still emerging in Boston, MA, where a proposed zoning ordinance will more explicitly allow urban agriculture, but will also probably require that all of the imported soil and compost undergoes expensive testing for heavy metal contamination[18]. Similarly, Cedar Rapids, IA recently passed an ordinance to expressly allow urban agricultural activities to occur, but included a limitation that only ‘walk-behind mechanical farm equipment’ and household chemicals and amendments be used[19]. Although well intentioned, these restrictions limit the scale, efficiency, and environmental and economic sustainability of urban farms.

Despite changes to city zoning ordinances permitting agricultural activities, farming activities often continue to be limited to commercial or industrial areas[18–20]. This preserves the intent of the zoning classification, but may limit the use of residential backyards in urban farming activities. In other cases, conflicting regulations administered by different governmental departments can leave growers confused and frustrated[21].

Although urban farms may have informal access to water, legal access to water can be an obstacle for many urban growers. In some cities, growers’ historic access to public hydrants is being phased out; in Milwaukee, WI, growers with no other water sources must consider alternative investments, such as rainwater catchment systems[22]. Water access is especially challenging for growers in water-scarce Los Angeles where additional regulations on water usage implemented by the State Water Resources Control Board and associated licensing and usage fees impede use by small-acreage growers. Once a grower receives the certified producer’s license required to market their goods, they are no longer eligible for the umbrella homeowners’ policy and must pay their own fee. Unlike larger commercial growers who typically pay water board fees as part of an association, urban farmers are subject to disproportionally expensive rates. On occasion, to help mitigate this issue, urban producers have been offered access to the nursery growers’ association lower rates.

Crop selection is, by default, shaped by policy where certain aspects of agricultural production are limited. Most notably, limitations on raising livestock vary considerably among cities, impacting the production options available for urban farms. Although many municipalities have begun to adopt ordinances that allow chickens or honeybees, others have chosen to specifically ban all livestock. Many cities that have not adopted specific urban agriculture ordinances have no laws specific to livestock, with husbandry neither explicitly allowed nor forbidden. In some cases, ordinances can vary even within a city. Despite the current re-zoning effort, land use in Boston is ultimately governed by neighborhood plans, thus the legality of rearing chickens will continue to vary among neighborhoods[18].

Many cities include urban agriculture in existing regulations concerning home-based businesses. This often includes a limitation on the number and activity of employees. In Los Angeles, CA, Tara Kolla of Silver Lake Farms discovered that the residential code allowed for one employee at a home-based business, but that the employee was only allowed to physically work inside the home, an impossible situation for urban agriculture (this code has since been changed). In Diamond Bar, CA, home-based produce sales are only allowed under rules governing garage sales and are limited to two days per year[23]. A 2012 ordinance adopted in Minneapolis, MN, although supported overall by the urban agricultural community, included provisions that were impractical for agricultural businesses such as limits on hoophouses and selling produce at a farm stand once per month[24,25]. As many urban farms lack cold storage, frequent marketing opportunities are especially critical, and regulations that limit the sale of fresh produce to monthly or even less frequent occasions are unworkable for these operations.

The business of urban farming

Urban agriculture projects are characterized by diverse missions that often embed food production in one or more social goals, such as community empowerment, nutrition, youth engagement, education and job training, or neighborhood beautification[13,26]. Although food production is a central focus for many operations, it is often a means to achieve other social benefits rather than the singular goal of producing crops. Social missions can both compete with and complement production goals and crop yield potential. Lack of agricultural experience of the employees and reliance on a volunteer workforce can diminish farm production potential or influence crop selection that fits the skill level and availability of volunteers or community members. For farming operations nested within larger mission-based organizations, production-related decision-making processes can be particularly challenging. Farm managers experience frustration when organizational decision makers' unfamiliarity with farming operations hinder their ability to advocate for and implement sound management decisions.

One of the most striking aspects of urban agriculture is the varied professional experience of many urban farm managers. Owing to the diverse skill sets needed to achieve broad organizational missions and the limited farming experience held by many urban growers, those who are responsible for managing food production of urban farms often lack agricultural production knowledge. The belief that farming required little more expertise than placing seeds in the soil was commonly expressed and often resulted in sub-optimal production. Limited financial resources to hire skilled labor and lack of awareness of the available farming resources unfortunately contribute to poor growing practices.

In addition to the farm manager, the labor force of an urban farm is often inexperienced, particularly among farms that recruit youth and neighborhood volunteers. Urban farms relying on labor pools that include volunteers, youth and job trainees face challenges regarding the productivity of workers being less familiar with common agricultural skills and requiring a higher level of supervision. Many farms with a high degree of unskilled labor find it necessary to select crops based on the ability of their labor rather than production and market factors. The nature of a farm's labor force and its organizational mission also has a formative impact on farm efficiency and profitability, with many farms with youth engagement goals explicitly *not* striving to create the most efficient operation possible and instead emphasizing hand labor and community involvement. Increasing the level of mechanization for greater production efficiency is often incompatible with the social goals of an urban farm project seeking to engage a large number of hands.

Many urban farm organizations rely heavily on donated resources such as compost, planting containers, tools, space, utilities, vehicle and equipment usage, and more. This goodwill often returns full-circle, with organizations donating a significant portion of their harvest to the workers or the local community. Defining farm success in a traditional business sense is a complex issue for operations that do not have traditional farm enterprise budgets, and instead incorporate the use of donated inputs, volunteer workforce and non-traditional markets. Furthermore, farms that are part of larger mission-based organizations generally rely on grants and income from training and other community programs to supplement their farm sales. Among the urban farms that are attempting to create a financially independent business model, examples of successful financial independence are rare, although several entities are working toward creating self-sustaining businesses (Silver Lake Farms, Los Angeles, CA; Stone's Throw Urban Farm, Minneapolis and St. Paul, MN; CityGrowers, Boston, MA and Needham Neighborhood Farm, Needham, MA).

Urban farmers often struggle with lack of informational resources. Some farmers recognize their need for more production-related information but struggle to find information and resources. University cooperative extension agriculture positions and related resources have been cut in many urban areas. Although strong support networks often exist, urban grower networks lack experienced farmers who can serve as mentors. Lack of other services such as equipment supply, small engine and tractor mechanics, lenders who understand and have experience with agriculture, animal feed and compost suppliers, and veterinary services were cited as challenges for many urban farmers.

Innovations: Meeting the Challenges of Urban Farming Through Space-Intensive Agriculture

Nearly all of the urban growers operate within the confines of space limitations, necessitating the use of space-intensive production practices. As interest in urban agriculture expands, so does the need for reliable information and recommendations regarding the techniques of space-intensive agriculture. However, efforts in this area to date have been largely limited to informally conducted applied research or on-farm experiments. The ability of urban agriculture to continue, to expand, and to significantly contribute to food production depends on the degree to which space-intensive production systems can be operationalized. Although many creative strategies employed by urban farmers are discussed in the context of the food system factors presented previously, the following section focuses on the production-specific strategies being employed by urban growers to maximize profitability in limited space.

Use of non-traditional agricultural space and growing media

Urban agriculture has embraced the creative use of non-traditional spaces, notably industrial buildings, rooftops and paved areas. Many of these 'alternative' spaces are characteristic of the urban farming landscape due to below market rate rent prices, particularly when located in the blighted areas of the city. Use of these spaces allows urban operations to grow food in very close proximity to dense populations and associated markets, recruit employees or volunteers from a large urban population, and, in many cases, meet non-production goals of revitalizing an ailing community through job creation, social engagement, education and beautification.

A creative approach to the use of urban space is rooftop gardening. Although almost always very small in scale, this approach is popular because of the environmental benefits associated with building cooling and the ability to bring food production into the most densely populated urban areas. Although many green roofs use ornamental species, greater interest in urban food production has encouraged the exploration of using rooftop gardens to supply produce to nearby restaurants, retail food markets or schools (The Urban Canopy, Chicago, IL)[27]. Although many examples of successful rooftop gardens exist, challenges remain, including the insufficient load-bearing capacity of the existing structures, especially buildings constructed in the past 30 years, and protecting plants from high rooftop wind exposure (The Urban Canopy, Chicago, IL)[28].

With concerns about possible soil contaminants and issues with poor soil structure of built urban environments, urban farms commonly grow crops in imported soil (Growing Home, Chicago, IL; John Muir School Garden, Pasadena, CA; The Food Project, Boston, MA; ReVision Urban Farm, Boston, MA; CityGrowers, Boston, MA; Groundwork Somerville, Somerville, MA; Matthew 25, Cedar Rapids, IA; The Urban Canopy, Chicago, IL; and Growing Power, Milwaukee, WI and Chicago, IL). A typical practice includes the layering of 18–24 inches of wood mulch and imported top soil or compost, thus creating a new growing base. In some cases, a clay cap or geo-textile barrier is laid down on the existing surface prior to building the new bed to limit the upward mobility of the contaminants. Smaller raised beds or collections of pots require less capital investment than remediating or importing soil, but also create less growing space. By using a system of raised beds or pots, many areas can be used productively; often in close proximity to the communities they intend to serve.

Although imported soil, raised beds and pots offer the flexibility to allow production atop asphalt parking lots or inside buildings; these production techniques also present limitations. The labor requirements to produce and harvest crops may be high, as pots often need to be moved on a regular basis and tended individually by hand. Plants in outdoor pots will be subject to cold damage more readily than an in-ground planting. Nutrient management may be more challenging relative to an in-ground planting. Capital investment in containers or raised bed materials can be substantial, although many urban farms have been able to secure donations of many necessary materials, and landscapers or waste haulers are often willing to dump organic matter free of charge. Although imported soil layered on top of a contaminated site or parking lot allows more traditional in-ground planting, farms built atop asphalt may have drainage and temperature issues very different from those of a standard farm field.

One of the most classic answers to limited space is to build up—the central idea behind vertical farming[29]. Many cities, particularly the historically industrial cities of the American Midwest, have a stock of cavernous industrial buildings that are sitting empty. As the cities look to new solutions to minimize blight and rebuild their economies, these buildings are often available at low cost to those willing to retrofit the space to suit their needs. Owing to the multi-story nature of these buildings, these operations are also sometimes called vertical farms. Many agricultural entrepreneurs have adopted these sites with plans to maximize year-round growing under artificial light (Growing Power, Chicago, IL; The Plant, Chicago, IL and Sweet Water Organics, Milwaukee, WI). Growing Power Inc., headquartered in Milwaukee, WI, is well known for their system that relies heavily on hanging pots and stacked aquaponics systems in order to take advantage of vertical space within their greenhouses, essentially a low-tech approach to vertical farming. The need for artificial light with its associated high utility cost remains an obstacle[30].

Aquaponics is garnering much interest based on the potential to create an integrated system in which fish manure fertilizes plants and creates the ability to grow a protein source within the city. Grown indoors in a soilless environment, the clean produce resulting from this system can be sold in high-value markets, although the financial viability of aquaponics systems remains an open question. In addition to the organizations mentioned above who are improving 'vertical' systems that include aquaponics, The Plant in Chicago aims to create refined aquaponics systems with improved fish nutrition and filtration/enzymatic digestion systems that process fish waste into plant-available nutrients without the risk of fecal contamination to the edible greens. Others, including Growing Power and EVO Farms, are working to create fly-rearing techniques that raise fish food for a more complete closed loop system.

Alternative inputs: soil and light

The innovative use of alternative growing media allows for many of these projects in non-traditional spaces to be possible. Significant efforts are underway to identify growing media that can sustainably be both produced and utilized in urban areas to create new growing spaces. The examples include compost, lightweight soilless mixes for rooftop use (expanded slate, shale, or clay mixed with sand and compost), and coir based potting material[31]. The weight of the growing media is particularly important in rooftop or other vertical applications, as the structural load limitations must be considered. Supplemental lighting is also critical to indoor agriculture, and several growers are actively researching the most efficient types, spectrum composition and arrangements of grow lights (Growing Power, Chicago, IL; The Plant, Chicago, IL).

Urban agricultural operations rely heavily on compost for crop nutrients and improved soil structure. Restaurants, food service facilities, grocery stores and food processors located in urban areas create abundant supplies of pre- and post-consumer food waste. Tree trimmings and collections of municipal yard waste supply an additional source of organic matter. Waste generators and haulers, who often are required to pay tipping fees at conventional disposal sites, are typically pleased to dump their waste at urban agricultural sites. This abundance of free or low cost organic material provides plentiful feedstock for those interested in producing compost, either as an input for their urban farm or as a stand-alone business (Growing Power, Milwaukee, WI and Chicago, IL; Bootstrap Compost, Boston, MA). In addition to standard composting, the use of vermicompost, a highly composted growing medium, is common. The vermicomposting process requires additional time compared to the conventionally produced compost but yields a finished product high in plant-available nitrogen[32]. Although compost plays a central role in supplying soil and nutrient resources to urban agriculture, compost can be highly variable and should be tested for its composition to ensure that the crop nutrient needs are sufficiently met and that contaminants are not present.

Despite the available resources to produce compost in urban environments, access to sufficient compost remains a challenge for some urban growers. Many municipalities or land-use agreements prohibit on-site composting or limit composting to materials collected on-site, preventing the growers from generating enough compost to meet their production needs. Off-farm vendors of quality compost are limited. Growers in many cities expressed concern about using municipal compost due to the inclusion of yard waste potentially treated with herbicides and a high concentration of viable weed seed[33]. Overall, the availability of quality compost sources varies considerably among regions.

Making the most of space: season extension and profit maximization

In addition to vertical farming, limited land availability has led to innovations requiring low capital investment while allowing maximum return on space. Various methods of season extension, intercropping and succession planting allow for the production of more crops for a longer time period. Crop selection is also an important consideration to maximize potential profits. To maximize yield and profit per area, the urban growers tend to focus on crops allowing for the greatest profit per square foot[33]. Root crops and vining crops are not often grown unless included in an educational or demonstration garden or integrated into a broader marketing strategy. Although most farms interviewed grow a wide variety of vegetables, high-value, space-efficient crops such as salad greens, tomatoes, peppers, herbs, fruit and flowers are grown more frequently. Many farms make an effort to cater to the cultural tastes of their surrounding community, which often includes a desire for cooking greens and specialty Asian or Mexican vegetables and herbs. High-value crops such as micro greens, salad mix, wheatgrass, cut flowers, honey or value-added products are especially popular (Growing Power, Milwaukee, WI and Chicago, IL; The Plant, Chicago, IL; The Urban Canopy, Chicago, IL; Silver Lake Farms, Los Angeles, CA; Growing Home, Chicago, IL; The CityFarm, Los Angeles, CA; Little Farm Fresh, Los Angeles, CA; CityGrowers, Boston, MA and the Food Project, Boston, MA).

Season extension for urban growers follows the same production and market principles applicable for rural growers. Produce offered at markets early in the season through production in greenhouses and high tunnels tends to bring higher prices and greater profits[34]. Season-extension structures often yield higher quality produce and reduce pest and disease pressure, as the plants are protected from wind and rain[35]. Urban growers also make use of the favorable micro-climates found along the outside of hoophouses, adjacent to buildings, and other unique areas created by built environments. Protected growing structures allow for continued harvests through a longer production season, providing income over a longer period of time.

Urban producers maximize physical space through alternative crop spacing and field design. Dense spacing and intercropping are common among space-intensive growers. Growing Power takes dense seeding a step further by overseeding—as lettuce and other greens mature, more seeds of the same crop is broadcast on top of the existing crop to create continuous production. These practices require high soil fertility and careful scouting to monitor insect and disease pressure. Despite greater yield potential per square foot, employing these techniques tends to be more labor intensive than using traditional crop spacing and may limit the potential for community member involvement. Kate Canney of the Needham Neighborhood Farm in Massachusetts observed that while dense inter-planted crops made sense when she was growing exclusively in a collection of suburban backyards, she has found traditional spacing and row layouts beneficial as she transitioned to a larger plot of land and needed more efficient larger-scale management.

On-going Challenges and Further Research

Urban agricultural production has expanded quickly in recent years by using a number of innovative models. Many of the approaches adopted by urban farms intrinsically link production methods and marketing through a focus on small-scale, relationship-based operations. Additionally, many operations have multiple goals in addition to food production, including community development and education projects that may compete with efficiency of production operations. As a result, any examination of a farm's organizational success must examine not only yields and profits but also associated positive outcomes absent from traditional operational balance sheets, such as increased community food security, community development, opportunities for teaching and learning, job skills training and crime prevention.

Although maximizing quality and yield may not be the primary goal of an organization with a strong social mission, more accessible technical assistance and small-scale specific production research could contribute to the improvement of production practices regardless of other goals. Urban growers create a new clientele group, distinct from the rural farmers that agricultural extension programs have traditionally served. Many do not have life experience or formal training in agriculture and lack the foundational knowledge of agricultural production science. To the degree that urban growers are aware of existing production resources, they may be skeptical that those resources, most of which were originally designed for much larger-scale growers, are applicable to their small-scale operations. Additionally, the vocabulary and the approaches of many traditional farm resources are often inaccessible to growers new to the agricultural field. In the absence of clear and relevant guidance, growers may make decisions based on unreliable information sources. Resource providers play an important role in interpreting and communicating reliable, appropriate, understandable production information to non-traditional growers. Adaptation of the existing resources into more accessible formats for a range of farming experience, as well as new small-scale specific research, will be important to provide urban growers with the information needed to be successful food producers.

Access to affordable, secure land is of primary importance to urban growers. Creative solutions for land access drive innovation in urban agriculture, but also create challenges related to infrastructure development, investment, soil building and community engagement. Greater use of publicly owned space, land trusts and increased public–private collaborations will be necessary to provide sufficient land to build farms of an adequate scale to support farming as an economically viable enterprise[13]. Space-constrained urban growers face unique challenges in fertility, disease and pest management based on their limited ability to rotate crops or employ cover cropping and fallowing practices. Researchers can collaborate with growers to devise workable solutions to effectively manage issues arising from continuous, intensive production.

As urban agriculture expands, it will be essential for urban producers to understand the implications of, and participate in development of, policy affecting urban agriculture. Producers need straightforward, reliable information regarding the impact of impending policy changes and strategies to meaningfully engage in the process of policy development.

Urban agriculture in the United States is at a point of great opportunity. Cities, community groups and individuals across the country are turning to urban agriculture as a means to redevelop and beautify unused land, engage youth, connect neighbors, provide job skills training and grow fresh, nutritious food. Cities, including Cincinnati, Detroit, Oakland, New York, Portland, San Francisco, Toronto, Vancouver and others, have undertaken land inventories to document land that may be appropriate for urban production and its potential availability[2]. In addition to land availability, other key site selection aspects include cost and length of tenure, access to sunlight and water, soil quality, potential for physical infrastructure, public safety and public access. Mechanisms such as land banks and trusts can begin to make additional land available to urban agriculture and will be particularly beneficial if occupancy lengths allow for capital investment and improvement of growing conditions. In addition to formal land access programs, existing urban growers' experiences illustrate the importance of building strong neighborhood relationships to both initially gain and further maintain land access. Public policy can play a defining role in urban agriculture, either as a support mechanism or as a barrier to expansion. Key supporting pieces include programs that increase land availability, promote marketing and distribution of produce within cities, or provide capital support for necessary infrastructure development.

Finally, as urban agriculture grows and matures in the United States, it will be critical that organizations clarify within their missions the specific goals in undertaking agricultural production. When community engagement, job training or other social goals are principal, production efficiency may reasonably become a lower priority. However, training and resource materials targeted toward urban growers may assist non-profit and commercial growers in maximizing both social and production goals.

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